October 1985

National
Historic
Mechanical
Engineering
Landmark

The American Society of Mechanical Engineers

the Geysers Unit 1

Pacific Gas and Electric Company

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In the late 1800s and early part of this century, The Geysers area was a modest tourist attraction. From 1922 to 1955 the talents of engineers were tested in many attempts to generate electricity from geothermal steam.

It's a familiar story to most anyone who has ever visited The Geysers. Hiking through the mountains between Cloverdale and Calistoga in search of grizzly bears one day in 1847, explorer-surveyor William Bell Elliott came upon a startling sight: great puffs of steam coming from the hillsides.

The awe-struck hunter looked over the scene briefly, then ran to inform his companions that he had come upon "the gates of hell."

What he had in fact seen, that day in 1847, was a glimpse at a powerful source of energy. More than a century later, the steam would be put to work spinning turbine generators and creating electricity.

Today the area is called The Geysers, a misnomer. The puffs of geothermal steam are not geysers, spouting jets of heated water, but fumaroles, venting steam. Perhaps that misnomer is just as well. Naming the area The Fumaroles wouldn't conjure up much of an image in the minds of most.

The awe-struck hunter looked over the scene briefly, then ran to inform his companions that he had come upon the "gates of hell."

Stagecoach service brings tourists

Stagecoach service began in 1863 and the area became a modest tourist attraction, visited by presidents Ulysses S. Grant and Theodore Roosevelt.

One account by Doctor Winslow Anderson described the area in 1888 as "this branch of Hades, nestling among the umbrageous oaks and firs in the pine-clad mountains, rich in manzanita groves, sweet-scented shrubbery and wild flowers, and surrounded on all sides by his Satanic Majesty's prodigious laboratory."

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He also wrote of the area's medicinal benefits.

"This is one of the best bathing waters on the coast," he said. "The borates and sulfates render the skin soft, white and pliable, cleansing the 7,000,000 little pores on the cutaneous surface of an average-sized man."

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Engineering talents tested

In 1922 the talents of engineers were tested when John D. Grant attempted to harness the energy of the geothermal steam. The solitary well he drilled successfully tapped the steam and in 1923, coupled to a small generator, it provided electricity to The Geysers resort. But because the pipes and turbines of the day couldn't stand up to the abrasion and corrosion of the particles and impurities in the steam, and because of a lack of financing, the project eventually was abandoned.

It would take about another 30 years before drilling efforts finally met with success. In the mid 1950s Magma Power Company and Thermal Power Company, working jointly, began a new attempt and in 1955 drilled the first commercial geothermal steam well in Sonoma County. By this time, materials had been developed to withstand the corrosive steam, and the field could be thus developed economically. Local entrepreneur B.C. McCabe of Magma Power Company negotiated with PG&E to generate electricity from the steam Magma and Thermal would supply from The Geysers.

A modest beginning

The first unit had a net capacity of 11 megawatts, and cost less than $2 million to build.

Unit 1 of PG&E's geothermal complex began commercial operation on September 25, 1960. That day marked PG&E's—and the nation's—entry into commercial geothermal electric power production.

It was a modest beginning. The first unit had a net capacity of 11 megawatts, and cost less than $2 million to build. Twenty five years later it is still operating.

Although classified as commercial, it was in reality more of a research project. At the time of its development, no one was completely sure the concept of geothermal energy would prove out. Nor was anyone certain of the economics. Those economics have since, of course, changed dramatically, especially with the sharp escalation of fossil fuel prices. Geothermal will probably always be one of the cheaper sources of energy available to PG&E.

FROM GEOTHERMAL STEAM TO GEOTHERMAL ENERGY

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The term geothermal energy refers to the usable heat energy that originates from the magma (or molten rock) in the earth's interior and from slow radioactive decay in solid rock formations.

Even though the thickness of the earth's crust averages 32 km (20 miles), in some locations it is thinner or there are localized weak spots. These regions are indicated by volcanic activity and, in areas where trapped bodies of subterranean water exist, by the presence of hot springs, geysers or fumaroles.

Magma transfers heat energy through the solid rock to the underground sources of water. The intense heat transforms the water to geothermal steam. Some of the steam finds its way to the surface through fissures in the underground rock and natural surface openings called fumaroles.

To increase the amount of hot water or steam reaching the surface, wells have been drilled to supply hot water for mineral baths, heat for hothouse gardening (hydroponics), residential and commercial space heating, industrial and food process work and electric power generation.

Wells used for most of these purposes are considerably more shallow than at The Geysers, where steam is obtained by drilling wells 7,000 to 10,000 feet deep through solid cap rock down to the steam reservoir area.

Providing the steam

When the steam reaches the surface, it is first cleansed of solid impurities such as rock dust that could erode pipes and damage turbine blades. This is done by "whirling" these particles off in centrifugal separators. If a power plant is suddenly shut down, the steam is vented directly to the atmosphere through large rock mufflers, which reduce the noise impact on neighboring communities.

Normally, however, the steam from about 10 to 15 wells flows through a network of insulated pipes and enters the turbine, where it is expanded through six stages and exhausted into the condenser.

Other impurities which exist in the geothermal reservoir but cannot be removed in centrifugal separators are various non-condensible gases. These gases must be separated and discharged in order to maintain vacuum in the condenser. This is done by multistage steam jet ejectors.

Normally, however, the steam from about 10 to 15 wells flows through a network of insulated pipes and enters the turbine, where it is expanded through six stages and exhausted into the condenser

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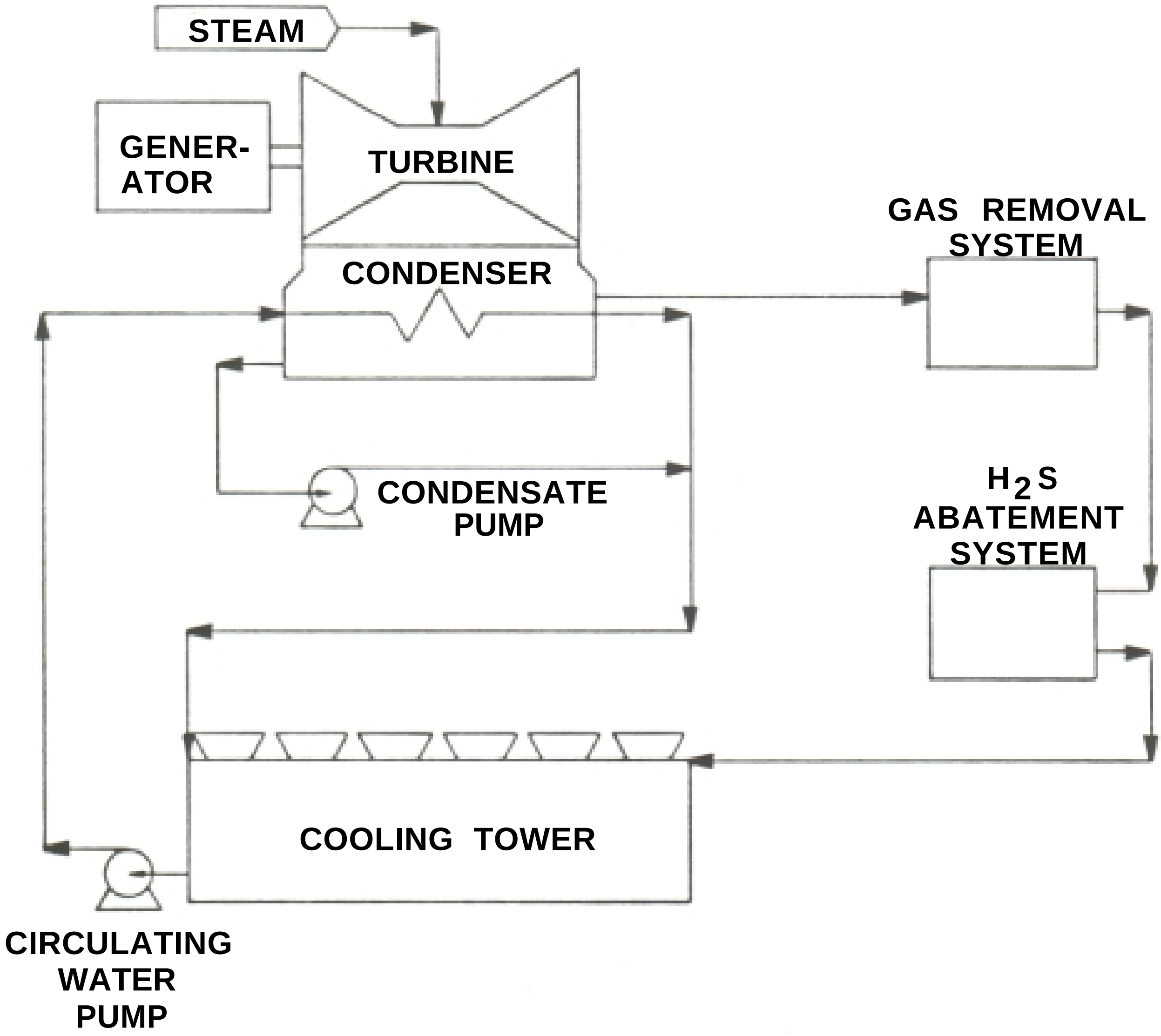
From Steam to Electricity

1. *Drilling rig probes reservoir in search of steam.*

2. *Well, when established, taps steam and conducts it to surface.*

3. *Generating unit uses energy of steam to produce electricity.*

The Geysers Flow Diagram



Because there is very little surface or well water available at The Geysers, the make-up water required to replace what is lost through evaporation in the cooling tower is obtained by mixing the steam condensate with the circulating cooling water.

The cooling water system

A closed loop system provides the necessary cooling water to condense the turbine exhaust steam. The warm water from the condenser is pumped to a mechanical draft cooling tower where its temperature is reduced, to be returned to the condenser again, thus closing the loop. Because there is very little surface or well water available at The Geysers, the make-up water required to replace what is lost through evaporation in the cooling tower is obtained by mixing the steam condensate with the circulating cooling water. In fact, there is more condensate available than what is necessary to replace the losses. This surplus water is reinjected into the steam field where it can be reheated, thus helping to preserve the life of the steam reservoir.

The steam turbine drives the electric generator, which along with other electrical equipment is of standard design, although special "clean rooms" or ventilated cabinets are required for control equipment (e.g., relays) whose copper and silver contacts are attacked by the corrosive atmosphere.

Detailed specifications of all generating units are shown on the table on pages 12 and 13.

Non-condensible gases

Most of the non-condensible gases are removed from the condenser in the gaseous form; however, up to 20 percent are dissolved in the condensate. These dissolved gases result in the highly corrosive nature of the cooling water which presents special challenges to power plant designers and metallurgists.

One constituent of the non-condensibles is hydrogen sulfide (H_2S). If released to the atmosphere, as was done in the early phases of development at The Geysers, H_2S can cause an odor problem even though in low concentrations it poses no health hazards. Recognizing the importance of minimizing the adverse effects of geothermal development, PG&E has developed and installed increasingly sophisticated and effective H_2S abatement systems at its various generating units.

In 1955 Magma Power Company leased 3,200 acres of land from The Geysers Development Company and drilled its first well. A year later, the company contracted with the newly formed Thermal Power Company to develop the area, share in the benefits and expenses of the property and generate electric power. After several wells were drilled, PG&E proceeded to construct a steam-electric power plant and a transmission line to connect the plant to the PG&E system.

On the basis of steam flow measurements made in December 1957, and feasibility and economic studies, PG&E signed a contract in 1958 with Magma-Thermal for construction of the power plant. Based on the negotiated pricing formula, PG&E would pay for the steam supply at a rate of 2.5 mills per net kwh of electric energy delivered to the transmission line.

After several wells were drilled, PG&E proceeded to construct a steam-electric power plant and a transmission line to connect the plant to the PG&E system.

Veteran turbine-generator put to work

Plans called for Unit 1 to generate 11,000 kw, and engineers looked around for a turbine-generator that small, one capable of operating at low inlet pressures. Eventually PG&E decided to use one of its own turbines, scrapped a few years earlier when Station B of the Sacramento streetcar line was retired. The veteran turbine-generator was refurbished and installed in the nation's first geothermal power plant at The Geysers. It proved a wise investment; not only did PG&E save about $500,000 off the price of a new one, but that turbine-generator, more than 60 years old now, is still producing kilowatts at Unit 1.

A 10-mile, 60 kv transmission line was constructed to connect the plant to the PG&E system. The final cost of that first generating plant and switchyard, including construction and general overhead, was less than $2 million.

The veteran turbine-generator was refurbished and installed in the nation's first geothermal power plant at The Geysers.

Construction survey crewman works against a backdrop of venting wells in November, 1959. To reduce H_2S emissions, wells are no longer vented directly to the atmosphere.

The control valves were replaced by two butterfly valves and the first three stages were removed.

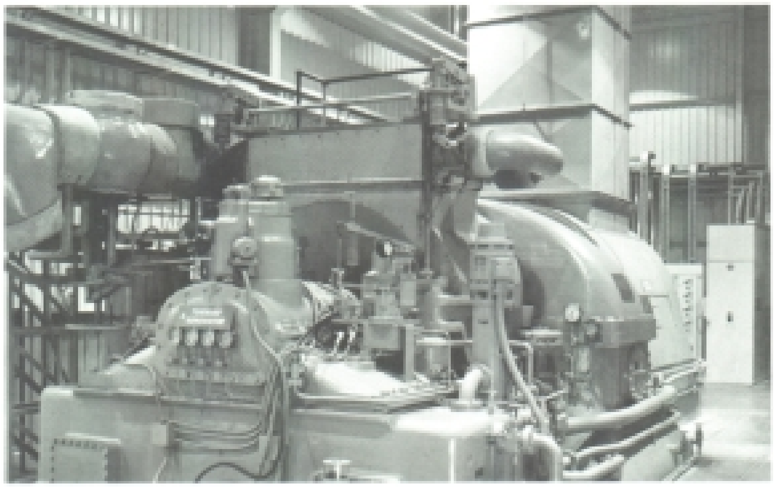
Turbine

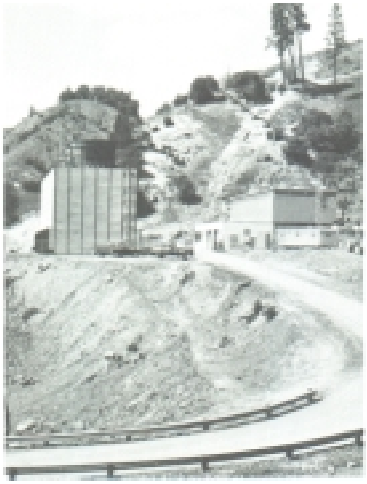
The turbine for the plant is designed for 100 lbs-per-square-inch and 350 degrees F inlet steam conditions with a back-pressure of 4 inches Hg absolute. It's a General Electric Company 9 stage, 1800 rpm, single casing, condensing turbine originally designed for inlet steam conditions of 175 psig with 100 degrees F superheat and 1½ inches Hg absolute exhaust pressure.

The turbine was modified by opening up the steam passages. The control valves were replaced by two butterfly valves and the first three stages were removed. The remaining six diaphragms were replaced because it was believed that the copper brazing used in the original construction would be deteriorated by the hydrogen sulfide in the steam. The last two rows were replaced with 13 percent chrome steel buckets to increase the flow through them. The diaphragms of these stages were also enlarged to permit more steam flow. The monel blades installed in the 4th and 7th stages were retained as no mercury, believed to be damaging to monel, was found in the steam.

Since there was fine mineral matter in the steam, which might cause the stem of the turbine throttle-trip valve to stick, an emergency trip valve of the swing check type was installed after the throttle valve. Simultaneous tripping of the two valves ensures positive stopping of the steam flow. In addition, a circulating lubrication system was used on the stems or shafts of the valves. The valves are lubricated to prevent sticking.

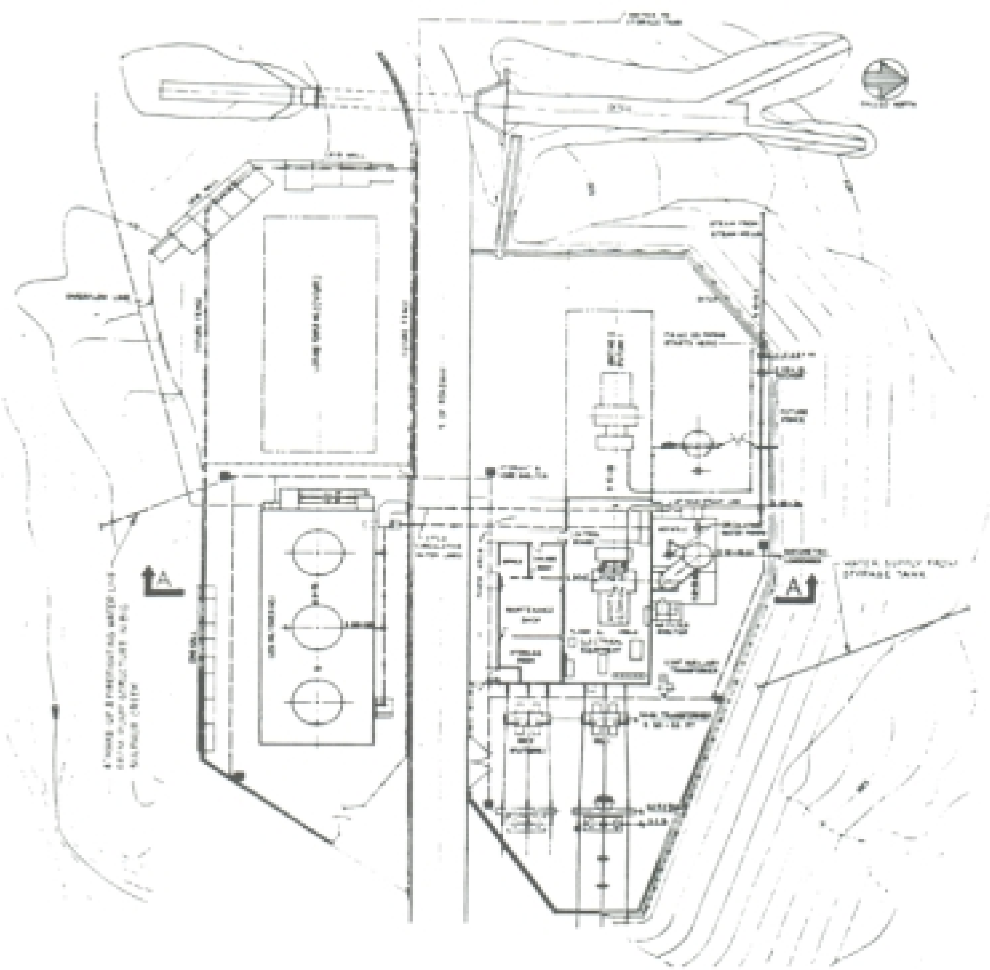
Engineers looked around for a small turbine-generator for Unit I, eventually deciding to use one of PG&E's own turbines, retired a few years earlier. Now more than 60 years old, it's still producing kilowatts.





Construction of Unit I was almost completed when this photograph was taken in April 1960.

Plant Layout
The Geysers Unit 1



A direct contact, barometric condenser was selected for Unit 1 because it was not necessary to keep the condensate separated to return to a boiler, since the geothermal unit required no boiler other than "Mother Nature."

Barometric Condenser

A condensing unit was used because, using the same steam flow, the unit can produce more than twice the electric output than that which can be obtained using an atmospheric exhaust turbine. A direct contact, barometric condenser was selected for Unit 1 because it was not necessary to keep the condensate separated to return to a boiler, since the geothermal unit required no boiler other than "Mother Nature." In the condenser, cooling water is introduced through a 24-inch pipe near the top and mixed with the turbine exhaust steam, which enters near the bottom through an 84-inch opening. The condensing is accomplished by the water falling over a succession of circular plates and annular rings.

The condenser vessel is 120 inches wide and about 23 feet high. It is mounted vertically 28 feet above grade. The elevation allows room for a 30-inch barometric leg, connected to the bottom of the condenser. The mixture of cooling water and condensate falls down to the hotwell, where the 30 inch pipe is sealed by a weir.

The non-condensible gases are removed at the top of the condenser by a two-stage steam jet gas ejector. The mixture of motive steam and steam vapor in the gases is condensed after each stage. Originally, the gases were exhausted to the atmosphere at high velocity through a 4-inch stainless steel pipe several feet above the condenser.

Circulating Water Pumps

The circulating water pumps are of a special design vertical turbine type which do not have a steeply rising characteristic at shutoff. The condenser supply pump, taking suction from the coldwell, has a rating of 11,600 gpm at 29-feet head. The cooling tower supply pump, taking suction from the hotwell, has a rating of 12,300 gpm at 50-feet head.

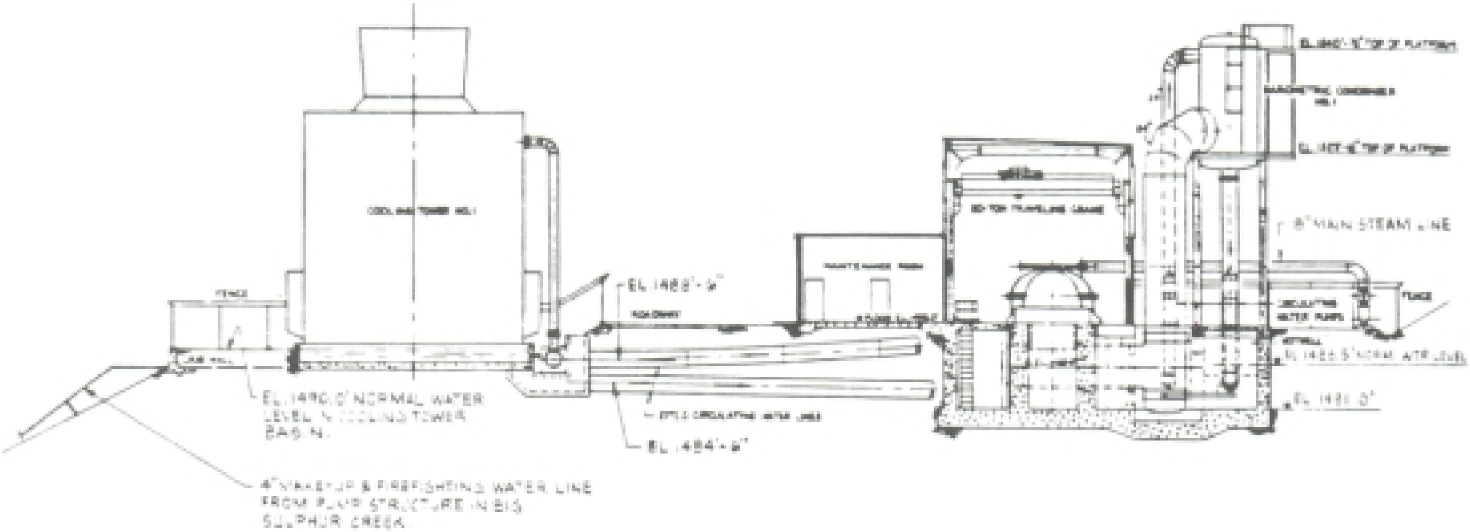
	UNIT 1	UNIT 2	UNITS 3 & 4	UNITS 5 & 6	UNITS 7 & 8	UNITS 9 & 10	UNIT 11	UNIT 12
DATE OF COMMERCIAL OPERATION	9/25/60	3/19/63	11/2/68	12/15/71	11/23/72	11/30/73	5/31/75	3/1/79
COST	$3,784,000		$7,534,000	$11,954,000	$11,520,000	$13,492,000	$19,761,000	$35,000,000
GROSS MW CAPACITY (NET)	12.5 (11)	14 (13)	28.8 (27) EACH	55 (53) EACH	55 (53) EACH	55 (53) EACH	110 (106)	110 (106)
LOCATION	SONOMA CO.	SONOMA CO.	SONOMA CO.	SONOMA CO.	SONOMA CO.	SONOMA CO.	SONOMA CO	SONOMA CO
TURBINE DATA								
MANUFACTURER	GENERAL ELECTRIC	ELLIOT DIV & CARRIER CO	ELLIOT DIV & CARRIER CO	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA
SPEED (RPM)	1800	3600	3600	3600	3600	3600	3600	3600
NUMBER OF STAGES	6	7	7	6 X 2	6 X 2	6 X 2	6 X 4	6 X 4
STEAM FLOW (lbs./hr)	240,000	232,750	517,000	907,530	907,530	907,530	1,906,000	1,906,000
GENERATOR								
MANUFACTURER	GENERAL ELECTRIC	ELECTRIC MACHINERY CO.	ELECTRIC MACHINERY CO.	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA
TYPE OF COOLING	AIR COOLED	AIR COOLED	AIR COOLED	HYDROGEN COOLED	HYDROGEN COOLED	HYDROGEN COOLED	HYDROGEN COOLED	HYDROGEN COOLED
NUMBER OF POLES	4	2	2	2	2	2	2	2
RATING (KVA)	12,500	15,625	32000	66,000	66,000	66,000	132,000	132,000
POWER FACTOR	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9
VOLTAGE (VOLTS)	11,500V	13.800V	13,800V	13,800V	13,800V	13,800V	13,800V	13,800V
CURRENT (AMPS)	628A	653A	1340A	2761A	2761A	2761A	5523A	5523A
MAIN TRANSFORMER								
MANUFACTURER	GENERAL ELECTRIC	GENERAL ELECTRIC	GENERAL ELECTRIC	McGRAW-EDISON CORP	McGRAW-EDISON CORP.	McGRAW-EDISON CORP.	ALLIS CHALMER MFG CO.	FEDERAL
TYPE	STEP UP	STEP UP	STEP UP	STEP UP	STEP UP	STEP UP	STEP UP	STEP UP
RATING (KV)	11.5 TO 60	13.8 TO 60	13.8 TO 60	13.8 TO 115	13.8 TO 115	13.8 TO 115	13.8 TO 115	13.8 TO 230
CONDENSER								
MANUFACTURER	INGERSOLL RAND	INGERSOLL RAND	ELLIOT CO.	INGERSOLL RAND	INGERSOLL RAND	INGERSOLL RAND	WESTINGHOUSE	WESTINGHOUSE
TYPE	BAROMETRIC	BAROMETRIC	BAROMETRIC	DIREST CONTACT	DIRECT CINTACT	DIRECT CONTACT	DIRECT CONTACT	DIRECT CONTACT
CONDENSER PRESSURE (IN Hg. Abs)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
COOLING WATER USED (GPM)	11,000	12,500	11,625	42,550	42,550	42,550	84,280	84,280
COOLING TOWER								
MANUFACTURER	FLOUR CO.	FOSTER WHEELER CORP	FLUOR CO.	MARLEY CO.	ECODYNE CORP.	ECODYNE CORP.	MARLEY CO. (REPLACEMENT TOWER)	ECODYNE CORP.
TYPE	COUNTER FLOW INDUCED DRAFT	CROSS FLOW MECH. DRAFT.	COUNTER FLOW INDUCED DRAFT	CROSS FLOW MECH DRAFT	CROSS FLOW MECH DRAFT	CROSS FLOW MECH DRAFT	CROSS FLOW MEC DRAFT	CROSS FLOW MECH DRAFT
NUMBER OF CELLS	3	3	3(6 FANS) EACH	5 EACH	5 EACH	5 EACH	9	9
COOLING CAPACITY (GPM)	12,000	14,000	29,000	50,000	50,000	50,000	100,000	1000,000
TEMPERATURE COOLING RATE	120° TO 80°	120° TO 80°	120° TO 80°	120° TO 80°	120° TO 80°	120° TO 80°	124° TO 79°	120° TO 80°
CRANE								
MANUFACTURER	MOFFET ENG CO.	MOFFET ENG CO.	CHECO	CHECO	SIERRA CRANE & HOIST CO.	SIERRA CRANE & HOIST CO.	SIERRA CRANE & HOIST CO	SIERRA CRANE & HOIST CO
NUMBER OF CRANES	1	1	1	1	1	1	1	1
LIFTING CAPACITY	20 TONS	20 TONS	20 TONS	25 TONS 5 TONS AUX HOOK	25 TONS 5 TONS AUX HOOK	25 TONS 5 TONS AUX HOOK	32 TONS W/ 12 TONS AUX HOIST	32 TONS W/ 12 TON AUX HOIST
STEAM SUPPLY								
SUPPLIER	UNION-THERMAL	UNION THERMAL	UNION THERMAL	UNION-THERMAL	UNION-THERMAL	UNION-THERMAL	UNION-THERMAL	UNION-THERMAL
NUMBER OF WELLS	4	4	4	9	10	10	18	18
ABATEMENT SYSTEM	INCINERATOR	INCINERATOR	IRON/CATALYST SYSTEM	IRON/CATALYST SYSTEM	INCINERATOR	IRON/CATALYST SYSTEM	IRON/CATALYST SYSTEM	IRON/CATALYST SYSTEM
SUPPLEMENTAL ABATEMENT	H_2O_2 & NaOH	H_2O_2 & NaOH	H_2O_2 &NaOH	H_2O_2 & NaOH	H_2O_2 & NaOH		H_2O_2 & NaOH	H_2O_2 & NaOH

PACIFIC GAS AND ELECTRIC COMPANY

THE GEYSERS POWER PLANT

UNIT 14	UNIT 15	UNIT 16	UNIT 17	UNIT 18	UNIT 20	UNIT 21
9/12/80	6/17/79	DEC. 85 (SCHED.)	12/18/82	2/15/83	DEC. 85 (SCHED)	DEC. 88 (SCHED)
$65,000,000	$37,000,000	UNDER CONST.	$93,000,000	$83,000,000	UNDER CONST.	BEING DESIGNED
118 (114)	60 (57)	120 (113.4)	120 (113.4)	120 (113.4)	120 (113.4)	151 (144)
SONOMA CO	SONOMA CO	LAKE CO.	SONOMA CO	SONOMA CO.	SONOMA CO.	LAKE CO.
TOSHIBA	GENERAL ELECTRIC	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	MITUBISHI
3600	3600	3600	3600	3600	3600	3600
6 X 4	5 X 2	6 x 4	6 x 4	6 x 4	6 x 4	6 x 4
1,873,000	973,000	1,905,550	1,905,550	1,905,550	1,905,550	2,100,000
TOSHIBA	GENERAL ELECTRIC	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	MITSUBISHI
HYDROGH COOLED	HYDROGEN COOLED	HYDROGEN COOLED	HYDROGEN COOLED	HYDROGEN COOLED	HYDROGEN COOLED	HYDROGEN COOLED
2	2	2	2	2	2	2
132,000	70,000	137,800	137,800	137,800	137,800	187,000
0.9	0.9	0.9	0.9	0.9	0.9	0.9
13,800V	13,800V	13,800V	13,800V	13,800V	13,800V	13,800V
5523A	2950A	5,766A	5,766A	5,766A	5,766A	7,824A
FEDERAL	FEDERAL	FEDERAL	FEDERAL	FEDERAL	FEDERAL	FERRANTI-PACKARD
STEP UP	STEP UP	STEP UP	STEP UP	STEP UP	STEP UP	STEP UP
13.8 TO 230	13.8 TO 115	13.8 TO 230	13.8 TO 230	13.8 TO 230	13.8 TO 230	13.8 TO 230
ECOLAIRE	ECOLAIRE	TRANSASM-DELAVAL	TRANSAM-DELAVAL	TRANSAM-DELAVAL	ECOLAIRE	COMBUSTION ENGINEERING
SURFACE	SURFACE	SURFACE	SURFACE	SURFACE	SURFACE	SURFACE
3.0	4.0	3.0	3.0	3.0	3.0	2.0
147,000	65,000	139,750	139,750	139,750	139,750	178,250
MARLEY CO.	MARLEY CO.	MARLEY CO.	MARLEY CO.	MARLEY CO.	MARLEY CO.	LILIE-HOFFMAN
CROSS FLOW MECH DRAFI	CROSS FLOW MECH DRAFT	CROSS FLOW MECH DRAFT	CROSS FLOW MECH DRAFT	CROSS FLOW MECH DRAFT	CROSSFLOW MECH. DRAFT	CROSS FLOW MECH. DRAFT
10	5	11	11	11	11	17
152,000	68,000	165,000	165,000	165,000	165,000	242,000
110° TO 80°	120° TO 80°	105° TO 80°	105° TO 80°	105° TO 80°	105° TO 80°	97° TO 79°
SERRA CRANE HOIST CO	SIERRA CRANE & HOIST CO.	SIERRA CRANE & HOIST CO	SIERRA CRANE & HOIST CO	SIERRA CRANE & HOIST CO.	SIERRA CRANE & HOIST CO.	SIERRA CRANE & HOIST
1	1	1	1	1	1	1
32 TONS W/ 12 TONS AUX HOIST	25 TONS W/ 10 TONS AUX HOIST	32 TONS W/ 12 TONS AUX HOIST	32 TONS W/ 12 TONS AUX HOIST	32 TONS W/ 12 TONS AUX HOIST	32 TONS W/ 12 TONS AUX HOIST	45 TONS W/ 12 TONS AUX HOIST
UNION-THERMAL	GEOTHERMAL RESOURCES, INC.	PHILLIPS USA INC	UNION-THERMAL	UNION-THERMAL	UNION-THERMAL	UNION-THERMAL
15	10	15	15	15	15	15
STRETFORD	STETFORD	STRETFORD	STRETFORD	STRETFORD	STRETFORD	STRETFORD
H_2O_2 & CATALYST	H_2O_2 & CATALYST	H_2O_2 & CATALYST	H_2O_2 & CATALYST	H_2O_2 & CATALYST	H_2O_2 & CATALYST	H_2O_2 & CATALYST

Section A-A
The Geysers Unit 1



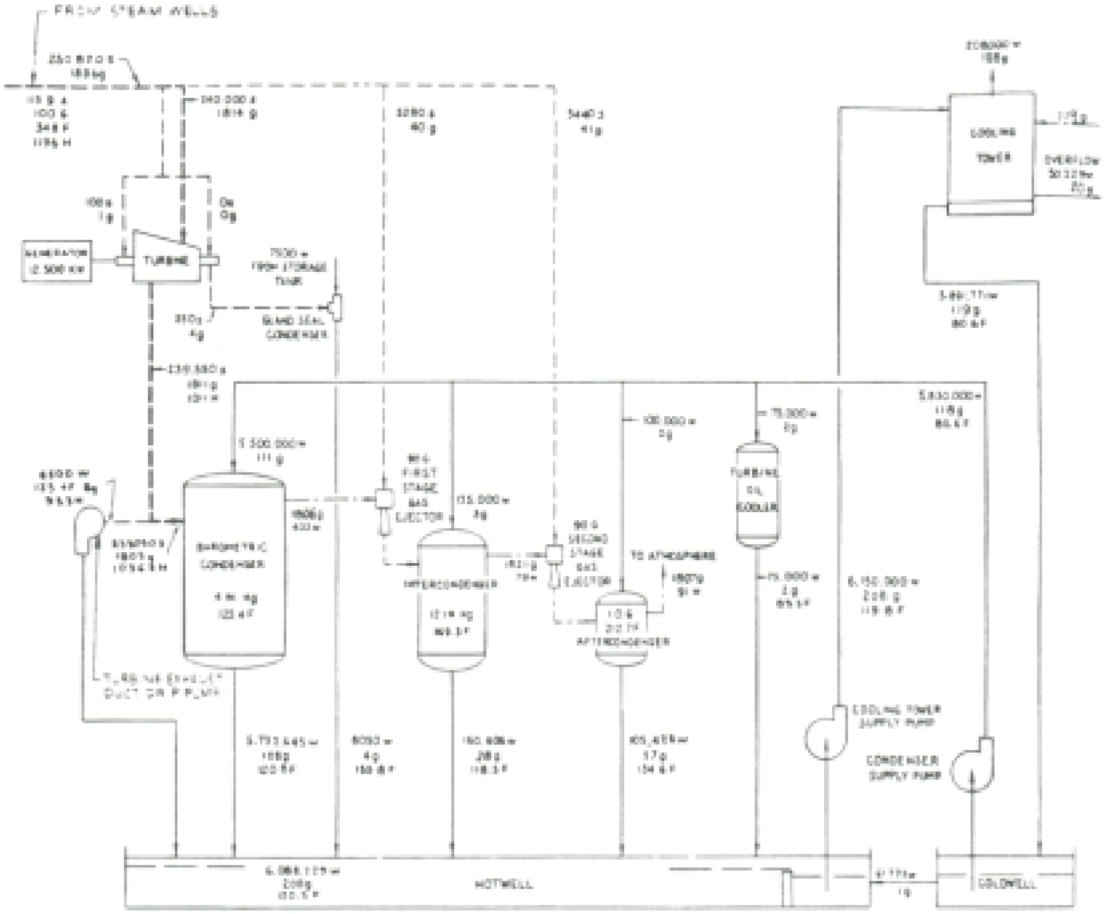
Cooling Tower

The three-cell induced draft cooling tower is made of specially treated California redwood and is designed to cool 12,000 gpm of water from 120 degrees to 80 degrees F with a wet-bulb air temperature of 65 degrees F. Each cell has a 16-inch aluminum riser pipe with an aluminum butterfly valve for equalizing the flow. The plant's original 27-inch reinforced concrete pipe main circulating water lines have been replaced by a fiberglass piping system. Other special corrosion-resistant materials are also used in the cooling tower.

H_2S Abatement System

Unit 1 was recently backfitted with an incinerator and a chemical water treatment system designed to reduce the amount of H_2S emitted to the air. Because there is a sufficient amount of methane in the condenser vent gas to permit combustion, whereby the H_2S is oxidized to SO_2, the burner exhaust gases are ducted to the cooling tower and injected in the air stream. There the cascading cooling water scrubs most of the SO_2 before the gas/air mixture is emitted to the atmosphere through the cooling tower fan stacks. To help with abatement, chelated iron catalyst is also added to the cooling water, and converts the dissolved H_2S to a form of sulfate that is not volatile, thereby reducing air emissions. This dissolved sulfate is eventually injected underground.

Heat Balance Diagram
The Geysers Unit No.1



PERFORMANCE

THROTTLE FLOW #/HR 240,000	
GENERATOR ELEC OUTPUT 12,500 KW	
AUXILIARY POWER (ELECTRICAL)	
CIRCULATING WATER PUMPS	229.0
COOLING TOWER FANS	96.2
EXCITER	69.0
OTHER	7.8
TOTAL	402 KW
NET UNIT OUTPUT	12,098 KW
HEAT INPUT	293×10^{6} Btu/HR
NET HEAT RATE	24,215 Btu/HR
REFFERRED TO 60• F	

CONDITIONS

GENERATOR POWER FACTOR = 1.0
CONDENSER BACK PRESSURE 4.0 Hg.
DRY BULB AIR TEMPERATURE = 96• F
WET BULB AIR TEMPERATURE = 66.5• F
GAS SHOWN ENTERING COOLING TOWER IS AIR ABSORBED BY WATER.
GASES TO AND FROM COOLING TOWER DO NOT INCLUDE COOLING AIR BUT ONLY THAT WHICH IS ABSORBED AND DEGASSED.
ANY AIR ABSORBED IN COOLING WATER IN HOTWELL IS NOT INCLUDED.

LEGEND

– – – MAIN STEAM LINE
— — WATER LINES
– – – STEAM LINES
—·— GAS LINES
s POUNDS PER HOUR STEAM
w POUNDS PER HOUR WATER
g POUNDS PER HOUR GASES
F DEGREES FAHRENHEIT
H STEAM ENTHALPY
A PRESSURE PSI ABSOLUTE
G PRESSURE PSI GAGE

THE GEYSERS OF TODAY

From its small beginning in 1960, PG&E's development at The Geysers has grown to include a complex of 17 geothermal power plants in Sonoma and Lake counties.

Over the years, things have changed at The Geysers. In 1967 Union Oil Company of California joined pioneering Magma and Thermal Power companies as a steam supplier to PG&E and was named field operator. This made technical and financial resources available to increase exploration and development of the steam field.

Later, Natomas Company acquired Thermal and Magma. Today, several developers conduct exploration, drilling, surface steam transportation and power generation in much of the geothermal field.

From its small beginning in 1960, PG&E's development at The Geysers has grown to include a complex of 17 geothermal power plants in Sonoma and Lake counties. At 1,137 megawatts owned by PG&E and 317 megawatts developed by others, it is the largest power production complex in the world that uses geothermal steam.

An impressive amount of energy

The Geysers of today supplies an impressive amount of energy to PG&E customers. In 1984, natural steam from below the earth's surface was harnessed to produce a record 7.1 billion kilowatthours of electricity.

That was more than 15 percent of all the power produced in PG&E plants. It was enough to meet the needs of more than a million customers.

Though one might expect geothermal energy production to be a mature technology, in a sense it has remained a developmental project at PG&E.

PG&E has been a pioneer in developing materials, design, siting, licensing, environmental controls and other areas which were uncharted territory in 1960.

Turbine blades failed and had to be redesigned, pipes corroded and deposits built up on parts. Engineers learned as they went along.

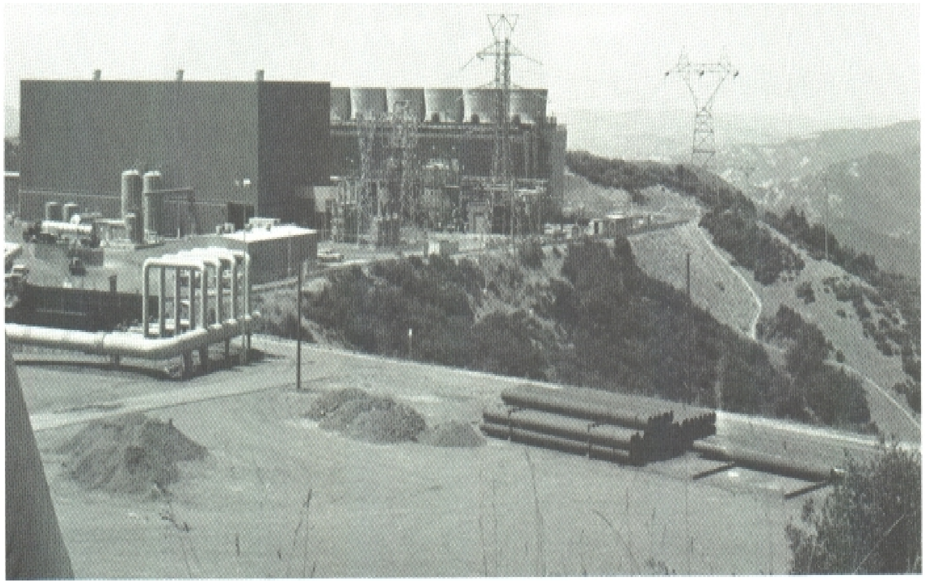
Today, all surplus water, including trapped rain runoff, is reinjected into the steam field through many injection wells.

Environmental concerns

One of the site's first environmental concerns surfaced when PG&E's steam suppliers, Magma-Thermal, disposed excess condensate from Unit 1 into adjacent Big Sulphur Creek. It was found that the presence of the naturally occurring elements in the condensed steam was detrimental to fish life, resort areas and irrigated crops in the watershed.

Later engineers discovered that returning the condensate underground eliminated pollution and helped to regenerate the steam reservoir. Today, all surplus water, including trapped rain runoff, is reinjected into the steam field through many injection wells.

Engineers have also learned that steam content and characteristics vary, making engineering modifications to the power plants necessary. At one unit, for example, the non-condensible gas levels in the steam increased three fold over initial concentrations during operation. This overloading of the gas removal system severely impaired the operation of the unit.



Today, PG&E's geothermal plants are more than ten times the size of Unit I. Unit 17, shown here, produces 113,000 net kilowatts, compared to Unit I's 11,000 kilowatts.

Hydrogen sulfide emissions

The most difficult environmental problem faced at The Geysers was how to control hydrogen sulfide emissions. As the production of geothermal steam for power increased, and the drilling of wells and construction of generating facilities moved toward the populated areas of Lake County, public awareness of hydrogen sulfide emissions increased. In 1972 California law set standards for emissions of pollutants such as hydrogen sulfide. Well before that time, however, PG&E had begun to develop ways to control hydrogen sulfide emissions.

PG&E's challenge in the early 1970s was to develop a method to reduce H_2S emissions at its 10 operating units. A variety of chemical abatement processes were tested and used, all of which were tailored to the already constructed power plants which had to be retrofitted with the new abatement systems.

At that time, effective abatement technology existed within the petroleum, coal and chemical industries, but had never been applied to geothermal systems. After extensive analysis, the system which appeared best suited for use at The Geysers, called the Stretford Process, was selected. Its use, however, required a departure from PG&E's traditional power cycle design for geothermal units.

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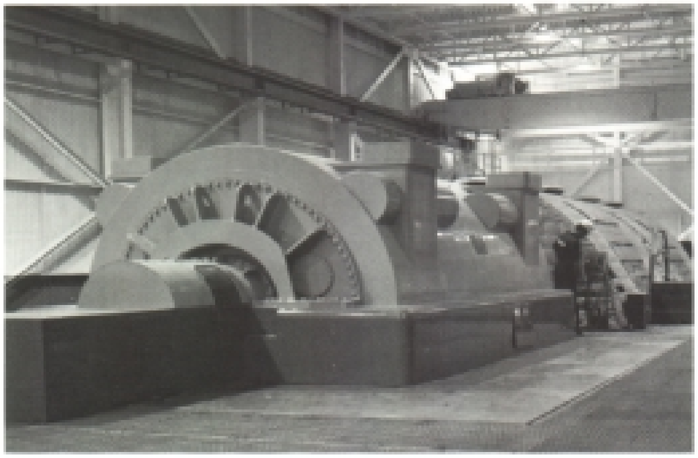
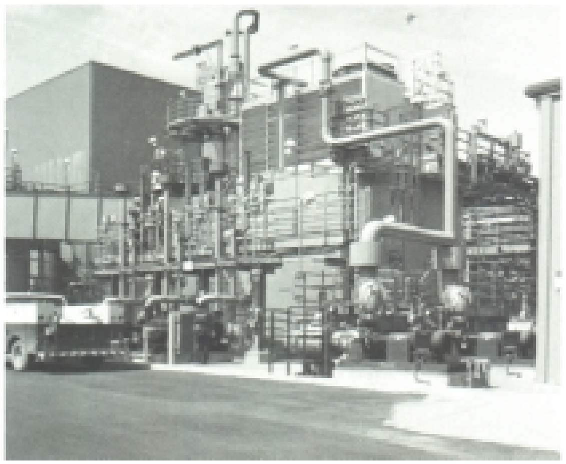


Larger turbine-generators are also needed to run newer plants. This one is in Unit 17.

This new design maximizes the H_2S "partition," the proportion of gas removed directly from the condenser.

The Stretford Process

The Stretford plants at The Geysers scrub the condenser vent gas with a vanadium solution converting the H_2S to high quality, molten elemental sulfur. It is therefore desirable to send most of the H_2S to the Stretford plant for treatment. This had to be done by maximizing the H_2S levels in the condenser exhaust rather than allowing the odorous gas to dissolve in the condensate. The earlier power plant designs that used direct contact condensers, like Unit 1, allowed up to 40 percent of the H_2S to dissolve in the cooling water. In such an installation this amount would have escaped treatment in the Stretford plant. This situation, of course, would have been unacceptable. Starting with Unit 13 the power plants were redesigned replacing the direct contact condensers with surface condensers. The new design maximizes the H_2S "partition," the proportion of the gas removed directly from the condenser. This could be accomplished because the flow of the condensate is significantly lower than the flow of cooling water. The surface condenser therefore has much less water inside than the direct contact condenser to dissolve the H_2S. To serve the requirements of the surface condenser, all the pumps and the pump circuits were redesigned. The Stretford system has proved to be an effective method of H_2S abatement at The Geysers.



PG&E's challenge in the early 1970's was to develop a method to reduce H_2S emissions. The answer lies in the Stretford process. Shown here is the Unit 18 Stretford plant.

Expanded geothermal development

Since tiny Unit 1 began operation in 1960, the engineers who turn geothermal steam into geothermal energy have learned much and are prepared to continue to face the challenges of geothermal power production.

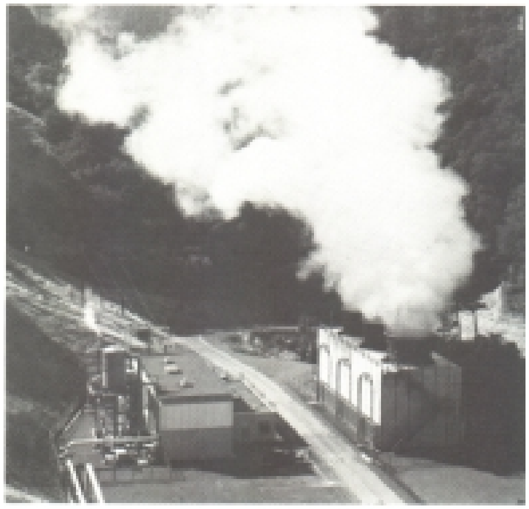
Today, PG&E's geothermal plants are more than ten times the size of Unit 1, and the company is continuing to expand geothermal development at The Geysers.

In early 1985, PG&E had 17 geothermal units in operation, with two more, Units 16 and 20, at 120 megawatts each, scheduled to be completed later that year, for a total generation of almost 1.4 million kilowatts.

On the drawing boards, PG&E engineers are preparing designs for the prototype of a new series of units, larger and more efficient than those built to date. PG&E has already received permission from the California Energy Commission to build what will be the largest geothermal electric generating unit in the world, 151-megawatt Unit 21.

Unit 1: The grandfather

And, while new units begin operation and others remain merely sketches and ideas in the minds of engineers, little Unit 1, the grandfather of geothermal energy in the United States, continues to produce power at The Geysers.



1985 marks PG&E's—and the nation's—25th anniversary of commercial power generation from geothermal steam. It all began with Unit I, pictured shortly after it went into operation.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

The principal goals of ASME are:

- *To provide a forum for the development, exchange and dissemination of technical information, particularly on mechanical engineering.*
- *To develop mechanical engineering standards, codes, safety procedures and operating principles for industry.*
- *To encourage the personal and professional development of practicing and student engineers.*
- *To aid members of the engineering profession in maintaining a high level of ethical conduct.*

The American Society of Mechanical Engineers (ASME) was founded in 1880 as an educational and technical society. ASME has consistently sought to provide an impetus for the continuing professional development of its individual members and advancement of state-of-the-art mechanical engineering.

The Society consists of more than 120,000 members, of whom 20,000 are engineering students. ASME members are active in private engineering firms, corporations, academic and government service. A ten-member board governs the Society. Its headquarters are in New York City and it has five field offices: Chicago; Dallas; San Francisco; Danbury, Connecticut; and Burke, Virginia, plus a government relations office in Washington, D.C.

THE HISTORY AND HERITAGE PROGRAM

The History and Heritage Landmark Program of ASME began in September 1971. To implement and achieve the goals of the landmark program, ASME formed a History and Heritage Committee, composed of mechanical engineers, historians of technology and a curator of mechanical engineering from the Smithsonian Institution who serves in an ex-officio capacity. The committee provides a public service by examining, noting, recording and acknowledging mechanical engineering achievements that were significant in their time.

The program, as with any study or record of history, illuminates our technological heritage. It also serves to encourage the preservation of the physical remains of historically important works; provides an annotated roster of landmarks for engineers, students, educators, historians and travelers; and calls attention to our industrial past. By dedicating mechanical engineering landmarks, we are establishing persistent reminders of where we have been, where we are and where we are going along the divergent paths of discovery.

Mechanical engineering accomplishments that are proclaimed landmarks fall into three categories: regional, national and international. International landmarks have been given this status because they represent a technology that has had a broad geographical influence.

Such artifacts are designated in the United States as well as in other countries, recognizing either American contributions that have influenced foreign technology or vice versa.

Mechanical engineering landmarks are characterized by being unique, first ever, oldest extant, last surviving examples of once widely used types of works or possessing some other important distinction.

Of a total of 109 ASME Regional, National and International Historic Mechanical Engineering Landmarks, the PG&E Geysers geothermal generating facility is the 82nd National Historic Mechanical Engineering Landmark to be designated since the program began in 1973.

For a complete list of the Society's Landmarks and information about the ASME History and Heritage Program, please contact:

The Public Information Department, ASME
345 East 47th Street
New York, NY 10017
(212-705-7740)

ACKNOWLEDGEMENTS

The San Francisco Section of the ASME gratefully acknowledges the efforts of all who participated in the landmark dedication of the largest domestic geothermal electrical power generating facility, particularly the officers and staff of Pacific Gas and Electric Company in San Francisco. A special thanks to Mr. Lee Ezzell and Mr. John Laszlo of PG&E for providing much of the documentation necessary to make this occasion a reality.

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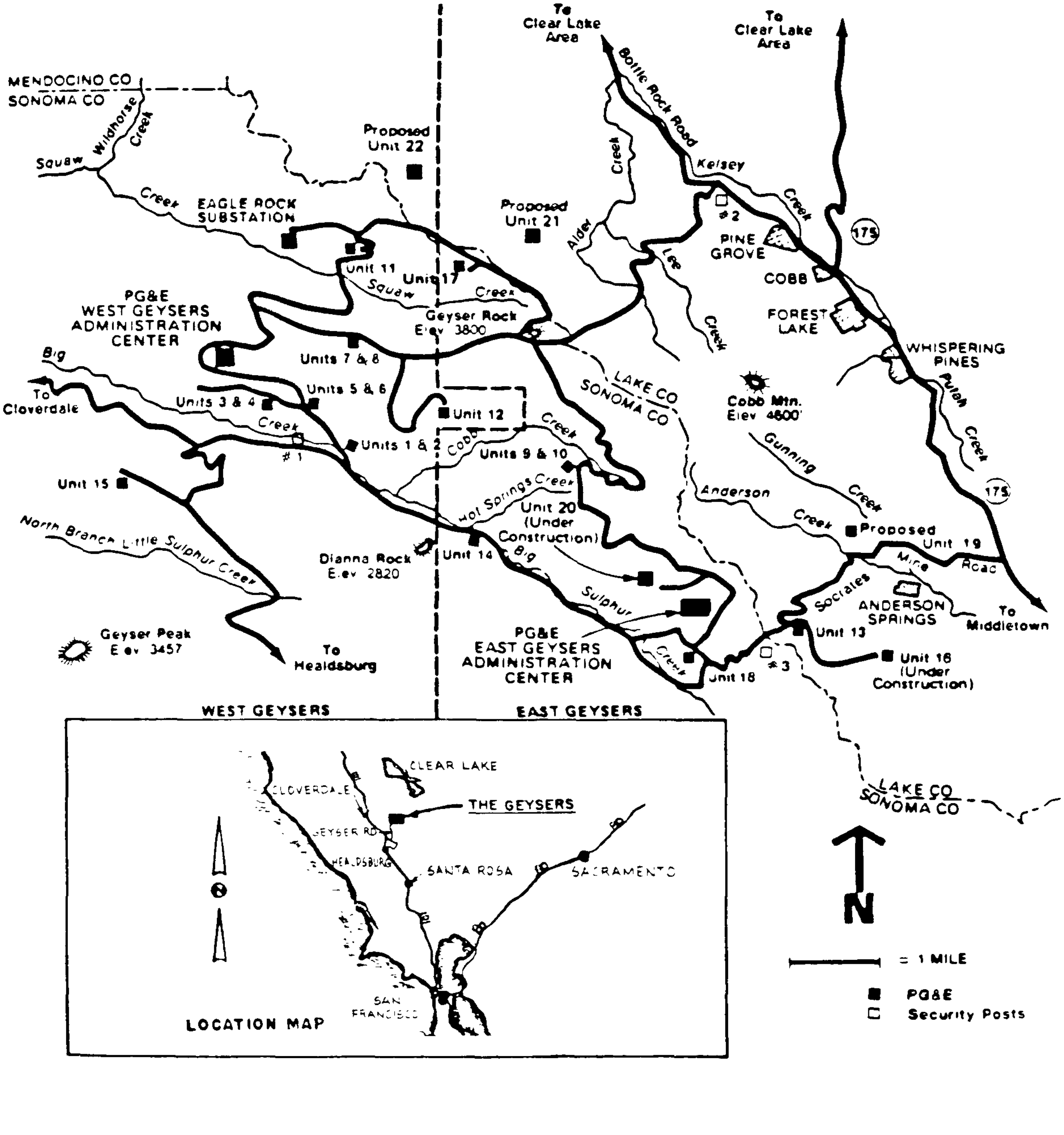
PACIFIC GAS AND ELECTRIC COMPANY

The success of Unit 1 and PG&E's entire geothermal program at The Geysers was made possible by the talent and dedicated hard work of hundreds of the company's employees over the past 28 years. It is probably not possible to list all the names here but this award is a tribute to each of them.

Unit I, the grandfather of geothermal energy in the United States, continues to produce power at The Geysers. Today it sits in its hillside home next to Unit II.

Map of The Geysers Area

Pacific Gas and Electric Company



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