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

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
10.2	=	Constant factor

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1. HYDROSTATIC PRESSURE (bar)

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

2. PRESSURE GRADIENT (bar/m)

$$\frac{\text{Mud Density (kg/l)}}{10.2}$$

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)

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

7. EQUIVALENT CIRCULATING DENSITY (kg/l)

$$\frac{\text{Annular Pressure Loss (bar)} \times 10.2}{\text{TVD (m)}} + \text{Mud Density (kg/l)}$$

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

$$\frac{\text{Safety Margin (bar)} \times 10.2}{\text{TVD (m)}} + \text{Mud Density (kg/l)}$$

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)

$$\frac{\text{Surface LOT Pressure (bar)} \times 10.2}{\text{Shoe TVD (m)}} + \text{LOT Mud Density (kg/l)}$$

12. MAASP (bar)

$$\frac{[\text{Maximum Allowable Mud Density (kg/l)} - \text{Current Mud Density (kg/l)}] \times \text{Shoe TVD (m)}}{10.2}$$

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)

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)

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

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

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

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

$$\frac{\text{Drilling Mud Density (kg/l)} \times \text{Metal Displacement (l/m)}}{(\text{Riser or Casing Capacity (l/m)} - \text{Metal Displacement (l/m)}) \times 10.2}$$

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

$$\frac{\text{Drilling Mud Density (kg/l)} \times \text{Closed End Displacement (l/m)}}{(\text{Riser or Casing Capacity (l/m)} - \text{Closed End Displacement (l/mt)}) \times 10.2}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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 FLOAT FAILS (bar)

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