TWO SHORT-TIME BUILDUP TEST ANALYSES FOR SHELL'S GEYSERS WELL D-6, A YEAR APART

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ABSTRACT

Pressure transient tests of Shell's geothermal Well D-6 were conducted in the Summer of 1978 and again in early Summer of 1979. On both occasions a pressure buildup test followed a short drawdown period. Analysis of the pressure data resulted in the calculation of the permeability-thickness product, the skin effect and the initial reservoir pressure. This paper presents the analysis that led to the calculation of these reservoir parameters. There is reasonable agreement between the two tests while observed changes were in the expected direction. The reduced data revealed a well that is within the norms of the Geysers area.

INTRODUCTION

Shell spudded its first geothermal well in the Geysers area, Well A-1, on October 26, 1974. Although that well was a dry hole, a number of producers have been completed since then. Testing of these wells points to a prolific and well-behaving reservoir. Well D-6 is located roughly at the middle of Shell's activity. During drilling, graywacke was penetrated at 3550 feet, below a melange unit. A minor steam entry, probably wet, was encountered at 3915 feet. The first major steam entry was at 4153 feet (20,000 lb/hr). Three additional steam entries were encountered between 6505 feet and 7130 feet. With a TD of 8030 feet the well was tested at 104,500 lb/hr using a 8-3/4" orifice. Figure 1 represents a schematic diagram of the well. In June, 1978, the well was tested at 132,000 lb/hr (8-3/4" orifice). Following a flow period of 9.75 hours the pressure buildup was recorded for the next 2.75 hours. A similar test was conducted in May, 1979. This time the well produced for 11 hours at 166,000 lb/hr using a 6" orifice. The subsequent pressure buildup was recorded for 5 hours.

The data reduction utilized established techniques. The development by Horner[1] formed the basis of this analysis while Ramey's[2] anthology and rationale permeated the thinking process. The skin effect was calculated via the Van Everdingen and Hurst[3] method.

DISCUSSION

The first and foremost exercise in well test analysis is to graph the pressure versus time data on log-log paper. The subject has been extensively treated by Ramey[4] and Agarwal, Al-Hussainy and Ramey[5]. The plots here are strictly treated as a diagnostic tool. Their utility is limited to the identification of the start of a semi-log straight line. A log-log plot may pinpoint wellbore storage effects in the shape of an early time straight line with a 45° slope. A feature of many geothermal reservoirs, large fractures penetrating the wellbore, can be identified by the presence of a straight line with a slope of 1/2.

There are two empirical "rules of thumb" that can be used for finding the start of the semi-log straight line. In the absence of a fracture, this point is approximately 1.5 log cycles removed from the cessation of wellbore storage effects. In the presence of a fracture, one may use the "Double ΔP" rule, which dictates that the start of the semi-log straight line is at a point where the pressure difference is twice the ΔP at the deviation from the 1/2 slope. It has been the experience of these writers, that in those cases that the data seems to include both storage and fracture, the start of the semi-log straight line falls roughly on the same point, irrespective of the criterion used. This is significant since the same field data may be interpreted as 1/2 slope or transition.

Figures 2 and 3 represent log-log plots of the pressure buildup data for Well D-6 in 1978 and 1979 respectively.

Since the fluid is saturated steam, the difference of pressure squared is plotted versus time. The start of the semi-log straight line is clearly marked. Both plots give strong evidence of a fracture with a pronounced half slope straight line.

The next step towards analyzing the test is the construction of the Horner buildup graph. Figures 4 and 5 are the Horner plots for 1978 and 1979, respectively. In both cases, following the straight line portion, one may observe that the remaining data are concave upwards and on top of a projected extension of the straight line. This is an indication of a negative skin effect and lends credence to the interpretation that fractures penetrate the well bore.

The equation necessary to calculate the formation permeability thickness product (kh) is given by:

$$kh = \frac{414.3\ W\mu ZT}{m} \qquad (1)$$

where: W = Mass flow rate, lb/hr
μ = Fluid viscosity, cp

Z = Gas deviation factor
T = Absolute temperature, ^oR
m = The slope of the Horner straight line, psi^2/cycle.

Equation (1) was developed during this work to suit geothermal steam wells.

A projection of the Horner straight line to infinite shut in time $((t + \Delta t)/ \Delta t = 1)$, provides the initial reservoir pressure P*. Ordinarily, if other wells operate on the same reservoir or if the latter exhibited any boundaries, the pressure obtained via the Horner method is an "average" pressure. In the case of D-6, though, it can be safely assumed that P* is very close to the initial reservoir pressure.

Finally the skin effect(S) can be calculated by:

$$S = 1.151 \left[\frac{P^2_{1hr} - P^2_{wf}}{m} - \log \left[\frac{k}{\phi \mu c r_w^2} \right] + 3.23 \right] \quad (2)$$

where: ϕ = Formation porosity
c = Total compressibility, psi^{-1}
r_w = Well diameter, feet

The value of P^2_{1hr} is read on the straight line or its extension at a Horner time function corresponding to a shut-in time of one hour.

Table 1 contains the values of the variables relevant to this analysis.

TABLE 1 PRESSURE BUILDUP DATA FOR WELL D-6

SYMBOL	VALUE
W (1978)	132000 lb/hr
W (1979)	166000 lb/hr
r_w	.365 ft
Φh	350 ft (estimate)
μ	.0158 - .0172 cp
c	.0042 - .0023 psi^{-1}
Z	.90 - .846
T	858 - 922° R
Wellhead conditions - saturated	

The results of the calculations appear on Table 2.

TABLE 2 RESERVOIR PARAMETERS FOR WELL D-6

	kh	p*	S
1978	6400	570 psia	-1.9
1979	8800	540 psia	-2.6

Both the skin effect and the kh changes from 1978 to 1979 can be attributed to the channelization and cleanup of passages and fractures. This phenomenon appeared in all the geothermal wells that Shell tested with a time interval of one year. As it appears from the results reported on Table 2, D-6 is a well typical of the Geysers, prolific and predictable.

REFERENCES

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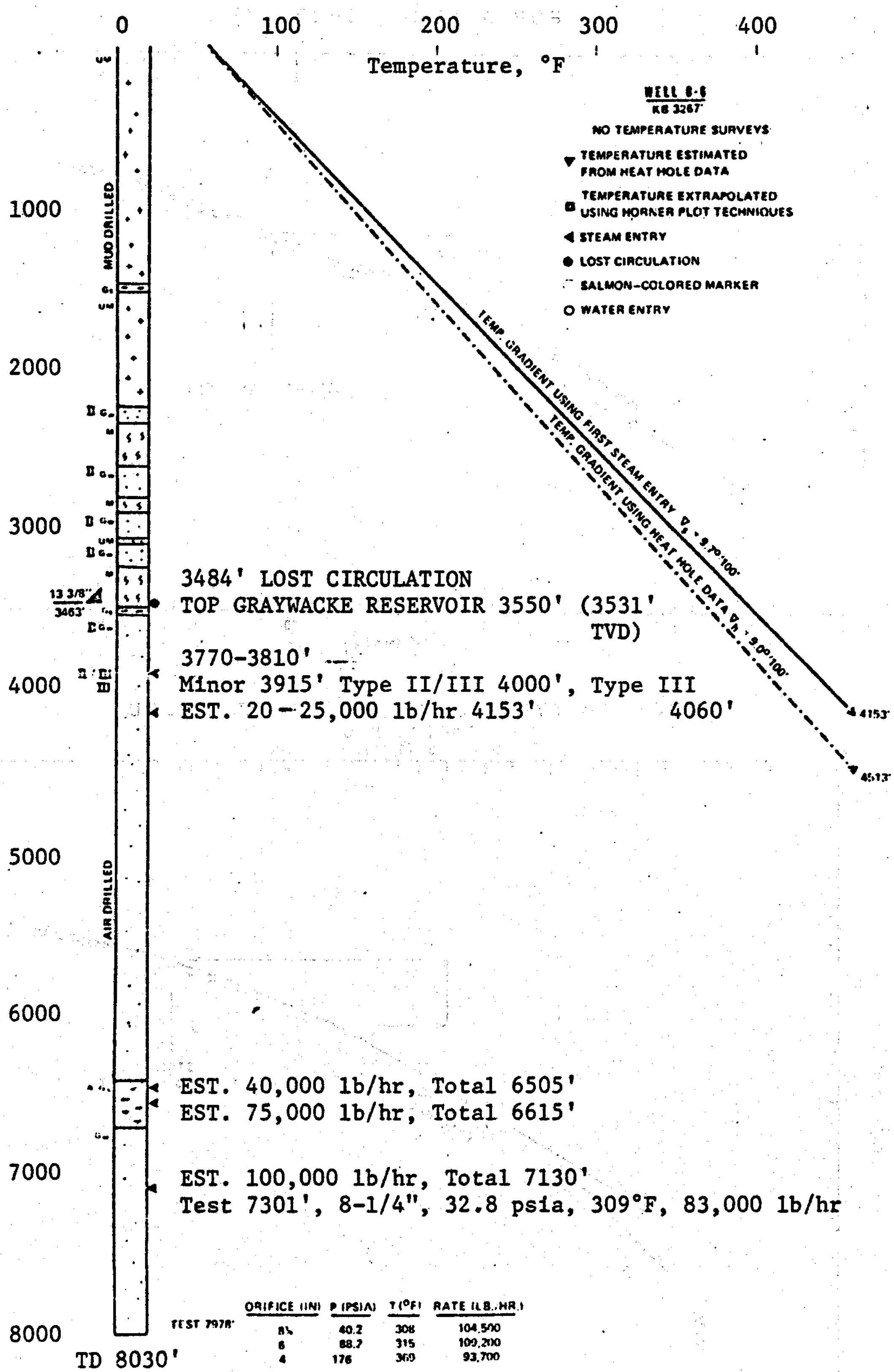
5. Agarwal, R. G., Al-Hussainy, R., and Ramey H. J., Jr., "An Investigation of Wellbore Storage and Skin Effect in Unsteady Liquid Flow - 1. Analytical Treatment"; Soc. Pet. Eng. Jour., Sept. 1970, p. 279.



ORIFICE (IN)	P (PSIA)	T (°F)	RATE (LB./HR.)
8¼	40.2	308	104,500
6	88.7	315	109,200
4	176	369	93,700

FIGURE 1

LOG-LOG PLOT, PRESSURE BUILDUP
FOR WELL D-6(6-22-78)

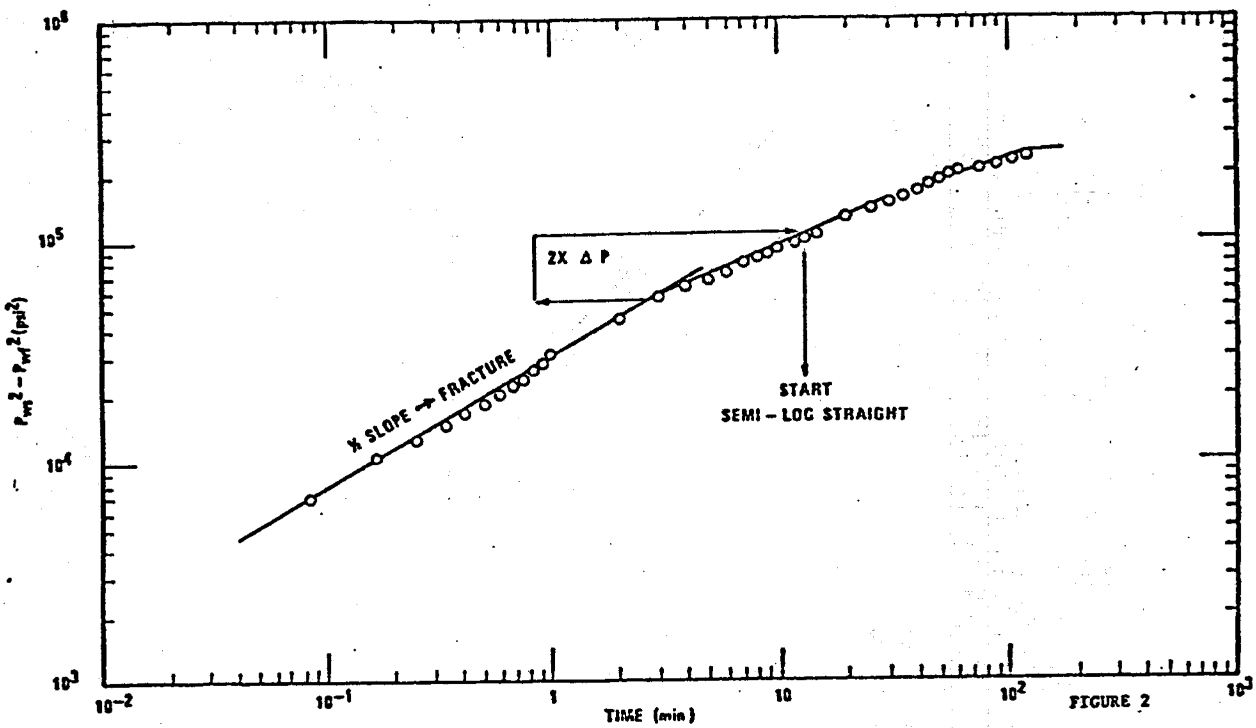


FIGURE 2

LOG-LOG TYPE CURVE, PRESSURE BUILDUP
WELL D-6
(5-15-79)

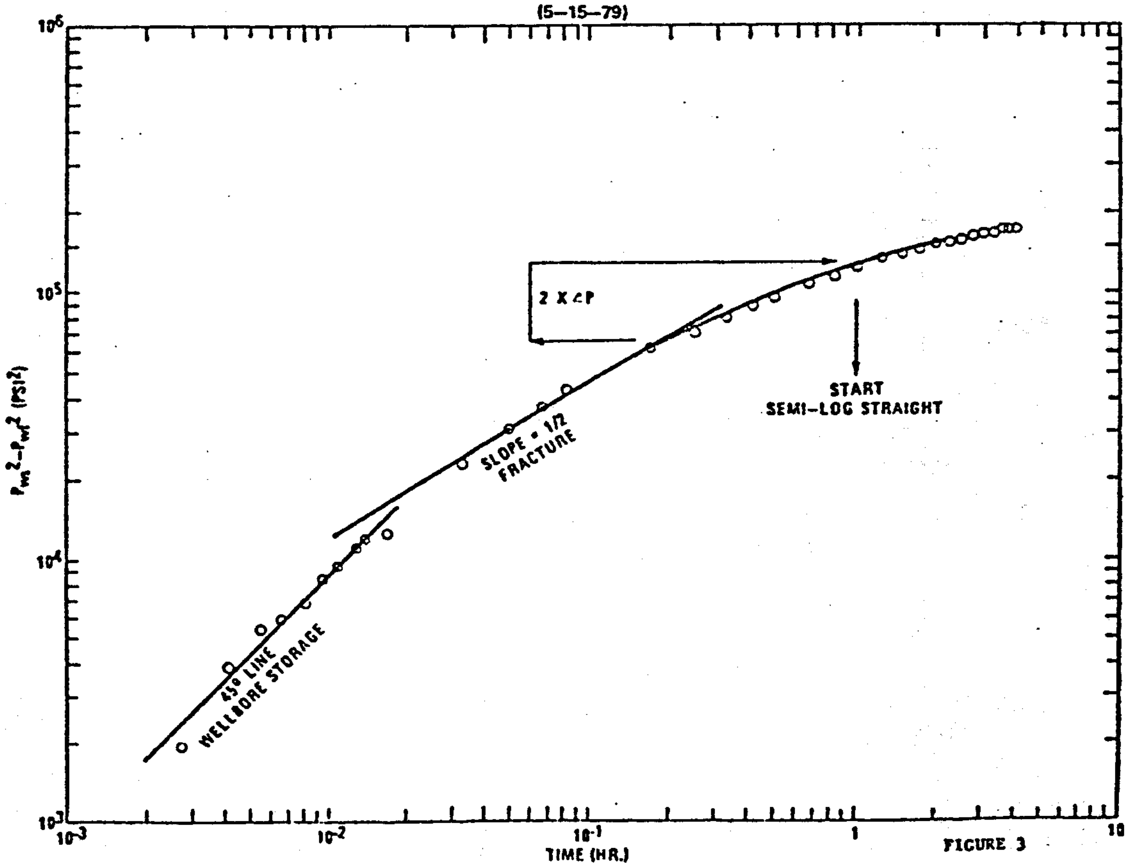


FIGURE 3

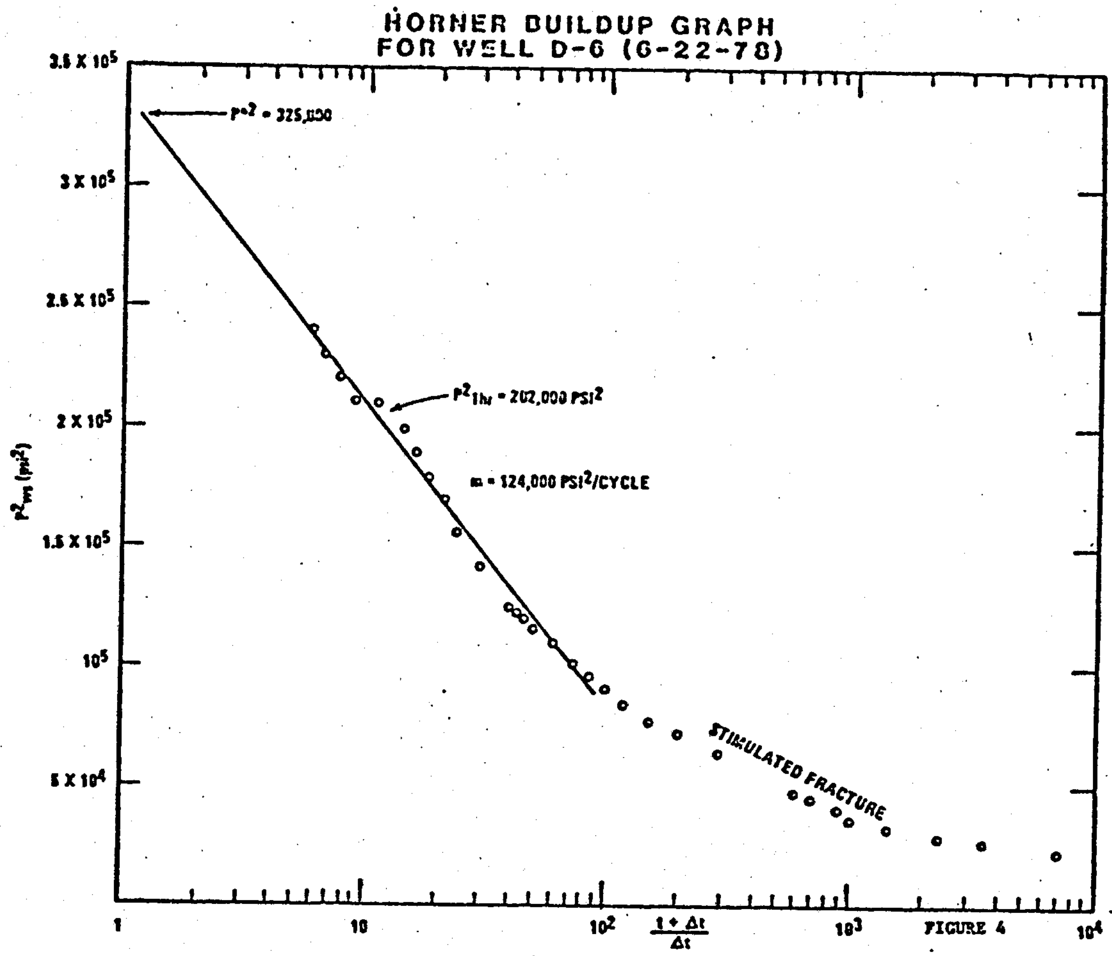


FIGURE 4

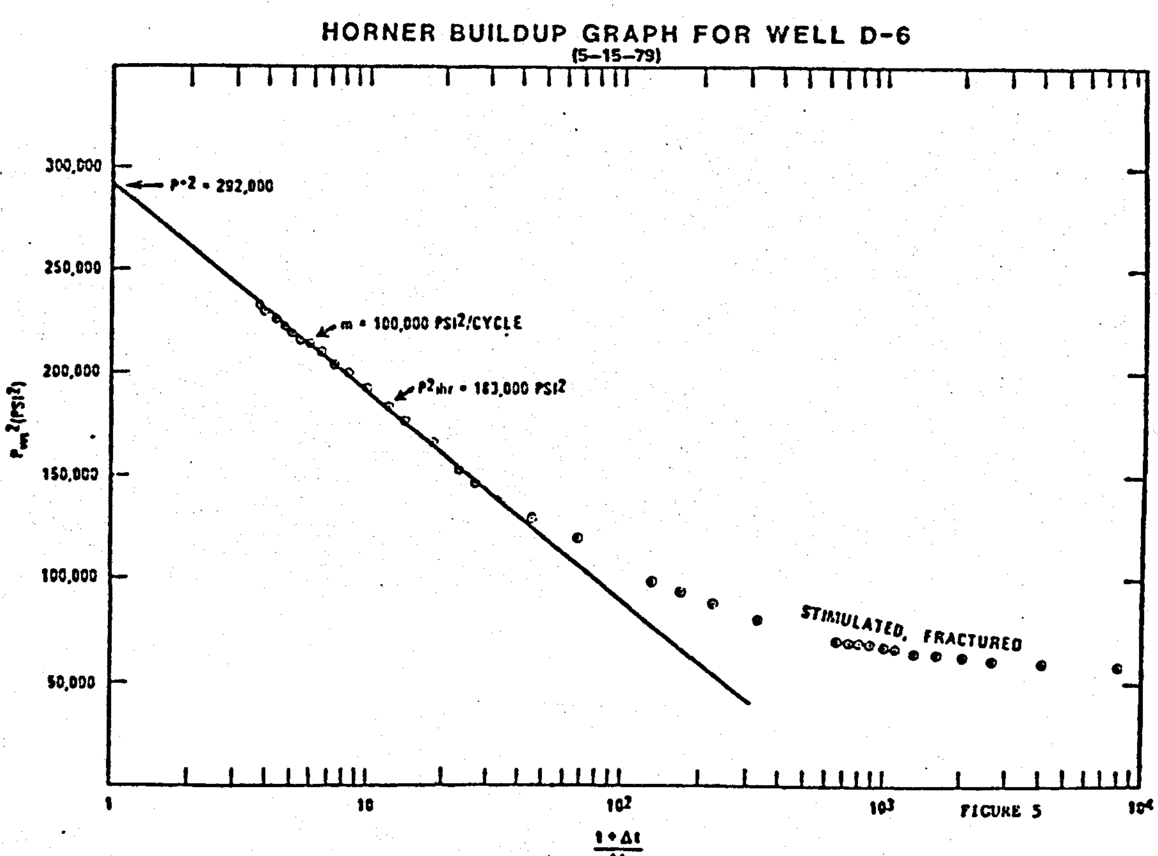


FIGURE 5