Circulation & Well Control

WILD WELL CONTROL

Learning Objectives

- You will learn the importance of pump rates and pressures during well control operations.
- You will learn pressure relationships.
- You will learn basic calculations necessary in well control for:
  - Capacity
  - Volume
  - Strokes

Circulation and Well Control

Overview

- Pumps are one of the basic tools used in well control.
  - Used to circulate kick fluids out.
  - Used to circulate kill fluid throughout well.
  - Used to pump cement, pills, plugs, etc.
- Usually measured in strokes per minute and output, bbls/min.
- Small changes in pump rate can greatly affect pressures throughout well.
  - So, in well control, to keep bottom hole pressure in a specified range, pump rate needs to be carefully controlled.

Kill Rate

- Kill rate is a reduced circulating rate used during well control operations.
  - Reduces circulating friction.
  - Allows kill fluid to be maintained during kill operations.
  - Reduces strain on pumps.
  - Allows more time to react to problems.
  - Allows adjustable chokes to work within orifice range.

Kill Rate

- Pump speed is critical because it affects pump pressure.
  - *Any change in speed may drastically affect circulating pressure!*
- Usually taken at 1/4, 1/3 and 1/2 normal circulating rate.
  - Often 20, 30 and 40 stk/min are used.
  - Sometimes based on rate to reach a certain pressure.
  - Sometimes based on bbls/min (e.g., 2 – 5 bbls/min).

Kill Rate Pressure

- Kill rate pressure is the circulating pressure at the kill rate pump speed.
- Kill rate pressures should be taken when:
  - There is a change in fluid density or fluid flow (rhelogical) characteristics.
  - There is a change in bit and bit nozzles.
  - BHA, downhole tools and string changes.
  - When 500 or more feet of new hole is drilled.
  - Each tour.
  - After pump repair.

Kill Rate Pressure

- Ideally, kill rate pressures should be taken through the kill manifold and choke.
  - Have to flush kill manifold and choke.
  - Usually taken with BOP stack open instead.
- A small change in rate can affect circulating pressure greatly.
- This can be mathematically calculated.
  - A pump pressure and rate must be known.
  - Fluid properties have to be the same.
  - Much better to get actual pressures than calculated.

$$P_2 = P_1 \times (SPM^2_2 \div SPM_1^2)$$

Where:

P_2 = original pump pressure at SPM_1, psi

P_1 = reduced or changed pump pressure at SPM_2, psi

SPM_1 = original pump rate, stks/min

SPM_2 = reduced or changed pump rate, stks/min

Initial Circulating Pressure

- Initial circulating pressure (ICP) - the combination of shut-in drillpipe pressure plus the pressure needed to circulate fluid at a given rate.

ICP = KRP + SIDPP

Where:

ICP = initial circulating pressure, psi

KRP = kill rate pressure, psi

SIDPP = shut in drill pipe pressure, psi

Initial Circulating Pressure

- ICP is the circulating pressure used once the pump is at kill rate speed.
  - If no kill fluid is pumped, then this is the circulating pressure necessary to maintain BHP constant at or slightly above FP.
  - If kill fluid is pumped ICP must be allowed to drop as the kill fluid fills the string increasing hydrostatic killing the pressure deficit.

Final Circulating Pressure

- Once kill fluid fills the string the circulating pressure is commonly referred to as Final Circulating Pressure (FCP).

  This change in circulating pressure can be calculated by:

$$FCP = KRP \times (KWM \div OMW)$$

Where:

FCP = final circulating pressure, psi

KRP = kill rate pressure, psi

KWM = kill weight mud (fluid), ppg

OMW = old mud weight, ppg

Surface to Bit, Pump Strokes and Time

- The number of strokes to pump a fluid, such as a kill fluid, from the surface to the end of the string is critical for successful well control and maintaining BHP constant.
- Also, the time to pump from the surface to the end of the string is important.
- The volume within the string must be calculated. This is the combined total of:
  - Volume of tubing or drill pipe.
  - Volume of BHA.
  - Additionally, the amount of strokes/time to clear the surface equipment should be known.

Surface to Bit, Pump Strokes and Time

- To calculate a pipe/string volume:

$$\textbf{Volume}_{\textbf{bbls}} = \textbf{Capacity}_{\textbf{bbl/ft}} \ \textbf{X} \ \textbf{Length}_{\textbf{ft}}$$

This is calculated for each section of the string (i.e. pipe, HWDP, BHA)

- The volumes are totaled for the entire string.
- To calculate the amount of strokes to displace the string volume:

$$\textbf{Strokes} = \textbf{Total String Volume}_{\textbf{bbls}} \div \textbf{Pump Output}_{\textbf{bbl/stk}}$$

Note: Capacity of pipe may be looked up in charts and tables.

Surface to Bit, Pump Strokes and Time

- If lookup tables are not available, the following formula can be used to calculate the capacity of a cylindrical object such as an open hole, casing, tubing, drill pipe, BHA or choke/kill lines in bbls/ft :

$$\textbf{Capacity}_{\textbf{bbls/ft}} = \textbf{Diameter}^2 \div 1029.4$$

Annular Volumes

- The calculation for annular volume is similar to that of capacity, but subtracting out the displacement of the tubulars in the well.
- There may be several different bbl/ft annulus capacity sections:
  - Based on well bore geometry and where different pipes are located.
  - Each section must be calculated individually:
    - Tubing/DP in casing, liner, open hole and/or riser.
    - Hevi wate in casing, liner, open hole and/or riser.
    - BHA/DC in casing, open hole and/or riser.

Annular Volumes

- If lookup tables are not available, the capacity for each section can be calculated by:

$$\textbf{Capacity}_{\text{bbls/ft}} = (OD^2 - ID^2) \div 1029.4$$

Where:

ID = ID of open or cased hole, inches

OD = OD of tubular in section, inches

Note: 1029.4 is the conversion factor between cylindrical area and volume

- Once the capacities are known, the volumes for each section and total volume can be calculated.
- Strokes to surface and time to surface for bottoms up can then be easily calculated.

Total Circulating Strokes and Time

- Simply by adding the volumes for each section, a total volume, strokes and circulating time down the string and back to surface can be calculated.
  - By adding separate volumes from surface, or the bottom of the string we can also calculate volume, strokes and time to circulate for:
    - End of string or bit to casing shoe
    - Choke and kill line
    - Any individual or combined lengths and sections