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

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 metres per minute**
m^3/stroke	**=**	**Cubic metres 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)

$$\text{Mud Density (kg/m}^3\text{)} \times 0.00981 \times \text{TVD (m)}$$

2. PRESSURE GRADIENT (kPa/m)

$$\text{Mud Density (kg/m}^3\text{)} \times 0.00981$$

3. DRILLING MUD DENSITY (kg/m^3)

$$\text{Pressure (kPa)} \div \text{TVD (m)} \div 0.00981$$

or

$$\frac{\text{Pressure (kPa)}}{\text{TVD (m)} \times 0.00981}$$

4. FORMATION PORE PRESSURE (kPa)

$$\text{Hydrostatic Pressure in Drill String (kPa)} + \text{SIDPP (kPa)}$$

5. PUMP OUTPUT (m^3/min)

$$\text{Pump Displacement } (m^3/\text{stroke}) \text{ x Pump Rate (SPM)}$$

6. ANNULAR VELOCITY (m/min)

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

7. EQUIVALENT CIRCULATING DENSITY (kg/m^3)

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

or

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

8. MUD DENSITY WITH TRIP MARGIN INCLUDED (kg/m^3)

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

or

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

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 (kPa) WITH NEW FLUID DENSITY approximate

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

11. MAXIMUM ALLOWABLE FLUID DENSITY (kg/m^3)

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

or

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

12. MAASP (kPa)

$$[\text{Maximum Allowable Mud Density } (kg/m^3) - \text{Current Mud Density } (kg/m^3)] \times 0.00981 \times \text{Shoe TVD (m)}$$

13. SICP (kPa)

$$\{[\text{Mud Density } (kg/m^3) - \text{Influx Density } (kg/m^3)] \text{ x } 0.00981 \text{ x Influx Vertical Height (m)}\} + \text{SIDPP (kPa)}$$

14. KILL MUD DENSITY (kg/m³)

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

or

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

15. INITIAL CIRCULATING PRESSURE (kPa)

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

16. FINAL CIRCULATING PRESSURE (kPa)

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

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

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

18. GAS MIGRATION RATE (m/hr)

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

19. GAS LAWS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

29. RISER MARGIN (kg/m³)

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

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

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

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
Internet site URL; http://www.iwcf.org

Chief Executive Officer; David Price