CONSTANT VOLUME DEPLETION (CVD) TEST

Note Title 2013-10-04

- Ch. 6
- SPE Paper: "Evaluating CVD Data" (Whitson & Torp)
  - e-note "PVT-Papers" directory
  - ⇒ Modified Black-Oil PVT (Ch. 7)

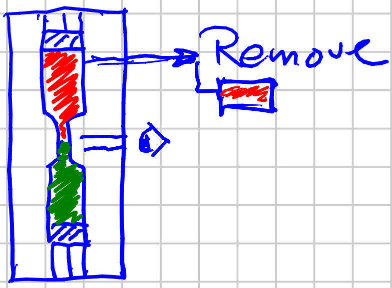
Conducted on -

- Gas Condensates
- High-GOR (>400 Sm^3/Sm^3) Oils → Near-Critical or Highly Volatile "Oils"

- Conducted @ T_R = constant
- Visual PVT Cell
  - Ruska 3-Windowed (Hg)
  - Hg-free

} V_t

V_o, V_g



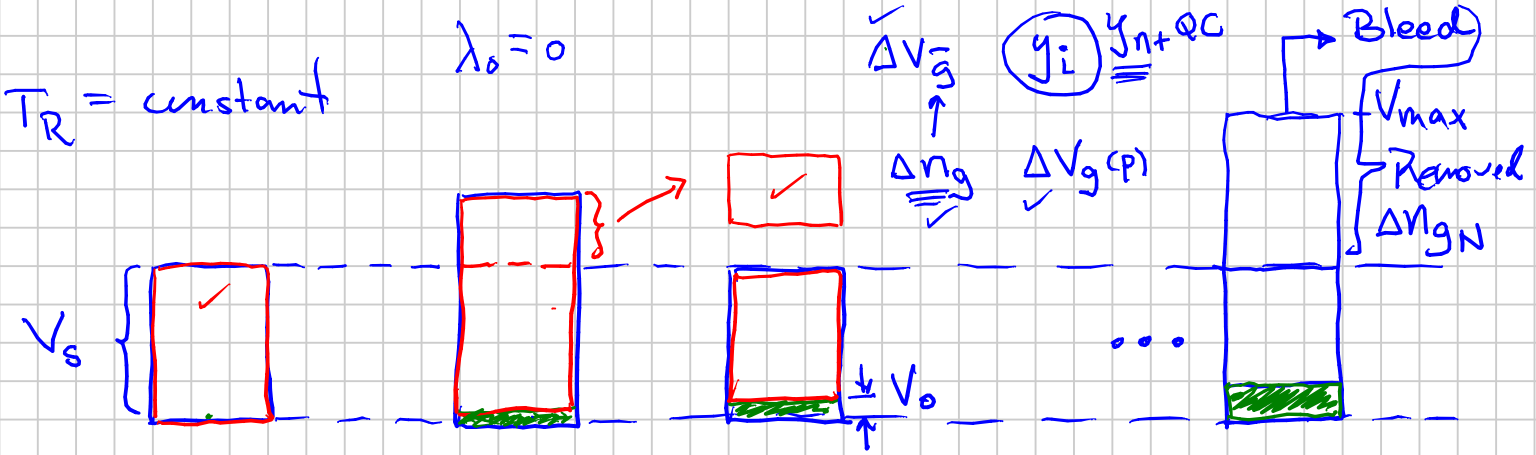
- Gas Removals ⇒ Molar Composition $y_{CVD\,i}$

! STO-forming ! components C_{5+}

1 cc loss

T_R = constant

$\lambda_o = 0$



$P_1 = P_s$ $\quad$ $P_2 < P_1$ $\quad$ P_2 $\quad$ P_{N-1} $\quad$ $P_N = 1$ atm

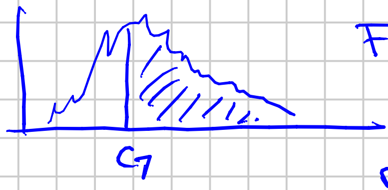
Stage 2 (~of 6-8)

~500-750 psia

In gas condensate reservoirs (all)

$(\bar{\lambda}_o)_{\text{Bulk of R}} \sim 0 \ll \bar{\lambda}_g$

~95%



Flashed oil from removed gas

Reported by the Lab:

① $y_{CVD\,i}(p)$; M_{7+} $\quad$ GC or M_g

② $\dfrac{\Delta n_g}{n_s}$ $\dfrac{\text{mol}}{\text{mol}}$ % $\quad$ $\dfrac{\Delta V_{\bar{g}w}}{(V_{\bar{g}w})_s}$ $\dfrac{\text{MMscf}}{\text{MMscf}}$ %

"wet gas (STC) volumes"

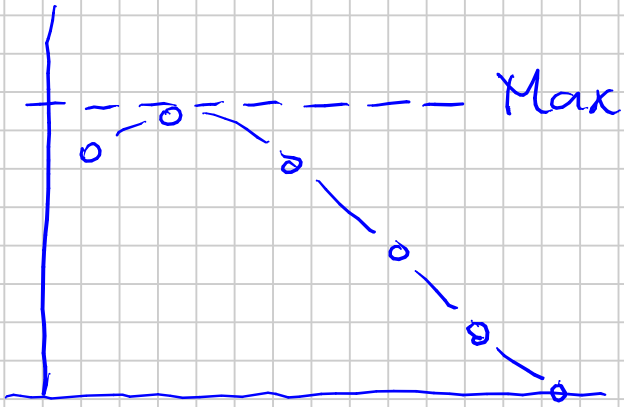
Ignores STO produced @ surface

③ $Z_g = \dfrac{p\,\Delta V_g}{\Delta n_g R T_R}$

④ μ_g Calculated

⑤ $\dfrac{V_o}{V_s}$ % $\quad$ Liquid Dropout Curve

(6) Final Residual Oil $(x_i)_N$



Max. LDC Value gauges the "richness" of G.C.

2 – 40+ %

Lean Rich

TABLE 1—MEASURED CONSTANT-VOLUME DEPLETION DATA FOR THE NS-1 FLUID AT 280°F (psia)

Compositions: Equilibrium Vapor y_i mol-%; Equilibrium Liquid

Stages: 1 (DP), 2, 3, 4, 5, 6, 7

Component	6764.7	5514.7	4314.7	3114.7	2114.7	1214.7	714.7	Experimental 714.7	Calculated 714.7
Carbon dioxide	2.37	2.40	2.45	2.50	2.53	2.57	2.60	0.59	0.535
Nitrogen	0.31	0.32	0.33	0.34	0.34	0.34	0.33	0.02	0.017
Methane	73.19	75.56	77.89	79.33	79.62	78.90	77.80	12.42	10.704
Ethane	7.80	7.83	7.87	7.92	8.04	8.40	8.70	3.36	3.220
Propane	3.55	3.47	3.40	3.41	3.53	3.74	3.91	2.92	2.896
isobutane	0.71	0.67	0.65	0.64	0.66	0.72	0.78	0.91	0.916
n-butane	1.45	1.37	1.31	1.30	1.33	1.44	1.56	2.09	2.103
isopentane	0.64	0.59	0.55	0.53	0.54	0.59	0.64	1.40	1.417
n-pentane	0.68	0.62	0.58	0.56	0.57	0.61	0.66	1.60	1.624
Hexanes	1.09	0.97	0.88	0.83	0.82	0.85	0.90	3.68	3.755
Heptanes-plus	8.21	6.20	4.09	2.64	2.02	1.84	2.12	71.01	72.815
Totals	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
$M_{C_{7+}}$	184.0	160.0	142.0	127.0	119.0	115.0	114.0	213.0	207.8
$\gamma_{C_{7+}}$	0.816	0.799	0.783	0.770	0.762	0.758	0.757	0.833	0.843
Z_g	1.238	1.089	0.972	0.913	0.914	0.937	0.960		
n_p, %	0.000	9.024	21.744	38.674	55.686	72.146	81.301		
S_L, %	0.0	14.1	19.7	21.6	21.3	20.2	19.3		

$C_7 - C_{30+}$ → $C_7 - C_{12}$

g = 9, o = 3 (9.3); Z_d → 1.238

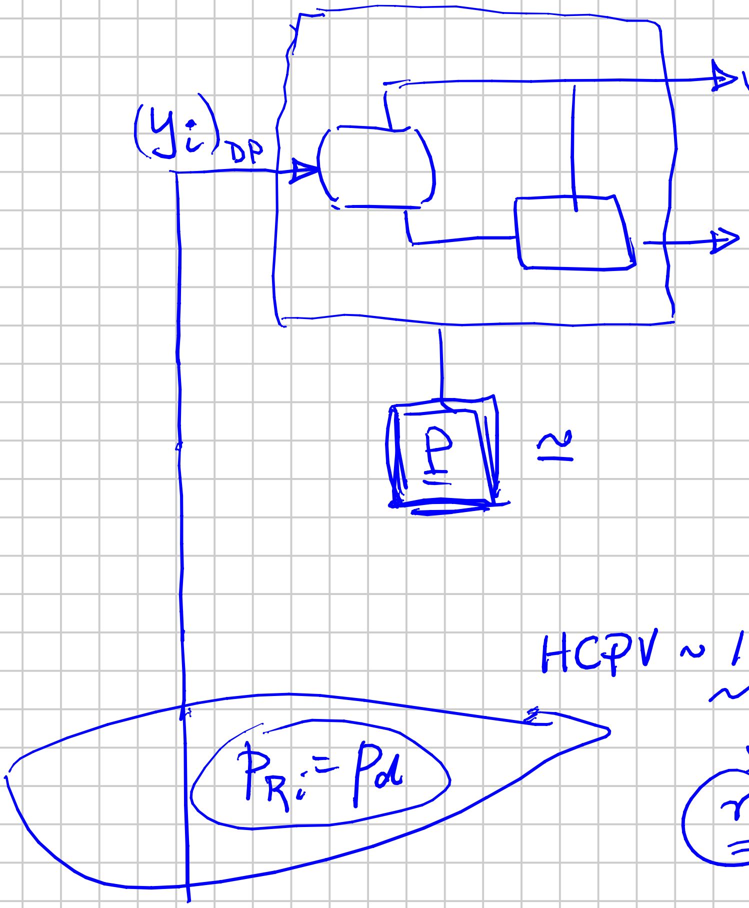
$Z_g(P, y_{i(P)})$

$$("n_p")_j = \left(\sum_{k=2}^{j} \Delta n_{pk}\right) / n_d$$

$$S_L = \frac{V_o}{V_d} \%$$

$$(\gamma_{C_{7+}}) = \frac{(\rho_{C_{7+}})_{\text{Liquid at STC}}}{\rho_{\bar{w}}}$$ Estimated usually

Example Application of the Data:



$2 \cdot 10^6\ Sm^3/d$ "y_{5-}" ($\bar{g}$)

$q_{\bar{o}}$? "y_{6+}" ($\bar{o}$)

$$pV = nRT_R Z_g$$

$HCPV \sim 10^9\ m^3$ → IGIP (Sm^3, Mscf); IOIP (Sm^3, STB)

$$n_R = \frac{P_{Ri} \cdot HCPV}{R\, T_R\, Z_{gd}}$$

Example:

$$q_{gm} = \frac{2.0 \cdot 10^6\ Sm^3/d}{23.68\ (Sm^3/\text{Kg-mole})} = 84.5 \cdot 10^3\ \text{Kg-mole/d}$$

C_{5-} stream

$$q_{om} =$$

$$\frac{C_{5-}}{C_{6+}} \quad \frac{q_{gm}}{q_{om}} = \frac{\overset{(90,70)}{100 - 9.30}}{(9.30)} = 9.75$$

$$q_{om} = \frac{(q_{gm})_{Test}}{9.75} = \frac{84.5 \cdot 10^3}{9.75} = 8667 \ \frac{kg\text{-mole}}{D}$$

$$M_{\bar{o}} = \frac{[1.09(86) + 8.21(184)]}{9.30} = 172$$

$$\rho_{\bar{o}} = \frac{[\quad]}{\frac{1.09(86)}{660} + \frac{8.21(184)}{816}} = 806 \ kg/m^3$$

$$\frac{STB}{D} \qquad \frac{Sm^3}{d}$$

$$q_{\bar{o}} = q_{om} \cdot \frac{M_{\bar{o}}}{\rho_{\bar{o}}} = 8667 \ \frac{172}{806} \ \frac{Sm^3}{d}$$

$$= 1850 \ Sm^3/d$$

$$\times 6.28 \ \frac{STB}{Sm^3}$$

$$= 11{,}600 \ STB/D$$

$$\frac{q_{\bar{o}}}{q_{\bar{g}}} = \frac{1850}{2 \cdot 10^6} = 925 \ \frac{Sm^3}{10^6 Sm^3}$$

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

$$OGR = 164 \ \frac{STB}{MMscf}$$

$8 /Mscf

$109 / STB

% Value from STO ?

$$R_{\bar{g}} = 2 \cdot 10^{6} \, \cancel{Sm^3} \times 35.31 \frac{\cancel{scf}}{\cancel{Sm^3}} \times \frac{Mscf}{10^3 \, \cancel{scf}} \times \frac{\$8}{\cancel{Mscf}} = \$ \, 565{,}000$$

$$R_{\bar{o}} = 11{,}600 \; STB \times 109 \frac{\$}{STB} = \$ \, 1\,260\,000 \; (69\,\%)$$

$$\frac{1850 \; Sm^3 \; STO}{\{ [84\,500 + 8667] \; Kg\text{-}moles \}} = \frac{\bar{o} \; \underline{\underline{IOIP}} \; Sm^3}{n_{Rd}}$$

n_{Rd} ← moles initially in reservoir

$$\frac{2 \cdot 10^{6} \; Sm^3}{\{ [84\,500 + 8667] \; Kg\text{-}moles \}} = \frac{\bar{g} \; \underline{\underline{IGIP}}}{n_{Rd}}$$