Suggested solution to the re-sit exam in Welltest Analysis, Dec. 6, 2011

Problem 1

a) A rough estimate based on the plot is that the derivatives will level off at 70 psi, and hence that we can set

$$70 \approx \left|\frac{d\Delta p}{d\ln\Delta t}\right| = \left|\frac{d\Delta p}{\ln(10) d\log\Delta t}\right| = \frac{m}{2.3026},$$

$$m \approx (70)(2.3026) = 161.2 \text{ psi/log-cycle},$$

and therefore

$$kh = \frac{162.6 qB\mu}{m} \approx \frac{(162.6)(1100)(1.23)(0.85)}{161.2} = 1160 \text{ md·m}$$

and

$$k = \frac{kh}{h} \approx \frac{1160}{200} = 5.8 \text{ md.}$$

b) For a large drainage area (and short flow) we can assume that the Horner straight line will extrapolate to the initial pressure, and hence that

$$p^* = p_i = 5000 \quad \text{at} \quad \log\frac{\infty}{t+\infty} = 0.$$

From the last buildup pressure listed we can therefore estimate the semilog slope by setting

$$m \approx \frac{5000 - 4808.09}{0 - \log(12/(240+12))} = 145.14 \text{ psi/log-cycle},$$

and therefore

$$kh = \frac{162.6 qB\mu}{m} \approx \frac{(162.6)(1100)(1.23)(0.85)}{145.14} = 1288.4 \text{ md·m}$$

and

$$k = \frac{kh}{h} \approx \frac{1288.4}{200} = 6.44 \text{ md.}$$

The pressure p_{1hr} at $\Delta t = 1$ hr can be determined by extrapolation from the pressure $p_{ws} = 4808.09$ psi at $\Delta t = 12$ hrs as follows:

$$p_{1hr} = 4808.09 + m\left\{\left[\log 1/(240+1)\right] - \log\left[12/(240+12)\right]\right\}$$

$$= 4808.09 + 145.14(-2.38202 + 1.32222) = 4808.09 - 153.82 = 4654.27 \text{ psi.}$$

The skin value can next be determined from the formula

$$S = 1.151\left(\frac{p_{1hr} - p_{wf,s}}{m} - \log\frac{t}{t+1} - \log\frac{k}{\phi\mu c_t r_w^2} + 3.23\right)$$

$$= 1.151\left[\frac{4654.27 - 2809.15}{145.14} - \log\frac{240}{240+1} - \log\frac{6.44}{(0.24)(0.85)(4\times10^{-5})(0.354)^2} + 3.23\right]$$

$$= 1.151(12.7127 + 0.0018 - 6.7992 + 3.23) = 10.53.$$

The added pressure drop at the wellbore can now also be computed as

$$\Delta p_S = \frac{m}{1.151}S = \frac{145.14}{1.151}(10.53) = 1327.82 \text{ psi.}$$

c) We clearly have storage dominated data in the beginning of the buildup, and hence can use the first two points from Table 2 to determine the slope

$$m' = \frac{2810.93 - 2810.57}{0.0013 - 0.0010} = \frac{0.36}{0.0003} = 1200 \text{ psi/hr,}$$

which in turn yields the storage constant

$$C = \frac{qB}{24m'} = \frac{(1100)(1.23)}{(24)(1200)} = 0.047 \text{ RB/psi.}$$

d) The radius of investigation at the end of the buildup is given by

$$r_{inv} = 0.0246\sqrt{\frac{k\Delta t}{\phi\mu c_t}} = 0.0246\sqrt{\frac{(6.44)(12)}{(0.24)(0.85)(4\times10^{-5})}} = 75.7 \text{ ft.}$$

Since 240 = 12*20, the radius of investigation after the flow period (240 hrs) will be

$$r_{inv} = 75.7\sqrt{20} = 338.5 \text{ ft.}$$

It follows that a sealing fault 500 ft from the well will not affect data within 240 hrs of flow.

e) If the skin value could be reduced to 0, the flowing pressure at the time of shut-in would be

$$p_{wfs,new} = p_{wfs,old} + \Delta p_{S,old} = 2809.15 + 1327.82 = 4136.97 \quad \text{psi},$$

f) Even with flow stopped early, and in the storage dominated period, the late-time buildup data will approach the expression

$$p_{ws}(\Delta t) = \frac{m}{1.151}\left[p_{wD}(t_D + \Delta t_D) - p_{wD}(\Delta t_D)\right] = \frac{m}{1.151}\frac{1}{2}\ln\frac{t_D + \Delta t_D}{\Delta t_D} = m\log\frac{t + \Delta t}{\Delta t} \ ,$$

with the proper semilog slope obtained if the gauge is accurate enough.

<u>Problem 2</u>

a) Since the key identity used to determine x_f takes the form

$$x_f = \frac{4.064qB}{hm'}\sqrt{\frac{\mu}{k\phi c_t}} = 470 \ \text{ft},$$

it follows that a change in thickness from 86 to 38 ft must be followed with a change in length from 470 ft to

$$x_f = \frac{(470)(86)}{38} = 1064 \ \text{ft}$$

if the permeability is kept unchanged. If the flow capacity is kept unchanged, then we get a new permeability

$$k = \frac{1.29}{38} = 0.034 \ \text{md},$$

and hence must update the half-length to

$$x_f = \frac{(470)(86)\sqrt{0.015}}{38\sqrt{0.034}} = 706.5 \ \text{ft}.$$

b) From the identity above it follows that the half-length must be changed to

$$x_f = \frac{470\sqrt{0.06}}{\sqrt{0.12}} = 332.3 \ \text{ft}$$

with a change in porosity from 0.06 to 0.12.

c) The area will extend from the axis made up of the fracture. Assume original results, with radius of investigation

$$r_{inv} = 0.0246\sqrt{\frac{kt}{\phi\mu c_t}} = 0.0246\sqrt{\frac{(0.015)(72)}{(0.06)(0.024)(9.2\times10^{-5})}} = 70.24\,\text{ft}$$

at 72 hrs. The area will be made up of a rectangle of width

$$2r_{inv} = (2)(70.24) = 140.48 \text{ ft}$$

and length

$$2x_f = (2)(470) = 940 \text{ ft,}$$

plus two half-circles of radius equal to the radius of investigation. The total area is therefore

$$A = 2r_{inv}2x_f + \pi r_{inv}^2 = (140.48)(940) + \pi 70.24^2 = 147551 \text{ sqft.}$$

Problem 3

a) Since the pressures are low we need to use a pressures-squared formulation. Therefore, if we use the first and the last transient points we get

$$\frac{\Delta p^2}{q} = \frac{131.21^2 - 125.41^2}{424750} = \frac{1488.396}{424750} = 0.0035\,.$$

and

$$\frac{\Delta p^2}{q} = \frac{131.21^2 - 114.51^2}{771630} = \frac{4103.524}{771630} = 0.00532$$

From these we get the slope

$$b = \frac{0.00532 - 0.0035}{771630 - 424750} = 5.247E - 9\,.$$

From the stable flow point

$$\frac{\Delta p^2}{q} = \frac{131.21^2 - 112.61^2}{652420} = \frac{4535.05}{652420} = 0.00695$$

we can next determine

$$a = 0.00695 - (5.247E - 9)(652420) = 0.00353\,.$$

The deliverability of the well will therefore be given by the identity

$$\overline{p}^2 - p_{wf}^2 = aq + bq^2 = 0.00353q + (5.247E-9)q^2 .$$

We furthermore get the open flow potential

$$\text{AOF} = \frac{1}{(2)(5.247E-9)}\left[-0.00353 + \sqrt{0.00353^2 + (4)(5.247E-9)(131.21^2)}\right] = 1505974 \text{ m}^3\text{/d.}$$

b) The points above can be re-used here, i.e., we can use the transient values

$$\Delta p_1^2 = 131.21^2 - 125.41^2 = 1488.396$$

and

$$\Delta p_2^2 = 131.21^2 - 114.51^2 = 4103.524$$

to determine the slope

$$\frac{1}{n} = \frac{\log \Delta p_2^2 - \log \Delta p_1^2}{\log q_2 - \log q_1} = \frac{\log(4103.524) - \log(1488.396)}{\log(771630) - \log(424750)} = 1.69873,$$

and hence the exponent $n = 0.5887$ for the back-pressure equation $q = C(\overline{p}^2 - p_{wf}^2)^n$. Using the stable point we next get

$652420 = C(131.21^2 - 112.61^2)^{0.5887} = C(142.112)$, and therefore $C = 4590.9$ with

$$AOF = C(\overline{p}^2)^n = (4590.9)(131.21^2)^{0.5887} = 1430843 \text{ m}^3\text{/d.}$$