Pressure Control Equations

The annular pressure profile for a gas kick is complicated by the expanding gas as the pressure is lowered as the kick comes up the hole.
The length of the kick at different pressures is calculated by

Basic equations

$$\rho_f = \frac{\gamma_f P}{53.3 z_b T_b} \qquad P_{mg} = P_b - P_{ma} - .5P_f$$

$$L_k = \frac{P_b z T}{P z_b T_b} L_k$$

ρ_f density of formation fluid psi/ft
P_{mg} Pressure equivalent mid point of the gas bubble psi
L_k Length of the bubble or kick

Constant mud weight

$$P_a = P_b - (D - L_k)\rho_m - P_f$$

P_a Pressure annulus psi
P_b Pressure Bottom hole psi
P_f Pressure from formation fluid mass psi
D Depth ft
L_k Length of kick ft
ρ_m Mud Gradient psi/ft

Changing mud weight

$$P_a = P_b - (D - L_k - D_1)\rho_m - D_1\rho_{m1} - P_f$$

D_1 height occupied by weighted mud in annulus ft
ρ_{m1} mud gradient of new mud psi/ft

So for constant mud we have

$$P = \frac{A}{2} + \left[\frac{A^2}{4} + \frac{P_b \rho_m z T h_b}{z_b T_b} \right]^{.5}$$

$$A = P_b (D - X) \rho_m - P_f$$

For changing mud weights

$$P = \frac{A}{2} + \left[\frac{A^2}{4} + \frac{P_b \rho_{m1} z T h_b}{z_b T_b} \right]^{.5}$$

$$A = P_b (D - X) \rho_m - P_f + D^* \left(\rho_{m1} - \rho_m \right)$$

D^* height occupied by the unweighted mud that was displaced from drill pipe

Pressure Control Example

Data

Depth 10,000’ Hole size 7 7/8” Drill Pipe 4 ½”

P_a 300 psi P_{dp} 200 psi Pit Gain 10 bbls

Mud 9.6 #/gal T_{sur} 70F Temp Grad 1.5F/100’

Find h

h = Pit gain * C_a $h = 10 \times 24.648$ **h=247’ or 250’**

Find P_b

$P_b = P_{dp} + D\rho_m$ $P_b = 200 + 10000 \cdot .5 = 5200\,psi$

Find P_f

$P_a = P_b - (D-h)\rho_m - P_f$ $P_f = P_b - (D-h)\rho_m - P_a$

$P_f = 5200 - (10000 - 250).5 - 300$ $P_f = 25\,psi$

Pressure @ casing seat 2000’

$A = P_b - (D - X)\rho - P_f$ $A = 5200 - (10000 - 2000).5 - 25$

$A = 1175\,psi$

$$P_X = \frac{A}{2} + \left[\frac{A^2}{4} + \frac{P_b \rho_m z T h_b}{z T_b}\right]^{.5} \qquad P_{2000} = \frac{1175}{2} + \left[\frac{1175^2}{4} + \frac{5200(.5)554(250)}{650}\right]^{.5}$$

$P_{2000} = 1535\,psi$

$$h_{2000} = \frac{5200 \cdot 554 \cdot 250}{1535 \cdot 650} \qquad h_{2000} = 720\,ft$$

$P_{a2000} = P_{2000} - X\rho_m$ $P_{a2000} = 1535 - 2000 \cdot .5 = 535\,psi$

Pressure @ surface

$A = 5200 - (10000 - 0).5 - 25$ $A = 175\,psi$

$$P_{sur} = \frac{175}{2} + \left[\frac{175^2}{4} + \frac{5200 \cdot .5 \cdot 530(250)}{650}\right]^{.5} \qquad P_{sur} = 820\,psi$$

$$h_{sur} = \frac{5200 \cdot 530 \cdot 250}{820 \cdot 650} \qquad h_{sur} = 1293\,ft$$

$$P_{2000sur} = (2000 - 1293).5 + 25 + 820 \qquad P_{2000sur} = 1199\,psi$$

$$P_b = 1199 + 8000 \cdot .5 = 5200\,psi$$

Pressures with weighted mud

Mud required 10#/gal

$D^* = 140bbl / .0406bbl / \ ft = 3448\,ft$ **Drill pipe capacity 140 bbls**

Pressures @ 2000'

$$A = P_b - (D - X)\rho_{m1} - P_f + D^*(\rho_{m1} - \rho_m)$$
$$A = 5200 - (10000 - 2000).52 - 25 + 3448(.52 - .5)$$
$$A = 1084\,psi$$

$$P_X = \frac{A}{2} + \left[\frac{A^2}{4} + \frac{P_b \rho_{m1} z T h_b}{z T_b}\right]^{.5} \qquad P_{2000} = \frac{1084}{2} + \left[\frac{1084^2}{4} + \frac{5200 \cdot .52 \cdot 554(250)}{650}\right]^{.5}$$

$$P_{2000} = 1475\,psi$$

$$h_{2000} = \frac{5200 \cdot 554 \cdot 250}{1475 \cdot 650} \qquad h_{2000} = 750\,ft$$

$$P_{a2000} = P_{2000} - X\rho_m \qquad P_{a2000} = 1475 - 2000 \cdot .5 = 475\,psi$$

Pressure @ surface

$$A = 5200 - (10000 - 0).52 - 25 + 3448(.52 - .5)$$
$$A = 44\,psi$$
$$P_{sur} = \frac{44}{2} + \left[\frac{44^2}{4} + \frac{5200 \cdot .52 \cdot 530(250)}{650}\right]^{.5}$$
$$P_{sur} = 765\,psi$$

$$h_{sur} = \frac{5200 \cdot 530 \cdot 250}{765 \cdot 650} \qquad h_{sur} = 1386\,ft$$

$$P_{2000sur} = (2000 - 1386).5 + 25 + 765 \qquad P_{2000sur} = 1097\,psi$$

$$P_b = 765 + 3448 \cdot .5 + (10000 - 3448 - 1386).52 + 25 = 5200\,psi$$