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)

\[ \text{Mud Density (ppg)} \times 0.052 \times \text{TVD (ft)} \]

2. PRESSURE GRADIENT (psi/ft)

\[ \text{Mud Density (ppg)} \times 0.052 \]
3. **DRILLING MUD DENSITY (ppg)**

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

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)**

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)**

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

or

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

8. **MUD DENSITY WITH TRIP MARGIN INCLUDED (ppg)**

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

or

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

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)**

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

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

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)**

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

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**

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

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

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)**

\[
\frac{\text{Drilling Mud Density (ppg) \times 0.052 \times Metal Displacement (bbl/ft)}}{\text{Riser or Casing Capacity (bbl/ft) - Metal Displacement (bbl/ft)}}
\]

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

\[
\frac{\text{Drilling Mud Density (ppg) \times 0.052 \times Closed End Displacement (bbl/ft)}}{\text{Riser or Casing Capacity (bbl/ft) - Closed End Displacement (bbl/ft)}}
\]
22. LEVEL DROP PULLING REMAINING COLLARS OUT OF HOLE DRY (ft)

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

23. LEVEL DROP PULLING REMAINING COLLARS OUT OF HOLE WET (ft)

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

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

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

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

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

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

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

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

\[ \text{Slug Volume (bbl)} \times \left( \frac{\text{Slug Density (ppg)}}{\text{Drilling Mud Density (ppg)}} - 1 \right) \]

29. 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)

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