

**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**

bbbl	=	Barrels (US)
bbbl/ft	=	Barrels (US) per foot
bbbl/min	=	Barrels (US) per minute
bbbl/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)**

$$\text{Mud Density (ppg)} \times 0.052 \times \text{TVD (ft)}$$

**2. PRESSURE GRADIENT (psi/ft)**

$$\text{Mud Density (ppg)} \times 0.052$$

**3. DRILLING MUD DENSITY (ppg)**

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

or

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

**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)**

$$[\text{Annular Pressure Loss (psi)} \div \text{TVD (ft)} \div 0.052] + \text{Mud Density (ppg)}$$

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)**

$$[\text{Safety Margin (psi)} \div \text{TVD (ft)} \div 0.052] + \text{Mud Density (ppg)}$$

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)**

$$[\text{Surface LOT pressure (psi)} \div \text{Shoe TVD (ft)} \div 0.052] + \text{LOT Mud Density (ppg)}$$

or

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

**12. MAASP (psi)**

$$[\text{Maximum Allowable Mud Density (ppg)} - \text{Current Mud Density (ppg)}] \times 0.052 \times \text{Shoe TVD (ft)}$$

**13. SICP (psi)**

$$\{[\text{Mud Density (ppg)} - \text{Influx Density (ppg)}] \times 0.052 \times \text{Influx Vertical Height (ft)}\} + \text{SIDPP (psi)}$$

**14. KILL MUD DENSITY (ppg)**

$$[\text{SIDPP (psi)} \div \text{TVD (ft)} \div 0.052] + \text{Original Mud Density (ppg)}$$

or

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

**15. INITIAL CIRCULATING PRESSURE (psi)**

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

**16. FINAL CIRCULATING PRESSURE (psi)**

$$\frac{\text{Kill Mud Density (ppg)}}{\text{Original Mud Density (ppg)}} \times \text{Kill Rate Circulating Pressure (psi)}$$

**17. BARYTE REQUIRED TO INCREASE DRILLING MUD DENSITY (lb/bbl)**

$$\frac{[\text{Kill Mud Density (ppg)} - \text{Original Mud Density (ppg)}] \times 1500}{35.8 - \text{Kill Mud Density (ppg)}}$$

**18. GAS MIGRATION RATE (ft/hr)**

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

or

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

**19. GAS LAWS**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**29. RISER MARGIN (ppg)**

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

**30. HYDROSTATIC PRESSURE LOSS IF CASING FLOAT FAILS (psi)**

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

**International Well Control Forum**

Inchbraoch House  
South Quay  
Montrose  
Angus DD10 9UA, Scotland,

Tel: 44-1674-678120  
Fax: 44-1674-678125

Email: [admin@iwcf.org](mailto:admin@iwcf.org)  
**Internet site URL; <http://www.iwcf.org>**

Chief Executive Officer; David Price

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