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Reservoir Characteristic and Potential Production Analysis of ARA Field Based on DST Data

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Abstract. SM-04 well located at ARA field, Musi Rawas district, South Sumatra, is an exploration well that has been closed (temporary shut-in) but now will be commercialized. SM-04 well has been done the drill stem test (DST) from July 27th to July 31st 2011 in zone#4 at the depth 2404 to 2418 ft-kb. Zone#4 is a part of the Air Benakat Formation (ABF) which is probably filled with natural gas. The drill stem test (DST) at SM-04 well is intended to determine reservoir characteristics from zone#4 and the maximum potential of SM-04 well. The drill stem test (DST) started by opening the well with three different constant flow rates for 36 hours (12 hours for each flow rate) and then it's shut-in for 57 hours. The DST data then analyzed with pressure build-up (PBU) test and deliverability test (back pressure test) by manual method and IHS well-test software, which the result of two methods are close. By IHS well-test, the composite model was chosen to represent the reservoir by assumption divide reservoir into two zones. The average reservoir pressure (P*) is 1358.3 Psia, permeability for zone 1 (k_1) is 16.98 md, and 1.65 md for zone 2 (k_2), skin factor (S') 1.76, and flow efficiency (FE) 0.79. The absolute open flow (AOF) of the SM-04 well is 3.67 MMSCFD.

Key Words: Drill stem test (DST), Pressure build-up (PBU), Deliverability test

INTRODUCTION

SM-04 well is one of the exploration wells in the ARA field. ARA field is located in the Middle-Eastern part of Merangin II Block. The field is located about 200 km west of Palembang City, within the Musi Rawas district, South Sumatra. SM-04 well has been closed (temporary shut-in) but now will be commercialized. SM-04 is a well with cased hole completion system with the true vertical depth (TVD) is 3790 ft-kb. SM-04 is known to have ten zones/layers which are estimated potentially to be produced. The targeted zone's/layer's is zone#4 at the depth 2404 to 2418 ft-kb (with the kelly bushing is 211 ft). The zone#4 is a part of the Air Benakat Formation (ABF) with composed of sandstone, carbonate, tuff, and shale. The zone#4 is estimated to fill by natural gas.

The SM-04 well has been done the drill stem test (DST) in zone#4 from July 27th to July 31st 2011. The drill stem test (DST) started by flowing the well for about 36 hours with the details, are as follows:

- Open the well for about 12 hours by using choke been size 36/64. There is a constant flow rate at 2.75 MMSCFD.
- Change the choke been size to 40/64 (without shut-in the well), the well still open for about 12 hours. There is a constant flow rate at 3.19 MMSCFD.

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- Change the choke been size to 44/64 (without shut-in the well), the well still open for about 12 hours. There is a constant flow rate at 3.25 MMSCFD.
- After 36 hours, the well is shut-in for 57 hours.

Because the SM-04 is a gas well that will soon be commercialized, it's necessary to analyze based on the drill stem test (DST) data. So it can be estimated the reservoir characteristic and maximum flow rate that can be produced. The drill stem test (DST) data will be analyzed by using the manual method and IHS well-test software. From the two analyze methods, it's expected to have a fairly close result, so the analyzed result can be used for the future purposes.

THEORY

The drill stem test (DST) is a method used to determine the characteristic of formation/layer/reservoir and fluid that is potential to be produced. The drill stem test (DST) process is before the completion of a well. Basically, a drill stem test (DST) is a temporary completion of a well. The drill stem test (DST) component is an arrangement of pressure and temperature gauge record, perforated anchor, one or more packers, and flow valve. When the arrangement is lowered into the well, the recorder starts to record pressure and temperature changes behavior when the well is flowing and shut-in.

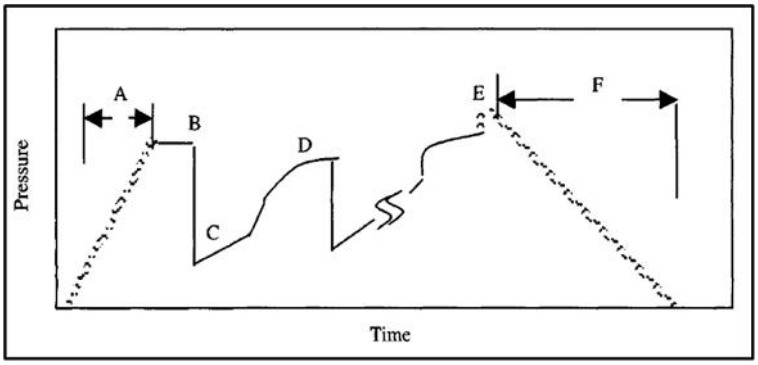


FIGURE 1. Pressure Record in Drill Stem Test (DST)[4]

Pressure Build-Up (PBU)

Pressure build-up (PBU) is a pressure transient test method that is done by flowing the well with a constant flow rate in a time period. After the production time has over, the well is shut-in for a time period. There are several methods can be used to analyze the pressure build-up (PBU). One of them is the Horner Plot method. In the horner plot method, the pressure transient data is analyzed by log-log plot graph, and semilog (horner plot) graph. For the gas well, the pressure data must be converted into the pseudo form (Ψ).

From the analysis of the two graphs, the reservoir characteristic can be determined by following the equation:

- Permeability (k)

To calculate the permeability (k) can use the following equation:

$$k \;\; \text{X } 1.637 \; \frac{q_{sc} T}{m\, h} \tag{1}$$

- Skin Factor (S')

To calculate the skin factor (S') can use the following equation:

$$S' \;\; \text{X} 1.151 \; \frac{\varphi(P_{1hr}) \; - \; \varphi(P_{wf})}{m} - \log \; \frac{k}{f \; \ll_g \; Ct \; r_w^{\;2}} \;\; \Gamma 3.23 \tag{2}$$

- Radius of Investigation (ri)

To calculate the radius of investigation (ri) can use the following equation:

$$ri \text{ X } 0.03\sqrt{\frac{k\ \zeta p}{\text{¤ «}_g\ Ct}} \tag{3}$$

J Flow Efficiency (FE)

To calculate the flow efficiency (FE) can use the following equation:

$$FE \text{ X} \frac{\cdot\ (P^*)\ -\ \cdot\ (P_{wf})\ -\ \cdot\ (\zeta P)_{skin}}{\cdot\ (P^*)\ -\ \cdot\ (P_{wf})} \tag{4}$$

With $\cdot\ (\zeta P)_{skin}$ can be calculated by following the equation:

$$\cdot\ (\zeta P)_{skin} \text{ X} 0.869ms' \tag{5}$$

Backpressure Test

Backpressure test or flow after flow test is one of the gas deliverability test to determine the maximum potential of a well/layer to be produced. In the backpressure test, a well opens at a constant flow rate (q_g) until the flowing pressure (P_{WF}) becomes stabilized. After that, the flow rate is changed (without shut-in the well), the well flows until the flowing pressure (P_{WF}) stabilizes again. There is needed three or more flow rate testing on backpressure test.

The maximum potential is also known as absolute open flow (AOF). The absolute open flow (AOF) is a maximum production flow rate assuming the flow pressure (P_{WF}) is equal to atmospheric pressure. There are several methods to calculate the value of absolute open flow (AOF). The ones by using Rawlins-Schellhardt equation (1935) as follows:

$$q_{sc}\ \text{ X } C\int P_r^2\ -\ P_{wf}{}^2 \text{Å}^n \tag{6}$$

The value of n (unit slope) and C (coefficient performance) can be determined by the deliverability curve, with the value of n ranges from 0.5 to 1.

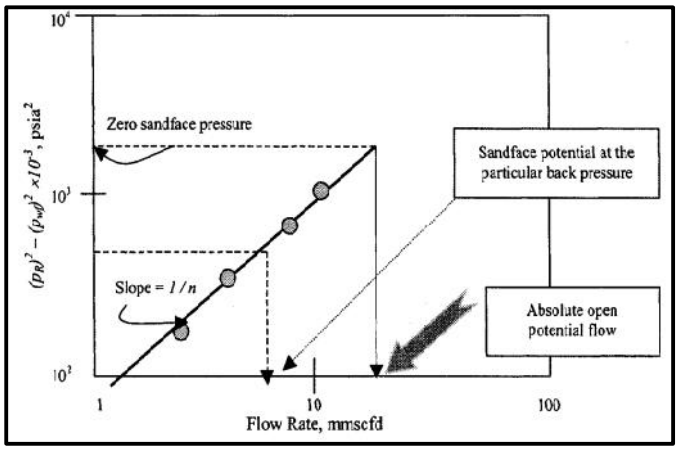


FIGURE 2. Deliverability Curve[3]

IHS Well-test

IHS well-test is an IHS Markit's and Fekete company's software, used to pressure transient and deliverability test analyzed. In the pressure transient analyzing, there are several steps, that is starting with data input, data synchronization, diagnostic analysis, choosing a model, and matching the model.

The reservoir and well models can be chosen in the software are the slant model, vertical model, horizontal model, composite model, wedge model, leaky-fault model, multilayer model, and fracture model.

RESULT AND DISCUSSION

Result

The petrophysics data of zone#4 and configuration of SM-04 well has been determined by logging process with the following result:

- Well radius, r_w = 3.5 inch.
- Interval perforated = 2404 – 2418 ft-kb.
- Net thickness, h = 12 ft.
- Porosity, ∅ = 25.2%.
- Water saturation, S_W = 52.1%.
- Total Compressibility, C_t = 3.98 x 10^{-4} $Psia^{-1}$.

From the DST process, the results of pressure transient and deliverability test data are as follows:

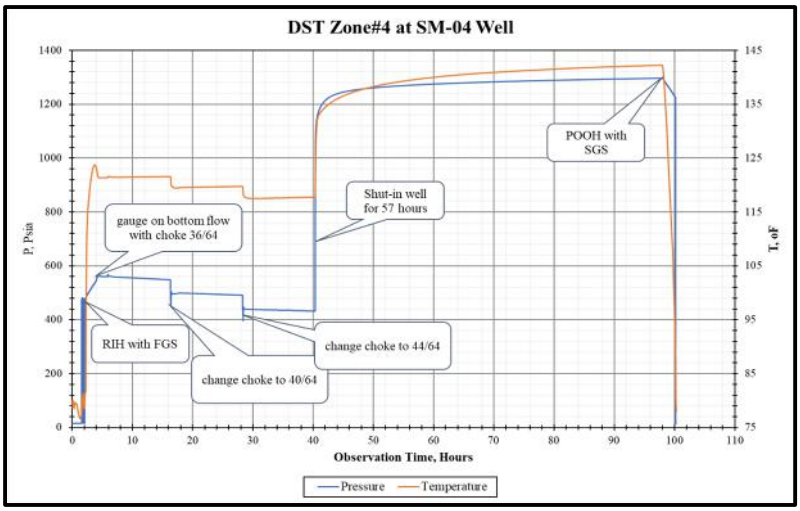
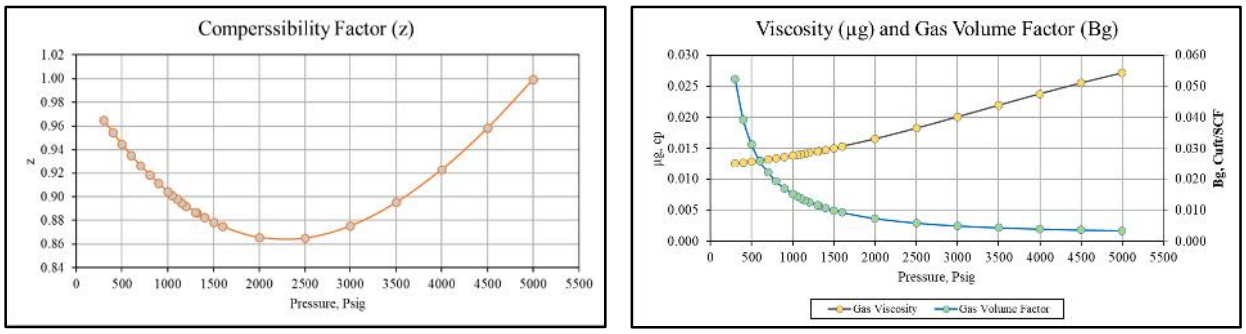


FIGURE 3. Drill Stem Test (DST) Process at SM-04 Well

TABLE 1. Deliverability Test Results

No. Test	qtest, MMSCFD	Pwf, Psia
1	2.75	548.35
2	3.19	490.94
3	3.26	432.18

From the laboratory analysis, the fluid properties and fluid phase diagram are as follows:



(a) (b)

FIGURE 4. Compressibility Factor Curve (a), Gas Viscosity and Gas Volume Factor Curve (b)

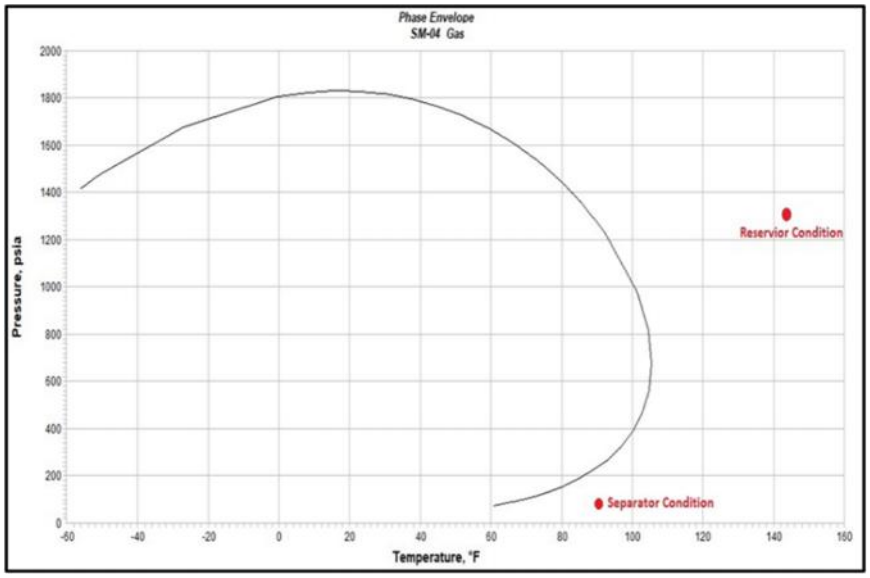


FIGURE 5. Fluid Phase Diagram of SM-04 Well

From the analyzing of pressure build-up (PBU) by manual method, the results of average reservoir pressure (P*) and pressure at 1 hour (P_{1hour}) are as follows:

TABLE 2. Result of Horner Plot Curve Analysis

Component	Ψ(P), MMPsia²/cp	P, Psia
P*	141.82	1329.8
P_{1jam}	115.59	1201.8

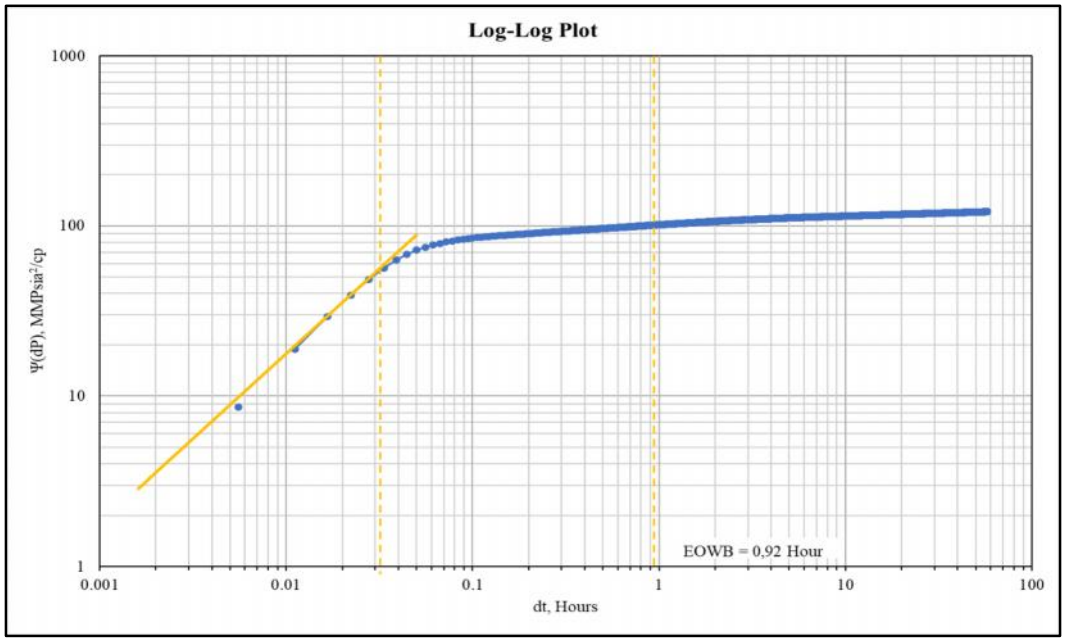


FIGURE 6. Log-Log Plot Graph of SM-04 Well

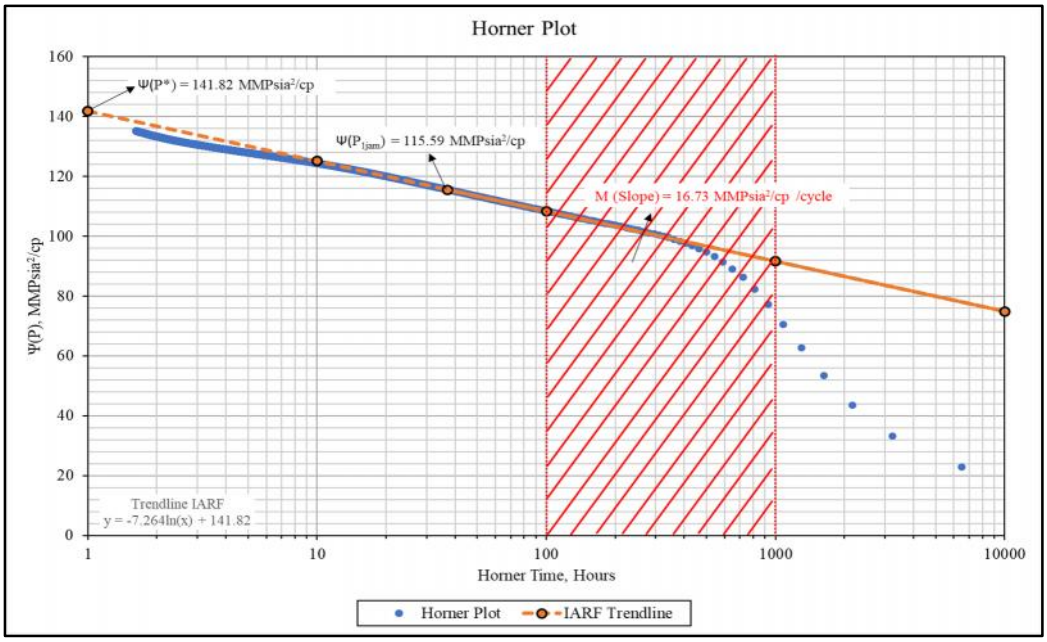


FIGURE 7. Horner Plot Graph of SM-04 Well

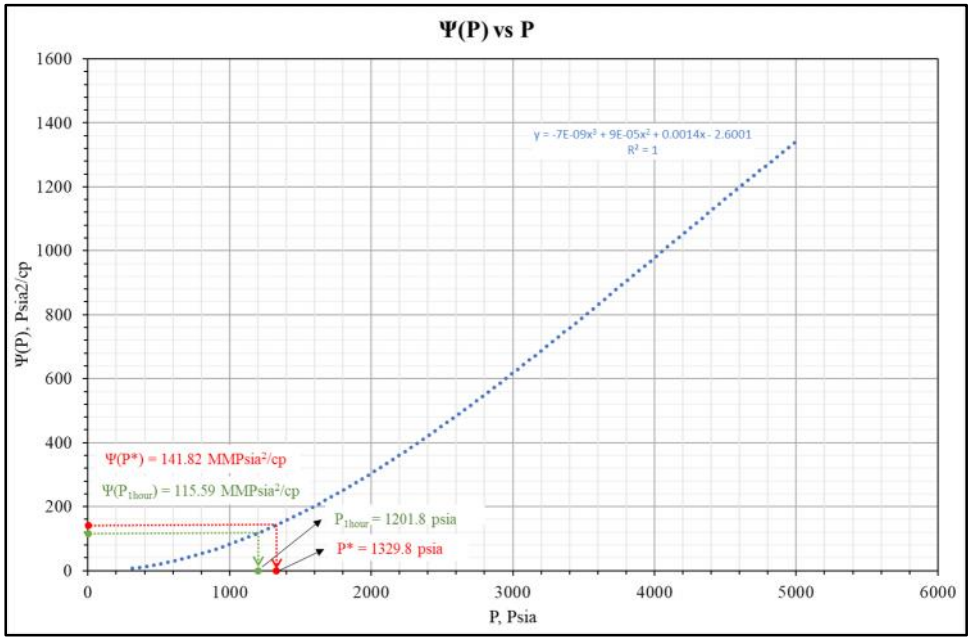


FIGURE 8. Pseudo Pressure (Ψ) Conversion Graph

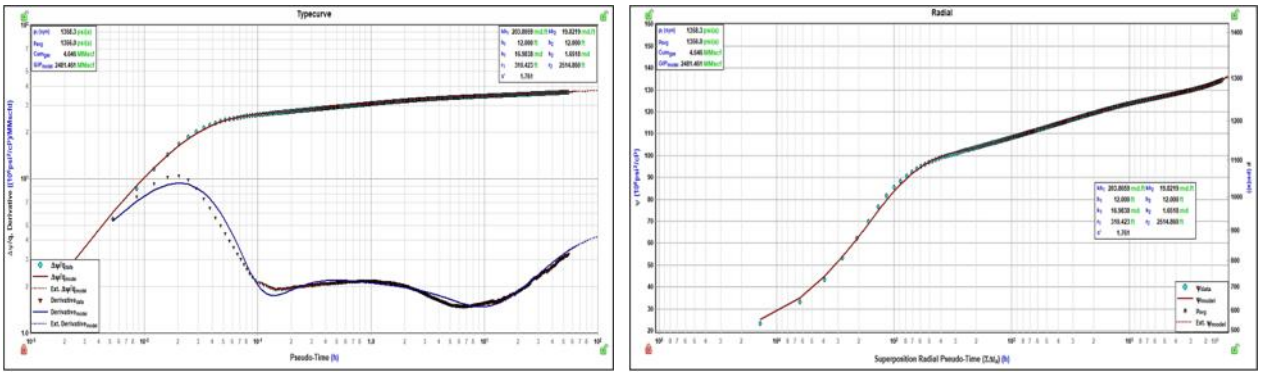
By using equations 1 to 5, the result of reservoir characteristic for zone#4 is as follows:

- Permeability (k) = 16.03 md
- Skin Factor (S') = 1.36
- Radius of investigation (ri) = 644.93 ft
- Flow Efficiency (FE) = 0.85

A composite model is chosen as a result of the IHS well-test software modelling, with the parameters are as follows:

TABLE 3. Result of Composite Model Parameters

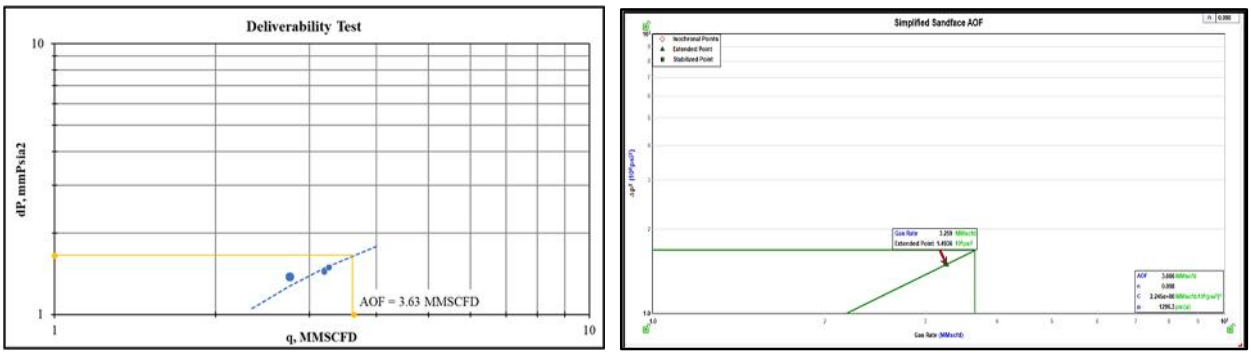
Parameters	Result	Unit
Well Model	Vertical with wellbore storage	
Reservoir Type	Homogeneous (with dual porosity)	
Boundary Model	*no-flow*	
k_1	16.98	md
S'	1.76	
P*	1358.3	Psia
r_{e1}	310.42	ft
ω_1	0.007	
λ_1	2.27 x10^{-04}	
k_2	1.65	md
r_{e2}	2514.86	ft
ω_2	0.051	
λ_2	3.11 x10^{-08}	
FE	0.79	



(a) (b)

FIGURE 9. Result of Log-Log Plot (a) and Horner Plot (b) Matching

By using the Rawlins-Schellhardt equation and IHS well-test software, the result of deliverability test for SM-04 well are as follows:



(a) (b)

FIGURE 10. Deliverability Curve of SM-04 Well by Rawlins-Schellhardt Equation (a) and IHS Well-test Software (b)

TABLE 4. Deliverability Test Result
by Rawlins-Schellhardt and IHS Well-test Software

Parameters	Rawlins-Schellhardt	IHS Well-test
n	0,998	
C, MMSCFD/MMPsia^2	2,16	2,24
AOF, MMSCFD	3,63	3,67

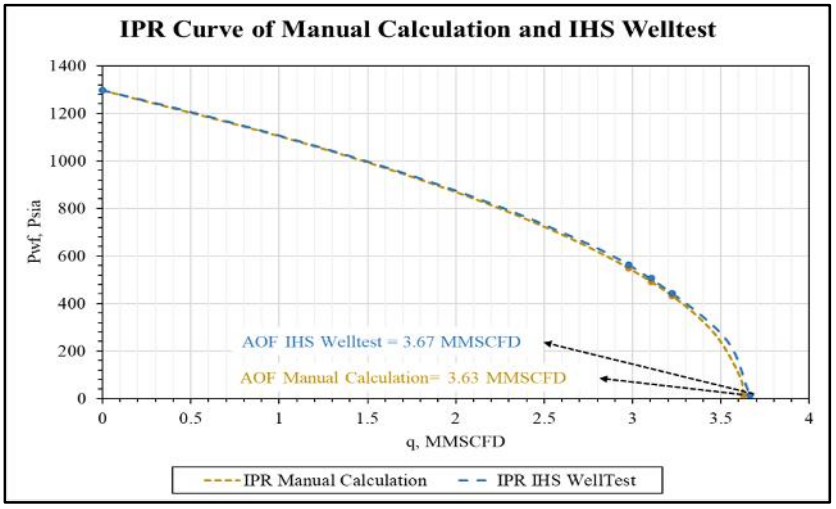


FIGURE 11. IPR Curve by Result of Manual Method and IHS Well-test Software

DISCUSSION

The zone's#4 fluid that will be produced is dry gas (**Figure 3**). The analyze result of reservoir characteristic and deliverability well by using the manual method and IHS well-test software are fairly close, so the result by using the simulation modelling can be used for the future purpose.

From the IHS well-test software, the composite model has been chosen because it's considered realistic about the reservoir condition. Although in the composite modelling result have dual-porosity parameters, but it can't be said the model is entirely a dual-porosity reservoir. Because the storativity ratio (ω) parameter is too small. So the fluid tends to be stored in the matrix. Therefore, the reservoir is still classified as homogeneous reservoir types.

CONCLUSIONS

1) From the results of the analysis, both of manual method and using the IHS well-test software, the results are fairly close.
2) By using the manual (Horner Plot) method, the results are the average reservoir pressure (P*) is 1329.80 Psia, permeability (k) is 16.03 md, skin factor (S') is 1.36, radius of investigation (ri) is 644.93 ft, and flow efficiency (FE) 0.85.
3) A composite model is selected from modeling by the IHS well-test software. The reservoir is divided into two zones with the permeability for zone 1 (k1) is 16.98 md, permeability for zone 2 (k2) is 1.65, S' is 1.76, FE is 0.79, and P* is 1358.3 Psia. No-flow boundary with a distance of 2514.86 ft from the well.
4) Although the composite model have dual-porosity parameters, but it can't be said the model is entirely a dual-porosity reservoir. Because the storativity ratio (ω) parameter is too small. So the fluid tends to be stored in the matrix. Therefore, the reservoir is still classified as homogeneous reservoir types.
5) The result of absolute open flow (AOF) value by manual method and IHS well-test software are close, that is 3.63 MMSCFD (using manual method) and 3.67 MMSCFD (using IHS well-test simulation)

REFERENCES

[1] M. G. Bishop, "South Sumatra Basin Province Indonesia: The Lahat/Talang Akar-Cenozoic Total Petroleum System," Colorado: U.S. Geology Survey, 2001.

[2] De Coster, G. L., "Central and South Sumatra Basins," The Geology of The Proceedings Indonesian Petroleum Association Third Annual Convention, 1974 [77- 110].

[3] A. U. Chaudhry, "Gas Well Testing Handbook," Texas: Elsevier, 2003.

[4] A. Tarek and P. D. McKinney, "Advanced Reservoir Engineering," Aberdeen: Elsevier, 2005.

[5] Ikoku, Chou U. "Natural Gas Reservoir Engineering". Florida. Krieger Publishing Company, 1992.

[6] J. Lee, "Well Testing," Texas: Society of Petroleum Engineering. 1992.

[7] Spivey, john P., and John lee, "Applied Well Test Interpretation". Texas: Society of Petroleum Engineering, 2013.