Application of Drilling Engineering

Drilling is used for the following main: -

1) **Drilling water wells:** to produce water for human and agricultural or industrial use.
2) **Exploration:** to explore new reservoirs or to ensure the capabilities of the present reservoirs.
3) **Production:** Production of oil and gas from oil and gas reservoirs.
4) **Drilling in mines:** to ventilate the mine or to remove water or as safety passages.

Although drilling is used in all the above-mentioned areas; still drilling for oil and gas is the main important use of drilling and was the most factor that caused the development of drilling engineering.

Drilling Fluids

Drilling fluid -mud - is usually a mixture of water, clay, weighting material and a few chemicals. Sometimes oil may be used instead of water, or oil added to the water to give the mud certain desirable properties. Drilling fluid is used to raise the cuttings made by the bit and lift them to the surface for disposal. But equally important, it also provides a means of keeping underground pressures in check.

In sometimes and in other references **the term "drilling fluid" includes air, gas, water and mud. "Mud" refers to the liquid that contains solids and water or oil.**

- **Drilling Fluid Properties**

The fundamental properties of drilling fluid are:

1. Density
2. Rheological properties
   - Plastic viscosity (Pv).
   - Yield point (Y_p).
   - Apparent viscosity (μ_a).
   - Effective viscosity (μ_e).
   - Flow behavior index (n).
   - Constancy index (k).
   - Gel strength.
3. Filtration
4. PH

1. Mud Density

Weight or mass per unit volume. Mud weight is dependent upon the quantity of solid in the liquid phase, either in solution or suspended by the particle of the liquid phase. The mud density **increases** by adding solid materials and **decreases by adding water or oil or aerating the liquid**. Calculated by sum of weighs over sum of volumes and expressed in lb/gal (ppg), lb/ft^3 (pcf), kg/m^3 or g/cm^3.

Mud weight controlled the hydrostatic pressure exerted at any depth of the hole, i.e.

$$\mathbf{P_{hyd.} = \frac{\rho}{8.33} * 0.433 * D}$$

$$\mathbf{P_{hyd} = 0.052\, \rho\, D}$$ **--- (1)**

Phyd.>Pf	Overbalance
Phyd.=Pf	Balance
Phyd.<Pf	Underbalance

Where:

ρ_w = 8.33 ppg = 62.4 Ib/ft^3

ρ = Fluid density, ppg

$P_{hyd.}$ = Hydrostatic pressure, psi

$P_{f.}$ = Formation pressure, psi

D = Depth, ft

The conversion factors for mud density can be written as:

$$\textbf{Specific Gravity (SG)} = \frac{lb_m/gal(ppg)}{8.33} = \frac{lb_m/ft^3}{62.4}$$ ---------------------------------- **(2)**

$$\textbf{Mud gradient } (MG_{FPS}) \textbf{ in psi/ft} = SG \times 0.433$$ --------------------------**(3)**

- **Drilling Mud Calculation**

Mud calculation are related to change in weigh and volume due to adding solids (weighting materials) or liquids (dilatants) to the system. Material balance equation is used to calculate changes in volume and weights.

$$\textbf{Total volume} = \sum \textbf{Volume}$$

$$\textbf{Total weight} = \sum \textbf{Weight}$$

$$\textbf{Total system mud volume} = \textbf{Pit volume} + \textbf{Well volume}$$

- Assume ideal mixture:

$$V_{m2} = V_{m1} + V_s$$ -- **(4)**

Total system mud volume = pit volume + well volume

Case-1: Weight – up of mud (solid material added)

Are solid materials which when suspended or dissolved in water will increase the mud weight? By assuming ideal mixture.

$\mathbf{V_{m2} = V_{m1} + V_s}$

$\mathbf{W_{m2} = W_{m1} + W_s}$

$\mathbf{\rho_{m2}\, V_{m2} = \rho_{m1}\, V_{m1} + \rho_s V_s}$ -- **(5)**

$\mathbf{V_{m1} = V_{m2} - V_s}$ -- **(6)**

Substitute eq. (6) into eq. (5)

$\mathbf{\rho_{m2} V_{m2} = \rho_{m1}\, (V_{m2} - V_s) + \rho_s V_s}$

$\mathbf{\rho_{m2} V_{m2} = \rho_{m1} V_{m2} - \rho_{m1} V_s + \rho_s V_s}$

Then, $\mathbf{V_s = \frac{Vm2\,(\rho m2 - \rho m1)}{\rho s - \rho m1}}$ volumetric --- **(7)**

Since $\mathbf{V_{m2} = V_{m1} + V_s}$

$$\mathbf{V_s = \frac{Vm1\,(\rho m2 - \rho m1)}{\rho s - \rho m2}}$$ --- **(8)**

In terms of volume percentage, Eq. (8) can be written as:

$$\mathbf{\frac{V_s}{Vm2} = \frac{(\rho m2 - \rho m1)}{\rho s - \rho m1} \times 100}$$ -- **(9)**

Multiply eq. (8) by ρ_s

or, $\boldsymbol{\rho_s v_s = \frac{\rho s\ Vm2\ (\ \rho m2 - \rho m1\ )}{\rho s - \rho m1}}$ weighting -------------------------------------- **(10)**

The weight percentage can now be calculated as:

$\boldsymbol{\frac{m_{sc}}{m_{m2}} = \frac{\rho s\ Vs}{\rho m2\ Vm2}}$ -- **(11)**

Where:

V_s: vol. of solids

V_{m1}: initial liquid vol.

V_{m2}: final liquid vol.

ρ_{m1}: initial liquid density

ρ_{m2}: final liquid density

ρ_s: solid density

Material	Principle component	Sp.gr
Common Barite	BaSo4	4.2 – 4.6
Hematite	Fe2O3	4.9 – 5.3
Galena	Pbs	7.4 – 7.7
Calcium carbonate	CaCo3	2.6 – 2.8

Note:

For Barite sp.gr = 4.3

ρ barite = 35.8 ppg = 268.32 lb/ft^3

Weight of 1 sack Barite = 100 lb

$$\text{Vol. of 1 sack} = \frac{100\ \text{lb/sack}}{35.8\ \text{ppg}} * \frac{\text{bbl}}{42\ \text{gal}} = 0.0665\ \text{bbl/sack}$$

or 1bbl of barite = 15 sack

For Bentonite sp.gr = 2.5

Weight of 1 sack = 100 lb

$$\text{Volume of 1 sack Bentonite} = \frac{100\ \text{lb/sack}}{20.8\ \text{ppg}} * \frac{\text{bbl}}{42\ \text{gal}} = 0.114\ \text{bbl/sack}$$

or 1 bbl Bentonite = 8.75 sack

1 bbl = 5.615 ft^3

- **Sacks calculations**

Assume: S_B = Number of barite sacks required to increase the density of 100 bbls from ρ_{m1} to ρ_{m2}

and

S_C = Number of bentonite sacks required to increase the density of 100 bbls from ρ_{m1} to ρ_{m2}

$$\frac{S_B}{15} = \frac{100(\rho_{m2} - \rho_{m1})}{35.8 - \rho_{m2}} \quad \text{(12)}$$

$$s_B = \frac{1500(\rho_{m2} - \rho_{m1})}{35.8 - \rho_{m2}} \quad (13)$$

$$\frac{s_C}{8.75} = \frac{100(\rho_{m2} - \rho_{m1})}{20.8 - \rho_{m2}} \quad (14)$$

$$s_C = \frac{875(\rho_{m2} - \rho_{m1})}{20.8 - \rho_{m2}} \quad (15)$$