TPG4230 FIELD DEVELOPMENT

Note Title 2015-01-26

SURFACE PROCESS CALCULATIONS

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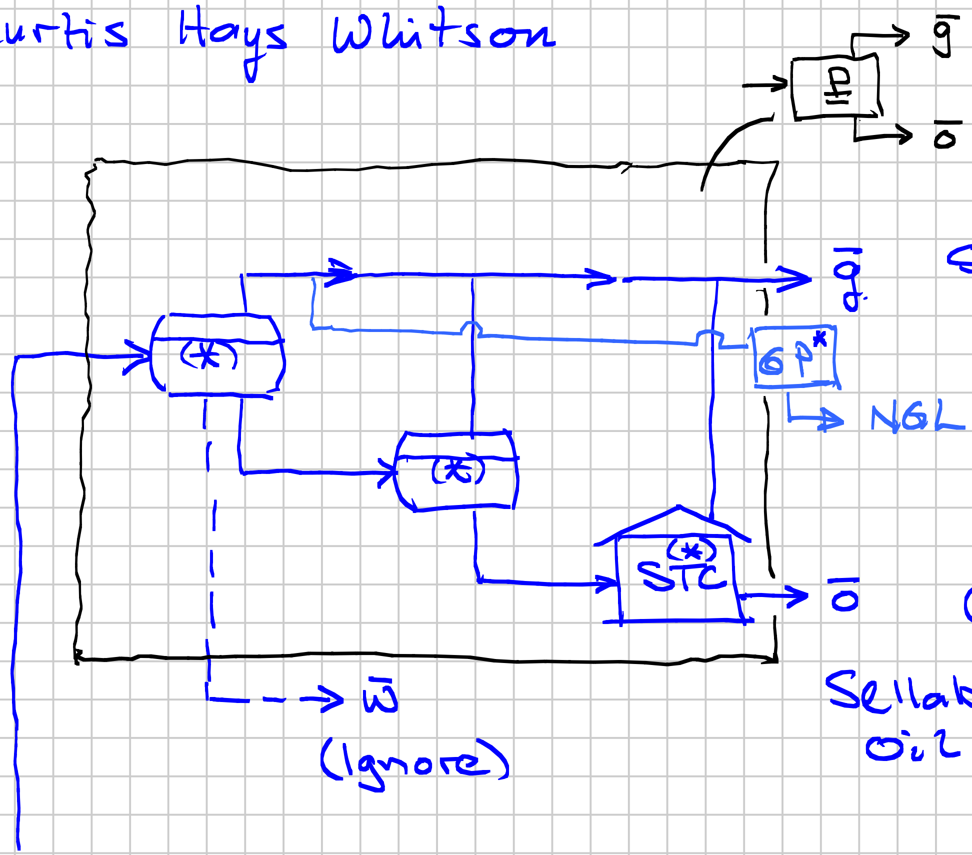


Sellable Gas

@ 1 atm 60 °F 15.56 °C

Sellable Oil

FEED SOURCES:

Well	z_{wi}	$\dot{n}_w$
Group	z_{Gi}	$\dot{n}_G$
Field	z_{Fi}	$\dot{n}_F$

z_i: Mole Fraction

(1) Molar Component Rates z_i & n

⇒ (2) Volumetric Rates

$q_g \quad q_o \quad q_w$

- Field Well Tests (Periodic)

  $q_{gsp1} \quad q_{osp} \; (\rightarrow q_{\bar{o}})$

SOURCE CONVERSION

Black Oil ($q_{\bar{g}}$ $q_{\bar{o}}$) to Compositional

(1) WTC

(2) BOZ

⋮

- Allocated rates (Daily)
  - well Tests + Metering
- Reservoir Simulation
  - using same $\underline{P}$ ($q_{\bar{g}}$ $q_{\bar{o}}$)

* Unit Flash Calculation

P–T Flash

- $z_i \rightarrow$ Entering the Unit
- p, T specified
- $\underbrace{K_i(p, T, z_i)}$ $\equiv \frac{y_i}{x_i}$
  - Correlations (modified Wilson)
  - Trial-and-Error w/ EOS
- Thermodynamic Consistency

$$\mu_{vi} = \mu_{Li}$$
$$\mu_{gi} = \mu_{oi}$$

EOS: Equal Chemical Energy

EQUATION OF STATE (EOS) – Gases & Oils

(1) Name : SRK (Soave Redlich Kwong)
PR (Peng Robinson)

(2) Table 1 – Component Properties

Name { p_c T_c ω } M $\underbrace{s\ (c)}$

N_2
CO_2
H_2S

Volume Shift (instead of COSTALD)

Rackett

C_1
⋮

(3) Table 2 – Binary Interaction Parameters (BIPs) k_{ij} ~ −0.1-ish to +0.2-ish

	N_2	CO_2	H_2S	C_1	...
N_2					
CO_2					
H_2S					
C_1					
⋮					

$k_{ii} = 0$ Diagonal

$k_{ij} = k_{ji}$ Symmetric

CO_2–HC
N_2–HC
H_2S–HC

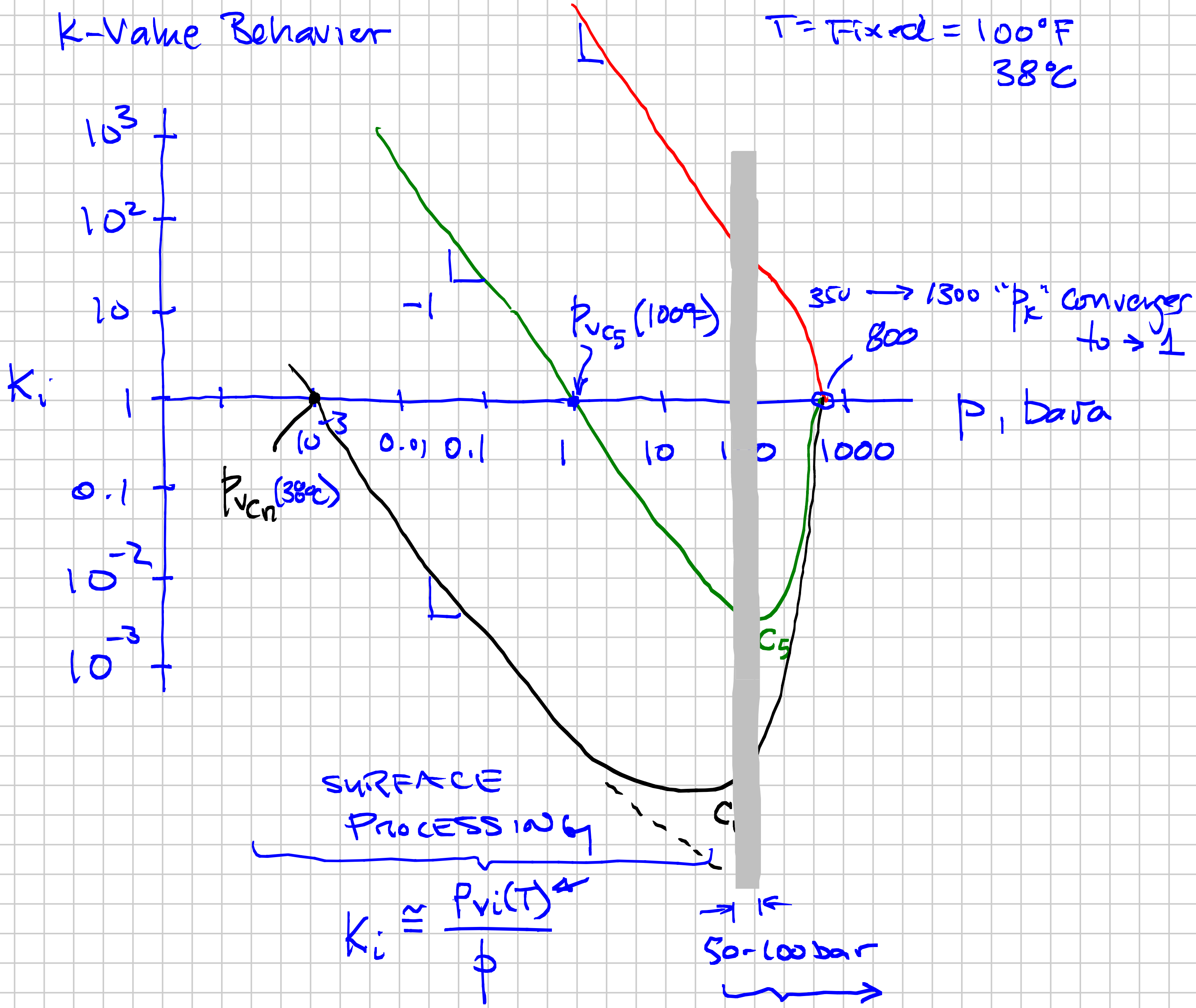
Defaults: ~ 0.05–0.15 – Bit different SRK & PR

SRK HC–HC ~ 0 default

PR HC–HC ~ 0 default EXCEPT $k_{C_1-C_{7+}}$ ~ 0.02–0.1

k_{ij} PRIMARILY Affect K_i & K_j at higher pressures (≳ 50–100 bara) & Near Critical Points

K-Value Behavior



$$K_i \cong \frac{p_{vi}(T)}{p}$$

~ Wilson Eq.

$K_i \sim f(p, T)$

NOT $\underline{z_i}$

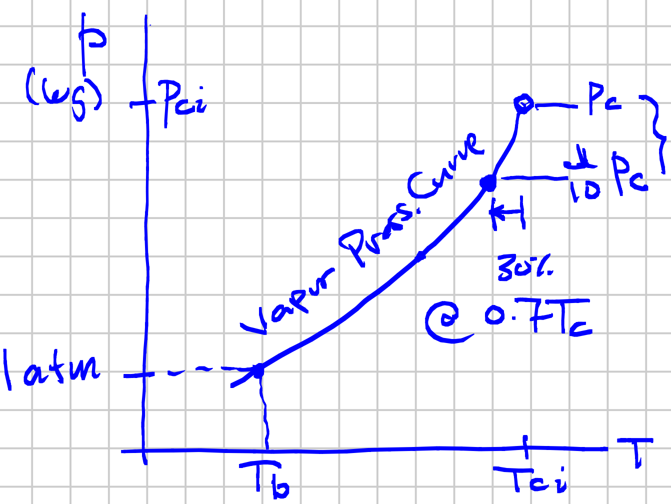
$K_i(p, T, \underline{\underline{z_i}})$

$K_i^{EOS}(p, T, z_i; \underline{\underline{BIPs}})$

EOS (Table 1): T_{c_i} p_{c_i} ω_i

Component $\underline{\underline{i}}$

Normal Pressure ⇒ 1 atm



Pitzer: $\omega \equiv -1 - \log_{10} \underbrace{\frac{p_v(0.7T_c)}{p_c}}_{0.1}$

He $\quad -1 - (-1)$

C_1 $\quad = 0$

C_{40} $\quad \frac{p_v(0.7T_c)}{p_c} \sim \frac{1}{100} \Rightarrow \omega \sim 1$

ω_i (with T_{c_i} P_{c_i}) $\Rightarrow$ guarantees EOS (PR or SRK)

gives ACCURATE $p_{v_i}(T)$

$\Rightarrow$ ACCURATE $K_i(T, p \lesssim \overset{50}{100}$ bara$)$

M SRK

EOS: $p = \underbrace{\frac{RT}{v-b}} - \underbrace{\frac{a \cdot \alpha_{SRK}(T,\omega)}{v(v+b)}}$ $\Bigg\}$ Given x_i: $\underbrace{\omega_i \; a_i \; b_i \; p, T}$ $\Downarrow$ $\boxed{v}$

$v \equiv \frac{V}{n}$

$\rho = \frac{M}{v} = \frac{m}{V}$ $\quad V/n$

$a = \Omega_a \frac{R^2 T_c^2}{p_c}$ $\quad \Omega_a = \sim 0.4$

$b = \Omega_b \frac{RT_c}{p_c}$ $\quad \Omega_b = \sim 0.1$

$$\alpha_i = [1 + m_i(1 - \sqrt{T_r})]^2$$

Soave 3 constants

$$m_i = \overbrace{m_0 + m_1 \omega_i + m_2 \omega_i^2}$$

$$T_r = \frac{T}{T_c}$$

Mixture x_i e.g.

$$\bar{a} = \sum_i \sum_j x_i x_j (a_i a_j)^{0.5} \cdot (1 - k_{ij})$$

$$\bar{b} = \sum_{i=1}^{N} x_i b_i$$

Liquid mixtures: $v_L^{EOS^2(SRK|PR)}$ ~ 10–35% high wrong!

1981: Peneloux, et al.

$$v = \underline{v^{EOS2}} - c$$

$$c = s \cdot b$$

dimensionless "shift" factor
(−0.2 → +0.3)

$$\bar{c} = \sum x_i c_i$$

ρ_L ~1–3%

(ρ_V ✓ 1-3%)

H49S9S: Allowed s_i to be input
(Beware!) (~2005)

$$v = v^{EOS2} + c \qquad \text{Input "}-s\text{"}$$

ECL300
EAP

EOS w/ S_i

Given $x_i \Rightarrow \mu_{Li}$
$\neq$
$y_i \Rightarrow \mu_{vi}$

wrong K_i

P-T FLASH CALCULATION
(In Each Separator Unit)

Rachford-Rice
Muskat-McDowell

$n, z_i \rightarrow$ $\begin{array}{|c|} \hline y_i, n_v \\ \hline x_i, n_L \\ \hline \end{array}$

$(P, T) =$ Fixed

$$n = n_v + n_L$$
$$n_i = n_{vi} + n_{Li}$$
$$n z_i = n_v y_i + n_L x_i$$

Define $\beta \equiv n_v / n \quad (= F_v)$ Ch. 3 & 4

$$\boxed{z_i = \beta y_i + (1-\beta) x_i} \Leftarrow$$

$$z_i \equiv \frac{n_i}{n}$$
$$y_i \equiv \frac{n_{vi}}{n_v}$$
$$x_i \equiv \frac{n_{Li}}{n_L}$$

$$\sum z_i = 1$$
$$\left.\begin{array}{l} \sum y_i = 1 \\ \sum x_i = 1 \end{array}\right\} \left(\sum y_i - \sum x_i\right) = 0$$

Given: z_i, Guess set of $K_i(p, T; z_i)$

Solve: β, y_i & x_i

$$K_i = \frac{y_i}{x_i}$$

$$\Rightarrow \boxed{z_i = \beta y_i + (1-\beta) x_i} \Leftarrow$$

$$\sum y_i - x_i = 0$$

$$z_i = \beta y_i + x_i - \beta x_i$$

$$z_i = \beta K_i x_i + x_i - \beta x_i$$

$$= x_i (\beta K_i - \beta + 1)$$

$$= x_i \cdot [\beta (K_i - 1) + 1]$$

$$y_i = K_i x_i$$

$$\boxed{x_i = \frac{z_i}{\beta (K_i - 1) + 1}}$$

$$0 = \sum y_i \; x_i$$

?

$$\sum (K_i - 1) x_i = 0$$

$$\left[\sum_i \frac{z_i (K_i - 1)}{\beta (K_i - 1) + 1} = 0 \right] = h(\beta)$$

One unknown β

One Eq. (RR)

Muskat-McDowell

$$c_i = \frac{1}{K_i - 1} \quad ; \quad c_i = 0 \text{ for } K_i = 1$$

$$h(\beta) = \sum_i \frac{z_i}{\beta + c_i} = 0$$

Once β solved:

$$x_i = \frac{z_i}{\beta (K_i - 1) + 1}$$

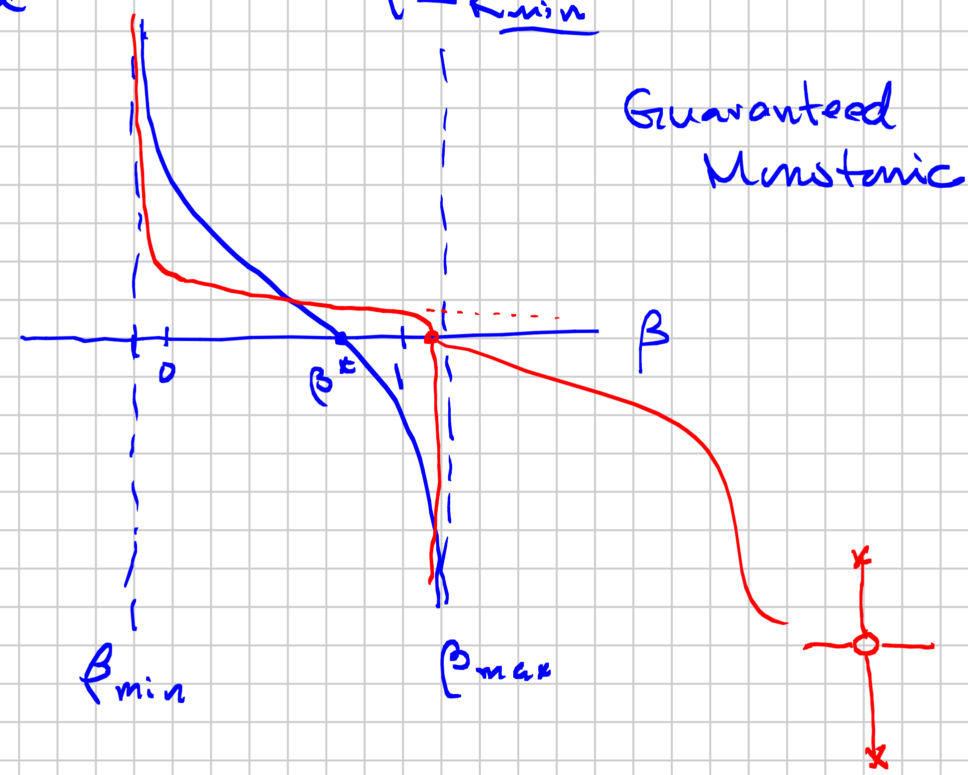
$$y_i = K_i \; x_i$$

* Multiple β solutions satisfying the Eq.

* Only one solution β^* where

$$\left.\begin{array}{l} \text{ALL } y_i > 0 \\ \qquad x_i > 0 \end{array}\right\} \text{ needed to be physical}$$

$$\underbrace{\beta_{min}}_{= \frac{1}{1-K_{max}}} < \beta^* < \underbrace{\beta_{max}}_{= \frac{1}{1-K_{min}}}$$



(g) $\beta^* < 0$
(o) $\beta^* > 1$
} z_i is a single phase

$\beta^* = 0 \quad \epsilon$: z_i is a oil at its bubblepoint $\quad z_i = x_i$

$\beta^* = 1 \quad\quad z_i$ is a gas at it dewpoint $\quad z_i = y_i$

Got $y_i \Rightarrow$ EOS $\left[\begin{array}{c}\mu_{V_i} \\ \overset{?}{=} \\ \mu_{L_i}\end{array}\right]$

$x_i \Rightarrow$ EOS

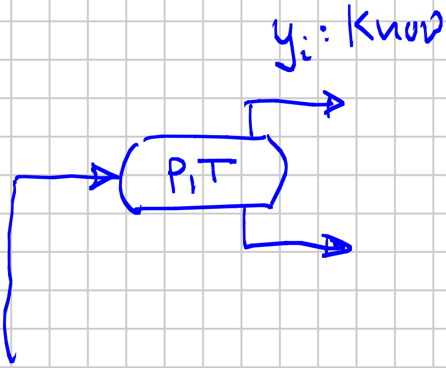
Fugacity f_i

$$\mu_i \equiv RT \cdot \ln f_i + \overset{\lambda_i(T)}{const}$$

- Not equal, guess new set $K_i^{new} = K_i^{old} \cdot \underbrace{\left(\frac{f_{L_i}}{f_{V_i}}\right)^{old}}_{Ch.4}$

- Equal, you've done with this unit calculation

App. B Phase Behavior monograph Example



Know : y_i, K_i

Want : z_i, x_i, β