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

bar	**=**	**Bar (pressure)**
bar/m	**=**	**Bar per metre**
bar/hr	**=**	**Bar per hour**
BHP	**=**	**Bottom hole pressure**
BOP	**=**	**Blowout Preventer**
kg/l	**=**	**Kilogram per litre**
l	**=**	**Litre**
l/m	**=**	**Litre per metre**
l/min	**=**	**Litre per minute**
l/stroke	**=**	**Litre per stroke**
LOT	**=**	**Leak-off Test**
m	**=**	**Metre**
m/hr	**=**	**Metre per hour**
m/min	**=**	**Metre per minute**
MAASP	**=**	**Maximum Allowable Annular Surface Pressure**
SICP	**=**	**Shut in Casing Pressure**
SIDPP	**=**	**Shut in Drill Pipe Pressure**
SPM	**=**	**Strokes per minute**
TVD	**=**	**True Vertical Depth**
0.0981	**=**	**Constant factor**

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1. HYDROSTATIC PRESSURE (bar)

$$\text{Mud Density (kg/l)} \times 0.0981 \times \text{TVD (m)}$$

2. PRESSURE GRADIENT (bar/m)

$$\text{Mud Density (kg/l)} \times 0.0981$$

3. DRILLING MUD DENSITY (kg/l)

$$\text{Pressure (bar)} \div \text{TVD (m)} \div 0.0981$$

or

$$\frac{\text{Pressure (bar)}}{\text{TVD (m)} \times 0.0981}$$

4. FORMATION PORE PRESSURE (bar)

$$\text{Hydrostatic Pressure in Drill String (bar)} + \text{SIDPP (bar)}$$

5. PUMP OUTPUT (l/min)

$$\text{Pump Displacement (l/stroke) x Pump Rate (SPM)}$$

6. ANNULAR VELOCITY (m/min)

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

7. EQUIVALENT CIRCULATING DENSITY (kg/l)

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

or

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

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

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

or

$$\frac{\text{Safety Margin (bar)}}{\text{TVD (m)} \times 0.0981} + \text{Mud Density (kg/l)}$$

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 FLUID DENSITY approximate

$$\text{Old Pump Pressure (bar)} \times \frac{\text{New Mud Density (kg/l)}}{\text{Old Mud Density (kg/l)}}$$

11. MAXIMUM ALLOWABLE FLUID DENSITY (kg/l)

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

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. SICP (psi)

$$\{[\text{Mud Density (kg/l)} - \text{Influx Density (kg/l)}] \text{ x } 0.0981 \text{ x Influx Vertical Height (m)}\} + \text{SIDPP (bar)}$$

14. KILL MUD DENSITY (kg/l)

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

or

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

15. INITIAL CIRCULATING PRESSURE (bar)

$$\text{Kill Rate Circulating Pressure (bar)} + \text{SIDPP (bar)}$$

16. FINAL CIRCULATING PRESSURE (bar)

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

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

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

18. GAS MIGRATION RATE (m/hr)

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

19. GAS LAWS

$$P_1 \text{ x } V_1 = P_2 \text{ x } V_2 \qquad P_2 = \frac{P_1 \times V_1}{V_2} \qquad V_2 = \frac{P_1 \times V_1}{P_2}$$

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

$$\frac{\text{Drilling Mud Density (kg/l)} \times 0.0981 \times \text{Metal Displacement (l/m)}}{\text{Riser or Casing Capacity (l/m)} - \text{Metal Displacement (l/m)}}$$

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

$$\frac{\text{Drilling Mud Density (kg/l)} \times 0.0981 \times \text{Closed End Displacement (l/m)}}{\text{Riser or Casing Capacity (l/m)} - \text{Closed End Displacement (l/m)}}$$

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

$$\frac{\text{Length of Collars (m)} \times \text{Metal Displacement (l/m)}}{\text{Riser or Casing Capacity (l/m))}}$$

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

$$\frac{\text{Length of Collars (m)} \times \text{Closed End Displacement (l/m)}}{\text{Riser or Casing Capacity (l/m))}}$$

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

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

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

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

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

$$\frac{\text{Increase in Surface Pressure (bar)} \times \text{Influx Volume (l)}}{\text{Formation Pressure (bar)} - \text{Increase in Surface Pressure (bar)}}$$

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

$$\frac{\text{Length of Dry Pipe (m)} \times \text{Pipe Capacity (l/m)} \times \text{Drilling Fluid Density (kg/l)}}{\text{Slug Density (kg/l)} - \text{Drilling Fluid Density (kg/l)}}$$

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

$$\text{Slug Volume (l)} \times \left(\frac{\text{Slug Density (kg/l)}}{\text{Drilling Fluid Density (kg/l)}} - 1\right)$$

29. RISER MARGIN (kg/l)

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

30. HYDROSTATIC PRESSURE LOSS IF CASING FLOAT FAILS (bar)

$$\frac{\text{Mud Density(kg/l)} \times 0.0981 \times \text{Casing Capacity (l/m)} \times \text{Unfilled Casing Height (m)}}{\text{Casing Capacity (l/m)} + \text{Annular Capacity (l/m)}}$$

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