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Optimization of The Physical Properties of Gas Fluids At the Stage of Field Exploitation Activity At Gas Field "X"

Cahyadi Julianto[1], Aldi Priambodo[2], Hidayat Tulloh[3], Muhammad Rizky Nugroho[4]
Petroleum Engineering Department, Faculty of Technology Mineral, Universitas Pembangunan Nasional Veteran Yogyakarta,
Jl. SWK 104, Condongcatur, Depok, Sleman, Yogyakarta 55283, Indonesia. Tel.486733, Fax. 486400
Email: cjulianto97@gmail.com[1], priambodoaldi01@gmail.com[2], hidayatulloh85@gmail.com[3], nugrohomuhammadrizky@gmail.com[4]

Abstract. Gas Field "X" is field gas located on Prabumulih, South Sumatra. The "X" Field consist of 12 active well which produce gas from the BRF Layer (Baturaja Formation). After calculating the gas reserves of field "X", Original Oil In Place (OGIP) is 526.48 BSCF. The purpose of optimization of the physical properties of gas fluids is to know the characteristics of gas fluids at the exploitation stage of the "X" gas field. From the gas composition, we know that the properties of gas from the field "X" dominated by methane, and the composition of impurities not so high. So, to know the fluid characteristic of reservoir required calculation with some correlation. If the characteristics of the gas fluid are known then it can calculate the welltest value, recovery factor value, and design of the surface gas production facilities. The methodology used to determine the physical fluid properties of gas at field "X" is to perform calculations on the physical fluid gas properties : Z factor, using Beggs And Brill correlation by consider the Pseudocritical Pressure (Ppc), Viscosity using Carr correlation, also viscosity of gas impurities (N2, CO2, and H2S), and Gas Formation Volume Factor (Bg) using Real gas equation-of-state correlation. Calculation of parameters, and analysis of PVT data conducted using Well X-01 as a research object. The results of PVT data analysis is considered to represent the real condition of BatuRaja Formation of Reservoir Gas Field "X". From the calculation, the value of physical properties obtained is Z factor of 0.804061 with Pseudocritical Pressure (Ppc) of 747,014 Psi, viscosity of 0.017115cp with N2 correction for gas viscosity of 0.000008, CO2 correction for gas viscosity of 0.001071, H2S correction for gas viscosity of 0. In addition, the value of the Gas Formation Volume Factor (Bg) is 0.00084 cuft/scf. These parameters are calculated at the same pressure value, then the fluid characteristics of the reservoir can be known at each pressure drop assuming the isothermal condition of reservoir.

Keywords: Gas Field, Physical Properties, exploitation, and Gas Fluid

Abbreviations : BSCF (Billion Standard Cubic Feet), ºF (Fahrenheit Degree), ºR (Rankine Degree), Ppc (Pseudocritical Pressure), Tpc (Pseudocritical Temperature), Ppr (Pseudoreduced Pressure), Tpr (Pseudoreduced Temperature), Z (Compressibility Factor), SG (Spesific Gravity), Bg (Gas Formation Volume Factor), Cuft/SCF (Cubicfoot per Standard Cubic Foot), cp (Centripoise).

INTRODUCTION

Natural gas is a natural resource consisting of hydrocarbon compounds and other non- hydrocarbon compounds. The main constituent of natural gas is methane and the remainder may consist of various amounts of the higher hydrocarbon gasses (ethane, propane, butane, ect), and the non-hydrocarbon gasses such as carbon dioxide (CO_2), nitrogen (N_2), hydrogen sulfide (H_2S), Helium (He), and Argon (Ar). Natural gas occurs in subsurface rock formations in association with oil (associated gas) or on its own (non-associated gas) (Hagoort, 1988). Commonly, there are two type of gas fluid, such as dry gas, and wet gas. Each type of gasses characteristic depends on its physical properties. The physical properties of gas fluid are the density, specific gravity, viscosity, gas compressibility factor (Z), and gas formation volume factor (Bg). The study of the physical properties of natural gas can be accurately calculated when considering the characteristics of each existing gas composition using dimensionless properties based on the pressure and critical temperature values of the constituent pure gases, in the form of a pseudocritical equation (Ahmed, 2001). However, the determination of the physical properties of the gas has not paid attention to the impurities in the form of CO_2, H_2S, and N_2 which will affect the calculation results, so that the pseudocritical equation needs to be corrected based on its impurities (Ahmed, 2001). Through the physical properties of gas and its correlation with the physical properties of existing reservoir rocks, it can be calculated Initial Gas In Place (IGIP) from a field.

The case study discusses about Field "X" which is located in Prabumulih, South Sumatra, Indonesia. Field "X" is a gas field with 12 active wells that have produced gas from the Baturaja Formation layer. The calculation of reserves (initial gas in place) that have done using the volumetric method with a result of 526.48 BSCF. In addition to the initial gas in place (IGIP), the optimization of the physical properties of natural gas fluid needs to be done to determine the characterization of the gas fluid at the gas field exploitation stage. By considering the gas composition and the existing impurity value, through the selection of the appropriate method, the characteristics of the gas fluid according to the actual conditions can be calculated. The Physical Properties as the result parameter can be used in determining the welltest value, the Recovery Factor value, and as a consideration in the planning / design of appropriate surface facilities in the gas production phase of the field "X".

MATERIALS AND METHODS

Basic Theory

The physical properties of gas include gas composition, gas specific gravity, gas viscosity, Z factor (compressibility factor), and gas formation volume factor (Bg). It is important to determine the physical properties of the gas accurately.

Gas Density

Density is defined as the mass per unit volume and in this case the mass can be replaced by the weight of the gas (m). In accordance with the ideal gas e the density formula for the ideal gas is as (Ahmed, 2001): (1)

$$P_g = \frac{m}{v} = \frac{PM}{RT}$$

$$Pg = \frac{P\ Ma}{Z\ R\ T} \quad (2)$$

Where :

m = Gas Weight, lb
V = Gas Volume, cuft
M = Gas Molecular Weight, lb/lb mole
P = Reservoir Pressure, psia
Z = Gas Compressibility Factor
Ma = Appear Molecular Weight
yi = Mole FractionComponent of Gas
Mi = I-Component Gas Molecules Weight

Spesific Gravity Gas

The specific gravity of a gas or gas mixture is defined as the ratio of the density of the gas to the density of air at the same pressure and temperature conditions (Ahmed, 2001).

Gas Compressibility Factor (Z)

From the real gas equation (z), it is known that z is the gas deviation factor (compressibility factor). z is the ratio of the volume of gas that is actually filled at a certain pressure and temperature to the volume of the gas that fills if the gas behaves like an ideal gas at the same pressure and temperature (Guo & Ghalambor, 2005).

Gas Formation Volume Factor (Bg)

The gas formation volume factor is the ratio of the volume of a number of gases in reservoir conditions with standard P and T conditions (P = 14.7 psi and T = 520 ºR so that z =1)

Gas Viscosity

Viscosity is a measure of fluid resistance to flow (Ahmed, 2001). Viscosity can be determined using the "Ball Pressure Viscometer" or "Rankine Capilary Viscometer". But because direct measurements are difficult to do, people usually use the indirect method of determining viscosity, namely by using the correlation method. Viscosity is influenced by pressure, temperature and composition.Viskositas merupakan suatu ukuran tahanan fluida terhadap aliran (Ahmed, 2001).

Gas Solubility in Water

Is the solubility level of the gas phase in a number of water. The price of gas solubility in water depends on the pressure, temperature and salinity of the water. The corelation of gas solubility in water and temperature shows that at each pressure value, with the higher the temperature, the gas solubility in water will also be higher. While the relationship of each parameter to the solubility of gas in water is calculated in the following equation:

$$\frac{R_{sw}}{R_{swp}} = 1 - XY.10^{-4} \quad (3)$$

Where :

R_{sw} = Gas Solubility Corrected, cuft/bbl
R_{swp} = Gas Solubility in Fresh Water, cuft/bbl
X = $3.471/T^{0.837}$
Y = Water Salinity, ppm

Water Solubility in Gas

Water solubility in gases depends on the pressure, temperature, and salinity of water. This corelation is shown in the following equation

$$\frac{w_s}{w_{sp}} = 1 - 2.87.10^{-8}\, \gamma^{1.266} \quad (4)$$

Where :

w_s = water solubility in gas, lbm/MMScf
w_{sp} = freshwater solubility in Gas
γ = water salinity, ppm

Data and Calculation of Physical Properties of gas

It is known that the composition of the gas is dominated by methane content and the value of impurities is not too large, so it is necessary to calculate the fluid characteristics of the reservoir with several correlations, by determining the following parameters.

Table 1. Composition Fluid of Field “X” (PT. Pertamina EP Asset 2, 2017)

Component		Fraction Mol (%)
Methane	CH_4	72.531
Ethane	C_2H_6	3.442
Propane	C_3H_8	2.233
Iso-Butane	i-C_4H_{10}	0.362
n-Butane	n-C_4H_{10}	0.593
Iso-Pentane	i-C_5H_{12}	0.228
n-Pentane	n-C_5H_{12}	0.185
Hexane	C_6H_{14}	0.240
Heptane	C_7H_{16}	0.313
Octane	C_8H_{18}	0.208
Nonane	C_9H_{20}	0.048
Decane	$C_{10}H_{22}$	0.060
Carbon dioxide	CO_2	19.466
Nitrogen	N_2	0.091
Hidrogen Sulfide	H_2S	0
Total		100

Table 2. Composition Fluid of Field "X" (PT. Pertamina EP Asset 2, 2017)

Parameter	Value	Unit
Field	"X"	-
Initial Pressure	1883	Psia
Temperature	205.55	^oF
Spesific Gravity Gas	0.829	-
% mol H_2S	0	-
% mol CO_2	19.466	-
% mol N_2	0.091	-

Calculation of Z Factor Using Beggs and Brill Correlation

1. The prices for Ppc and Tpc use the pressure and critical temperature values for the constituent pure gas and are presented in the following equation (Ahmed, 2001):

$$P_{pc} = \sum (y_i P_{ci}) \quad (5)$$

$$T_{pc} = \sum (y_i T_{ci}) \quad (6)$$

Where:
Ppc = Pseudo Critical Pressure, psia
Pci = The critical pressure, psia
Tpc = Pseudo Critical Temperature, ^oR
Tci = Critical Temperature Component i, ^oR
yi = The mole fraction of the ith component

This equation does not pay attention to the presence of impurities in the form of CO2, H2S and N2 which will affect the calculation results, so that the pseudocritical equation for mixed gas is generalized with the following impurity correction (Ahmed, 2001):

$$Ppc = 678 - 50\,(\gamma g - 0.5) - 206.7\,\gamma_{N2} + 440\,\gamma_{CO2} + 606.7\,\gamma_{H2S} \quad (7)$$

$$Tpc = 326 - 315.7\,(\gamma g - 0.5) - 240\,\gamma_{N2} + 83.8\,\gamma_{CO2} + 133.3\,\gamma_{H2S} \quad (8)$$

Where:
γg = Spesific Gravity Gas
γ_{N2} = Spesific Gravity N_2
γ_{CO2} = Spesific Gravity CO_2
γ_{H2S} = Spesific Gravity H_2S

2. Pseudo Reduced Pressure dan Temperature

The study of these physical properties can be obtained accurately by taking into account the characteristics of each composition using the following dimensionless properties (Ahmed, 2001):

$$P_{pr} = \frac{P}{P_{pc}} \quad (9)$$

$$T_{pr} = \frac{T}{T_{pc}} \quad (10)$$

Where :
Ppr = Pseudo Reduced Pressure, psia
Ppc = Pseudeo Critical Pressure, psia
Tpr = Pseudo Reduced Temperature, oR
Tpc = Pseudo Critical Temperature, oR

3. Calculate coefficients A, B, C, dan D

$$A = 1.39\,(Tpr - 0.92)^{0.5} - 0.36Tpr - 0.1 \quad (11)$$

$$B = (0.62 - 0.23T_{pr})P_{pr} + \left(\frac{0.066}{T_{pr} - 0.86}\right)P_{pr}^2 + \frac{0.32\,P_{pr}^6}{10^E} \quad (12)$$

$$C = 0.132 - 0.32\log(T_{pr}) \quad (13)$$

$$D = 10^{0.3106 - 0.49T_{pr} + 0.1824\,T_{pr}2} \quad (14)$$

4. Calculating Value Z-*Factor*

$$Z = A + \frac{1 - A}{e^B} + C\,P_{pr}^D \quad (15)$$

Viscosity Calculations Using Carr, Kobayashi, and Burrows Correlation

1. Calculate *Pseudocritical Pressure* (Ppc) dan *Pseudocritical Temperature* (Tpc)
2. Calculate Pseudoreduced Pressure dan Pseudoreduced Temperature
3. Calculate Viskositas Gas (Uncorrected)

$\mu 1$ = [1.709 x 10^{-5} - 2.06 x 10^{-6} (γg)] + 8,188 = x 10^{-3} – 6.15 x 10^{-3}log(γg) (16)

Where :
$\mu 1$ = Viskositas Gas *Uncorrected*, cp
γg = Specific gravity gas

5. Calculating Viscosity of a Gas with Correction for Impurities

N_2 *correction for* μ_g =
γN_2 [8.48 x 10^{-3}log (γg) + 9.59 x 10^{-3}] (17)

CO_2 *correction for* μ_g =
γCO_2[9.08 x 10^{-3} log (γg) + 6.24 x 10^{-3}] (18)

H_2S *correction for* μ_g =
γ H_2S [8.94 x 10^{-3} log (γg) + 3.73 x 10^{-3}] (18)

Where :
γ_{N2} = Spesific Gravity N_2
γ_{CO2} = Spesific Gravity CO_2
γ_{H2S} = Spesific Gravity H_2S

6. Calculating the Viscosity of a Corrected Gas

$\mu_{corr} = (\mu_1)_{uncorrected} + (\Delta\mu)_{N2} + (\Delta\mu)_{CO2} + (\Delta\mu)_{H2S}$ (19)

Where :

μ_{corr}	=	Viskositas Gas *Corrected*, cp
$\mu 1$	=	Viskositas Gas *Uncorrected*, cp
μ_{N2}	=	Viskositas Gas N_2 *impurities corrected*, cp
μ_{CO2}	=	Viskositas Gas CO_2 *impurities corrected*, cp
μ_{H2}	=	Viskositas Gas H_2S *impurities corrected*, cp

7. Calculate $\ln\left(\frac{\mu_g}{\mu_1 x} x\mathrm{T}_{pr}\right)$

$$\ln\left(\frac{\mu_g}{\mu_1 x} x\mathrm{T}_{pr}\right) = a_0 + a_1 P_r + a_2 P_r^2 + a_3 P_r^3 + T_r(a_4 + a_5 P_r + a_6 P_r^2 + a_7 P_r^3) + T_r(a_8 + a_9 P_r + a_{10} P_r^2 + a_{11} P_r^3) + T_r(a_{12} + a_{13} P_r + a_{14} P_r^2) \quad (20)$$

Where :

a_0	=	-2.4621182	a_8	=	-7,93385684 x 10^{-1}
a_1	=	2,97054714	a_9	=	1,39643306
a_2	=	-2,86264054 x 10^{-1}	a_{10}	=	-1,4944925 x 10^{-1}
a_3	=	8,05420522 x 10^{-3}	a_{11}	=	4,41015512 x 10^{-3}
a_4	=	2,80860949	a_{12}	=	8,39387178 x 10^{-2}
a_5	=	-3,49803305	a_{13}	=	-1,86408848 x 10^{-1}
a_6	=	3,6037020 x 10^{-1}	a_{14}	=	2,03367881 x 10^{-2}
a_7	=	-1,04432413 x 10^{-2}	a_{15}	=	-6,09579263 x 10^{-4}

8. Calculating gas viscosity

$$\mu_g = \frac{\mu_{corr}}{T_{pr}}\ x\ e^{\ln\left(\frac{\mu_g}{\mu_{corr}} xT_{pr}\right)} \quad (21)$$

Where :
μ_g = viskositas gas, cp

Calculating Gas Formation Volume Factor (Bg)
Real Gas-Equation-Of-State Correlation

1. Calculating Pseudocritical Pressure (Ppc) and Pseudocritical Temperature (Tpc)
2. Calculating the Gas Compressibility Factor (Z)

$$Bg = \frac{0.0282\ x\ Z\ x\ T}{p} \quad (22)$$

Where :

Bg	= formation volume factor cuft/scf
Z	= Compresbillty Factor
T	= Temperature, °R

RESULTS AND DISCUSSION

At this stage of exploitation, analysis and calculation of the physical properties of the gas fluid can be carried out. In the Field "X", it is known that the composition of the gas is dominated by methane and the value of impurities such as H2S, CO2 and N2 is not too large with H2S values of 0%, CO2 of 19,466%, and N2 of 0.091%. With this impurity factor in gas, it is necessary to have some correlation to determine the physical properties of the fluid. For the calculation of the physical properties of this gas, the gas produced from the well X-1 is carried out and the calculation is not carried out on other wells because the gas composition of the well X-1 can represent other wells in the calculation of the physical properties of gas because other wells are in the same reservoir formation as the well. X-1. In general, gas fields are not much different from oil fields in terms of drilling operations, but different from an exploitation aspect. During exploitation, gas fields generally require more complex equipment because the type of production fluid is also different from oil. Even though the physical properties of the fluid are generally the same as specific gravity, formation volume factor, and viscosity. But what distinguishes it is the measurement of the physical properties of gas and oil fluid, that in gas fluid there is a Z-Factor calculation. Z-Factor is a gas deviation factor / compressibility factor, namely the ratio between the actual and ideal gas volume. In this paper, the calculated physical properties of the fluid are the Z-factor value, the gas formation volume factor, and the gas viscosity. Meanwhile, the specific gravity on the field "X" is known to be 0.829.

Z-Factor

In calculating the z-factor value, Beggs and Brill correlation can be used. The first stage is Calculating Pseudocritical Pressure (Ppc) and Pseudocroitical Temperature (Tpc). Based on the calculation results, the value of Pseudocritical Pressure (Ppc) is 747,014 and the Pseudocroitical Temperature (Tpc) is 413,418. next is calculating the Pseudo-reduced Pressure and Temperature. Based on the results of the calculation of the value of the Pseudo-reduced Pressure of 2.52 and the

Pseudo-reduced Temperature of 1.61. Furthermore, we can calculate the coefficients A, B, C and D. After the coefficients A, B, C, and D are known, the z-factor value can be calculated. So that the z-factor value is 0.84061.

Gas Viscosity

Furthermore, the calculation made on the physical properties of the gas fluid is the calculation of viscosity. The viscosity calculation was performed using the Carr, Kobayashi, and Burrows Correlations. The input parameters in the calculation such as reservoir pressure and temperature, the specific gravity of the gas, and the presentation of molecular weight of each impurities.

The parameters that are calculated for the first time at this stage are pseudo pressure (ppc) and pseudo critical temperature (Tpc) in the form of dimensionless properties. Furthermore, the calculation is continued with parameters in the form of pseudo reduced pressure and pseudo reduced temperature as in the previous calculation phase of the physical properties of the gas. Each parameter is then used to calculate the viscosity of the uncorrected gas with a result of 0.0111851 cp. The gas viscosity has not considering the value of existing impurities such as CO_2, N_2, and H_2S, so that the results of the gas viscosity must be corrected for each impurities component. From the results of this calculation, the correction of N_2, CO_2 and H_2S is obtained for the viscosity value. Furthermore, the uncorrected viscosity is added with the correction of each of these impurities values to obtain the final result in the form of corrected gas viscosity. The final result of this calculation process is a gas viscosity of 0.017155 cp.

Gas Formation Volume Factor (Bg)

The calculation of the Gas Formation Volume Factor is carried out by inputting the parameter such as compressibility factor (Z), reservoir pressure (P) and temperature (T). The calculation process is carried out with dimensionless properties with the output parameters are pseudo-critical pressure (Ppc), Pseudo-critical Temperature (Tpc), Pseudo- reduced Pressure (Tpr), and Pseudo-reduced Temperature (Tpr) where the calculation results of each parameter is the same as the previous calculation of the physical properties of the fluid.

Furthermore, the calculation of the formation volume factor was carried out using the Real Gas Equation Station correlation with the final result of 0.0084 cuft / SCF. This Formation Volume Factor parameter is required in the calculation of the initial gas in place, and furthermore in the well test analysis to determine the plateu rate of production gas at Field "X".

Analysis of the Physical Properties of the Gas

In calculating the physical properties of gas in the field "X", several pressure variations can be made. This pressure variation is below the initial pressure of the gas reservoir pressure so that it will produce a graph of the physical properties of the gas that can be analyzed.

Table 3. Results of the Calculation of the Physical Properties of the Gas at Each Pressure

Pressure (Psia)	Z Factor	Bg (ft³/SCF)	Gas Viscosity (Cp)	
14.7	0.9987721	1.278366999	0.011468167	-
100	0.9912785	0.186510023	0.011703328	-
150	0.9867322	0.123769762	0.011842299	P abandon
200	0.9821021	0.092391734	0.011982097	-
300	0.972645	0.061001372	0.012264141	-

Tabel 3. Continue

400	0.9630019	0.045297437	0.012549405	-
415	0.9615736	0.043626966	0.012591607	-
500	0.9532542	0.035871143	0.012837832	-
600	0.9434771	0.029586023	0.01312936	-
700	0.9337407	0.025097748	0.013423929	-
800	0.9241111	0.021734051	0.013721474	-
900	0.9146498	0.019121363	0.014021928	-
1000	0.9054144	0.017035461	0.014325223	-
1100	0.8964579	0.015333585	0.014631289	-
1200	0.887829	0.013920492	0.014940053	-
1300	0.8795719	0.012730179	0.015251441	-
1400	0.8717263	0.01171544	0.015565377	-
1500	0.8643272	0.010841601	0.015881783	-
1600	0.8574053	0.010082604	0.01620058	-
1700	0.8509868	0.009418471	0.016521687	-
1800	0.8450934	0.00883362	0.016845022	-
1833	0.8406135	0.008399483	0.017115022	P initial

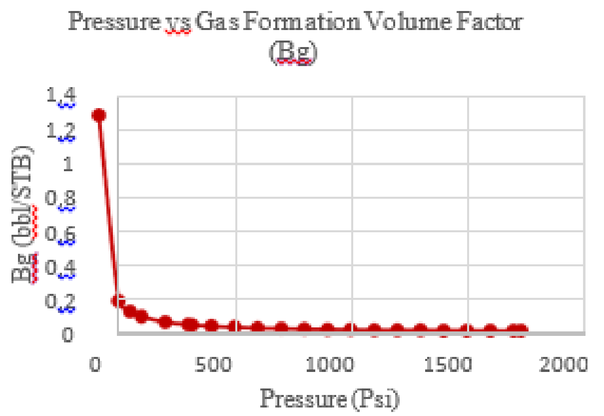

Figure 1. Pressure vs Gas Formation Volume Factor

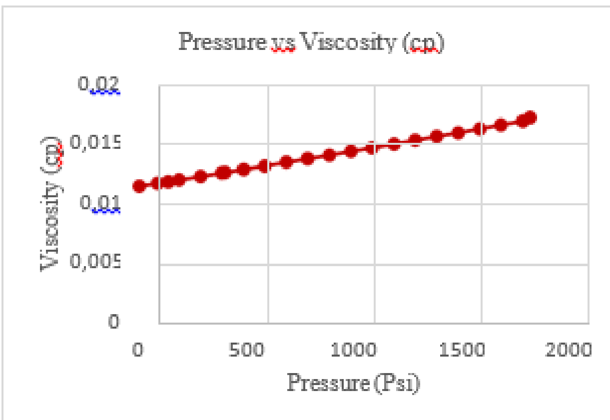

Figure 2. Pressure vs Viscosity

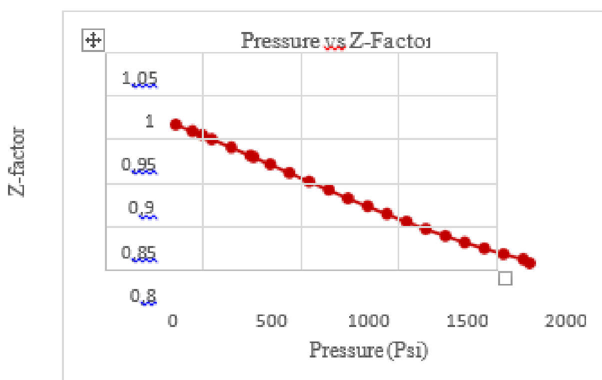

Figure 3. Pressure vs Z-Factor

In (Figure 1) illustrates the relationship between pressure to the gas formation volume factor where along with the decrease in pressure, the formation volume factor value increases because with decreasing pressure, the gas volume in the reservoir also expands or enlarges. In (Figure 2) illustrates the viscosity value at each pressure drop value, where the lower the pressure value, the viscosity value also decreases because the gas expands, the lighter, and the easier it is to flow. Whereas in (Figure 3) illustrates the compressibility factor or gas deviation factor at each price of pressure drop, where as the pressure decreases, the compressibility factor of the gas is getting closer to unity because the gas is getting closer to the ideal gas condition. This is important to know because gas is compressible. The values and graphs of these relationships will be used in the Real Gas Pseudo Pressure calculation approach in the Pressure Build Up analysis. The physical properties of this gas will be very useful in the well-test calculation because the well-test calculation will also lead to the determination of the plateau gas flow rate. Determination of plateau gas flow rate will greatly affect the development of gas fields, especially in meeting production targets at the exploitation stage.

CONCLUSIONS

Based on the analysis that has been carried out in the case study of calculating the physical properties of gas in field X, some of the main points are as follows:

1. Physical properties of gas fluid consist of gas density, gas specific gravity, gas composition, gas compressibility factor, gas formation volume factor, gas solubility in water, and water solubility in gas.
2. The X.X graph shows the relationship between pressure to the gas formation volume factor, where with the decrease in pressure the gas formation volume factor value will be greater. This is because the decrease in the pressure value will cause the volume of gas in the reservoir to expand or enlarge, so that the formation volume factor will be even greater.
3. Analysis of the X.X graph, showing changes in the value of the viscosity of gas at each change in pressure value. This change shows that the decrease in reservoir pressure is directly comparable to the viscosity value. This is due to the fact that the gas is expanding, lighter, and easier to flow with each decrease in pressure value.
4. Analysis of the X.X graph illustrates the relationship between pressure drop and changes in the value of the gas compressibility factor (Z). The lower the reservoir pressure value, the more the formation volume factor approaches the value 1. This shows that the gas is compressible and the gas condition is getting closer to the ideal gas condition.
5. The calculation of the physical properties of gas is needed to determine the characterization of the gas fluid in Field "X". The physical properties of the gas

will be used in the analysis of Initial Gas In Place (IGIP) determination, the approach to well test analysis, planning of gas production facilities, and the field development in the gas field “X”.

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