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 kg/cm^2 or more above the expected pressures.

Section 2. Calculation formula

Abbreviation	Term
10	constant factor
l	litres
l/m	litres per minute
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
kg/l	kilogramme per litre
LOT	leak-off test
MAASP	maximum allowable annular surface pressure
kg/cm^2	kilogram per square centimetre (pressure)
kg/cm^2/m	kilogram per square centimetre per metre
kg/cm^2/hr	kilogram per square centimetre per hour
SICP	shut-in casing pressure
SIDPP	shut-in drillpipe pressure
SPM	strokes per minute
TVD	true vertical depth

1. **Hydrostatic pressure (kg/cm²)**

$$\frac{\text{fluid density (kg/l)} \times \text{TVD (m)}}{10}$$

2. **Pressure gradient (kg/cm²/m)**

$$\frac{\text{fluid density (kg/l)}}{10}$$

3. **Fluid density (kg/l)**

$$\text{hydrostatic pressure}\left(\text{kg/cm}^2\right) \div \text{TVD (m)} \times 10$$

or

$$\frac{\text{hydrostatic pressure}\left(\text{kg/cm}^2\right) \times 10}{\text{TVD (m)}}$$

4. **Formation pressure (kg/cm²)**

$$\text{hydrostatic pressure in drillstring}\left(\text{kg/cm}^2\right) + \text{SIDPP}\left(\text{kg/cm}^2\right)$$

5. **Pump output (l/min)**

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

6. **Equivalent circulating density (kg/l)**

$$\text{fluid density (kg/l)} + \left(\text{annular pressure loss}\left(\text{kg/cm}^2\right) \div \text{TVD (m)} \times 10\right)$$

or

$$\text{fluid density (kg/l)} + \left(\frac{\text{annular pressure loss}\left(\text{kg/cm}^2\right) \times 10}{\text{TVD (m)}}\right)$$

7. **Fluid density (kg/l) with trip margin (kg/cm²) included**

$$\text{fluid density (kg/l)} + \left(\text{trip margin}\left(\text{kg/cm}^2\right) \div \text{TVD (m)} \times 10\right)$$

or

$$\text{fluid density (kg/l)} + \left(\frac{\text{trip margin}\left(\text{kg/cm}^2\right) \times 10}{\text{TVD (m)}}\right)$$

8. New pump pressure (kg/cm²) with new pump rate (SPM) (approximate)

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

9. New pump pressure (kg/cm²) with new fluid density (kg/l) (approximate)

$$\text{current pump pressure}\left(\text{kg/cm}^2\right) \times \left(\frac{\text{new fluid density (kg/l)}}{\text{current fluid density (kg/l)}}\right)$$

10. Maximum allowable fluid density (kg/l)

$$\text{LOT fluid density (kg/l)} + \left(\text{surface LOT pressure}\left(\text{kg/cm}^2\right) \div \text{casing shoe TVD (m)} \times 10\right)$$

or

$$\text{LOT fluid density (kg/l)} + \left(\frac{\text{surface LOT pressure}\left(\text{kg/cm}^2\right) \times 10}{\text{casing shoe TVD (m)}}\right)$$

11. MAASP (kg/cm²)

$$\frac{(\text{maximum allowable fluid density (kg/l)} - \text{current fluid density (kg/l)}) \times \text{casing shoe TVD (m)}}{10}$$

12. Kill fluid density (kg/l)

$$\text{current fluid density (kg/l)} + \left(\text{SIDPP}\left(\text{kg/cm}^2\right) \div \text{TVD(m)} \times 10\right)$$

or

$$\text{current fluid density (kg/l)} + \left(\frac{\text{SIDPP}\left(\text{kg/cm}^2\right) \times 10}{\text{TVD (m)}}\right)$$

13. Initial circulating pressure (kg/cm²)

$$\text{circulating pressure at kill rate}\left(\text{kg/cm}^2\right) + \text{SIDPP}\left(\text{kg/cm}^2\right)$$

14. Final circulating pressure (kg/cm²)

$$\left(\frac{\text{kill fluid density (kg/l)}}{\text{current fluid density (kg/l)}}\right) \times \text{circulating pressure at kill rate}\left(\text{kg/cm}^2\right)$$

15. Gas migration rate (m/hr)

$$\text{rate of increase in surface pressure}\left(\text{kg/cm}^2\text{/hr}\right) \div \text{fluid density (kg/l)} \times 10$$

or

$$\frac{\text{rate of increase in surface pressure}\left(\text{kg/cm}^2\text{/hr}\right) \times 10}{\text{fluid density (kg/l)}}$$

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 (kg/cm²/m)

$$\frac{\text{fluid density (kg/l)} \times \text{metal displacement (l/m)}}{\left(\text{riser or casing capacity (l/m)} - \text{metal displacement (l/m)}\right) \times 10}$$

18. Pressure drop per metre tripping wet pipe (kg/cm²/m)

$$\frac{\text{fluid density (kg/l)} \times \text{closed end displacement (l/m)}}{\left(\text{riser or casing capacity (l/m)} - \text{closed end displacement (l/m)}\right) \times 10}$$

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)

$$\frac{\text{overbalance}\left(\text{kg/cm}^2\right) \times \left(\text{riser or casing capacity (l/m)} - \text{metal displacement (l/m)}\right)}{\text{fluid gradient}\left(\text{kg/cm}^2\text{/m}\right) \times \text{metal displacement (l/m)}}$$

or

$$\frac{\text{overbalance}\left(\text{kg/cm}^2\right) \times 10 \times \left(\text{riser or casing capacity(l/m)} - \text{metal displacement (l/m)}\right)}{\text{fluid density (kg/l)} \times \text{metal displacement (l/m)}}$$

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

$$\frac{\text{overbalance}\left(\text{kg/cm}^2\right) \times \left(\text{riser or casing capacity (l/m)} - \text{closed end displacement (l/m)}\right)}{\text{fluid gradient}\left(\text{kg/cm}^2\text{/m}\right) \times \text{closed end displacement (l/m)}}$$

or

$$\frac{\text{overbalance}\left(\text{kg/cm}^2\right) \times 10 \times \left(\text{riser or casing capacity (l/m)} - \text{closed end displacement (l/m)}\right)}{\text{fluid density (kg/l)} \times \text{closed end displacement (l/m)}}$$

23. Volume to bleed due to gas migration (l)

$$\text{working pressure to bleed}\left(\text{kg/cm}^2\right) \times \left(\frac{\text{annular capacity (l/m)}}{\text{pressure gradient}\left(\text{kg/cm}^2\text{/m}\right)}\right)$$

or

$$\text{working pressure to bleed}\left(\text{kg/cm}^2\right) \times \left(\frac{\text{annular capacity (l/m)} \times 10}{\text{fluid density (kg/l)}}\right)$$

24. Slug volume (l) 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 (l)

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

26. Riser margin (kg/l)

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

27. Hydrostatic pressure loss if casing float fails (kg/cm²)

$$\frac{\text{fluid density (kg/l)} \times \text{casing capacity (l/m)} \times \text{unfilled casing height (m)}}{\left(\text{casing capacity (l/m)} + \text{annular capacity (l/m)}\right) \times 10}$$