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 500 kPa 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>BHP</td>
<td>Bottom Hole Pressure</td>
</tr>
<tr>
<td>BOP</td>
<td>Blowout Preventer</td>
</tr>
<tr>
<td>kg/m³</td>
<td>Kilogram per cubic metre</td>
</tr>
<tr>
<td>kPa</td>
<td>Kilopascal (pressure)</td>
</tr>
<tr>
<td>kPa/m</td>
<td>Kilopascal per metre</td>
</tr>
<tr>
<td>kPa/hr</td>
<td>Kilopascal per hour</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>m³</td>
<td>Cubic Metre</td>
</tr>
<tr>
<td>m³/m</td>
<td>Cubic metres per metre</td>
</tr>
<tr>
<td>m³/min</td>
<td>Cubic Metre per minute</td>
</tr>
<tr>
<td>m³/stroke</td>
<td>Cubic Metre per stroke</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>0.00981</td>
<td>Constant factor</td>
</tr>
</tbody>
</table>

1. **HYDROSTATIC PRESSURE (kPa)**
   
   Mud Density (kg/m³) x 0.00981 x TVD (m)

2. **PRESSURE GRADIENT (kPa/m)**
   
   Mud Density (kg/m³) x 0.00981
3. **DRILLING MUD DENSITY (kg/m³)**

\[
\text{Pressure (kPa)} \div \text{TVD (m)} \div 0.00981
\]

or

\[
\frac{\text{Pressure (kPa)}}{\text{TVD (m)} \times 0.00981}
\]

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

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

5. **PUMP OUTPUT (m³/min)**

Pump Displacement (m³/stroke) x Pump Rate (SPM)

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

\[
\frac{\text{Pump Output (m³/min)}}{\text{Annular Capacity (m³/m)}}
\]

7. **EQUIVALENT CIRCULATING DENSITY (kg/m³)**

\[
\left[\frac{\text{Annular Pressure Loss (kPa)}}{\text{TVD (m)} \div 0.00981}\right] + \text{Mud Density (kg/m³)}
\]

or

\[
\frac{\text{Annular Pressure Loss (kPa)}}{\text{TVD (m)} \times 0.00981} + \text{Mud Density (kg/m³)}
\]

8. **MUD DENSITY WITH TRIP MARGIN INCLUDED (kg/m³)**

\[
\left[\frac{\text{Safety Margin (kPa)}}{\text{TVD (m)} \div 0.00981}\right] + \text{Mud Density (kg/m³)}
\]

or

\[
\frac{\text{Safety Margin (kPa)}}{\text{TVD (m)} \times 0.00981} + \text{Mud Density (kg/m³)}
\]

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

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

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

\[
\text{Old Pump Pressure (kPa)} \times \left(\frac{\text{New Mud Density (kg/m³)}}{\text{Old Mud Density (kg/m³)}}\right)
\]
11. **MAXIMUM ALLOWABLE FLUID DENSITY (kg/m³)**

\[
\text{[Surface LOT Pressure (kPa) + Shoe TVD (m) ÷ 0.00981] + LOT Mud Density (kg/m³)}
\]

or

\[
\frac{\text{Surface LOT Pressure (kPa)}}{\text{Shoe TVD (m) x 0.00981}} + \text{LOT Mud Density (kg/m³)}
\]

12. **MAASP (kPa)**

\[
\text{[Maximum Allowable Mud Density (kg/m³) – Current Mud Density (kg/m³)] x 0.00981 x Shoe TVD (m)}
\]

13. **KILL MUD DENSITY (kg/m³)**

\[
\text{[SIDPP (kPa) + TVD (m) ÷ 0.00981] + Original Mud Density (kg/m³)}
\]

or

\[
\frac{\text{SIDPP (kPa)}}{\text{TVD (m) x 0.00981}} + \text{Original Mud Density (kg/m³)}
\]

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

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

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

\[
\frac{\text{Kill Mud Density (kg/m³)}}{\text{Original Mud Density (kg/m³)}} \times \text{Kill Rate Circulating Pressure (kPa)}
\]

16. **BARYTE REQUIRED TO INCREASE DRILLING MUD DENSITY (kg/m³)**

\[
\frac{\text{[Kill Mud Density (kg/m³) - Original Mud Density (kg/m³)] x 4200}}{4200 - \text{Kill Mud Density (kg/m³)}}
\]

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

\[
\frac{\text{Rate of Increase in Surface Pressure (kPa/hr)}}{\text{Drilling Mud Density (kg/m³) x 0.00981}}
\]

18. **GAS LAWS**

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

19. **PRESSURE DROP PER METRE TRIPPING DRY PIPE (kPa/m)**

\[
\text{Drilling Mud Density (kg/m³) x 0.00981 x Metal Displacement (m³/m)}
\]

\[
\text{Riser or Casing Capacity (m³/m) - Metal Displacement (m³/m)}
\]
20. **PRESSURE DROP PER METRE TRIPPING WET PIPE (kPa/m)**

\[
\text{Drilling Mud Density (kg/m}^3\text{) x 0.00981 x Closed End Displacement (m}^3\text{/m)} \div \text{Riser or Casing Capacity (m}^3\text{/m) - Closed End Displacement (m}^3\text{/m)}
\]

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

\[
\text{Length of Collars (m) x Metal Displacement (m}^3\text{/m)} \div \text{Riser or Casing Capacity (m}^3\text{/m)}
\]

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

\[
\text{Length of Collars (m) x Closed End Displacement (m}^3\text{/m)} \div \text{Riser or Casing Capacity (m}^3\text{/m)}
\]

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

\[
\text{Overbalance (kPa) x [Riser or Casing Capacity (m}^3\text{/m) - Metal Displacement (m}^3\text{/m)]} \div \text{Drilling Mud Gradient (kPa/m) x Metal Displacement (m}^3\text{/m)}
\]

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

\[
\text{Overbalance (kPa) x [Riser or Casing Capacity (m}^3\text{/m) - Closed End Displacement (m}^3\text{/m)]} \div \text{Drilling Mud Gradient (kPa/m) x Closed End Displacement (m}^3\text{/m)}
\]

25. **VOLUME TO BLEED OFF TO RESTORE BHP TO FORMATION PRESSURE (m}^3\)**

\[
\text{Increase in Surface Pressure (kPa) x Influx Volume (m}^3\text{)} \div \text{Formation Pressure (kPa) - Increase in Surface Pressure (kPa)}
\]

26. **SLUG VOLUME (m}^3\) FOR A GIVEN LENGTH OF DRY PIPE**

\[
\text{Length of Dry Pipe (m) x Pipe Capacity (m}^3\text{/m) x Drilling Mud Density (kg/m}^3\text{)} \div \text{Slug Density (kg/m}^3\text{) - Drilling Fluid Density (kg/m}^3\text{)}
\]

27. **PIT GAIN DUE TO SLUG U-TUBING (m}^3\)**

\[
\text{Slug Volume (m}^3\text{)} \times \left(\frac{\text{Slug Density (kg/m}^3\text{)}}{\text{Drilling Fluid Density (kg/m}^3\text{)}} - 1\right)
\]

28. **RISER MARGIN (kg/m}^3\)**

\[
\text{[Air Gap (m) + Water Depth (m)] x Mud Density (kg/m}^3\text{)} - \text{[Water Depth (m) x Sea Water Density (kg/m}^3\text{)]} \div \text{TVD (m) - Air Gap (m) - Water Depth (m)}
\]

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

\[
\text{Mud Density (kg/m}^3\text{) x 0.00981 x Casing Capacity (m}^3\text{/m) x Unfilled Casing Height (m)} \div \text{Casing Capacity (m}^3\text{/m) + Annular Capacity (m}^3\text{/m)}
\]