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

BHP	=	Bottom Hole Pressure
BOP	=	Blowout Preventer
kg/m^3	=	Kilogram per cubic metre
kPa	=	KiloPascal (pressure)
kPa/m	=	KiloPascal per metre
kPa/hr	=	KiloPascal per hour
LOT	=	Leak-off Test
m	=	Metre
m/hr	=	Metre per hour
m/min	=	Metre per minute
m^3	=	Cubic Metre
m^3/m	=	Cubic metres per metre
m^3/min	=	Cubic Metre per minute
$m^3/stroke$	=	Cubic Metre per stroke
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
0.00981	=	Constant factor

1. HYDROSTATIC PRESSURE (kPa)

Mud Density (kg/m^3) x 0.00981 x TVD (m)

2. PRESSURE GRADIENT (kPa/m)

Mud Density (kg/m^3) x 0.00981

3. DRILLING MUD DENSITY (kg/m³)

Pressure (kPa) ÷ TVD (m) ÷ 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)

$$\frac{\text{Pump Output (m}^3\text{/min)}}{\text{Annular Capacity (m}^3\text{/m)}}$$

7. EQUIVALENT CIRCULATING DENSITY (kg/m³)

[Annular Pressure Loss (kPa) ÷ TVD (m) ÷ 0.00981] + Mud Density (kg/m³)

or

$$\frac{\text{Annular Pressure Loss (kPa)}}{\text{TVD (m)} \times 0.00981} + \text{Mud Density (kg/m}^3\text{)}$$

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

[Safety Margin (kPa) ÷ TVD (m) ÷ 0.00981] + Mud Density (kg/m³)

or

$$\frac{\text{Safety Margin (kPa)}}{\text{TVD (m)} \times 0.00981} + \text{Mud Density (kg/m}^3\text{)}$$

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

$$\text{Old Pump Pressure (kPa)} \times \frac{\text{New Mud Density (kg/m}^3\text{)}}{\text{Old Mud Density (kg/m}^3\text{)}}$$

11. MAXIMUM ALLOWABLE FLUID DENSITY (kg/m³)

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

or

$$\frac{\text{Surface LOT Pressure (kPa)}}{\text{Shoe TVD (m) x 0.00981}} + \text{LOT Mud Density (kg/m}^3\text{)}$$

12. MAASP (kPa)

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

13. KILL MUD DENSITY (kg/m³)

[SIDPP (kPa) ÷ TVD (m) ÷ 0.00981) + Original Mud Density (kg/m³)

or

$$\frac{\text{SIDPP (kPa)}}{\text{TVD (m) x 0.00981}} + \text{Original Mud Density (kg/m}^3\text{)}$$

14. INITIAL CIRCULATING PRESSURE (kPa)

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

15. FINAL CIRCULATING PRESSURE (kPa)

$$\frac{\text{Kill Mud Density (kg/}m^3\text{)}}{\text{Original Mud Density (kg/}m^3\text{)}} \text{ x Kill Rate Circulating Pressure (kPa)}$$

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

$$\frac{\text{[Kill Mud Density (kg/}m^3\text{) - Original Mud Density (kg/}m^3\text{)] x 4200}}{\text{4200 - Kill Mud Density (kg/}m^3\text{)}}$$

17. GAS MIGRATION RATE (m/hr)

$$\frac{\text{Rate of Increase in Surface Pressure (kPa/hr)}}{\text{Drilling Mud Density (kg/m}^3\text{) x 0.00981}}$$

18. GAS LAWS

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

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

$$\frac{\text{Drilling Mud Density (kg/}m^3\text{) x 0.00981 x Metal Displacement (}m^3\text{/m)}}{\text{Riser or Casing Capacity (}m^3\text{/m) - Metal Displacement (}m^3\text{/m)}}$$

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

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

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

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

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

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

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

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

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

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

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

$$\frac{\text{Increase in Surface Pressure (}kPa\text{) x Influx Volume (}m^3\text{)}}{\text{Formation Pressure (kPa) - Increase in Surface Pressure (kPa)}}$$

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

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

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

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

28. RISER MARGIN (kg/m^3)

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

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

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