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
0.0981	=	Constant factor

1. HYDROSTATIC PRESSURE (bar)

Mud Density (kg/l) x 0.0981 x TVD (m)

2. PRESSURE GRADIENT (bar/m)

Mud Density (kg/l) x 0.0981

3. DRILLING MUD DENSITY (kg/l)

Pressure (bar) ÷ TVD (m) ÷ 0.0981

or

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

4. FORMATION PORE PRESSURE (bar)

Hydrostatic Pressure in Drilling 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)

[Annular Pressure Loss (bar) ÷ TVD (m) ÷ 0.0981] + Fluid Density (kg/l)

or

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

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

[Safety Margin (bar) ÷ TVD (m) ÷ 0.0981] + Mud Density (kg/l)

or

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

9. NEW PUMP PRESSURE (bar) WITH NEW PUMP RATE approximate

$$\text{Old Pump Pressure (bar) x } \left(\frac{\text{New Pump Rate (SPM)}}{\text{Old Pump Rate (SPM)}}\right)^2$$

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

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

11. MAXIMUM ALLOWABLE FLUID DENSITY (kg/l)

[Surface LOT Pressure (bar) ÷ Shoe TVD (m) ÷ 0.0981] + 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)

[Maximum Allowable Mud Density (kg/l) – Current Mud Density (kg/l)] x 0.0981 x shoe TVD (m)

13. KILL MUD DENSITY (kg/l)

[SIDPP (bar) ÷ TVD (m) ÷ 0.0981) + Original Mud Density (kg/l)

or

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

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. GAS MIGRATION RATE (m/hr)

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

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)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

28. RISER MARGIN (kg/l)

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

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

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