PARAMETERS AND CORRELATIONS

1. PVT OIL

1.1 Bubble Point Pressure

1) Standing Correlation

$$p_b = 18.2\,[(R_s/\gamma_g)^{0.83}\,(10)^a - 1.4]$$

with

$$a = 0.00091\,(T - 460) - 0.0125\,(API)$$

where p_b = bubble-point pressure, psia
T = system temperature, °R

2) Vasquez-Beggs

$$p_b = \left[(C_1 R_s/\gamma_{gs})\,(10)^a\right]^{C_2}$$

with

$$a = -\,C_3\,API/T$$

Coefficient	API ″ 30	API > 30
C_1	27.624	56.18
C_2	0.914328	0.84246
C_3	11.172	10.393

1.2 Gas Oil Ratio (Rs)

1) Standing Correlation

$$R_s = \gamma_g \left[\left(\frac{p}{18.2} + 1.4\right)10^x\right]^{1.2048}$$

$$x = 0.0125\,API - 0.00091(T - 460)$$

where T = temperature, °R
p = system pressure, psia
γ_g = solution gas specific gravity

2) Vasquez-Beggs

$$R_s = C_1\,\gamma_{gs}\,p^{C_2}\,\exp\left[C_3\left(\frac{API}{T}\right)\right]$$

Values for the coefficients are as follows:

Coefficient	API ″ 30	API > 30
C_1	0.0362	0.0178
C_2	1.0937	1.1870
C_3	25.7240	23.931

$$\gamma_{gs} = \gamma_g\left[1 + 5.912\,(10^{-5})\,(API)\,(T_{sep} - 460)\,\log\left(\frac{p_{sep}}{114.7}\right)\right]$$

where γ_{gs} = gas gravity at the reference separator pressure
γ_g = gas gravity at the actual separator conditions of p_{sep} and T_{sep}
p_{sep} = actual separator pressure, psia
T_{sep} = actual separator temperature, °R

1.3 Formation Volume Factor of Oil (Bo)

a. *Saturated* : *Standing's Correlation*

$$\beta_o = 0.9759 + 0.000120\left[R_s\left(\frac{\gamma_g}{\gamma_o}\right)^{0.5} + 1.25(T-460)\right]^{1.2}$$

b. *Undersaturated* :*Vasquez-Beggs Correlation*

$$B_o = 1.0 + C_1 R_s + (T-520)\left(\frac{API}{\gamma_{gs}}\right)[C_2 + C_3 R_s]$$

Coefficient	API ″ 30	API > 30
C_1	4.677×10^{-4}	4.670×10^{-4}
C_2	1.751×10^{-5}	1.100×10^{-5}
C_3	-1.811×10^{-8}	1.337×10^{-9}

1.4 Oil Viscosity (μ_o)

a. Saturated : *Beggs-Robinson's Correlation*

Can be calculated after getting dead oil viscosity through Beggs-Robinson's Correaltion

$$\mu_{ob} = a(\mu_{od})^b$$

where $a = 10.715(R_s + 100)^{-0.515}$

$b = 5.44(R_s + 150)^{-0.338}$

b. Undersaturated : *Vasquez-Beggs' Correlation*

Can be calculated after getting saturated oil viscosity through Beggs-Robinson's Correaltion

$$\mu_o = \mu_{ob}\left(\frac{p}{p_b}\right)^m \qquad m = 2.6\, p^{1.187}\, 10^a$$

$$a = -3.9(10^{-5})\, p - 5$$

1.5 Oil Density

Standard method

$$\rho_o = \frac{62.4\gamma_o + 0.0136 R_s \gamma_g}{B_o}$$

where γ_o = specific gravity of the stock-tank oil

R_s = gas solubility, scf/STB

ρ_o = oil density, lb/ft^3

1.6 Oil Isothermal Compressibility (Co)

a. Saturated : Correlation B-51 in McCain

$$c_o = 10^{-6} e^{\left[\frac{\rho_{ob} + 4.347\times10^{-3}(p-p_b)-79.1}{7.141\times10^{-4}(p-p_b)-12.938}\right]}$$

b. Undersaturated : *Vasquez-Beggz's correlation*

$$c_o = \frac{-1{,}433 + 5R_{sb} + 17.2(T-460) - 1{,}180\,\gamma_{gs} + 12.61°\,API}{10^5 p}$$

where T = temperature, °R
p = pressure above the bubble-point pressure, psia
R_{sb} = gas solubility at the bubble-point pressure

2. PVT GAS

2.1 Critical Properties (Ppc, Tpc, P'pc, and T'pc)

Data of hydrocarbon's specific gravity needed.

Kay's Mixture Rule Pseudocritical Pressure and Pseudocritical Temperature Correlation and Correction

a. Natural Gas Pseudocritical Pressure and Pseudocritical Temperature

1) Standing's Correlation

Case 1: Natural Gas Systems

$$T_{pc} = 168 + 325\,\gamma_g - 12.5\,\gamma_g^2$$

$$p_{pc} = 677 + 15.0\,\gamma_g - 37.5\,\gamma_g^2$$

Case 2: Gas-Condensate Systems

$$T_{pc} = 187 + 330\,\gamma_g - 71.5\,\gamma_g^2$$

2) Sutton's Correlation

$$p_{pc} = 756.8 - 131.07\gamma_g - 3.6\gamma_g^2.$$

$$T_{pc} = 169.2 + 349.5\gamma_g - 74.0\gamma_g^2$$

b. Gas Condensate Pseudocritical Pressure and Pseudocritical Temperature

Carr-Kobayashi-burrows method, pseudocritical pressure correction, pseudocritical temperature correction

2.2 Pseudoreduce Pressure (Ppr) and Pseudoreduce Temperature (Tpr)

We can find PPr by divide P over the Ppc, also the Tpr by dividing T over Tpc.

$$Ppc = \frac{P}{Pc}$$
$$Tpc = \frac{T}{Pc}$$

$$T'_{pc} = T_{pc} - 80\, y_{CO_2} + 130\, y_{H_2S} - 250\, y_{N_2}$$
$$p'_{pc} = p_{pc} + 440\, y_{CO_2} + 600\, y_{H_2S} - 170\, y_{N_2}$$

2.3 Z-Factor Calculation

Hall-Yarborough's Method

$$z = \left[\frac{0.06125\, p_{pr} t}{Y}\right] \exp[-1.2(1-t)^2] \qquad (2\text{-}3\text{(}$$

where p_{pr} = pseudo-reduced pressure
t = reciprocal of the pseudo-reduced temperature, i.e., T_{pc}/T
Y = the reduced density that can be obtained as the solution of the following equation:

$$F(Y) = X1 + \frac{Y + Y^2 + Y^3 + Y^4}{(1-Y)^3} - (X2)\, Y^2 + (X3)\, Y^{X4} = 0$$

where $X1 = -0.06125\, p_{pr}\, t \exp[-1.2\,(1-t)^2]$
$X2 = (14.76\, t - 9.76\, t^2 + 4.58\, t^3)$
$X3 = (90.7\, t - 242.2\, t^2 + 42.4\, t^3)$
$X4 = (2.18 + 2.82\, t)$

2.4 Gas Isothermal Compressibility (Cg)

Dranchuk-Purvis-Robinson's Method

$$1 + T_1\, \rho_r + T_2 \rho_r^2 + T_3 \rho_r^5 + [T_4 \rho_r^2\, (1 + A_8\, \rho_r^2) \exp(-A_8\, \rho_r^2)] - \frac{T_5}{\rho_r} = 0$$

$$T_1 = \left[A_1 + \frac{A_2}{T_{pr}} + \frac{A_3}{T_{pr}^3}\right]$$
$$T_2 = \left[A_4 + \frac{A_5}{T_{pr}}\right]$$
$$T_3 = [A_5\, A_6/T_{pr}]$$
$$T_4 = [A_7/T_{pr}^3]$$
$$T_5 = [0.27\, p_{pr}/T_{pr}]$$

$A_1 = 0.31506237$
$A_2 = -1.0467099$
$A_3 = -0.57832720$
$A_4 = 0.53530771$
$A_5 = -0.61232032$
$A_6 = -0.10488813$
$A_7 = 0.68157001$
$A_8 = 0.68446549$

2.5 Formation Volume Factor (FVF) of gas (Bg)

Real Gas EOS Ratio

Since in this book $T_{sc} = 520°R$, $p_{sc} = 14.65$ psia, and for all practical purposes $z_{sc} = 1$, then

$$B_g = \frac{zT(14.65)}{(1.0)(520)p} = 0.0282 \frac{zT}{p} \frac{cu\ ft}{scf}. \quad (6\text{–}2)$$

Also,

$$B_g = \left(0.0282 \frac{zT}{p} \frac{cu\ ft}{scf}\right)\left(\frac{bbl}{5.615\ cu\ ft}\right) = 0.00502 \frac{zT}{p} \frac{res\ bbl}{scf}, \quad (6\text{–}3)$$

2.6 Density Of Gas

Gas Equation of State Modification

R = 10.732

MW_AIR = 28.965

Density of Gas = SG * Air Molar Weight * p / (Z * R * (T + 460))

2.7 Viscosity of gas (μ_g)

Lee-Gonzalez-Eaking Method

$$\mu_g = 10^{-4} K \exp\left[X\left(\frac{\rho_g}{62.4}\right)^Y\right]$$

where

$$K = \frac{(9.4 + 0.02 M_a) T^{1.5}}{209 + 19 M_a + T}$$

$$X = 3.5 + \frac{986}{T} + 0.01 M_a$$

$$Y = 2.4 - 0.2 X$$

ρ_g = gas density at reservoir pressure and temperature, lb/ft^3
T = reservoir temperature, °R
M_a = apparent molecular weight of the gas mixture

3. PVT Formation Water

3.1 Water Formation Volume Factor (Bw)

McCain

$$B_w = (1 + \Delta V_{wp})(1 + \Delta V_{wT}),$$

$$\Delta V_{wp} = -1.0001 \times 10^{-2} + 1.33391 \times 10^{-4} T + 5.50654 \times 10^{-7} T^2,$$

$$\Delta V_{wT} = -1.95301 \times 10^{-9} pT - 1.72834 \times 10^{-13} p^2 T$$
$$-3.58922 \times 10^{-7} p - 2.25341 \times 10^{-10} p^2,$$

3.2 Water Viscosity (μ_w)

1) Standard Method

$$\mu_w = \mu_{wD} [1 + 3.5 \times 10^{-2} p^{-2} (T - 40)]$$

$$\mu_{wD} = A + B/T$$

$$A = 4.518 \times 10^{-2} + 9.313 \times 10^{-7} Y - 3.93 \times 10^{-12} Y^2$$

$$B = 70.634 + 9.576 \times 10^{-10} Y^2$$

μ_w = brine viscosity at p and T, cp
μ_{wD} = brine viscosity at p = 14.7, T, cp
p = pressure of interest, psia
T = temperature of interest, T °F
Y = water salinity, ppm

2) Beggs & Brill (1978)

Beggs & Brill (1978)

$$\mu_w = \exp(1.003 - 1.479 \times 10^{-2} T + 1.982 \times 10^{-5} T^2)$$

3.3 Density of Brine

McCain

$$\rho_w = 62.368 + 0.438603 \times S + 1.60074 \times 10^{-3} \times S^2, \quad \text{.....................(1)}$$

where density is in lbm/ft^3, and S is salinity in weight percent. Then, density at reservoir conditions is calculated by dividing the density in **Eq. 1** by the brine FVF at the reservoir temperature and pressure of interest.

3.4 Solubility of Methane in Pure Water (Rsw)

McCain

3.5 Water Isothermal Compressibility

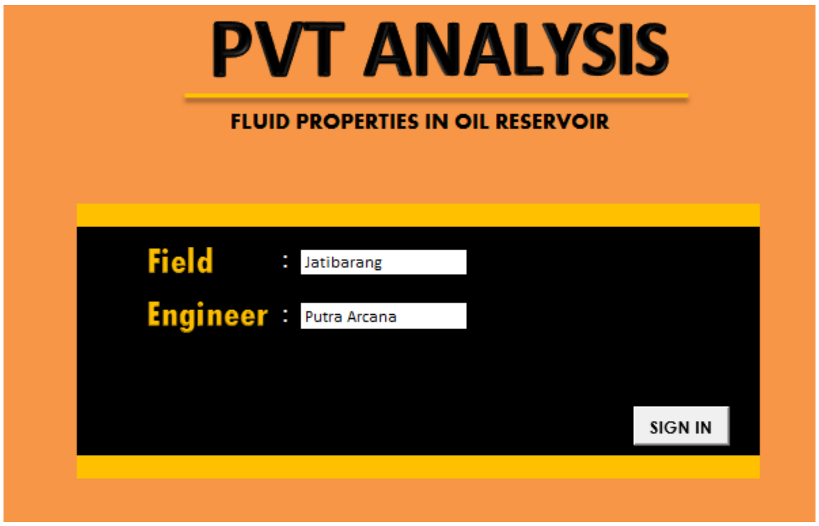
$$C_w = (C_1 + C_2 T + C_3 T^2) \times 10^{-6}$$

$C_1 = 3.8546 - 0.000134\ p$
$C_2 = -0.01052 + 4.77 \times 10^{-7}\ p$
$C_3 = 3.9267 \times 10^{-5} - 8.8 \times 10^{-10} p$
T = °F
p = psia
C_w = psi^{-1}

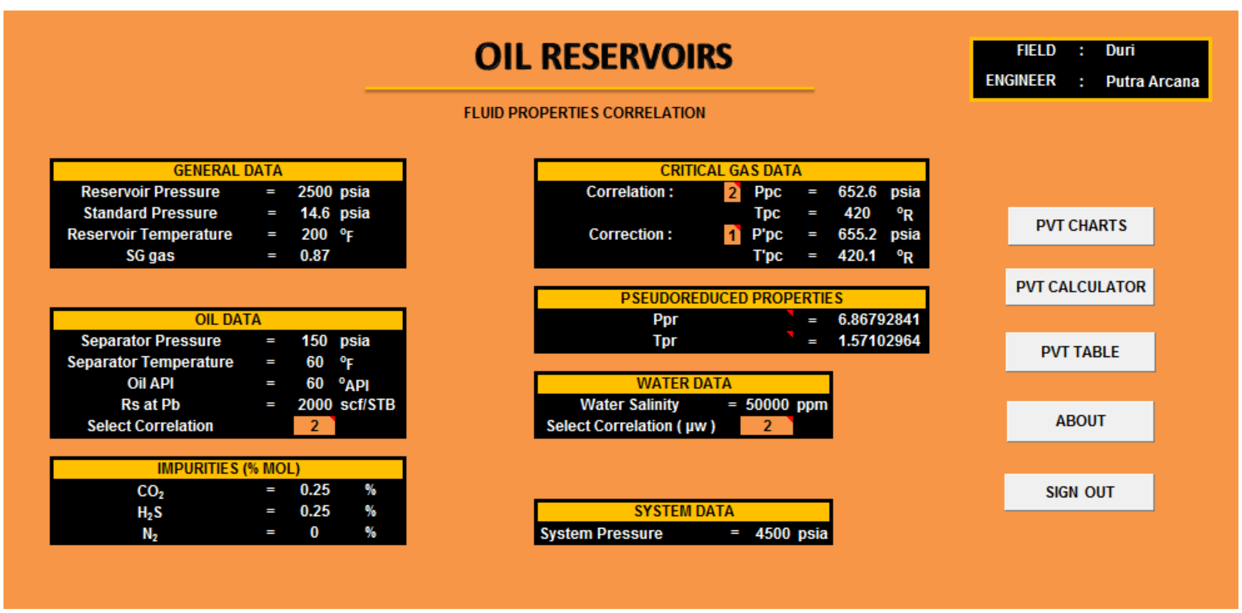
FEATURES ON SPREADSHEET

1. There are 5 sheets on our excel, which are:
   a. **Sign In** : Sheets where we input the oil field and the engineer
   b. **Main** : Sheet where we input the known data, and choose which correlation we want to use.
   c. **PVT Calculator** : Sheet that show the result of our calculation
   d. **Table** : Sheet that show the table of pressure for 36 pressures from initial reservoir pressure which is input value until pressure at standard condition
   e. **Grafik** : Sheet that show the graph of the properties

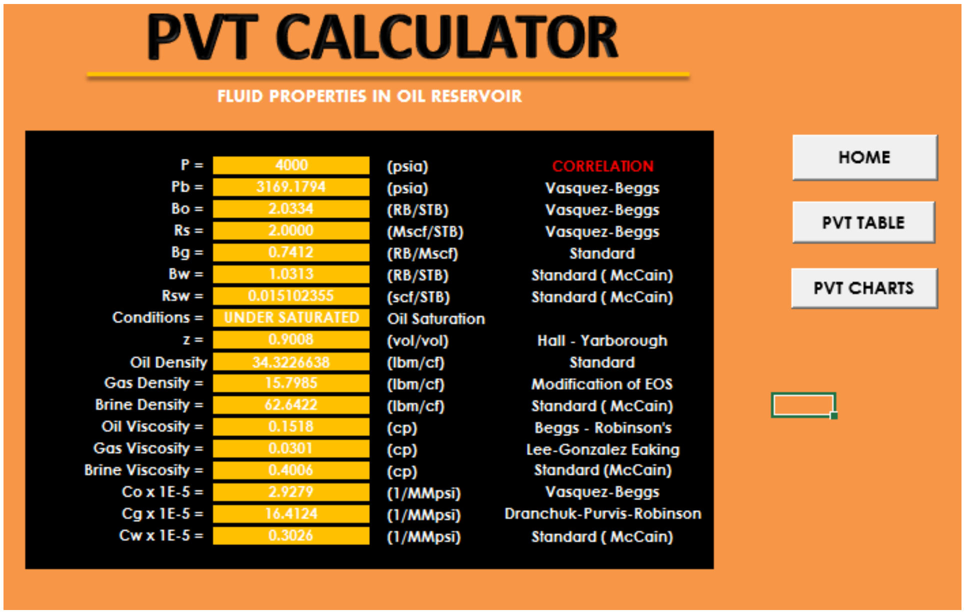
2. This excel can calculate the properties of oil, gas, and formation water.
3. The data of oil, gas, and separator can be input by user.
4. There is table that show all the result of properties calculation for different pressure.
5. We can see the graphs of each properties.
6. We can sign in to the excel
7. We can see the identity of creators by click “ABOUT” button on main sheet



SIGN IN SHEET



MAIN SHEET



PVT CALCULATOR SHEET

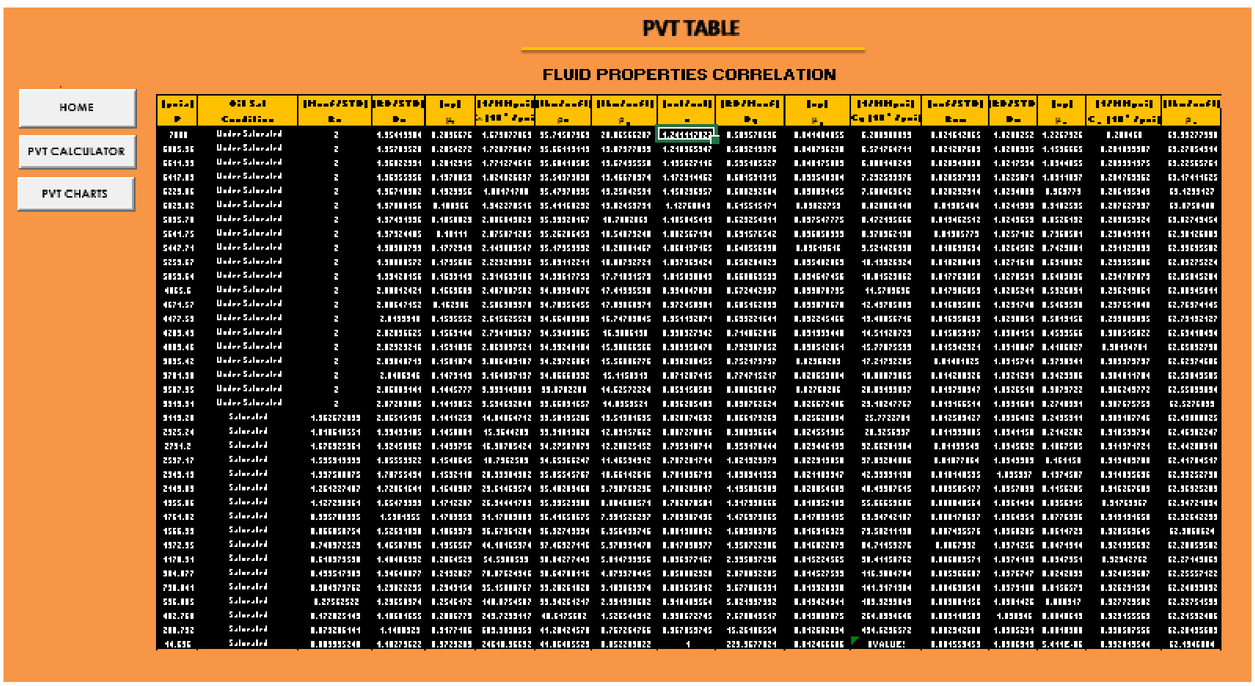
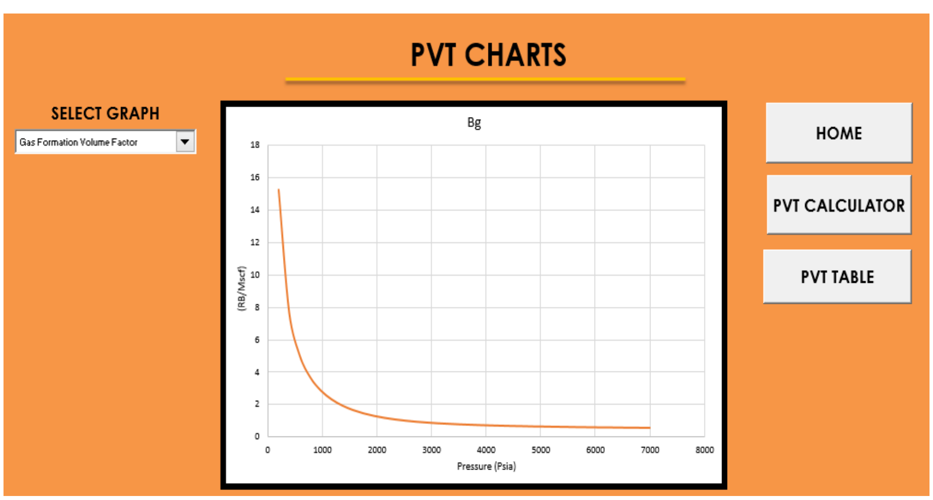


TABLE SHEET



GRAFIK SHEET