## 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 70 psi or more above the expected pressures.

## Section 2. Calculation formula

| Abbreviation | Term |
|---|---|
| 0.052 | constant factor |
| bbl | barrels (us) |
| bbl/ft | barrels (us) per foot |
| bbl/min | barrels (us) per minute |
| bbl/stroke | barrels (us) per stroke |
| BHP | bottomhole pressure |
| BOP | blowout preventer |
| ft | feet |
| ft/hr | feet per hour |
| ft/min | feet per minute |
| lb/bbl | pounds per barrel |
| LOT | leak-off test |
| MAASP | maximum allowable annular surface pressure |
| ppg | pounds per gallon |
| psi | pounds per square inch (pressure) |
| psi/ft | pounds per square inch per foot |
| psi/hr | pounds per square inch per hour |
| SICP | shut-in casing pressure |
| SIDPP | shut-in drillpipe pressure |
| SPM | strokes per minute |
| TVD | true vertical depth |

**1. Hydrostatic pressure (psi)**

fluid density (ppg) × 0.052 × TVD (ft)

**2. Pressure gradient (psi/ft)**

fluid density (ppg) × 0.052

**3. Fluid density (ppg)**

hydrostatic pressure (psi) ÷ TVD (ft) ÷ 0.052

or

$$\frac{\text{hydrostatic pressure (psi)}}{\text{TVD (ft)} \times 0.052}$$

**4. Formation pressure (psi)**

hydrostatic pressure in drillstring (psi) + SIDPP (psi)

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

pump displacement (bbl/stroke) × pump rate (SPM)

**6. Equivalent circulating density (ppg)**

fluid density (ppg) + (annular pressure loss (psi) ÷ TVD (ft) ÷ 0.052)

or

$$\text{fluid density (ppg)} + \left(\frac{\text{annular pressure loss (psi)}}{\text{TVD (ft)} \times 0.052}\right)$$

**7. Fluid density (ppg) with trip margin (psi) included**

fluid density (ppg) + (trip margin (psi) ÷ TVD (ft) ÷ 0.052)

or

$$\text{fluid density (ppg)} + \left(\frac{\text{trip margin (psi)}}{\text{TVD (ft)} \times 0.052}\right)$$

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

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

**9. New pump pressure (psi) with new fluid density (ppg) (approximate)**

$$\text{current pump pressure (psi)} \times \left(\frac{\text{new fluid density (ppg)}}{\text{current fluid density (ppg)}}\right)$$

**10. Maximum allowable fluid density (ppg)**

LOT fluid density (ppg) + (surface LOT pressure (psi) ÷ casing shoe TVD (ft) ÷ 0.052)

or

$$\text{LOT fluid density (ppg)} + \left(\frac{\text{surface LOT pressure (psi)}}{\text{casing shoe TVD (ft)} \times 0.052}\right)$$

**11. MAASP (psi)**

(maximum allowable fluid density (ppg) - current fluid density (ppg)) × 0.052 × casing shoe TVD (ft)

**12. Kill fluid density (ppg)**

current fluid density (ppg) + (SIDPP (psi) ÷ TVD (ft) ÷ 0.052)

or

$$\text{current fluid density (ppg)} + \left(\frac{\text{SIDPP (psi)}}{\text{TVD (ft)} \times 0.052}\right)$$

**13. Initial circulating pressure (psi)**

circulating pressure at kill rate (psi) + SIDPP (psi)

**14. Final circulating pressure (psi)**

$$\left(\frac{\text{kill fluid density (ppg)}}{\text{current fluid density (ppg)}}\right) \times \text{circulating pressure at kill rate (psi)}$$

**15. Gas migration rate (ft/hr)**

rate of increase in surface pressure (psi/hr) ÷ fluid density (ppg) ÷ 0.052

or

$$\frac{\text{rate of increase in surface pressure (psi/hr)}}{\text{fluid density (ppg)} \times 0.052}$$

## 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 foot tripping dry pipe (psi/ft)

$$\frac{\text{fluid density (ppg)} \times 0.052 \times \text{metal displacement (bbl/ft)}}{\text{riser or casing capacity (bbl/ft)} - \text{metal displacement (bblft)}}$$

## 18. Pressure drop per foot tripping wet pipe (psi/ft)

$$\frac{\text{fluid density (ppg)} \times 0.052 \times \text{closed end displacement (bbl/ft)}}{\text{riser or casing capacity (bbl/ft)} - \text{closed end displacement (bbl/ft)}}$$

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

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

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

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

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

$$\frac{\text{overbalance (psi)} \times \left(\text{riser or casing capacity (bbl/ft)} - \text{metal displacement (bbl/ft)}\right)}{\text{fluid gradient (psi/ft)} \times \text{metal displacement (bbl/ft)}}$$

or

$$\frac{\text{overbalance (psi)} \times \left(\text{riser or casing capacity (bbl/ft)} - \text{metal displacement (bbl/ft)}\right)}{\text{fluid density (ppg)} \times 0.052 \times \text{metal displacement (bbl/ft)}}$$

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

$$\frac{\text{overbalance (psi)} \times \left(\text{riser or casing capacity (bbl/ft)} - \text{closed end displacement (bbl/ft)}\right)}{\text{fluid gradient (psi/ft)} \times \text{closed end displacement (bbl/ft)}}$$

or

$$\frac{\text{overbalance (psi)} \times (\text{riser or casing capacity (bbl/ft)} - \text{closed end displacement (bbl/ft)})}{\text{fluid density (ppg)} \times 0.052 \times \text{closed end displacement (bbl/ft)}}$$

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

$$\text{working pressure to bleed (psi)} \times \left(\frac{\text{annular capacity (bbl/ft)}}{\text{pressure gradient (psi/ft)}}\right)$$

or

$$\text{working pressure to bleed (psi)} \times \left(\frac{\text{annular capacity (bbl/ft)}}{\text{fluid density (ppg)} \times 0.052}\right)$$

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

$$\frac{\text{length of dry pipe (ft)} \times \text{pipe capacity (bbl/ft)} \times \text{current fluid density (ppg)}}{\text{slug density (ppg)} - \text{current fluid density (ppg)}}$$

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

$$\text{slug volume (bbl)} \times \left(\frac{\text{slug density (ppg)}}{\text{current fluid density (ppg)}} - 1\right)$$

**26. Riser margin (ppg)**

$$\frac{((\text{air gap (ft)} + \text{water depth (ft)}) \times \text{fluid density (ppg)}) - (\text{water depth (ft)} \times \text{water density (ppg)})}{\text{TVD (ft)} - \text{air gap (ft)} - \text{water depth (ft)}}$$

**27. Hydrostatic pressure loss if casing float fails (psi)**

$$\frac{\text{fluid density (ppg)} \times 0.052 \times \text{casing capacity (bbl/ft)} \times \text{unfilled casing height (ft)}}{\text{casing capacity (bbl/ft)} + \text{annular capacity (bbl/ft)}}$$