Mud Program - before drilling commence, drilling engineer have to come up with the mud program based on the expected geology

consist of

fluid specs @ diff depth

once drilling started.

Drilling Fluid Operations r commonly contracted to service companies

ex

MI SWACO A Schlumberger Company
BAROID
Baker Hughes
Weatherford

provides

Mud Engineer: ensure mud specs follow the mud program
- to correct any changes to the properties of d.F during drilling operation
- responsible in modifying the d.F properties when necessary.

gives input to

Mud Logger: report on progress through geological zones
: test physical n chemical properties of d.F
ex
→ Marsh funnel (viscosity test)
→ mud balance (density test)
- inspect cuttings brought up to surface
- monitor gas levels

→ Present in the form of graphic log

3rd Party Mudlogging Companies

OILSERV
OROGENIC GROUP OF COMPANIES

Drilling Fluid (d.F) – liq/gas/mixture tht r circulated during rotary drilling process to :-

\# remove drill cuttings ← **main function**

\# prevent flow of formation fluid (F.F) into wellbore (kick)

└→ drilling usually r to be done in overbalance cond.

$P_{df} - P_{ff} = \Delta P > 0$

if → Normal P, $G_{ff} \approx 0.433$ psi/ft

Abnormal P, $G_{ff} > 0.433$ psi/ft

Subnormal P, $G_{ff} < 0.433$ psi/ft

\# Hole stabilization

– chemically &/ mechanically

Prevent borehole failure due to

> unbalance of in situ stresses @ borehole walls
> Erosion
> Chemical rxn between d.F & formation

Type of failures

- Hole Enlargement – erosion due to friction with drillstring or encounter with high P shale
- Hole Fracturing – $P_{df} > P_{fracture}$
- Hole Collapse
  └ P_{df} too low to maintain structural integrity of borehole

Other function

\# cools bit & string
\# transmit hydraulic h.p to bit
\# formation evaluation
\# reduction in weight of casing string & drilling string

Drilling Fluid Circulating System

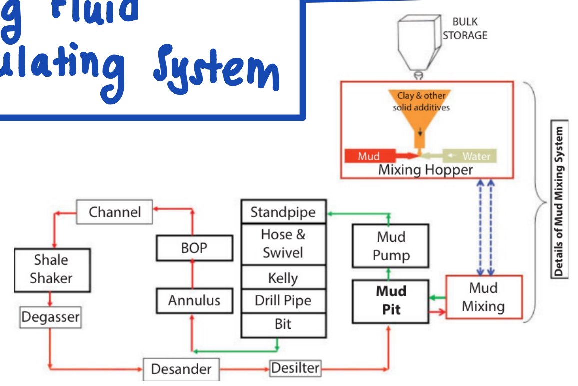


Figure 3.1 A block diagram for drilling fluid circulating system.

Situation to avoid

└ Loss of circulation
- ↓ of ROP
- Borehole Swelling
- Borehole Erosion
- Pipe Sticking
- Wear on pump
- Retention of undesired solids in d.F

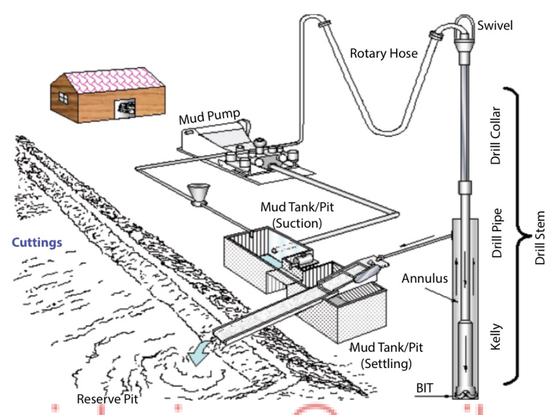
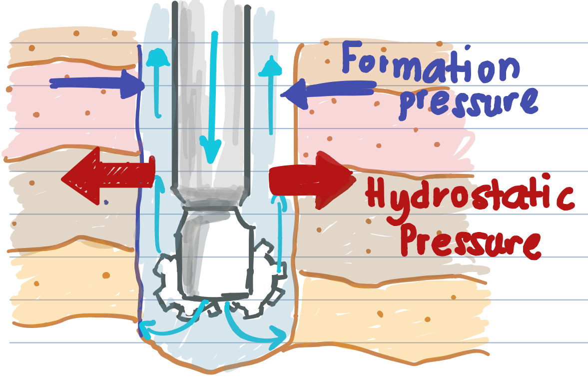
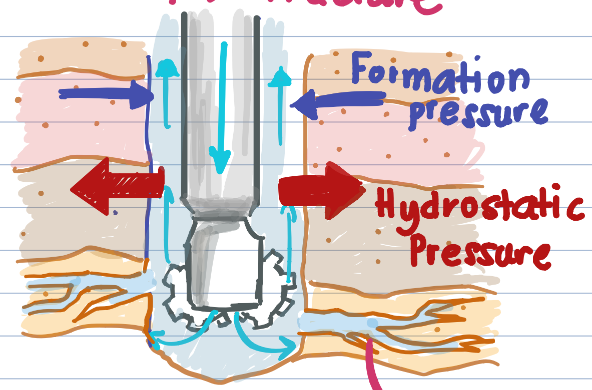


Figure 3.2 Different functions of drilling fluid.



if $P_{df} > P_{fracture}$



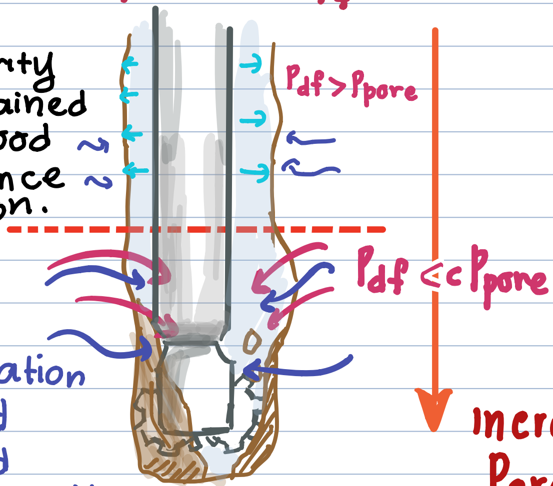
fractures in the formation

loss circulation

[require additional d.F, ↑↑ cost]

if $P_{df} << P_{pore}$ or P_{Ff}

hole integrity is maintained under good overbalance condition.



increasing Pore pressure

Formation fluid would enter the borehole, displacing the d.F

[causing a kick]

↳ The high flowrate of fluid may then also cause the walls of the borehole to collapse.*

leads to → stuck pipe

↳ fishing
sidetracking } ↑↑ cost

* more prevalent in poorly consolidated formation

Classification of d.F

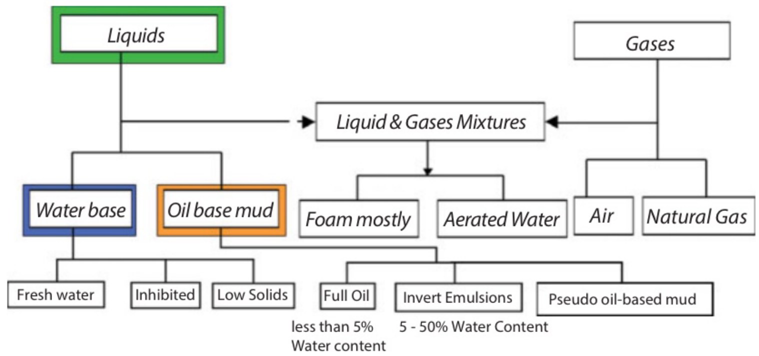


Figure 3.3 Classification of different drilling fluids.

Factors in Selection

1. (i) minimum overall well cost
2. (ii) formation type
3. (iii) range of formation data
4. (iv) Problem formations
5. (v) FE procedure
6. (vi) Water quality available
7. (vii) Production, exp, envi, safety concern
8. (viii) Logistics

$\boxed{\text{Gases}}$ (Pneumatic)

i. Dry Air
- yield highest ROP, good hole cleaning
- costly
- cant handle : W-O producing formation
  : mechanically unstable wellbore

ii. Foam : water + surfactants + air
- applied in : loss circulation zones & can't be economically sealed

iii. Mist : water + air
- used in minor water producing zones.
- costly
- can't handle : unstable wellbore

(Foam & Mist:)
> suppress dust
> combat small water inflow
> remove sticky clay, wet sand, fine gravels

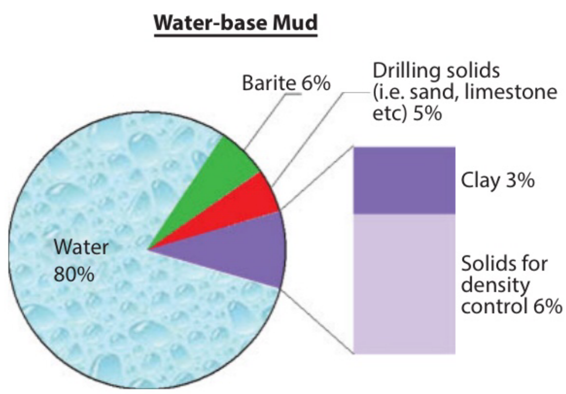
Liquid
- clearwater (freshwater/seawater)
- oil-based
- Synthetic-based (inhibited mud)

Clearwater (WBM)
- water as the continuous phase

Adv.
- most economical
  - > longer bit life
  - > less loss circulation
- > High ROPs
- > Good borehole stability

Limitations
- > Increase in ΔP due to friction
- > may cause Clay swelling

Water–Based Mud
- Bentonite (0 to 50)
- Barite (0 to 500)
- Caustic Soda (0 to 5)
- Soda Ash (0 to 3)
- Sodium bicarbonate (0 to 3)
- Seawater (any portion)
- Freshwater (any portion)
- Drill solids (0 to 100)



oil-based (OBM)
- invert emulsion
- pseudo oil
- full oil

oil is the continuous phase, water is <2-5%

used when : high T (>2,000 F)
deep (>16,000 ft) wells
salt/unconsolidated formation/soft shale

Adv.

→ able to withstand high T (up to 500 °F)
> more inhibitive
> effective against corrosion
> superior lubricating characteristics

→ Limitations

- more costly
- more polluting
- reduce effectiveness of logging tools
- difficult detection of gas kick (soluble in oil)

Oil–Based Mud
– Barite (60.8%)
– Base oil (31.3 %)
– $CaCl_2$ (3.3%)
– Emulsifier (2.2 %)
– Filtrate control/ wetting agent (1.8%)
– Lime (0.2%)
– Viscosifier (0.2%)

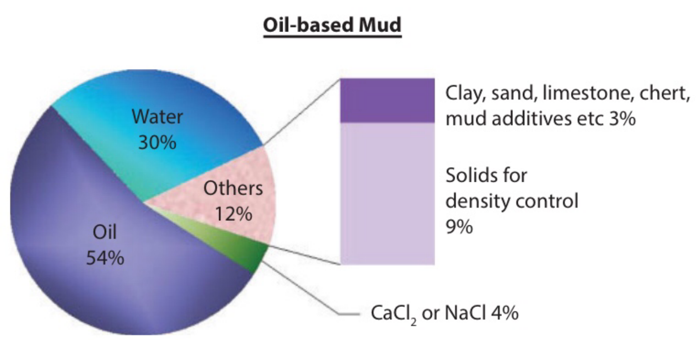


Figure 3.5 Different compositions of oil-base mud.

D.F Properties

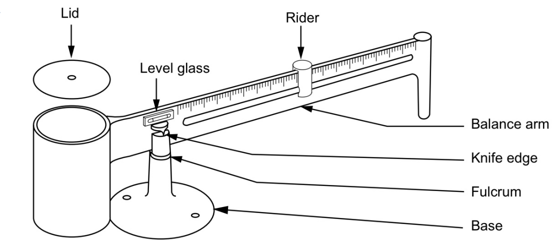
Function	Physical/Chemical Property
Transport cuttings from the Wellbore	Yield Point, Apparent Viscosity, Velocity, Gel Strength
Prevent Formation Fluids Flowing into the Wellbore	Density
Maintain Wellbore Stability	Density, Reactivity with Clay
Cool and Lubricate the Bit	Density, velocity,
Transmit Hydraulic Horsepower to Bit	Velocity, Density, Viscosity

Mud Density

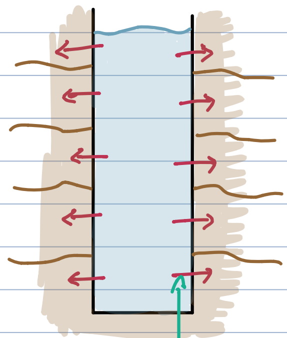
a.k.a mud weight (m.w)
in ppg (lbs per gallon) or lbs/ft³ or psi/ft or S.G

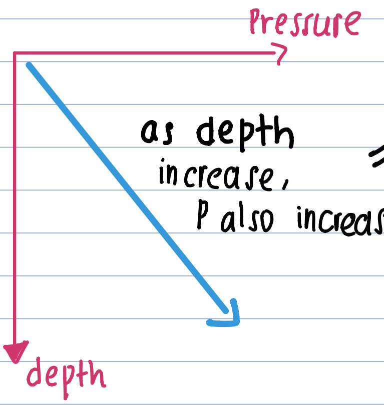
↳ **ideal** : 1 S.G ≈ water density → minimize fracturing
8.33 ppg

but ↳ usually not enough to contain P_{ff}

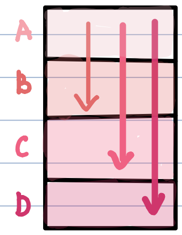


on field,
"mud balance" is used to determine the m.w





as depth increase, P also increases ⇒ due to overburden →



- support weight from A
- support weight from A,B
- support weight from A,B,C

the pressure exerted by the d.F in the column of mud is deemed as the **mud hydrostatic pressure**

conversion factor

$P_{hyd} = 0.052 \cdot MW \cdot D$

P_{hyd} → psi; MW → ppg; D → ft

Mw control : solid removals → shale shaker → desander → desilter

due to overburden

ECD (equivalent circulating density)

↳ for small holes, ΔP_f in annulus can cause ↑ Mw
(< 9⅞")

↓

thus, ECD → defines the actual mw during the mud circulation in the hole

$$ECD = MW + \frac{P_f}{0.052\,D}$$

MW → at surface (ppg)
P_f → annulus friction loss (psi)
D → depth

Mud Rheology : study of the deformation of fluids

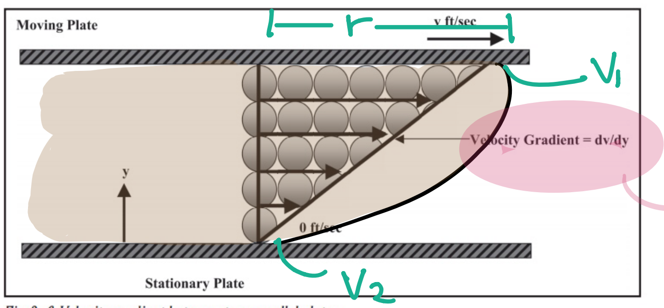


Fig. 2–6. Velocity gradient between two parallel plates

Shear stress, $\tau = \frac{F}{A}$ → force to deform the fluid.

Shear rate, $\gamma = \frac{dv}{dy} = \frac{dv}{dr}$

└→ change in velocity of a fluid moving along the x-axis

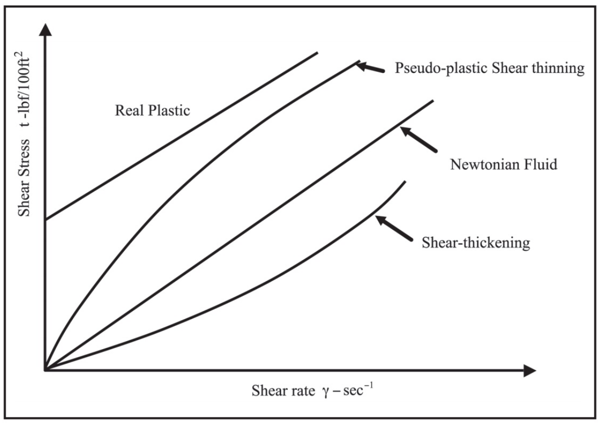


Fig. 2–8. Shear rate–shear stress relationship of time-independent non-Newtonian fluids

d.F can be classified into 2 :-

i. **Newtonian** : shear rate ∝ shear stress

- its flow behaviour can fully be described by the **Newtonian Viscosity, μ**
- ex: water, light oil

$\tau = \mu \gamma$ — c.p (for μ), s^{-1} (for γ)

└ dyne/cm² = 4.79 lbs/100 ft²

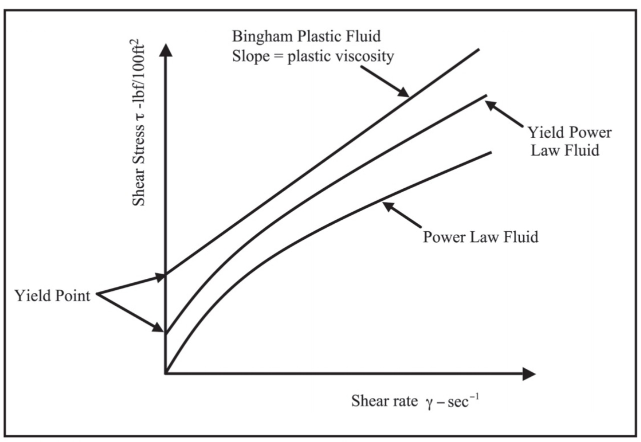


Fig. 2–9. Shear rate–shear stress relationship of non-Newtonian fluids

ii. **Non-newtonian** - viscous property r complex

└ require approximation using :-

i. Bingham's model: $\tau = \tau_y + \mu_o \gamma$

ii. Power Law: $\tau = k\gamma$

Measurement of Viscosity

→ i) using **Marsh Funnel** @ field

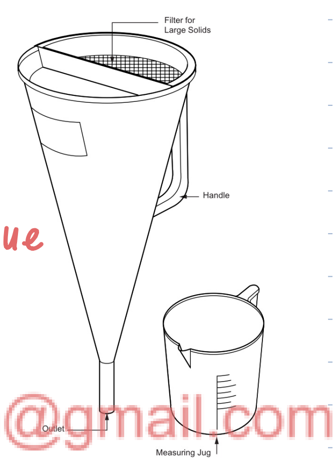
= gives indication of = viscosity * not true value

recorded in **seconds of a quart**

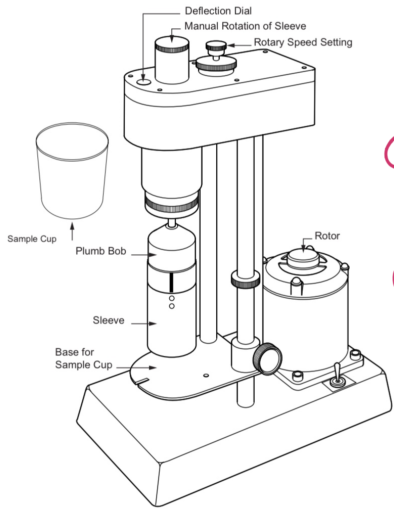
⟸

$\mu_e = \rho_m (t_m - 25)$ — s (for t_m), g/cm³ (for ρ_m)

effective viscosity, cp (for μ_e)



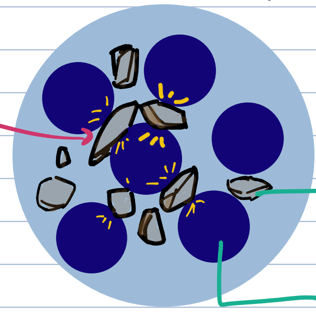
II. Using Viscometer



Plastic Viscosity, μ_p – flow resistance which is caused by interaction between solid & liquid particles of the d.F

affected by

1. Size, concentration, shape of solids
2. Flocculants or deflocutant
3. Contaminants



solid particles

liq particles

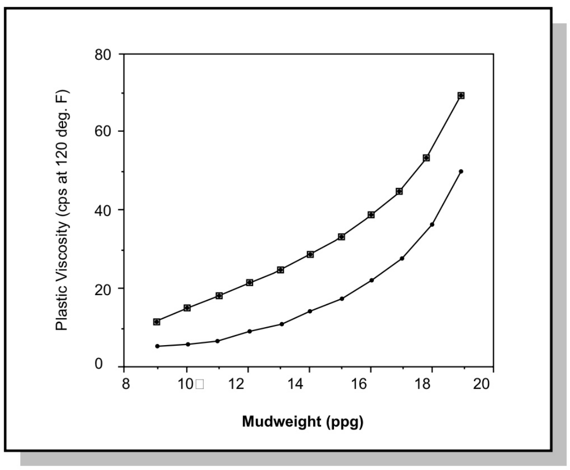
Procedure :

- Set rotor speed @ 600 rpm
- record reading after stabilized
- repeat for 300, 200, 100, 6 & 3 rpm

$$\mu_{app} = \frac{300\,\phi_N}{N}$$

ϕ_N → torque reading @ RPM, N

N → rotor speed



if shear rate ∝ shear stress;

Calculate :

PV = Ɵ600 – Ɵ300

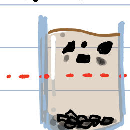
Yield Point (YP) = Ɵ300 – PV ($lb/100\,ft^2$)

↳ elastic limit
once exceeded, deformation is permanent

Gel Strength → properties of the mud during static condition

↳ force/pressure required to initiate flow after the d.F has been static for some time

how well solids r able to be suspended in the mud



← good suspension

bad suspension

Procedure;

after initial operation,

let the d.F remained static for 10s or 10 min – operate rotor at 3rpm
↓
take note of deflection

Alkalinity
- important in controlling calcium
  - high pH – good for drilling in carbonates
    - tend to erode n occur dissolution in acidic conditions
- min 9.5 should be maintained to prevent O_2 corrosion of d.P, casing, etc.

Other properties : **Solid content** – if too high, ↓↓ ROP & bit life
- controls the MW

Fluid Loss – ability to form controlled filter cake on sidewalls of borehole
- < 1/16"
- Tested using Filter press

Chloride content – salt contamination from formation

Electrical properties – mud resistivity – effects formation evaluation calculation
- R 1/α Temp
- inversely proportional to salt concentration

Drilling-mud additives may be grouped into seven categories:

1. Viscosifiers:
   - Bentonite
   - Attapulgite
   - Polymers
2. Viscosity reducers:
   - Phosphates
   - Tannates
   - Lignites
   - Lignosulfonates
   - Sodium polyacrylates
3. Weighting materials:
   - Barite
   - Iron oxide
   - Calcium carbonate
   - Dissolved salts
   - Galena
4. Fluid-loss reducers:
   - Bentonite
   - Starch
   - Polymers
5. Emulsifiers
6. Lost circulation materials:
   - Walnut shells
   - Fibrous
   - Cellophane flakes
   - Diesel/bentonite
7. Special additives:
   - Flocculants
   - Corrosion control chemicals
   - Defoamers
   - pH control additives