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Parameter Study on Tracer Flow Test

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ABSTRACT

Periodic measurement of flow rate in production wells is essential to monitor performance of geothermal wells and reservoir. Tracer dilution method has been introduced as a reliable, cheap and environment friendly technique to measure mass flow rate and enthalpy in two phase geothermal systems. In this study, Sodium Fluorescein is used to measure liquid phase mass flow rate in a two phase production line and in a single phase liquid injection line. The study includes the effect of flow regime and flowrate on the accuracy of tracer flow test. The test results obtained for several wells in Alaşehir and Kizildere geothermal fields are confirmed with silencer-weir box method and results of the test in a single phase liquid line is verified with orifice plate meter.

1. INTRODUCTION

Flow rate and enthalpy of wells are the two parameters that directly affect the ultimate output electricity generation of geothermal power plants. The two parameters are also required to be known for reservoir evaluation and modeling studies. The flow rate of liquid and steam can be easily measured by using orifice meter and venturi meter if each phase flows through a separate production line. If there is only single phase liquid enter the wellbore, enthalpy can be measured by conducting P T survey in the well. Enthalpy can also be calculated from steam fraction when flow rate and enthalpy of steam and brine are known at the measurement point on the surface.

In the geothermal power projects that have individual separators on production well pad, it is easy to measure steam and brine flow rates by using a flow meter. However, instead of using individual separator, it is cost effective to construct a gathering system that collects all of the produced fluid in a central separator. In such a gathering system, both steam and brine flow in the same production line which make it difficult to measure the flow rate. A method developed by (James, 1970) uses a silencer and a weir box to measure flow rate and enthalpy of two phase production line. The method provides reasonable good results. Due to wasting of energy and impacts on the environment, silencer and weir box method is not preferred. However it is still widely used, especially in testing geothermal wells in Turkey.

Tracer dilution test is a sophisticated method to measure mass flow rate in a two phase production pipeline without wasting energy and impacts on the environment. The method is simply implemented by injecting a liquid tracer and a vapor tracer into the dedicated pipeline at a constant and measured rate. Diluted tracers are sampled at the sampling points. In order to have fully mixed liquid and gas tracers flow in respective phases, the test requires a certain distance between injection point and sampling point. Existence of elbow and valve between injection and sampling point may affect development of fully mixed flow. The method and its theoretical background is reported by Hirtz et al. (1993) and Hirtz (1995) respectively. The formula given in Equation (1) defines the dilution of a tracer provided that its injection concentration and rate are known. The test has been improved with new advancements which are given in, Broaddus et al. (2010).

$$Q_{L,V} = \frac{Q_T}{C_T - C_B} \tag{1}$$

Where Q_T, C_T and C_B are the tracer injection mass rate, tracer concentration, by weight and background concentration, respectively.

2. FIELD APPLICATIONS

Sodium Fluorescein dye was used as liquid tracer to conduct tracer dilution tests at several wells in Alaşehir and Kizildere geothermal fields in Turkey.

2.1 Test Results from Alaşehir Geothermal Field

Alaşehir geothermal field lies on Alaşehir graben in Manisa province. The field lies on a Alaşehir Graben in Western Turkey. More than 100 wells have been drilled in the field. There are 6 binary power plants and a combined flashing-binary power plant are actively generating electricity from the field with total installed capacity of 210 MWe. Meteoric origin reservoir fluid is liquid dominated and Paleozoic aged reservoir rock consists from marble, mica schist, calcshist and quartz. The field has reservoir temperature ranging from 140°C to 250°C, Gurel, (2016). In Alaşehir geothermal field, the steam fraction in the well head production line ranges from 1.3 % to 7.5 %.

Sodium Florescein (28 Litre, 500 ppm) was prepared in a tank and injected into two phase production line at a constant flow rate. Based on pressure of production line, injection rate of pump was different for each tested well. Injection pump rate changed from 50 L/hour to

80 L/hour. The injection port was near to wellhead. Tracer effluent was sampled from the downstream of production separator on the two phase production line. The distance between injection port and sampling separator was at least 15 meter for all tests. There was also 90° bend and a flow control valve in between injection and sampling points. It helps to develop fully mixed tracer flow in the production line. Once a steady state injection rate was attained, brine samples were collected from the downstream of sampling separator at 1 minute time intervals. While conducting the tracer dilution test, two phase production line was diverted to the silencer and weir box. Brine samples were also collected from the weir box for further evaluation.

Sodium Florescein concentration was detected by using Quantus Fluorometer, which has a single point calibration. By introducing a blank sample (brine background) and a standard sample to the fluorometer, the calibration process completed before starting concentrations detection. Brine background correction may be needed for each test. In order to eliminate this effect, brine samples were collected to be introduced as the blank sample before starting tracer injection.

Figure 1: Test Apparatus

The tests were conducted at different flow regimes, flow rates and in the wells which have different enthalpy. During the tests, it was aimed to increase the number of collected brine samples as much as possible to decrease the uncertainty and to obtain the most accurate effluent concentration. The test results showed that for all the tests conducted in Alaşehir Geothermal Field, the difference between tracer dilution test and the silencer weir box method was less than 10% (Table 1, Figures 2 through 4). However, it was found that all the flow rates calculated from tracer dilution tests were somewhat larger than the rates measured using the weirbox. In an ideal tracer dilution test, it is not possible to calculate flow rate higher than its actual and correct value. The tracer amount that can be diluted depends on the actual flow rate. One reason of measuring the higher flow rate could be that some of injected Sodium Florescein may be decayed at the wellhead temperature conditions, which were ranging from 165°C to 190°C. However, since the tracer was exposed to such temperatures in less than 20 seconds, it was found unlikely. Therefore, the tracer concentration in the weirbox was checked. The results were very similar to the flow rate measured at the weir box and an overestimation was present. This means that the tracer was not decayed. Another reason could be that the tracer may be carried not only in the liquid but also in the steam phase. Condensed steam samples were analyzed and the fluorometer did not detect any concentration higher than blank. The last possible reason of the over dilution was that while collecting brine samples, steam also flow into the 1/4 inch sampling line mixing with brine and it is condensed to water in the separator. Although, the downstream of the sampling separator was attached to the bottom of two phase production line that only enable brine to flow into the separator, the sampling separator is not far enough away to 90° bend and flow control valve. Therefore, fully mixed turbulent flow occurs in the production line. As the distance from the bending point increases, laminar flow starts to occur. Therefore, brine sample concentrations were corrected with steam fraction to eliminate the contribution of steam that extra dilutes the tracer using Equation-2 and Equation-3. It was found that for the wells which have steam fraction less than 2 % in the wellhead production line, there was no need to correct the concentration.

$$X = \frac{E_C - E_B}{E_S - E_B} \tag{2}$$

$$C_C = \frac{C_M}{1 - X} \tag{3}$$

Where X, E_C, E_B, E_S, C_C and C_M are steam fraction, enthalpy at the top of slotted liner where single phase exist, brine enthalpy at the production line, steam enthalpy at the production line, corrected tracer concentration and measured tracer concentration respectively.

Another observation was about fluctuation in measured concentration. As the steam fraction increased, the fluctuation of measured concentration also increased. Similarly, the lower flow rates caused higher fluctuation of concentration. Therefore, to decrease the uncertainty, number of brine samples increased. One other reason of the fluctuation is that, as the level of the tracer tank decreased to a certain depth, injection pump ceases to inject at a constant flow rate. Thus, pump should be tested to understand the critical level of tank to prevent fluctuation in pump rate. The test should be terminated before reaching this critical tank level.

Tracer dilution test was also conducted in a single phase liquid injection line. The test verification was conducted with orifice plate meter. It was observed that the error was less than 1 % and there was no need to correct the concentration because there was not steam in the line for extra dilution (Figure 5).

Table 1: Test Results for Two Phase Production Line at Alaşehir Geothermal Field

Well ID	Silencer-Weirbox (ton/h)	Tracer (ton/h)	Error %	Corrected Error %
X-1	172	164	4.5	No need
X-2	106	108.7	-2.5	3.6
X-3	377	390	-3.4	2.9

Table 2: Test Results for Single Phase Liquid Line at Alaşehir Geothermal Field

ID	Orifice Meter(ton/h)	Tracer (ton/h)	Error %
LP Brine	1186	1175	0.9

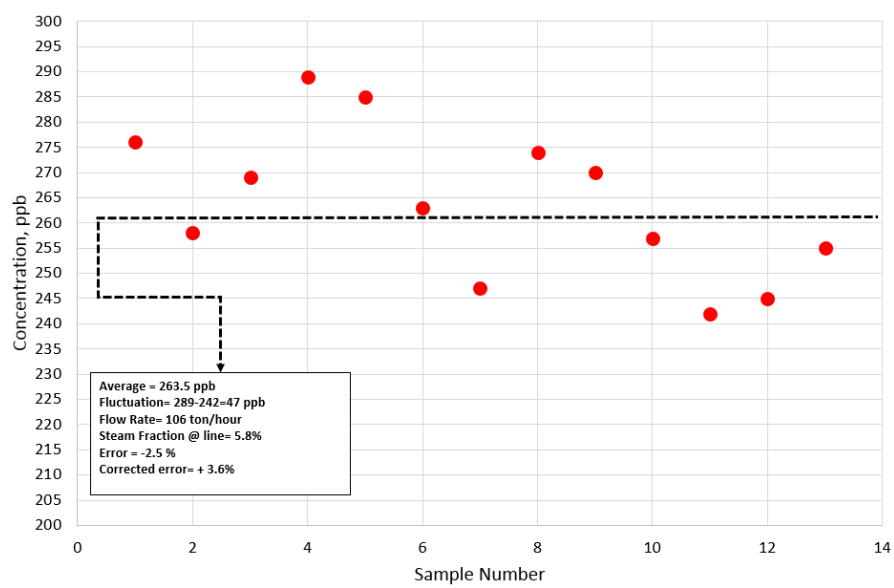

Figure 2: Tracer Concentrations of Samples for Well X-2

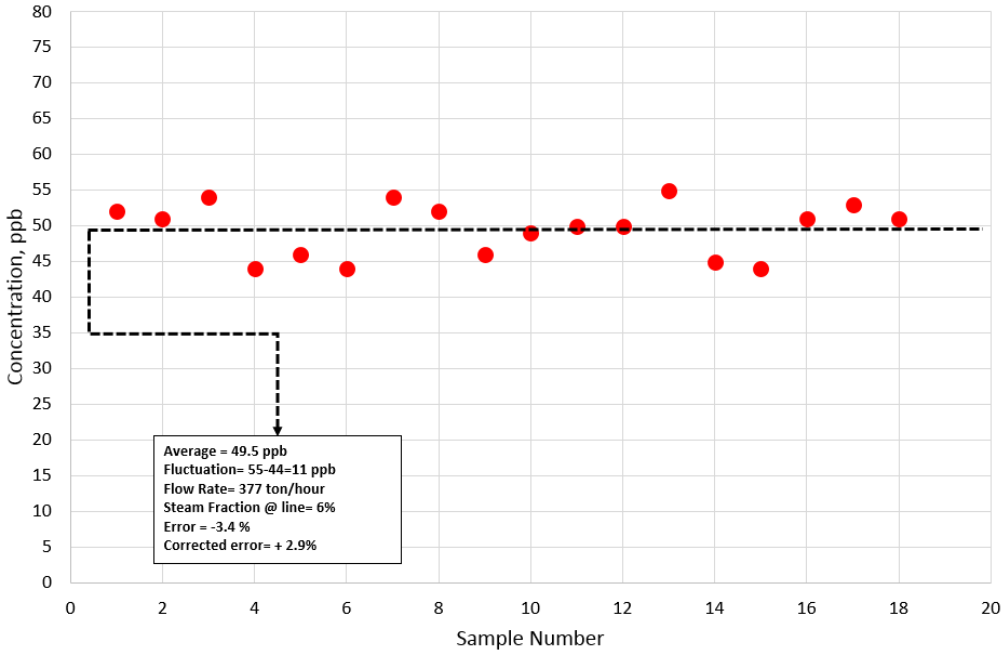

Figure 3: Tracer Concentrations of Samples for Well X-3

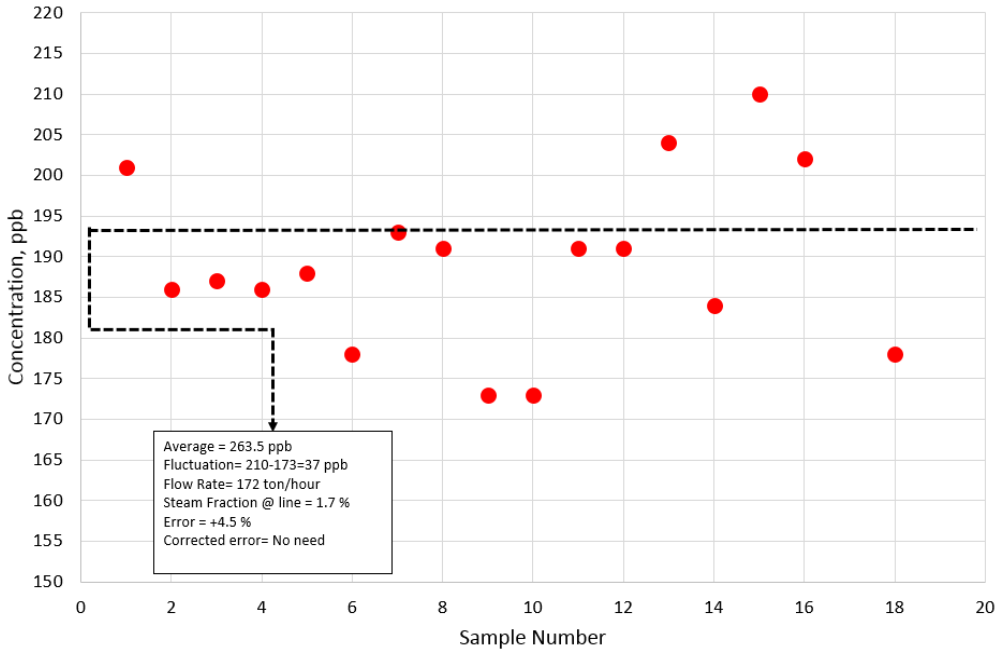

Figure 4: Tracer Concentrations of Samples for Well X-1

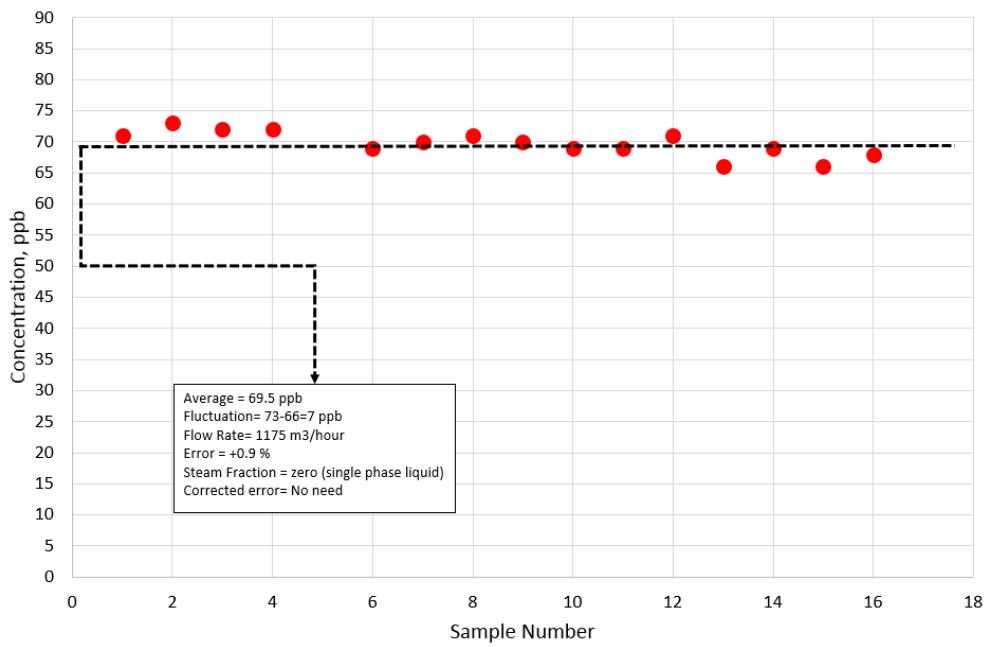

Figure 5: Tracer Concentrations of Samples for Single Phase Line LP Brine

2.2 Test Results from Kizildere Geothermal Field

Kizildere geothermal field is located in the Denizli and Aydin provinces of western Turkey on Büyük Menderes graben. It has moderate to high enthalpy, liquid dominated geothermal fluid has the highest temperature of 245°C with certain amount of noncondensable gas up to 3% by weight. Zorlu Energy produces from the field with total installed power capacity of 260 MWe.

The test procedure applied in Alaşehir Geothermal field was applied also in Kizildere Geothermal field, except that in this case a different type injection pump was used and injection rate was ranging from 10 L/h to 13 L/h. In Kizildere Geothermal Field, steam fraction in the wellhead production line was ranging from 12% to 18%. Therefore, initial error percentage was higher than 10%. However, as measured concentration was corrected by eliminating the contribution of steam in diluting tracer, the error percentage decreased to below 5%. The fluctuation of tracer concentration because of steam fraction was more dominant than well flow rate.

Table 3: Test Results for Two Phase Production Line at Kizildere Geothermal Field

Well ID	Silencer-Weirbox (ton/h)	Tracer (ton/h)	Error %	Corrected Error %
Y-1	267	321	-16.8	2.2
Y-2	224	242.4	-7.71	4.5

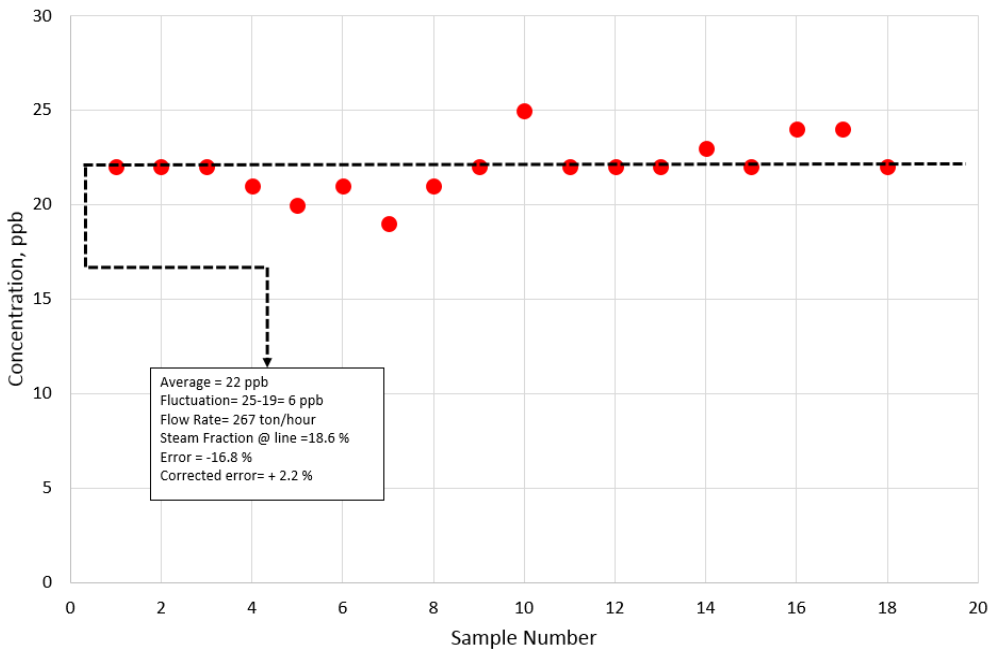

Figure 6: Tracer Concentrations of Samples for Well Y-1

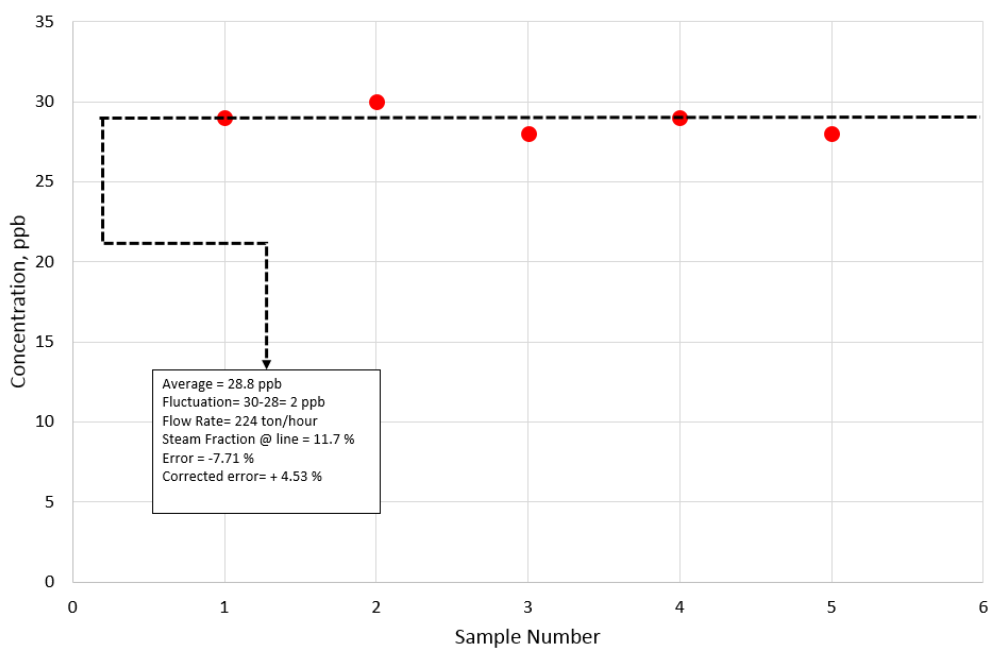

Figure 7: Tracer Concentrations of Samples for Well Y-2

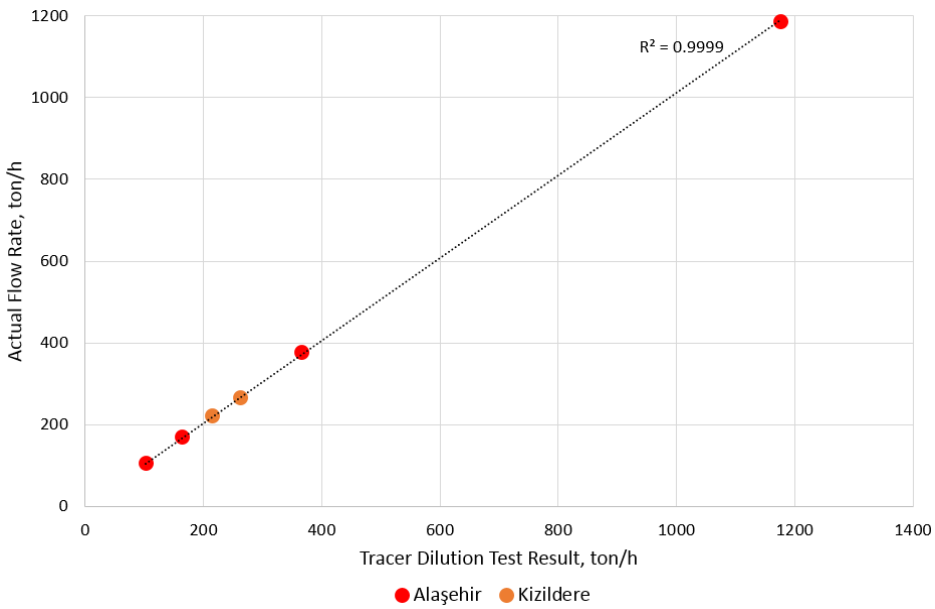

Figure 8: Tracer Dilution Test Comparison with Actual Rates

3. CONCLUSION

Liquid Tracer dilution test successfully conducted to measure brine flow rate in a two phase production line and in a single phase liquid injection line at Alaşehir and Kizildere Geothermal Fields in Turkey. It was concluded that tracer concentrations detected in brine samples were also diluted by steam condensate which causes over estimate flow rate measurement. To eliminate that effect, the measured concentrations were corrected by steam fraction. If steam fraction is less than 2%, it is not required to use correction factor. In high enthalpy wells with low flow rate, it is expected to have high fluctuation of measured concentrations. To decrease uncertainty and obtain the most accurate result, the number of collected samples should be increased. Fluctuation of tracer concentration in Kizildere Geothermal Field was much smaller than that of Alaşehir geothermal field. The main reason of that is the type of injection pump used. The lower pump rate, the lower fluctuation observed in concentration.

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