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# DEVELOPMENT OF THE THERMAL SHALLOW RESERVOIR

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## ABSTRACT

The Geysers was discovered in 1847, and its therapeutic mineral baths were widely recognized by 1880. It was not until 1921, however, that the first steam well at The Geysers was drilled. Between 1922 and 1925, eight additional wells were drilled and tested as reported by Allen and Day[1]. Development activity ceased until 1955 when Magma Power Company drilled the first "commercial' well. This success led to additional drilling in the Thermal Shallow Reservoir and the commissioning of a 12 MW power plant in September 1960, followed by a 14 MW power plant in February, 1963. This completed the commercial development of the Thermal Shallow Reservoir.

## INTRODUCTION

The Geysers geothermal field is roughly 80 miles north of San Francisco in the Mayacmas Mountains of the Coast Range. The Thermal Shallow Reservoir was the site of the first resource development at The Geysers. It underlies an area of active surface manifestations, characterized by numerous fumaroles and hot springs as well as extensive hydrothermal rock alteration. It was this thermal activity that led developers to explore fot geothermal energy for electrical power generation.

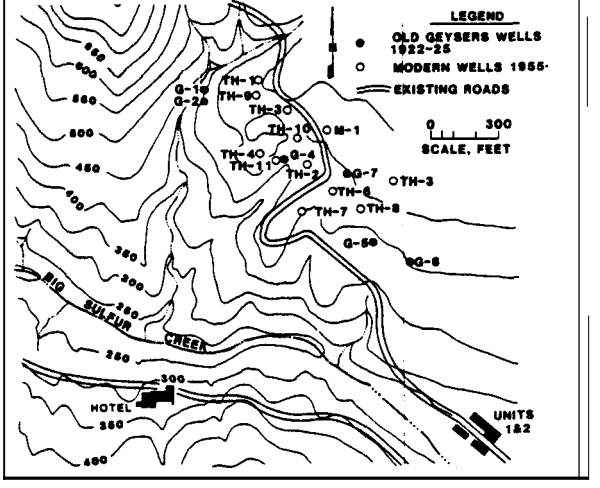
## EARLY DEVELOPMENT (1921-1925)

J.D. Grant began drilling for commercial steam in the summer of 1921. After completing his first shallow well, the wellhead valve was closed and the casing blew out of the ground. The well was then abandoned. The following summer his next well, Geysers 1, was drilled to a depth of 203 feet. The first 80 feet of drilling penetrated landslide material before reaching the graywacke reservoir rock. An 8-inch steel casing was lowered and 'anchored. in place by pouring molten zinc around the pipe which 'congealed and furnished a firm and tight joint."[1] After completion the static wellhead pressure was recorded at 62, psig. A second well was spudded within 50 feet of the first well in October, 1922. Geysers 2 took 275 days to complete at a total depth of 318 feet and a static wellhead pres- sure of 61 psig. Steam from the first well was used to furnish power for drilling the second well. The first geothermal interference test at The Geysers (and maybe the world) was condudted when it, was noted that "notwithstanding that the wells were so close together, the pressure of neither seemed to be affected by the discharge of the other."[1] In 1924, one more well, Geysers 3, was attempted, but was abandoned at 154 feet.

In 1925, the Diamond Drill Contracting Company of Los Angeles, using rotary equipment, drilled wells 4 through 8. The depth of these five wells ranged from 400 to 650 feet. Static pressures were between 107 and 276 psig.

FIGURE-1

**THERMAL SHALLOW RESERVOIR WELL LOCATION MAP FROM ALLEN AND DAY[1]**



There was extensive chemical and flow testing of wells 4, 5, 6 and 7 as reported by Allen and Day[1]. They found that there was sufficient deliverability for 4500 kW, but a commercial power plant was never installed due to the remote location and the availability of cheap hydroelectric power throughout the state.

## COMMERCIAL DEVELOPMENT (1955-1963)

B.C. McCabe organized the Magma Power Company and drilled the Magma 1 well in 1955. This commercial discovery pro- duced over 180,000 lbs/hr at 100 psig wellhead pressure. Magma Power then formed a partnership with the Thermal Power company and drilled eleven more wells, Thermal 1 through 11 between 1957 and 1959. All of these wells except one reached a total depth between 500 and 1000 feet. The major steam producing interval in the Thermal shallow Reservoir found consistently between 500 and 600 feet vertical depth.

In 1957, development drilling began with the first three wells with less than spectacular results. Table 1 presents the flowrates for the Thermal Shallow Reservoir wells as tested in January 1960. Thermal 4 blew out with an estimated flowrate about 300,000 lbs/hr. Subsequent kill attempts failed to control the flow of steam and eventually Thermal 11 was successfully drilled as a relief well, reducing the flow from Thermal 4. Development continued with Thermal 5, completed in September, 1957.

In December, 1957, flow tests were performed on Magma 1 and Thermal 1, 2 and 5. On the basis of these tests, a steam sales agreement was signed on July 16, 1958 with Pacific Gas and Electric Company. On September 28, 1960, PGandE Geysers Power Plant No. 1 was declared commercial. The turbine-generator, a General Electric unit, was salvaged from the scrap yard. It had been originally installed in 1924 to provide power for Sacramento's streetcar system[2]. It was modified for geothermal steam by removing the first three stages of the nine-stage turbine and increasing the size of the flow path through the last two stages. The inlet steam conditions were specified at 100 psig and 348 °F.

Drilling resumed in 1959 with Thermal 6 through 11. These wells developed sufficient deliverability to justify the construction of PGandE Geysers Power Plant No. 2. This plant, a 14 MW Elliot turbine-generator was designed to be compatible with the low-pressure, slightly-superheated resource. The designed turbine inlet pressure is 40 psig. Unit No. 2 began commercial operation on February 19, 1963.

TABLE-1

### THERMAL RESERVOIR WELL PRODUCTIVITY

| Well | Pressure psig | Flowrate lbs/hr | Total Depth, ft | Well Status on 1/1/60 | Well Status on 12/31/81 |
|---|---|---|---|---|---|
| Magma 1 | 101.5 | 144,200 | 602 | Producer | Producer |
| Thermal 1 | 100.0 | 11,700 | 523 | Noncommercial | Noncommercial |
| Thermal 2 | 78.5 | 27,900 | 537 | Noncommercial | Noncommercial |
| Thermal 3 | — | — | 1,404 | Dry | Plugged & Abandoned |
| Thermal 4 | Atm | 250,000 (est.) | 523 | Blowout | Blowout |
| Thermal 5 | 118 | 50,000 | 747 | Producer | Plugged & Abandoned |
| Thermal 6 | 80 | 36,000 | 858 | Noncommercial | Noncommercial |
| Thermal 7 | lle | 34,000 | 966 | Producer | Producer |
| Thermal 8 | 110 | 70,000 | 1,000 | Producer, but Wet | Injector |
| Thermal 9 | 107.5 | *36.700* | 775 | Producer | Suspended |
| Thermal 10 | 101 | 138,000 | 936 | Producer | Producer |
| Thermal 11 | 99 | 137,400 | 528 | Producer | Producer |

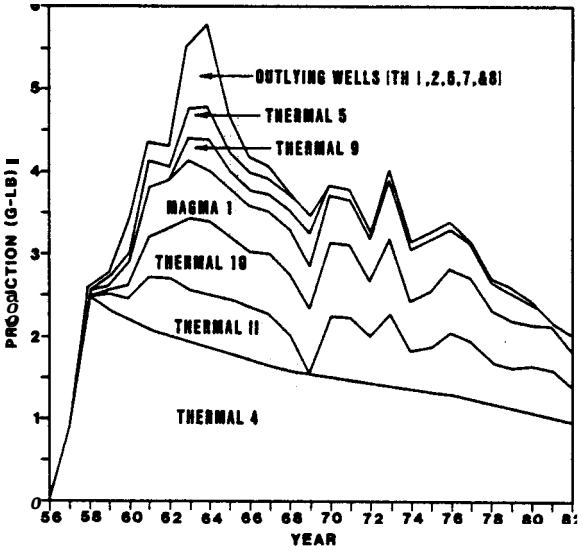
## FIELD OPERATIONS (1963-1981)

Three additional wells were drilled in 1963, Thermal 12, 13 and 14, and production operations proceeded without any major problems. As the pressure in the Thermal Shallow Reservoir declined the primary steam producing wells to Unit 1, Thermal 7, 13 and 14 were recompleted in the deeper, high-pressure reservoir. Magma 1 and Thermal 9, 10 and 11 continued to produce exclusively to Unit 2. At the end of 1981, of the 23 wells drilled in the Thermal Shallow Reservoir, two wells were converted to injectors (Thermal 8 and 12) and nine wells were abandoned (Thermal 3, 5, 9 and 13 and Geysers 1, 2, 3, 6 and 8). Six wells were idle due to low productivity (Geysers 4, 5 and 7 and Thermal 1, 2 and 6). Thermal 14 was suspended and Thermal 4 was still flowing uncontrolled. By the end of 1981 a total of 89.6 billion pounds of steam had been produced from the Thermal Shallow Reservoir. Almost 45% or 40.5 billion pounds was vented through Thermal 4.

It is desirable to control Thermal 4 both from environmental and resource management considerations. However, our understanding of the Thermal Shallow Reservoir was not complete enough to properly evaluate different options. This led to the initiations of an extensive reservoir study in 1982[3] and the ultimate drilling of a relief well in 1983[4].

FIGURE-2

**ANNUAL STEAM PRODUCTION FROM THE THERMAL SHALLOW RESERVOIR**




## SUMMARY

Like many other geothermal projects around the world, development at The Geysers began in an area of extensive surface manifestations. Drilling in the 1920's did not result in a commercial project but it did establish the existence of the highly productive Thermal Shallow Reservoir. Production from this reservoir continues to date both through the Thermal 4 blowout and the producing wells to Geysers Power Plant No. 2, a combined production of about 300,000 lbs/hr. Despite its limitations, it was the performance of the Thermal Shallow Reservoir that convinced PGandE that there was a future for geothermal in their base-load energy mix, which has led to the subsequent development of The Geysers.

## REFERENCES

1 Allen, E.T. and Day, Arthur L., 'Steam Wells and Other Thermal Activity at 'The Geysers' California', Carnegie Institution of Washington, 1927.

2 Bruce, A.W. and Albritton, B.C., 'Generation of Power from Geothermal Steam at The Geysers Power Plant,' presented at the ASCE Convention, February 9-13, 1959.

3 Mogen, P.G., Pittinger, L.F. and Magers, M.A., "1982 Thermal Reservoir Testing,' Proceedings for the Tenth workshop on Geothermal Reservoir Engineering, Stanford, California, January 22-24, 1985.

4 Mogen, P.G. and Maney, J. 'The Thermal 15 Relief Well,' Proceedings for the Tenth Workshop on Geothermal Reservoir Engineering, Stanford, California, January 22-24, 1985.