A Statistical Analysis for Comparison Between Lip Pressure and Separator in Production Well Testing at Lahendong and Ulubelu Field

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ABSTRACT

In order to determine the potential of power generation in a geothermal well that have been completed; there should be a series of production tests to determine precisely and accurately the characteristics of the geothermal production well in terms of physical and chemical properties. There are several methods in geothermal well testing, but there are two methods commonly used, lip pressure and separator method. Lip pressure method can be performed in an upright (vertical discharge) or in a flat configuration (horizontal discharge). Basically, both methods have the same purpose; it's to clean the drill cuttings or mud drilling from the well and to get an estimate of the potential electrical energy that can be generated by these wells.

During the progress of a production test, the separator method can present the characteristics of the data in a more comprehensive way than lip pressure. However, separator method need longer preparation, larger costs, more man power and more complicated calculations than the lip pressure method. From that background, a comparative analysis between the two methods was made by using the statistical tool of the t-test method. The comparisons were done on one well at Lahendong (North Sulawesi) and seven wells at Ulubele (Lampung) geothermal fields.

The comparison was conducted on the rate of vapor and enthalpy for both test methods by calculating the error value and the standard deviation at 95% confidence level obtained by the normal distribution curve. Acceptance range for enthalpy is between 596 kJ/kg to 1,850 kJ/kg and for steam rate is between 23 tons/hour to 98 tons/hour. In other words, when the lip pressure method is used and the results are inside those ranges, then we can say that this method is accurate with a confidence level of 95%.

1. INTRODUCTION

Geothermal energy is a renewable energy that currently is urgent because the demand of energy increase every year significantly, particularly in Indonesia. While the majority of energy sources in use today are based on petroleum. As one type of non-renewable energy, oil reserves in Indonesia and its production continue to decline. Therefore, with the largest geothermal reserves in the world (40% of world reserves), geothermal is an excellent alternative to address the energy crisis in the country and its development must be massive and consistent.

PT. Pertamina Geothermal Energy (PGE), a subsidiary of PT. Pertamina (Persero) currently has seven new projects and four existing areas. PGE is given a task by the government to accelerate the program of geothermal energy utilization in Indonesia. To meet the existing targets, it is needed to drill in the new projects and build make up wells in the existing areas.

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 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. For lip methods the well potential is calculated based on the Russell James equation. While in the separator method, two-phase fluid is separated in the separator and then measurements of the mass flow of steam and brine are done. Separator method has better accuracy than the lip methods.

2. ULUBELU AND LAHENDONG FIELD

2.1 Ulubelu Field

Ulubelu Geothermal Field is located in Indonesia, Sumatra, Lampung Province, the District Ulubelu Tanggamus - Lampung, about 100 km west of Bandar Lampung. Geothermal Project Ulubelu can be reached by car via a paved road from Bandar Lampung to the District Stage Island, then proceed to Ulubelu through rocky roads and paved most of the approximately 15 km, with an average elevation of 800 meters above sea level.

The location of production and reinjection wells is divided into five (5) clusters, which are Cluster A, B, C, D and F. Steam supplied from three (3) clusters (B, C and D) and separated brine will be injected with the condensate from the plant to the reinjection wells in clusters A and F.

2.2 Lahendong Field

Lahendong Geothermal Field is located in Indonesia, Sulawesi, North Sulawesi Province, the District Tomohon – North Sulawesi, about 30 km southwest of Manado. Lahendong Geothermal Field can be reached by car via a paved road from Manado to the Tomohon, with an average elevation of 800 meters above sea level.

The location of production wells is divided into five (5) clusters which are Cluster 4, 13, 5, 37 and 24. Steam supplied from these five (5) clusters together with separated brine will be injected with the condensate from the plant to the reinjection wells in Cluster 7.

3. BASIC THEORY

Production tests are conducted to determine the potential, physical and chemical characteristics of a well. Production test methods are based on the type of fluid and different methods can be distinguished in Figure 1.
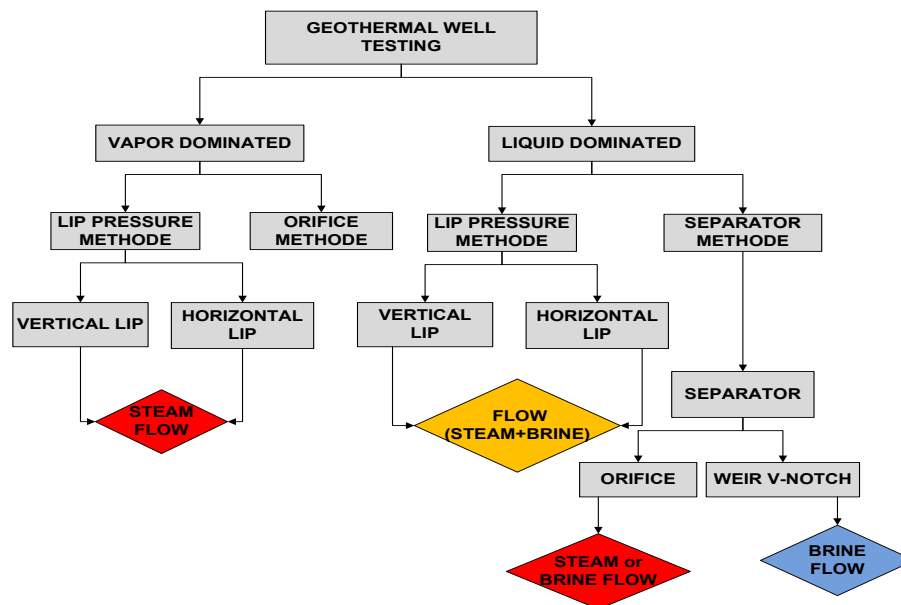

Figure 1: Flowchart of well testing methods based on fluid characteristics.

Figure 1 is divided into three test methods; separator, vertical lip, and horizontal lip. Separator method have the greater accuracy compared to lip methods. The principle of the separator method is the separation of the two phase fluid in the separator; steam and brine come out separately from the outlet of the separator. The rate of steam can be determined by using an orifice-meter, while the rate of brine could be measured using a weir box equipped with a V-Notch.

3.1 Vertical Lip Test

In the method of vertical lip, enthalpy values are obtained from the reservoir temperature. By using the Russel James equation, the total mass flow of the well can be obtained (Figure 2).


$$m = \frac{5.198805 x P^{0.96} x d^2}{H^{1.102}}$$
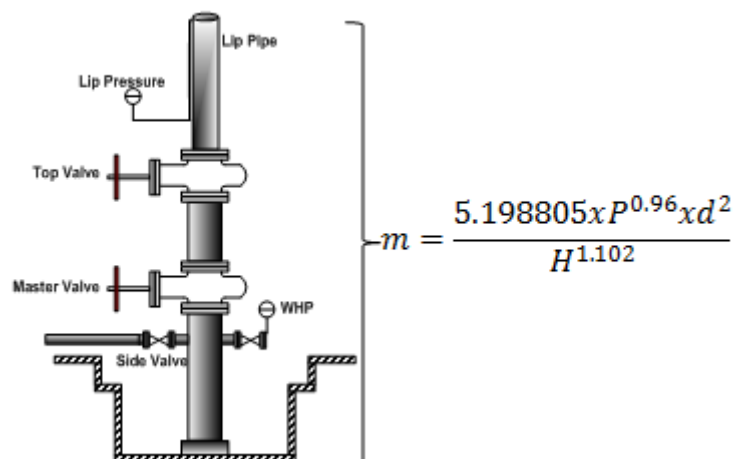
Figure 2: Vertical lip method facilities.

According to Figure 2, m is two-phase mass flow rate (t/h), H is specific enthalpy of the discharge fluid (kJ/kg), d is lip pressure pipe diameter (mm), and P is lip pressure (bar abs). The weakness of this method is that the value of the enthalpy of the well is not calculated, but assumed from reservoir temperature obtained from the downhole measurement (P&T). In its application, this method is only used to clean the wells and calculate the potential of the wells. Another significant weakness worth to mention (especially for lower-enthalpy wells) is the discharge of brine all over the well pad and surrounding areas. This is a significant disincentive for the vertical discharge method in environmentally sensitive areas.

3.2 Horizontal Lip Test

In the horizontal lip method, the enthalpy is obtained from the correlation of lip pressure and water flow (through the weir box). The accuracy of this method is better than vertical lip. The horizontal lip test facilities can be seen in Figure 3.
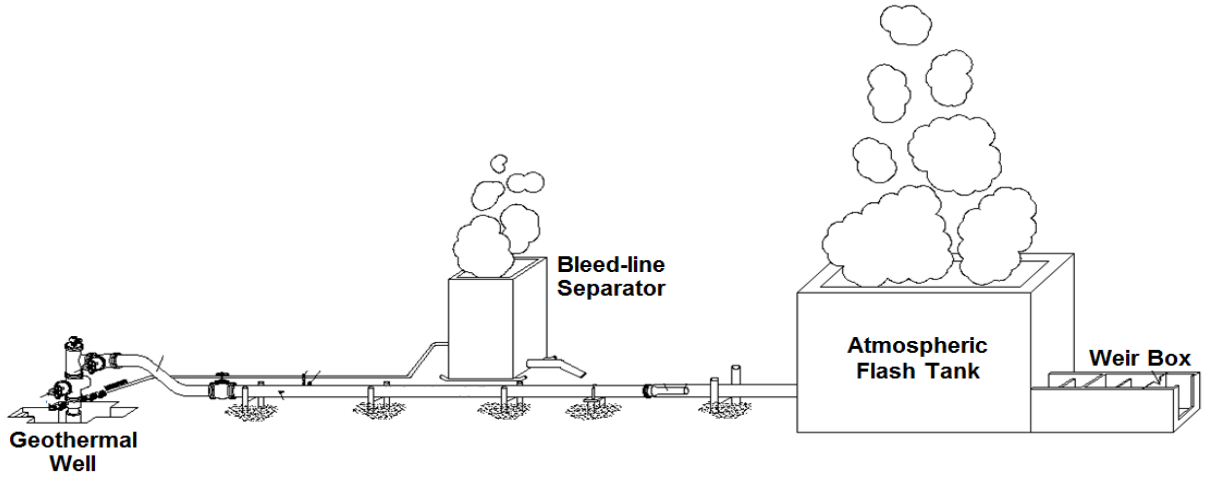
Figure 3: Horizontal lip method facilities.

The calculation of enthalpy and total mass flow is conducted using the Russell James equation (James, 1970). The flowing enthalpy and two-phase flow can be calculated using the following equation:

$$\frac{Gxh^{1,102}}{P^{0,96}} = 0,184$$

$$G = \frac{m}{A}$$

$$m = \frac{0.184 \; xAxP^{0,96}}{H^{1.102}}$$

Where $m_{w(atm)}$ is brine mass flow rate at weir box (t/h) and A is a lip pipe area (cm^2).

Brine flow rate from the Atmospheric Flash Tank (AFT) is correlated with the total mass flow rate using Flash Correction Factor (FCF) as below:

$$m = m_{w(atm)} xFCF$$

$$FCF = \frac{1}{1-X}$$

$$m = \frac{m_{w(atm)} xh_{fgatm}}{h_{gatm} - H}$$

Substitution of the above equation to Russell James equation produces:

$$\frac{m_{w(atm)} xh_{fgatm} xH^{1.102}}{3600 \; xAxP^{0.96} x(h_{gatm} - H)} = 0,184$$

For atmospheric pressure at 1 bar absolute (hg atm = 2675 kJ/kg and hfg atm = 2258 kJ/kg) next is obtained:

$$\frac{m_{w(atm)}}{AxP^{0.96}} = \frac{0,184 \; x\,3600 \; x(2675 - H)}{2258 \; xH^{1.102}}$$

$$= \frac{0.293 \; x(2675 - H)}{H^{1.102}}$$

by using the previous equation, $m_{W(atm)}/(A \; x \; P^{0.96})$ can be calculated for a range of H. If H is plotted vs $\log[m_{W(atm)}/(A \; x \; P^{0.96})]$, then an almost linear relationship is obtained:

$$Y = \frac{m_{w(atm)}}{AxP^{0.96}}$$

If we assumed the atmospheric pressure is 1 bara, the equation is:

Mubarok et al.

$$H = \frac{2675 + 925Y}{1 + 7.85Y}$$

After flowing enthalpy is obtained, the total mass flow rate can be calculated by using the Flash Correction Factor (FCF), the above equation becomes:

$$m = \frac{2258 x m_{w(atm)}}{2675 - H}$$

In horizontal lip test, two-phase fluid flows into an atmospheric flash tank (AFT) which will be flashing. Brine flow measurement methods can use the V-Notch Weir as in Figure 4 below.
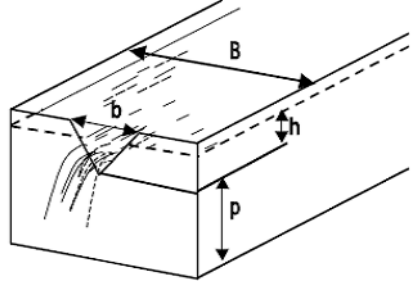
Figure 4: Schematic picture of weir box (v-notch).

Brine flow can be calculated by using this equation (Hirowatari, 1986):

$$k = 81.2 + \frac{0.24}{h} + \left\{ \left(8.4 + \frac{12}{p^{0.5}} \right) \left(\frac{h}{B} - 0.09 \right)^2 \right\}$$

$$m_{w(atm)} = k x h^{2.5} x 60 x \rho_f$$

Where h is the water level height through v-notch (m), p is the height of weir box excluding v-notch (m), B is the width of the weir box (m), $m_{w(atm)}$ is the brine flow at atmospheric condition (t/h) and ρ_f is the density of brine (kg/m3).

3.3 Separator Method

In the test separator method, the two phase fluid is separated in the separator. The rate of steam is measured using an orifice flow meter and brine rate using the weir box. The schematic drawing of the separator test facility can be seen in Figure 5 below.
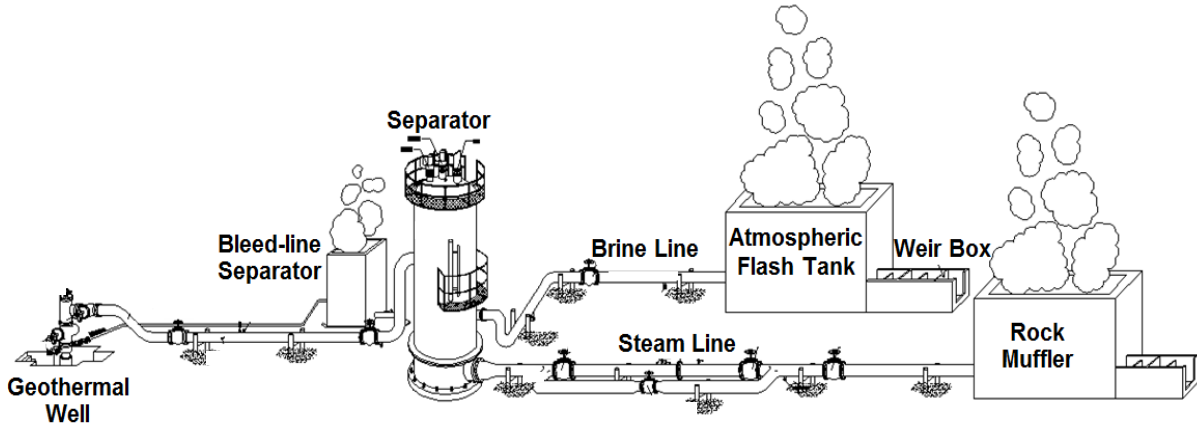
Figure 5: Separator method facilities.

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 vapor can be calculated:

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

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).

3.4 t-test as Comparison Method Tool

One of the functions of statistic is to compare between two methods. The comparison of two methods in general can be made using the t-test and f-test. If the data used in the analysis is more than 30 samples, the appropriate method is f-test. Vice versa, if the sample size is less than 30, then it is better to use the t-test.

In the t-test, the first step is making a hypothesis; H_0 and H_1. H_0 is the average values of the two methods are same and H_1 otherwise. (Kurniawan, 2008).

H_0 will be accepted if the t-calculated is smaller than t-table, t-calculated can be obtained using the following equation:

$$t - test = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{S_1^2}{(n)}} + \sqrt{\frac{S_2^2}{(n)}}}$$

Where $\bar{x}$ is the mean, S is the standard deviation, and n is the size of population. The value of t-table, which can be seen in the reference, varies and depends on the level of confidence. In this case, the level of confidence that is used is 95%.

If the calculation results show that H0 is accepted, the next step is to create a normal distribution curve for both methods. The area of intersection of two normal distributions is a range of acceptance areas at a certain confidence level. The scheme of the distribution curve is shown in Figure 6 below.
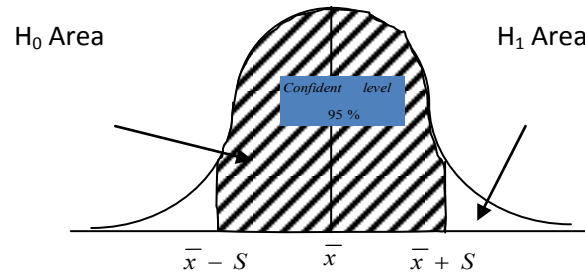
Figure 6: Distribution curve for two tails and 95% acceptance range

3. RESULT AND ANALYSIS

Production testing in Lahendong and Ulubelu was done using two different methods, which are horizontal lip and separator method. The test results were analyzed using statistical tools to determine the extent to which the accuracy of horizontal lip approaches the separator estimate. Moreover, the final product of this statistical analysis is to obtain an accurate value range of horizontal lip if it will be used as a replacement method of the separator technique.

Separator method has a higher accuracy compared to other methods; however, it requires long preparation times and a huge cost. Therefore, in consideration of cost and time constraints, the horizontal lip method is expected to replace the separator method as a test method of production with relatively low costs and short time, but also having a good accuracy.

In this experiment, the test results were compared to enthalpy and steam rate data. The hypothesis H0 is that the values of the enthalpy and steam rate for both methods are relatively equal and H1 otherwise. Table 1 below presents the results of the calculation of the t-test.

NO	WELL	ENTHALPY (kJ/kg)		STEAM (t/h)	
		LIP	SEPARATOR	LIP	SEPARATOR
1	UBL-A	1,189.27	1,025.96	53.64	55.27
2	UBL-B	1,480.45	1,097.38	91.49	79.04
3	UBL-C	1,258.15	1,269.37	56.67	162.03
4	UBL-D	1,232.55	1,230.89	50.34	50.02
5	UBL-E	1,294.87	1,300.24	59.27	90.41
6	UBL-F	1,278.63	1,283.75	59.16	119.34
7	UBL-G	1,279.09	1,282.77	59.88	42.92
8	LHD-A	1,078.80	1,145.20	38.89	40.46
	MEAN (x)	1,261.48	1,204.45	58.67	79.94
	STANDARD DEV	112.82	102.36	14.97	42.82
	t-calculated	1.06		1.33	
	t-table, α=0.05, n=8	2.145		2.145	

Table 1: t-test analysis for the two methods under study.

From Table 1 it is seen that the value of t-calculated is less than t-table. In other words, the hypothesis H_0 is accepted, the accuracy of enthalpy and steam measurements for both methods are relatively equal. To obtain an accurate range for the lip method, a distribution curve for each variable enthalpy and steam is created (Figure 7).
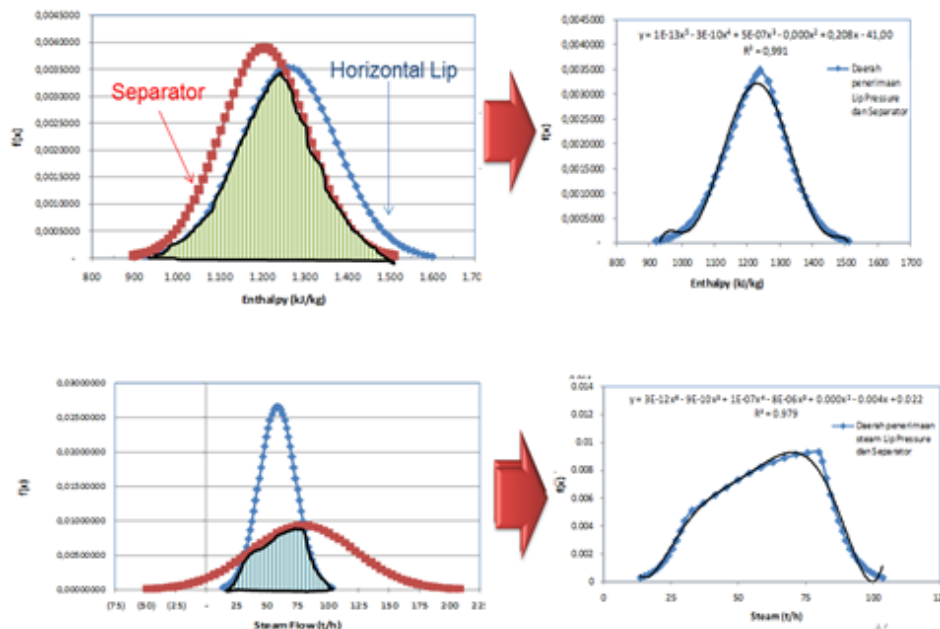
Figure 7: Distribution curve for lip and separator methods for enthalpy and steam flow.

The acceptance range is the area under the intersection of the two normal distributions. From the graph with the normal distribution overlapping ranges, the obtained acceptance range with the 95% confidence level is as follows:

Parameter	S	X	X-S	X+S	Acceptance Range
Enthalpy (kJ/kg) - H	627.11	1223.43	596.33	1850.54	$596.33 < H < 1850.54$
Steam Flow (ton/jam) - m steam	37.49	60.45	22.97	97.94	$22.97 < m_{steam} < 97.94$

Table 2: The result of acceptance ranges for the horizontal lip method

From Table 2 above, it can be said that the horizontal lip method will be accurate with a 95% confidence level if the enthalpy of the well is in the range between 596 to 1,850 kJ/kg. Whereas, for the steam rate the range is between 23 to 98 t/h.

The horizontal lip method is quite reasonable to be able to replace the separator method on geothermal production testing. Normally, the average value of steam rate and enthalpy of two-phase wells in Indonesia enter into the acceptance range obtained. The advantages of the horizontal lip method is the simplicity of facilities, low cost (50% smaller), faster preparation and test execution times than the separator method, but with the same relative accuracy.

4. CONCLUSION

In conclusion, horizontal lip is an alternative method that can be used to replace the separator method. The comparative study of the two methods with the t-test shows that the steam rate and enthalpy using the horizontal lip method has good accuracy with a 95% of confidence level.

The majority of wells in Indonesia are two-phase, thus horizontal lip can be used as a standard method for obtaining the characteristics and potential of the well. The test results using a horizontal lip can refer to the acceptance range. The acceptance range of steam rate and the enthalpy is 596-1850 kJ/kg and 23-98 t/h, respectively.

To increase the confidence level of accuracy, well numbers should be added and then compared with tracer flow test results (Broaddus et. al., 2010) and two-phase orifice flow meter (Helbig & Zarrouk, 2012).

REFERENCES

Broaddus, M., Katz, J.I.K., Hirtz, P., Kunzman, R.: Advancements in Tracer Flow Testing: Development of Real-Time Technology for Flow and Enthalpy Measurements, Proceedings World Geothermal Congress, Bali, Indonesia, (2010).

DiPippo, R.: Geothermal Power Plants, Dartmouth, (2007)

Grant, M. A, Donaldson, L. G, Bixley, P. F.:Geothermal Reservoir Engineering', 2nd Edition, New York, (2011)

Helbig, S. ,Zarrouk S. J.: Measuring Two-Phase Flow in Geothermal pipelines Using Sharp Edge Orifice Plates, Geothermics 44, p. 52-64, (2012)

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

James, R.: Maximum Discharge of Geothermal Wells, DSIR, Wairakei, Taupo, New Zealand, (1970).

Kurniawan, D.: Tabel Distribusi, FORUM STATISTIKA, Jakarta, (2008).

(http://ineddeni.wordpress.com)

SNI 13-6987-2005,: Fluida Sumur Panasbumi-Prosedur Uji Alir, Jakarta, (2005)

SNI 13-7123-2005,: Kriteria Peralatan Uji Alir Fluida Sumur Panasbumi, Jakarta, (2005)