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

bbl	=	Barrels (US)
bbl/ft	=	Barrels (US) per foot
bbl/min	=	Barrels (US) per minute
bbl/stroke	=	Barrels (US) per stroke
BHP	=	Bottom Hole Pressure
BOP	=	Blowout Preventer
ft	=	Feet
ft/hr	=	Feet per hour
ft/min	=	Feet per minute
lb/bbl	=	Pounds per barrel
LOT	=	Leak-off Test
MAASP	=	Maximum Allowable Annular Surface Pressure
ppg	=	Pounds per gallon
psi	=	Pounds per square inch
psi/ft	=	Pounds per square inch per foot
psi/hr	=	Pounds per square inch per hour
SICP	=	Shut in Casing Pressure
SIDPP	=	Shut in Drill Pipe Pressure
SPM	=	Strokes per minute
TVD	=	True Vertical Depth
0.052	=	Constant factor

1. HYDROSTATIC PRESSURE (psi)

Mud Density (ppg) x 0.052 x TVD (ft)

2. PRESSURE GRADIENT (psi/ft)

Mud Density (ppg) x 0.052

3. DRILLING MUD DENSITY (ppg)

Pressure (psi) ÷ TVD (ft) ÷ 0.052

or

$$\frac{\text{Pressure (psi)}}{\text{TVD (ft) x 0.052}}$$

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)

[Annular Pressure Loss (psi) ÷ TVD (ft) ÷ 0.052] + Mud Density (ppg)

Or

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

8. MUD DENSITY WITH TRIP MARGIN INCLUDED (ppg)

[Safety Margin (psi) ÷TVD (ft) ÷ 0.052] + Mud Density (ppg)

Or

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

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)

[Surface LOT pressure (psi) ÷ Shoe TVD (ft) ÷ 0.052] + LOT Mud Density (ppg)

or

$$\frac{\text{Surface LOT Pressure (psi)}}{\text{Shoe TVD (ft)} \times 0.052} + \text{LOT Mud Density (ppg)}$$

12. MAASP (psi)

[Maximum Allowable Mud Density (ppg) – Current Mud Density (ppg)] x 0.052 x Shoe TVD (ft)

13. KILL MUD DENSITY (ppg)

[SIDPP (psi) ÷ TVD (ft) ÷ 0.052] + Original Mud Density (ppg)

or

$$\frac{\text{SIDPP (psi)}}{\text{TVD (ft)} \times 0.052} + \text{Original Mud Density (ppg)}$$

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

$$\frac{\text{Rate of Increase in Surface Pressure (psi/hr)}}{\text{Drilling Mud Density (ppg)} \times 0.052}$$

18. GAS LAWS

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

19. PRESSURE DROP PER FOOT TRIPPING DRY PIPE (psi/ft)

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

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

$$\frac{\text{Drilling Mud Density (ppg)} \times 0.052 \times \text{Closed End Displacement (bbl/ft)}}{\text{Riser or Casing Capacity (bbl/ft)} - \text{Closed End Displacement (bbl/ft)}}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

28. RISER MARGIN (ppg)

$$\frac{[\text{Air Gap (ft)} + \text{Water Depth (ft)}] \times \text{Mud Density (ppg)} - [\text{Water Depth (ft)} \times \text{Sea Water Density (ppg)}]}{\text{TVD (ft)} - \text{Air Gap (ft)} - \text{Water Depth (ft)}}$$

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

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