Aeon Petroleum Consultants Quarterly Newsletter

Aeon Petroleum Consultants is a professional engineering firm registered in the State of Texas. We specialize in estimating resources and reserves. Our intent on publishing this newsletter is to highlight topics of interest to those involved in estimating, reviewing, or reporting oil and gas resources and reserves.

In this issue, we will discuss the following:

- Aeon Petroleum Consultants website
- Properties of Production Decline Curves
    - Exponential
    - Hyperbolic
    - Harmonic
- How to Calculate Static Bottom-Hole Pressure from Surface Wellhead Pressure for an Oil Well

We hope to make this quarterly newsletter informative and useful. If there are any topics you would like us to discuss in future newsletters, please contact us on our website and let us know.

Aeon Petroleum Consultants Website

The website for Aeon Petroleum Consultants can be found at:

www.aeon-petro.com

The website contains topics and items that should be of interest to those estimating, reviewing or reporting oil and gas resources and reserves. Besides listing the services that Aeon Petroleum Consultants can provide to the oil and gas industry, there are items available for download, software created by Aeon Petroleum Consultants available for download or demo, videos, and resource and reserve guidelines for viewing and download.

Check out our offerings here:

https://aeon-petro.com/supplement/shop/

Please feel free to contact us regarding our services, software, or items you would like us to discuss in these newsletters.

Properties of Production Decline Curves

Although most engineers performing decline curve analysis use software for that purpose, it is always nice to know and understand the equations used to estimate production rates and cumulative volumes.

Listed on the next page are the basic equations of rate vs time and cumulative volume vs rate and cumulative volume vs time for each of the decline types: exponential, hyperbolic, and harmonic. This is a complete reference table that can be printed out and kept handy for future reference.

The parameters used in these equations are as follows:

q = production rate at time t
q_i = initial production rate
b = b factor
d_i = initial hyperbolic decline rate (not the initial effective decline rate – see below)
t = time
Np = cumulative production

The decline rate is a hyperbolic decline rate and must be calculated from the effective decline rate. The effective decline rate is the decline that would occur if it were exponential. To calculate the hyperbolic decline rate use:

$$d_i = -\ln(1 - d_e)$$

where d_e is the effective decline rate.

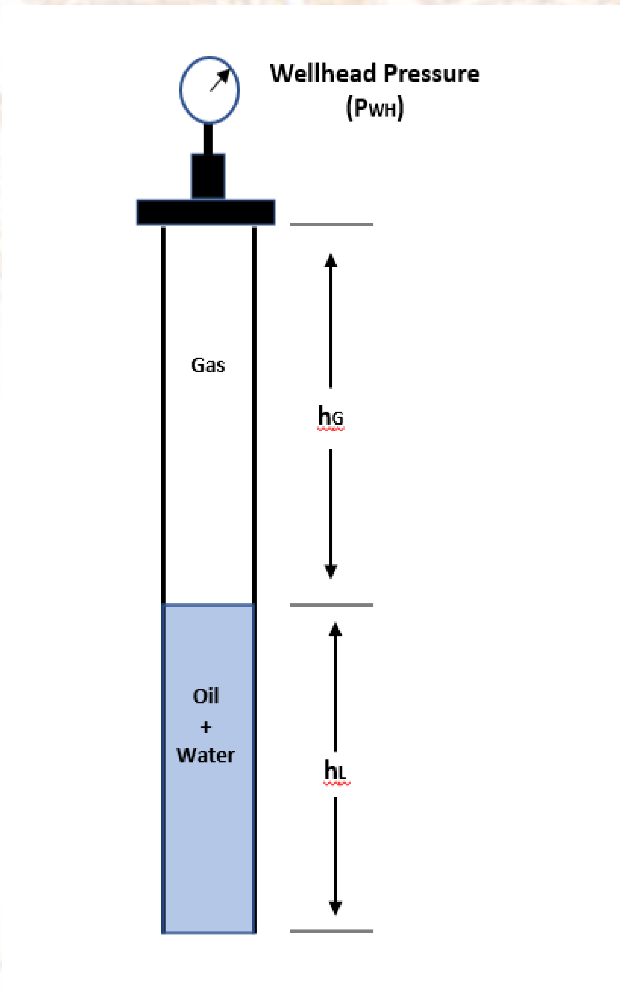
Properties of Decline Types

Decline Type	Rate Time	Cumulative Volume
Exponential	$q = q_i * (1 - d)^t$	$N_p = \frac{(q_i - q)}{-\ln(1 - d)}$ or $N_p = \frac{q_i * (1 - (1 - d)^t)}{-\ln(1 - d)}$
Hyperbolic	$q = \frac{q_i}{(1 + b * d_i * t)^{\frac{1}{b}}}$	$N_p = \frac{{q_i}^b}{d_i * (1 - b)} * (q_i^{(1-b)} - q^{(1-b)})$ or $N_p = \frac{q_i}{d_i * (1 - b)} * (1 - (1 + b * d_i * t)^{\left(\frac{b-1}{b}\right)})$
Harmonic	$q = \frac{q_i}{(1 + d_i * t)}$	$N_p = \frac{q_i}{d_i} * \ln\left(\frac{q_i}{q}\right)$ or $N_p = \frac{q_i}{d_i} * \ln(1 + d_i * t)$

How to Calculate Static Bottom-Hole Pressure from Surface Wellhead Pressure for an Oil Well

Last quarter we showed a method to calculate bottom-hole pressure from surface pressure for a dry gas well. This quarter we will show a method that can be used to calculate bottom hole pressure for an oil well using wellhead pressure and fluid level.

The diagram below shows an oil well with a measured fluid level and wellhead pressure. Data for this particular diagram is shown to the right.



Wellhead Pressure = 350 psia
Fluid Level = 844 ft
Formation Depth = 1,678 ft
Oil Gravity = 36 API
Water Sp. Gr. = 1.03
Average Oil Cut = 42%
Formation Temp = 83 °F
Surface Temp = 70 °F
Gas Sp. Gr. = 0.72

To obtain the bottom-hole pressure, one calculates the pressure due to the compressed gas column and the oil+water column and add them together. Each of these calculations is independent of each other and can be easily calculated.

Calculation of Gas Column Pressure

The gas column pressure is calculated using the same formula introduced in our last newsletter. However, instead of using the reservoir as our reference depth, we use the fluid level as our base. The formula then becomes:

$$P_{FL} = P_{WH} * e^{(\frac{0.01875\gamma_g * H_G}{z_{ave} * T_{ave}})}$$

where,

P_{FL} = fluid level pressure (psia)
P_{WH} = wellhead pressure (psia)
γ_g = gas gravity (air = 1)
H_G = height of gas column (fluid level - vertical feet)
z_{ave} = average z factor
T_{ave} = average temperature (°R)

Since z_{ave} is unknown until the fluid level pressure is calculated, it is initially estimated and calculations performed iteratively until a constant value is reached.

Since the fluid level is quite shallow the formula can be used "as is" to calculate the fluid level pressure. The data and calculations for the gas column is as follows:

Data:

P_{WH} = 350 psia
H_{GC} = 844 ft
Gas gravity = 0.720

Wellhead temperature = 70 ^{o}F
Reservoir temperature = 83 ^{o}F

Solution:

Calculate the temperatures in ^{o}R:

> Wellhead temperature = 70 + 460 = 530 ^{o}R
> Estimated fluid level temperature = 70 + 460 + 844*(83-70)/1678 = 537 ^{o}R
> Average temperature (Tave) = (530 + 537)/2 =533 ^{o}R

Set up a table (or use Excel) to iteratively calculate the gas column pressure at the fluid level until a constant value is obtained. Initially set the fluid level pressure as the wellhead pressure and calculate z_{ave} for that pressure and T_{ave}. Shown below is a table for the gas column of the wellbore.

Est. Gas Pressure at Fluid Level (psia)	P_{ave} (psia)	Pr at P_{ave}	z_{ave}	Exponent	Gas Pressure at Fluid Level (psia)
350	350	0.524	0.931	0.02294985	358
358	354	0.530	0.929	0.02294985	358

Notice that by the second iteration a constant value of pressure was obtained. The pressure at the fluid level is 358 psia.

Calculation of Oil + Water Column Pressure

The pressure exerted by the oil + water column is simply the fluid density multiplied by the height of the fluid column. It is important to consider the makeup of the fluid as a column composed of only oil would result in too low a pressure and one of water a column pressure that is too high. Assuming the well was shut in and producing at some oil cut (or water cut if you prefer) gives a good indication of the average makeup of the fluid column.

Calculation of the oil + water column pressure is as follows:

Data:

Oil Sp. Gr. = 36 API
Water Sp. Gr. = 1.03
Oil Cut = 42%
Column height = 1,678 – 844 = 834 ft

Calculations:

Oil Sp. Gr. = 141.5/(131.5 + 36) = 0.845
Fluid Sp. Gr. = 0.42 * 0.845 + 0.58 * 1.03 = 0.952
Fluid Density = 0.952 * 0433 psi/ft = 0.412 psi/ft

Oil + Water column pressure = 0.412 psi/ft * 834 ft = 344 psia

Calculation of Bottom-hole Pressure

Now simply add together the two calculated pressures to get the bottom-hole pressure:

Bottom-hole pressure = 358 + 344 = 702 psia