Kimia Fisika-TKG 1108

PVT data

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Outline

Multiphase phenomena
- Introduction
- Wettability
- Capillary pressure
- Relative permeability

PVT data
- Introduction
- Equation of state (EOS)
- PVT data
- Case study

Introduction

To express the relationship between surface and reservoir hydrocarbon volumes.

oil in place

$$OIP = V\phi(1-S_{wc}) \quad \text{(res.vol.)} \quad (1.1)$$

where V = the net bulk volume of the reservoir rock

ϕ = the porosity, or volume fraction of the rock which is porous

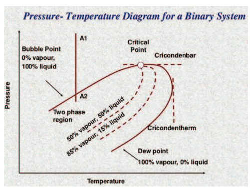
and S_{wc} = the connate or irreducible water saturation and is expressed as a fraction of the pore volume.

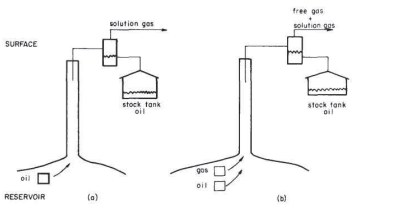
stock tank oil initially in place

$$STOIIP = N = V\phi(1-S_{wc})/B_{oi} \quad \text{(stock tank volume)} \quad (1.2)$$

where B_{oi}, is the oil formation volume factor, under initial conditions, and has the units reservoir volume/stock tank volume, usually, reservoir barrels/stock tank barrel (rb/stb). Thus a volume of B_{oi}, rb of oil will produce one stb of oil at the surface together with the volume of gas which was originally dissolved in the oil in the reservoir

Production of reservoir hydrocarbon

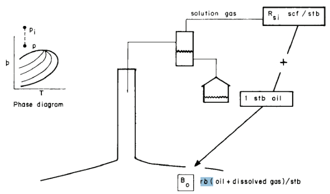




Above bubble point pressure

Below bubble point pressure

Application of PVT parameters



stock tank oil initially in place

$$STOIIP = N = V\phi(1-S_{wc})/B_{oi} \quad \text{(stock tank volume)} \quad (1.2)$$

Equation of state (EOS)

$$pV = nRT \quad (1.13)$$

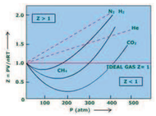
in which, for the conventional field units used in the industry

p = pressure (psia); V = volume (cu.ft)

T = absolute temperature – degrees Rankine (°R=460+°F)

n = the number of lb. moles, where one lb. mole is the molecular weight of the gas expressed in pounds.

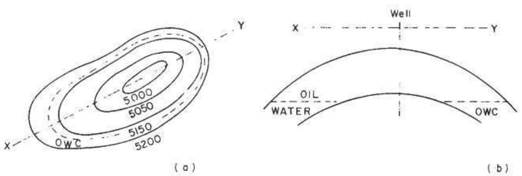
and R = the universal gas constant which, for the above units, has the value 10.732 psia.cu.ft/lb. mole.°R.



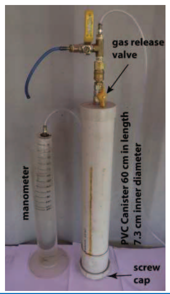
$$pV = ZnRT$$

$$E = \frac{p}{p_{sc}} \times \frac{T_{sc}}{T} \times \frac{1}{Z} = 35.37 \frac{p}{ZT} \quad \text{(scf/rcf)}$$

Contour map and cross-section through the reservoir



Case study: Coal bed methane



Moore, 2012
Chiper coal, 2015

Gas saturation

1. **Desorption Isotherms**
   - "slow", "fast" or "in between"
   - reservoir temperature
2. **Adsorption Isotherms**
   - reservoir temperature
   - fresh samples!

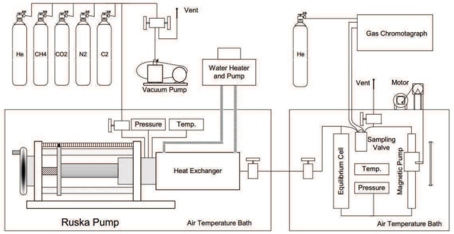
%g = 1-((a-d)/a)*100

where,
%g, is gas saturation
a, is maximum gas holding capacity [adsorption]
d, is total measured gas [desorption]

Moore, 2010

Adsorption test

PVT Apparatus, Kyushu University-Japan



Gasem et al., 2009

Adsorption test

Client	Micah Global CBM
Sample Location	Brandon Basin Tonto Mine

Gas	Methane
Sample No	Rollo-20-7A
Formation	Jasper Fm
Depth (m)	**410**
Easting	N/A
Northing	N/A
Density (t/m^3)	1.33

Adsorption Equation

$$V = \frac{a \cdot P}{P + b}$$

where
V - Gas content (m^3/t)
P - Pressure (kPa)
a - Langmuir Volume (m^3/t)
b - Langmuir Pressure (kPa)

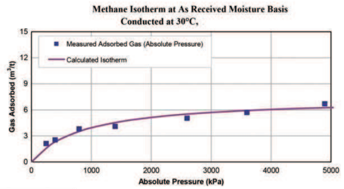
Proximate Analysis (%)	
Inherent Moisture	3.3
Ash	1.1
Volatile	32.8

Test Summary

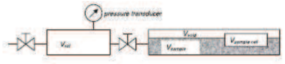
Absolute Pressure (kPa)	Gas Adsorbed (m^3/t) Measured	Calculated
101		0.77
251	2.09	1.65
401	2.50	2.32
801	3.78	3.53
1401	4.07	4.54
2601	5.01	5.51
3601	5.67	5.92
4901	6.67	6.25

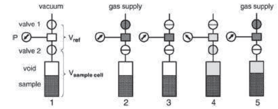
Isotherm Parameters

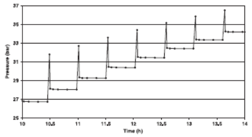
Parameter	At Gauge Pressure	At Absolute Pressure
a - Langmuir Volume (m^3/t)	**6.59**	**7.36**
b - Langmuir Pressure (kPa)	**971.72**	**870.40**
Calculated gas content at 1 atm =	**0.77**	m^3/t



PVT measurements



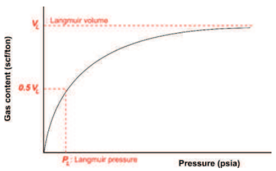


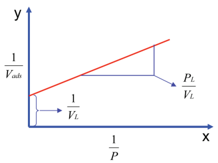


pV = ZnRT

Peng-Robinson (1976)
Span and Wagner (1994)

Langmuir parameters

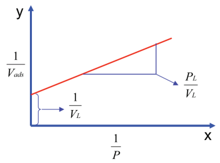




$$Vads = V_L \frac{p}{P_L + p} \qquad \frac{1}{V_{ads}} = \frac{P_L}{V_L}\left(\frac{1}{p}\right) + \frac{1}{V_L}$$

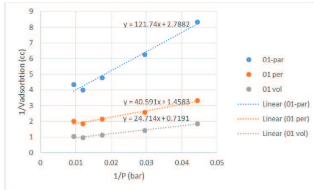
PVT data-1

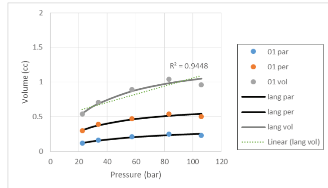
Sample	P	T	V	1/p	1/V
KS-101	bar	C	cc		
par	22.5	46	0.12	0.044444	8.333333
	33.8	46	0.16	0.029586	6.25
	57.2	46	0.21	0.017483	4.761905
	83.2	46	0.25	0.012019	4
	106	46	0.23	0.009434	4.347826
per	22.5	46	0.3	0.044444	3.333333
	33.8	46	0.39	0.029586	2.564103
	57.2	46	0.47	0.017483	2.12766
	83.2	46	0.54	0.012019	1.851852
	106	46	0.5	0.009434	2
vol	22.5	46	0.54	0.044444	1.851852
	33.8	46	0.71	0.029586	1.408451
	57.2	46	0.89	0.017483	1.123596
	83.2	46	1.04	0.012019	0.961538
	106	46	0.96	0.009434	1.041667



$$Vads = V_L \frac{p}{P_L + p} \qquad \frac{1}{V_{ads}} = \frac{P_L}{V_L}\left(\frac{1}{p}\right) + \frac{1}{V_L}$$

PVT data-2

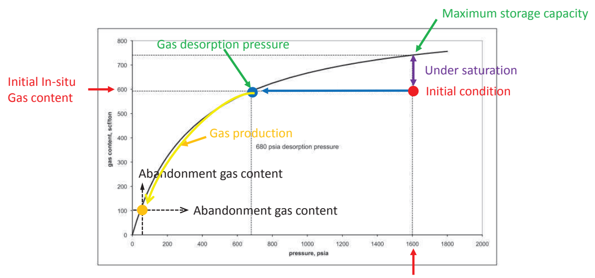




$$V = \frac{V_L\, p}{p + P_L}$$

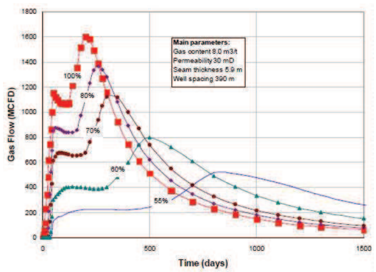
P_L=43.67 bar; V_L=0.36 cc
P_L=27.83 bar; V_L=0.69 cc
P_L=34.37 bar; V_L=1.39 cc

Gas saturation and desorption pressure



Seidle, 2011

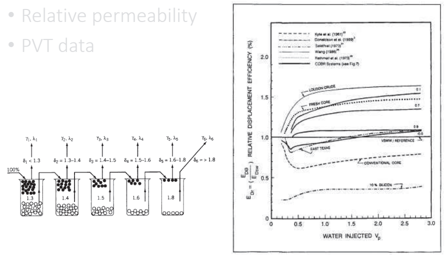
Effect of gas saturation

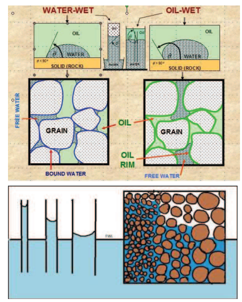


William, 2007

Summarizes-1

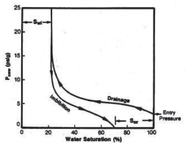
- Wettability and capillary pressure
- Relative permeability
- PVT data

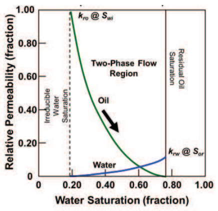


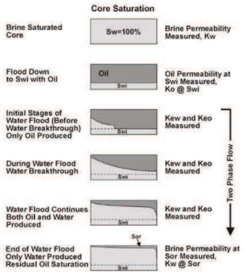


Summarizes-2

- Wettability and capillary pressure
- Relative permeability
- PVT data







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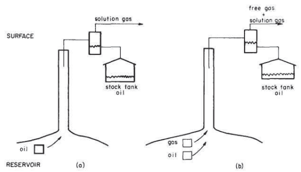
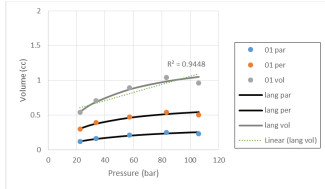
Summarizes-3

- Wettability and capillary pressure
- Relative permeability
- PVT data





P_L=43.67 bar; V_L=0.36 cc

P_L=27.83 bar; V_L=0.69 cc

P_L=34.37 bar; V_L=1.39 cc

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End