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)**

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

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)**

\[
\text{Pump Displacement (bbl/stroke)} \times \text{Pump Rate (SPM)}
\]

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

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

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

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

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)**

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

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)**

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

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)

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

or

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

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)

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

17. GAS MIGRATION RATE (ft/hr)

Rate of Increase in Surface Pressure (psi/hr) ÷ Drilling Mud Density (ppg) ÷ 0.052

or

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

18. GAS LAWS

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

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

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

\[ \text{Drilling Mud Density (ppg) × 0.052 × Metal Displacement (bbl/ft)} \]

\[ \text{Riser or Casing Capacity (bbl/ft) - Metal Displacement (bbl/ft)} \]

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

\[ \text{Drilling Mud Density (ppg) × 0.052 × Closed End Displacement (bbl/ft)} \]

\[ \text{Riser or Casing Capacity (bbl/ft) - Closed End Displacement (bbl/ft)} \]

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

\[ \text{Length of Collars (ft) × Metal Displacement (bbl/ft)} \]

\[ \text{Riser or Casing Capacity (bbl/ft)} \]
22. LEVEL DROP PULLING REMAINING COLLARS OUT OF HOLE WET (ft)

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

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

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

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

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

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

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

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

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

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)

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

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

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