Note Title 3/17/2017

CVD TEST – Finish Up

BLACK-OIL PVT (Ch. 7)

CVD TEST – What Lab Study "Reports"

T_R = constant

p	y_i (y_{n+}!) "$\bar{o}$"	$V_{ro}^{CVD} = \frac{V_o}{V_s}$	Z_g	($\frac{\Delta n_g}{n_s}$)(%)	{...}	"Z_2"
$p_s = p_1$	$= z_i$ 8 mol-%	0 (DP)	$Z_g(p, y_i)$	(Reservoir Gas Recovery from p_s & Not Surface Gas Recovery)	~~~> Ch. 6	
p_2	6.5	3				
⋮	5.2	12				
* p_{N-1}	1.3	22				
p_N		40 19				

$(RF_{\bar{o}})$

$\underbrace{\quad}_{\text{Little Importance}}$ $\lambda_o \sim 0$

* $\{x_{oNi}, (M_{n+}, \gamma_{n+})_{oN}\}$ maybe stage N-1

Bleeding process N-1 → N

z_{wi} = producing wellstream composition of a gas condensate reservoir

$\simeq y_i^{CVD}(p_R = p_{CVD})$

Surface Condensate C_{5+}

INDEPENDENT of Rock Relative Permeabilities

$$\underbrace{pV}_{\text{same}} = n\,R\,T_R\,Z(p)$$

same ✓ ✓

80%

constant

A vs B

$V_A > V_B$

A : $HCPV_i$ = const

B : $HCPV < HCPV_i$

$\underbrace{p_A < p_B}$

$q_{gA} < q_{gB}$

More money / day

Darcy Law

$q_g \propto (\bar{p}_R - p_{wf})$

Control w/ Choke

(Whitson-Torp SPE paper)

(Ch. 7)

BLACK-OIL PVT PROPERTIES

[[4 P-dependent tables]]

	ρ	or γ	COMPONENTS
SURFACE DENSITIES (Specific Gravities)	$\rho_{\bar{g}}$	γ_g	Surface Gas ✓
Assumed Constant	$\rho_{\bar{o}}$	γ_o	Surface Oil ✓

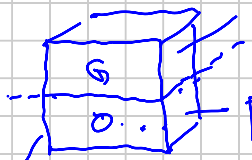
OIL PHASE PVT @ (p,T)

p	R_s	B_o	μ_o ✓

GAS PHASE PVT @ (p,T)

p	r_s	B_{gd}	μ_g ✓

ρ_o (R_s, B_o) ρ_g (r_s, B_{gd})



$p = p_d$

$p = p_b$

(p, T)

same oil composition

(1) SATURATED PROPERTIES

$p = p_b$ OIL Phase

$p = p_d$ GAS Phase

(2) UNDERSATURATED PROPERTIES

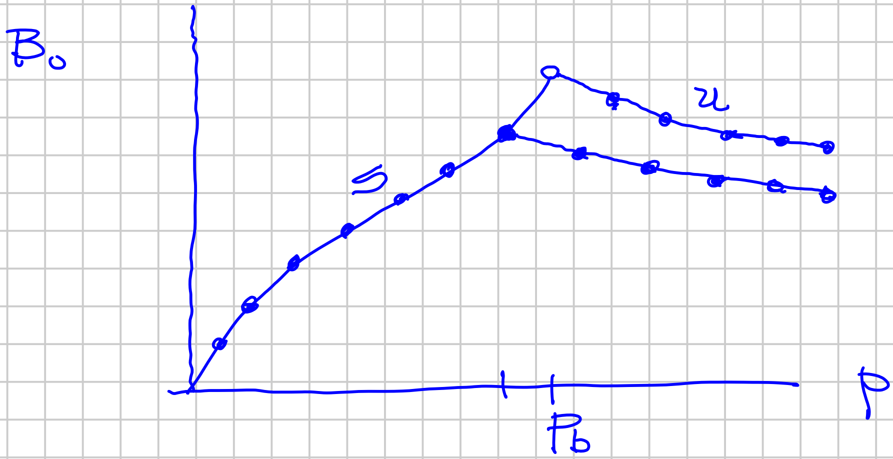
"R_s" same ~ "x_i"

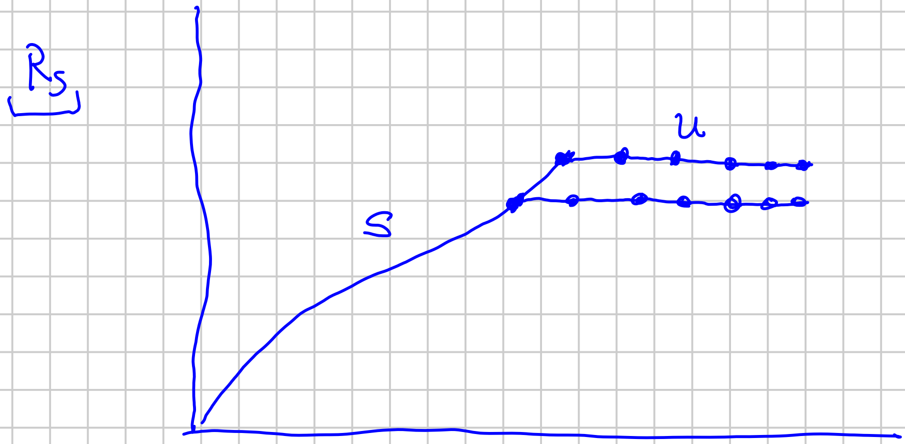
$\boxed{o}$ u:

$p > p_b$

$p > p_b$ OIL Phase with "R_s" (x_i)

$p > p_d$ GAS Phase with "r_s" (y_i)





BO PVT Model conserves surface gas component volume ($V_{\bar{g}}$)
surface oil component volume ($V_{\bar{o}}$)

Ekofisk

Initially $V_{\bar{g}i} \approx 6 \cdot 10^{12}$ scf — all in solution initially

$V_{\bar{o}i} \approx 6 \cdot 10^{9}$ STB — all free oil

Troll

$V_{\bar{g}i} = 45 \cdot 10^{12}$ scf — $42 \cdot 10^{12}$ free gas cap; $3 \cdot 10^{12}$ in solution

$V_{\bar{o}i} = 6 \cdot 10^{9}$ STB — $0.x \cdot 10^{9}$ STB in solution in gas cap; $5.9x \cdot 10^{9}$ STB free "oil rim"

Surface gas ($\bar{g}$) can be found in both reservoir gas and reservoir oil phases

Surface oil ($\bar{o}$) can be found in both reservoir gas and reservoir oil phases

At any time (Surface Component Volumetric Material Balance)

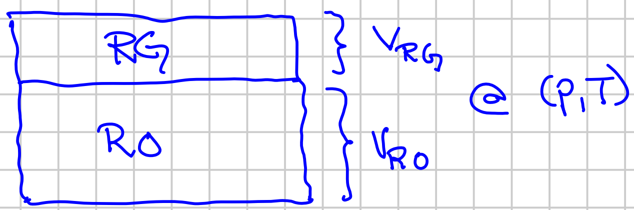
$$\underbrace{V_{\bar{g}i}} = V_{\bar{g}gR} + V_{\bar{g}oR} + V_{\bar{g}p} - V_{\bar{g}inj}$$

$V_{\bar{g}gR}$ = surface gas component in current reservoir gas phase.

$V_{\bar{g}oR}$ = surface gas component in (solution in) current reservoir oil phase

$V_{\bar{g}p}$ = cumulative produced surface gas component volume

$V_{\bar{g}inj}$ = cumulative injected surface gas component volume



$$V_{\bar{a}i} = V_{\bar{a}gR} + V_{\bar{a}oR} + V_{\bar{o}p} - \underbrace{V_{\bar{a}inj}}_{(=0)}$$

If the surface components truly had invariant mass densities ($\rho_{\bar{g}}$ & $\rho_{\bar{o}}$) then the "Volumetric Material Balance" would also guarantee a "Mass Material Balance".

$\gamma_o \equiv \frac{\rho_{\bar{o}}}{\rho_w}$

$\gamma_g \equiv \frac{\rho_{\bar{g}}}{\rho_{air,sc}}$

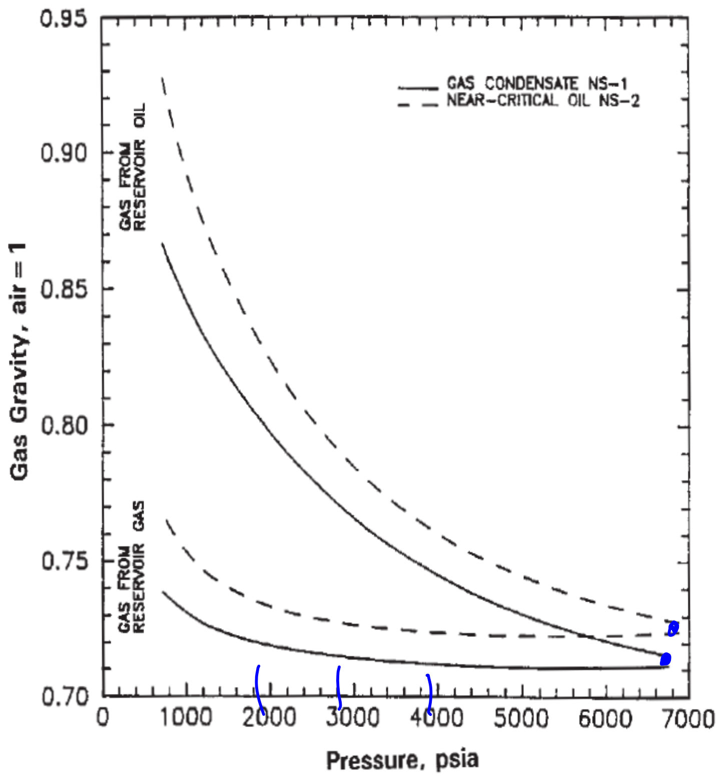


Fig. 7.12—Surface-gas gravities vs. pressure during depletion.

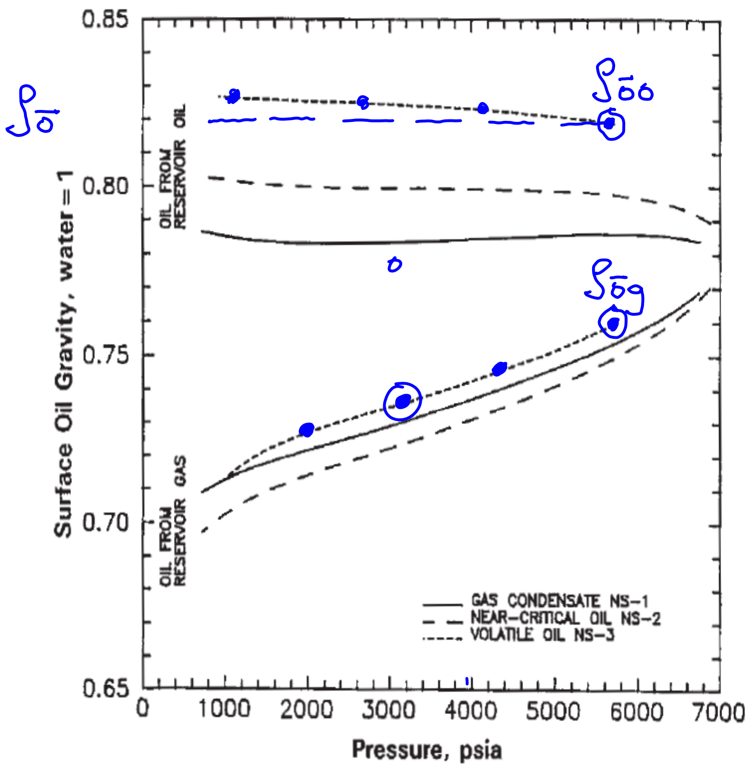


Fig. 7.13—Surface-oil gravities vs. pressure during depletion.

Why do we need, and do we use $\rho_{\bar{g}}$ $\rho_{\bar{o}}$

Any engineering application (R, T, P) needs 3 PVT quantities (p, T) for each phase

① V_{ro} $\begin{cases} =1 & \text{OIL} \\ & \text{GAS+OIL} \\ =0 & \text{GAS} \end{cases}$ ② μ ③ ρ

$$* \quad \rho_o(p) = \frac{\rho_{\bar{o}} + \rho_{\bar{g}} R_s(p)}{B_o(p)} = \frac{m_o}{V_o} = \frac{m_{\bar{o}o} + m_{\bar{g}o}}{V_o}$$

$$* \quad \rho_g(p) = \frac{\rho_{\bar{g}} + \rho_{\bar{o}} r_s(p)}{B_{gd}(p)} = \frac{m_g}{V_g} = \frac{m_{\bar{g}g} + m_{\bar{o}g}}{V_g}$$

Use $\rho_{\bar{g}}$ & $\rho_{\bar{o}}$ gets the best $\rho_g(p)$ & $\rho_o(p)$

densities

How needed