Petroleum and Mining Engineering College
Department of Petroleum Reservoir Engineering
Third stage
Petroleum Product Engineering
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8:30 Am

Flow efficiency

$$F = \frac{I \quad P \quad d \quad which\ i \ r \quad t\ p \quad c \quad r \quad f \quad the\ w}{A \quad P \quad d \quad which\ i\ r \quad t\ p \quad s \quad r \quad f \quad sa \quad w}$$

$$\Delta p\,(a \quad) = \Delta p\,(T \quad) = \Delta p\,(I \quad) + \Delta p\,(s \quad)$$

Or

$$(p_e - p_{wf})_{actual} = (p_e - p_{wf})_{total} = (p_e - p_{wf})_{ideal} + (\Delta p)_{skin}$$

Then

$$F = \frac{(p_e - p_{wf})_a \quad - (\Delta p_s \quad)_t \quad]}{[(p_e - p_{wf})_a \quad]}$$

- Ideal case (S_t = 0)

$$(Q\ )_i = 7.08 * 10^{-3}\ \frac{k * h * (p_e - p_{wf})\ i}{\mu o * B \quad * \ln({}^{r}e/r_w)}$$

- Actual case

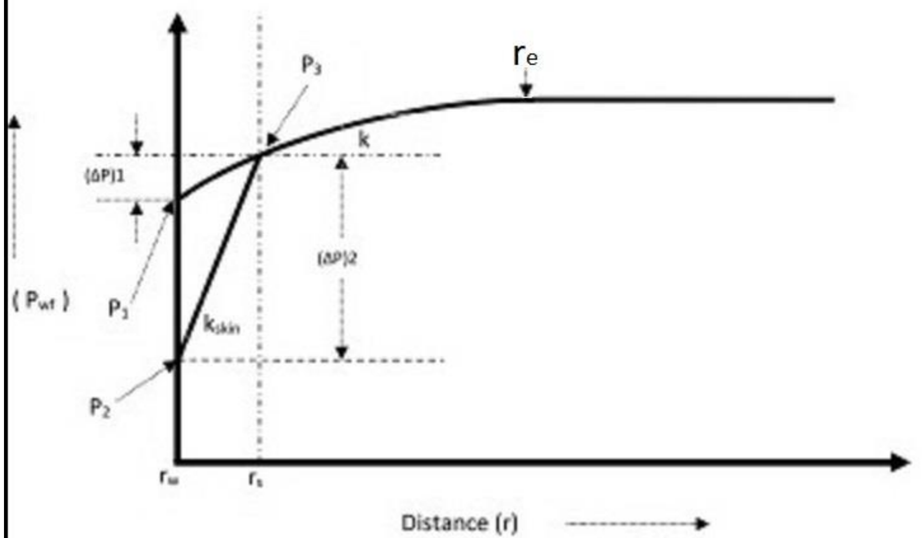
$$(Q\ )a = 7.08 * 10^{-3}\ \frac{k * h * ((p_e - p_{wf})\ a}{\mu o * B \quad * \ln({}^{r}e/r_w)}$$

$$(Q\ )a = 7.08 * 10^{-3}\ \frac{k * h * [\ (p_e - p_{wf})\ i \quad + (\Delta p\ s \quad)t}{\mu o * B \quad * \ln({}^{r}e/r_w)}$$

Or

$$(Q\ )a = 7.08 * 10^{-3}\ \frac{k * h * [(p_e - p_{wf})\ t \quad]}{\mu o * B_o * [\ln({}^{r}e/r_w) + S\ ]}$$

FE > 1 Stimulation
FE < 1 Damage
p_e = Average reservoir pressure.
p_{wf} = Flowing bottom hole pressure.



$$\Delta P\ s. = (\Delta P_2 - \Delta P_1) = (P_3 - P_2) - (P_3 - P_1) \ldots\ldots\ldots (1)$$

or

$$\Delta P\ s. = (P_1 - P_2) \ldots\ldots\ldots (2)$$

Example;

From this data:

Oil column thickness = 25 ft, ko = 100 md, μo = 0.5 cp, Perforated zone thickness = 15 ft (from upper oil zone), Radius of drainage area =660 ft, Total pressure drop = 1000 psi, well bore radius = (3/8) ft, Bo (oil formation volume factor) = 1.4 RB/STB, Perforating diameter = 2 inch, perforating (shots) density = 4 perforation(shots) / ft.

Jet guns used to perforation operation, and the bullet penetrate the casing and cement only (formation penetration = zero), and perforation phase in one side (all perforation in one side).

1- Ideal flow rate.

$(Q_o)_{ideal} = 7.08*10^{-3}\ kh\ (p_e - p_{wf})\ /\ \mu_o\ B_o \ln(r_e/r_w)$

$(Q_o)_{ideal} = 7.08*10^{-3} *100*25*1000/\ [0.5*1.4* \ln(660/0.375)$

$(Q_o)_{ideal} =$ 3383.5 STB/DAY.

2- Actual flow rate.

$(Q_o)_{actual} = 7.08*10^{-3}\ kh\ (p_e - p_{wf})\ /\ \mu_o\ B_o\ \{\ln(r_e/r_w) + St\}$

$St = S_{fm} + (S_c)_{cor} + S_{PP}$

$S_{fm} = 0 \rightarrow$ no information

$S_{PP} \rightarrow$

$ht//r_w = 25/0.375 = 66.67$

$hp/ht = 15/25 = 0.6$

From figure (1-40) $S_{PP} = 1.7$

$(S_c)_{cor} \rightarrow$

From figure (1-42) $(S_c)_{chart} = 4.25$

$(S_c)_{cor} = (S_c)_{chart}\ \ (h_t / h_p)$

$(S_c)_{cor} = 4.25*\ \ (25 / 15) = 6.88$

So:

$S_t = 0 + 6.88 + 1.7 = 8.58$

$(Q_o)_{actual} = 7.08*10^{-3} * 100*25*1000 / 0.5*1.4\mu_o\ B_o\ \{\ln(660/0.375) + 8.58\}$

$(Q_o)_{actual} =$ 1555.4 STB/DAY

3- Pressure drop due to skin.

$(\Delta P_{skin})_{total} =\ 141.2\ \ Q_o\ \mu_o\ B_o\ /\ kh\ (S_t)$

$(\Delta P_{skin})_{total} =\ 141.2\ \ *1555.4*0.5*1.4\ /\ 100*25\ (8.58)$

$(\Delta P_{skin})_{total} =$ 528.74 psi

$FE = [\ (p_e - p_{wf}) - (\Delta P_{skin})_{total}\ ]\ /\ [\ p_e - p_{wf}\ ]$

$FE = [\ 1000 - 528.74\ ]\ /\ [\ 1000\ ]$

$FE = 0.47$

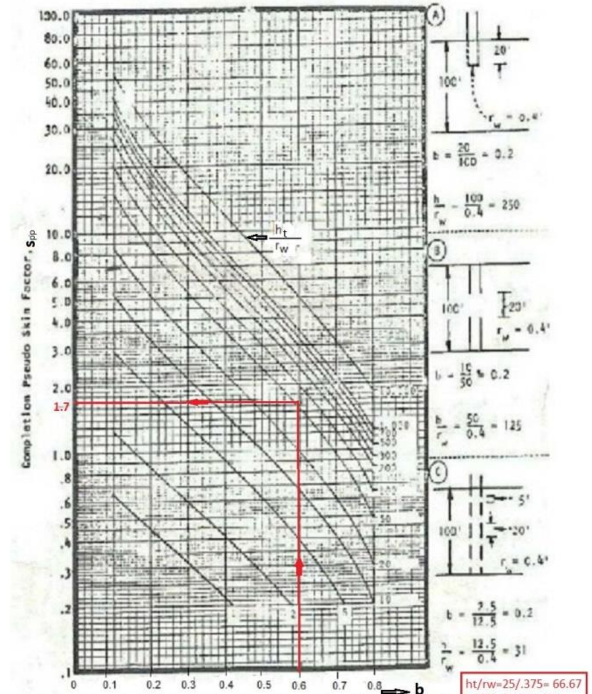
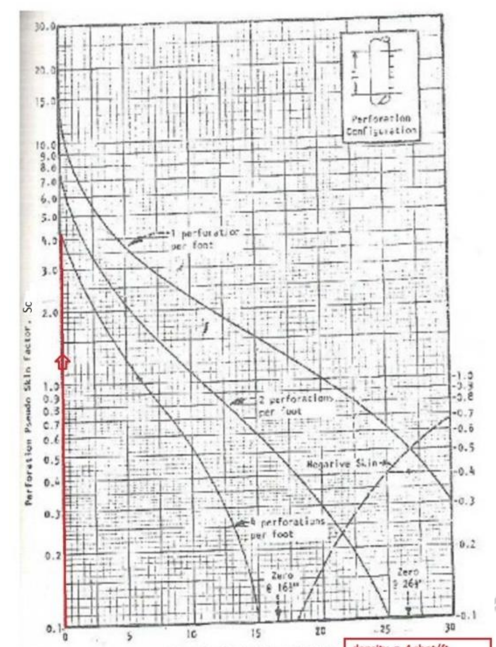


Figure – 21 skin factor due to partial penetration of the formation, S_{pp}



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