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.**

### Abbreviations Used in this Document

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>bar</td>
<td>Bar (pressure)</td>
</tr>
<tr>
<td>bar/m</td>
<td>Bar per metre</td>
</tr>
<tr>
<td>bar/hr</td>
<td>Bar per hour</td>
</tr>
<tr>
<td>BHP</td>
<td>Bottom hole pressure</td>
</tr>
<tr>
<td>BOP</td>
<td>Blowout Preventer</td>
</tr>
<tr>
<td>kg/l</td>
<td>Kilogram per litre</td>
</tr>
<tr>
<td>l</td>
<td>Litre</td>
</tr>
<tr>
<td>l/m</td>
<td>Litre per metre</td>
</tr>
<tr>
<td>l/min</td>
<td>Litre per minute</td>
</tr>
<tr>
<td>l/stroke</td>
<td>Litre per stroke</td>
</tr>
<tr>
<td>LOT</td>
<td>Leak-off Test</td>
</tr>
<tr>
<td>m</td>
<td>Metre</td>
</tr>
<tr>
<td>m/hr</td>
<td>Metre per hour</td>
</tr>
<tr>
<td>m/min</td>
<td>Metre per minute</td>
</tr>
<tr>
<td>MAASP</td>
<td>Maximum Allowable Annular Surface Pressure</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>10.2</td>
<td>Constant factor</td>
</tr>
</tbody>
</table>

1. **HYDROSTATIC PRESSURE (bar)**

\[
\text{Mud Density (kg/l)} \times \frac{\text{TVD (m)}}{10.2}
\]

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

\[
\text{Mud Density (kg/l)} \times 10.2
\]

3. **DRILLING MUD DENSITY (kg/l)**

\[
\frac{\text{Pressure (bar) \times 10.2}}{\text{TVD (m)}}
\]
4. FORMATION PORE PRESSURE (bar)
   Hydrostatic Pressure in Drill String (bar) + SIDPP (bar)

5. PUMP OUTPUT (l/min)
   Pump Displacement (l/stroke) x Pump Rate (SPM)

6. ANNULAR VELOCITY (m/min)
   Pump Output (l/min)
   Annular Capacity (l/m)

7. EQUIVALENT CIRCULATING DENSITY (kg/l)
   \[
   \text{Annular Pressure Loss (bar) } \times \frac{10.2}{\text{TVD (m)}} + \text{Mud Density (kg/l)}
   \]

8. MUD DENSITY WITH TRIP MARGIN INCLUDED (kg/l)
   \[
   \text{Safety Margin (bar) } \times \frac{10.2}{\text{TVD (m)}} + \text{Mud Density (kg/l)}
   \]

9. NEW PUMP PRESSURE (bar) WITH NEW PUMP RATE approximate
   \[
   \text{Old Pump Pressure (bar)} \times \left(\frac{\text{New Pump Rate (SPM)}}{\text{Old Pump Rate (SPM)}}\right)^2
   \]

10. NEW PUMP PRESSURE (bar) WITH NEW MUD DENSITY approximate
    \[
    \text{Old Pump Pressure (bar)} \times \frac{\text{New Mud Density (kg/l)}}{\text{Old Mud Density (kg/l)}}
    \]

11. MAXIMUM ALLOWABLE MUD DENSITY (kg/l)
    \[
    \text{Surface LOT Pressure (bar) } \times \frac{10.2}{\text{Shoe TVD (m)}} + \text{LOT Mud Density (kg/l)}
    \]

12. MAASP (bar)
    \[
    \left[\text{Maximum Allowable Mud Density (kg/l) } - \text{Current Mud Density (kg/l)}\right] \times \text{Shoe TVD (m)} \times 10.2
    \]

13. KILL MUD DENSITY (kg/l)
    \[
    \frac{\text{SIDPP (bar) } \times 10.2}{\text{TVD (m)}} + \text{Original Mud Density (kg/l)}
    \]

14. INITIAL CIRCULATING PRESSURE (bar)
    \[
    \text{Kill Rate Circulating Pressure (bar) } + \text{SIDPP (bar)}
    \]

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)

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

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

17. GASMIGRATION RATE (m/hr)

\[
\frac{\text{Rate of Increase in Surface Pressure (bar/hr)}}{\text{Drilling Mud Density (kg/l)}} \times 10.2
\]

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)

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

\[
\frac{(\text{Riser or Casing Capacity (l/m)} - \text{Metal Displacement (l/m)}) \times 10.2}{(\text{Riser or Casing Capacity (l/m)} - \text{Closed End Displacement (l/m)}) \times 10.2}
\]

20. PRESSURE DROP PER METRE TRIPPING WET PIPE (bar/m)

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

\[
\frac{(\text{Riser or Casing Capacity (l/m)} - \text{Closed End Displacement (l/m)}) \times 10.2}{(\text{Riser or Casing Capacity (l/m)} - \text{Closed End Displacement (l/m)}) \times 10.2}
\]

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

\[
\text{Length of Collars (m)} \times \text{Metal Displacement (l/m)}
\]

\[
\frac{\text{Riser or Casing Capacity (l/m)}}{}
\]

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

\[
\text{Length of Collars (m)} \times \text{Closed End Displacement (l/m)}
\]

\[
\frac{\text{Riser or Casing Capacity (l/m)}}{}
\]

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

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

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

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

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

\[
\text{Increase in Surface Pressure (bar)} \times \text{Influx Volume (l)}
\]

\[
\text{Formation Pressure (bar)} - \text{Increase in Surface Pressure (bar)}
\]

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

\[
\text{Length of Dry Pipe (m)} \times \text{Pipe Capacity (l/m)} \times \text{Drilling Mud Density (kg/l)}
\]

\[
\frac{\text{Slugs Density (kg/l)}}{-\text{Drilling Mud Density (kg/l)}}
\]

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

\[
\text{Slug Volume (l)} \times \frac{\text{Slugs Density (kg/l)}}{\text{Drilling Mud Density (kg/l)}} - 1
\]
28. **RISER MARGIN (kg/l)**

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

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

\[
\frac{\text{Mud Density (kg/l)} \times \text{Casing Capacity (l/m)} \times \text{Unfilled Casing Height (m)}}{\left( \text{Capacity (l/m)} + \text{Annular Capacity (l/m)} \right) \times 10.2}
\]