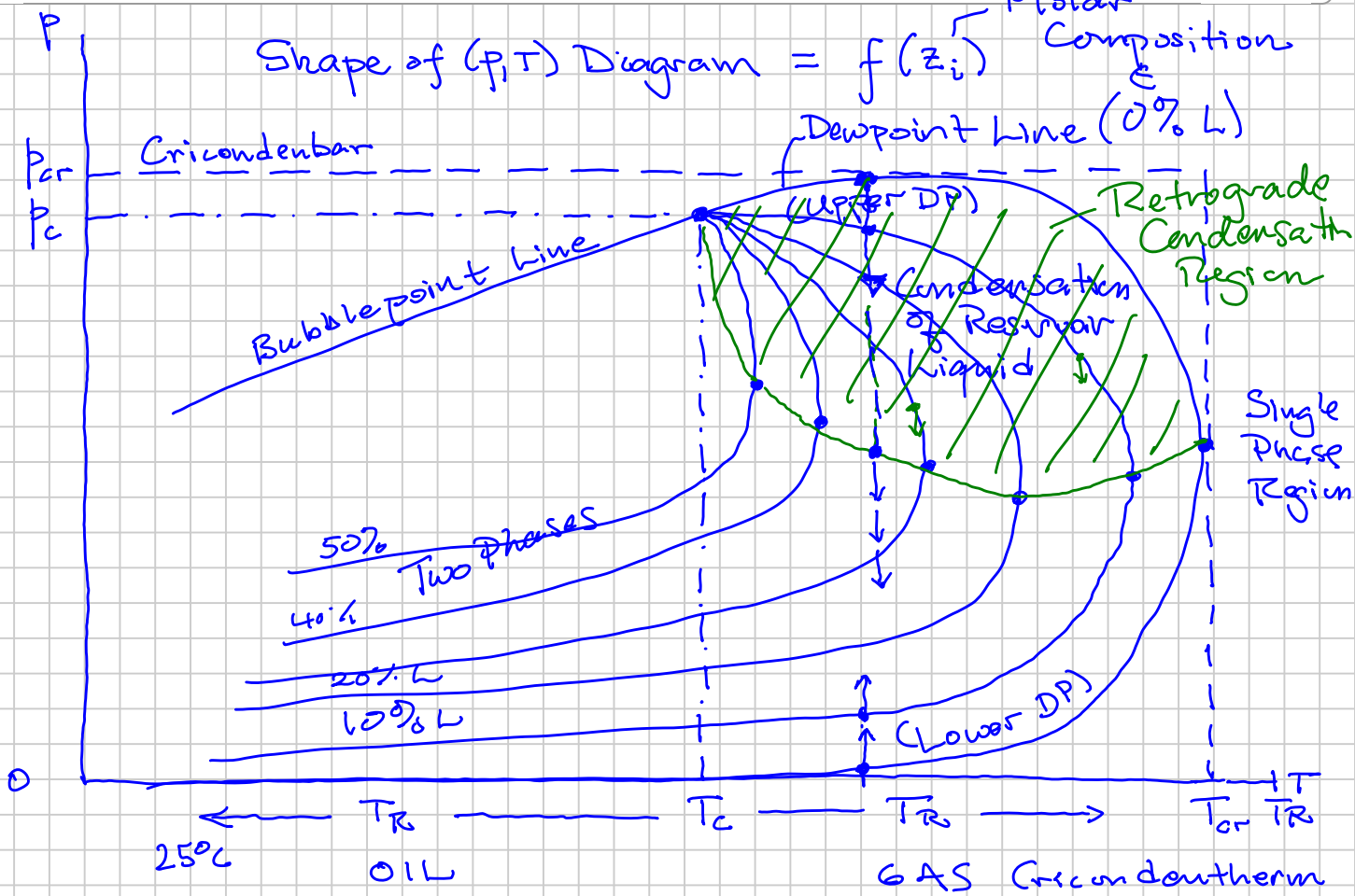
Reservoir Fluid Types (Gas | Oil)

Note Title 1/27/2017



OIL: $T_R < T_c$ $(z_{Ri} = x_{Ri})$

	GOR [scf/STB]	OGR	API
Heavy ($\mu_o \gtrsim 100$ cp)	<100		<15
Dead	<100		any
Black	100 – 1000 (1500)		any
Volatile	1000 – 2500		BO (25–40)
Near-critical	2500 – 4000		VO (35–50)
			NCO (45–50)

GAS: $T_R > T_c$ $(z_{Ri} = y_{Ri})$

GAS CONDENSATE: $T_{cr} > T_R > T_c$

$p_R \geq p_{dew}(T_R)$

Reservoir condensation of liquid

"Retrograde" Condensation

	OGR [STB/MMscf]
Lean GC	20 – 50
Average GC	50 – 150
Rich GC	150 – 250
Near-Critical GC	250 – 400

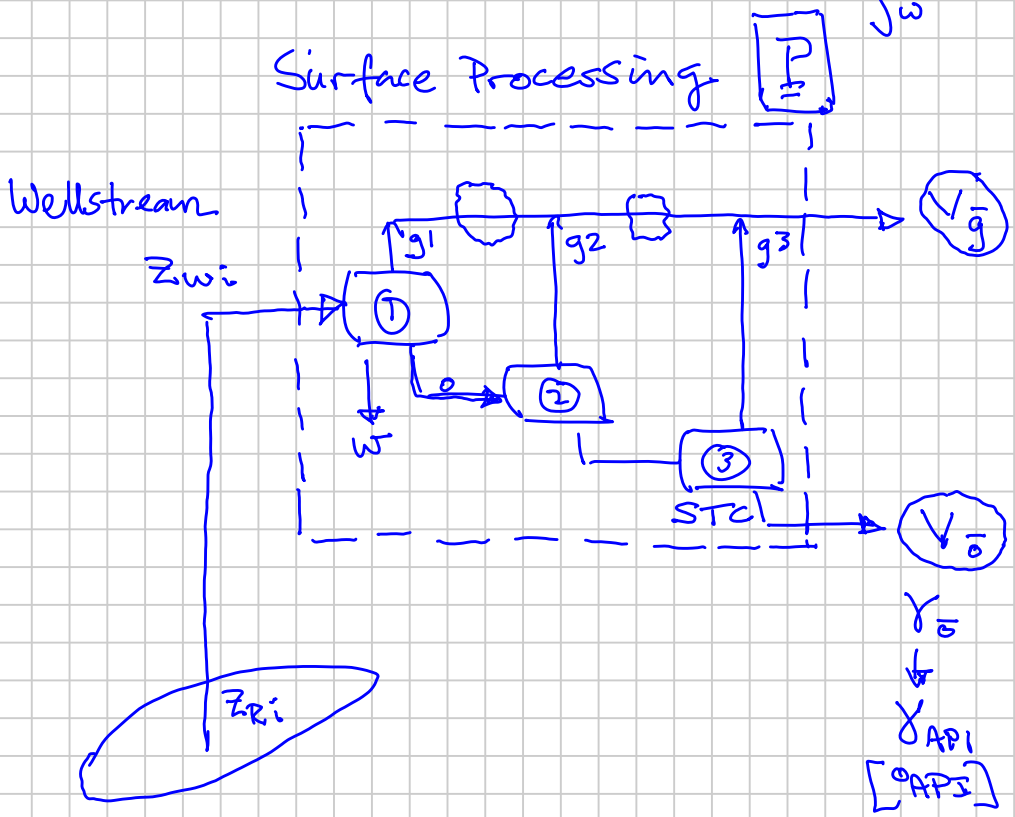
WET / DRY GAS $T_R > T_{cr}$

Some Liquid condenses at Surface Conditions — NO

No liquid condensation in the reservoir

API Gravity $= \gamma_{API} \equiv \dfrac{141.5}{\gamma_o} - 131.5$ $\Bigg\|$ $\gamma_o = \dfrac{141.5}{131.5 + \gamma_{API}}$

$\gamma_o \equiv$ Specific Gravity (Liquid) $= \dfrac{\rho_o}{\rho_w}$ @ 1 atm, 60°F (15.56°C)



Total Surface Gas Product

$P_g \left[\dfrac{MSD}{M_{scf}}\right] = f(\text{Location}, t, H)$ ← heating value

Surface Oil Product

STO (STC)

$\gamma_o \rightarrow \gamma_{API}$ [°API]

Stock-Tank Oil

Stock-Tank Condensate

$P_o \left[\dfrac{MSD}{STB}\right] = f(t, {}^{\circ}API)$

$GOR \equiv \dfrac{V_g}{V_o}$ [R]

$OGR \equiv \dfrac{V_o}{V_g}$ [r]

Producing GOR $= R_p$

Producing OGR $= r_p$

If $z_{wi} \simeq z_{Ri}$

Reservoir Oil ($T_R < T_c$)

$R_p = R_s =$ "solution" GOR

all produced gas is in solution in the reservoir oil

Reservoir Gas ($T_{cr} > T_R > T_c$)

$r_p = r_s =$ "solution" OGR

all produced surface oil is in solution in reservoir gas

$$GOR\left[\frac{Sm^3}{Sm^3}\right] \sim GOR\left[\frac{scf}{STB}\right]\frac{1}{5}$$

$5.615 \ \frac{ft^3}{bbl}$

$$OGR\left[\frac{Sm^3}{10^6 Sm^3}\right] \sim OGR\left[\frac{STB}{10^6 scf}\right].5$$

Field units

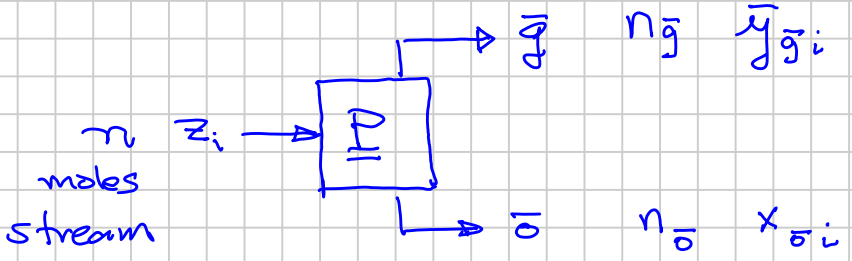
$Msct = 10^3 \ ft^3 @ STC$ / scf

$MMscf = 10^6 \ ft^3 @ STC$

bcf / $bscf = 10^9$ scf

Tcf / $Tscf = 10^{12}$ scf

~ Relationship between GOR (OGR) and z_i

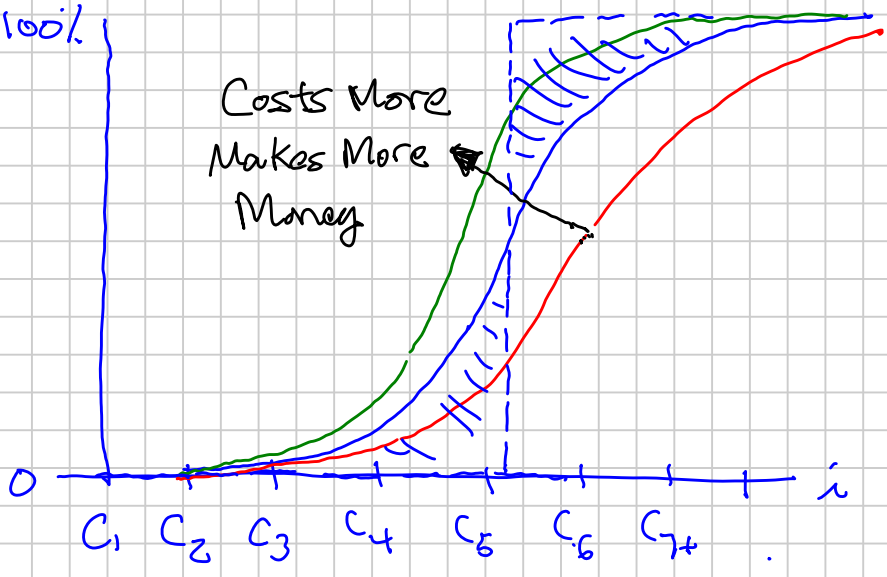


$n_i = n \cdot z_i$

Purpose of P to maximize the moles $n_{\bar{o}}$ $(n_{\bar{o}i})$

$$RF_i = \frac{n_{\bar{o}i}}{n_i}$$

Recovery Factor in $\bar{o}$



Normal 2-3 stg P

$\bar{g} \simeq C_{4-}$ C_{5-} $(\bar{o}) \simeq (C_{5+})$ (C_{6+})

$\frac{GOR}{OGR} \sim z_{n+}$ simple, but 1st-order accurate

$$OGR \equiv \frac{V_{\bar{o}}}{V_{\bar{g}}}$$

Assume $\bar{o} = C_{n+}$ e.g. C_{5+} or C_{6+}

$$V_{\bar{o}} = n_{\bar{o}} \cdot \left(\frac{M_{\bar{o}}}{\rho_{\bar{o}}}\right)$$

$$V_{\bar{g}} = n_{\bar{g}} \cdot \underbrace{\left(\frac{RT_{sc}}{P_{sc}}\right)}$$ assume: ideal gas at STC

23.68 $Sm^3/kg\text{-mole}$

379.5 $scf/lb\text{-mole}$

$\frac{0.08314(15.56+273.15)}{1.0135}$

$\frac{10.7315(60+459.67)}{14.696}$

$n = 1$ mole (arbitrary choice)

$$n_{\bar{o}} = n \cdot \underbrace{z_{n+}}_{\text{"}\bar{o}\text{"}} = z_{n+}$$

$$n_{\bar{g}} = 1 - n_{\bar{o}} = 1 - z_{n+}$$

$$OGR = \frac{V_{\bar{o}}}{V_{\bar{g}}} = \frac{z_{n+}(M/\rho)_{n+}}{(1-z_{n+})(RT_{sc}/P_{sc})} = \left(\frac{z_{n+}}{1-z_{n+}}\right) \cdot \text{Constant}$$

$$\rightarrow \frac{(M/\rho)_{n+}}{(RT_{sc}/P_{sc})}$$

Ch. 3 Cragoe $M \sim \rho$ of STC

$$M = \frac{6084}{\gamma_{API} - 5.9}$$

e.g. C_{n+} assume $(\gamma_{API})_{n+} \Rightarrow M_{n+}$ (Cragoe)

Field Units: $\gamma_{API} = 50 \Rightarrow \gamma_o = \dfrac{141.5}{131.5 + API} = 0.780$

$M_o \simeq 138$ lb/lb-mole $\qquad \rho_o = \gamma_o \cdot \rho_w$

62.4

$= 48.65$ lb/ft^3

$$OGR = \frac{z_{n+}}{1-z_{n+}} \cdot \frac{(138/48.65)}{379.5} \cdot \frac{\cancel{ft^3}}{\cancel{ft^3}} \cdot \underbrace{\frac{10^6 \cancel{ft^3}}{MMscf}}_{1} \cdot \frac{STB}{5.615 \cancel{ft^3}}$$

$$\boxed{OGR = \frac{z_{n+}}{1-z_{n+}} \cdot 1331} \quad 50°API$$

Lean GC 0.01 $\qquad$ Rich/NC GC 0.15

Gas Condensate z_{n+} (C_{5+}) ~ 1 mol-% → 15 mol-%

$13 \dfrac{STB}{MMscf} \qquad 235 \dfrac{STB}{MMscf}$

Ekofisk $\gamma_{API} \sim 36$

$$GOR = \frac{1-z_{n+}}{z_{n+}} \cdot \frac{379.5}{(M/\rho)} \cdot \frac{5.615 \cancel{ft^3}}{STB} \qquad \left[\frac{scf}{STB}\right]$$

ft^3

$\cancel{ft^3}$

OILS

$\gamma_{API} \sim 25\text{-}45$

Sm^3/MSm^3

$Sm^3/10^6 Sm^3$

Homework Exercise: develop $OGR, GOR = f(z_{n+})$ metric

Given γ_{API}

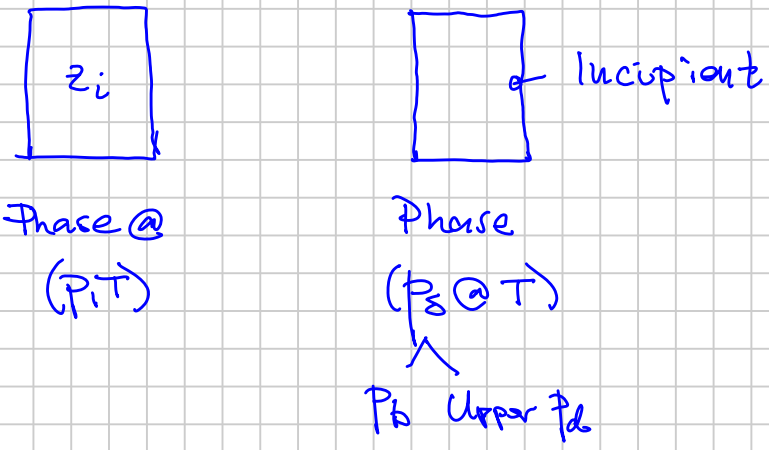
Sm^3/Sm^3

2-component

... GOR | OGR ~ represent the "composition"

SATURATED vs UNDERSATURATED FLUID STATES

One phase saturated or undersaturated wrt another phase.



Traditional definition is relative to the incipient phase.

Saturated: If $p = p_s$ @ T

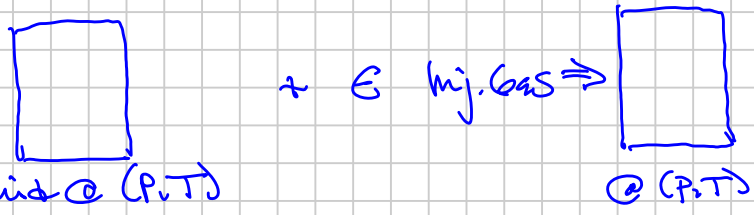
$\Rightarrow$ Two phases in equilibrium @ (p,T)

Undersaturated: If $p > p_s$ @ T

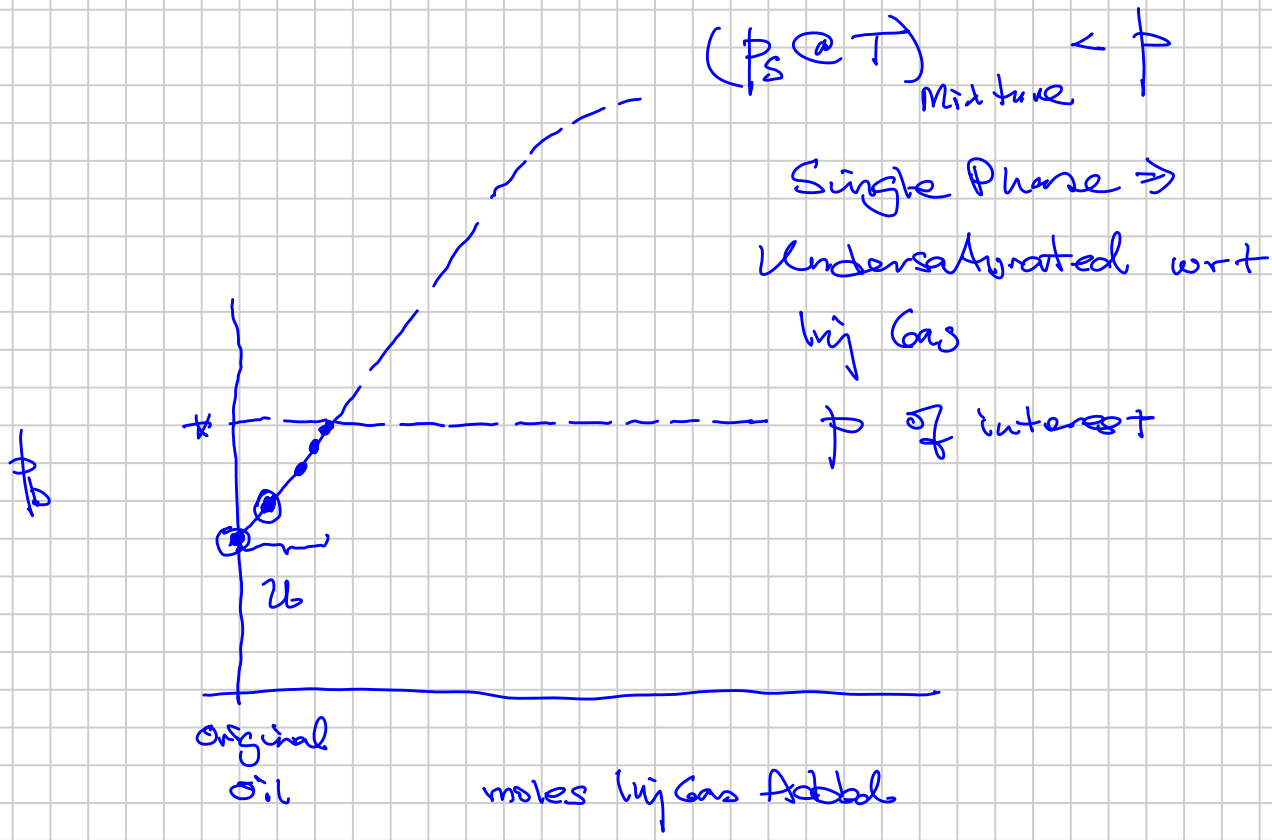
$\Rightarrow$ Only one phase

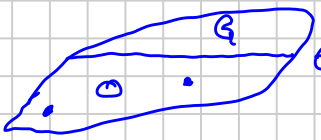
Alternative meaning in gas EOR

Is my reservoir fluid saturated wrt injection gas



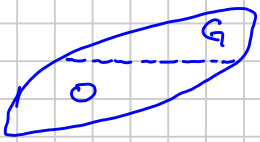
If Two-Phase $\Rightarrow$ "Saturated"





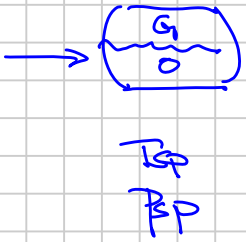
Gas-oil Contact $p_{R\,GOC} = p_{b\,GOC} = p_{d\,GOC}$

SATURATED GAS-OIL SYSTEM @ GOC



GOC $p_R > p_s$ (all depths)

UNDERSATURATE FLUID SYSTEM



Always have a saturated oil & a saturated gas

Two equilibrium phases are always saturated with each other!