Production Test Analysis Using Separator Method with Respect to Separator Efficiency

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ABSTRACT

Production test is one of very crucial activities in the geothermal field development process. The condition of the well, reservoir characteristics, and production capacity of the well can be determined by production test. This study describes the production analysis results based on case studies of XYZ-well production test at Lahendong geothermal field in Indonesia using Separator Method. The steam is measured using orifices and water is measured using a weir box. The appropriate test separator used is a separator that has a separation efficiency design that can reach over 99% of steam product. The result of production test must be processed first to calculate the mass flow rate of the well and the data should be processed carefully to get the best possible determination. The production test unit facility used can affect to the accuracy of the obtained data. Errors in production test data processing would decrease the production efficiency and will affect the deliverability curve. Therefore, it is necessary to analyze the deliverability curve and the performance of separator test by looking at the result of separator efficiency value.

1. INTRODUCTION

Lahendong is one of geothermal field owned by PT. Pertamina Geothermal Energy (PGE) that located in Indonesia, North Sulawesi Province, the District Tomohon – North Sulawesi, about 30 km southwest of Manado. The high-temperature geothermal systems in this area are divided into two different categories based on reservoir temperatures, those with very high temperatures (350°C) in the south and those with more modest temperatures in the north (250°C). The wells produce two-phase fluid a mixture of water and steam with water dominance. Steam that supplied from the clusters generates 120 MW and the separated brine will be injected with the condensate from the plant to the reinjection wells.

When geothermal wells finish its drilling stage, production tests need to be done. Production test are performed to determine the characteristics of the wells based on the mass flow rate and enthalpy at a variable wellhead pressure (WHP). In general, production test methods can be divided into three types: vertical lip, horizontal lip and the separator method. Each method has different test unit used and the method selection depends on the equipment, estimated production rate and required accuracy. Data from the well test results should be analyzed to find out information about the well production and the test unit used specially the efficiency of separator test.

2. SEPARATOR METHOD

This method is suitable for measuring high flow rates during production tests and for a relatively long time, making it the most accurate method. The fluid flow will be separated in the separator into water and steam flow at the separator pressure. The flow rate of each phase can be measured later, where the steam flow can be measured by the orifice flow meter and the water phase can be measured by a weir box after passing through the silencer.
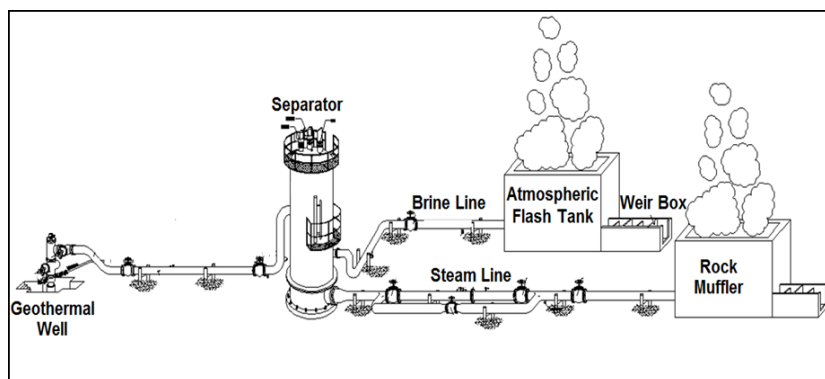

Figure 1: Separator method facilities.

2.1 Steam Flow Rate Measurement

Measurements of the steam rate that comes out from the outlet of the separator are made by using orifice meters. The principle of speed measurement by using a disturbance is used, so the next parameters may be obtained: the upstream pressure (PU), downstream pressure (PD) and differential pressure (ΔP). By using the principle of Bernoulli's law, the rate of steam can be calculated:

$$M = (0.001252)(C)(Z)(\epsilon)(E)(d^2)\sqrt{(\Delta P.\rho)} \tag{1}$$

where M is steam flow (t/h), C is basic coefficient, Z is the correction factor, ϵ is the expansion factor, E is velocity factor, d is inside diameter orifice (mm), ΔP is delta pressure of upstream and downstream of orifice (kg/cm3) and ρ is density of steam (kg/m3).

2.2 Brine Flow Rate Measurement

The weir box is used for measuring the water flow rate from the separator. Similar to the case of the orifice meter, a standard formula for the weir box is used for calculating brine flow rate as shown in below (Hirowatari, 1986).

$$k = 81.2 + \frac{0.24}{h} + \left(8.4 + \frac{12}{\sqrt{D}}\right) x \left(\frac{h}{B} - 0.09\right)^2 \tag{2}$$

$$M_{w(atm)} = K x h^{2.5} \tag{3}$$

where k is discharge coefficient, h is the water level height through v-notch (m), D is the height of weir box excluding v-notch (m), B is the width of the weir box (m), Mw(atm) is the brine flow at atmospheric condition (t/h). In order, to make such above calculations, the water level in the weir box must be determined. The water level is measured by using the conventional method (ruler). By applying the measured water level into the equation above, the brine flow rate can be determined.
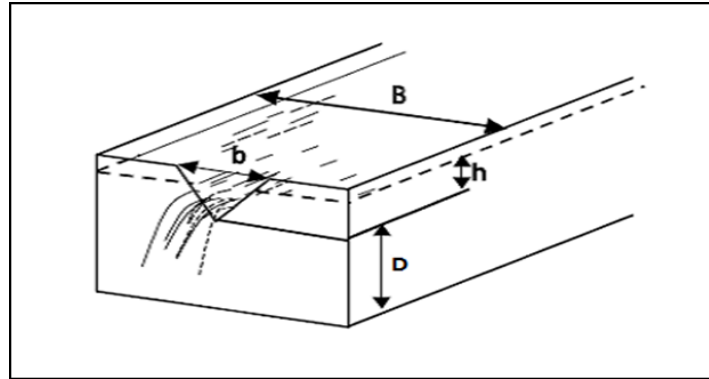

Figure 2: Schematic picture of weir box (v-notch).

2.3 Separator Efficiency

Separator is one of the production facilities that separate the fluid from the two-phase production well. In general, the separator used in geothermal field is Cyclone Separator which average efficiency can reach 99%. Computation for separator efficiency is implemented using the guidelines by Lazalde and Crabtree (1984) that defined the geothermal vertical separator efficiency as a product of centrifugal (mechanical) efficiency and annular (entrainment) efficiency:

$$\eta_{ef} = \eta_m \; x \; \eta_A \tag{4}$$

where η_{ef} is the separator efficiency, ηm is the centrifugal efficiency, and ηA is the annular efficiency.

The approach is considered for finding the appropriate separator dimensions. The inlet pipe to the separator (Dt) should be equal to the steam pipe (De) and the liquid outlet pipe (Db). Separation pressure, flow enthalpy and total mass flow in the separator are major parameters in determining the size of the separator. Table 1 show a summary of design guideline by Lazalde-Crabtree design. Care is necessary so as to try as much as possible to take separator dimensions that are practical in construction point of view. This is due to the fact that vertical cyclone separators are used as the separator of choice in the study.

Table 1: Vertical separator design guideline by Lazalde-Crabtree

Parameter	Design
D (Separator Diameter)	3.3 Dt
De (Steam Outlet Diameter)	1 Dt
Db (Brine Outlet Diameter)	1 Dt
α	-0.15 Dt
β	3.5 Dt
z	5.5 Dt

The separator efficiency determined above is considered the theoretical separator efficiency. It does not really represent the actual efficiency since other mechanisms such as liquid re-entrainment is not adequately addressed in that correlation. When a geothermal fluid separates, the steam phase has a greater enthalpy content than the residual liquid phase. Loss of steam is therefore associated with a loss of mass and reduction in enthalpy. In addition, separator efficiency can be measured by the amount of brine carryover in steam. This definition has been "universally accepted" as the way to measure separator efficiency. Bangma and White, included Sodium (*Na*) and Chloride (*Cl*) as the chemical signatures to measure carryover and separator efficiency. This method used requires the accurate measurement of the Chloride or Sodium concentrate in brine and steam. The equation below calculates the brine carryover (m_b):

$$m_b = \frac{c_s^{Cl}}{c_{sb}^{Cl}} \tag{5}$$

Where C_s^{Cl} is the mass flow rate of Chloride in separated steam in mg/s and C_{sb}^{Cl} is the Chloride in separated brine (Zarrouk and Purnanto, 2014). In many geothermal fields, Chloride analysis of samples in the first drain pot right after separator is used to compute the efficiency of separation through brine carryover.

$$\eta_{ef} = \left[1 - \frac{c_s^{Cl}}{c_{sb}^{Cl}}\right] x \ 100\% \tag{6}$$

Chloride is the dominant anion and Sodium is the major cation in geothermal reservoir fluids. Fluid boils with subsequent loss of steam and Chloride content decreases on the steam phase where is detectable in the steam. However, the carryover can be measured indirectly using the chemical signature of the geothermal brine namely Chloride and Sodium.

3. RESULT
Production test with separator method, which performed on ABC-well at Lahendong geothermal field, used one orifice flow meter on the steam flow line and one weir box. Orifice and weir box specifications used are summarized in **Table 2**.

Table 2: Orifice and weir box specification used in ABC-well production test

Orifice Meter		Weir-box	
Diameter (d)	215.9 mm	Type	V-Notch
Material Type	Stainless Steel	B	120 cm
Type Tapping	Radius	D	45.5 cm

The production test was performed from July 28th to August 16th, 2015. By calculate the steam flow at orifice flow meter and the brine flow at weir box, we can calculate the total mass flow rate of the well during the production test. Production test profile during the time interval is shown in **Figure 1**. Production test measurements graph obtained shows inconsistent results in some particular time. Theoretically, the larger the valve is opened the wellhead pressure will be smaller and will be stabilized at a certain pressure during valve is opened at the same conditions. Therefore, production test data obtained need to be selected and validated more in accordance with the theory.
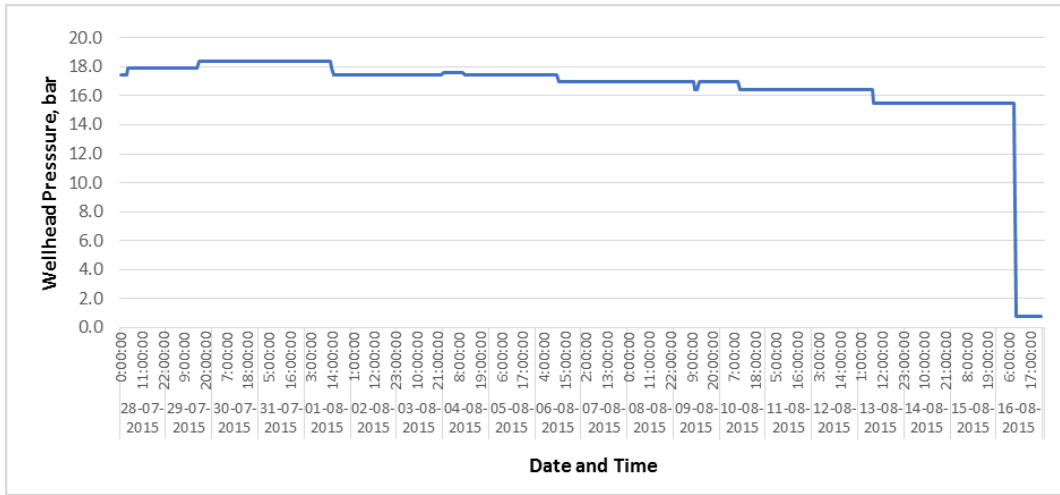
Figure 3: Wellhead pressure profile of ABC well production test.

With the valid production test data, subsequent data processing can be conducted that begins with the mass flow rate calculation process of orifice and weir box. Mass flow rate of both are next combined to obtain total mass flow rate, so that it can be used to calculate total enthalpy of the fluid produced from ABC-well.

Production potential of ABC-well and its reservoir conditions can be predicted based on the *Wellhead Pressure vs. Total Rate* and *Wellhead Pressure vs. Enthalpy* plot. Analysis of the two plots is explained in Grant, Malcolm A. and Bixley, Paul F.: Geothermal Reservoir Engineering Second Edition, *Elsevier Inc.*, (2011), Oxford. A plot for ABC-well are shown in **Figure 2** and **Figure 3** According to the plot, it can be analyzed that ABC-well producing two-phase fluid and the result is appropriate with the actual condition.
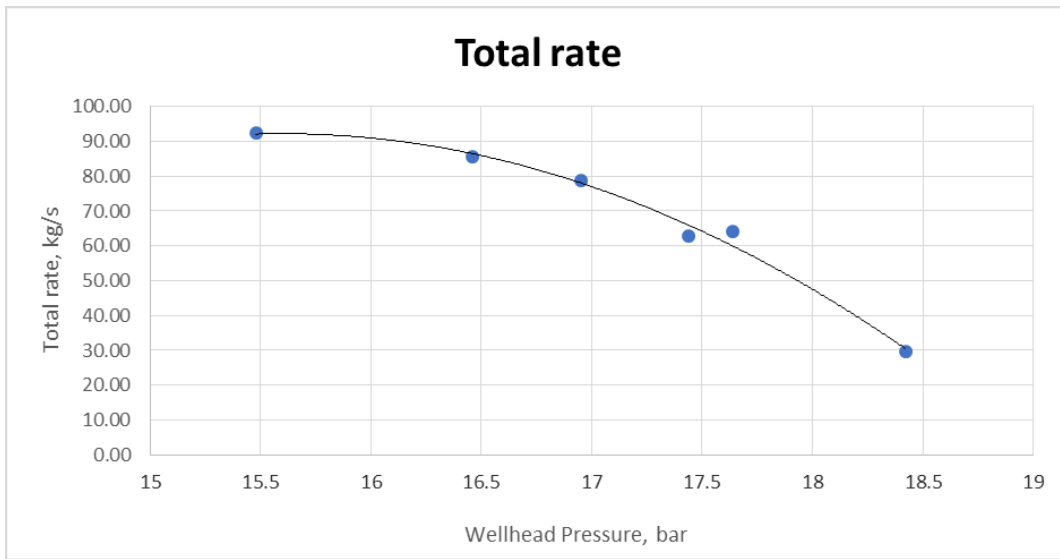

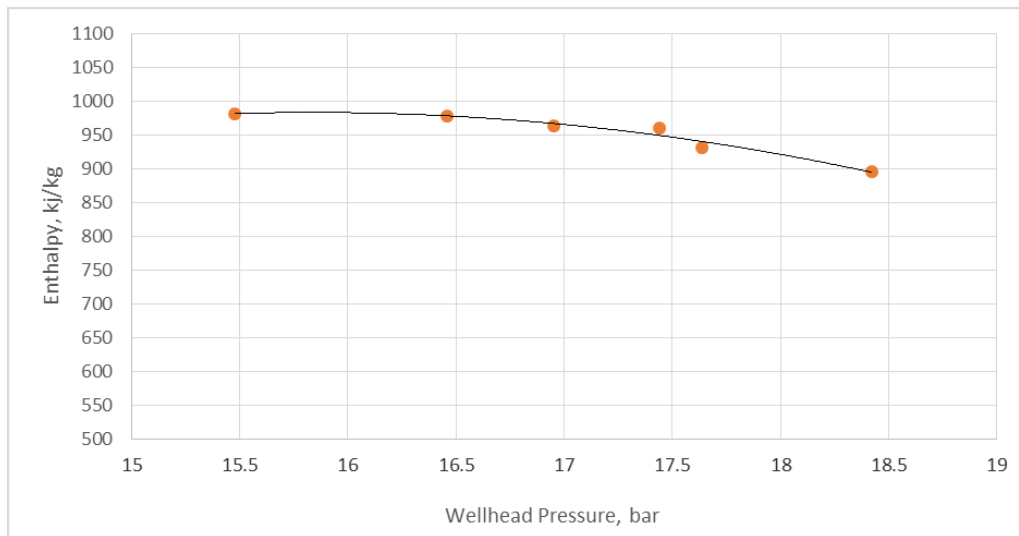**Figure 4: ABC-well flow rate plot after data selection process**

Figure 5: ABC-well enthalpy plot after data selection process.

The test unit facility that used during production test will also affect the accuracy of the data obtained. The good test separator designed is a separator that has a separation efficiency of up to 99%. Therefore, it is necessary to calculate the efficiency to know how the performance of the separator test used based on the results of the well production test data. The separator test used during production test has specification that summarized in **Table 3**.

Table 3: Separator test specification used in ABC-well production test

Separator Type	Vertical Cyclone (Webre)
Cyclone Diameter (D)	1.8 meter
Inlet Diameter (Dt)	20 inch
Steam Outlet Diameter (De)	20 inch
Brine Outlet Diameter (Db)	10 inch
Capacity	400 ton/hour

The efficiency is also dependent on several parameters that can be affected also by the design of the separator. We can calculate the efficiency by using the design/specification data of the separator test. So that, the separator efficiency values can representative the performance of separator used. Efficiency value of each mass flow rate at same separator pressure (8.1 bara) is shown in **Figure 4**. According to *the* plot, it can be analyzed that the separator test that used has a good efficiency up to 99%.
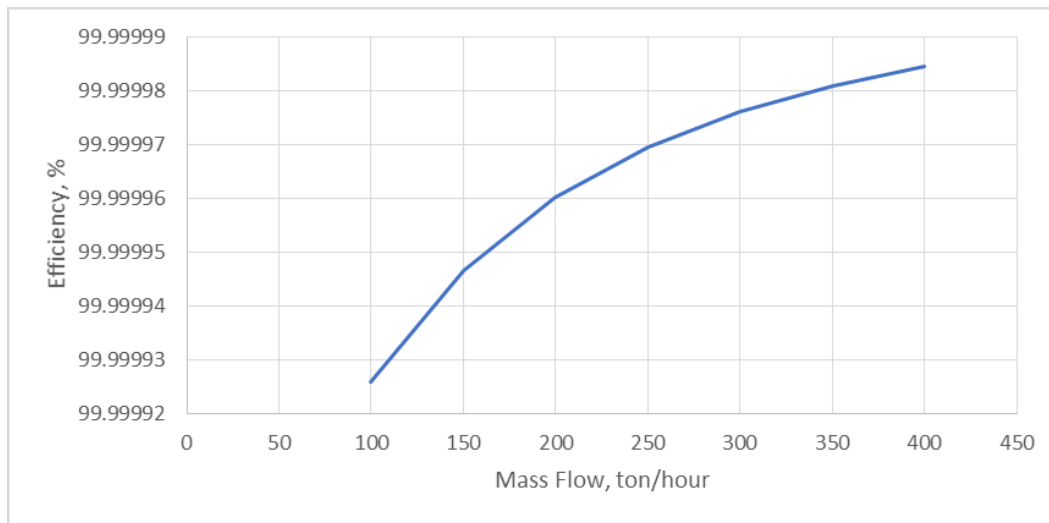
Figure 6: Separator efficiency of each mass flow rate at 8.1 bara separator pressure.

We can calculate the separation efficiency by measured the amount of the Chloride concentrate (Cl) of steam and brine flow given by the sampling data after the fluid separated by the separator test. The result of separation efficiency based on the measured Chloride concentrate by using the equation (6) is shown in **Table 4** which is the measured can show the actual condition of separation efficiency during the production test.

Table 4: Separator efficiency based on sampling data

Wellhead Pressure	Separator Pressure	Cl⁻		η_s
bar	bar	Brine (ppm)	Steam (ppm)	%
18.42	8	571	1	99.82
17.44	8	691	1	99.86
16.95	8	687	1	99.85
16.46	8	670	1	99.85
15.48	8	677	2	99.70

Based on Nicholson, Keith: Volatile species (eg.CO2) are concentrated in the separated steam phase and solutes (eg.CI) remain in the liquid phase. From the sampling data result it can be analyzed that the steam has a lower Chloride concentrate (in ppm) than the brine flow. So, it indicates that less brine carryover on the steam flow after the separator which means the separation process is good. According to the results of the calculation of efficiency it known that the separator test has a higher efficiency (99%) based on the separator design used and Chloride concentrate data.

CONCLUSION

1. The production test result of ABC well production has not been able to fully represent the characteristics of the well because the lack of data that can be obtained and analyzed.

2. ABC well produces two-phase fluid based on a result of production test data analysis.

3. The results of the calculation of the analysis obtained that the separator test used has efficiency up to 99% and showed that the separator test in the field is feasible to use.

4. The separation efficiency of separator will affect the accuracy data obtained of test production.

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REFERENCES

Bangma, P.: The Development and Performance of a Steam-Water Separator for Use on Geothermal Bores, U.N. Symposium on the Development and Utilization of Geothermal Resources Vol.3, (1961), Rome.

Grant, Malcolm A. and Bixley, Paul F.: Geothermal Reservoir Engineering Second Edition, Elsevier Inc., (2011), Oxford.

Hirowatari, K.: Field Training of Geothermal Production Engineering, Kyushu University, Japan, (1986).

Hugo, Lazalde-Crabtree: Design Approach of Steam-Water Separators and Steam Dryers for Geothermal Applications. Geothermal Resource Council Bulletin, (1984), Mexico.

Nicholson, Keith: Geothermal Fluids, The Robert Gordon University, (1993), Scotland.

Rizaldy, Zarrouk, Sadiq J. and Morris, Chris: Liquid Carryover in Geothermal Steam-Water Separator, Proceeding Geothermal Workshop, (2016), New Zealand.

Saptadji, Nenny Miryani: Teknik Panas Bumi, ITB (2001).

Zarrouk, S. J., and Purnanto, M. H.: Geothermal Steam-Water Separators: Design Overview, Geothermics, (2014).

Onyango, Stephen Odhiambo: Design of Steam Gathering System for Menengai Geothermal Field, Kenya, United Nations University, (2015), Iceland.