CIRCULATION & WELL CONTROL
Learning Objectives

You will learn:

- The importance of pump rates and pressures during well control operations
- Pressure relationships
- Basic calculations necessary in well control for:
  - Capacity
  - Volume
  - Strokes
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.
Circulation and Well Control

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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 (rheological) 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.

\[ P_2 = P_1 \times \left( \frac{SPM_2^2}{SPM_1^2} \right) \]

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 drill pipe 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:

\[ FCP = KRP \times \left( \frac{KWM}{OMW} \right) \]

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:
  \[ \text{Volume}_{\text{bbls}} = \text{Capacity}_{\text{bbl/ft}} \times \text{Length}_{\text{ft}} \]

  *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:

  \[ \text{Strokes} = \frac{\text{Total String Volume}_{\text{bbls}}}{\text{Pump Output}_{\text{bbl/stk}}} \]

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

\[
\text{Capacity}_{\text{bbls/ft}} = \frac{\text{Diameter}^2}{1029.4}
\]
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:
  \[
  \text{Capacity}_{\text{bbls/ft}} = \frac{(OD^2 - ID^2)}{1029.4}
  \]
  Where:
  \[
  ID = \text{ID of open or cased hole, inches}
  \]
  \[
  OD = \text{OD of tubular in section, inches}
  \]

  **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
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