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Application of the Flow Production Test to Update Well Production Capacity in Lahendong Geothermal Field

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ABSTRACT

Lahendong geothermal field is the first geothermal field in North Sulawesi, Indonesia. Lahendong is a two phase geothermal system where the dryness of each production well cluster varies between 10% up to 100%. In determining the decline for two-phase wells, subsurface data acquisition is needed and routine production wells are re-tested. However, limited back-up wells become a challenge for routine re-production tests due to operation needs.

This "Flow Production Test" method is an alternative choice to frequently update the deliverability curves of wells in order to detect changes in individual performance by minimizing the disruption of the generation and power plant deration. This method is applicable when production wells deliver fluid to share separator and power plant. This method has been successfully tested in several production wells in Lahendong field and this paper would offer the method and overview of the result

1. INTRODUCTION

Lahendong Geothermal Exploration began in 1973, since the first commercial operation date (COD) in 2001 with a capacity of 1 x 20 MW, the field continues to grow to reach 120 MW (6 x 20 MW). Electricity generated from the Lahendong Geothermal field is included in the SulutGo transmission system (North Sulawesi - Gorontalo) in which contributes about 20% the electricity needs of North Sulawesi.

The production test is generally carried out before the operation of a well to determine the characteristics and production capacity of the well. Periodically production tests need to be carried out as long as the well operates to determine changes in the characteristics of well production. However, limited availability of steam has caused all production wells not to have the opportunity to maneuver the wells, where one of the objectives is to conduct production re-testing, so that the well productivity curve cannot be generated to determine changes in the production capacity of the well.

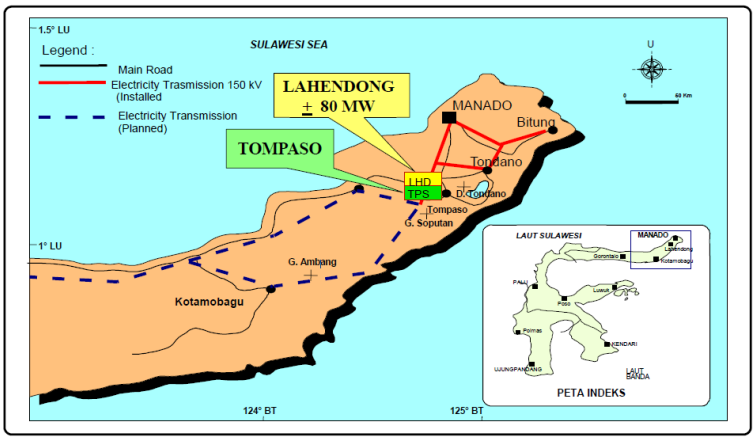


Figure 1 Lahendong Location Map (Prabowo, 2015)

On the other hand, to obtain a decline calculation for ideal two-phase wells, subsurface data acquisition is needed and routine production well re-tests are needed to maintain data availability. The decline in production calculation itself is important in reservoir management in terms of planning well needs for makeup and field development.

Currently there is no measuring instrument that can be used to determine the two phase flow rate of each well. Since 2010 Tracer Flow Test has been carried out which aims to determine the steam and water flow rates of each well even though the production wells are flowsteam to the power plant. From the results of the Tracer Flow Test, the steam and water flow rates, separation pressure, steam fraction (dryness) and total fluid enthalpy are obtained. The disadvantages of this Tracer Flow Test method are the relatively expensive costs and the availability of data that is not immediately available because it awaits the results of laboratory analysis.

2. FLOW PRODUCTION TEST METHODS

Flow production test begins by changing the throttle valve opening of the tested well until the wellhead pressure reaches the preferred value and maintaining other production wells and separator at normal operation condition. If separator pressure decreasing due to lower fluid supply, the throttle valve opening of the separator should be reduced in order to maintain separator pressure. Each wellhead pressure setting has several parameters to notice, including separator pressure, steam flow rate, brine flow rate and water level in the separator.

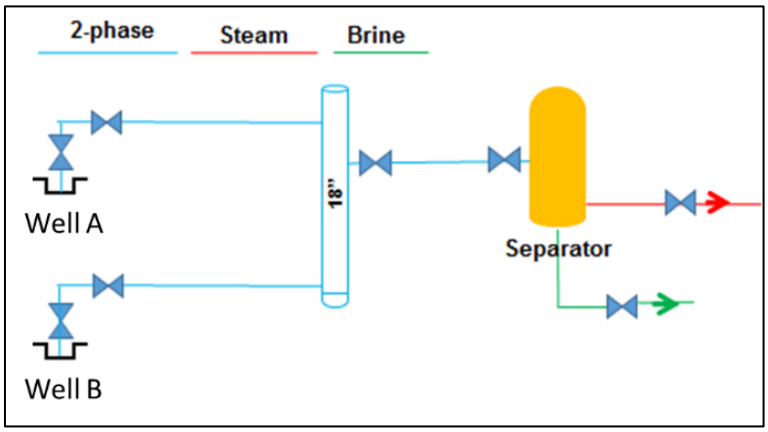


Figure 2: Production Diagram

As long as well testing takes place, well parameters such as well head pressure that are not tested must be maintained at normal operation condition, as well as pressure and water level in the separator. The test is ended by measuring the maximum discharge pressure or shut-in pressure of the well. Next, we use that data to get a new deliverability curve.

The deliverability curve is a form of parabolic equation, we assume the y-axis as wellhead pressure and the x-axis as the steam flow rate

$$WHP = aW^2 + bW + c \tag{1}$$

Peak point of the equation

$$W_{MDP} = -\frac{b}{2a} \tag{2}$$

$$\text{MDP} = -\frac{D}{4a} = -\frac{(b^2 - 4ac)}{4a} = \text{c} - \frac{b^2}{4a} \tag{3}$$

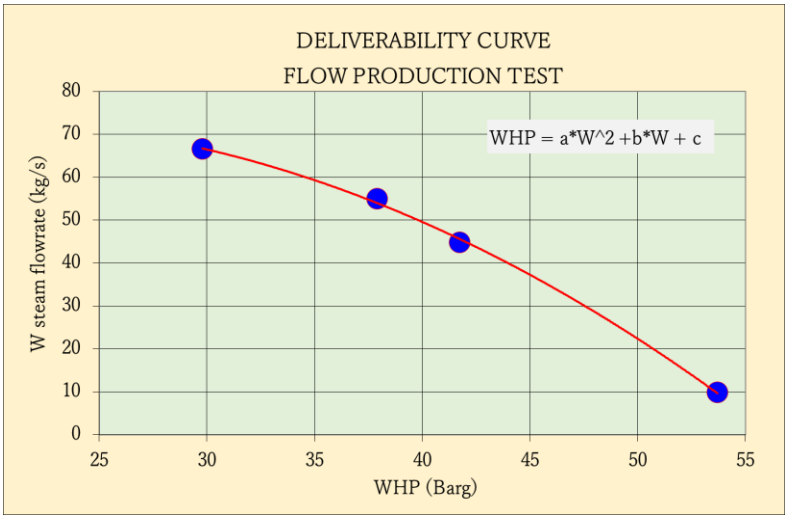


Figure 3 : Deliverability Curve Flow Production Test

$$aW^2 + bW + c - WHP = 0$$

Root of the equation

$$W = -\frac{b \pm \sqrt{b^2 - 4a\,(c - WHP)}}{2a}$$

use the positive one

$$W = -\frac{b}{2a} + \frac{\sqrt{b^2 - 4a\,(c - WHP)}}{2a}$$

$$W = -\frac{b}{2a} + \sqrt{\frac{b^2 - 4a\,(c - WHP)}{4a^2}}$$

$$W = W_{MDP} + \sqrt{\frac{b^2}{4a^2} - \frac{(c - WHP)}{a}}$$

$$W = W_{MDP} + \sqrt{\frac{1}{a}\left[\frac{b^2}{4a}\right] - c + WHP}$$

$$W = W_{MDP} + \sqrt{\frac{1}{a}\left[\frac{b^2}{4a} - c + WHP\right] x \frac{-1}{-1}}$$

$$W = W_{MDP} + \sqrt{\frac{1}{-a}\left[\left(c - \frac{b^2}{4a}\right) - WHP\right]}$$

$$W = W_{MDP} + \sqrt{\frac{(MDP - WHP)}{-a}}$$

$$W = W_{MDP} + \frac{\sqrt{(MDP - WHP)}}{\sqrt{-a}}$$

$$W = W_{MDP} + \frac{1}{\sqrt{-a}}\sqrt{MDP - WHP} \qquad (4)$$

Than we plot W vs $\sqrt{MDP - WHP}$ to obatain a, b, c value

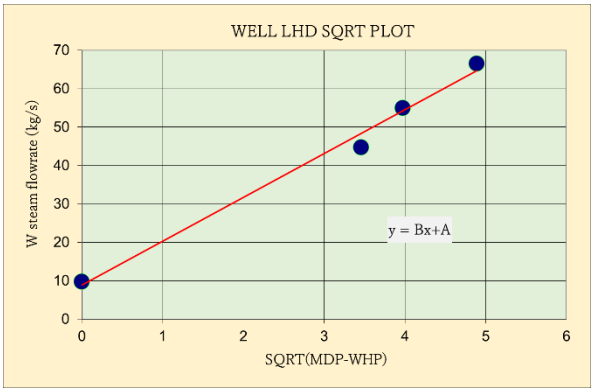


Figure 4 : Square Plot

$$a = W_{MDP} \qquad (5)$$

$$b = -W_{MDP}\, x\, 2a \qquad (6)$$

$$c = MDP + \frac{b^2}{4a} \qquad (7)$$

If we don't know the maximum discharge pressure value, but we know the Wmax value, maximum discharge pressure is obtained by James (1989)

$$\left(\frac{\mathbf{W}}{\mathbf{W_{max}}}\right)^2 + \left(\frac{\mathbf{P}}{\mathbf{P_{max}}}\right)^2 = \mathbf{1} \qquad (8)$$

MDP becomes equal to P_{max} determined with this equation.

Davilla (2016) proposed plot Log (W) versus Log (MDP-WHP) for two phase geothermal well, give a straight line; coefficients determined by linear least squared fitting will be used to get the Deliverability Output curve equation. Davilla (2017) has been observed that the Deliverability curve equation (Power equation) obtained by means Linearization analysis overestimates production rate at low wellhead pressure; in order to improve the forecasting it has been matched the Power Equation with the Offset Elliptical Equation, in that way the Linearization analysis is a helpful tool for determining the Offset elliptical equation parameters

Grant (2011) states that the most common form of decline assumption is exponential decline, where flow decreases with a constant fraction or percentage each year. Exponential decline arises from a simple model, a well that produces from a fixed resource. Where the exponential decline curve type equation is as follows:

$$q_t = q_i e^{-Dt} \qquad (9)$$

3. CASE STUDY

Data obtain on LHD-H4 and LHD-L6 at Lahendong Geothermal Field, Indonesia, have been analyzed using the graph Wsteam versus $\sqrt{MDP - WHP}$ in order to determine update deliverability curve equation.

3.1 LHD-H4

LHD-H4 is a well that has a depth of 1756 m, in May 31, to June 1, 2016 flow production tests were carried out for LHD-H4. Table 1. Flow production tests that have been carried out for two days, six different wellhead pressure settings have been carried out. Table 2, red dots data are not being considered in the analysis.

Table 1 : Lahendong Geothermal Field LHD-H4 Flow Production Test 2016

LHD-H5		LHD-H4		Pressure Separator	Steam Flowmeter	Steam flow LHD-H4
FCV	WHP	FCV	WHP			
(%)	(Barg)	(%)	(Barg)	(Barg)	(kg/s)	(kg/s)
100	11,95	100	11,41	10,42	15.86	6.97
100	11,98	35,2	15,56	10,42	15.17	6.28
100	11,99	31,7	20,29	10,42	14.52	5.63
100	12,00	29,7	25,47	10,48	12.88	3.99
100	12,02	20,7	34,92	10,46	10.96	2.07
100	11,99	5	39,7	10,46	9.28	0.39
100	11,87	0	39,8	10,42	8.89	0

Table 2 : Lahendong Geothermal Field LHD-H4 Deliverability Curve Analysis 2016

WHP	Steam flow	$\sqrt{MDP-WHP}$	WHP calc	Steam flow calc (kg/s)		Different
(barg)	(kg/s)		(barg)	◆	●	(%)
11,41	6.97	5.32	5.32	6.84		2
15,56	6.28	4.91	4.91	6.34		1.1
20,29	5.63	4.41	4.41	5.73		1.7
25,47	3.99	3.77	3.77		4.95	24.3
34,92	2.07	2.19	2.19		3.03	45.9
39,7	0.39	0	0	0.37		5.4
MDP	39.7	barg		a	-0.676	
W_{MDP}	0.367	kg/s		b	0.496	
slope	1.216			c	39.61	

Fig no. 4 shows the plot W_{steam} versus $\sqrt{MDP-WHP}$, value a, b and c can be determined and deliverability curve equation yielded by substitution where WHP = -0.676 $W_{steam}{}^2$ + 0.496 W_{steam} + 39.6 which shown in Fig No. 5; blue square are calculated curve and the correlation respect to actual data is between 95-98%.

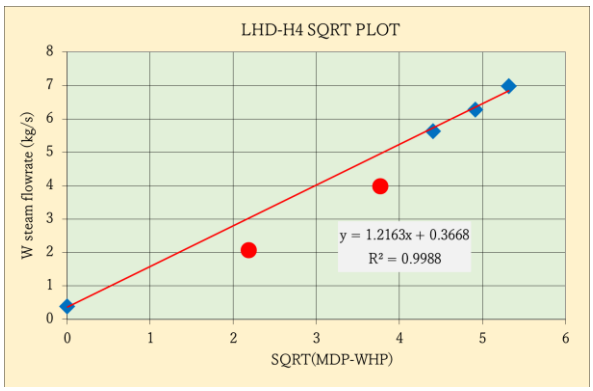


Figure 5 : LHD-H4 Square Plot

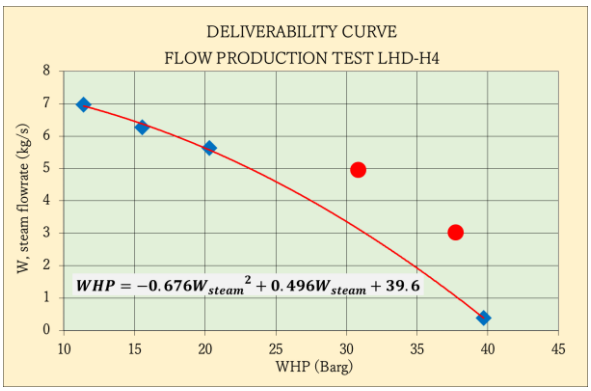


Figure 6 : Deliverability Curve LHD-H4

To calculate the decline production when production test in 2005 with flow production test in 2016, we use equation (9), at an operating wellhead pressure of 12 barg the value of the decline in production is 3.4%/year.

3.2 LHD-L6

LHD-L6 is a well that has a depth of 1639 m, in Jan 19, 2018 flow production tests were carried out for LHD-L6. Table 3. Flow production tests the tests that have been carried out, four different wellhead pressure settings have been carried out. Table 4, red dots data are not being considered in the analysis. Different from the previous discussion, maximum discharge pressure was not obtained at this test because the process was carried out from a small throttle valve opening to a larger opening,

Table 3 : Lahendong Geothermal Field LHD-L6 Flow Production Test 2018

LHD-L5		LHD-L6		Pressure Separator	Steam Flowmeter	Steamflow LHD-L6
FCV	WHP	FCV	WHP			
(%)	(Barg)	(%)	(Barg)	(Barg)	(kg/s)	(kg/s)
25	13.1			7.2	8	0
25	13.29	40	23.6	7.2	23	15
25	12.91	61	22.3	7.4	31	23
25	13.15	71	21.3	7.4	38	30
25	12.98	81	20.2	7.6	41	33

Table 4 : Lahendong Geothermal Field LHD-L6 Deliverability Curve Analysis 2018

WHP	Steamflow	$\sqrt{MDP-WHP}$	WHP calc	Steamflow calc (kg/s)		Different
(barg)	(kg/s)		(barg)	◆	●	(%)
23.6	23	0	24	15		0.1
22.3	31	1.16	23		26	14.9
21.3	38	1.52	21	30		0.2
20.2	41	1.85	20	33		0.1
MDP*	23.6	barg		a	-0.011	
W_{MDP}	15.06	kg/s		b	0.329	
slope	9.57			c	21.161	

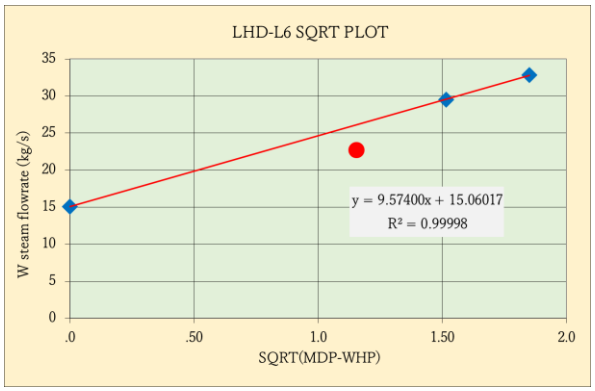


Figure 7 : LHD-L6 Square Plot 2018

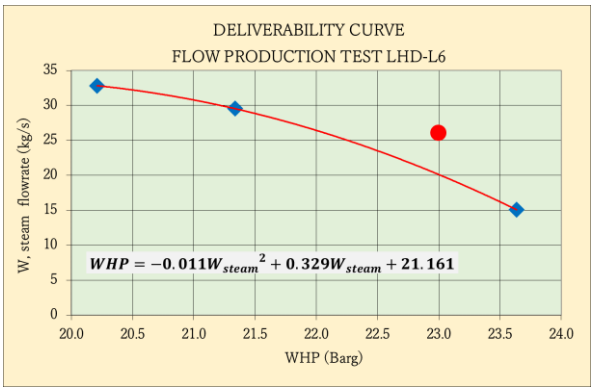


Figure 8 : Deliverability Curve LHD-L6 2018

Fig no. 6 shows the plot W_{steam} versus $\sqrt{MDP-WHP}$, value a, b and c can be determined and deliverability curve equation yielded by substitution $WHP = -0.011W_{steam}^{2} + 0.329\ W_{steam} + 21.161$ which is shown in Fig No. 7 blue square are calculated curve and the correlation respect to actual data is around 99%.

Table 5. Flow production tests the tests that have been carried out, six different wellhead pressure settings have been carried out. Table 6, all data are considered in the analysis. Different from the previous discussion, maximum discharge pressure was not obtained at this test because the process was carried out from a small throttle valve opening to a larger opening,

Table 5 : Lahendong Geothermal Field LHD-L6 Flow Production Test 2019

LHD-L5		LHD-L6		Pressure	Steam	Steam flow
FCV	WHP	FCV	WHP	Separator	Flowmeter	LHD-L6
(%)	(Barg)	(%)	(Barg)	(Barg)	(kg/s)	(kg/s)
25	12.5	46	22.4	7.3	28	19
25	12.4	64	21.1	7.5	36	28
25	12.5	72	20.3	7.6	38	30
25	12.5	76	20.0	7.6	39	31
25	12.5	80	19.6	7.6	40	32
25	12.6	85	19.0	7.7	41	33

Table 6 : Lahendong Geothermal Field LHD-L6 Deliverability Curve Analysis 2019

WHP	Steam flow	$\sqrt{MDP-WHP}$	WHP calc	Steam flow calc	Different
(barg)	(kg/s)		(barg)	(kg/s)	(%)
22.4	19	0	22	19	0.8
21.1	28	1.1	21	28	0.9
20.3	30	1.5	20	30	1.4
20.0	31	1.6	20	31	0.4
19.6	32	1.7	20	32	0.3
19.0	33	1.8	19	33	0.9
MDP*	22.4	barg		a	-0.018
W_{MDP}	19.31	kg/s		b	0.69
slope	7.5			c	15.73

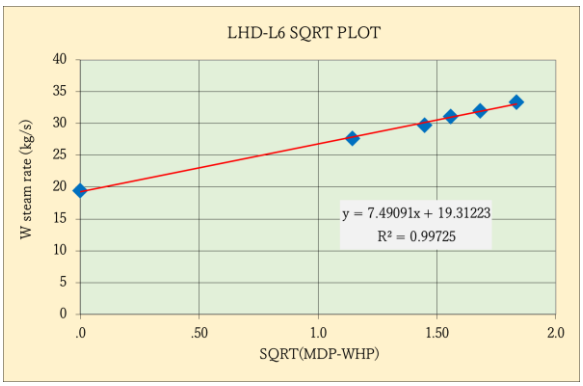


Figure 9 : LHD-L6 Square Plot 2019

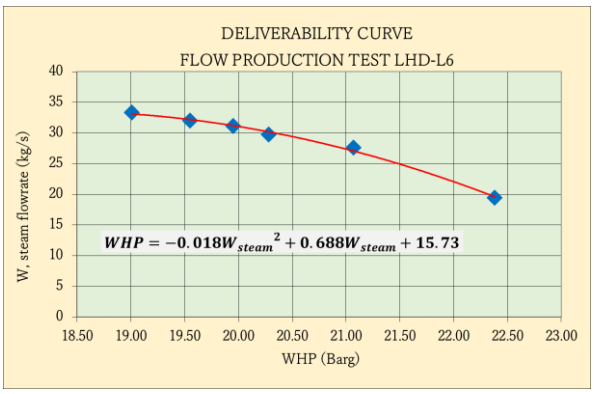


Figure 10 : Deliverability Curve LHD-L6 2019

Fig no. 8 shows the plot W_{steam} versus $\sqrt{MDP - WHP}$, value a, b and c can be determined and deliverability curve equation is yield by substitution WHP = -0.018 $W_{steam}{}^2$ + 0.688 W_{steam} + 15.73 which is shown in Fig No. 9; blue square are calculated curve and the correlation respect to actual data is around 99%.

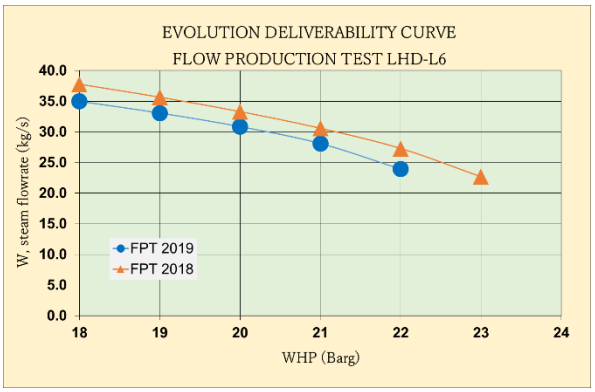


Figure 11 : Deliverability Curve Evolution LHD-L6

In the Figure 10, blue dots are the flow production test data in 2018 and the orange triangle are the flow production test data in 2019, To calculate the decline in production we use equation (9), at a pressure of 18 barg the decline LHD-L6 value is 7.7%/year.

4. CONCLUSION

1. Flow production test can be applied as alternative solution for the acquisition of production well productivity data.
2. Based on flow production test data with initial production test data there is a decrease in production at LHD-H4 by 3.4%/year, while LHD-L6 well decreased 7.7%/year
3. Routine data flow production test is expected to evaluate changes in the characteristics of production wells

RECOMMENDATIONS

1. It is necessary to update production capacity regularly at each well.
2. Flow production test applications on production wells regularly.
3. Flow production test is used to evaluate well characterization.

ACKNOWLEDMENTS

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REFERENCES

Davila, H. A.:Two phase geothermal well deliverability output curve linearization analysis. PROCEDINGS, 41st Workshop on Geothermal Reservoir Engineering Stanford University, California, February 22-24, 2016 SGP-TR-209

Davila, H. A.:Deliverability Output Curve Linearization Analysis: Matching the Power Equation with the Offset Ellipstical Equation. PROCEDINGS, 42st Workshop on Geothermal Reservoir Engineering Stanford University, California, February 13-15, 2017 SGP-TR-212

Grant, M. A. and Bixley P. F., 2011, Geothermal Reservoir Engineering, Academic Press

James, R.:One Curve Fit All. PROCEDINGS, 14st Workshop on Geothermal Reservoir Engineering Stanford University, California, January 24-26, 1989, SGP-TR-122

Prabowo, T., Yuniar, D.M., Suryanto, S. & Silaban, M.: Tracer Test Implementation and Analysis in Order to Evaluate Reinjection Effects in Lahendong Field. Proc. World Geothermal Congress 2015, Melbourne, Australia (2015).