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 5 bar or more above the expected pressures.

Section 2. **Calculation Formula.**

<table>
<thead>
<tr>
<th>Abbreviations used in this document</th>
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<tbody>
<tr>
<td>bar = Bar (pressure)</td>
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<tr>
<td>bar/m = Bar per metre</td>
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<tr>
<td>bar/hr = Bar per hour</td>
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<tr>
<td>BHP = Bottom Hole Pressure</td>
</tr>
<tr>
<td>BOP = Blowout Preventer</td>
</tr>
<tr>
<td>kg/l = Kilogram per litre</td>
</tr>
<tr>
<td>l = Litre</td>
</tr>
<tr>
<td>l/m = Litre per metre</td>
</tr>
<tr>
<td>l/min = Litre per minute</td>
</tr>
<tr>
<td>l/stroke = Litre per stroke</td>
</tr>
<tr>
<td>LOT = Leak-off Test</td>
</tr>
<tr>
<td>m = Metre</td>
</tr>
<tr>
<td>m/hr = Metre per hour</td>
</tr>
<tr>
<td>m/min = Metre per minute</td>
</tr>
<tr>
<td>MAASP = Maximum Allowable annular Surface Pressure</td>
</tr>
<tr>
<td>SICP = Shut in Casing Pressure</td>
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<tr>
<td>SIDPP = Shut in Drill Pipe Pressure</td>
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<tr>
<td>SPM = Strokes per minute</td>
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<tr>
<td>TVD = True Vertical Depth</td>
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<td>0.0981 = Constant factor</td>
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### 1. HYDROSTATIC PRESSURE (bar)

Mud Density (kg/l) x 0.0981 x TVD (m)

### 2. PRESSURE GRADIENT (bar/m)

Mud Density (kg/l) x 0.0981
3. DRILLING MUD DENSITY (kg/l)

\[
\text{Pressure (bar) ÷ TVD (m) ÷ 0.0981}
\]

or

\[
\frac{\text{Pressure (bar)}}{\text{TVD (m) x 0.0981}}
\]

4. FORMATION PORE PRESSURE (bar)

Hydrostatic Pressure in Drilling String (bar) + SIDPP (bar)

5. PUMP OUTPUT (l/min)

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

6. ANNULAR VELOCITY (m/min)

\[
\frac{\text{Pump Output (l/min)}}{\text{Annular Capacity (l/m)}}
\]

7. EQUIVALENT CIRCULATING DENSITY (kg/l)

\[
[\text{Annular Pressure Loss (bar) ÷ TVD (m) ÷ 0.0981}] + \text{Fluid Density (kg/l)}
\]

or

\[
\frac{\text{Annular Pressure Loss (bar)}}{\text{TVD (m) x 0.0981}} + \text{Fluid Density (kg/l)}
\]

8. MUD DENSITY WITH TRIP MARGIN INCLUDED (kg/l)

\[
[\text{Safety Margin (bar) ÷ TVD (m) ÷ 0.0981}] + \text{Mud Density (kg/l)}
\]

or

\[
\frac{\text{Safety Margin (bar)}}{\text{TVD (m) x 0.0981}} + \text{Mud Density (kg/l)}
\]

9. NEW PUMP PRESSURE (bar) WITH NEW PUMP RATE approximate

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

10. NEW PUMP PRESSURE (bar) WITH NEW MUD DENSITY approximate

\[
\text{Old Pump Pressure (bar) x \left(\frac{\text{New Mud Density (kg/l)}}{\text{Old Mud Density (kg/l)}}\right)}
\]
11. **MAXIMUM ALLOWABLE FLUID DENSITY (kg/l)**

   \[\text{Surface LOT Pressure (bar)} + \text{Shoe TVD (m)} \times 0.0981 + \text{LOT Mud Density (kg/l)}\]

   or

   \[\frac{\text{Surface LOT Pressure (bar)}}{\text{Shoe TVD (m)} \times 0.0981} + \text{LOT Mud Density (kg/l)}\]

12. **MAASP (bar)**

   \[\text{Maximum Allowable Mud Density (kg/l)} - \text{Current Mud Density (kg/l)} \times 0.0981 \times \text{TVD (m)}\]

13. **KILL MUD DENSITY (kg/l)**

   \[\text{SIDPP (bar)} + \text{TVD (m)} \times 0.0981 + \text{Original Mud Density (kg/l)}\]

   or

   \[\frac{\text{SIDPP (bar)}}{\text{TVD (m)} \times 0.0981} + \text{Original Mud Density (kg/l)}\]

14. **INITIAL CIRCULATING PRESSURE (bar)**

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

15. **FINAL CIRCULATING PRESSURE (bar)**

   \[\frac{\text{Kill Mud Density (kg/l)}}{\text{Original Mud Density (kg/l)}} \times \text{Kill Rate Circulating Pressure (bar)}\]

16. **BARYTE REQUIRED TO INCREASE DRILLING MUD DENSITY (kg/l)**

   \[\frac{\text{Kill Mud Density (kg/l)}}{- \text{Original Mud Density (kg/l)}} \times 4.2\]

17. **GAS MIGRATION RATE (m/hr)**

   \[\frac{\text{Rate of Increase in Surface Pressure (bar/hr)}}{\text{Drilling Mud Density (kg/l)} \times 0.0981}\]

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 METRE TRIPPING DRY PIPE (bar/m)**

   \[\text{Drilling Mud Density (kg/l)} \times 0.0981 \times \text{Metal Displacement (l/m)}\]

   \[\text{Riser or Casing Capacity (l/m)} - \text{Metal Displacement(l/m)}\]
20. **PRESSURE DROP PER METRE TRIPPING WET PIPE (bar/m)**

   \[ \text{Drilling Mud Density (kg/l) x 0.0981 x Closed End Displacement (l/m)} \]
   \[ \quad \text{Riser or Casing Capacity (l/m) - Closed End Displacement (l/m)} \]

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

   \[ \text{Length of Collars (m) x Metal Displacement (l/m)} \]
   \[ \quad \text{Riser or Casing Capacity (l/m)} \]

22. **LEVEL DROP PULLING REMAINING COLLARS OUT OF HOLE WET (metre)**

   \[ \text{Length of Collars (m) x Closed End Displacement (l/m)} \]
   \[ \quad \text{Riser or Casing Capacity (l/m)} \]

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

   \[ \text{Overbalance (bar) x [Riser or Casing Capacity (l/m) - Metal Displacement (l/m)]} \]
   \[ \quad \text{Drilling Mud Gradient (bar/m) x Metal Displacement (l/m)} \]

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

   \[ \text{Overbalance (bar) x [Riser or Casing Capacity (l/m) - Closed End Displacement (l/m)]} \]
   \[ \quad \text{Drilling Mud Gradient (bar/m) x Closed End Displacement (l/m)} \]

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

   \[ \text{Increase in Surface Pressure (bar) x Influx Volume (l)} \]
   \[ \quad \text{Formation Pressure (bar) - Increase in Surface Pressure (bar)} \]

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

   \[ \text{Length of Dry Pipe (m) x Pipe Capacity (l/m) x Drilling Mud Density (kg/l)} \]
   \[ \quad \text{Slug Density (kg/l) - Drilling Fluid Density (kg/l)} \]

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

   \[ \text{Slug Volume (l) x} \left( \frac{\text{Slug Density (kg/l)}}{\text{Drilling Fluid Density (kg/l)}} - 1 \right) \]

28. **RISER MARGIN (kg/l)**

   \[ \frac{[\text{Air Gap (m) + Water Depth (m)}] \times \text{Mud Density (kg/l)} - [\text{Water Depth (m) x Sea Water Density (kg/l)}]}{\text{TVD (m) - Air Gap (m) - Water Depth (m)}} \]

29. **HYDROSTATIC PRESSURE LOSS IF CASING FLOAT FAILS (bar)**

   \[ \text{Mud Density (kg/l) x 0.0981 x Casing Capacity (l/m) x Unfilled Casing Height (m)} \]
   \[ \quad \text{Casing Capacity (l/m)+Annular Capacity (l/m)} \]