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 500 kPa or more above the expected pressures.

Section 2. Calculation formula

Abbreviation	Term
0.00981	constant factor
m^3	cubic metres
m^3/m	cubic metres per metre
m^3/min	cubic metres per minute
m^3/stroke	cubic metres 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/m^3	kilogram per cubic metre
kPa	kilopascal (pressure)
kPa/m	kilopascal per metre
kPa/hr	kilopascal per hour
SICP	shut-in casing pressure
SIDPP	shut-in drillpipe pressure
SPM	strokes per minute
TVD	true vertical depth

1. Hydrostatic pressure (kPa)

$$\text{fluid density } (\text{kg/m}^3) \times 0.00981 \times \text{TVD (m)}$$

2. Pressure gradient (kPa/m)

$$\text{fluid density } (\text{kg/m}^3) \times 0.00981$$

3. Fluid density (kg/m³)

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

or

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

4. Formation pressure (kPa)

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

5. Pump output (m³/min)

$$\text{pump displacement } (\text{m}^3\text{/stroke}) \times \text{pump rate (SPM)}$$

6. Equivalent circulating density (kg/m³)

$$\text{fluid density } (\text{kg/m}^3) + (\text{annular pressure loss (kPa)} \div \text{TVD (m)} \div 0.00981)$$

or

$$\text{fluid density } (\text{kg/m}^3) + \left(\frac{\text{annular pressure loss (kPa)}}{\text{TVD (m)} \times 0.00981}\right)$$

7. Fluid density (kg/m³) with trip margin (kPa) included

$$\text{fluid density } (\text{kg/m}^3) + (\text{trip margin (kPa)} \div \text{TVD (m)} \div 0.00981)$$

or

$$\text{fluid density } (\text{kg/m}^3) + \left(\frac{\text{trip margin (kPa)}}{\text{TVD (m)} \times 0.00981}\right)$$

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

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

9. New pump pressure (kPa) with new fluid density (kg/m³) (approximate)

$$\text{current pump pressure (kPa)} \times \left(\frac{\text{new fluid density }(\text{kg/m}^3)}{\text{current fluid density }(\text{kg/m}^3)}\right)$$

10. Maximum allowable fluid density (kg/m³)

$$\text{LOT fluid density }(\text{kg/m}^3) + (\text{surface LOT pressure (kPa)} \div \text{casing shoe TVD (m)} \div 0.00981)$$

or

$$\text{LOT fluid density }(\text{kg/m}^3) + \left(\frac{\text{surface LOT pressure (kPa)}}{\text{casing shoe TVD (m)} \times 0.00981}\right)$$

11. MAASP (kPa)

$$(\text{maximum allowable fluid density }(\text{kg/m}^3) - \text{current fluid density }(\text{kg/m}^3)) \times 0.00981 \times \text{casing shoe TVD (m)}$$

12. Kill fluid density (kg/m³)

$$\text{current fluid density }(\text{kg/m}^3) + (\text{SIDPP(kPa)} \div \text{TVD (m)} \div 0.00981)$$

or

$$\text{current fluid density }(\text{kg/m}^3) + \left(\frac{\text{SIDPP (kPa)}}{\text{TVD (m)} \times 0.00981}\right)$$

13. Initial circulating pressure (kPa)

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

14. Final circulating pressure (kPa)

$$\left(\frac{\text{kill fluid density }(\text{kg/m}^3)}{\text{current fluid density }(\text{kg/m}^3)}\right) \times \text{circulating pressure at kill rate (kPa)}$$

15. Gas migration rate (m/hr)

rate of increase in surface pressure (kPa/hr) ÷ fluid density (kg/m^3) ÷ 0.00981

or

$$\frac{\text{rate of increase in surface pressure (kPa/hr)}}{\text{fluid density (kg/m}^3\text{)} \times 0.00981}$$

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 (kPa/m)

$$\frac{\text{fluid density (kg/m}^3\text{)} \times 0.00981 \times \text{metal displacement (m}^3\text{/m)}}{\text{riser or casing capacity (m}^3\text{/m)} - \text{metal displacement (m}^3\text{/m)}}$$

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

$$\frac{\text{fluid density (kg/m}^3\text{)} \times 0.00981 \times \text{closed end displacement (m}^3\text{/m)}}{\text{riser or casing capacity (m}^3\text{/m)} - \text{closed end displacement (m}^3\text{/m)}}$$

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

$$\frac{\text{length of collars (m)} \times \text{metal displacement (m}^3\text{/m)}}{\text{riser or casing capacity (m}^3\text{/m)}}$$

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

$$\frac{\text{length of collars (m)} \times \text{closed end displacement (m}^3\text{/m)}}{\text{riser or casing capacity (m}^3\text{/m)}}$$

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

$$\frac{\text{overbalance (kPa)} \times \left(\text{riser or casing capacity}\left(\text{m}^3/\text{m}\right) - \text{metal displacement}\left(\text{m}^3/\text{m}\right)\right)}{\text{fluid gradient (kPa/m)} \times \text{metal displacement}\left(\text{m}^3/\text{m}\right)}$$

or

$$\frac{\text{overbalance (kPa)} \times \left(\text{riser or casing capacity}\left(\text{m}^3/\text{m}\right) - \text{metal displacement}\left(\text{m}^3/\text{m}\right)\right)}{\text{fluid density}\left(\text{kg/m}^3\right) \times 0.00981 \times \text{metal displacement}\left(\text{m}^3/\text{m}\right)}$$

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

$$\frac{\text{overbalance (kPa)} \times \left(\text{riser or casing capacity}\left(\text{m}^3/\text{m}\right) - \text{closed end displacement}\left(\text{m}^3/\text{m}\right)\right)}{\text{fluid gradient (kPa/m)} \times \text{closed end displacement}\left(\text{m}^3/\text{m}\right)}$$

or

$$\frac{\text{overbalance (kPa)} \times \left(\text{riser or casing capacity}\left(\text{m}^3/\text{m}\right) - \text{closed end displacement}\left(\text{m}^3/\text{m}\right)\right)}{\text{fluid density}\left(\text{kg/m}^3\right) \times 0.00981 \times \text{closed end displacement}\left(\text{m}^3/\text{m}\right)}$$

23. Volume to bleed due to gas migration in a vertical well (m³)

$$\text{working pressure to bleed (kPa)} \times \left(\frac{\text{annular capacity}\left(\text{m}^3/\text{m}\right)}{\text{pressure gradient (kPa/m)}}\right)$$

or

$$\text{working pressure to bleed (kPa)} \times \left(\frac{\text{annular capacity}\left(\text{m}^3/\text{m}\right)}{\text{fluid density}\left(\text{kg/m}^3\right) \times 0.00981}\right)$$

24. Slug volume for a given length of dry pipe (m³)

$$\frac{\text{length of dry pipe (m)} \times \text{pipe capacity}\left(\text{m}^3/\text{m}\right) \times \text{current fluid density}\left(\text{kg/m}^3\right)}{\text{slug density}\left(\text{kg/m}^3\right) - \text{current fluid density}\left(\text{kg/m}^3\right)}$$

25. Pit gain due to slug U-tubing (m³)

$$\text{slug volume}\left(\text{m}^3\right) \times \left(\frac{\text{slug density}\left(\text{kg/m}^3\right)}{\text{current fluid density}\left(\text{kg/m}^3\right)} - 1\right)$$

26. Riser margin (kg/m³)

$$\frac{\left(\left(\text{air gap (m)} + \text{water depth (m)}\right) \times \text{fluid density}\left(\text{kg/m}^3\right)\right) - \left(\text{water depth (m)} \times \text{water density}\left(\text{kg/m}^3\right)\right)}{\text{TVD (m)} - \text{air gap (m)} - \text{water depth (m)}}$$

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

$$\frac{\text{fluid density }(\text{kg/m}^3) \times 0.00981 \times \text{casing capacity }(\text{m}^3/\text{m}) \times \text{unfilled casing height }(\text{m})}{\text{casing capacity }(\text{m}^3/\text{m}) + \text{annular capacity }(\text{m}^3/\text{m})}$$