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**

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

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)
   
   Pressure (psi) ÷ TVD (ft) ÷ 0.052
   or
   
   Pressure (psi) ÷ TVD (ft) x 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)
   \[
   \left[\frac{\text{Annular Pressure Loss (psi)}}{\text{TVD (ft)}} \times 0.052\right] + \text{Mud Density (ppg)}
   \]
   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)
   \[
   \left[\frac{\text{Safety Margin (psi)}}{\text{TVD (ft)}} \times 0.052\right] + \text{Mud Density (ppg)}
   \]
   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)
    \[
    \left[\frac{\text{Surface LOT pressure (psi)}}{\text{Shoe TVD (ft)}} \times 0.052\right] + \text{LOT Mud Density (ppg)}
    \]
    or
    \[
    \frac{\text{Surface LOT Pressure (psi)}}{\text{Shoe TVD (ft)} \times 0.052} + \text{LOT Mud Density (ppg)}
    \]

12. MAASP (psi)
    \[
    \left[\text{Maximum Allowable Mud Density (ppg)} - \text{Current Mud Density (ppg)}\right] \times 0.052 \times \text{Shoe TVD (ft)}
    \]

13. KILL MUD DENSITY (ppg)
    \[
    \left[\frac{\text{SIDPP (psi)}}{\text{TVD (ft)} \times 0.052}\right] + \text{Original Mud Density (ppg)}
    \]
    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)**
   \[
   \frac{\text{Rate of Increase in Surface Pressure (psi/hr)} + \text{Drilling Mud Density (ppg)}}{0.052}
   \]
   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. **ACCUMULATOR BOTTLE USEABLE FLUID (gallons)**
   \[
   \left(\frac{\text{Precharge Pressure (psi)}}{\text{Minimum Pressure (psi)}} - \frac{\text{Precharge Pressure (psi)}}{\text{Maximum Pressure (psi)}}\right) \times \text{Bottle size (gallons)}
   \]

20. **PRESSURE DROP PER FOOT TRIPPING DRY PIPE (psi/ft)**
    \[
    \text{Drilling Mud Density (ppg)} \times 0.052 \times (\text{Riser or Casing Capacity (bbl/ft)} - \text{Metal Displacement (bbl/ft)})
    \]

21. **PRESSURE DROP PER FOOT TRIPPING WET PIPE (psi/ft)**
    \[
    \text{Drilling Mud Density (ppg)} \times 0.052 \times (\text{Riser or Casing Capacity (bbl/ft)} - \text{Closed End Displacement (bbl/ft)})
    \]

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

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

24. **LENGTH OF TUBULARS TO PULL DRY BEFORE OVERBALANCE IS LOST (ft)**
    \[
    \frac{\text{Overbalance (psi)} \times ([\text{Riser or Casing Capacity (bbl/ft)} - \text{Metal Displacement (bbl/ft)}] \times \text{Mud Gradient (psi/ft)} \times \text{Metal Displacement (bbl/ft)})}{\text{Mud Gradient (psi/ft)} \times \text{Closed End Displacement (bbl/ft)}}
    \]

25. **LENGTH OF TUBULARS TO PULL WET BEFORE OVERBALANCE IS LOST (ft)**
    \[
    \frac{\text{Overbalance (psi)} \times ([\text{Riser or Casing Capacity (bbl/ft)} - \text{Closed End Displacement (bbl/ft)}] \times \text{Mud Gradient (psi/ft)} \times \text{Closed End Displacement (bbl/ft)})}{\text{Mud Gradient (psi/ft)} \times \text{Closed End Displacement (bbl/ft)}}
    \]

26. **VOLUME TO BLEED OFF TO RESTORE BHP TO FORMATION PRESSURE (bbl)**
    \[
    \frac{\text{Increase in Surface Pressure (psi)} \times \text{Influx Volume (bbl)}}{\text{Formation Pressure (psi)} - \text{Increase in Surface Pressure (psi)}}
    \]
27. **SLUG VOLUME (bbl) FOR A GIVEN LENGTH OF DRY PIPE**

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

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

\[
\text{Slag Volume (bbl)} = \frac{\text{Slag Density (ppg)}}{\text{Drillpipe Capacity (bbl/ft)}} - 1
\]

29. **RISER MARGIN (ppg)**

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

30. **HYDROSTATIC PRESSURE LOSS IF CASING FLOAT FAILS (psi)**

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