## 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)**

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

**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)**

rate of increase in surface pressure (kg/cm$^2$/hr) ÷ fluid density (kg/l) × 10

or

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

**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)**

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

or

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

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

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

or

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

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

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

or

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

**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)**

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

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

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