S A&M UNIVERSITY
spe
TOPS PRINTING
College Station, TX

PROBLEM # 1

Refer to Example 2-8 and Figure 2-32 on page 75-76 of ABW. Assume that the solids removed during filtering alter the permeability of the bed and that the alteration is reversal, making it necessary to remove the solids periodically by reversing the flow; that is, by flowing the water vertically upward through the bed. What head of water is required to remove the solids if the reverse flow rate is (a) 5000 gallons/hr, and (b) 1000 gallons/hr?

THEORY

$$\frac{q_s}{A} = -\frac{k}{\mu}\left(\frac{dp}{ds} - \rho g \frac{dz}{ds}\right), \quad z^+ \downarrow$$

SOLUTION

comparison of Eqs. 2-23 and 2-24

$$q = \frac{kA}{\mu}\rho g\left(\frac{h}{L}+1\right) \downarrow \quad \text{and} \quad q = \frac{kA}{\mu}\rho g\left(\frac{h}{L}\right) \uparrow$$

a) Using the data of Ex 2-8, the value of $\left(\frac{h}{L}\right)$ for upward flow is 2.72 or

$$\frac{h}{L} = 2.72 \Rightarrow \underline{h = 10.9 \text{ ft}}$$

b) when the rate is 1000 gallons/hr

$$\frac{h}{L} = (0.2)(2.72) = 0.54 \Rightarrow h = \underline{2.18 \text{ ft}}$$

CHECK

$$\left(\frac{h}{L}\right) = \frac{q\mu}{kA\rho g} = \left|\frac{5000 \text{ gal}}{\text{hr}}\right|\frac{1 \text{ cp}}{1 \text{ g/cm}^3}\left|\frac{1}{1.2 \text{ d}}\right|\frac{1}{980 \text{ cm/s}^2}\left|\frac{\text{gm-cm/s}^2}{\text{dyne}}\right|$$

$$\cdot\left|\frac{1.01325\times10^6 \text{ dyne/cm}^2}{\text{atm}}\right|\frac{3785.41 \text{ cm}^3}{\text{gal}}\left|\frac{\text{h}}{3600 \text{ s}}\right|\frac{1}{1600 \text{ ft}^2}\left|\frac{\text{ft}^2}{(30.48)^2 \text{ cm}^2}\right| =$$

2.70885

AS A&M UNIVERSITY
spe
TOPS PRINTING
College Station, TX

PROBLEM # 2

Derive an equation for horizontal, radial flow of an incompressible liquid from a general radius r to the radius of the wellbore, $r = r_w$. List the assumptions made. Graph the pressure at a general radius r, as a function of radius (r = 0.1 to 1000 m). For graphing purposes, assume $q\mu/(2\pi kh)$ = 5.0 atmospheres and the flowing pressure at the wellbore is 50 atmospheres. What do you conclude from your graph?

THEORY

$$\frac{q_s}{A} = -\frac{k}{\mu}\left(\frac{dp}{ds} - \rho g \frac{dz}{ds}\right), \quad z^+ \downarrow$$

SOLUTION

1) Assumptions

- Darcy's Law (darcy flow, ss flow, non-reactive fluid, single phase ($S=1$))
- PVT (incompressible liquid, isothermal conditions)
- Geometry (radial flow, $ds = -dr$, $A = 2\pi rh$ (h const), $\frac{dz}{ds} = 0$)

2) $v_s = \frac{q_s}{A} = -\frac{k}{\mu}\left(\frac{dp}{ds} - \frac{\rho g}{c}\frac{dz}{ds}\right)$

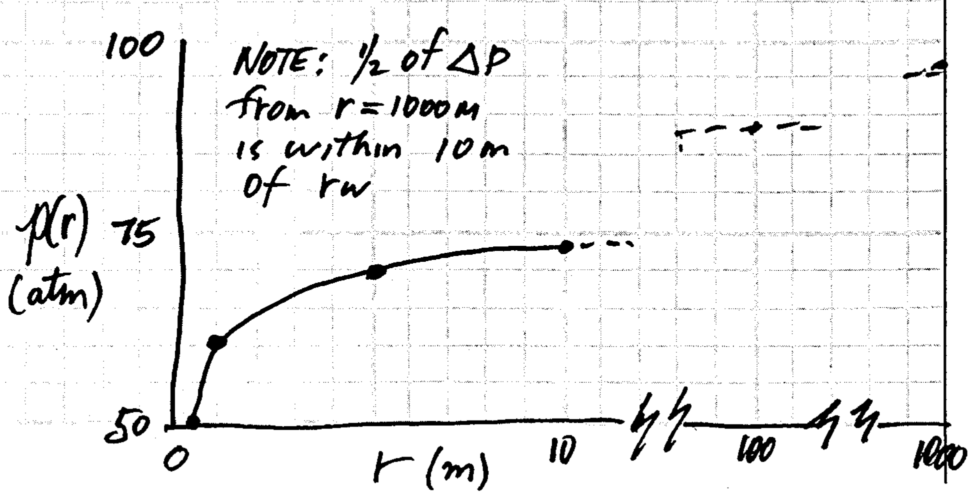
$$q_r = 2\pi r h \frac{k}{\mu}\frac{dp}{dr}$$

3) Separate variables & integrate $r_w \to r$, $p_w \to p(r)$

$$q_r \int_{r_w}^{r} \frac{dr}{r} = \frac{2\pi k h}{\mu}\int_{p_w}^{p(r)} dp \Rightarrow p(r) = p_w + \frac{q_r \mu}{2\pi k h}\ln\left(\frac{r}{r_w}\right)$$

4)

r	p(r)
0.1 = r_w	50
1	61.5
10	73.0
100	84.5
1000	96.1



AS A&M UNIVERSITY

spe

PROBLEM # 3

Calculate real gas pseudopressure at a pressure of 1902.7 psia using the following data and a base pressure of 102.7 psia. Was the calculation of real gas pseudopressure necessary for this gas? Explain your answer.

p (psia)	z	μ_g (cp)
1902.7	0.87155	0.0164
1602.7	0.88030	0.0153
1302.7	0.89426	0.0144
1002.2	0.91298	0.0136
702.7	0.93565	0.0129
402.7	0.96155	0.0123
102.7	0.98987	0.0120

THEORY

$$m(p) = 2\int_{p_b}^{p} \frac{p}{\mu z}\, dp$$

SOLUTION

pressure	z-factor	viscosity	μz	$2p/\mu z$	Area	m(p)
psia		cp	cp	psia/cp	$psia^2/cp$	$psia^2/cp$
1902.7	0.87155	0.0164	0.0143	2.66E+05	7.56E+07	2.78E+08 ←
1602.7	0.88030	0.0153	0.0135	2.38E+05	6.60E+07	2.03E+08
1302.7	0.89426	0.0144	0.0129	2.02E+05	5.47E+07	1.37E+08
1002.2	0.91298	0.0136	0.0124	1.61E+05	4.16E+07	8.21E+07
702.70	0.93565	0.0129	0.0121	1.16E+05	2.77E+07	4.05E+07
402.70	0.96155	0.0123	0.0118	6.81E+04	1.28E+07	1.28E+07
102.70	0.98987	0.0120	0.0119	1.73E+04	0.00E+00	0.00E+00

Note that $\mu z \approx$ constant $= 0.0131$ cp and

$$\int_{p=107.7}^{p=1902.7} \frac{2p}{\mu z}\, dp \approx \frac{2}{0.0131}\left[\frac{(1902.7)^2-(102.7)^2}{2}\right]$$

$$= 2.76 \times 10^8 \ psia^2/cp$$

CONCLUSION

$m(1902.7) = 2.78 \times 10^8 \ psia^2/cp$

Not necessary in this case because $\mu z \approx$ constant

TOPS PRINTING College Station, TX

(AS A&M UNIVERSITY
spe

PROBLEM # 4

Find the required constant and its units to convert the Darcy equation for linear, horizontal flow

$$q = \frac{kA\Delta p}{\mu L}$$

to the following unit system ($q, k, L, A, \Delta p, \mu$): liters per minute, millidarcy, centimeters, centimeters squared, dynes/square centimeter, and centipoise.

THEORY

Convert the units of the "hidden constant"

SOLUTION

"1" has units $\dfrac{cp \cdot cm^2}{d \cdot atm \cdot s}$

$$\frac{1\ cp \cdot cm^2}{d \cdot atm \cdot s} \cdot \frac{d}{10^3\ md} \cdot \frac{atm}{1.01325 \times 10^6\ dynes/cm^2} \cdot \frac{cm}{cm} \cdot \frac{liter}{10^3\ cm^3} \cdot \frac{60\ s}{min} =$$

$$5.9215 \times 10^{-11}\ \frac{cp \cdot liter}{md \cdot dynes/cm^2 \cdot min \cdot cm}$$

TOPS PRINTING
College Station, TX