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NEW WELL TEST MEASUREMENT TECHNIQUE FOR LOW ENTHALPY GEOTHERMAL WELLS

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ABSTRACT

A new well test measurement technique was devised to utilize for testing the low enthalpy, non-artesian geothermal wells. The test is simple and easy to apply in newly completed wells with no need to run a pressure recording gauge into the well. Usually, injection tests are being conducted after the completion of geothermal wells. Sometimes, transmissivity figures obtained by injection tests do not comply with the results of production tests (build-up and drawdown) for various reasons. The new method enables us to carry out a drawdown test just after the completion of geothermal wells.

The drawdown test in Dikili-Kaynarca field were conducted by using this new technique in three different wells with temperatures varying between 94^{o}C and 105^{o}C, and lasted 2 and 5 hours. They were analyzed by modern well test methods, and their results were reported.

INTRODUCTION

Dikili-Kaynarca geothermal field is situated in the Aegean cost of Turkey as shown in Fig. 1. The region is significantly affected by extensional tectonics. The area has complex magmatic and volcanic geological structures and numerous graben-horst structures (Ercan et al., 1984). Yuntdag-3 volcanites are widespread formations in the region.

In the Dikili-Kaynarca region, there are numerous hot springs with a natural flow rate of 200 kg/s and temperatures ranging from 70^{o}C to 92^{o}C, creating a big marshy place in the area. After starting with uncontrolled exploitation geothermal fluids for greenhouse heating water table has dropped and consequently, natural springs disappeared immediately and only to appear to a limited extent in summer season.

Of a total 23 wells 10 are gradient wells with depths ranging from 50m to 80 m. One of the wells reached to a depth of 1500 m with a maximum recorded temperature of 134^{o}C at 700 m. Currently 10 wells are producing with a total flow rate of 350 kg/s of which probably 100 kg/s are reinjected. No wonder lately water table is rapidly being lowered. Dikili-Kaynarca geothermal field currently provides heat for a 420 decare of greenhouses.

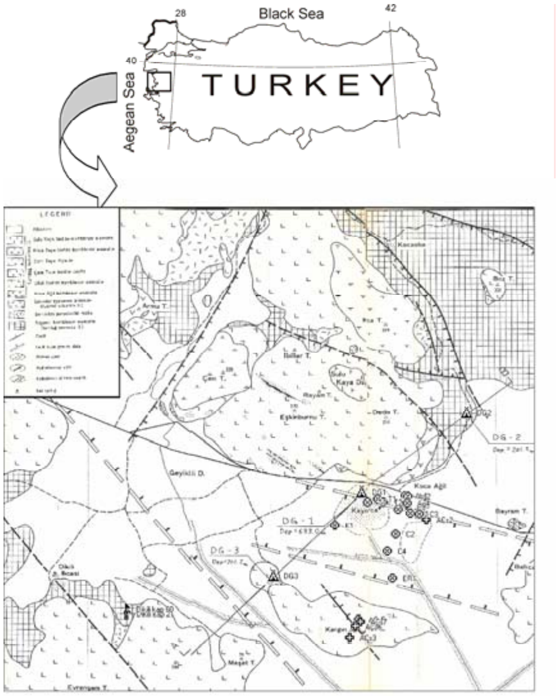

Figure. 1. *Location of Dikili-Kaynarca geothermal field and geological map (JICA-MTA, 1986).*

Only three drawdown tests were conducted in Dikili-Kaynarca geothermal field of Turkey by using the measurement technique described in this paper. They are analyzed by using modern well test analysis.

METHODOLOGY

The application of this method is similar to air lifting or inducing of well to discharge. Drill pipes of 3½ ” are submerged into water column within the geothermal well to a pre-calculated depth and tubing head is connected to a compressor (Fig.2). The test starts with compressed air flowing through tubing and air lifting the water column in the annulus, and subsequently the well starts to discharge. During the test compressed air flow is held constant, tubing wellhead pressure is recorded by a sensitive manometer and well production rate is measured by a weir. As the well produces, water level in the wellbore starts to decline because of reservoir pressure drop in response to production.

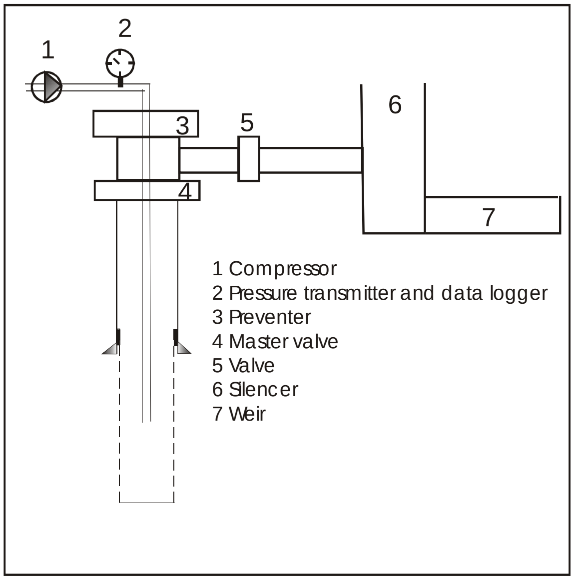

Figure. 2 New well test measurement arrangement.

In water and low enthalpy geothermal wells, after completion, in order to clean sandface and improve flow from the pay zone into the well the use of air lifting is a standard practice. In this technique, non-flowing wells and wells with small flow rates are induced to flow by reducing bottom hole pressure through pumping compressed air into annulus between pipe and casing. By applying this technique, substantial pressure differential is created between reservoir and well bottom, and formation damage caused by drilling mud and etc. are partly or totally eliminated.

Pumping compressed air after the completion is an easy, cheap and efficient practice. By installing a pump into the well a similar operation can be applied (Fig. 3), but cuttings and formation particles carried by the produced fluid may damage moving parts of the pump in very short time. Moreover, installation of a pump is a long-term operation and it may require the withdrawal of drilling rig from the location. On the other hand, in the case of pump installation, pressure exerted in the casing annulus for corrosion prevention, acting directly against the reservoir, reduces well productivity.

Compressor tests also helps by providing information on flow performance of the well and therefore, pump selection can be more correctly done by avoiding the selection of oversized or undersized pumps. On the other hand, it eliminates a test trial with a pump for the pump selection.

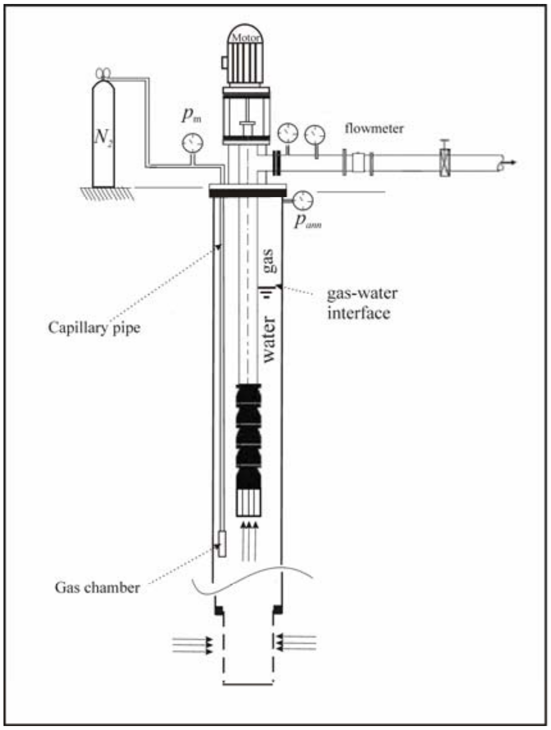

Figure. 3. Pump installed in a geothermal well.

In discharging and developing of a geothermal well by air lifting technique, preferably drill pipes are run into the wells. Submerged pipe length is related to the compressor pressure, which must be greater than the hydrostatic pressure of the depth where the pipes are set. On the other hand, blow-out preventers should be installed against a risk of a eventual blow-out and they should be controlled before testing.

In these tests $3^{1/2}$” in DP’s are used for compressed air flow, and they are run to 150 m in C2 and C3 and 192 m in C4 wells. In all three tests Atlas Copco XRVS compressor with pressure of 25 bars and flow rate of 35 m^3/min were utilized.

TEST IMPLEMENTATION

As shown in Fig.2, test setup is prepared. At the beginning BOP (3) is closed, master valve (4) and lateral flow control valve (5) are set open. When the compressor (1) starts to pump compressed air manometer pressure (2) rises until the air is reached the pipe shoe. Ten, pipe string becomes full with air at the maximum pressure. Since the pipe is not too long, frictional pressure drop during air flow and static pressure due to air weight can be neglected, and pressure recorded at the surface can be practically considered equal to the pressure (p_i) at the pipe shoe. When the air enters into pipe-casing annulus density of fluid at that place is decreased and starts to flow while rising. In that case pressure recorded at the surface manometer can be considered flowing pressure (p_{wf}) at the pipe shoe. If the flowing pressure p_{wf} is greater than the saturation pressure of the fluid flowing from the pay zone to the pipe shoe the fluid will be in liquid phase. Therefore, by using flowing pressure (p_{wf}) and initial static pressure (p_i) corresponding pressures at the feeding zone can be calculated.

When the well flows to the surface, produced water, steam and air are directed to the silencer (6) and liquid flow rate is measured at the weir (7).

TEST APPLICATION

Well test measurement technique was tested in well tests carried out in wells C-2, C-3 and C-4 wells, whose locations are shown in Fig.4. Information about those wells is given in Table 1.

Figure. 4. Well locations in Dikili-Kaynarca field.

Table 1. Information on wells tested.

Wells	Water level, m	Depth, m	Casing Shoe, m	BHT, °C.
C-2	2	405	114	105
C-3	17.4	258	79.5	102
C-4	6	436	340	94

Pressure measurements are carried out using a digital manometer with sensitivity of ±0.2% for whole manometer scale and with a resolution of 0.01 bar. A data logger automatically records the pressure with 1 second intervals and pressure values are transferred to a PC.

Fig. 5 illustrates wellhead pressures recorded during the test on C-3. Although general character of pressure response in the pressure drawdown test is observed from the graph, the recorded data is a little bit noisy due to compressor produced impulses.

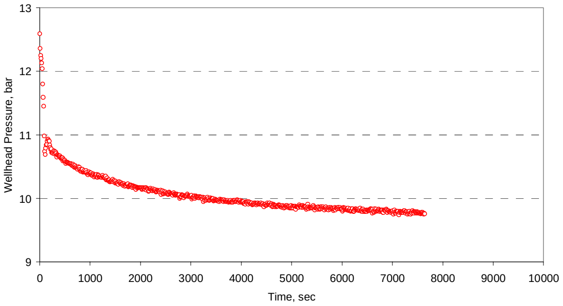

Figure. 5. Wellhead pressures recorded during the test on well C-3.

Though this would not create a problem in conventional test interpretation methods, it is difficult to interpret derivative data as shown in Fig.6. As seen in the Fig. 6, derivative data are spread out making difficult to fit the correct model. A homogeneous reservoir with infinite boundary model matched in C-4 drawdown test as seen in the Fig.6.

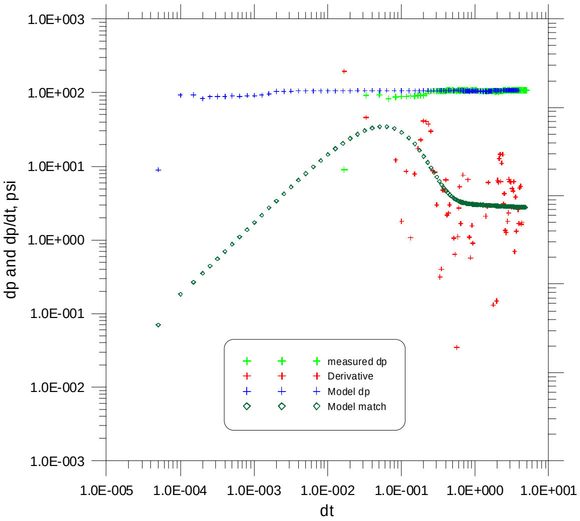

Figure. 6. Interpretation of well test in C-4.

A better model matching was obtained after smoothing the derivative data, as shown in Fig. 7. A better match is obtained in Fig. 7 for a homogenous reservoir with a circle boundary.

Although they are not shown in this paper semi-log matches look like reasonably good. Matches for Δp's are very good as seen in Fig.'s 6 to 9. Smoothing the derivative data helped a lot for matching a better model.

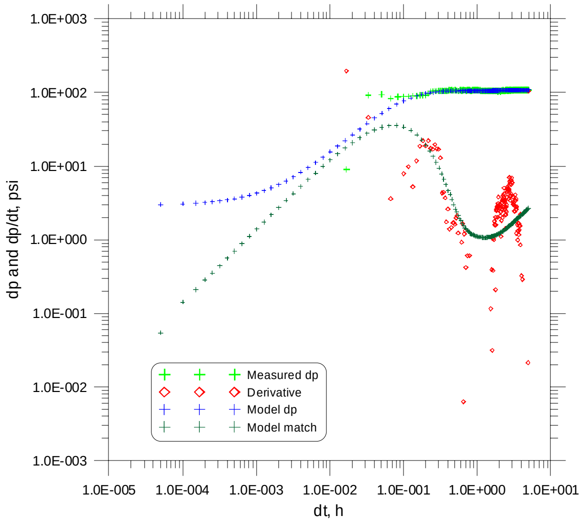

Figure. 7. Model matching in well, C-4.

As seen in Fig. 7, a homogeneous reservoir with a circle boundary model matched for the test carried out in well C-4. Model analysis resulted in a permeability of 118.5 D-m with a skin of 48.4.

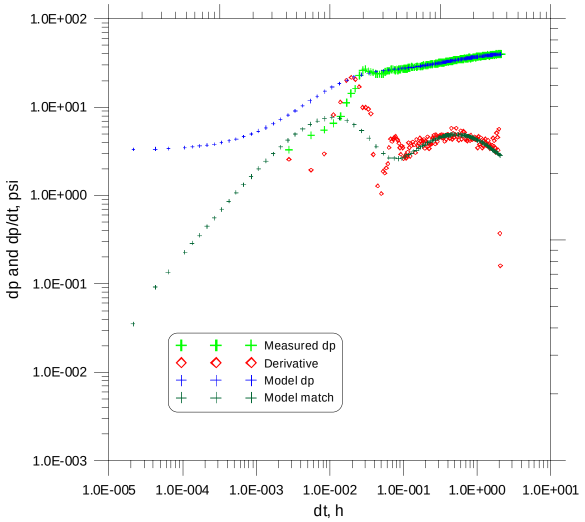

Figure. 8. Model matching after smoothing the derivative data in well, C-3.

Fig. 8 shows model matches for differential pressure and derivative data. Wellhead pressure data in Fig. 5 are used for model matching obtained in Fig. 8. As seen, a reasonably well match for derivative data is obtained for radial composite model with infinite boundary. Analysis of the model resulted in a permeability of 215 D-m with a skin of 3.

Fig.9 illustrates modern well test analysis results for the well C-2. Changing wellbore storage, two porosity and one fault boundary model match was obtained for this well. Analysis of the model resulted in a permeability of 45 D-m with a skin of 30. The distance to fault was found 777 m.

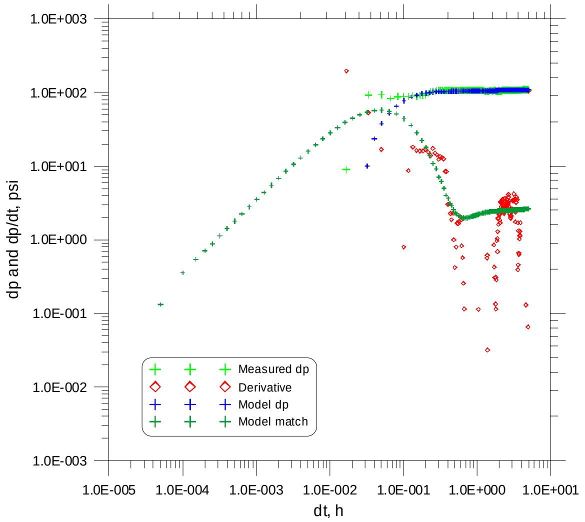

Figure. 9. Model matching in well, C-2.

DISCUSSION

Although the pressures are recorded at every second, pressure values at every 10 seconds are used in order to be able to handle the large data. Even these data seemed a little bit noisy as seen in Fig. 5 and consequently, derivative data widely spread out. They were smoothed, and better data for analysis were obtained.

In the proposed technique, the pressure of compressed air injected into well is measured. In order to have a reliable measurement air flow should be constant, continuous and without interruption. Since screw type compressors can produce stable and continuous air flow they are suitable for this technique. Because pressure differential, Δp is taken into account in the analysis, frictional losses in air pipes and annulus can be neglected.

It is unfortunate that only drawdown test can be conducted by this measurement technique. A pressure buildup would have improved the reliability of the well test results. On the other hand, a multi-rate drawdown test could be carried out and its results could be used for subsurface pump selection.

Unfortunately, there is no available geological model which caused difficulties in analyzing the test by computer-aided analysis methods. For instance, the fault detected in C-2 test could not be traced because of the lack of geological information. On the other hand, composite model matched for the test in C-3 might be meaningful in the sense that reinjection operation was being carried out in a well 524 m east with a flow rate of 150 kg/s. And, the boundary between cold and hot banks was found 300 m away from the production well. Moreover, homogenous model with circle boundary would not be proper because of short test period. A homogeneous model with infinite boundary could be tried. This information might be very useful for the exploiters of the geothermal field.

The tests conducted have provided other valuable information such as very high skins which indicates bad drilling practices applied in this geothermal field. We know that drillers working in the area are not experienced people and they have no proper drilling rig and equipment. The field seems large, since in one test drainage radius of R_e =3 km was obtained and in another infinite reservoir model was indicated. This also complies with large manifestations found originally around the field.

Unless proper geological model coupled with a proper control of geothermal field (with a owner) are provided, information obtained by these test can be evaluated with some concern.

RESULTS

In the light of the above mentioned the following results are obtained:

- A new well test measurement technique for non-flowing and low enthalpy geothermal resources was introduced and successfully used.
- The technique is easy, reliable and inexpensive to use, and provides substantial information on near wellbore and reservoir properties at early stage of field development.
- The result of multi-flow drawdown tests using this technique could be used for proper pump selection.

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