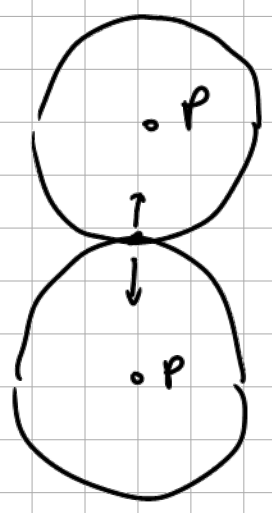
Video 09 - Skin effect for IPR of vertical, undersaturated oil well

$$q_o = \frac{kh}{(\mu_o B_o)_{av}\left(\underbrace{\ln\left(\frac{r_e}{r_w}\right)}_{s} - 0.5\right)\cdot 18.68}(p_e - p_{wf})$$

pseudo steady-state psi @ r_e → no-flow boundary



$$\int_{r_w}^{@p_e}\frac{dr}{r} = \frac{kh}{q_o\cdot 18.68}\int_{p_{wf}}^{p_e}\frac{dp}{B_o\mu_o}$$

for pss r at which $p = \bar{p}_e$ $r = 0.47\, r_e$

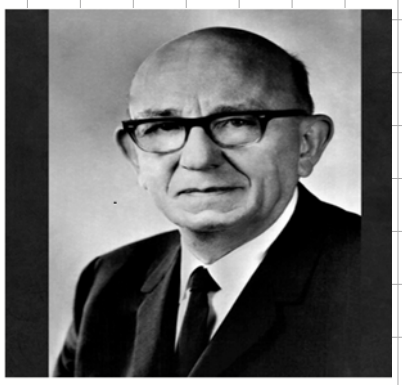
$$\ln\left(\frac{0.47\, r_e}{r_w}\right) = \ln\left(\frac{r_e}{r_w}\right) - 0.75$$

$$J = \frac{kh}{(\mu_o B_o)_{av}\left[\ln\left(\frac{r_e}{r_w}\right) - 0.75\right]18.68}$$

Skin factor

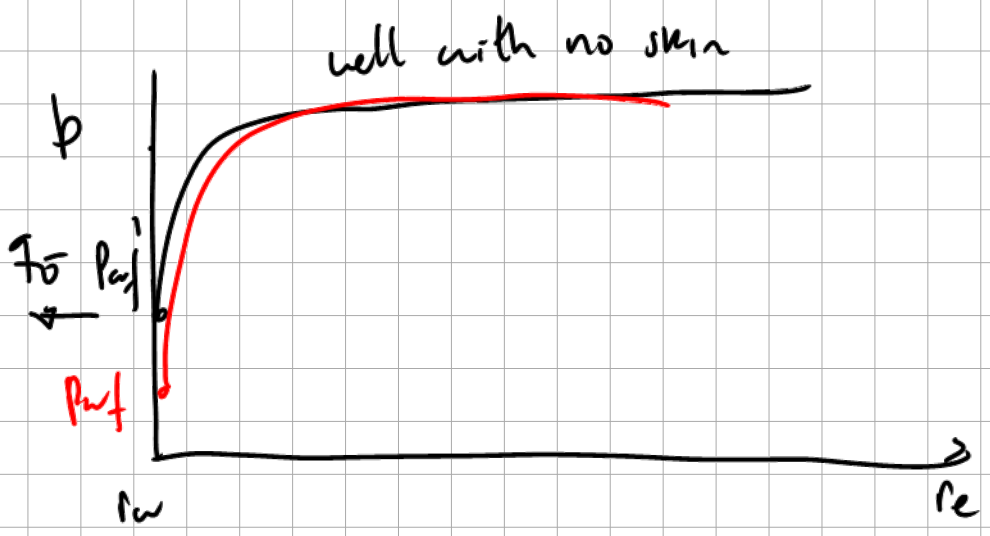
1953 → Hurst

↳ Antonius Van Everdingen (Dutch mining engineer) shell



THE SKIN EFFECT AND ITS INFLUENCE ON THE PRODUCTIVE CAPACITY OF A WELL

A. F. VAN EVERDINGEN, SHELL OIL CO., HOUSTON, TEXAS, MEMBER AIME



$$(p_{wf}' - p_{wf}) = \Delta p_{skin} = S\left[\frac{18.68\,(\mu_o B_o)_{av}\cdot q_o}{kh}\right]$$

p_{wf}': ideal → no skin; p_{wf}: actual → with skin

bar

$$P_R - P_{wf}' = \frac{q_o \; 18.68 \; (\mu_o B_o)_{av}}{k.h} \left[\ln\left(\frac{r_e}{r_w}\right) - 0.75 \right]$$

$$P_{wf}' - P_{wf} = \frac{q_o \; 18.68 \; (\mu_o B_o)_{av}}{kh} S$$

$$P_R - P_{wf} = \frac{q_o \; 18.68 \; (\mu_o B_o)_{av}}{kh} \left[\ln \frac{r_e}{r_w} - 0.75 + S \right]$$

$$J = \frac{kh}{18.68 \; (\mu_o B_o)_{av} \left[\ln \frac{r_e}{r_w} - 0.75 + S \right]}$$

convergence | boundary | skin (near wellbore non-idealities)

other definitions "equivalent" to skin

- flow efficiency $$f_F = \frac{P_R - P_{wf}'}{P_R - P_{wf}} = \frac{\frac{q_o}{J'}}{\frac{q_o}{J}} = \frac{\ln\left(\frac{r_e}{r_w}\right) - 0.75}{\ln\left(\frac{r_e}{r_w}\right) - 0.75 + S} \simeq \frac{7}{7 + S}$$

- apparent wellbore radius

$$\ln\left(\frac{r_e}{r_w}\right) + S = \ln\left(\frac{r_e}{r_{wa}}\right) \qquad r_{wa} = r_w \, e^{-S}$$

if $S > 0$ ⇝ damage (less than ideal) $(P_{wf}' - P_{wf}) > 0$

if $S = 0$ ⇝ ideal

if $S < 0$ ⇝ "stimulation" ⇝ productivity more than ideal

- Drainage area shape → 1965 Daniel Dietz

Determination of Average Reservoir Pressure From Build-Up Surveys

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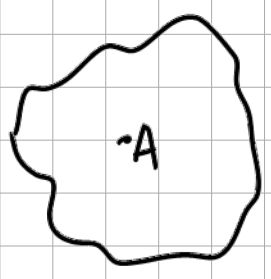
KONINKLIJKE/SHELL LABORATORIUM
RIJSWIJK, THE NETHERLANDS

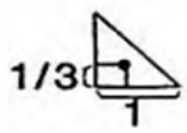
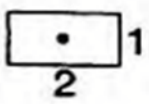
$$\ln\left(\frac{r_e}{r_w}\right) - 0.75 + S + \underbrace{S_A}_{\text{shape - area skin}}$$

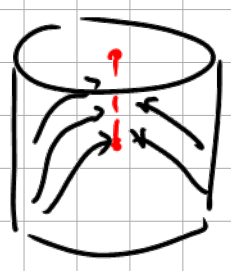


$$A = \pi \cdot r_e^2 \qquad r_e = \sqrt{\frac{A}{\pi}}$$

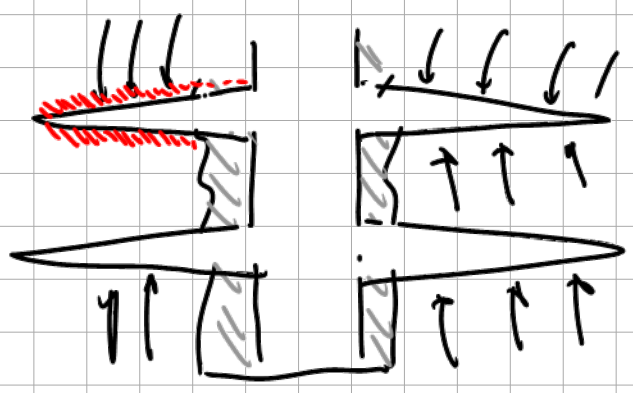
~ well performance (2nd edition)
Golan, Whitson

Table 2.4 Shape Factors for Nonradial Outer Boundary Geometries

Geometry	C_A	s_A	t_{DA}	t_{DA}
	31.62	0.000	0.1	0.1
	30.88	0.012	0.09	0.1
	31.60	0.000	0.1	0.1
	27.6	0.068	0.09	0.2
	27.1	0.077	0.09	0.2
	21.9	0.184	0.08	0.4
	21.84	0.185	0.025	0.3

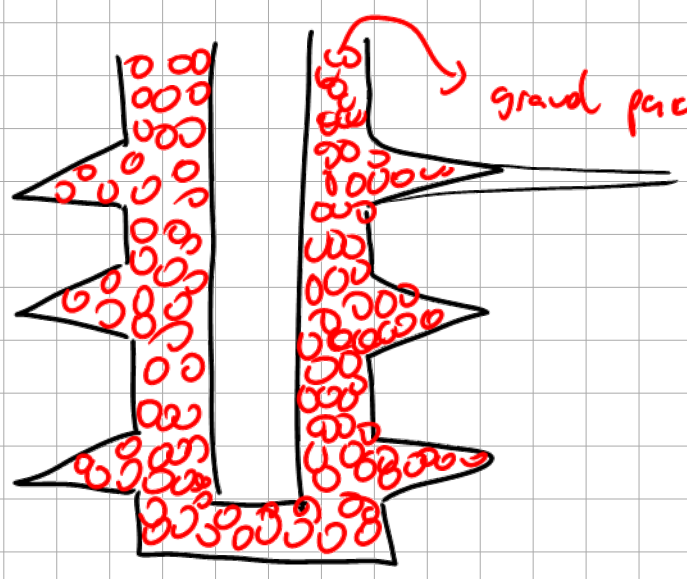
- other cases than can be modeled (represented) with skin
  - formation damage (due to drilling) $S > 0$
  - partial penetration  $k_v << k_H$ $S > 0$

- perforation



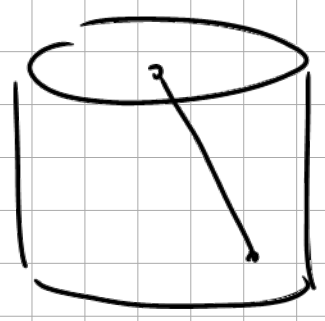
$S > 0$

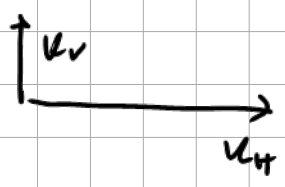
- sand control (gravel pack)



$S > 0$

- wellbore inclination
  (permeability anisotropy)





- acidizing (stimulation)
- fracking

$S < 0$