Section 1. Filled-in kill sheet exercises – Gauge problem exercises

Gauge problem exercises are created from a pre-completed kill sheet containing all relevant volume and pressure calculations.

Each question is based on strokes, pump rate, drillpipe and casing gauge readings at a specific point in time during 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 drillpipe pressures will only be relevant to the action if:

- The casing and/or drillpipe pressures given in the question are below the expected pressures.

or

- The casing and/or drillpipe pressures given in the question are 5 bar or more above the expected pressures.

Section 2. Calculation formula

Abbreviation	Term
0.0981	constant factor
l	litres
l/m	litres per metre
l/min	litres per minute
l/stroke	litres per stroke
BHP	bottomhole pressure
BOP	blowout preventer
m	metres
m/hr	metres per hour
m/min	metres per minute
LOT	leak-off test
MAASP	maximum allowable annular surface pressure
kg/l	kilograms per litre
bar	bar (pressure)
bar/m	bar per metre
bar/hr	bar per hour
SICP	shut-in casing pressure
SIDPP	shut-in drillpipe pressure
SPM	strokes per minute
TVD	true vertical depth

1. Hydrostatic pressure (bar)

$$\text{fluid density (kg/l)} \times 0.0981 \times \text{TVD (m)}$$

2. Pressure gradient (bar/m)

$$\text{fluid density (kg/l)} \times 0.0981$$

3. Fluid density (kg/l)

$$\text{hydrostatic pressure (bar)} \div \text{TVD (m)} \div 0.0981$$

or

$$\frac{\text{hydrostatic pressure (bar)}}{\text{TVD (m)} \times 0.0981}$$

4. Formation pressure (bar)

$$\text{hydrostatic pressure in drillstring (bar)} + \text{SIDPP (bar)}$$

5. Pump output (l/min)

$$\text{pump displacement (l/stroke)} \times \text{pump rate (SPM)}$$

6. Equivalent circulating density (kg/l)

$$\text{fluid density (kg/l)} + (\text{annular pressure loss (bar)} \div \text{TVD (m)} \div 0.0981)$$

or

$$\text{fluid density (kg/l)} + \left(\frac{\text{annular pressure loss (bar)}}{\text{TVD (m)} \times 0.0981}\right)$$

7. Fluid density (kg/l) with trip margin (bar) included

$$\text{fluid density (kg/l)} + (\text{trip margin (bar)} \div \text{TVD (m)} \div 0.0981)$$

or

$$\text{fluid density (kg/l)} + \left(\frac{\text{trip margin (bar)}}{\text{TVD (m)} \times 0.0981}\right)$$

8. New pump pressure (bar) with new pump rate (SPM) (approximate)

$$\text{current pump pressure (bar)} \times \left(\frac{\text{new pump rate (SPM)}}{\text{current pump rate (SPM)}}\right)^2$$

9. New pump pressure (bar) with new fluid density (kg/l) (approximate)

$$\text{current pump pressure (bar)} \times \left(\frac{\text{new fluid density (kg/l)}}{\text{current fluid density (kg/l)}}\right)$$

10. Maximum allowable fluid density (kg/l)

$$\text{LOT fluid density (kg/l)} + (\text{surface LOT pressure (bar)} \div \text{casing shoe TVD (m)} \div 0.0981)$$

or

$$\text{LOT fluid density (kg/l)} + \left(\frac{\text{surface LOT pressure (bar)}}{\text{casing shoe TVD (m)} \times 0.0981}\right)$$

11. MAASP (bar)

$$(\text{maximum allowable fluid density (kg/l)} - \text{current fluid density (kg/l)}) \times \text{casing shoe TVD (m)} \times 0.0981$$

12. Kill fluid density (kg/l)

$$\text{current fluid density (kg/l)} + (\text{SIDPP (bar)} \div \text{TVD (m)} \div 0.0981)$$

or

$$\text{current fluid density (kg/l)} + \left(\frac{\text{SIDPP (bar)}}{\text{TVD (m)} \times 0.0981}\right)$$

13. Initial circulating pressure (bar)

$$\text{circulating pressure at kill rate (bar)} + \text{SIDPP (bar)}$$

14. Final circulating pressure (bar)

$$\left(\frac{\text{kill fluid density (kg/l)}}{\text{current fluid density (kg/l)}}\right) \times \text{circulating pressure at kill rate (bar)}$$

15. Gas migration rate (m/hr)

$$\text{rate of increase in surface pressure (bar/hr)} \div \text{fluid density (kg/l)} \div 0.0981$$

or

$$\frac{\text{rate of increase in surface pressure (bar/hr)}}{\text{fluid density (kg/l)} \times 0.0981}$$

16. Gas laws

$$P_1 \times V_1 = P_2 \times V_2$$

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

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

17. Pressure drop per metre tripping dry pipe (bar/m)

$$\frac{\text{fluid density (kg/l)} \times 0.0981 \times \text{metal displacement (l/m)}}{\text{riser or casing capacity (l/m)} - \text{metal displacement (l/m)}}$$

18. Pressure drop per metre tripping wet pipe (bar/m)

$$\frac{\text{fluid density (kg/l)} \times 0.0981 \times \text{closed end displacement (l/m)}}{\text{riser or casing capacity (l/m)} - \text{closed end displacement (l/m)}}$$

19. Level drop pulling remaining collars out of well dry (m)

$$\frac{\text{length of collars (m)} \times \text{metal displacement (l/m)}}{\text{riser or casing capacity (l/m)}}$$

20. Level drop pulling remaining collars out of well wet (m)

$$\frac{\text{length of collars (m)} \times \text{closed end displacement (l/m)}}{\text{riser or casing capacity (l/m)}}$$

21. Length of tubulars to pull dry before overbalance is lost (m)

$$\frac{\text{overbalance (bar)} \times \left(\text{riser or casing capacity (l/m)} - \text{metal displacement (l/m)}\right)}{\text{fluid gradient (bar/m)} \times \text{metal displacement (l/m)}}$$

or

$$\frac{\text{overbalance (bar)} \times \left(\text{riser or casing capacity (l/m)} - \text{metal displacement (l/m)}\right)}{\text{fluid density (kg/l)} \times 0.0981 \times \text{metal displacement (l/m)}}$$

22. Length of tubulars to pull wet before overbalance is lost (m)

$$\frac{\text{overbalance (bar)} \times \left(\text{riser or casing capacity (l/m)} - \text{closed end displacement (l/m)}\right)}{\text{fluid gradient (bar/m)} \times \text{closed end displacement (l/m)}}$$

or

$$\frac{\text{overbalance (bar)} \times \left(\text{riser or casing capacity (l/m)} - \text{closed end displacement (l/m)}\right)}{\text{fluid density (kg/l)} \times 0.0981 \times \text{closed end displacement (l/m)}}$$

23. Volume to bleed due to gas migration in a vertical well (l)

$$\text{working pressure to bleed (bar)} \times \left(\frac{\text{annular capacity (l/m)}}{\text{pressure gradient (bar/m)}}\right)$$

or

$$\text{working pressure to bleed (bar)} \times \left(\frac{\text{annular capacity (l/m)}}{\text{fluid density (kg/l)} \times 0.0981}\right)$$

24. Slug volume (litre) for a given length of dry pipe

$$\frac{\text{length of dry pipe (m)} \times \text{pipe capacity (l/m)} \times \text{current fluid density (kg/l)}}{\text{slug density (kg/l)} - \text{current fluid density (kg/l)}}$$

25. Pit gain due to slug U-tubing (litre)

$$\text{slug volume (l)} \times \left(\frac{\text{slug density (kg/l)}}{\text{current fluid density (kg/l)}} - 1\right)$$

26. Riser margin (kg/l)

$$\frac{\left(\left(\text{air gap (m)} + \text{water depth (m)}\right) \times \text{fluid density (kg/l)}\right) - \left(\text{water depth (m)} \times \text{water density (kg/l)}\right)}{\text{TVD (m)} - \text{air gap (m)} - \text{water depth (m)}}$$

27. Hydrostatic pressure loss if casing float fails (bar)

$$\frac{\text{fluid density (kg/l)} \times 0.0981 \times \text{casing capacity (l/m)} \times \text{unfilled casing height (m)}}{\text{casing capacity (l/m)} + \text{annular capacity (l/m)}}$$