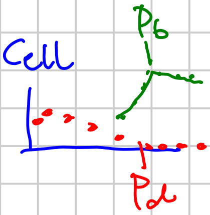
LABORATORY PVT TESTS (Ch. 6)

Note Title 3/3/2017

* CCE (Constant Mass Composition Expansion)

- p_s (T_R ; T's) Blind Cell ($GOR \lesssim 1000 \frac{scf}{STB}$) Windowed Cell
- $p > p_s$: $V_t(p)$: Cell Discontinuities $V_t(p)$ $\rho = m / V_t(p)$ ρ_o $Z_g(p > p_d)$ $V_o(p)$



$p \geq p_d$ $\rho_g = \frac{m_{cell}}{V_t(p) = V_g(p)} = \frac{p M_g}{R T Z_g} \Rightarrow Z_g = \frac{p M_g}{R T \rho_g}$

Report: p_s (BP/DP) $V_t(p)$ $\{ V_o(p) / V_s = V_{ro}(p) \}$* Windowed Cells 5%

$\rho_o (p \geq p_b)$ $Z_g (p \geq p_d)$

* $V_{ro}(p) = \frac{V_o(p)}{V_t(p)}$ 95%

* SEP (Multi-Stage Separator Test)

* DLE (Differential Liberation Experiment)

* CVD (Constant Volume Depletion test)

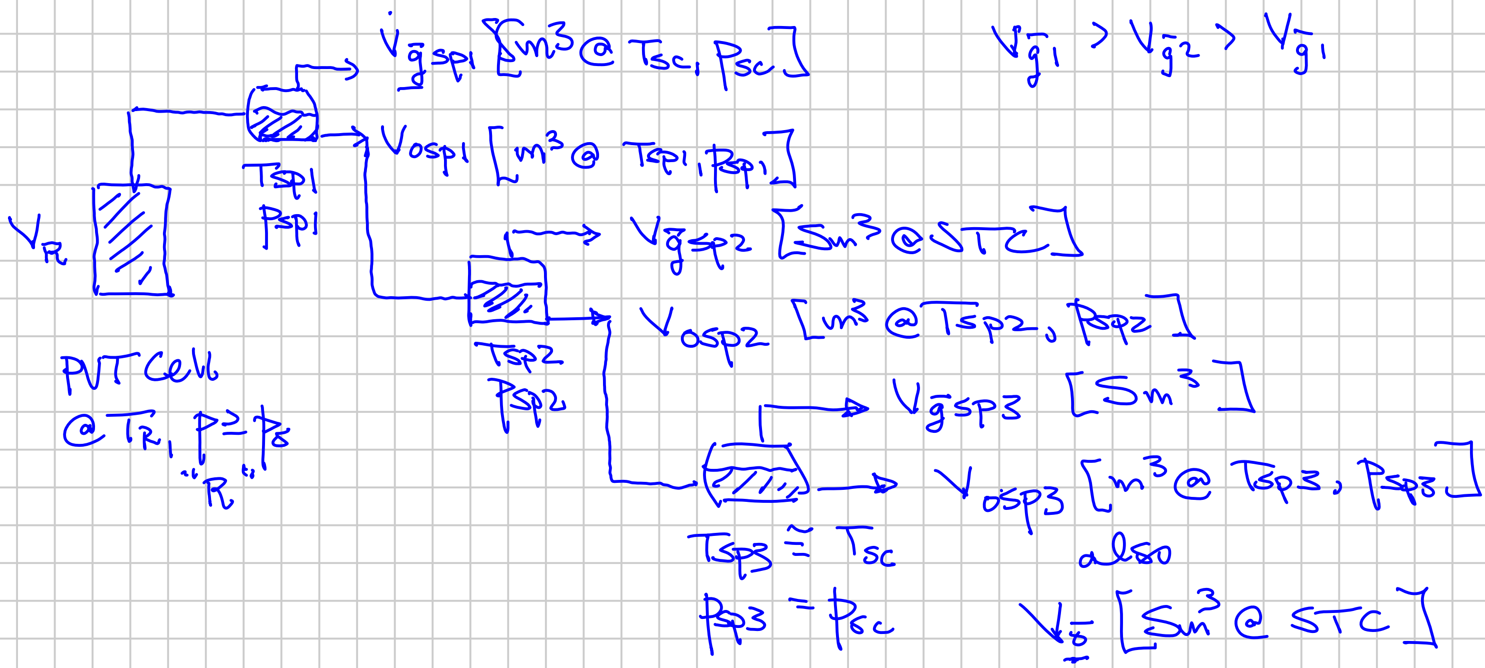
GOR ⟶

	OILS			GAS CONDENSATES		
	Black	Volatile	(Near Critical)	Rich	Lean	Dry
CCE	✓ (Blind Cell)	✓	✓	✓	✓	(✓)
		Windowed Cell				
SEP	✓	✓	✓	✓	× × ×	×
DLE						
CVD						

GOR ≳ 15000 scf/STB
3,000 Sm^3/Sm^3

✓ All sample types (BHS, "MDT", SEP)

SEP TEST (Multi-Stage Separator Test)



$V_{\bar{g}1} > V_{\bar{g}2} > V_{\bar{g}1}$

$\rho_{\bar{o}}$ γ_o γ_{API}

Ekofisk:

Stage	Tsp (F)	Psp (psia)
1	155	1000
2	80	250
3	60	14.7

Lab Reports: Stage k

Always Reported:

① GOR

(a)

$$GOR_1 = \frac{V_{\bar{g}1}}{V_{\bar{o}}}$$

$$GOR_2 = \frac{V_{\bar{g}2}}{V_{\bar{o}}}$$

$$GOR_3 = \frac{V_{\bar{g}3}}{V_{\bar{o}}}$$

$$\boxed{GOR_t = \sum_{k=1}^{3} GOR_k} = \frac{V_{\bar{g}1} + V_{\bar{g}2} + V_{\bar{g}3}}{V_{\bar{o}}}$$

(b)

$$GOR'_1 = \frac{V_{\bar{g}1}}{V_{osp1}} \leftarrow$$

$$GOR'_2 = \frac{V_{\bar{g}2}}{V_{osp2}} \leftarrow$$

$$GOR'_3 = \frac{V_{\bar{g}3}}{V_{osp3}} \leftarrow$$

~~$GOR'_t \neq \sum_{k=1}^{3} GOR'_k$~~

GOR ~ GOR' may differ by 1% to 15%

$\{ OGR_k \quad OGR'_k \}$ $\qquad$ $Sm^3_{\bar{o}} / 10^6 Sm^3_{\bar{g}}$

$= 1/GOR_k \quad = 1/GOR'_k$

or

$OGR_t = 1/GOR_t$ (not summing) $\qquad$ $STB_{\bar{o}} / MMscf_{\bar{g}}$

② Separator Oil Volume Ratio B_{osp}

(Shrinkage Factor) $b_{osp} = 1/B_{osp}$

$$B_{osp\,k} = \frac{V_{osp\,k}}{V_{\bar{o}}} \qquad \begin{matrix} b_{osp\,k} \\ SF_k \end{matrix} = \frac{V_{\bar{o}}}{V_{osp\,k}}$$

$B_{osp\,1}$	$b_{osp\,1}$	SF_1	of interest
1.05	0.95	(5%)	
1.25	0.75	(25% "shrinkage")	

Physical Shrinkage (%) = $100(1-b_{osp})$

$100(1-SF)$

③ $\rho_{\bar{o}} \quad \gamma_{API} \quad \gamma_o \qquad$ (\$/USD = f(API))

{Also $\rho_{osp\,k}$} usually

④ $\gamma_{gk} \quad M_{gk}$

Today's lab studies: $y_{spki} \Rightarrow \gamma_{g_{sp}} \; M_{g_{sp}}$

⑤ OILS:

$\frac{V_{oR}}{V_{\bar{o}}}$ usually $\frac{V_{ob}}{V_{\bar{o}}} \equiv B_{ob}$

GAS CONDENSATES

@ p_d @ p_{Ri} T_R

$\frac{V_{gR}}{V_{\bar{g}t}} = B_g$ gas FVF

$V_{\bar{g}t} \leftarrow \Sigma V_{\bar{g}k}$

B_o: oil volume ratio

B_o: oil formation volume factor

oil FVF

$V_o = V_{oR}$ @ T_R, P_R

$V_o = V_{ob}$ B_{ob}

$V_o = V_{oi}$ @ T_R, P_{Ri} B_{oi}

(6) Sometimes Reported Data

(a) Surface oil ($\bar{o}$) $M_{\bar{o}}$, $x_{\bar{o}i}$

(b) Older studies: Surface gas ($\bar{g}$) $y_{\bar{g}i}$ ⇑ Potential added value

Same i → liquid form

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Example Ch. 6 various tables

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

Separator Pressure (psia)	Separator Temperature (°F)	GOR[b] (ft^3/bbl) (GOR′)	GOR[c] (ft^3/bbl) (GOR)	Stock-Tank Gravity (°API) ($\gamma_{\bar{o}}$)	FVF[d] (bbl/bbl) (B_{ob})	Separator Volume Factor[e] (bbl/bbl) (B_{osp})	Flashed-Gas Specific Gravity (γ_g)
50	75	715	737			1.031	0.840
to							
0	75	41	41	40.5	1.481	1.007	1.338
100	75	637	676			1.062	0.786
to							
0	75	91	92	40.7	1.474	1.007	1.363
200	75	542	602			1.112	0.732
to							
0	75	177	178	40.4	1.483	1.007	1.329
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.

4 separate 2-stage tests

SEPARATOR TESTS OF Reservoir Fluid SAMPLE

Separator		GOR[1]		Stock-Tank Gravity (°API at 60°F)	Shrinkage Factor V_{or}/V_{ob} [2]	Formation Volume Factor V_{ob}/V_{or} [3]	Flashed Gas Specific Gravity
Pressure (psi gauge)	Temperature (°F)	Separator	Stock Tank				
0	75	1,206	0	45.6	0.5456	1.833	0.942
50	74	1,011	35	48.1	0.5872	1.703	
100	75	950	68	48.5	0.5949	1.681	
200	73	875	134	48.5	0.5974	1.674	

[1]Separator and stock-tank gas/oil ratio in cubic feet of gas at 60°F and 14.7 psi absolute per barrel of STO at 60°F.
[2]Shrinkage factor, V_{or}/V_{ob}, is barrels of STO at 60°F per barrel of saturated oil at 3,236 psi gauge and 258 °F.
[3]FVF, V_{ob}/V_{or}, is barrels of saturated oil at 3,236 psi gauge and 258°F per barrel of STO at 60°F.

This table provides results of four separate two-stage separator tests. The first two columns of data give the primary-separator conditions. In all tests, the second (final) separator is at standard (stock-tank) conditions. For example, conditions for the first two-stage separator test are (1) $p_{sp1}=0$ psig and $T_{sp1}=75$°F and (2) $p_{sp2}=0$ psig and $T_{sp2}=60$°F, with total $R_{sb}=1{,}206+35=1{,}241$ scf/STB, $B_{ob}=1.833$, $\gamma_{API}=45.6$°API, and $\gamma_{\bar{g}}=0.942$.

TABLE 2

FLASH LIBERATION OF 1st-STAGE SEPARATOR LIQUID

3-stage sep test of the sampled separator oil

SEPARATOR CONDITIONS and FLUID PROPERTIES						
Conditions	Pressure psia	Temperature °F	GOR (1)	Separator Oil Volume Factor (2)	Oil Density (3)	Gas Specific Gravity (4)
1st Stage Separator	665	94	N/A	1.2573	0.7071	0.705
2nd Stage Separator	91	80	263	N/A	N/A	0.926
3rd Stage Separator	45	120	47	N/A	N/A	1.264
Ambient Lab Condition	14.65	75	104	1.0079	0.7888	1.758
Stock Tank	14.65	60	0	1.0000	0.7961	1.758
TOTALS	-----	-----	414		-----	-----

Stock Tank Oil Gravity: 46.06 °API at 60 °F

(1) Gas-Oil Ratio (GOR) is the cubic feet of gas at standard conditions per barrel of stock tank oil.
(2) Barrels of oil at indicated separator conditions per barrel of stock tank oil.
(3) Oil Density (g/cc) at indicated separator conditions.
(4) Air = 1.000

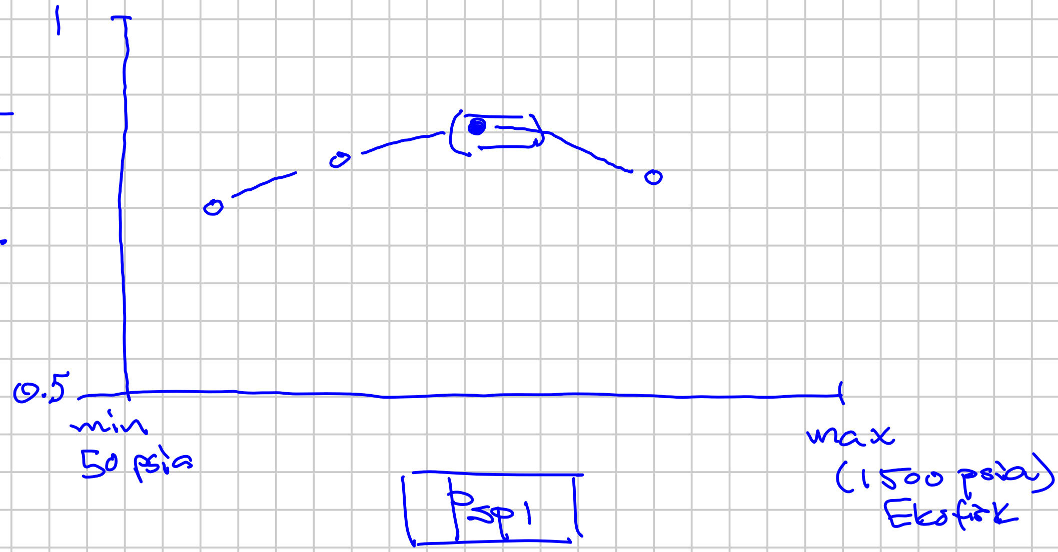
Why conduct SEP?

① Pre-1980s

To find p_{sp1} that gave max V_o

$b_{ob} = \frac{1}{B_{ob}}$

$\frac{STB}{bbl @ p_b}$



(2) Help build the black-oil PVT model used for all petroleum engineering calculations, (together with the DLE test for oils)   Ch. 7

OILS

App. D

Post-1980s & Pre-1980s

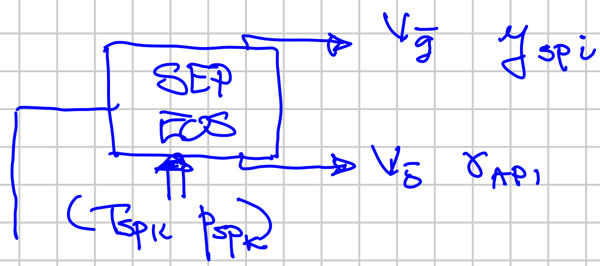
(1) Get measured y_{spi}

(2) Get surface oil shrinkage B_{ob} B_{osp}

(3) γ_{API} $\gamma_{\bar{o}}$

(1)-(3) Today (post 1980s) used to help build/verify Equation of State PVT models (EOS) Ch. 4

EOS built: Simulate SEP test



Optimize:

max $V_{\tilde{o}}$ by changing

\# stages

&

T_{spk} P_{spk}

DIFFERENTIAL LIBERATION TEST
(OILS ONLY)

Identical procedure as SEP test,
EXCEPT $T_{sp} = T_R$

5–8 stages

To provide gas & oil properties and behavior at reservoir conditions: T_R $p_{low} < p_R < p_{Ri}$

$\left.\begin{array}{l} \rho_o \ \rho_g \\ \mu_o \ \mu_g \\ V_o(p) \end{array}\right\}$ $p < p_b$

$y_i(p)$