

Advanced Petrophysics

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HW #5

10/19/2023

$$\begin{aligned} ① \quad R_T &= 117 \text{ ohm-cm} & a &= 1 \\ R_w &= 0.03 \text{ ohm-cm} & m &= 2 \\ S_w &= 0.2 & n &= 2 \end{aligned}$$

$$R_T = R_w \frac{a}{\phi^m S_w^n} \rightarrow \phi = \sqrt[n]{\frac{R_w}{R_T S_w^2}}$$

$$\rightarrow \phi = \sqrt[2]{\frac{0.03}{(0.2)^2 \times 117}} = 8\%$$

$$F = \frac{a}{\phi^m} = \frac{1}{(0.08)^2} = 156$$

$$\tau = F \cdot \phi = 156 \times 0.08 = 12.5$$

$$k = \frac{D^3 \phi^3}{72 \tau (1-\phi)^2} = \frac{(120 \times 10^6)^2 (0.08)^3}{(72) (12.5) (0.92)^2} = 9.679 \times 10^{-15}$$

$$k = 9.8 \text{ mD}$$

②

$$Z = \left(\frac{L_c}{L} \right)^2 = \left(\frac{\pi d/2}{D} \right)^2 = \pi^2/4$$

$$K = \frac{\phi r^2}{8Z} = \frac{\phi (d/2)^2}{8Z} = \frac{\phi d^2}{32 \pi^2/4}$$

$$K = \frac{\phi d^2}{8 \pi^2}$$

3) a) $\phi = \frac{V_{\text{pore}}}{V_{\text{bulk}}} = \frac{L \times \bar{A}_{\text{pore}}}{L \times A_{\text{bulk}}} \Rightarrow \boxed{\phi = 23\%}$

b)

$$K = \frac{\phi}{32\pi} \frac{\int_0^{\infty} f(s) s^4 ds}{\int_0^{\infty} f(s) s^2 ds}$$

(1) (2)

$$K = \frac{\phi}{32\pi} \frac{\int_2^4 s^4 ds + \int_6^{10} s^4 ds}{\int_0^4 s^2 ds + \int_6^{10} s^2 ds} = \frac{\phi}{32\pi} \left[\frac{\frac{1}{5}(4^5 - 2^5 + 10^5 - 6^5)(10^{-6})^5}{\frac{1}{3}(4^3 - 0 + 10^3 - 6^3)(10^{-6})^3} \right]$$

$\phi + \pi = 1$:

$$K = 4.3 \times 10^{-15} \left[\frac{93216}{848} \right] = 4.73 \times 10^{-13} = 479 \text{ md}$$

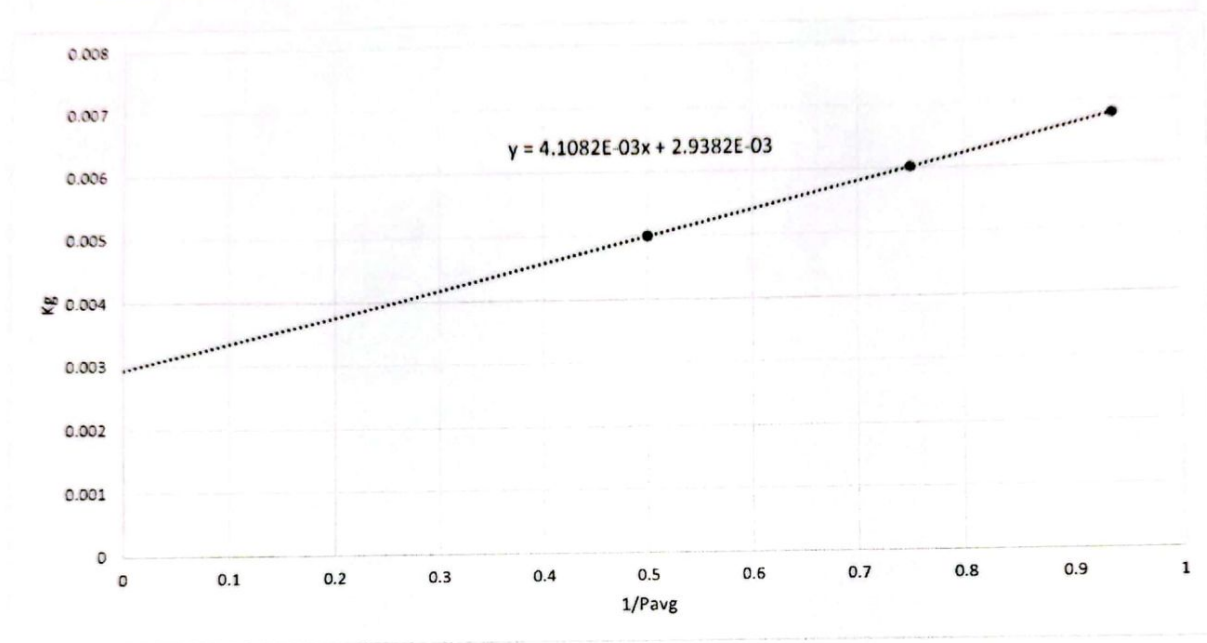
$$\boxed{k = 479 \text{ md}}$$

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Pup (mmhg)	Pup (atm)	Pdwn (atm)	q (cc/min)	q (cc/sec)	1/Pavg	Kg
101	1.132894737	1	6.4	0.106666667	0.937692782	0.006790948
507	1.667105263	1	35.6	0.593333333	0.749876665	0.006017875
1520	3	1	132.8	2.213333333	0.5	0.004992703

D	2.54	cm
L	2.54	cm
mu	0.018	
Patm	760	mmHg

Kl	0.0029382	D
	2.9382	md



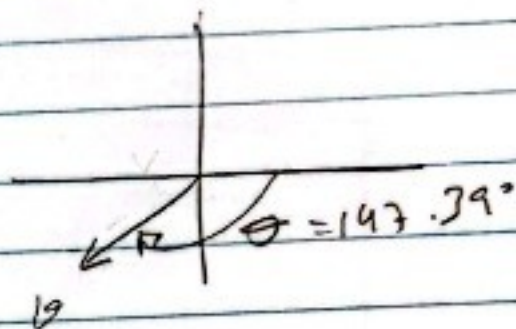
$$(5) \quad \bar{k} = \begin{bmatrix} 0.07 & 0.02 \\ 0.02 & 0.05 \end{bmatrix}, \quad \Phi = \begin{bmatrix} 0.3 \\ 0.2 \end{bmatrix} \text{ cm/cm}$$

(a)

$$\vec{v} = -\frac{\bar{k}}{\mu} \nabla \Phi = \begin{bmatrix} -0.025 \\ -0.016 \end{bmatrix}$$

$$\|\vec{v}\| = \sqrt{v_x^2 + v_y^2} \Rightarrow \|\vec{v}\| = 0.0297 \text{ cm/s}$$

$$\theta = \arccos\left(\frac{\vec{v} \cdot \vec{v}}{\|\vec{v}\|\|\vec{v}\|}\right) = 147.39^\circ$$



(b)

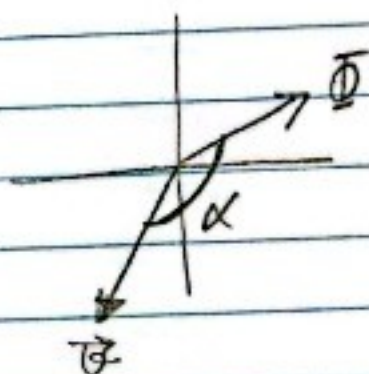
$$\alpha = \arccos\left(\frac{\vec{v} \cdot \vec{\Phi}}{\|\vec{v}\|\|\vec{\Phi}\|}\right) =$$

$$\|\vec{\Phi}\| = 0.3605$$

$$\vec{v} \cdot \vec{\Phi} = 0.3(-0.025) + (0.2)(-0.016)$$

$$v \cdot \Phi = -0.0075 - 0.0032 = -0.0107$$

$$\alpha = \arccos(-0.999) \approx 178^\circ$$



(c)

$$\begin{vmatrix} 40-\lambda & 20 \\ 20 & 50-\lambda \end{vmatrix} = (40-\lambda)(50-\lambda) - 400 = 0$$

$$3500 - 120\lambda + \lambda^2 - 400 = 0$$

$$\lambda^2 - 120\lambda + 3100 = 0$$

$$\lambda = \frac{120 \pm \sqrt{2000}}{2}$$

$$\left. \begin{array}{l} 37.64 \\ 82.36 \end{array} \right\}$$

(5 - c)

$$\det \begin{bmatrix} 40 - \lambda & 20 \\ 20 & 50 - \lambda \end{bmatrix} = 0$$

$$(40 - \lambda)(50 - \lambda) - 400 = 0$$

$$3500 + \lambda^2 - 120\lambda - 400 = 0$$

$$\lambda^2 - 120\lambda + 3100 = 0$$

$$\lambda = \frac{120 \pm \sqrt{2000}}{2} \rightarrow \lambda_1 = 37.64$$

$$\lambda_2 = 82.36$$

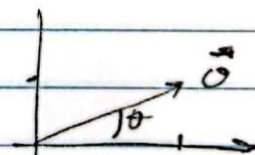
$$\bar{K}_W = \begin{bmatrix} 37.64 & 0 \\ 0 & 82.36 \end{bmatrix}$$

$$\vec{u} \Rightarrow (40 - 37.64)x + 20y = 0 \rightarrow y = -1.62x$$

$$v \Rightarrow (40 - 82.36)x + 20y = 0 \rightarrow y = 0.62x$$

$$\vec{u} = \begin{bmatrix} 1 \\ -1.62 \end{bmatrix} \quad \vec{v} = \begin{bmatrix} 1 \\ 0.62 \end{bmatrix}$$

$$\theta = \arccos\left(\frac{1}{\sqrt{1+0.62^2}}\right) = \arccos(0.851) = 31.7^\circ$$



$$\theta = 31.7^\circ$$

Maximum directional
stiffness: $K_W = 82.36 \text{ kN}$

⑥ from the drawdown plot, $m = -15.91$
 $p_{wf}(1h) = 3678$

① $K = -162.6 \frac{q B \mu}{m h}$

$\Rightarrow K = 398 \text{ mD}$

$B = 1.06$

$q = 519 \text{ stb/d}$

$r_w = 0.27 \text{ ft}$

$\phi = 22.3\%$

$\mu = 0.92 \text{ cP}$

$c_t = 1.3 \times 10^{-5}$

$p_i = 3793$

$$S = 1.1513 \left[\frac{p_{wf,1h} - p_i}{\left(\frac{-162.6 q B \mu}{K h} \right)} - \log \left(\frac{K}{\phi \mu q r_w^2} \right) + 3.23 \right]$$

$S = 1.32$

$P = 3787 \text{ psi}$

from the long term response of the buildup.

② It is damaged, because $S > 0$.

③

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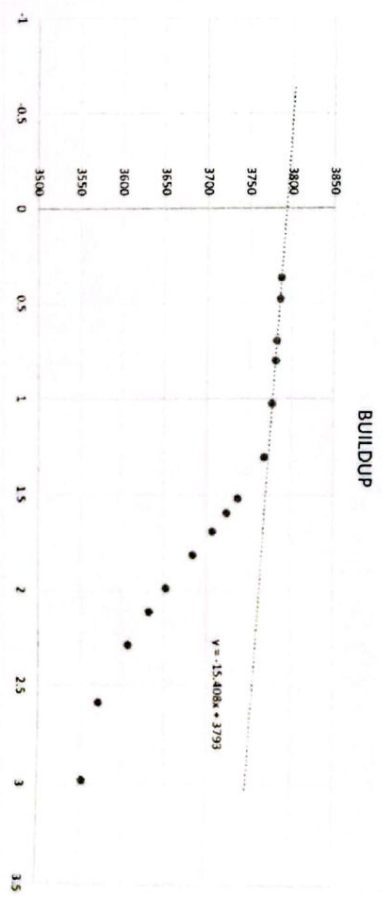
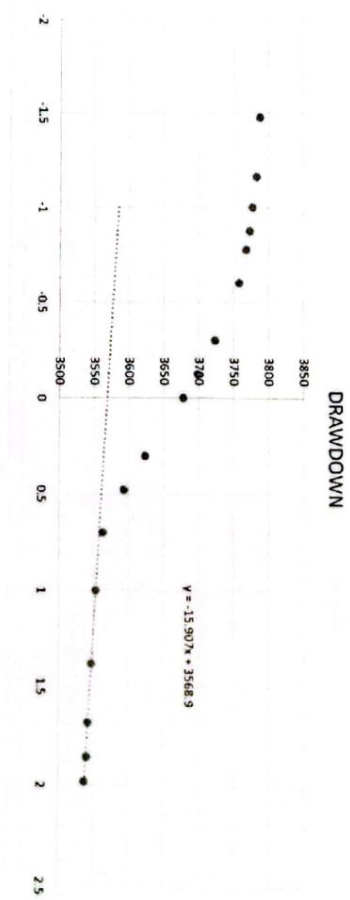
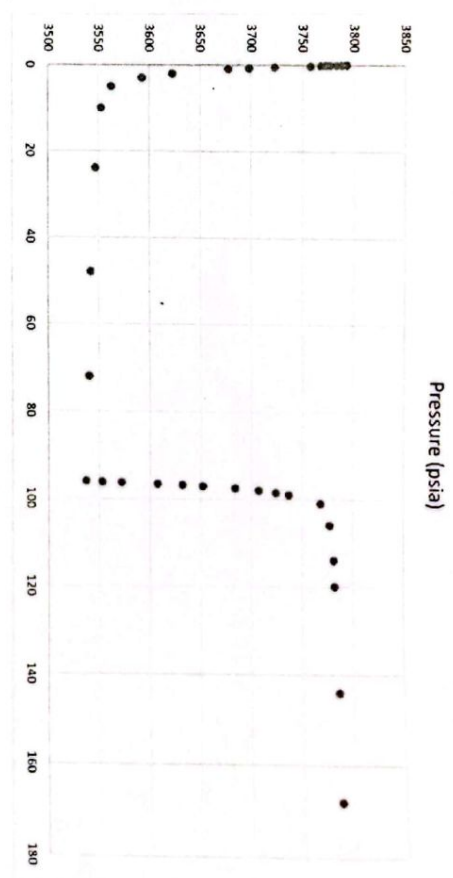
dp	96
m	-15.907
B	1.06
Q	519
RW	0.27
FOR	22.30%
MLU	0.92
CT	1.30E-05
H	13
K	397.9696548
BU - M	-15.408
	410.8582099
Skid	1.32E+00

Time (hrs)	Pressure (psia)	Delta T	log(ct)
0	3793	0	
0.0334	3788	0.0334	-1.476254
0.0688	3783	0.0688	-1.162412
0.1	3777	0.1	-1
0.133	3773	0.133	-0.876148
0.167	3768	0.167	-0.777284
0.25	3758	0.25	-0.60206
0.5	3723	0.5	-0.30103
0.75	3698	0.75	-0.124939
1	3678	1	0
2	3623	2	0.30103
3	3599	3	0.477121
5	3563	5	0.69897
10	3553	10	1
24	3547	24	1.380211
48	3542	48	1.681241
72	3540	72	1.857332
96	3537	96	1.982771

dp	dpdt
0	5
	2202.65
	3028.746
	2080.347
	2316.12
	1176.819
	540.9023
	340
	260
	124
	70
	35
	230
	15.28571
	2.022556
	0.434054
	0.210069
	-0.136285

96	3537	0
96.1	3553	0.1
96.25	3572	0.25
96.5	3607	0.5
96.75	3622	0.75
97	3652	1
97.5	3664	1.5
98	3707	2
98.5	3724	2.5
99	3737	3
101	3768	5
106	3777	10
114	3781	18
120	3782	24
144	3786	48
168	3787	72

HORNER T log(h)	
961	2.982723
385	2.585461
193	2.285557
129	2.11059
97	1.986772
65	1.812913
49	1.690196
39.4	1.595496
33	1.518514
20.2	1.305351
10.6	1.025306
6.333333	0.801632
5	0.69897
3	0.477121
2.333333	0.367977



④

@ Bulk area: $\pi \cdot 25^2 = 625\pi$

Tube area: $\pi (3^2 + 4 \times (3/2)^2) = 11.25\pi$

$\phi = \frac{11.25}{625} \rightarrow \boxed{\phi = 2.9\%}$

⑤

$k = 4 \times k_1 + k_2$

$\phi_1 = \left(\frac{3}{2}\right)^2 / 625 = 0.0036$

$\phi_2 = 3^2 / 625 = 0.0144$

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$k_1 = \frac{\phi_1 r_1^2}{8 \cdot z} = 1026 \text{ D}$

$k_2 = \frac{\phi_2 r_2^2}{8 \cdot z} = 16,415 \text{ D}$

$\boxed{k = 2.05 \times 10^4 \text{ D}}$

⑥

$S_1 = \frac{2\pi \cdot 3/2}{625\pi} = 0.0048$

$S_2 = \frac{2\pi \cdot 3}{625\pi} = 0.0096$

$S = 4S_1 + S_2$
 $\boxed{S = 0.0288 \text{ mm}^2/\text{mm}^3}$