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 Conditions $T_R,\ p \le p_b$

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

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

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

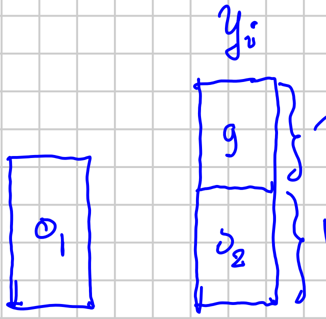
(c) $\{x_i\ (p)\}$

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

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

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

Simple experiment : Blind PVT Cell.



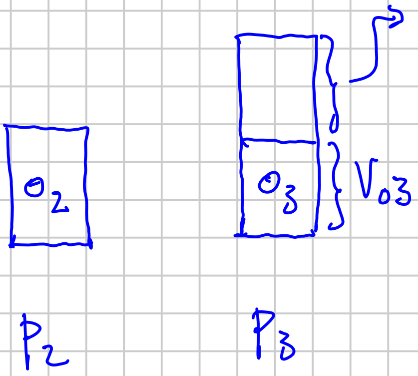
Remove @p_2 V_{g2} ✓ → Flash to STC gas meter $\sim V_{\bar{g}}$

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

Calc. $$\boxed{Z_{g2} = \frac{p_2 V_{g2}}{R T_R n_{g2}}}$$

$$\rho_g = \frac{p M_g}{R T_R Z_g}$$

T_R = const $p_1 = p_b$ p_2



ΔV_g, Δn_g, Z_g, ρ_g $\mu_g = f(\rho_g, T_R)$

Lee-Gonzalez

Ch. 3

y_i

Skeptical to the amounts of C_{5+}

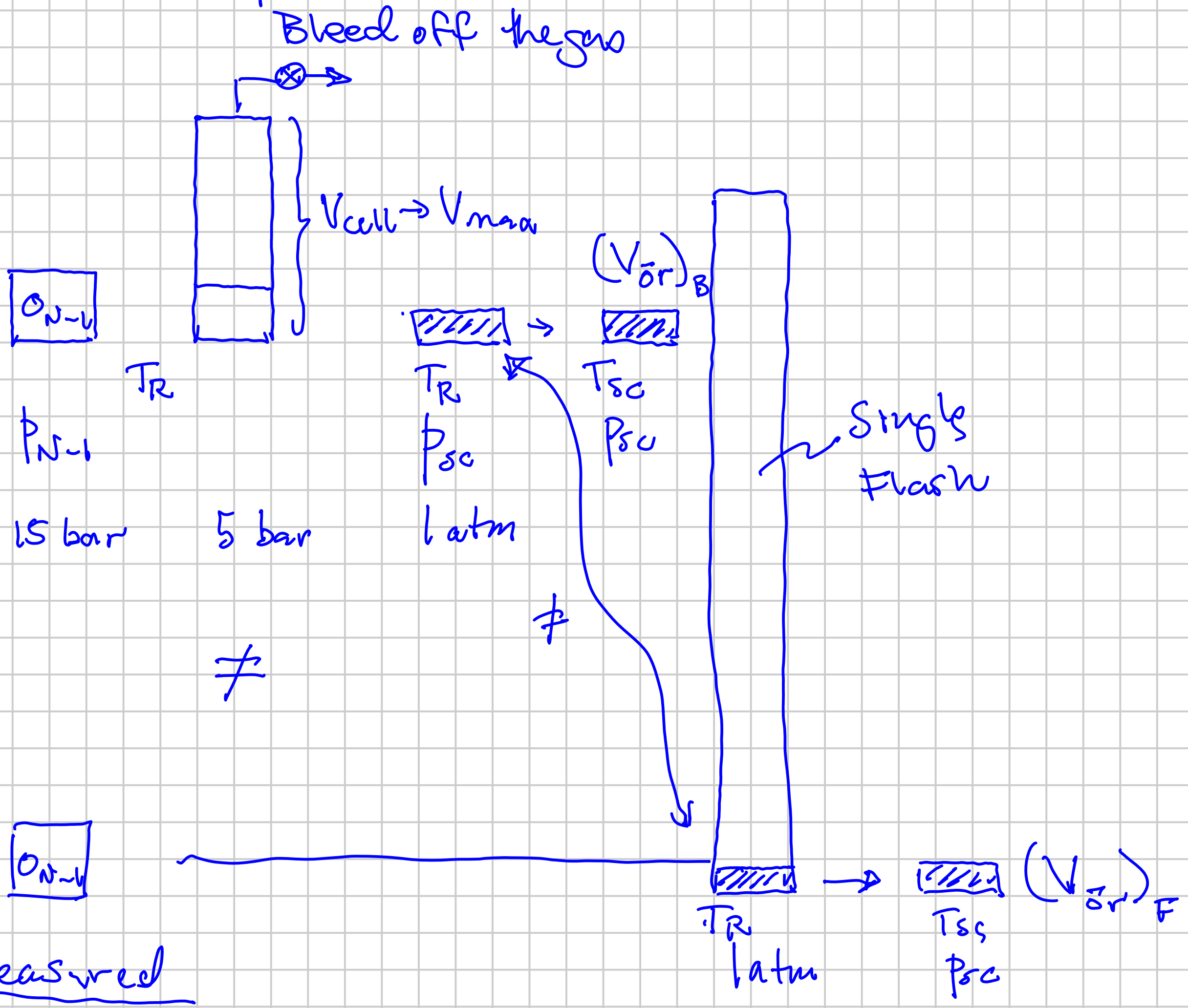
→ Step repeated 5-8 times

ρ_o = calculated by material balance

μ_o = measured in a separate parallel DL test

±5% → ±15%

$p_{N-1} \rightarrow p_N = p_{sc}$



Measured

$\underline{P}$ $\underbrace{\underline{V_o} \quad \underline{\Delta V_g}}_{@\, p,\, T_R}$ $\underline{\Delta n_g}$ $\underline{\Delta m_s}$ $\underline{y_i^{\pm}}$

$(V_{\bar{o}r})_B$

PVT Report

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

OIL Phase

p

p_b

:

p_4

:

p_8

$$B_{od} = \frac{V_o}{(V_{\bar{or}})_B} \qquad \rho_o \qquad \{\mu_o\}$$

$$\uparrow$$

$$f(V_{\bar{or}})$$

GAS Phase

$$\underbrace{\Delta R_{sd} = \frac{(\Delta n_g)\left(\frac{RT_{sc}}{p_{sc}}\right)}{(V_{\bar{or}})_B} \qquad R_{sd} = \sum_{N}^{k+1} \Delta R_{sd}}_{\sim f(V_{\bar{or}})} \qquad Z_g \; (B_g) \; y_i \, ; \; \gamma_g \quad \mu_g$$

Calc.

$$\rho_{o,k} = \frac{(m_{\bar{or}})_B + \left\{\sum_{s=N}^{k+1} \Delta m_{g,s}\right\}}{V_{o,k}} \qquad \pm 1\text{-}2\%$$

NB! If you use DLE data as input to a PVT program based on EOS (PVTsim, PhazeComp, PVTp, PVTi, PVTx ...) → Simulate DLE

Use by default Single Flash

$$p_{N-1} \rightarrow p_N$$

EOS Calc's

p	V_o cc	B_{od}		Lab V_o cc	B_{od}
	13.62			13.62	
	12.45			12.45	
	11.32		≈	11.32	
	:		=	:	
	:		=	:	
	:		=	:	
$\{p_{N-1}$: Add 5-10 steps ~Bleeding$\}$					
p_{sc} p_N	5.00⇒5.92			6.00	
	(Flash)			(Bleeding)	

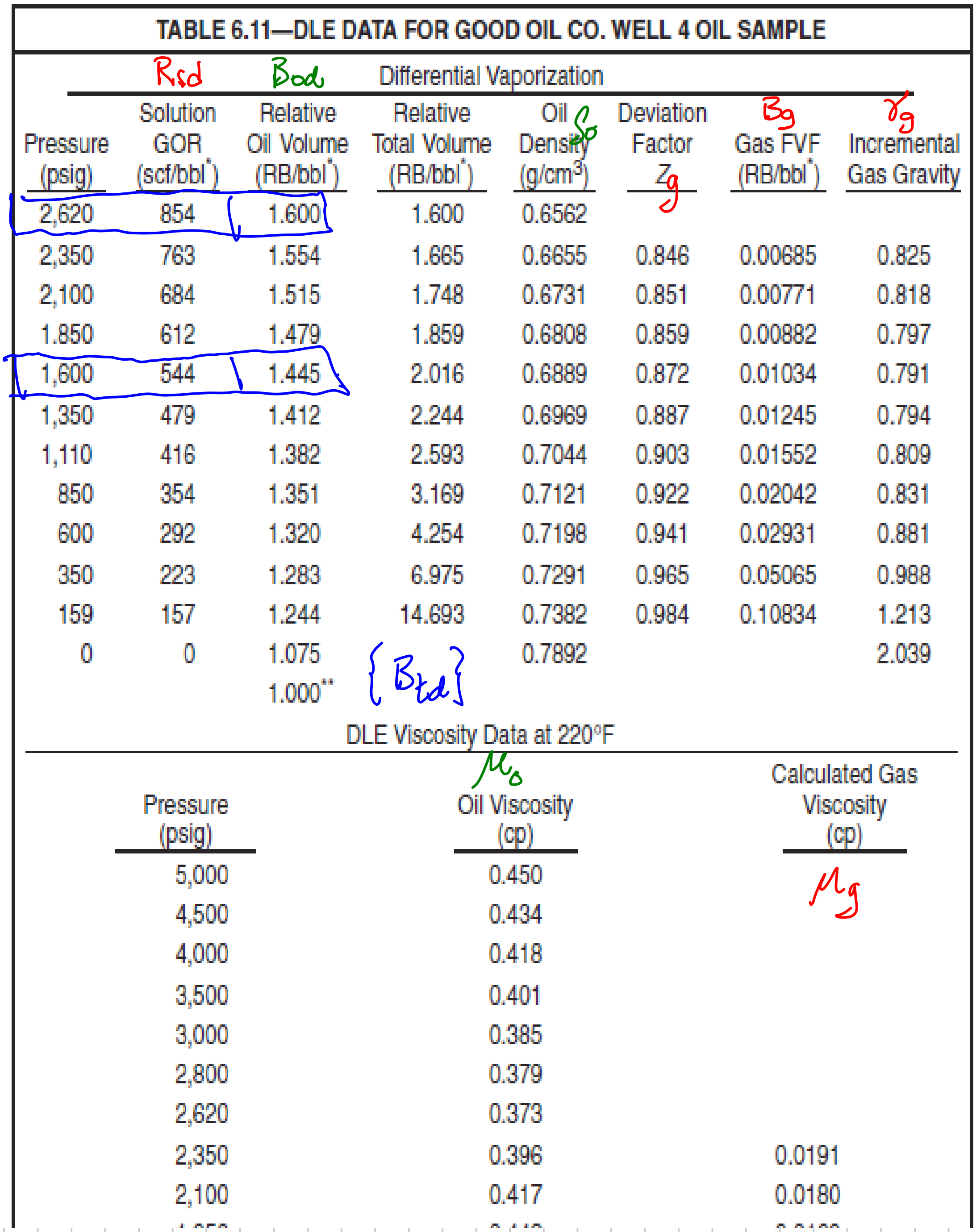


TABLE 6.11—DLE DATA FOR GOOD OIL CO. WELL 4 OIL SAMPLE

Differential Vaporization

Pressure (psig)	R_{sd} Solution GOR (scf/bbl*)	B_{od} Relative Oil Volume (RB/bbl*)	Relative Total Volume (RB/bbl*)	Oil Density (g/cm³) ρ_o	Deviation Factor Z Z_g	B_g Gas FVF (RB/bbl*)	γ_g Incremental Gas Gravity
2,620	854	1.600	1.600	0.6562			
2,350	763	1.554	1.665	0.6655	0.846	0.00685	0.825
2,100	684	1.515	1.748	0.6731	0.851	0.00771	0.818
1,850	612	1.479	1.859	0.6808	0.859	0.00882	0.797
1,600	544	1.445	2.016	0.6889	0.872	0.01034	0.791
1,350	479	1.412	2.244	0.6969	0.887	0.01245	0.794
1,110	416	1.382	2.593	0.7044	0.903	0.01552	0.809
850	354	1.351	3.169	0.7121	0.922	0.02042	0.831
600	292	1.320	4.254	0.7198	0.941	0.02931	0.881
350	223	1.283	6.975	0.7291	0.965	0.05065	0.988
159	157	1.244	14.693	0.7382	0.984	0.10834	1.213
0	0	1.075	$\{B_{td}\}$	0.7892			2.039
		1.000**					

DLE Viscosity Data at 220°F

Pressure (psig)	μ_o Oil Viscosity (cp)	Calculated Gas Viscosity (cp) μ_g
5,000	0.450	
4,500	0.434	
4,000	0.418	
3,500	0.401	
3,000	0.385	
2,800	0.379	
2,620	0.373	
2,350	0.396	0.0191
2,100	0.417	0.0180

$$B_{td} = \frac{V_o + V_g}{(V_{\bar{o}r})_B}$$

$$B_{od} + B_g\left(\underbrace{R_{sd,b} - R_{sd}}_{\text{Cumulative Gas Out of Solution}}\right)$$

Using DLE data with SEP data to generate tables of "black oil" PVT (Ch. 7) properties for petroleum engineering calculations.

- Reservoir :
  - Material Balance
  - Rate Equations
  - Reservoir Simulation
- Production & Pipe Flow

('Old School', Not use an EOS model)

Appendix D ⇒ Standing Ch. 6

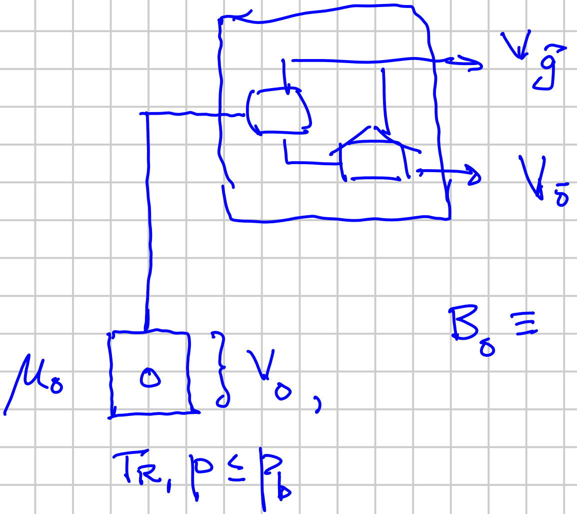
Oil Phase:

B_o = Oil FVF

R_s = Solution GOR

μ_o Report directly

Lab SEP of the original oil



$$B_o \equiv \frac{V_o(T_R,p)}{V_{\bar o}}$$

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

SEP Test : B_{ob}, R_{sb}

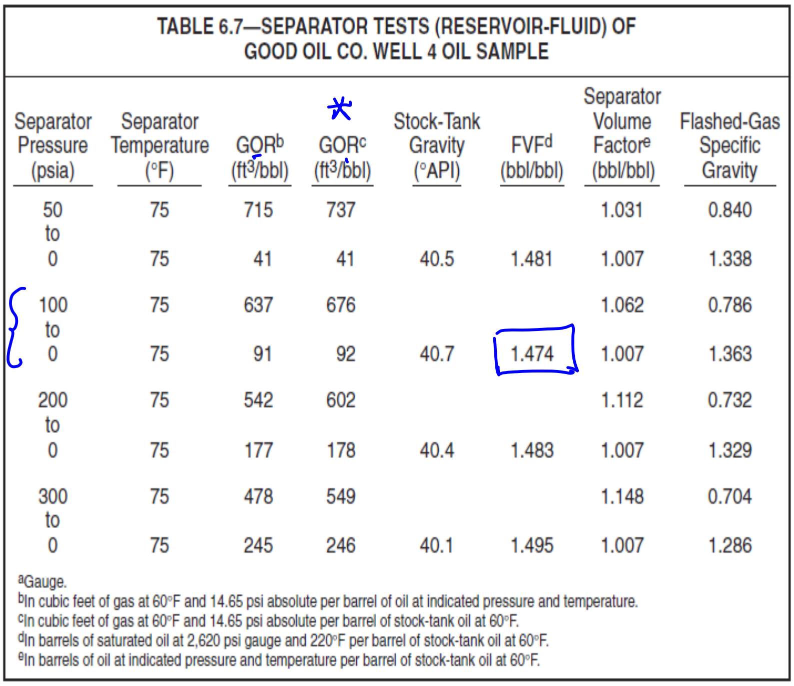


TABLE 6.7—SEPARATOR TESTS (RESERVOIR-FLUID) OF GOOD OIL CO. WELL 4 OIL SAMPLE

	Separator Pressure (psia)	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
	50 to	75	715	737			1.031	0.840
	0	75	41	41	40.5	1.481	1.007	1.338
*	100 to	75	637	676			1.062	0.786
	0	75	91	92	40.7	$\boxed{1.474}$	1.007	1.363
	200 to	75	542	602			1.112	0.732
	0	75	177	178	40.4	1.483	1.007	1.329
	300 to	75	478	549			1.148	0.704
	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.

RB/STB

$$B_{ob} = \underset{bbl/STB}{1.474} = \frac{V_{ob}}{V_{\bar o}}$$

$$R_{sb} = \underset{scf/STB}{676} + \underset{scf/STB}{92}$$

$$= 768 \text{ scf/STB}$$

We want need saturated oils $\underset{\uparrow}{B_o(p<p_b)}$ $\underset{\uparrow}{R_s(p<p_b)}$

Standard Method: $\boxed{p \le p_b}$

$$B_o(p) \cong \overset{\text{DLE}}{B_{od}(p)} \cdot \frac{\overset{\text{SEP}}{B_{ob}}}{\underset{\text{DLE}}{B_{od,b}}}$$

{OK for $R_{sb} \lesssim 1000 \ \frac{\text{scf}}{\text{STB}}$}

$p = 1600$ psig $\quad B_{od}(1600) = 1.445 \ \frac{\text{RB}}{\text{residual bbl}}$

$p_b \Rightarrow B_{od,b} = 1.600 \ \frac{\text{RB}}{\text{res. bbl}}$ Don't use directly

$\hookrightarrow B_{ob} = 1.474 \ \frac{\text{RB}}{\text{STB}}$

$$B_o(1600) = 1.445 \left(\frac{1.474}{1.600}\right) = 1.331 \ \frac{\text{RB}}{\text{STB}}$$

{high-T, low-p bad surface separation}

$$R_s(p) \cong R_{sb} - \left(R_{sd,b} - R_{sd}(p)\right) \cdot \frac{B_{ob}}{B_{od,b}}$$

1600psig: $R_{sb} = 768$ scf/STB

$R_{sd,b} = 854$ scf/residual-bbl

$R_{sd}(1600) = 544$ scf/res. bbl

$$R_s(1600) \cong 768 - (854-544)\left(\frac{1.474}{1.600}\right) = 482 \ \frac{\text{scf}}{\text{STB}}$$