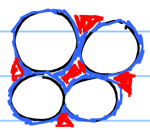
Water content in natural gas

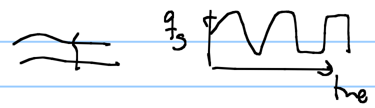
Gas is always saturated with water @ a given p, T

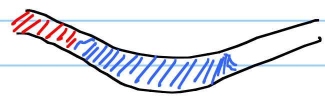


with p, T changes along the production system, water solubility in gas will change

typically with p↓, T↓ solubility is decreased ⇝ water comes out of solution (free water)

can cause some issues
- corrosion
- hydrates
- slugging (in transportation pipelines)



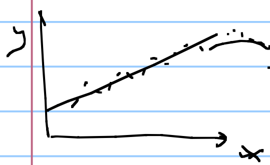


- scale

we need a way to estimate expected free water / water content in gas at any position of production system

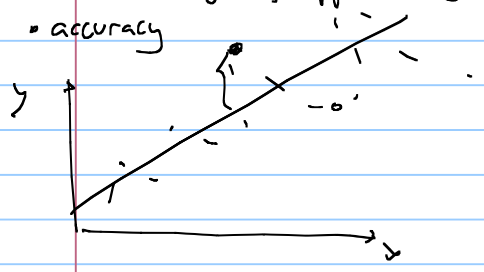
Correlations

- mathematical expressions derived from measurements in lab / field
- often not based in physics



p = 10 – 50 bar
T = 10 – 90°C

- advantages
  - easy to use
  - low computational expenses
- disadvantages
  - limited range of applicability
  - accuracy



EOS

equation of state

- not so accurate "out of the box"
- more general for wide range of conditions
- are usually customized with experimental data (by adjusting the default BIPs)

$$A = \sum_{i=1}^{N}\sum_{j=1}^{N} z_i \cdot z_j \cdot (1 - BIP_{ij}) \cdot \sqrt{A_i \cdot A_j}$$

for more information read section 9.3 of chapter 9 Whitson's monograph

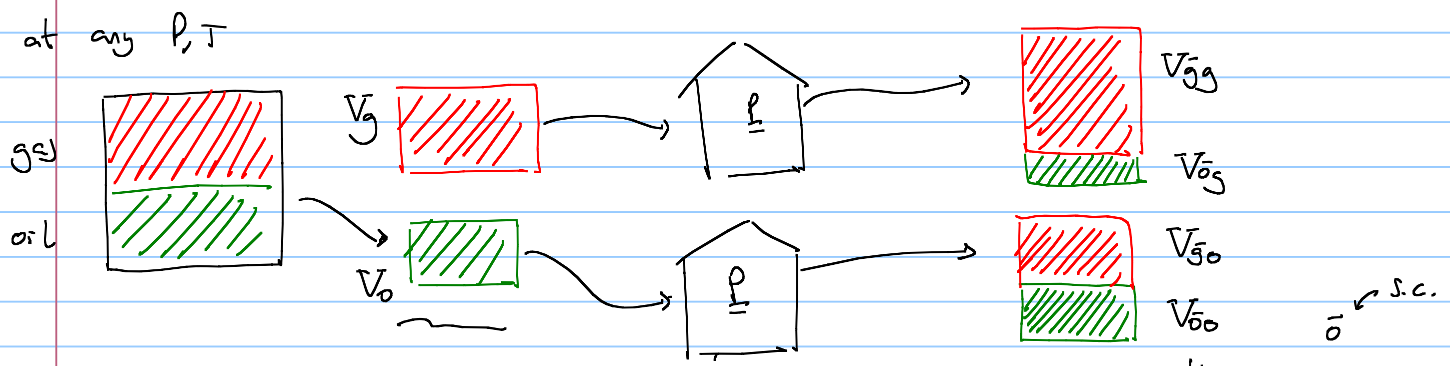
- Review user manual for recommended EOS

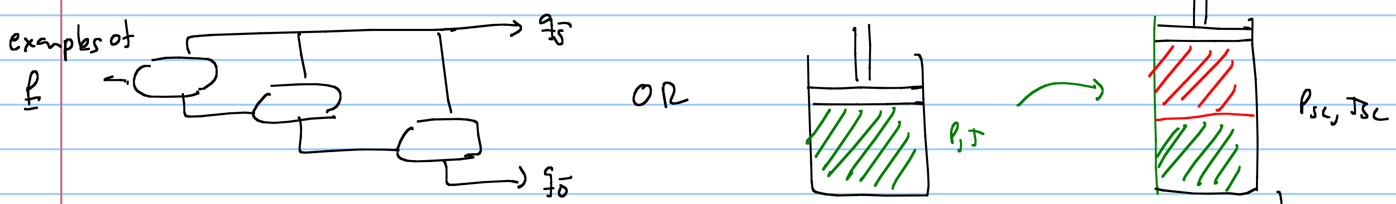
Type of System	Recommended Property Method
TEG Dehydration	PR
Sour Water	PR, Sour PR
Cryogenic Gas Processing	PR, PRSV
Air Separation	PR, PRSV
Atm Crude Towers	PR, PR Options, GS
Vacuum Towers	PR, PR Options, GS (<10 mm Hg), Braun K10, Esso K
Ethylene Towers	Lee Kesler Plocker
High H2 Systems	PR, ZJ or GS (see T/P limits)
Reservoir Systems	PR, PR Options
Steam Systems	Steam Package, CS or GS
Hydrate Inhibition	PR
Chemical systems	Activity Models, PRSV
HF Alkylation	PRSV, NRTL (Contact Hyprotech)
TEG Dehydration with Aromatics	PR (Contact Hyprotech)
Hydrocarbon systems where H2O solubility in HC is important	Kabadi Danner
Systems with select gases and light hydrocarbons	MBWR

Correlations are built following the same principle as Black oil properties

Black oil formulation (modified)

P_{sc}, T_{sc}





oil volume factor $B_o = \dfrac{V_o}{\bar{V}_{\bar{o}o}} = f(P,T)$ always > 1 {1.1 – 1.8}

heavy — light crude

Solution gas-oil ratio $R_s = \dfrac{\bar{V}_{\bar{g}o}}{\bar{V}_{\bar{o}o}}$ typically {80 → 1000}

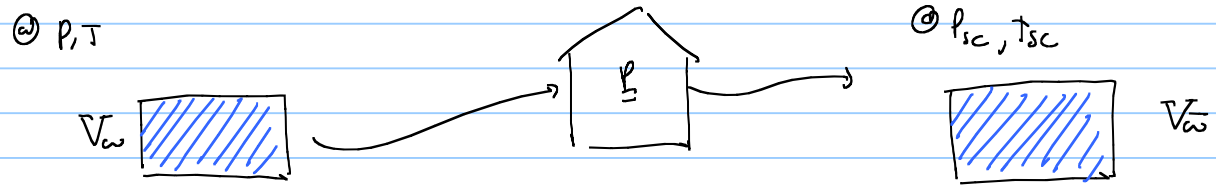
volatile crude

gas volume factor $B_g = \dfrac{V_g}{\bar{V}_{\bar{g}g}}$ {1E-4 → 1E-2}

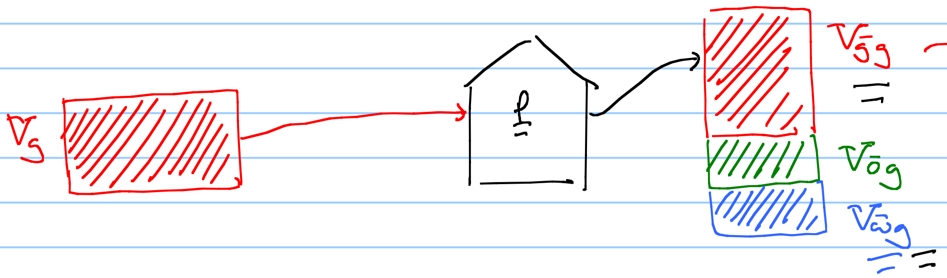
solution oil-gas ratio (r_v) $r_s = \dfrac{\bar{V}_{\bar{o}g}}{\bar{V}_{\bar{g}g}}$

BO properties are usually generated:
- by lab measurements
- correlations (e.g. Glasø, Standing)
- Use EOS simulator

for water, a similar approach is used



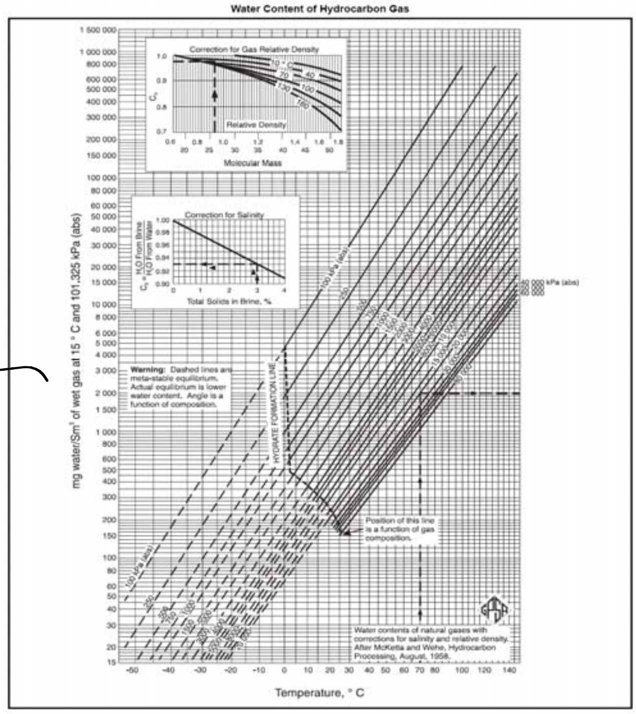
water volume factor $\quad B_w = \dfrac{V_w}{\bar{V}_w}$ $\quad$ due to compressibility of water
$B_w > 1$



$\bar{V}_{gg} \rightarrow$ 20 E6 Sm^3/d

solution water-gas ratio $\quad r_{sw} = \dfrac{\bar{V}_{wg}}{\bar{V}_{gg}}$

FIG. 20-4
Water Content of Hydrocarbon Gas



20-5

$r_{sw} \cdot \rho_{\bar{w}}$

$r_{sw} = \dfrac{Sm^3}{Sm^3} \rightarrow \dfrac{mg}{[Sm^3]}$

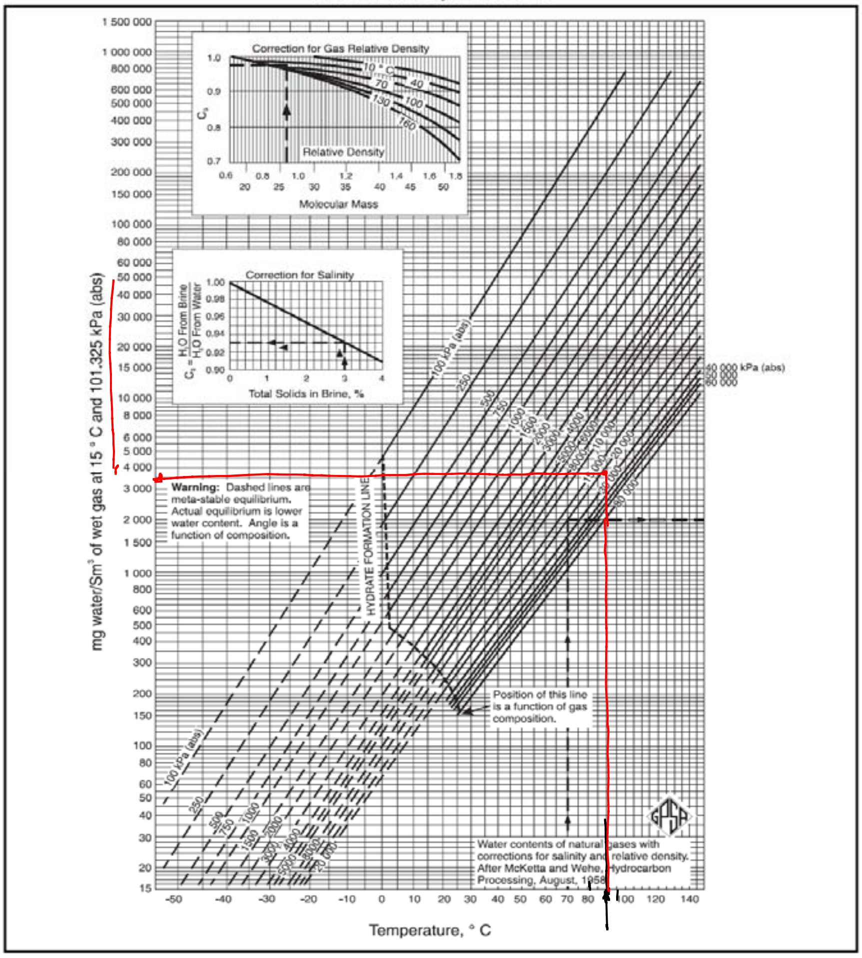
$r_{sw} \cdot \rho_{\bar{w}} \rightarrow \dfrac{kg}{[Sm^3]}$

$\rho_{\bar{w}}$ = 1000 kg/m^3

Prof. Milan Stanko. TPG4135 - Water content in gas field				
Gas MW	16	[Kg/Kmol]		
Gas gravity	0.552			
Water salinity	0.0	[ppm]		
CO2	0.0	[mole %]		
H2S	0.0	[mole %]		
Gas field rate	2.00E+07	[Sm^3/d]		
Nwells	8			
Well gas rate	2.50E+06			
Location	p	T	rsw	qw
[-]	[bara]	[C]	[Sm^3/1E06 Sm^3]	[m^3/d]
Reservoir	276	90		
Wellhead	160	70		
Choke downstream	120			
Separator	30	5		

@ P_R, T_R

FIG. 20-4
Water Content of Hydrocarbon Gas



20-5

$P_R = 276$ bara ~ 27600 kPa

1 bar = 1E5 Pa

1 bar = 100 kPa

3500 mg/Sm^3 = $r_{sw} \cdot \rho_{\bar{w}}$

$3.5 \dfrac{kg}{Sm^3} = r_{sw} \cdot \rho_{\bar{w}}$

$r_{sw} = \dfrac{3.5 \ kg}{1000 \left(\dfrac{kg}{Sm^3}\right) \cdot m^3}$

$r_{sw} = 3.5E-3 \ Sm^3/Sm^3$

r_{sw} is typically expressed in Sm^3/1E06 Sm^3

$r_{sw} = 3.5E-3 \dfrac{Sm^3}{Sm^3} \cdot \dfrac{1E6 \ Sm^3}{[M \ Sm^3]}$

$r_{sw} = 3500 \dfrac{Sm^3}{[M \ Sm^3]}$

SI stands for Mega

$q_{\bar{w}} = q_{\bar{g}} \cdot r_{sw}$

$q_{\bar{w}} = 20 \left[\dfrac{M \ Sm^3}{d}\right] \cdot 3500 \left[\dfrac{Sm^3}{M \ Sm^3}\right] = 70000 \ Sm^3/d$