Petr 311
Wellbore pressures and Kick Control

Remember

\[ P_b = \rho_m 0.052D \]

Consider the wellbore static hydraulic system

The pressures in the drill string and the annulus can be represented as a U-tube. The sum of the pressures in the drill string and the annulus must be equal.

\[ P_{dp} + P_{ha} = P_a + P_{ha} = P_{bh} \]

When not pumping mud the pressure at the surface should be zero if the system is balanced.

When reservoir pressure exceeds the pressure in the wellbore, reservoir fluids will be produced into the wellbore. The first indication of this the level in the mud pits will raise. This is referred to as a KICK. You are losing control of the well!

WHAT TO DO???

Step one, stop the pumps
Step two, close the BOP
Step three, allow the well to stabilize and record the \( P_{dp} \) & \( P_a \)
Step four, record the increase in the pits
Step five, calculate the \( P_{bh} \) using \( P_{dp} \) and the density of the mud
Step six, calculate the size and density of the kick from the pit data
Step seven, plan how to get it out

For step five we know that the mud in the drill pipe is constant because the formation fluid cannot flow up into the drill pipe, so just use the mud density to calculate the \( P_{dp} \).

For step six we have to assume the hole diameter and that it is constant. The diameter of the drill string will change in many cases because you have drill collars above the bit and then drill pipe.
By calculating the length of the kick we can determine the density of the kick, which tells what the fluid that entered the well is, liquid or gas. This is needed when we draw up a plan to get the kick out.

\[ L_k = L_c + \left( V_k - \frac{L_c}{C_c} \right) C_{dp} \]

Using the pressure balance of the static system the density can be calculated

\[ \rho_k = \rho_m - \frac{P_a - P_{dp}}{.052L_k} \]

If the density of the kick is less than 4#/gal it is gas, greater than 8 it is liquid. A kick with gas in it we have to take in to account the expansion of the kick as it comes up the hole.

Example

A kick of 10 bbls is encountered at a depth of 6000’. The BOP is closed and a drill pipe pressure of 500 psi and an annular pressure of 700 psi. The hole has 9.6# mud with 500’ of 8” collars drilling a 10” hole.

\[ P_{bh} = .5 \times 6000 + 500 = 3500 \text{ psi} \]

\[ C_c = 28.6 \text{ ft/bbl} \quad 15 \text{bbl x 28.9} = 434’ \]

So kick just across the collars

\[ L_k = 434’ \]

\[ \rho_k = \rho_m - \frac{P_a - P_{dp}}{.052L_k} = 9.6 - \frac{700 - 500}{.052 \times 434} = .74 \quad \text{kick is gas} \]
If kick is 25 bbls

\[ C_{dp} = 12.9 \text{ ft/bbl for 4 } \frac{1}{2}'' \text{ drill pipe} \]

\[ L_k = L_c + \left( V_k - \frac{L_c}{C_c} \right) C_{dp} = 500 + \left( 25 - \frac{500}{28.9} \right) 12.9 = 600 \text{ ft} \]

This assumes no mixing of the mud and the kick fluid.

For a more accurate lick length and density of the kick mixing of the kick fluids and mud should be taken into account. The mud and kick mix as the mud is pumped across the zone giving up the fluid. This is the time between the start of the kick and the closing of the BOP. The volume of the mud in the kick is the pump rate of the mud during the kick time.

\[ V_m = qt_d \]

So the kick volume is the volume of the mud plus the pit gain

\[ V_k = G + qt_d \]

Now use this volume to calculate the length of the kick and its density.

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

\[ L_k = \frac{P_a_zT}{P_m zT} - L_{k8} \]

So the pressure in the annulus is

\[ P_a = P_a - (D - L_k) \rho_m \cdot 052 - P_f \quad \text{for no change in mud density} \]

\[ P_a = P_a - (D - L_k - D_1) \rho_m \cdot 052 - D_1 \rho_m_1 - P_f \quad \text{mud weight increase} \]
The solution to give the pressure at any point in the annulus
For no mud change

\[ P = \frac{A}{2} + \left[ \frac{A^2}{4} + \frac{P_B \rho_m \cdot 0.052 z T L B}{z T B} \right]^5 \]

Let \( A = P_B - (D - X) \rho_m \cdot 0.052 - P_f \)

Increasing the mud weight

\[ P = \frac{A}{2} + \left[ \frac{A^2}{4} + \frac{P_B \rho_m \cdot 1.052 z T L B}{z T B} \right]^5 \]

Let \( A = P_B - (D - X) \rho_m \cdot 1.052 - P_f + D^* (\rho_m - \rho_m \cdot 0.052) \)

Example
Well depth 10,000’ Hole size 7 7/8”
Drill pipe 4 1/2” Surface casing @ 2000’
Mud Weight 9.6# Pit gain 10 bls
Pdp 200 psi Pa 300 psi
Pump rate of 6 BPM

First calculate \( P_B \)
\[ P_B = 10000 \cdot 0.5 + 200 = 5200 \text{ psi} \]

New mud weight to maintain a pressure 50 psi above \( P_B \).
\[ 5250/(0.052 \cdot 10,000) = 10.1 \# \]

Length of the kick
Annular volume is .042 bpf
\[ L_k = 23.8 \cdot 10 = 238 \text{ ft} \]

Calculate \( P_f \)
\[ P_f = P_B - (D - L_k) \rho_m \cdot 0.052 - P_a = 5200 - (10000 - 238) \cdot 0.5 - 300 \]
\[ P_f = 19 \text{ psi} \]

With a temperature gradient of 1.2F/100ft, temp at surface 70F. Find the pressure at the casing seat when the kick gets there. Also when the kick reaches the surface.
First without a change in the mud

\[ A = P_B - (D - X)\rho_m \cdot 0.52 - P_f = 5250 - (10000 - 2000) \cdot 5 - 19 = 1231 \]

\[
P = \frac{A}{2} + \left[ \frac{A^2}{4} + \frac{P_B \rho_m \cdot 0.52 z TL_{kB}}{z_B T_B} \right]^5 = \frac{1231}{2} + \left[ \frac{1231^2}{4} + \frac{5250 \cdot 0.5 \cdot 554 \cdot 238}{650} \right]^5
\]

\[ P_{2000} = 1570 \text{ psi} \]

\[
L_k = \frac{P_B z T}{P z_B T_B} \cdot L_{kB} = \frac{5250 \cdot 554}{1570 \cdot 650} \cdot 238 = 678
\]

\[ P_a = 5250 - (10000 - 678) \cdot 5 - 19 = 570 \text{ psi} \]

Kick at surface

\[ A = P_B - (D - X)\rho_m \cdot 0.52 - P_f = 5250 - (10000 - 0) \cdot 5 - 19 = 231 \]

\[
P = \frac{A}{2} + \left[ \frac{A^2}{4} + \frac{P_B \rho_m \cdot 0.52 z TL_{kB}}{z_B T_B} \right]^5 = \frac{231}{2} + \left[ \frac{231^2}{4} + \frac{5250 \cdot 0.5 \cdot 530 \cdot 238}{650} \right]^5
\]

\[ P_{sur} = 838.5 \text{ psi} \]

\[
L_k = \frac{P_B z T}{P z_B T_B} \cdot L_{kB} = \frac{5250 \cdot 530}{838.5 \cdot 650} \cdot 238 = 1215' \]

\[ P_B = (10000 - 1215) \cdot 5 + 19 + 838.5 = 5250 \text{ psi} \]

With the new mud

The internal volume of the drill pipe is .014 bbl/ft

The total volume at 10,000’ is 141 bbls

\[
D' = 141 / .042 = 3357' \]

\[
A = P_B - (D - X)\rho_m \cdot 0.52 - P_f + D' (\rho_{m1} - \rho_m) \cdot 0.52
\]

\[
A = 5250 - (10000 - 2000) \cdot 52 - 19 + 3357(.52 - .5) = 1138
\]
\[ P = \frac{A}{2} + \left[ \frac{A^2}{4} + \frac{P_B \rho m \cdot 0.052 z T_{kB}}{z_B T_B} \right]^5 = \frac{1138}{2} + \left[ \frac{1138^2}{4} + \frac{5250 \cdot 0.52 \cdot 554 \cdot 238}{650} \right] = 1505 \text{ psi} \]

\[ L_k = \frac{P_B \cdot z T}{P z_T B} = \frac{5250 \cdot 554}{1505 \cdot 650} 238 = 707' \]

\[ P_a = 1505 - 2000 \cdot 0.5 = 505 \text{ psi} \]

**Kick at surface**

\[ A = 5250 - (10000 - 0) \cdot 0.52 - 19 + 3357 \cdot 0.52 + 0.5 = 98 \]

\[ P = \frac{A}{2} + \left[ \frac{A^2}{4} + \frac{P_B \rho m \cdot 0.052 z T_{kB}}{z_B T_B} \right]^5 = \frac{98}{2} + \left[ \frac{98^2}{4} + \frac{5250 \cdot 0.52 \cdot 530 \cdot 238}{650} \right] = 779 \text{ psi} \]

\[ L_k = \frac{P_B \cdot z T}{P z_T B} = \frac{5250 \cdot 530}{779 \cdot 650} 238 = 1308' \]

\[ P_B = (3357) \cdot 0.5 + (10000 - 3357 - 1308) \cdot 0.52 + 19 + 779 = 5250 \text{ psi} \]

**The length of the kick if mixing is considered,**

5 minutes from when the kick started till pump is shut down.

\[ V_k = G + q t_a = 10 + 6 \cdot 5 = 40 \text{ bbls} \]

\[ L_k = 23.8 \cdot 40 = 952 \text{ ft} \]

\[ P_f = P_B - (D - L_k) \rho_m \cdot 0.052 - P_a = 5200 - (10000 - 95237) \cdot 0.5 - 300 \]

\[ P_f = 376 \text{ psi} \]

**The drill pipe pressure during the kill operation can be calculated.**

**During regular drilling operations kill rate drill pressures are recorded.**

This will include the friction and bit pressure drops at this rate.