Section 1. **Filled-in Kill Sheet Exercises - Gauge Problem Actions.**

Gauge Problem Exercises are constructed from a completed kill sheet ‘filled-in’ with all relevant volume and pressure calculations.

Each question is based on the strokes, pump rate, drill pipe and casing gauge readings at a specific point in time during a well kill operation. Any one or a combination of these readings could indicate the action required. Options are shown in the multiple-choice answers.

The casing and/or drill pipe pressures will only be relevant to the action if –

- The casing and/or drill pipe pressures given in the question are below the expected pressures, or
- The casing and/or drill pipe pressures given in the question are 70 psi or more above the expected pressures.

**Section 2. Calculation Formula.**

**Abbreviations used in this document**

- bbl = Barrels (US)
- bbl/ft = Barrels (US) per foot
- bbl/min = Barrels (US) per minute
- bbl/stroke = Barrels (US) per stroke
- BHP = Bottom Hole Pressure
- BOP = Blowout Preventer
- ft = Feet
- ft/hr = Feet per hour
- ft/min = Feet per minute
- lb/bbl = Pounds per barrel
- LOT = Leak-off Test
- MAASP = Maximum Allowable Annular Surface Pressure
- ppg = Pounds per gallon
- psi = Pounds per square inch
- psi/ft = Pounds per square inch per foot
- psi/hr = Pounds per square inch per hour
- SICP = Shut in Casing Pressure
- SIDPP = Shut in Drill Pipe Pressure
- SPM = Strokes per minute
- TVD = True Vertical Depth
- 0.052 = Constant factor

**1. HYDROSTATIC PRESSURE (psi)**

Mud Density (ppg) x 0.052 x TVD (ft)

**2. PRESSURE GRADIENT (psi/ft)**

Mud Density (ppg) x 0.052
3. **DRILLING MUD DENSITY (ppg)**

   \[
   \text{Pressure (psi)} + \frac{\text{TVD (ft)}}{0.052}
   \]

   or

   \[
   \frac{\text{Pressure (psi)}}{\text{TVD (ft)}} \times 0.052
   \]

4. **FORMATION PORE PRESSURE (psi)**

   Hydrostatic Pressure in Drill String (psi) + SIDPP (psi)

5. **PUMP OUTPUT (bbl/min)**

   Pump Displacement (bbl/stroke) x Pump Rate (SPM)

6. **ANNULAR VELOCITY (ft/min)**

   \[
   \frac{\text{Pump Output (bbl/min)}}{\text{Annular Capacity (bbl/ft)}}
   \]

7. **EQUIVALENT CIRCULATING DENSITY (ppg)**

   \[
   \left\{ \frac{\text{Annular Pressure Loss (psi)}}{\text{TVD (ft)}} + 0.052 \right\} + \text{Mud Density (ppg)}
   \]

   Or

   \[
   \frac{\text{Annular Pressure Loss (psi)}}{\text{TVD (ft)} \times 0.052} + \text{Mud Density (ppg)}
   \]

8. **MUD DENSITY WITH TRIP MARGIN INCLUDED (ppg)**

   \[
   \left\{ \frac{\text{Safety Margin (psi)}}{\text{TVD (ft)}} + 0.052 \right\} + \text{Mud Density (ppg)}
   \]

   Or

   \[
   \frac{\text{Safety Margin (psi)}}{\text{TVD (ft)} \times 0.052} + \text{Mud Density (ppg)}
   \]

9. **NEW PUMP PRESSURE (psi) WITH NEW PUMP RATE approximate**

   \[
   \text{Old Pump Pressure (psi)} \times \left( \frac{\text{New Pump Rate (SPM)}}{\text{Old Pump Rate (SPM)}} \right)^2
   \]

10. **NEW PUMP PRESSURE (psi) WITH NEW MUD DENSITY approximate**

    \[
    \text{Old Pump Pressure (psi)} \times \frac{\text{New Mud Density (ppg)}}{\text{Old Mud Density (ppg)}}
    \]

11. **MAXIMUM ALLOWABLE MUD DENSITY (ppg)**

    \[
    \text{Surface LOT Pressure (psi)} + \frac{\text{Shoe TVD (ft)}}{0.052} + \text{LOT Mud Density (ppg)}
    \]

    or

    \[
    \frac{\text{Surface LOT Pressure (psi)}}{\text{Shoe TVD (ft)} \times 0.052} + \text{LOT Mud Density (ppg)}
    \]
12. MAASP (psi)

\[ \text{Maximum Allowable Mud Density (ppg) – Current Mud Density (ppg)} \times 0.052 \times \text{Shoe TVD (ft)} \]

13. KILL MUD DENSITY (ppg)

\[ \frac{\text{SIDPP (psi)}}{\text{TVD (ft) \times 0.052}} + \text{Original Mud Density (ppg)} \]

or

\[ \frac{\text{SIDPP (psi)}}{\text{TVD (ft) \times 0.052}} + \text{Original Mud Density (ppg)} \]

14. INITIAL CIRCULATING PRESSURE (psi)

Kill Rate Circulating Pressure (psi) + SIDPP (psi)

15. FINAL CIRCULATING PRESSURE (psi)

\[ \frac{\text{Kill Mud Density (ppg)}}{\text{Original Mud Density (ppg)}} \times \text{Kill Rate Circulating Pressure (psi)} \]

16. BARYTE REQUIRED TO INCREASE DRILLING MUD DENSITY (lb/bbl)

\[ \frac{[\text{Kill Mud Density (ppg)} - \text{Original Mud Density (ppg)}]}{35.8 - \text{Kill Mud Density (ppg)}} \times 1500 \]

17. GAS MIGRATION RATE (ft/hr)

\[ \frac{\text{Rate of Increase in Surface Pressure (psi/hr)}}{\text{Drilling Mud Density (ppg) \times 0.052}} \]

or

\[ \frac{\text{Rate of Increase in Surface Pressure (psi/hr)}}{\text{Drilling Mud Density (ppg) \times 0.052}} \]

18. GAS LAWS

\[ P_1 \times V_1 = P_2 \times V_2 \]

\[ P_2 = \frac{P_1 \times V_1}{V_2} \]

\[ V_2 = \frac{P_1 \times V_1}{P_2} \]

19. PRESSURE DROP PER FOOT TRIPPING DRY PIPE (psi/ft)

\[ \frac{\text{Drilling Mud Density (ppg) \times 0.052 \times Metal Displacement (bbl/ft)}}{\text{Riser or Casing Capacity (bbl/ft) - Metal Displacement (bbl/ft)}} \]

20. PRESSURE DROP PER FOOT TRIPPING WET PIPE (psi/ft)

\[ \frac{\text{Drilling Mud Density (ppg) \times 0.052 \times Closed End Displacement (bbl/ft)}}{\text{Riser or Casing Capacity (bbl/ft) - Closed End Displacement (bbl/ft)}} \]

21. LEVEL DROP PULLING REMAINING COLLARS OUT OF HOLE DRY (ft)

\[ \frac{\text{Length of Collars (ft) \times Metal Displacement (bbl/ft)}}{\text{Riser or Casing Capacity (bbl/ft)}} \]
22. LEVEL DROP PULLING REMAINING COLLARS OUT OF HOLE WET (ft)

\[
\frac{\text{Length of Collars (ft) } \times \text{ Closed End Displacement (bbl/ft)}}{\text{Riser or Casing Capacity (bbl/ft)}}
\]

23. LENGTH OF TUBULARS TO PULL DRY BEFORE OVERBALANCE IS LOST (ft)

\[
\frac{\text{Overbalance (psi) } \times [\text{Riser or Casing Capacity (bbl/ft) } - \text{Metal Displacement (bbl/ft)}]}{\text{Mud Gradient (psi/ft) } \times \text{Metal Displacement (bbl/ft)}}
\]

24. LENGTH OF TUBULARS TO PULL WET BEFORE OVERBALANCE IS LOST (ft)

\[
\frac{\text{Overbalance (psi) } \times [\text{Riser or Casing Capacity (bbl/ft) } - \text{Closed End Displacement (bbl/ft)}]}{\text{Mud Gradient (psi/ft) } \times \text{Closed End Displacement (bbl/ft)}}
\]

25. VOLUME TO BLEED OFF TO RESTORE BHP TO FORMATION PRESSURE (bbl)

\[
\frac{\text{Increase in Surface Pressure (psi) } \times \text{Influx Volume (bbl)}}{\text{Formation Pressure (psi) } - \text{Increase in Surface Pressure (psi)}}
\]

26. SLUG VOLUME (bbl) FOR A GIVEN LENGTH OF DRY PIPE

\[
\frac{\text{Length of Dry Pipe (ft) } \times \text{ Pipe Capacity (bbl/ft) } \times \text{Drilling Mud Density (ppg)}}{\text{Slug Density (ppg) } - \text{Drilling Mud Density (ppg)}}
\]

27. PIT GAIN DUE TO SLUG U-TUBING (bbl)

\[
\text{Slug Volume (bbl)} \times \left(\frac{\text{Slug Density (ppg)}}{\text{Drilling Mud Density (ppg)}} - 1\right)
\]

28. RISER MARGIN (ppg)

\[
\frac{[\text{Air Gap (ft)} + \text{Water Depth (ft)}] \times \text{Mud Density (ppg)} - [\text{Water Depth (ft)} \times \text{Sea Water Density (ppg)}]}{\text{TVD (ft)} - \text{Air Gap (ft)} - \text{Water Depth (ft)}}
\]

29. HYDROSTATIC PRESSURE LOSS IF CASING FLOAT FAILS (psi)

\[
\frac{\text{Mud Density (ppg)} \times 0.052 \times \text{Casing Capacity (bbl/ft)} \times \text{Unfilled Casing Height (ft)}}{\text{Casing Capacity (bbl/ft)} + \text{Annular Capacity (bbl/ft)}}
\]