Production capability prediction of a reservoir gas by using gas deliverability analysis to supply gas energy in Indonesia

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Abstract. The production of a gas reservoir is different from an oil reservoir. The production of recoverable gas is not constant. Therefore, the capability of a well or a gas field to produce needs to be predicted. By knowing the well's production capacity, it can also be estimated that steps can be taken to increase the flow rate of gas production so that the existing reserves can be taken to the optimum. The purpose of this study was to determine the production capacity of the gas field. Gas well deliverability tests are conducted to determine the production capability of gas wells. The deliverability test performed on this layer uses the modified isochronal test method. AOFP analysis was carried out using conventional methods. This deliverability test is carried out in the "X" layer which is classified as a dry gas reservoir. Based on the deliverability test analysis, it can be seen that this layer has gas reserves of 2420425 MMSCF and has five wells still in production. The gas well has a value of \( n = 0.645810875 \) and a value of \( C = 0.014353581 \) MMSCFD / psi². From the results of the discussion it can be concluded that the gas well in the field has a good productivity with an AOFP 38.34201321 MMSCFD. This shows that the potential for gas reserves in the area is still quite large.

1. Introduction
In the development of a gas field, the amount of gas production is not always constant. The gas production will decrease along the time because of various problems. One of which is the decreasing reservoir pressure level that is no longer able to improve flow speed of the gas. Because of that, the production ability of a well or a gas field needs to be predicted. By acknowledging the production ability of a well, steps to improve gas production flow to reach optimum level will also be measured. The objective of this research is to acknowledge production ability of a gas field. By predicting the production ability of a well, it also allows us to predict the optimum amount of available reserve. Generally, there are two types test conducted on gas well, namely back pressure test and isochronal test. The goal of these tests is to determine the gas productivity of a well. Tests are conducted by opening the well and connect it with atmospheric pressure. The result aimed by conducting this test is to acknowledge AOFP (Absolute Open Flow Potential) value which is defined as the ability of a well to produce gas to the surface with maximum flow speed.

2. Literature review
Gas deliverability is a relationship between production flow decrease and reservoir pressure caused by depletion process of a gas reservoir. Deliverability tests of a gas well consists of at least three flow speeds or more with pressure and other data obtained as a function of time. This test is conducted to
acknowledge the production ability of a gas well which will be utilized to gather information of reservoir study and the production level of the well. Besides that, the data can also be used as policy making data for companies. Gas well deliverability test is periodically conducted on new and old wells. To determine deliverability, there are several subjects that needs to be accounted such as gas physical natures, type of test to be conducted and the analysis method used. Natural gas is a homogenous fluid that possesses low density and viscosity values and does not possess certain volume. Because of that, gas will fill any shape of containers. Most of gas molecules are more distanced than molecules of liquid compounds. Natural gas is a complex mixture of highly flammable hydrocarbon gas, and non-hydrocarbon gas known as impurities [1].

The definition of an ideal gas is a gas with constant total molecule volume regardless of its container and there is no pulling force between these molecules [2]. Because of that, an ideal gas must fulfill the following formula: PV=NRT. Real gas is unable to fulfill the presented formula, but shows a deviation factor of z. Based on that, the formula above transformed into: PV=znRT.

The value of this gas deviation can be determined by using correlation graphic of Katz and Standing methods. The determination of Z value requires pseudo reduced pressure (Ppr) and pseudo reduced temperature (Tpr) factors [3]. If the mole fraction value of each components is known, the Pseudo critical pressure (Ppc) can be determined by using the following formula: Ppc = Σ[Yi.Pci] and Tpc = Σ[Yi.Tci]. If we only know the specific gravity gas (SG) data, the price of Ppc and Tpc can be acknowledge based on its correlation graphic to fulfill the standing formula: Tpc = 168+325(SG)-12.5 ([SG]^2) and Ppc =667+[15(SG)-37.5 ([SG]^2)]. From the obtained Ppc and Tpc values, we can determine Ppr and Tpr prices by using Kats and Standing graphic correlation. The production ability of a layer can be predicted when the reservoir’s characteristic of the layer is acknowledged. Because of that, we need supporting data to be able to determine the well production ability.

3. Methodology
The method utilized in this research is a deliverability test with modified isochronal method test to produce a stable flow speed of the “X” layer. The analysis of AOFP (Absolute Open Flow Potential) value for “X” layer is conducted by using conventional method on every producing well. Meanwhile the reservoir AOFP value is obtained from the average n and C coefficient values taken from the data of all five wells. This deliverability test is conducted in “X” layer which is categorized as dried gas reservoir. This layer contains 2420425 MMSCF amount of gas and also possesses five functional wells that still producing. This “X” layer possesses a high amount of gas reserve. Generally, there are two types of well tests namely, back pressure test and isochronal test. The objective of this research is to acknowledge the gas well productivity. The targeted result in this test is the AOFP (Absolute Open Flow Potential) value which is defined as the ability of a gas well to produce gas to the surface with maximum flow speed on well base pressure levelled with atmosphere pressure. Gas deliverability test is conducted to determine gas productivity indicators shown by AOFP (Absolute Open Flow Potential) value. The method utilized to obtain AOFP value is the conventional method.

The initial data required to determine well age is pressure and critical temperature, based on pressure data and the current reservoir. The initial step conducted to predict the well’s ability is by calculating Reynolds numbers value [4]. Reynolds numbers are non-dimensional used to predict flow pattern on a different situation of fluid flows. This Reynolds numbers is usually connected with fluid’s nature such as viscosity. When NRe value is smaller than 2,000, the flow is considered as laminar. When the result obtained is between 2,000 < NRe < 4,000, the flow is located at critical or transitional zone between laminar and turbulent. When NRe value is higher than 4,000 the flow is considered as turbulent [5].

4. Results and discussion
Layer “X” is a dried gas reservoir with 98.574% of methane contain. The gas contained inside it is categorized as sweet gas that possesses impurities value less than 5% of the total gas content. On the following table, we can see the composition of layer “X” along with its molecule and pressure weights also critical temperature of each compound. Based on the data, we can determine the pseudo critical
pressure and pseudo critical temperature values of layer “X”. The deliverability test conducted on this layer is using a modified isochronal test method [6]. The AOFP analysis conducted is utilized by using conventional method. The early step of a conventional method is to transfer the measured pressure into pressure square shape. After that, we calculate the square pressure difference between pressure during well opening and when the well is closed. The next step is to calculate n and C coefficients values which further completed with final calculation analysis which is to determine AOFP value. On layer “X”, there are five producing wells. The calculation values of these five wells are enough to represent other wells. Because of that, deliverability test conducted should focus on the calculation of coefficient n and C average values to calculate AOFP value of layer “X”.

### Table 1. Gas composition data in field “X”.

| Composition | % mole | MW (xi) | Pci | Tc (°F) |
|-------------|--------|---------|-----|---------|
| H2S         | 0.00   | 34.08   | 1306| 212     |
| CO2         | 0.175  | 44.01   | 1079| 88      |
| N2          | 0.7249 | 28.013  | 493 | -233    |
| C1          | 98.574 | 16.043  | 667.8| -116.63 |
| C2          | 0.462  | 30.07   | 707.8| 90.09   |
| C3          | 0.0368 | 44.097  | 616.3| 206.01  |
| i-C4        | 0.0061 | 58.124  | 529.1| 274.98  |
| n-C4        | 0.0069 | 58.124  | 550.7| 305.65  |
| i-C5        | 0.002  | 72.151  | 490.4| 369.1   |
| n-C5        | 0.0016 | 72.151  | 488.6| 385.7   |
| C6          | 0.0019 | 86.178  | 436.9| 453.7   |
| C7          | 0.0018 | 100.205 | 396.8| 512.8   |
| C8          | 0.0027 | 114.232 | 360.6| 564.22  |
| C9          | 0.0024 | 128.259 | 332  | 610.68  |
| C10         | 0.0019 | 142.286 | 304  | 652.1   |
| **Total**   | 100    |         |     |         |

Pseudo critical (Ppc) pressure and temperature pseudo critical (Tpc) values should be calculated to determine the physical nature of the gas [7]. From the Ppc and Tpc values, we can determine Ppr and Tpr values with the following formula:

\[ Ppr = \frac{Pr}{Ppc} = \frac{890}{667.3628} = 1.284159012 \]

\[ Tpr = \frac{Tr}{Tpc} = \frac{604.4}{344.1017} = 1.756457456 \]

By acknowledging the initial pressure and temperature of the well, we can determine the physical gas natures to predict reservoir condition [8]. From the available data, we can determine the reservoir’s SG value. The calculation is conducted by using the following formula \( SG = 0.561100765 \). Next, we can determine the volume factor value of the layer’s initial formation with the following formula:

\[ Bgi = 0.00504 \times ZT/P \]

\[ = 0.00504 \times \frac{(0.561100765 \times 604.4)}{890} \]

\[ = 0.00239289 \text{ bbl/scf} \]

In the development of gas field, it is important to acknowledge the initial gas reserve value to determine recovery factor value and the available gas reserve to reach optimum level of production. Reserve on layer “X” is calculated by using a material balance method. In this method, a plot between P/Z and Gp is conducted. Based on the plot result, we obtain a reserve value of 2401950 MMSCF. Layer “X” contains 735456.8 MMSCF available areal reserves. On Figure 1, we can see the result of plot P/Z
versus Gp. The pressure utilized pressure value is obtained from extrapolation result of reservoir pressure from PBU test result.

The deliverability test conducted on this layer is utilizing a modified isochronal test method. AOFP analysis is conducted by using a conventional method [9]. The initial step in conventional method is conducted by transferring the measured pressure into square pressure. After that, the step is continued to calculation of square pressure, well pressure when the well is opened, and when it’s closed [10]. The step is further continued by calculating n and C coefficients which is completed with the last calculation analysis which is to determine AOFP value [8]. On Layer “X” there are five producing wells. Because of that, deliverability tests should focus on the calculation of n and C coefficients to determine AOFP value on layer “X”. the following table show the AOFP calculation result of wells on layer “X”:

### Table 2. Conventional Method Calculation Result on Layer “X” Gas wells.

| No | Condition       | Time (hour) | Pressure (psia) | Flow Speed (MMSCFD) | Δp² (psia²) |
|----|-----------------|-------------|-----------------|---------------------|-------------|
| 1  | Initial Shut-in | 24          | 449.83          |                     |             |
| 2  | Flow 1          | 4           | 395.6           | 18.317              | 131212.8    |
|    | Shut-in 1       | 4           | 449.23          |                     |             |
| 3  | Flow 2          | 4           | 383.56          | 20.454              | 141819.9    |
|    | Shut-in 2       | 4           | 449.57          |                     |             |
| 4  | Flow 3          | 4           | 378.27          | 21.611              | 144185      |
|    | Shut-in 3       | 4           | 449.63          |                     |             |
| 5  | Flow 4          | 4           | 377.76          | 21.619              | 139572.4    |
| 6  | Extended Flow   | 10          | 373.19          | 18.062              | 139677.5    |
|    | Final Shut-in   |             | 449.83          |                     |             |

The following figure shows the plot result between ΔP² with water flow speed on the well based on isochronal modified test [6] result as shown in the following figure:
Based on the plot calculation result, we can determine the value of coefficient n, C, and AOFP value of the well by using the following formula:

\[
\frac{1}{n} = \frac{\log 59464.52 - \log 45847.67}{\log 21.619 - \log 18.317} = 1.548440942
\]

\[n = 0.645810875\]

\[C = \frac{18.062}{449.83^2 - 373.19^2} = 0.014353581\]

\[AOFP = C \left( Pr^2 - Pwf^2 \right)^n\]

\[AOFP = 0.014353581 \times \left( 202347 - 14.7^2 \right)^{0.645810875} = 38.34381219\text{ MMSCFD}\]

The gas well possesses n value of 0.645810875 and C value of 0.014353581 MMSCFD/psi². The AOFP value is at 38.34201321 MMSCFD, which shows the gas well production capacity indicator. From the calculation and analysis of gas deliverability, it can be seen the condition of a gas reservoir. Gas field “X” in Indonesia has potential reserves of 38.34201321 MMSCFD, while the gas produced only reaches 2401950 MMSCF, so there is still a lot of gas in the reservoir in the field that can be produced to maintain gas energy needs in Indonesia.

5. Conclusion

Based on the deliverability analysis and gas production ability of the “X” layer, we can produce several conclusions as follows that in the calculation of reserves, using the P / Z versus Gp method will be able to present results that are close to the real conditions of the well where the productivity of the well has an AOFP value. the good one. From the produced gas data of 2401950 MMSCF, after being analyzed using Gas Deliverability Analysis, it turns out that it still has great potential with a potential value of
Gas reserves of 38.34201321 MMSCFD. This shows that “X” field still has great gas potential that can maintain energy supply in Indonesia.

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