Advanced Petrophysics Fall 2023

Renato Poli: rap2656

HW#5 10/19/2023

(1) $R_T = 117$ ohm-m $\quad a = 1$

$R_w = 0.03$ ohm.m $\quad m = 2$

$S_w = 0.2$ $\quad n = 2$

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

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

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

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

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

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

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② $$z = \sqrt{\frac{L_e}{L}} = \sqrt{\frac{2\pi D/2}{D}} = \sqrt{\pi}$$

$$k = \frac{\phi r^2}{8z} = \frac{\phi (d/2)^2}{8z} = \frac{\phi d^2}{32\sqrt{\pi}}$$

$$\boxed{k = \frac{\phi d^2}{32\sqrt{\pi}}}$$

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(3)

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

(b)

$$K = \frac{\phi}{32\tau^2} \frac{\int_0^\infty f(\delta)\delta^4 d\delta}{\int_0^\infty f(\delta)\delta^2 d\delta} \quad \begin{matrix} (1) \\ (2) \end{matrix}$$

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

$\underline{\phi + \tau = 1}$:

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

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

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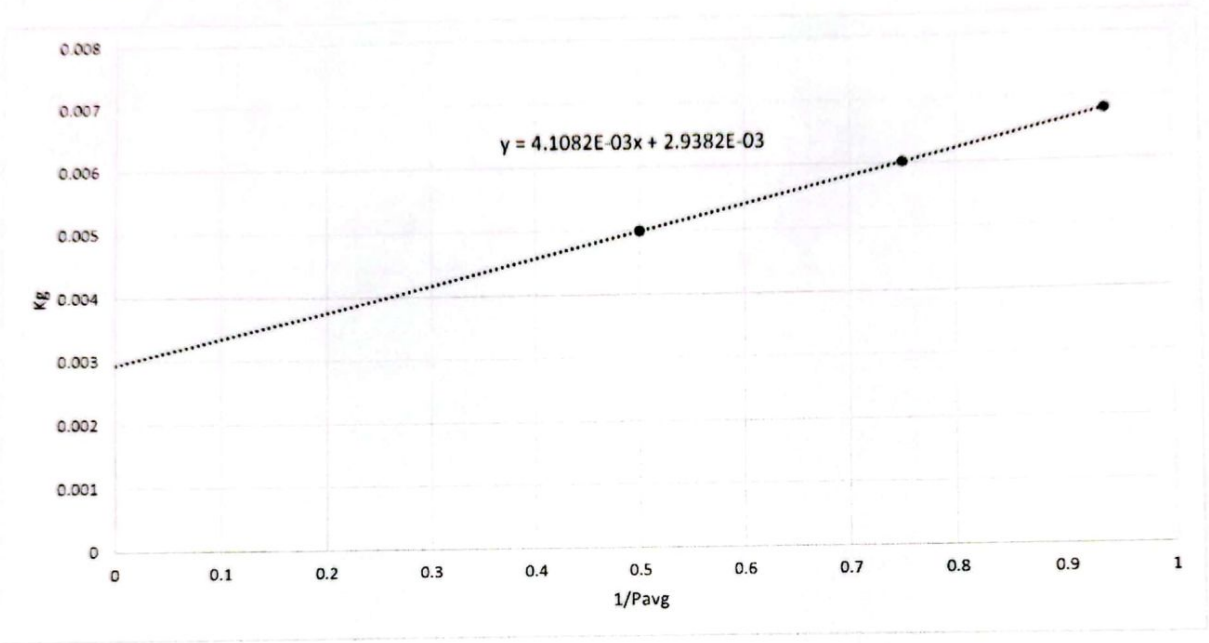
(4)

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

KI	0.0029382	D
	2.9382	md



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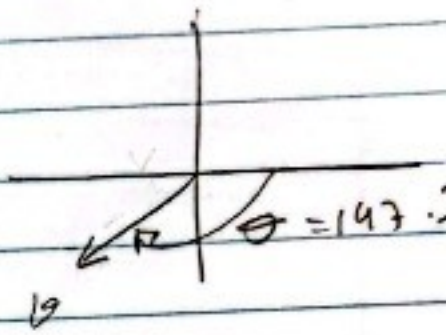
(5) $\bar{\bar{k}} = \begin{bmatrix} 0.07 & 0.02 \\ 0.02 & 0.05 \end{bmatrix}$ D $\Phi = \begin{bmatrix} 0.3 \\ 0.2 \end{bmatrix}$ atm/cm

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

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

$\boxed{\theta = \arccos\left(\frac{\vec{v}\cdot\vec{i}}{|\vec{v}||\vec{i}|}\right) = 147.39°}$



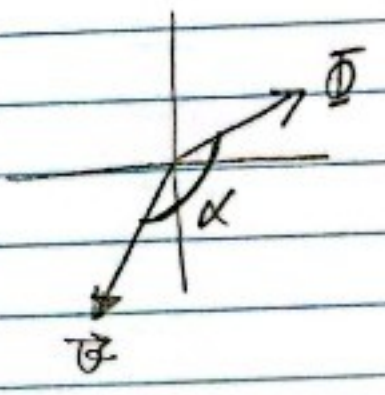
(b) $\alpha = \arccos\left(\frac{\vec{v}\cdot\vec{\Phi}}{|\vec{v}||\vec{\Phi}|}\right) =$

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

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

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

$\boxed{\alpha = \arccos(-0.999) \cong 178°}$



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

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

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

$\lambda = \frac{120 \pm \sqrt{2000}}{2}$ $\begin{matrix} 37.64 \\ 82.36 \end{matrix}$

5 - c

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

$$(40-\lambda)(50-\lambda) - 400 = 0$$
$$3500 + \lambda^2 - 120\lambda - 400 = 0$$
$$\lambda^2 - 120\lambda + 3100 = 0$$

$$\lambda = \frac{120 \pm \sqrt{2000}}{2} \rightarrow \lambda_1 = 37.64$$
$$\lambda_2 = 82.36$$

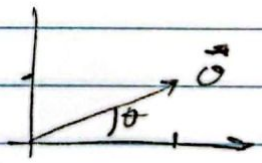
$$\bar{K}_w = \begin{bmatrix} 37.64 & 0 \\ 0 & 82.36 \end{bmatrix}$$

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

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

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

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



$\theta = 31.7°$

Maximum directional permeability: $K_v = 82.36$ mD

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(6) From the drawdown plot, $m = -15.91$

$p_{wf}(1h) = 3678$

(a) $k = -162.6 \frac{qB\mu}{mh}$

$B = 1.06$

$q = 519$ stb/d

$r_w = 0.27$ ft

$\phi = 22.3\%$

$\mu = 0.92$ cp

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

$p_i = 3793$

$\rightarrow \boxed{k = 398 \text{ mD}}$

$$S = 1.1513 \left[\frac{p_{wf1h} - p_i}{\left(\frac{-162.6\, qB\mu}{kh}\right)} - \log\left(\frac{k}{\phi\mu c_t r_w^2}\right) + 3.23 \right]$$

$\boxed{S = 1.32}$

$\boxed{\bar{p} = 3787 \text{ psi}}$ from the long term response of the buildup.

(b) It is damaged, because $S_{skin} > 0$.

(c)

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(6)

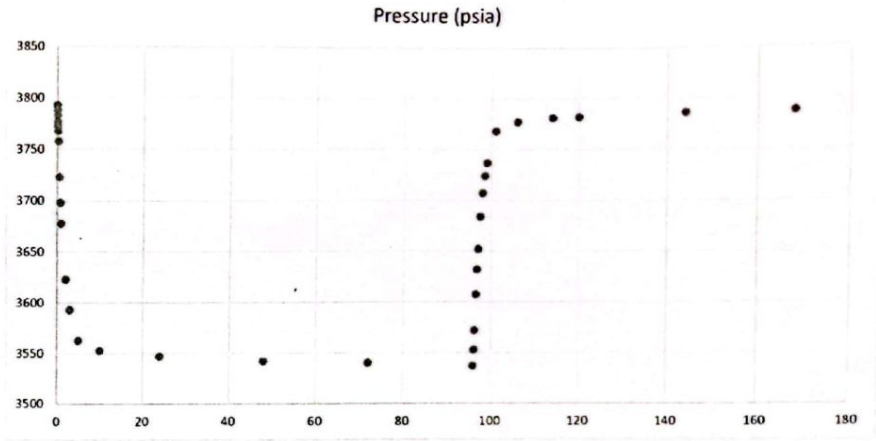
tp	96
m	-15.907
B	1.06
Q	519
RW	0.27
POR	22.30%
MU	0.92
CT	1.30E-05
H	13
K	397.9696548
BU - M	-15.408
	410.8582099
Skin	1.32E+00

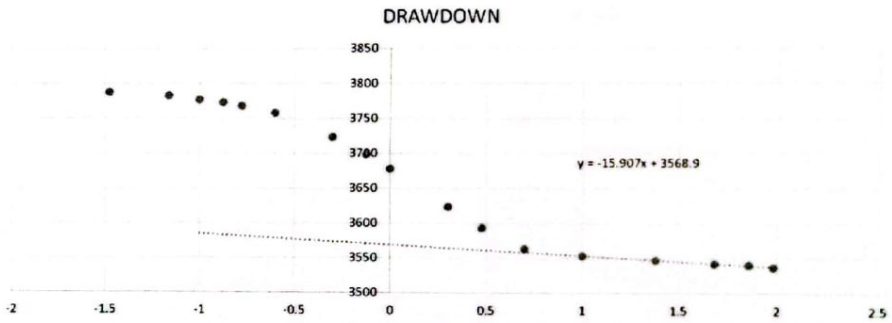
Time (hrs)	Pressure (psia)	Delta T	log(dt)
0	3793	0	
0.0334	3788	0.0334	-1.476254
0.0688	3783	0.0688	-1.162412
0.1	3777	0.1	-1
0.133	3773	0.133	-0.876148
0.167	3768	0.167	-0.777284
0.25	3758	0.25	-0.60206
0.5	3723	0.5	-0.30103
0.75	3698	0.75	-0.124939
1	3678	1	0
2	3623	2	0.30103
3	3593	3	0.477121
5	3563	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	1.982271

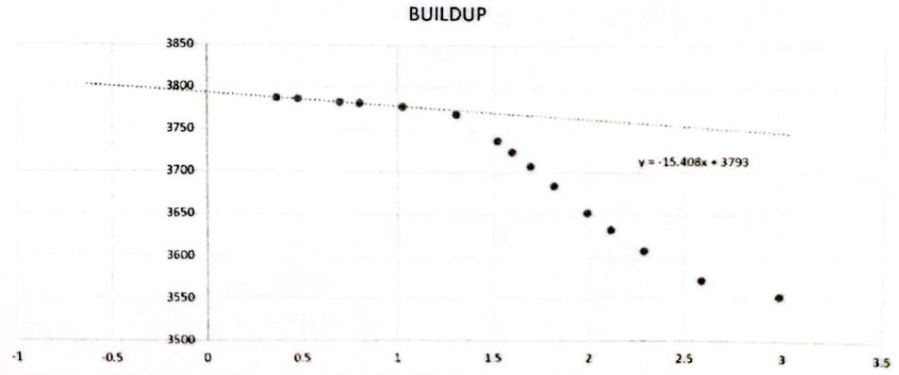
dp	dpdt
0	
5	2202.65
10	3028.746
16	2080.347
20	2316.12
25	1176.819
35	540.9023
70	340
95	260
115	124
170	70
200	35
230	15.28571
240	2.022556
246	0.434054
251	0.210069
253	-0.136285

96	3537	0
96.1	3553	0.1
96.25	3572	0.25
96.5	3607	0.5
96.75	3632	0.75
97	3652	1
97.5	3684	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 TI	log(ht)		
961	2.982723	16	666.6667
385	2.585461	35	476.6667
193	2.285557	70	340
129	2.11059	95	260
97	1.986772	115	165.3333
65	1.812913	147	110
49	1.690196	170	80
39.4	1.595496	187	60
33	1.518514	200	32.2
20.2	1.305351	231	15.75714
10.6	1.025306	240	1.838462
6.333333	0.801632	244	0.511905
5	0.69897	245	0.172222
3	0.477121	249	0.167535
2.333333	0.367977	250	







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(7)

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

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

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

(5)

$k = 4 \times k_1 + k_2$

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

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

$\tau = 1$

$k_1 = \frac{\phi_1 r_1^2}{8\tau} = 1026\ D$

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

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

(c)

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

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

$S = 4S_1 + S_2$

$\boxed{S = 0.0288\ mm^2/mm^3}$

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