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INTERFERENCE TEST ANALYSIS at MENENGAI PHASE I GEOTHERMAL PROJECT, KENYA

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ABSTRACT

Cheap and stable energy supply is required to achieve industrialization of any country. Geothermal energy can be exploited for long period without depleting the resource. To determine how to effectively utilize geothermal energy, interference tests are conducted to measure the pressure drawdown at an observation well which is caused by the discharge of other wells tapping the reservoir. The main objective of the test is to determine the degree of reservoir continuity and determine the inter-well reservoir properties such as transmissivity (T) and storativity (S) within the field. This paper captures the analysis of interference test done in Menengai Phase I over a ten-month period in 2016, involving four observation wells and five production wells. The reservoir is assumed to be an isothermal, isotropic, homogeneous, porous medium of constant thickness and infinite areal extent. The production well is modeled based on a line source, which fully penetrates the reservoir. Pressure data from the observation well was analyzed with the line source solution by adapting principle of superposition for parameter values of T and S. Different scenarios were run to get the best estimates and yielded parameter values ranging from S= 1.76 x 10-7 to 1.76 x 10-8 m/Pa and T= 1.85 x 10-9 to 2.75 x 10-10 m^3/Pa.s

INTRODUCTION

Geothermal energy is a renewable source of energy that can be exploited for a long period without depleting the resource. To achieve sustainable geothermal energy utilization involves an in-depth study and analysis of geothermal field in all aspects of geology, geochemistry, environment and reservoir engineering. Continuous tests are carried out in the geothermal field, by using completed wells to assess the reservoir. These tests include production tests, injection tests, pressure build up tests, tracer tests and interference tests. These tests give results that are useful in understanding the geothermal reservoir and give a clear way forward in utilizing the resource. Interference tests are usually carried out to determine the continuity of the reservoir and get parameter values of transmissivity and storativity. High transmissivity values indicate the ability of the field to transmit geothermal fluid. Figure 1shows location of geothermal prospects in Kenya, with Menengai geothermal field highlighted in green. It is located on the outskirts of Nakuru town, covers an area of about 110 km^2. Exploration drilling started in February 2011. It is divided in four phases with Menengai phase I production drilling complete. To date forty three wells have been drilled and drilling is ongoing in phase II of the project.

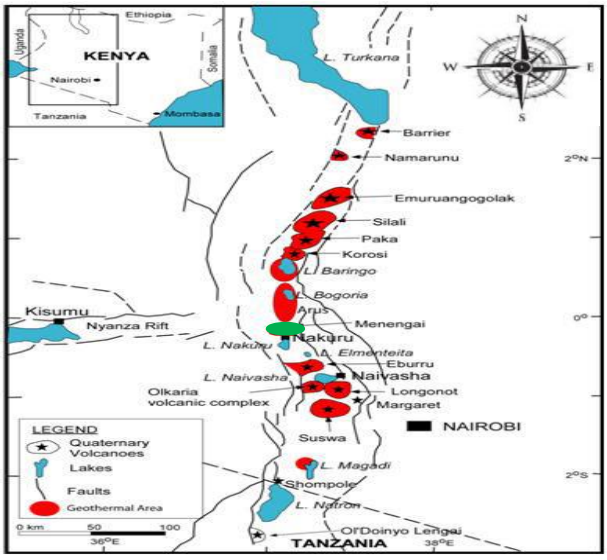


Figure 1: Location of geothermal prospects in Kenya

INTERFERENCE TEST AT MENENGAI PHASE I

Interference test started on 28th March 2016 and ended on 31st January 2017. The test consisted a total of nine wells, four observation wells and five production wells. The equipment used to collect field data from the observation well included data logger, which was programmed to record pressure and temperature values with a time interval every one-minute or thirty seconds and was collected after every two-weeks. Quartz crystal transducers, capillary tubing, pressure chamber assembly, pressure purge unit, nitrogen gas and a field laptop. Production wells were discharged sequentially in order to distinguish the effect of each well on pressure response. James lip pressure method was used to monitor the wells and measure parameter values such as mass flow, weir, enthalpy and dryness fraction.

METHODOLOGY

Pressure response at an observation well can be expressed by the line source solution on assumptions of homogeneity; isotropy and an infinite porous reservoir have been taken into account. The superposition principle states that any pressure drop observed at an observation well is caused by the total sum of pressure change seen at the production wells in the vicinity. Conventional methods of type curve matching have some difficulties in analyzing actual scenarios of multiple production wells varying their flowrate with time. With the advancement in technology over the years, it has become critical to integrate it in reservoir test analysis and simulations. In this case, technology allows analysis of multiple production wells effect on different observation wells simultaneously. Variable flow rates can be processed by dividing them into a series of linear segments of flow, these flow rates are assumed representative of the sand face flow rate and not the bulk flow rate recorded at the wellhead. In addition, volumetric flow rates are used, not mass flow rates.

$$\Delta p = \frac{q}{4\pi T}\int_u^\infty \frac{\exp(-u)}{u}\,du = -\frac{q}{4\pi T}\,Ei(-u) \quad \text{..... (1)}$$

Where

$$u = \frac{r^2 S}{4Tt} \quad \text{..... .(2)}$$

$$S = \phi c h \quad \text{..... (3)}$$

$$T = \frac{kh}{\mu} \quad \text{..... (4)}$$

$$Ei(-u) = 0.5772 + \ln(u) - u + \frac{u^2}{2\cdot 2!} - \frac{u^3}{3\cdot 3!} + \frac{u^4}{4\cdot 4!} - \cdot \quad \text{..... (5)}$$

S is storativity, c is compressibility, ϕ porosity T transmissivity, k is permeability, h reservoir thickness, μ viscosity of fluid, Ei(-u) is the exponential integral function of u.

Pressure change caused by variable flow rate is calculated by use of superposition in time and is expressed as:

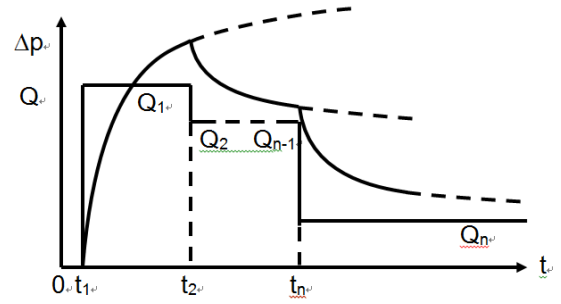
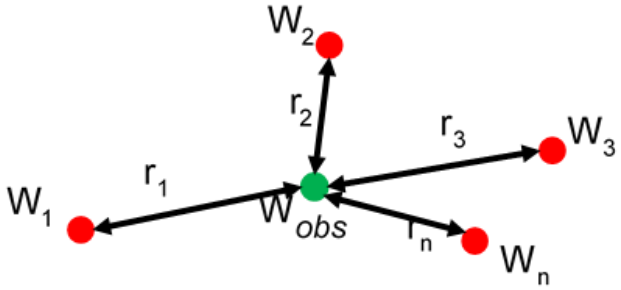


Figure 2: Variable flowrate pressure change

$$\Delta p_{vr}(t) = Q_1 \Delta p(t - t_1, r) + (Q_2 - Q_1)\Delta p(t - t_2, r) + \cdots + (Q_n - Q_{n-1})\Delta p(t - t_n, r) \quad t > t_n$$

…… (6)

The total pressure change at the observation well caused by production wells is calculated by use of superposition in space and is expressed as;



$$\Delta p_{\sup}(t) = \Delta p_1(r_1, t) + \Delta p_2(r_2, t) + \cdots + \Delta p_n(r_n, t)$$

…….. (7)

Where W is production well, r is distance between observation well and production well and obs is observation well.

ANALYSIS

Equations discussed in previous section were coded into excel program and used to analyze the data from interference test. These equations give transmissivity and storativity estimates, which are critical assessing the performance or productivity of a well. The excel program runs different scenarios of one observation well against multiple production wells at a time. Processed data from both observation wells and production wells are input into the program. The program compares pressure values between the observed pressure change at the observation well and the calculated pressure change caused by the production wells. The circle in Figure 3 and Figure 4 represents the observed pressure change while the line represents the calculated pressure change. Initial values of T=1 x 10^{-7} m^3/Pa.s and S=1 x 10^{-7} m/Pa are assigned before running the *Solver* function. The objective is to determine the parameter estimates T and S by changing them from their initial values to values which iteratively reduce the residual sum of squares.

RESULTS

Pressure data from four observation wells MW-01, MW-01A, MW-09A and MW-10A have been collected. Upon subjecting MW-01A and MW-09A for analysis, the pressure data did not reflect any pressure drop hence focus was limited to MW-01 and MW-10A based on an infinite reservoir model since a correlation existed.

Observation Well MW-01

Figure 3 shows simulation results of observation well MW-01. Iterative runs were done to get the best results acceptable parameter estimates and a small residual sum of squares. MW-17 and MW-20 contribute to the pressure change in observation well MW-01. The final estimates obtained are
$T = 1.57 \times 10^{-9}$ m^3/Pa.s and $S = 1.94 \times 10^{-7}$ m/Pa

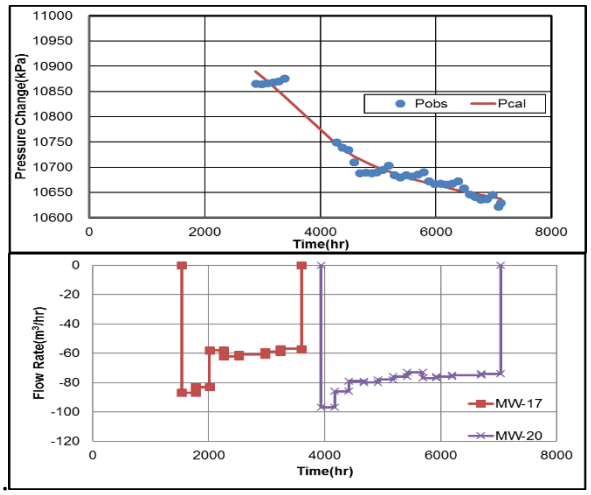


Figure 3: MW-01 simulation results

Observation Well MW-10A

Figure 4 shows simulation results from observation well MW-10A. Careful examination shows pressure drop in observation well MW-10A occurred around five hundred hours after discharge of wells MW-17 and MW-17A. After iterative runs, MW-17 and MW-17A were observed to contribute to the pressure drawdown observed in MW-10A. The final estimates obtained are $T = 3.38 \times 10^{-10}$ m^3/Pa.s and $S = 1.27 \times 10^{-8}$ m/Pa

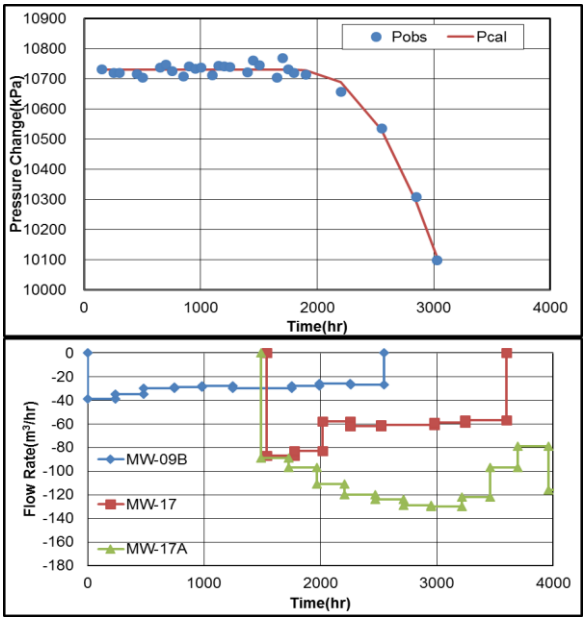


Figure 4: MW-10A simulation results

DISCUSSION

Transmissivity estimates for wells MW-01 and MW-10A are of a lower magnitude compared to the ones from individual well tests. Ideally results from interference tests give higher transmissivity values compared to completion test which is not the case with these two wells. Previous discharge tests show Menengai geothermal field is complex, having both vapor dominated wells and liquid dominated well. Propagation of pressure in such a field is slow and the results can be a challenge to interpret. Such cases require a more advanced software such as TOUGH2 to interpret the interference data.

CONCLUSION

Interference test done at Menengai phase I were analyzed using the line source solution for two observation wells. The results are summarized as follows:

1) The results clearly show the heterogeneous nature of Menengai field.
2) Reservoir continuity is clearly shown from results of observation wells MW-01 and MW-10A
3) Results show observation well MW-01 is hydrologically connected to production wells MW-17 and MW-20, which are vertical wells, confirming the fault that cuts across them.
4) Results show observation well MW-10A is hydrologically connected to production wells MW-17 and MW-17A, confirming the faults that cuts across the three wells.

RECOMMENDATIONS

1) Observation well monitoring to start one month before discharging production well to attain stable pressure readings.
2) Discharge of production wells should be done after purging effects have minimized.
3) Stationing of pressure tool at observation well should be at the feed zone.
4) Tracer flow tests to be conducted to ascertain the connectivity and continuity between the wells.
5) Time interval of pressure data recording increased from one minute to an hourly basis.
6) Regular checks on all the equipment for any pressure leakages, faulty electrical system etc.
7) Use TOUGH2 for further analysis of interference tests to incorporate the complex nature of Menengai geothermal field.

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REFERENCES

Itoi, Ryuichi, Michihiro Fukuda, Kenji Jinno, and Hiroki Gotoh. "Interference Test Analysis at the Takigami Geothermal Field, Japan." *Geothermal Reservoir Engineering* 18 (1993): 267–72.

McEdwards, D. G., and S. M. Benson. "*User's Manual for Analyze: A Variable-Rate, Multiple-Well, Least Squares Matching Routine for Well-Test Aanalysis*," 1981, 1–67.