PRESSURE BUILDUP TESTS OF WELL CPC-CS-4T, CHINSHUI GEOTHERMAL FIELD

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Well CPC-CS-4T is located in the Chinshui Geothermal Field in the north-east of Taiwan. The first deep well drilled in this area, its total depth is 1,505 m. The well was spudded on April 16, 1976, and completed with 7 in. liner hanger and slotted liner on June 17, 1976. The production hole is from 539 to 1,505 m.

Eight centralizers were used during setting of the 9-5/8 in. production casing in a 12-1/4 in. hole at 529 m. The full casing cement job was performed with silica flour cement, with a slurry weight of 1.60 specific gravity. About 10 kiloliters of cement slurry was flowed out at the surface through the annulus during cementing. This implied that a good cement job had been done.

In drilling the 8-1/2 in. production hole, much lost circulation was encountered. A total of 740 kiloliters of drilling mud was lost between the drilling interval from 724 m to the total depth. The main loss zone was from 750 to 800 m. The weight of the lost mud was between a specific gravity of 1.06 and 1.15.

The reservoir is within the Lushan formation, of Miocene age. The lithologies encountered are all dark gray slate, slightly intercalated with light gray fine-grained to very fine-grained compact sandstone. It is a water-dominated geothermal reservoir.

Temperature and pressure-depth surveys were performed during flow tests. These data were plotted on the phase diagram of water. Flash points between the surface and 230 m were observed clearly. Thus single-phase flow in the reservoir is evident, making the pressure analysis simple.

FIRST PRESSURE BUILDUP TEST

After the well was completed, many kinds of flow tests were performed. A pressure buildup test was performed on October 20, 1976, when a cumulative reservoir fluid of 133,000 tons had been produced.

Table 1 presents the pressure buildup data. The pressure gauge was lowered to 1,500 m, and the wellhead valve was completely closed. Figure 1 graphs pressure increase versus shut-in time on a log-log scale. The initial 45° line shows the after-flow effect. The other part of the flat straight line indicates a probable homogeneous reservoir. The latter part should be used to estimate the flow conductivity, skin effect, and flow efficiency, etc., on a Horner plot.

Figure 2 is a Horner pressure-time semilog plot. From the straight line on the graph:

$$kh = \frac{162.6\ q\mu B}{m} = \frac{(162.6)(20{,}000)(0.14)(1.13)}{49}$$

$$= 10{,}500 \text{ md-ft}$$

$$S = 1.151 \left[\frac{p_{1\,hr} - p_{wf}}{m} - \log \frac{kh}{\phi \mu c_t r_w^2 h} + 3.23 \right]$$

$$= 1.151 \left[\frac{1{,}916 - 1{,}357}{49} - \log \frac{10{,}500}{(0.2)(0.14)(10^{-5})\left(\frac{8.5}{24}\right)^2 (2{,}600)} + 3.23 \right]$$

$$= + 6.6$$

$$\Delta p_{skin} = 0.87\ ms = (0.87)\ (49)\ (6.6) = 281 \text{ psi}$$

$$FE = \frac{p^* - p_{wf} - \Delta p_s}{p^* - p_{wf}} = \frac{1{,}967 - 1{,}357 - 281}{1{,}967 - 1{,}357} = 0.54$$

The porosity and thickness of the geothermal reservoir are not known. We assume porosity to be 20% of the reservoir bulk volume, and the thickness to be 2,600 ft. If porosity were only 2%, then the argument of the log term in the skin effect calculation would increase by ten times, and the skin effect would decrease by 1.15. The same observation applies for the thickness in the calculation of skin effect.

SECOND PRESSURE BUILDUP TEST

A small oil boiler steam turbine generator was installed at the well site for demonstration. Well 4T began supplying steam for the power plant by the end of October, 1977. Another pressure buildup test was run on September 2, 1979, after about 1.1 million tons of reservoir fluid had been produced. This time, the pressure gauge was lowered to only 750 m, just at the top of the main lost circulation zone. After testing several different flowrates, the well was shut in. Then we kept the wellhead bleeding through a 2 in. pipeline with a choke to prevent hydrogen embrittlement of the wellhead system. Table 2 shows the pressure buildup data. Figures 3 and 4 are again plotted by the same procedures as in Figs. 1 and 2. The two log-log Δp-time plots are exactly coincident. This appears to indicate that pressure transmission is the same at any water phase depth, because the water is almost incompressible.

By analysis of Fig. 4 we obtain:

$$kh = 17,600 \text{ md-ft}$$

$$S = +12.6$$

$$\Delta p_{skin} = 350 \text{ psi}$$

$$FE = 0.46$$

Before the multiple flowrate and second pressure buildup tests were begun, many different sizes of Go-Devil were run for detecting the internal diameters of the casing pipe. No Go-Devil would pass 1,460 m. A bottomhole sample was taken out by sand bailer through a wire line operation. It was completely fine dark gray slate cuttings, implying that sloughing had occurred in the 8-1/2 in. production hole. It is believed that the height of the fine slate precipitate in the annulus should be greater than the height of the precipitate of 45 m in the inner 7 in. slotted pipe. This probably caused the increase of skin effect and decrease of flow efficiency compared with the first pressure buildup test. However, it is not evident why the kh increased between the two tests.

DISCUSSION

During multiple flowrate tests prior to shut-in, temperature-depth surveys were run for each rate in well 4T. A strange result was observed: the temperature of the produced fluids drops with increasing production rate. Thus there was also a drop in wellstream enthalpy at high producing rates. This appears to indicate that as the flowrate increases and well pressure drops, colder fluid enters the well in some manner and blends with the hot water. The same phenomenon was observed in other wells completed later in this area.

The most obvious reason for cold water entry with reduced wellbore pressure would be a poor cement bond to the casing. This would allow colder water from formations near the surface to dump-flood the well. Well 4T was not cement bond logged, but other wells were. An inspection of cement bond logs did indicate some poor cement bonds.

Another reason for cold water entry would be that there is no cap rock on the top of the geothermal reservoir. Most wells drilled are along the bank of the Chingshui River. Thus it is also inferred that the fall in temperature could be caused by a vertical fracture inflow of cold water beneath the river bed.

The communication between cold water and hot water formations would obviously affect the pressure buildup analyses. Remedial work for preventing cold water entry is underway at this area.

REFERENCES

Matthews, C.S., and Russell, D.G.: "Pressure Buildup and Flow Tests in Wells," SPE Monograph Series (1967), I.

Ramey, H.J., Jr.: "Pressure Transient Analysis for Geothermal Wells," Proc., Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, May 20-29, 1975.

Table 1 Pressure Buildup Data of First Test

Flowing Period: 0630 - 1630, October 20, 1976

Shut-in Period: 1630 - 0630, October 20-21, 1976

q = 126 Tons/hr = 20,000 BBL/D

μ = 0.14 CP

B = 1.13 res.bbl/surface bbl

C_t = 1×10^{-5} psi^{-1}

t = 600 minutes

P_i = 1957 psig at reference depth of 1500 meters

Δt,Min	$\frac{t+\Delta t}{\Delta t}$	P_{ws}, psig	ΔP,psi	Δt,Min	$\frac{t+\Delta t}{\Delta t}$	P_{ws},psig	ΔP,psi
0	-	1357	0	210	3.9	1937	580
3	201	1417	60	240	3.5	1940	583
6	101	1549	192	270	3.2	1942	585
9	67.7	1647	290	300	3	1944	587
12	51	1731	374	330	2.8	1944	587
15	41	1796	439	360	2.7	1944	587
30	21	1877	520	390	2.5	1947	590
45	14.3	1892	535	420	2.4	1947	590
60	11	1901	544	450	2.3	1949	592
75	9	1906	549	480	2.25	1949	592
90	7.7	1913	556	510	2.2	1949	592
105	6.7	1918	561	540	2.1	1949	592
120	6	1920	563	570	2.05	1952	595
150	5	1932	575	600	2	1952	595
180	4.3	1932	575	630	1.95	1954	597

Table 2 Pressure Buildup Data of Second Test

Flowing Period: 0900 August 18, 1979 - 1000 September 2,1979
(Continued Multiple flow rate tests)

Shut-in Period: 1000-0800 September 2-3, 1979

q = 138 Tons/hr = 21,900 BBL/D
t = 20,076 Minutes (Equivalent flowing time of 138 tons/hr)
P_i = 988 psig at reference depth of 750 meters

Δt,Min	$\frac{t+\Delta t}{\Delta t}$	P_{ws},psig	ΔP,psi	Δt,Min	$\frac{t+\Delta t}{\Delta t}$	P_{ws},psig	ΔP,psi
0	-	350	0	210	97	932	582
5	4016	444	94	240	85	935	585
10	2009	580	230	300	68	940	590
15	1340	703	353	360	57	940	590
20	1005	778	428	420	49	940	590
25	804	802	452	480	43	944	594
30	670	833	483	540	38	947	597
35	575	848	498	600	34	949	599
40	503	850	500	660	31	949	599
45	447	855	505	720	29	949	599
50	403	862	512	780	27	949	599
60	336	874	524	840	25	949	599
70	288	887	537	900	23	952	602
80	252	896	546	960	22	952	602
90	224	901	551	1020	21	954	604
100	202	906	556	1080	19.6	954	604
110	184	911	561	1140	18.6	954	604
120	168	913	563	1200	17.7	954	604
140	144	920	570	1260	16.9	957	607
160	126	923	573	1320	16.2	957	607
180	113	928	578				

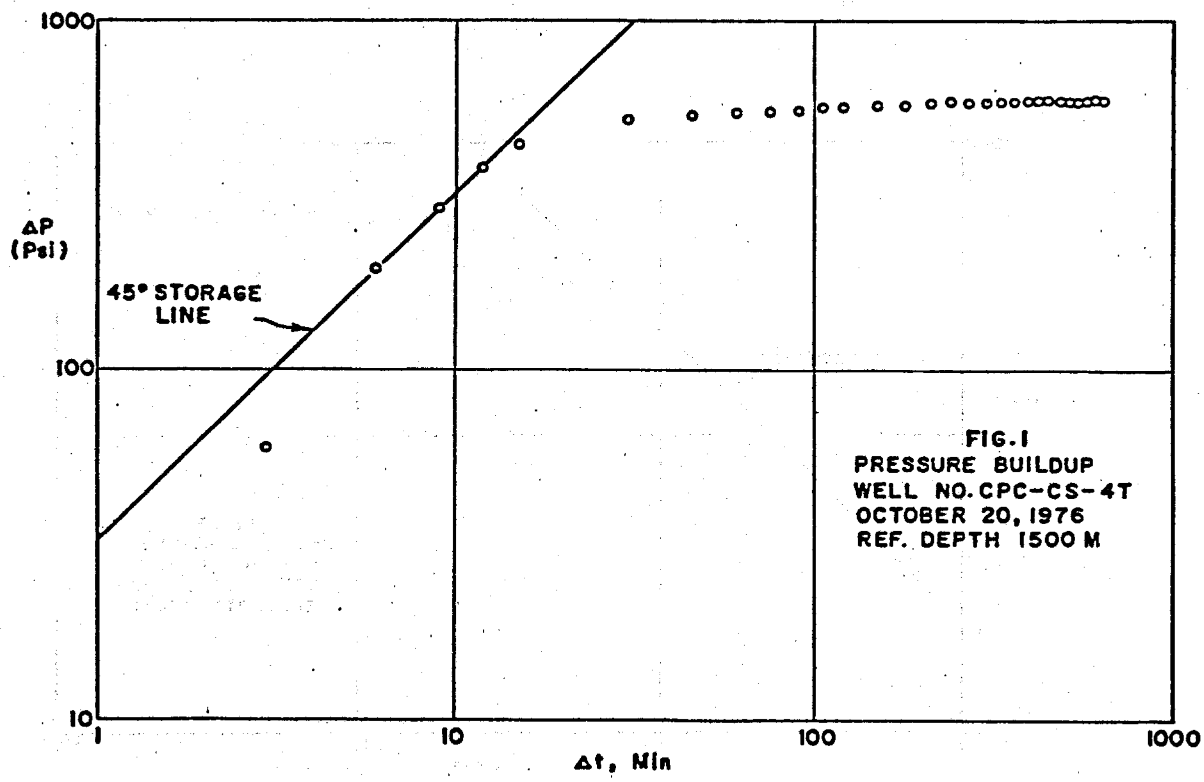

FIG.1
PRESSURE BUILDUP
WELL NO. CPC-CS-4T
OCTOBER 20, 1976
REF. DEPTH 1500 M

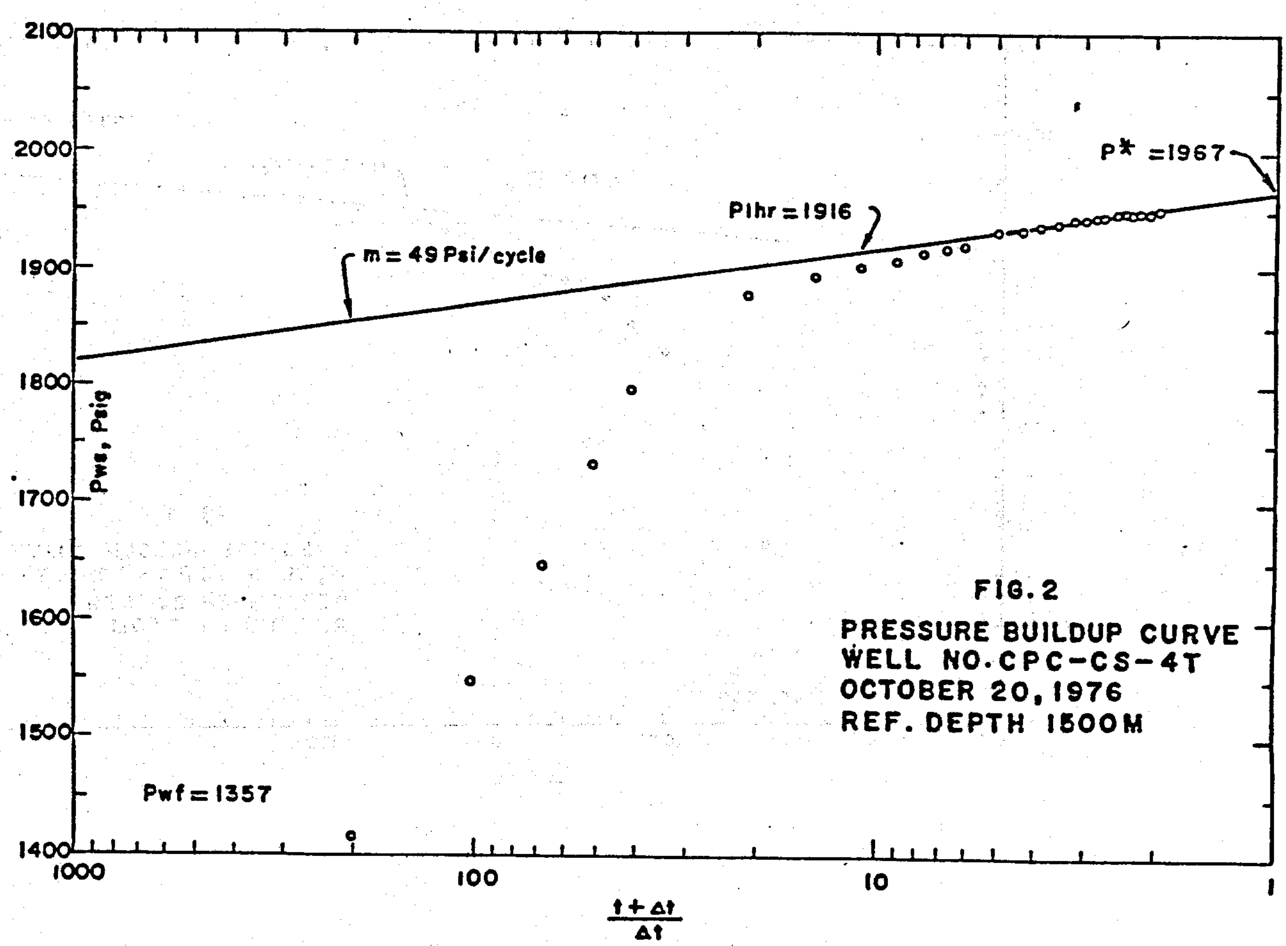

FIG. 2
PRESSURE BUILDUP CURVE
WELL NO. CPC-CS-4T
OCTOBER 20, 1976
REF. DEPTH 1500M

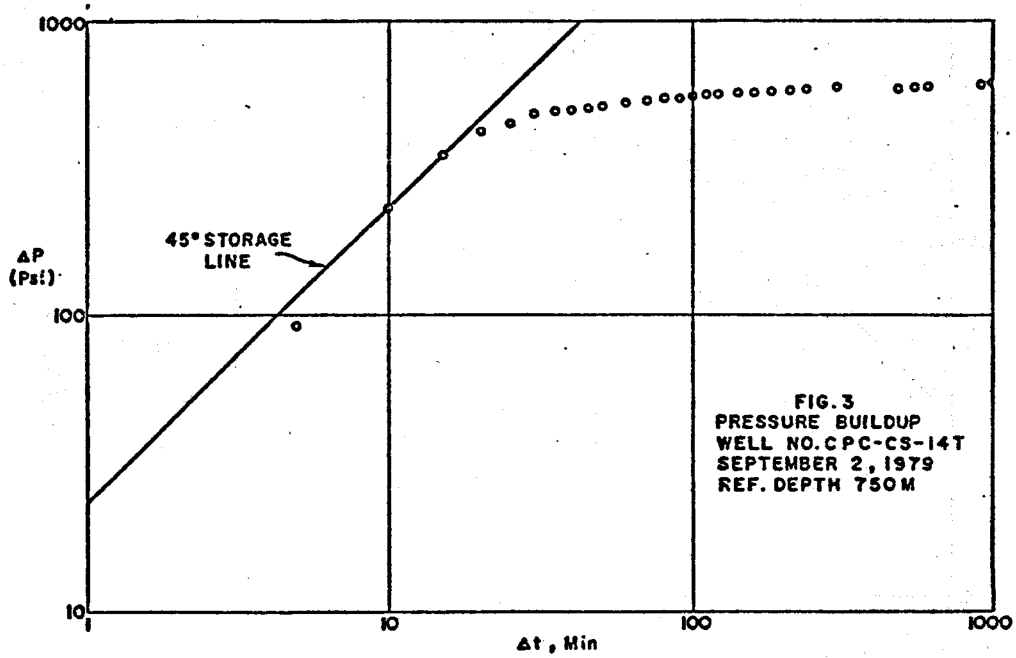

FIG. 3
PRESSURE BUILDUP
WELL NO. CPC-CS-14T
SEPTEMBER 2, 1979
REF. DEPTH 750 M

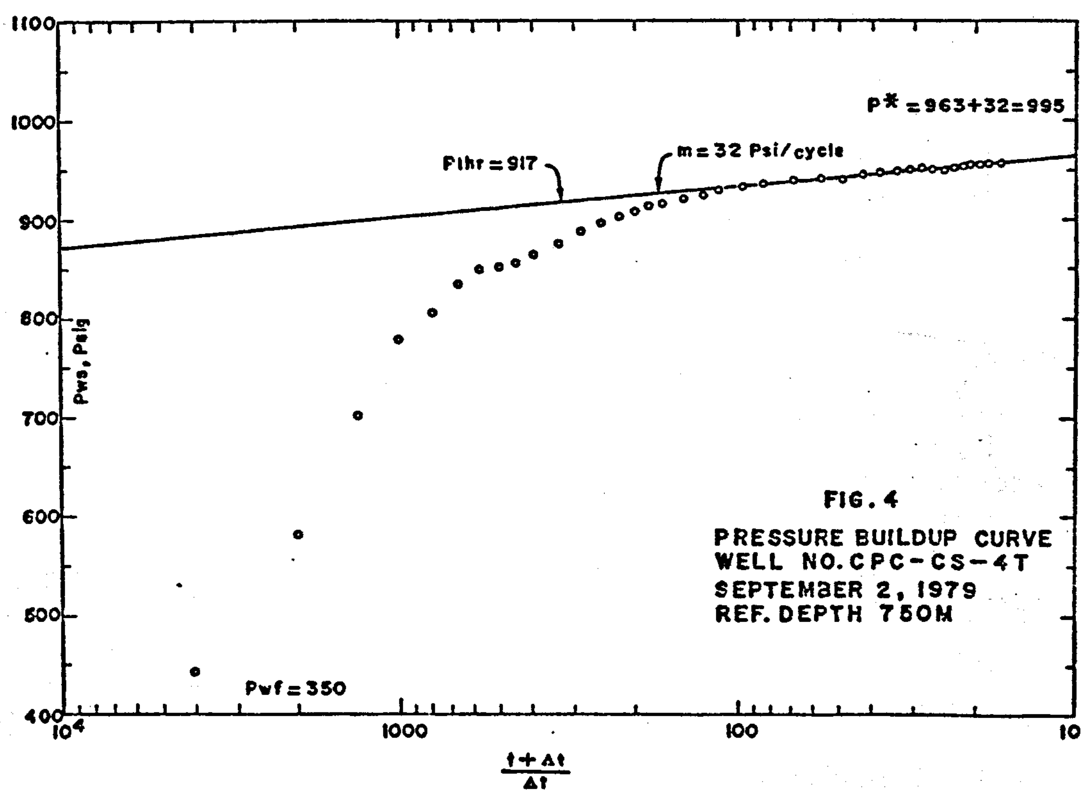

FIG. 4

PRESSURE BUILDUP CURVE
WELL NO. CPC-CS-4T
SEPTEMBER 2, 1979
REF. DEPTH 750M