Annular Pressure Calculations

To find the pressure at any point X in the annulus start with

\[ P_X = P_B - (D - X - L_{kx})\rho_m - P_f \]  

(1)

The key here is to find \( L_{kx} \) which is pressure dependent. Using the gas law

\[ \frac{P_B V_{kB}}{z T_B} = \frac{P_X V_{kx}}{z T_x} \]

\[ V_{kx} = \frac{P_B z T_B V_{kB}}{z T_B} \]

\[ L_{kx} = \frac{P_B z T_B V_{kB}}{z T_B C_a} \]

Sub this into first equation

\[ P_X = P_B - \rho_m \left( D - X - \frac{P_B z T_B V_{kB}}{z T_B C_a} \right) - P_f \]

In quadratic form

\[ P_X^2 - \left[ P_B - \rho_m (D - X) - P_f \right] P_X - \frac{P_B \rho_m z T_B V_{kB}}{z T_B C_a} = 0 \]

\[ \frac{b + \sqrt{b^2 + 4ac}}{ac} \]

\[ a = 1 \quad c = \frac{P_B \rho_m z T_B V_{kB}}{z T_B C_a} \]
\[
P_x = \frac{P_B - (D - X) \rho_m - P_f}{2} + \frac{\sqrt{(P_B - (D - X) \rho_m - P_f)^2 + 4 \rho_m z_T V_{k_B}}}{z_T B C_a}
\]

\[
P_x = \frac{P_B - (D - X) \rho_m - P_f}{2} + \frac{\sqrt{(P_B - (D - X) \rho_m - P_f)^2 + 4 \rho_m z_T V_{k_B}}}{z_T B C_a}
\]

\[
L_{k_B} = \frac{V_{k_B}}{C_a}
\]

\[
P_x = \frac{P_B - (D - X) \rho_m - P_f}{2} + \frac{\sqrt{(P_B - (D - X) \rho_m - P_f)^2 + 4 \rho_m z_T L_{k_B}}}{z_T B}
\]

\[b = A = P_B - (D - X) \rho_m - P_f\]

\[
P_x = \frac{A}{2} + \frac{A + \frac{P_B \rho_m z_T V_{k_B}}{z_T B}}{4}
\]
Other problems controlling wells

Volumetric Control
If you cannot pump down the drill pipe, or completely out of the hole with drill string. The plan here is allow the gas to migrate up the hole using successive mud bleeding off periods.

Procedure
Phase one
1) Allow casing pressure to increase by 100 psi
2) Allow additional increase in pressure Δp
3) Bleed through the choke a volume of mud which corresponds to the additional pressure Δp. \[ V_m = \frac{962C}{\rho_m} \]
4) Repeat till gas reaches the surface
Phase two
1) Calculate the mud weight needed to kill the well. Inject a volume of this mud until the casing pressure is increased by 100 psi. Measure the volume. \[ V_m \]
2) Convert this volume to pressure \[ \Delta p = 0.052 \Delta V_m / C \rho_{km} \]
3) Allow time for the mud to fall down the well. Then bleed the gas through the choke until the casing pressure drops by 100+Δp
4) Repeat till well is full of kill mud.