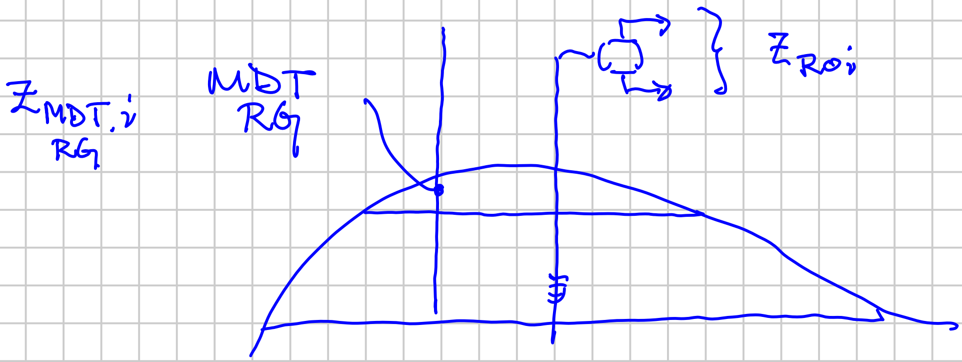


✓ z_{ROi} $\quad$ i : all components

✓ x_{obmi} $\quad$ ✓ w_{obmi}

$$* \quad z_{ROi} \to \boxed{w_{ROi}} = \frac{m_{ROi}}{m_{RO}} = \left\{ \frac{(z_{ROi} \cdot M_i)}{\sum_{j=1}^{N} z_{ROj} \cdot M_j} \right\}$$

Column

Column

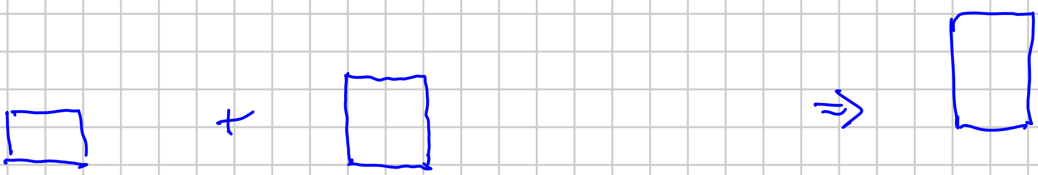
C_{7+} Basis :

$$\hat{w}_{ROi} = \frac{w_{ROi}}{\sum_{j=7}^{N+} w_{ROj}}$$

RO in C_{7+} Basis

C_{7+} Lab 34 wt-% obm in C_{7+}

$$\hat{f}_{obm,wt} = 0.34 = \frac{(m_{obm})_{C_{7+}} \text{ in MDT sample mixture}}{(m_{obm})_{C_{7+}} + (m_{RO})_{C_{7+}}} =$$



obm (34 g) + C_{7+} in flashed oil (66 g) ⇒ 100 g C_{7+} in the

Sample MDT mixture

MDT Sample C_{7+}:

$$C_{7+} \rightarrow \hat{w}_{MDT\,i} = 0.34\, w_{obm,i} + 0.66\, \hat{w}_{RO,i}$$

$$\xrightarrow{C_{7+}}\ \Rightarrow \hat{x}_{MDT\,i} = ✓$$

$$= (x_{\bar{o}i})$$

$\hat{w}_{MDT\,i}$, $\bar{M}_i \sim M_{RO\,i}$

Avg OBM & RO but just use $M_{RO\,i}$

How to get $(z_{MDT\,i})$?

$$= x_{\bar{o}i} = \underbrace{\hat{x}_{MDT\,i}}\ \text{of the}\ \underbrace{\text{flashed oil}}_{C_{7+}\ \text{only}}\ \text{from MDT}$$

$+$

Flashed Gas $y_{\bar{g}i}$ from MDT sample C_{6-}

$$z_{MDT\,i} = \overset{?}{f_{\bar{g}}} \cdot \overset{?}{y_{\bar{g}i}} + (1 - f_{\bar{g}})\, x_{\bar{o}i}$$

$$= \left(\frac{n_{\bar{g}}}{n_{\bar{g}} + n_{\bar{o}}}\right)_{MDT}$$

$$Z_{MDT\,i} = x_{obm\,i} \cdot \boxed{f_{obm}} + Z_{RO\,i} \cdot (1 - f_{obm})$$

$$\left[\frac{n_{obm}}{n_{obm} + n_{RO}} \right] \quad ?$$

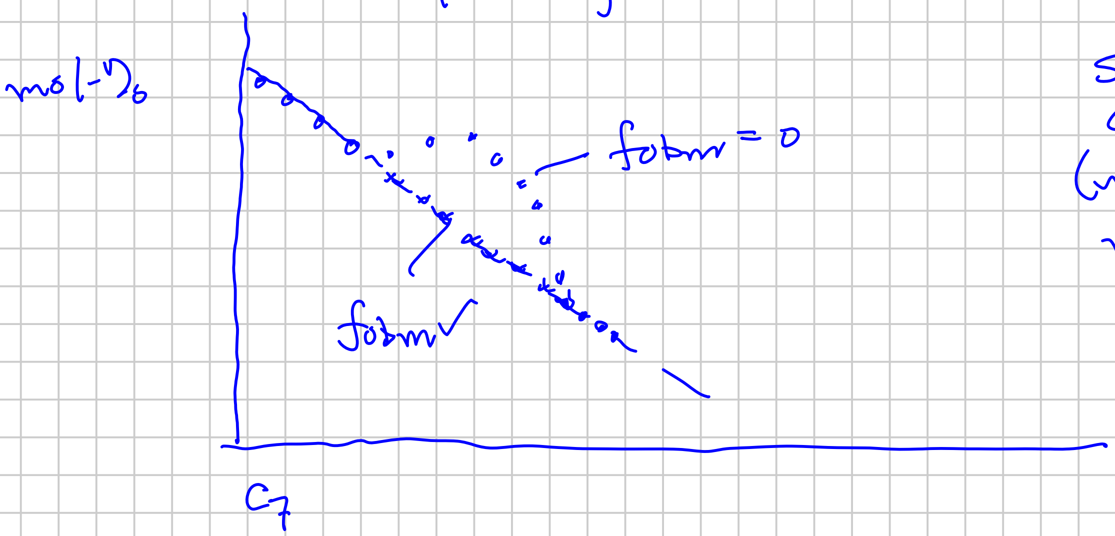
$$f_{obm} \leftrightarrow \underbrace{\hat{f}_{obm,wt}} = 0.34$$

?

RG MDT

$$Z_{MDT\,i,\,RG} = Z_{RG\,i}\,(1 - f_{obm}) + x_{obm\,i} \cdot f_{obm}$$

Guess f_{obm} ⇒ Back-Calc. $\boxed{Z_{RG\,i}}$



Smooth, continuous (no bump, no valley)

M_i

SCN, i

$$f_{obm} \leftrightarrow \left. \begin{array}{l} f_{obm\,7+\,wt} \\ f_{obm,wt} \end{array} \right\}$$

Lab PVT Tests

① CCE (CME) Constant Composition (Mass) Exp.

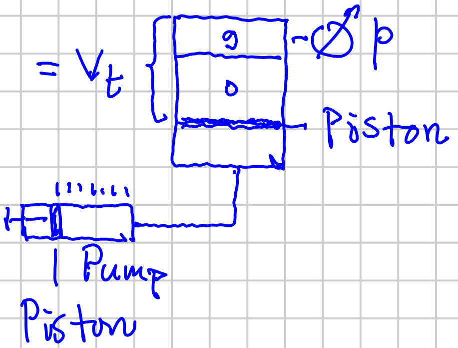
Slightly Compressible Oils

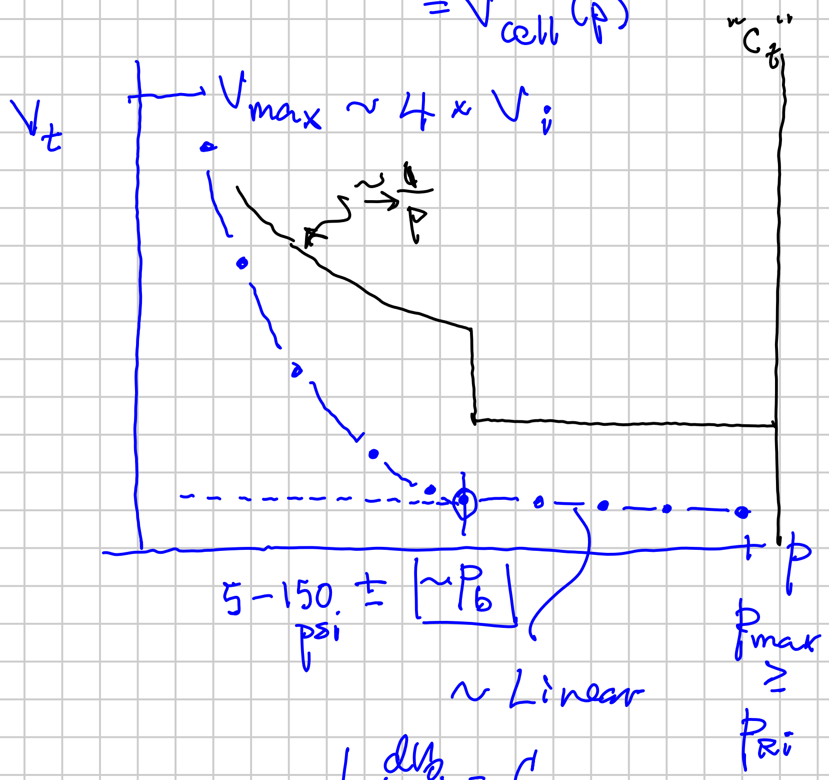
* Oils – Lower GORs ($\lesssim$ 1000 scf/STB ~ 200 Sm³/Sm³)

– "Blind" PVT Cell : $\boxed{T_R = \text{const}}$ | $\underline{V_t(p)} = V_g(p) + V_o(p)$

$= V_{cell}(p)$

$V_{cell} = V_t$





$$c_t \equiv -\frac{1}{V_t}\left(\frac{dV_t}{dp}\right)$$

$$-\frac{1}{V_o}\left(\frac{dV_o}{dp}\right) = C_o$$

p	$\frac{V_t}{V_{ob}}$	$\rho_o\ (p \geq p_b)$
P_i		✓
		✓
		✓
		✓
~ $\boxed{P_b}$	1.	✓
		–
		–
		–
		–
		–
		–
1500 psia	~4	–

TABLE 6.9—CCE DATA (RESERVOIR-FLUID) FOR GOOD OIL CO. WELL 4 OIL SAMPLE

Saturation (bubblepoint) pressure*, psig	2,620
Specific volume at saturation pressure*, ft^3/lbm	0.02441
Thermal expansion of undersaturated oil at 5,000 psi = V at 220°F/V at 76°F	1.08790
Compressibility of saturated oil at reservoir temperature	
From 5,000 to 4,000 psi, vol/vol-psi	13.48×10^{-6}
From 4,000 to 3,000 psi, vol/vol-psi	15.88×10^{-6}
From 3,000 to 2,620 psi, vol/vol-psi	18.75×10^{-6}

$(v)_{mass} = \frac{1}{\rho}$

Pressure/Volume Relations* V_t / V_{ob}

Pressure (psig)	Relative volume (L)†	Y function‡
5,000	0.9639	
4,500	0.9703	
4,000	0.9771	
3,500	0.9846	
3,000	0.9929	
2,900	0.9946	
2,800	0.9964	
2,700	0.9983	
2,620**	1.0000	
2,605	1.0022	2.574
2,591	1.0041	2.688
2,516	1.0154	2.673
2,401	1.0350	2.593
2,253	1.0645	2.510
2,090	1.1040	2.422
1,897	1.1633	2.316
1,698	1.2426	2.219
1,477	1.3618	2.118
1,292	1.5012	2.028
1,040	1.7802	1.920
830	2.1623	1.823
640	2.7513	1.727
472	3.7226	1.621

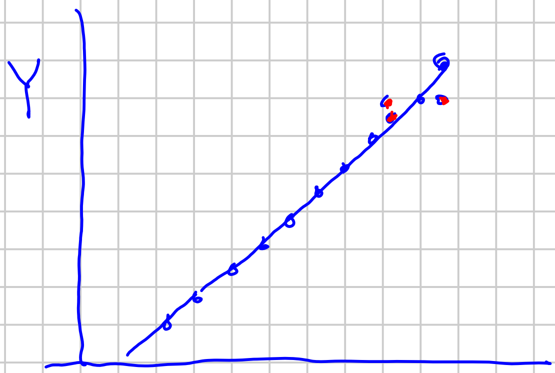
* At 220°F.

** Saturation pressure.

† Relative volume = V/V_{sat} in barrels at indicated pressure per barrel at saturation pressure.

‡ Y function = $(p_{sat} - p)/(p_{abs})(V/V_{sat} - 1)$.

V_t ($@\ p \lesssim p_b$) show scatter



② CCE – OILS & GAS CONDENSATES

* Windowed PVT Cell (know m_{cell}, n_{cell})

p	Measured: V_o	V_g	V_t	Reported: $V_{rt}=V_t/V_s$	V_o/V_t (1) or V_o/V_s (2)	$\geq p_s$ RO: ρ_o	RG: Z_g / B_g^*
$\geq p_{Ri}$							
$\boxed{p_s(BP/DP)}$ $\pm 10 \to 100$'s psi				1			
⋮							
p_{min}			$\sim 4 \cdot V_s$	~ 4			

$V_{ro} = (1) = \dfrac{V_o(p)}{V_t(p)}$

$(2) = \dfrac{V_o(p)}{V_s}$

$V_{ro2} = V_{ro1} \cdot V_{rt}$

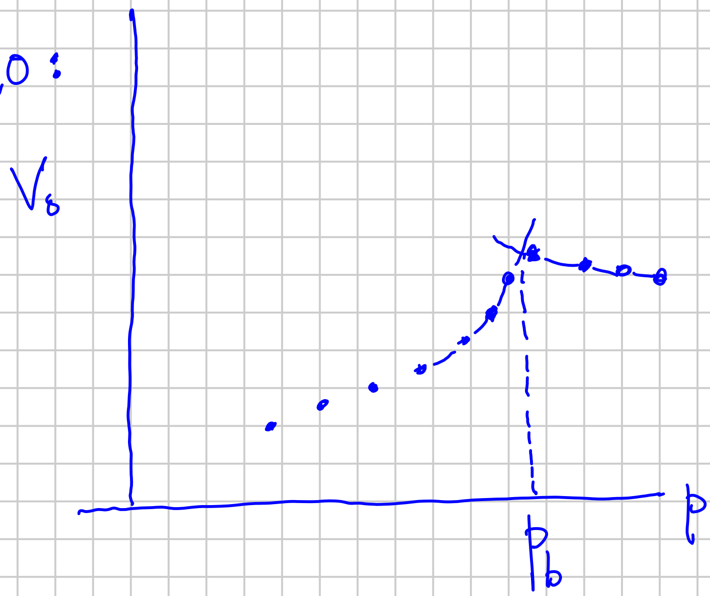
$$* \; B_g = \frac{p_{sc}}{T_{sc}} \cdot \frac{T_R Z_g}{p}$$

Traditional Definition of Gas FVF

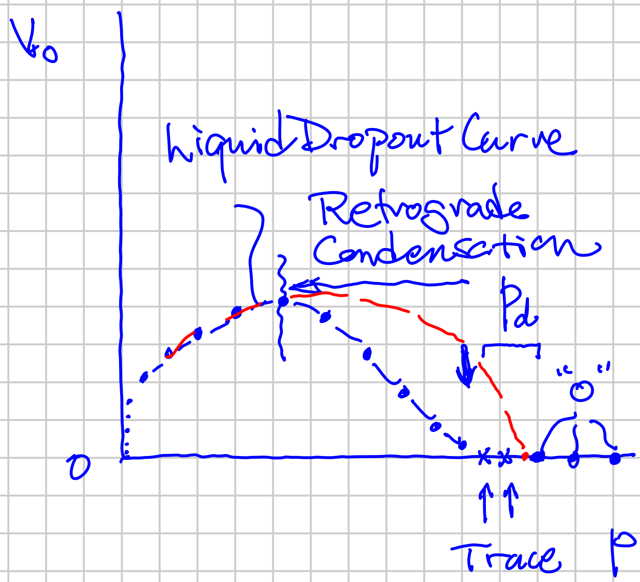
p_{sat} Determination

Plot $V_o(p)$

RO:



RG: Gas Condensate

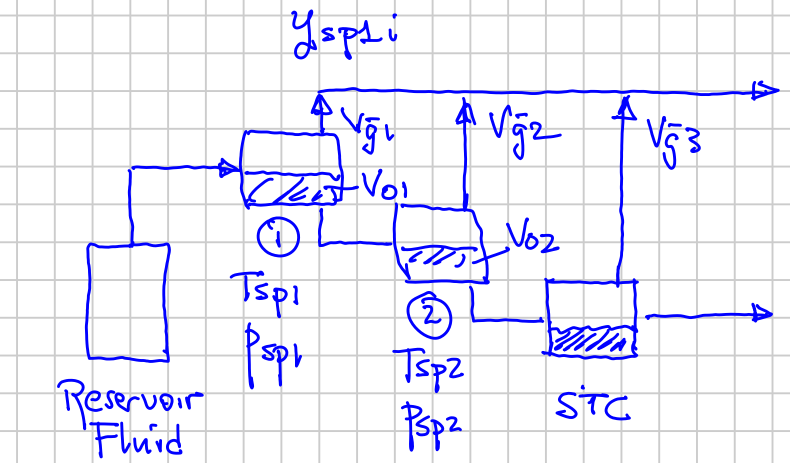


(*) Depends

① How many, how close p's nearby p_b

② Bring all points to equilibrium

② MULTI-STAGE SEPARATOR TEST $N_{stages} = 2-4$



$T_R,\ p \geq p_s$

(Single Phase)

$$V_{\bar{g}t} = \sum_{k=1}^{3} V_{\bar{g}k}$$

(2) $GOR_k = \dfrac{V_{\bar{g}k}}{V_{ok}}$

*(1) $GOR_k = \dfrac{V_{\bar{g}k}}{V_{\bar{o}}}$

$$GOR = \frac{V_{\bar{g}t}}{V_{\bar{o}}}$$

$$SF = 1/B_o \equiv b_o$$

Oil FVF @ p_b, T_R

Reasons : (1) $V_{\bar{o}}(T_{sp1}, p_{sp1}) \Rightarrow B_{ob} = \dfrac{V_{ob}(T_R, p_b)}{V_{\bar{o}}}$

Only used today if
$GOR \lesssim 5\text{-}10{,}000\ \frac{scf}{STB}$

$1\text{-}2000\ Sm^3/Sm^3$

any oil, and
"richer" gas condensates

(3) $y_{sp\,i,k}$: Est. potential
$\gamma_{\bar{g},k}$ NGL gas liquids
(C_3 C_4 C_{5+})

(2) GOR
(OGR)

(*) Helps build EOS PVT
model specifically for
optimizing surface
process
maximizing surface
liquids (oil, condensate
Gas Liquids)

4 SEP Tests, each 2-stage separator system

TABLE 6.7—SEPARATOR TESTS (RESERVOIR-FLUID) OF GOOD OIL CO. WELL 4 OIL SAMPLE

	Separator Pressure (psig)[a]	Separator Temperature (°F)	GOR[b] (ft³/bbl)	GOR[c] (ft³/bbl)	Stock-Tank Gravity (°API)	FVF[d] (bbl/bbl)	Separator Volume Factor[e] (bbl/bbl)	Flashed-Gas Specific Gravity
I	50	75	715	737			1.031	0.840
	to							
	0	75	41	41	40.5	1.481	1.007	1.338
II	100	75	637	676			1.062	0.786
	to							
	0	75	91	92	40.7	1.474	1.007	1.363
III	200	75	542	602			1.112	0.732
	to							
	0	75	177	178	40.4	1.483	1.007	1.329
IV	300	75	478	549			1.148	0.704
	to							
	0	75	245	246	40.1	1.495	1.007	1.286

[a]Gauge.
[b]In cubic feet of gas at 60°F and 14.65 psi absolute per barrel of oil at indicated pressure and temperature.
[c]In cubic feet of gas at 60°F and 14.65 psi absolute per barrel of stock-tank oil at 60°F.
[d]In barrels of saturated oil at 2,620 psi gauge and 220°F per barrel of stock-tank oil at 60°F.
[e]In barrels of oil at indicated pressure and temperature per barrel of stock-tank oil at 60°F.

$q_o = 1000$ STB/D 50 psig = P_{sp1}

\$30/STB

$$q_o = 1000 \cdot \frac{(B_{ob})_{50}}{(B_{ob})_{100}} \cdot \frac{1.481}{1.474}$$ 100 psig P_{sp2}

$= 1005$ STB/D

5 STB/D × 365 D × 30 \$/STB = 54750 USD/yr

③ DIFFERENTIAL LIBERATION EXP (DLE) : Only Oils

Same process as SEP test BUT $T_{stage} = T_R$

$N_{stage} \sim 5-10$

PVT properties at Reservoir Condition

T_R, $p \le p_b$

Purpose : (a) $\rho_o \; (p < p_b)$ $\qquad \mu_o \; (p < p_b)$

(b) Oil shrink $[V_o^{(p)} / V_{ob}]$ = oil shrinkage

$\sim S_o$

$k_o \propto S_o^{\,n}$, $n \sim 2-5$ $\qquad q_o \propto k_o$

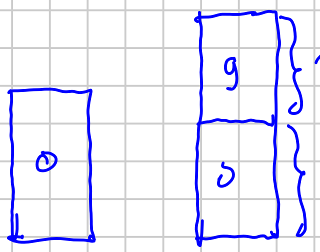
(c) $\{ x_i \; (p) \}$

(a') $\rho_g \; (p < p_b)$ $\qquad \mu_g \; (p < p_b)$

(b') $S_g = 1 - S_o$: Gas Released

(c') $y_i \; (p < p_b)$

Simple experiment : Blind PVT Cell.



Remove V_{g2} @ P_2 → Flash to STC $\qquad$ gas meter

V_{o2} $\qquad \sim V_{\bar g}$

$n_{g2} \Leftarrow \{ n_{\bar o} \} + n_{\bar g}$

Calc. $Z_{g2} = \dfrac{P_2 V_{g2}}{R T_R \, n_{g2}}$

$p_1 = p_b$ $\qquad P_2$