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THE THERMAL 15 RELIEF WELL AND PRODUCTION PERFORMANCE OF THE THERMAL SHALLOW RESERVOIR

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ABSTRACT

Thermal 15 was drilled in November, 1983, to a TD of 700 feet. A steam entry encountered at 490 feet was found to communicate with the high-permeability upflow zone of the Thermal Shallow Reservoir. A low-flow-rate, higher-pressure steam entry at 600 feet was not detected while drilling but was indicated during a subsequent spinner survey.

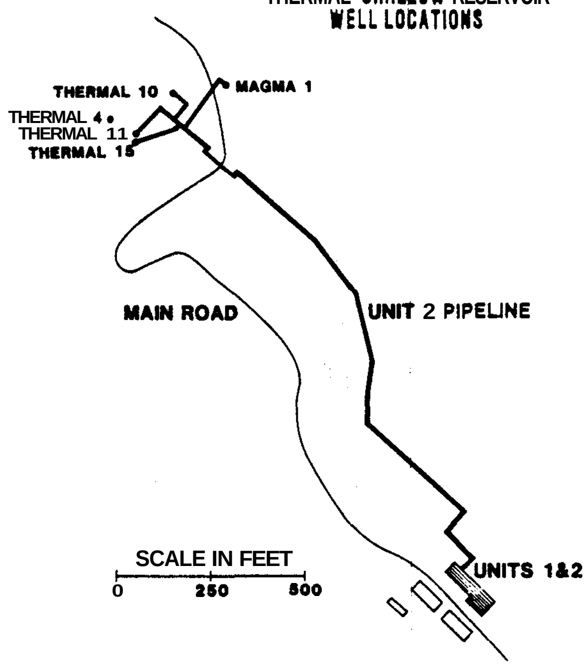
The pressure, flowrate, and enthalpy of the five wells completed in the upflow zone, including the Thermal 4 blowout, were monitored and recorded over a four month period before, during and after Thermal 15 was drilled. It was found that the Thermal 4 blowout communicates with the upflow zone of the Thermal Shallow Reservoir, the Thermal 4 flowrate is controlled by the shallow reservoir pressure, and the high permeability of the upflow zone allows such strong interference effects that three of the four commercial production wells will maximize production from this reservoir. A simple model was developed which describes the pressure-production characteristics of the reservoir over the normal range of operating conditions.

INTRODUCTION

The Thermal Shallow Reservoir was the site of the first development for The Geysers steam field. Steam has been produced from this reservoir over an area of approximately twenty acres, but sustained commercial production has been maintained in a relatively small, central area of about five acres. The locations of wells in this central area are shown in Figure 1 and include Magma 1, Thermal 4, Thermal 10, Thermal 11 and Thermal 15. Thermal 15, completed in 1983, is the only well drilled into the Thermal Shallow Reservoir since 1963.

The Thermal Reservoir has been studied extensively. Published analyses are

FIGURE I
THERMAL SHALLOW RESERVOIR
WELL LOCATIONS



provided in Allen and Day (1927), and Lipman, et. al. (1978). The most comprehensive reservoir study was performed in 1982, as reported by Mogen, et. al. (1985). They found that the Thermal Shallow Reservoir is a convection cell with upflow from the main Geysers reservoir into the commercially productive zone, and with condensation occurring in the outlying portions of the reservoir. Testing in 1983 concentrated on the pressure-production characteristics of the commercial zone. Five wells were monitored over a four month period before, during and after drilling of Thermal 15: the three commercial wells (Magma 1, Thermal 10 and Thermal 11), the new well Thermal 15, and the Thermal 4 blowout. The wells were monitored for wellhead pressure, differential pressure across an orifice and flowing steam temperature.

THERHAL 15 - STEAM ENTRIES AND DRILLING DATA

Thermal 15 was spudded on 11/21/83, and completed on 12/5/83. A casing schematic and formation cross section are shown in Figure 2. The bottom of the serpentine Thermal landslide discussed by Vantine (1985) was reached at 170 feet. Graywacke bedrock was drilled from that point to the 700 feet TD. Thermal 15 was directionally drilled to pass as close as possible tc the source of the Thermal 4 steam. The cross section in Figure 3 shows that Thermal 15 passed within 15 feet of the most probable bottomhole location of Thermal 4. The true location of the Thermal 4 wellbore is not known, so the wellbore shown is vertical from the most probable location of the original wellhead.

A steam entry which communicates with the Thermal Shallow Reservoir was encountered at 490 feet and was indicated by a 35 psi increase in air compressor circulating pressure. Communication of Thermal 15 with Magma 1, Thermal 10 and Thermal 11 was established by decreases in their shut-in wellhead pressures of 5 to 7 psi and with Thermal 4 by a decrease in flowrate from 161,000 to 154,000 lb/hr.

FIGURE 2
THERMAL 15 DRILLING DATA

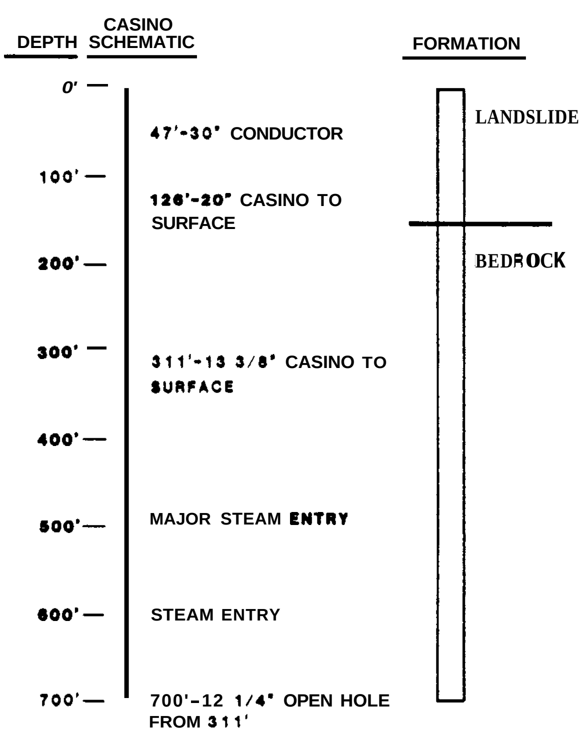
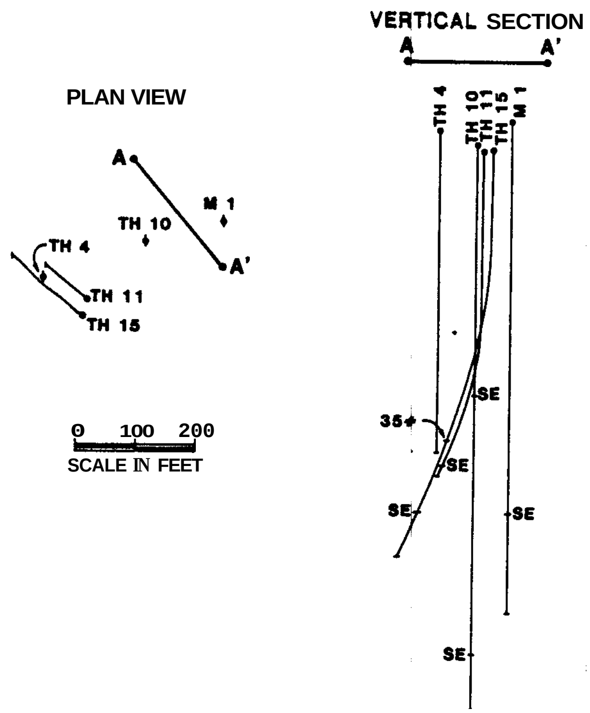


FIGURE 3
THERMAL 15 WELLCOURSE



No further steam entries were recorded while drilling. A second steam entry at 600 feet was found, however, by a spinner survey conducted after the well was completed. The entry at 600 feet appeared to supply about 25% of the 60,000 lb/hr produced by Thermal 15 during a flowing survey. A static survey showed crossflow out of the 600 feet entry and into the 490 feet entry. This crossflow implies higher steam pressure at 600 feet than at 490 feet, and provides additional evidence of vertical steam flow from the deeper main reservoir into the Thermal Shallow Reservoir (Mogen, et. al., 1985) in the vicinity of Thermal 4.

THERMAL 15 PRODUCTION

Thermal 15 was first produced to Unit 2 on 1/11/84. Magma 1, Thermal 10 and Thermal 11 were already on production. Figure 4 shows the flowrates and pressures prior to and during this flow period. Table 1 is a brief summary of the flowrate information.

Thermal 15 immediately decreased the flowrates from the other yells. Table' 1 indicates that at most 13,000 lb/hr or about 20% of Thermal 15 flowrate was increased production from the Thermal Shallow Reservoir.

TABLE 1

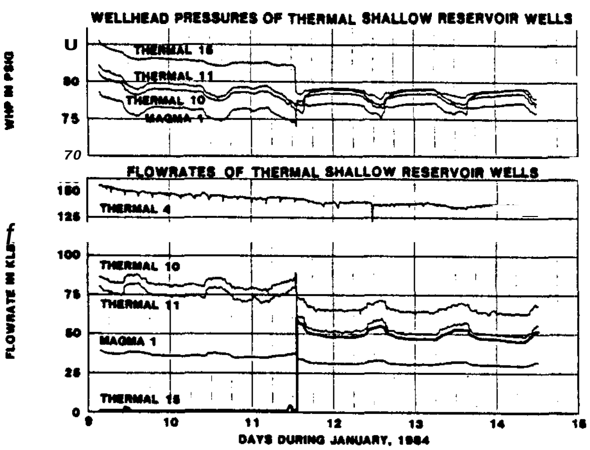
Effect of Thermal 15 on Thermal Shallow Reservoir

Date	Thermal 15 Flowrate (lb/hr)	Average Pressure (psig)	Total Flowrate (lb/hr)
1/11/84	0	78	202,000
1/12/84	58,000	77	215,000
1/18/84	51,000	77	203,000

The data from 1/18/84 indicate virtually no increase in production from the Thermal Shallow Reservoir resulting from Thermal 15. The total production rate throughout this period was slightly higher than normal due to the fact that the wells had been shut-in for ten days prior to being put on production and thus were still experiencing the effects of the buildup.

Thermal 15 apparently also had little effect on the Thermal 4 flowrate. The Thermal 4 flowrate had declined about 10,000 lb/hr from 1/11/84 to 1/18/84 but Figure 4 clearly shows that the decline trend was established before Thermal 15 was put on production and was dependent on the total extraction rate from the Thermal Shallow Reservoir and not from Thermal 15 specifically.

FIGURE 4
THERMAL SHALLOW RESERVOIR
RESPONSE TO THERMAL 15 PRODUCTION



UNIT 2 LOW PRESSURE OPERATION

On 12/22/83, a piping configuration change at PGandE Unit 2 power plant resulted in an inlet pressure reduction from 76 to 64 psig. The Unit 2 wells responded by increasing their total flowrate by 50,000 lb/hr. Thermal 4 decreased 8,000 lb/hr.

Figure 1 shows the Unit 2 pipeline configuration. The power plant inlet pressure was measured in the Unit 2 pipeline just outside the pbwer plant. Approximately 1800 feet of pipeline between the wells and Unit 2 accounts for a significant amount of friction pressure loss. The 12 psi drop in turbine inlet pressure resulted in a 6 psi decrease in wellhead producing pressure, the remainder was lost to increased friction. Figure 5 shows the wellhead pressure and flowrate data for approximately one week after the decrease in Unit 2 turbine inlet pressure. It is clear that the increased production from the Unit 2 wells resulted in a measpreable decrease in the Thermal 4 flowrate.

Table 2 is a summary of the Unit 2 pressure-production response. Average wellhead pressure is the mean of the Unit 2 wells' pressures and the total production is the sum of the flowrates for the three wells.

TABLE 2

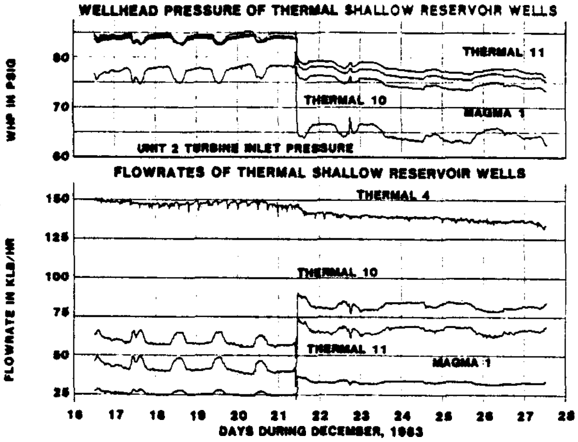
Response to Decrease in Unit 2 Pressure

Date	Unit 2 Pressure (psig)	Average WHP (psig)	Total Production (lb/hr)	Thermal 4 Flowrate (lb/hr)
12/21/83	76	83	136,000	148,000
12/23/83	64	77	187,000	140,000
12/28/83	62	75	197,000	135,000

FIGURE 5

THERMAL SHALLOW RESERVOIR

RESPONSE TO DECREASED UNIT 2 TURBINE INLET PRESSURE



It was found that a change of 8,000 lb/hr in steam production from the Thermal Shallow Reservoir results from each psi of change in producing pressure over the normal range of operating wellhead pressures. Unfortunately, the Thermal 4 flowrate decreases by only 1,000 lb/hr for each psi decrease at the producing wells. Although the total production rate from the Thermal Shallow Reservoir at a given pressure varies depending on the recent producing history, the data in Table 2 is representative of normal production rates.

MECEANICS OF THE THERMAL SHALLOW RESERVOIR

The Thermal Shallow Reservoir is a complex convection system but the essentials of the pressure-production behavior of the reservoir can be modelled simply as shown in Figure 6. Shown are four pressures and three arrows representing flowrates. Flowrate along any of the three paths is proportional to the pressure differential between the beginning and end of the flow path and the permeability of that path. If it is assumed that the three permeabilities are both very large and remain constant, and **P(atm)** and P(deep zone) are also constant, then it becomes apparent that the only controllable variable, P(Unit 2 turbine), will have an impact on steam production to the power plant, but will have very little effect on the Thermal 4 flowrate.

CONCLUSIONS

Drilling Thermal 15 and the subsequent testing of the Unit 2 production system found that:

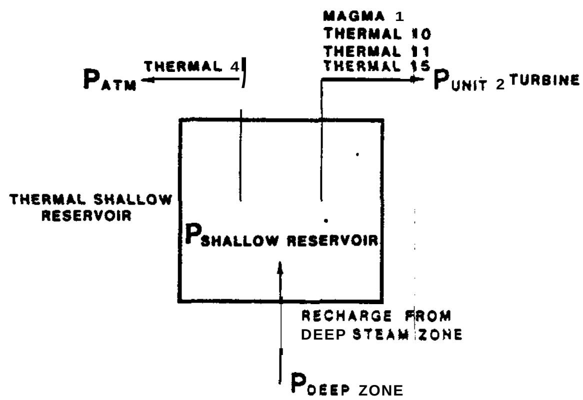
1) The Thermal Shallow Reservoir has achieved a pressur@-production equilibrium that can only be altered by changes in the main reservoir pressure, P(deep zone); the producing pressure, P(Unit 2 turbine); or the Thermal 4/Shallow Reservoir flow path.

2) Any three of the four Unit 2 wells will extract steam from the Thermal Shallow Reservoir at the maximum rate, i.e., production from the Thermal Shallow Reservoir is not wellbore limited.

3) Due to the highly permeable nature of the reservoir and the upflow zone, additional relief wells will not reduce the discharge through Thermal 4.

FIGURE 6

THERMAL SHALLOW RESERVOIR MECHANICS



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