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Comparing Murdock Equation and Mubarok Equation with the Tracer Flow Test to Get the Right Flow Rate Calculations in the Field "X"

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ABSTRACT

Research on geothermal wells in Field "X", namely Well-A, Well-B, and Well-C have different steam and brine production. Therefore, an accurate measurement is needed in calculating the flow rate to determine the behavior of production wells. The use of a flow meter using the Tracer Flow Test (TFT) method can be the first step to measure the flow rate of production wells. However, the calculations that should be used to calculate the flow rate in these wells cannot be determined accurately. In measurements using a flow meter, the output from the production well is in the form of different pressure which is used to calculate the flow rate using several equations, including the Murdock equation and the Mubarok equation. To determine the feasibility of using these two equations, it is necessary to compare the actual data using TFT. Sequential steam data obtained in field 'X "in Well-A, Well-B, and Well-C through the Murdock equation, namely, 37.1 kg/s, 10 kg/s, and 6.8 kg/s, while the brine data is 0.009 kg/s, 7.6 kg/s, and 7.4 kg/s. Steam data in the same well using the Mubarok equation are 27.4 kg/s, 7.8 kg/s, and 5.1 kg/s, while the brine data is shown at 0.007 kg/s, 1.6 kg/s, and 5.5 kg/s. The actual steam data from TFT, respectively, from Well-A, Well-B, and Well-C obtained from the field results are 32 kg/s, 10.9 kg/s, and 7.5 kg/s. Meanwhile, the brine data obtained from TFT were 0 kg/s, 7.8 kg/s, and 7.3 kg/s, respectively. The result of the percentage error with the Murdock equation compared to the actual TFT data obtained results of 16% steam and 0% brine in Well-A, 8% steam and 2% brine in Well-B, 9% steam and 2% brine in Well-C using the Murdock equation. While the error in the Mubarok equation results in 15% steam and 0% brine in Well-A, 28% steam and 2% brine in Well-B, and 58% steam and 26% brine in Well-C. From the comparison results of the Murdock and Mubarok equations, it can be concluded that the equation that can be applied to the Field "X" is Murdock's equation because it has a smaller error value. However, Murdock's equation is still ineffective for use in the "X" field because there is an error value of > 10% in the steam value of well A which is a single-phase well. If this equation is to be used, it must be applied to wells producing two-phase fluid.

1. INTRODUCTION

I Indonesia as a country known for its abundant natural resources has a lot of potentials to be developed. One of the existing natural resources is geothermal as energy for power generation and other industrial needs. Field X is a geothermal field located in Indonesia that has produced a geothermal system with a total production of 227 MWe consisting of 31 production wells, 13 monitoring wells, 5 injection wells, 6 plug and abandonment wells, and 5 slim hole wells. Most wells in Field "X" are dominated by water with a separated system cycle generator system. This system is used because the fluid in most wells are a mixture of two-phase fluids (steam and liquid) which must be separated first.

Accurate and reliable measurement of flow rate is a major challenge in observing production well behavior. To get the flow rate value, a flow meter is used as a first step in measuring geothermal production wells. The flow meter used in the well in Field "X" is expected to produce an output in the form of a flow rate, but in fact, the resulting output is not a flow rate but a differential pressure. To calculate flow rates, equations such as the Murdock and Mubarok equations are needed. From the two equations used, a suitable equation will be looked for to be used in Field "X". These two equations will be analyzed and calculated with another test in the form of a Tracer Flow Test (TFT) or a Separator Test that has been proven valid.

The two equations used in Field "X" in observing the behavior of production wells have different development patterns. Murdock developed a one-phase material equation modification with one of the experimental constant equations available in the ASME Fluid Meters Research Committee Publications. Meanwhile, Mubarok developed Pressure Differential Flow Meters by using the latest correlation for two-phase orifice plate geothermal which includes the calculation of mass flow rate, namely variable accuracy.

2. THEORY

2.1 Production Test

Production Test (commonly called discharge or output test) is performed to determine:

a. Type of reservoir fluid and production fluid.
b. Well production capability, namely the amount of production rate and fluid enthalpy at various wellhead pressures.
c. Fluid characteristics and gas content.

Above data is needed to determine at what wellhead pressure the well should be operated. Fluid enthalpy mass flow rate data will be very useful for calculating the well potential at various wellhead pressures.

One of the results of the production test is the production curve (output curve), which is a curve that describes the production capacity of the well in the form of an image, which is the relationship between total mass flow rate, vapor mass flow rate, enthalpy, and vapor fraction or dryness. As an example, in Figure 1 shows the good production curves from various geothermal fields.

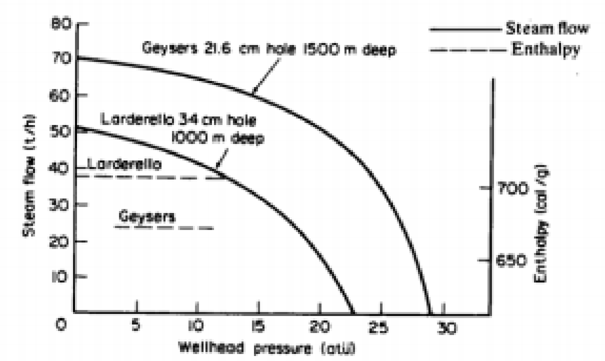


Figure 1 : Well production curves from various geothermal fields are dominated by steam (Armsted, 1983)

There are several production test methods that are commonly used(Saptadji, N., 2001), namely:

a. Single-phase measurement method.
b. Calorimeter method.
c. Lip pressure method.
d. Separator method

2.2 Tracer Flow Test

Tracer Flow Test (TFT) is a measurement of the flow of a fluid by injecting a chemical in order to determine the performance of each production well by monitoring the total enthalpy and mass production rate. The chemicals used are sulfur hexafluoride (SF6) and thermo trace. Sulfur hexafluoride (SF6) is used to measure the rate of steam production while thermo trace is used to measure the rate of brine production. Another objective is to determine the dryness level and geochemical content of each production well. The Tracer Flow Test method can be used to determine the condition of a geothermal reservoir, by monitoring the results of the Tracer Flow Test measurement in the form of enthalpy. A decrease in enthalpy over a period of time can be an indication of a thermal breakthrough. However, if the opposite is true, namely the increase in enthalpy, it can be said that the well is turning into a dry-steam well. Until recently, the direct method for measuring steam and water flow in a two-phase pipeline was the Tracer Flow Test. This method is routinely used and is sometimes called the tracer dilution method. The Tracer Flow Test procedure for well outflow testing was developed in the early 1990s by workers in the United States (Hirtz et al, 2001).

Tracer Flow Test can produce a big advantage when implemented in steam field design, better than previous piping. With the latest geothermal field developments, it is only natural to abandon the wellhead testing equipment as it is more profitable to use the Tracer Flow test method. In addition to well testing, the Tracer Flow Test itself can be used to measure the flow at the separator output and at the scrubber output.

In simple terms the Tracer Flow Test procedure can be seen in Figure 2 below:

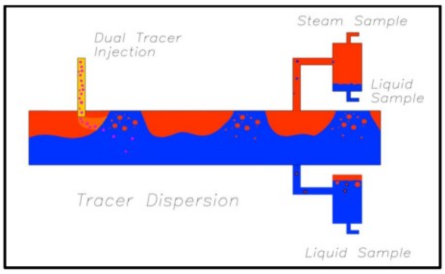


Figure 2. Working Principle of TFT

a. Liquid Phase Tracer

- Halides like iodide (I) or bromide (Br)
- Radioactive tracers like isotopes iodide- 125 (125I) and iodide-131 (131I)
- Fluorescent dyes such as fluorescein and rhodamine
- Aromatic acids such as benzoic acid
- Naphthalene sulfonates

b. Steam Phase Tracer

- Fluorinated hydrocarbons such as R-134a and R-23
- Sulphur hexafluoride (SF6)

In the tracer method, the mass flow rate of water and steam is calculated by the following formula.

$$\mathrm{M_w} = \frac{M_r}{(C_{Tw} - C_{Bw})} \quad (1)$$

$$M_V = \frac{M_r}{(C_{Tv} - C_{Bv})} \quad (2)$$

where:

M_w = mass flow rate water mass flow
M_v = rate vapor mass flow
M_T = rate tracer injection mass flow rate tracer
C_{Tw} = weight concentration in water
C_{Tv} = tracer weight concentration in steam
C_{Bw} = base concentration tracer element weight in water
C_{Bv} = basic concentration tracer element weight in steam

To calculate the dryness and enthalpy of two-phase flow using the following formula.

$$X = \frac{M_V}{M_V + M_W} \quad (3)$$

$$h = h_r + X.h_{fg} \quad (4)$$

where:

x = dryness
h = enthalpy of bursts
hf = enthalpy of water
hfg = latent enthalpy of steam and water

2.3 Mubarok Equation

Accurate measurement of the total mass flow rate of a two-phase geothermal well is one of the challenges in observing well production behavior. Based on his research, Mubarok stated that there are several two-phase measurement techniques used in the geothermal industry, however, some of the methods used are expensive and are imposed on production costs, in addition, this technique does not provide real-time measurements. Pressure differential flow meters are the method most expected to be an alternative to the previous method, and orifice plates with the concentric sharp-edged type have been used by many groups since 1980, but using variable accuracy. Recent correlations for geothermal two-phase orifice plates covering a broad calculation of mass flow rates have been reported by Mubarok et al. (2020). This correlation has several advantages including the ease of large capacity and good accuracy and is also written as a function of the fluid enthalpy, which allows integration with the enthalpy meter for more accurate measurements. To find the steam rate and brine rate, the Mubarok equation uses the total M formula, namely:

$$m = \frac{\left(\frac{P1}{P2}\right)^{\sqrt[D]{\frac{10^{-5}\Delta P}{D}}}\left(\frac{\pi d^2}{4}\right) ch\sqrt{2\Delta P}}{\sqrt{1} - \beta^4} \quad (5)$$

where:

m = total mass flow (kg/s)
P_1 = pressure upstream (Pa)
P_2 = pressure downstream (Pa)
D = inside pipe diameter (m)
d = orifice diameter (m)
Ch = enthalpy coefficient (kg/m^3)
= (9.7 x 10^5) (h)$^{-1.27}$
h = enthalpy (kJ/kg)
Δp = pressure different (Pa)
β = ratio of orifice diameter to internal pipe diameter

2.4 Murdock Equation

Murdock developed an equation by modifying the one-phase metering equation with one of the experimental constant equations available in the ASME Fluid Meters Research Committee publications. These experimental constants were obtained from 90 test points for the two-phase flow of water-vapor, air-water, water-gas, brine-gas, and natural gas distillation combinations. These three tests are divided into orifice equipment with radius, flange, pipe tap locations in 2 1⁄2, 3, 4 inches with a ratio between 0.25-0.50. Pressure ranged from the atmosphere between 920 psia, differentials from 10-500 inches of water, and liquid weight fraction from 2 to 89%. The temperature is between 50-500 F and Reynolds Number for liquids from 50-50000 and for gases from 15000-1000000. The data were tolerated with a standard deviation of 0.75% (Murdock, 1962). To find the value of the steam rate and brine rate with the Murdock equation using the following equation:

a. Steam :

$$\left(\frac{359 \times kG \times steam\ exp.\ \times thermal\ exp.\ \times d^2 \times Steam\ \Delta P \times steam\ density}{1000}\right) 0.125998 \qquad (6)$$

b. Brine :

$$\left(\frac{359 \times kL \times thermal\ exp.\ \times d^2 \times brine\ \Delta P \times liquid\ density}{1000}\right) 0.125998 \qquad (7)$$

3. RESEARCH METHODS

3.1 Required data

Following is a description of the stages of research carried out in solving the following problems :

a. Study of literature

Conduct a earch for various written sources, in the form of books, papers, journals, etc. Which are relevant to research

b. Collecting Data

Data needed to conduct research include :

- Enthalpy
- Pipe internal diameter (ID)
- Diameter Orifice Meter
- Pressure Upstream

c. Processing and Presentation of Data

Data will be processed in the form of calculations which are then presented in tables and analysis results.

3.2 Work Flow Chart

The stages of carrying out the research written by the author will be shown in the following flow chart:

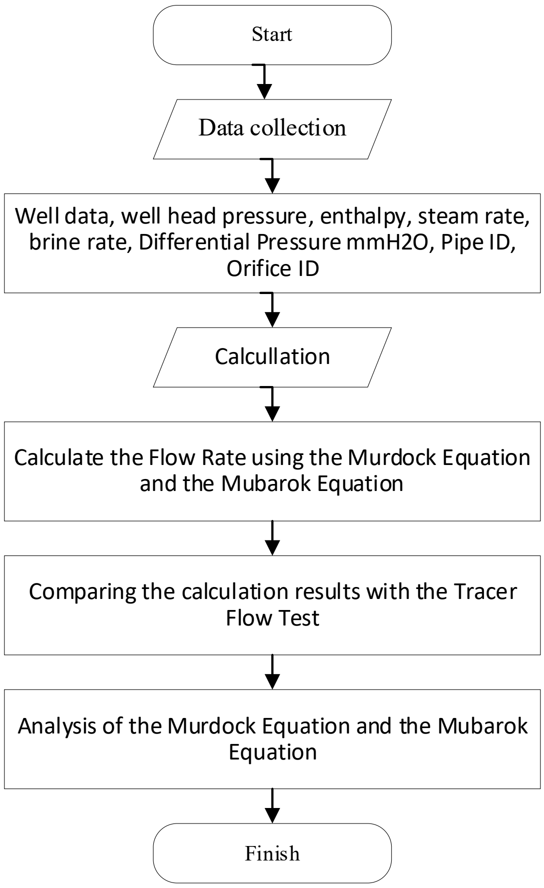


Figure 2: Work Flow Chart of Research

4. DISCUSSION

4.1. Field Data

The Murdock and Mubarok equation is an equation used to calculate the flow rate, to ensure that this equation can be used or not in the "X" well, an analysis of the calculation results of the equation is required with other test results, in this case using the Tracer Flow Test. . To calculate the flow rate using the Murdock and Mubarok equations required data in the form of:

Table 1. Enthalpy Result
(Star Energy Geothermal Wayang Windu, Ltd. Data Center)

Well	Date	P Upstream WHP	Enthalpy	*Steam Rate*	*Brine Rate*
		Barg	kj/kg	kg/s	kg/s
Well-A	30-Jul-19	12.82	2788.4	32	0
Well-B	12-Feb-20	14.56	1951.9	10.9	7.8
Well-C	26-Nov-19	17	1801.1	7.5	7.3

Table 2. Parameter
(Star Energy Geothermal Wayang Windu, Ltd. Data Center)

Well	Date	Differential Pressure	Pipe ID (D)	Orifice ID (d)
		mmH2O	mm	mm
Well-A	30-Jul-19	3718.1	409.5	305
Well-B	12-Feb-20	937.5	428.6	240.9
Well-C	26-Nov-19	595.2	298.4	210.3

Here the authors use data from 3 wells, namely Well-A wells which is a single-phase well, then Well-B and Well-C wells which are two-phase wells.

4.2 Production Process

In Field “X” there is a total production of 227 Mwe with 60 wells consisting of 31 production wells, 13 monitoring wells, 5 injection wells, 6 plug and abandonment wells, and 5 slim hole wells. "It has a dominant amount of water production and uses a separated steam cycle generator system. The use of this system is because the fluid in the well is a mixture of two-phase fluids (steam and liquid), so it must be separated first.

The two-phase fluid from the well first flows to the separator to be separated between steam and brine. The steam from the separator will go directly to the generator which is in charge of turning the turbine, while the brine from the separator will flow directly to the brine injection well. The steam flowing to the generator must meet generator needs and must have good quality which can be seen in the dryness, total dissolved solids (TDS), silica, pressure, and steam temperature. Wells in Field “X” also have a Flow Meter installed to read the pressure near the well.

4.3 CALCULATION

4.3.1 Murdock Equation

In order to find the value of the steam rate and brine rate of a well, you can use the Murdock equation with the following equation:

- **Steam**

$$\left(\frac{359 \times KG \times steam\ exp. \times thermal\ exp. \times d^2 \times steam\ \Delta P \times steam\ density}{1000}\right) 0.125998 \tag{8}$$

- **Brine**

$$\left(\frac{359 \times KL \times thermal\ exp. \times d^2 \times brine\ \Delta P \times liquid\ density}{1000}\right) 0.125998 \tag{9}$$

Pressure Armospheric, bara = 0.825

Conversion factor kg/m to lbm/hr.ft = 2419.08

Conversion factor lbm/hr.ft to lbf.s/ft^2 = 8.63E-06

Drischarge Coefficient (CD) at Rd > 50000 = 0.6

Ratio Specific Heat at Pressure satured = 1.3

Temperature degF = steam table

ΔP , inch H2O = ΔP , mmH2O / 25.4

a. Well-A

In order to fulfill the data needed to calculate the Murdock equation, the following data are needed:

- **Steam Expantion Factor for Orifice**

In order to find out the value of steam exp to meet the Murdock equation data, the following formula can be used:

$$= 1- (0.41 + 0.35 \times \beta^4) \times ((\Delta P\ .\ inch)/\frac{(27.68\times(P,psia))}{Ratio\ Spesific\ Heat})) \quad (10)$$
$$= 1- \left((0.41 + 0.35 \times 0.74471^4) \times \left(146.38149/\frac{(27.68\times197.8525)}{1.3}\right)\right)$$
$$= 0.989356689$$

- **Fraction**

Steam Fraction :

In order to find out what fraction value is obtained from well data, the following formula can be used:

$$H= hf + Xhfg \quad (11)$$
$$X=\frac{H-hf}{hfg}$$
$$X = \frac{2788.455679-824.8823}{1964.0941} = 0.9993$$

Liquid Fraction :

To find out the value of the liquid fraction of a well, the following formula can be used

$$1 - X \quad (12)$$
$$1\text{-}0.997 = 0.00027$$

- **Density**

To find the density value of steam and brine in a geothermal well, the following formula can be used:

$$\text{Steam Density} = \left(\frac{1}{spesific\ volume\ of\ steam}\right)^{0.5} \quad (13)$$
$$= (1/2.31159)^{0.5}$$
$$= 0.65772\ (lb/ft^2)^{0.5}$$

$$\text{Brine Density} = \left(\frac{1}{spesific\ volume\ of\ brine}\right)^{0.5}$$

- **Specific Density of Pure Water**

$$= (62.459111 + 0.0028272181 \times 380.913 - 0.000082792001 \times (T^2) + 0.000000052194682 \times T^3)$$
$$= (62.459111 + 0.0028272181 \times 380.913 - 0.000082792001 \times (380.913^2)0.000000052194682 \times 380.913^3)$$
$$= 54.408073$$

- **Two Phase ΔP**

To find the difference in pressure that occurs in a two-phase well, the following formula can be used

$$= \Delta P^{0.5} \quad (14)$$
$$= 146.381496^{0.5}$$
$$= 12.09882 \text{ inch H2O}$$

- **Steam ΔP**

To find the value of the pressure difference in the steam of a geothermal production well, the following formula can be used:

$$=\left(\frac{Two\ Phase\ \Delta P}{1+\left(\frac{1.26\times liquid\ fraction}{1-0.00026}\right)\times\left(\frac{Steam\ density}{Liquid\ density}\right)}\right) \quad (15)$$
$$= \left(\frac{12.09882}{1+\left(\frac{1.26\times0.00026}{1-0.00026}\right)\times\left(\frac{0.65772}{7.37771}\right)}\right) = 12.09846 \text{ inch H2O}$$

- **Brine ΔP**

To find the value of the pressure difference in the brine of a geothermal production well, the following formula can be used:

$$= {(two\ phase\ \Delta P - steam\ \Delta P)}/{1.26} \tag{16}$$

$$= {(12.09882 - 12.09846)}/{1.26} = 0.000286\ kg/s$$

- **Steam Rate and Brine Rate**

In order to get the steam rate and brine rate from a geothermal production well, the following formula can be used:

Steam:

$$\left(\frac{359\ \times 0.721056\ \times 0.9893566\ \times\ 1.00347788\ \times\ 12.00787^2\ \times 12.09846\ \times 0.657725374}{1000}\right)0.125998$$
$$= 37.15312\ kg/s$$

Brine :

$$\left(\frac{359 \times 0.721056 \times 1.00347788 \times 12.00787^2 \times 0.000286 \times 7.377713423}{1000}\right)0.125998$$
$$= 0.009\ kg/s$$

This calculation is also carried out for Well-B and Well-C wells. The calculation results of the steam rate and brine rate from the calculation can be seen in the following table:

Table 3. Result Calculation Equation Murdock

Well	Murdock	
	Steam (kg/s)	Brine (kg/s)
Well-A	37.1	0.009
Well-B	10	7.6
Well-C	6.8	7.4

From Table 3, the data obtained from the well steam and brine using the equation Murdock shows that Well-A has a value steam of 37.1 kg/s and a brine of 0.009 kg/s. Well-B has a yield steam of 10 kg/s and brine 7.6 kg/s. And the Well-C has a value of 6.8 kg/s and brine 7.4 kg/s.

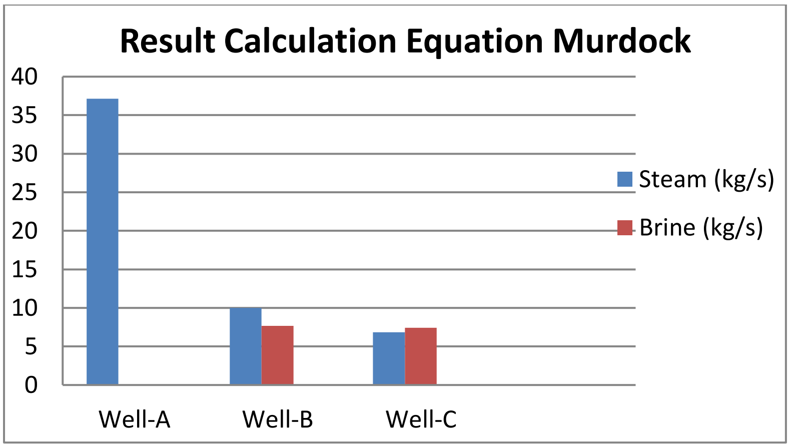


Figure 3. Hasil Perhitungan Murdock

From table 1, we get a bar chart with the highest steam value from Well-A, which is 37.1 kg / s, and the lowest is Well-C with a value of 6.8 kg / s. In this bar chart, we also see the highest brine results at Well-B of 7.6 kg / s, and the lowest Brine values at Well-A with a value of 0.009 kg / s

4.3.2 Mubarok Equation

In calculating the Mubarok equation, to find the value of the steam rate and brine rate of a geothermal production well, some data is needed from the production well, while to find the value of the Mubarok equation in a geothermal production well, the total M formula can be used, namely :

$$m = \frac{\left(\frac{P1}{P2}\right)^{\sqrt[D]{\frac{10^{-5}\Delta P}{D}}}\left(\frac{\pi d^2}{4}\right)ch\sqrt{2\Delta P}}{\sqrt{1-\beta^4}} \quad (17)$$

Table 4. The data needed to find the Mubarok equation

Well	P1	P2	ΔP	D	D	β ratio
	(pa)	(pa)	(pa)	(m)	(m)	
Well-A	1364144.9	1327682.9	36462.007	0.4	0.3	0.7
Well-B	1538099.6	1528906.02	9193.7	0.4	0.2	0.7
Well-C	1782036.2	1776199.3	5836.9	0.3	0.2	0.7

a. Well-A

- **Finding the enthalphy coefficient (Ch value)**

To get the Ch value of a geothermal production well, the following formula can be used:

Ch = $(9.7 \times 10^5)(h)^{-1.72}$ (18)

Ch = $(9.7 \times 10^5)(2788.455679)^{-1.72}$

= $1.150127774 \left(\frac{kg}{m^3}\right)^{\frac{1}{2}}$

- **Finding the fraction value**

To get the steam and liquid fraction values in geothermal production wells, we can use the following formula:

Steam Fraction :

$$H = hf + Xhfg$$

$$X = \frac{H - hf}{hfg}$$

$$X = \frac{2788.455679 - 824.8823}{1964.0941} = 0.9993$$

Liquid Fraction

$1 - X$

$1 - 0.997 = 0.00027$

- **Total Mass Flow :**

In order to get the value of the total mass flow of a geothermal production well, we can use the following formula:

$$m = \frac{\left(\frac{P1}{P2}\right)^{\frac{\sqrt[D]{10^{-5}\Delta P}}{D}}\left(\frac{\pi d^2}{4}\right)ch\sqrt{2\Delta P}}{\sqrt{1-\beta^4}} \quad (19)$$

$$m = \frac{\left(\frac{1364144.965}{1327682.957}\right)^{0.40955\sqrt{\frac{10^{-5}(36462.0073)}{0.40955}}} \left(\frac{\pi 0.305^2}{4}\right) 1.150127774\sqrt{2(36462.0073)}}{\sqrt{1 - 0.744719814^4}}$$

$$m = 27.3913857\ kg/s$$

- **Flow Rate :**

In order to get the flow rate value in the form of steam rate and brine rate in a geothermal production well, we can use the following formula:

$$Fraction \times m \quad (20)$$

$$Steam\ Rate = 0.9997 \times 27.3913857$$
$$Steam\ Rate = 27.38412372$$

$$Brine\ Rate = 0.0003 \times 27.3913857$$
$$Brine\ Rate = 0.007262015$$

This calculation is also carried out for Well-B and Well-C wells. The results of calculating the steam rate and brine rate from this calculation can be seen in the following table:

Table 5. Results Calculation Equation Mubarok

Well	Mubarok	
	Steam, kg/s	Brine, kg/s
Well-A	27.4	0.007
Well-B	7.8	5.9
Well-C	5.1	5.5

From Table 5, data is obtained in the form of calculation results with the Mubarok equation. At Well-A, the steam and brine values were obtained, respectively, of 27.4 kg/s and 0.007 kg/s. At Well-B, the steam and brine values were 7.8 kg/s and 5.9 kg/s. Meanwhile, the Well-C values were 5.1 kg/s and 5.5 kg/s.

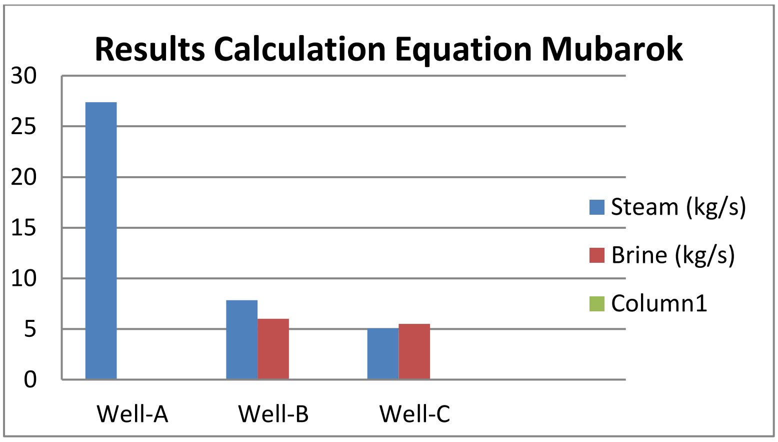


Figure 4. Results Calculation Equation Mubarok

Bar chart (Figure 4) shows the calculated value of the Mubarok equation obtained from Table 5 with the highest value of steam obtained at Well-A, which is 27.4 kg/s, and the lowest is obtained at Well-C with a value of 5.1 kg/ s. Bar chart (Figure 4) shows the highest brine value at Well-B with a value of 7.8 kg/s and the lowest at Well-A with a value of 0.007 kg/s.

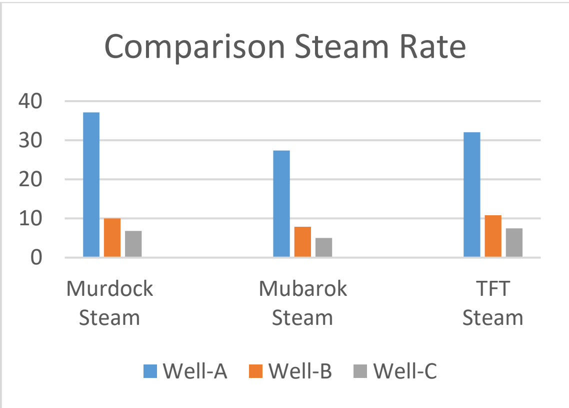
4. ANALYSIS

Flow meter installation is the first step in determining the flow rate, but what is needed is an equation that will be used to calculate the flow rate because the output of the flow meter is a differential pressure value. From the calculations that have been done, the final results are in the form of steam rate and brine rate from the Murdock and Mubarock equations, then the steam rate and brine rate are compared with the results of the Tracer Flow Test which can be seen in (Table 6).

Table 6. Comparison of Steam Rate and Brine Rate Results

Well	Murdock		Mubarok		TFT	
	Steam, kg/s	Brine, kg/s	Steam, kg/s	Brine, kg/s	Steam, kg/s	Brine, kg/s
Well-A	37.1	0.009	27.4	0.007	32	0
Well-B	10	7.6	7.8	5.9	10.9	7.8
Well-C	6.8	7.4	5.1	5.5	7.5	7.3

Comparison table of steam and brine values using the Murdock equation, Mubarok equation, and TFT. The value of steam and brine using TFT obtained steam values at Well-A of 32 k /s, and brine of 0 kg/s. At Well-B, the steam value is 10.9 kg/s and the brine value is 7.8 kg/s. And at Well C, the steam value is 7.5 kg/s, and the brine value is 7.3 kg/s.



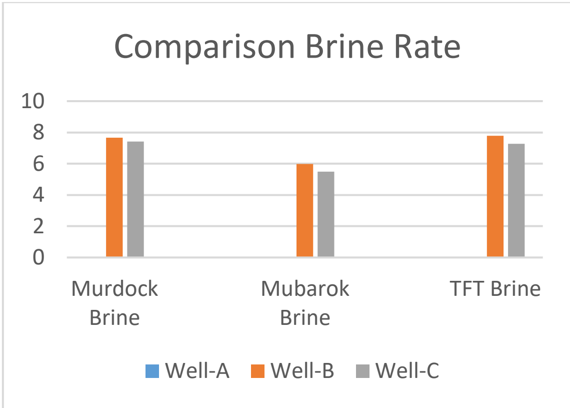


Figure 5. Comparison of Steam Rate and Brine Rate Results

From the comparison table of steam and brine values using the Murdock, Mubarok, and TFT equations (Table 6), it is obtained a bar chart with the highest steam value using TFT, namely at Well-A with a value of 32 kg/s and the lowest at Well-C with a value of 10.9 kg/s. While the highest brine value using TFT in this bar chart can be seen the highest value at Well-B with a value of 7.8 kg/s, and the lowest at Well-A with a value of 0 kg/s.

From the above comparison then look for the error value from the flow results the rate obtained to see how big the deviation is:

Table 7. Comparison Error Value

Well	Error Murdock		Error Mubarok	
	Steam	Brine	Steam	Brine
Well-A	16%	0%	15%	0%
Well-B	8%	2%	28%	23%
Well-C	9%	2%	58%	26%

Table 7 shows the comparison of error values in steam and brine using the Murdock and Mubarok equations. By using the Murdock equation, the error values for steam and brine are 16% and 0%, respectively, at Well-B are 8% and 2%, and at Well-C are 9% and 2%. By using the Mubarok equation, the error values for steam and brine are obtained, respectively, at Well-A of 15% and 0%, at Well-B of 28% and 23%, and at Well-C of 58% and 26%.

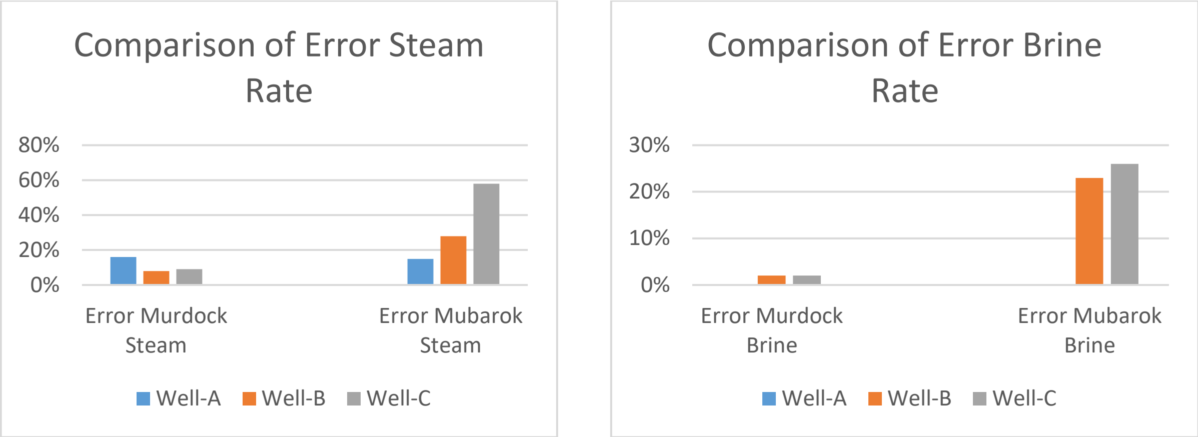


Figure 6. Comparison Error Value

In Table 7 it can be seen that the steam error in the Well-A well is 16% for the Murdock equation, while the steam error in the Mubarok equation is 15%, the difference between the two is only 1%. The brine error in the Murdock and Mubarok equations both shows a value of 0%, which means that there is no error in the brine rate calculation. Furthermore, for the Well-B well, the steam error of the Murdock equation is 8%, while in the Mubarok equation it is 28%, much greater than the Murdock equation. For the error brine, the Mubarok error is 23%, much greater than the error brine rate of Murdock's equation which is only 2%. And finally, the Well-C well error steam rate in the Murdock equation is 9%, while in the Mubarok equation it is much greater than the Murdock equation, which is 58%. The brine rate error in the Murdock equation is very small, 2%, while the Mubarok equation is 26%. From the comparison and analysis of the two equations, namely the Murdock equation and the Mubarok equation, it can be seen that the calculation error of the Murdock equation is much smaller than the Mubarok equation. For the Mubarok equation, the resulting error value is quite large because it reaches 20% and some even exceed 50%, with a large error value like this, the possibility that the Mubarok equation can be applied is very small because the calculation results will be far different from the actual. Therefore it can be concluded that the equation that can be applied to wells in Field "X" is the Murdock equation because it has a small error value. With a small error value, the probability of the calculation being successful is much greater so that the results are closer to the field data. The Murdock equation does have a small error value compared to the Mubarok equation, but on the other hand, there is still an error value of> 10% which is found in the Well-A well steam value which is a single-phase well, which is 16%. The comparison between the results of Murdock's calculations for the steam rate value in the Well-A well with TFT, namely 37.2 kg/s and 32 kg/s. These results indicate that Murdock's calculation results are greater than TFT. The possibility of having an effect on the economic calculation of this well is a target that can not be achieved because this result means that Murdock's count is 16% greater than the field yield. If this equation will still be applied, it is better to use two-phase wells, because in the calculations for two-phase wells (Well-B and Well-C) the resulting error value is still below 10%.

5. CONCLUSION

1. Flow rate calculation results from the Murdock equation for Well-A wells: 37.1 kg/s steam and 0.009 kg/s brine, Well-B wells: 10 kg/s steam and brine 7 kg/s, Well-wells C: 6.8 kg/s and brine 7.4 kg/s. Whereas for the Mubarok equation, Well-A well: steam 27.4 kg/s and brine 0.007 kg/s, Well-B well: steam 7.8 kg/s and brine 5.9 kg/s, Well-C steam well 5.1 kg/s and brine 5.5 kg/s.
2. Comparison of errors from the flow rate results of the Murdock equation Well-A steam wells 16% and brine 0%, Well-B steam wells 8% and brine 2%, Well-C steam wells 9% and brine 2% while the Mubarok well wells equation -A steam 15% and brine 0%, Well-B steam 28% and brine 23%, Well-C steam well 58% and brine 26%.
3. The equation that can be applied in Field "X" is the Murdock equation because it has a small error value so that the probability of the calculation results approaching field data is much greater.
4. But however, in the Murdock equation, there is still an error value of > 10% which is found in the Well-A well steam value which is a single-phase well, which is 16%. If this equation will still be applied then it is better to use in well two

6. ACKNOWLEDGMENT

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