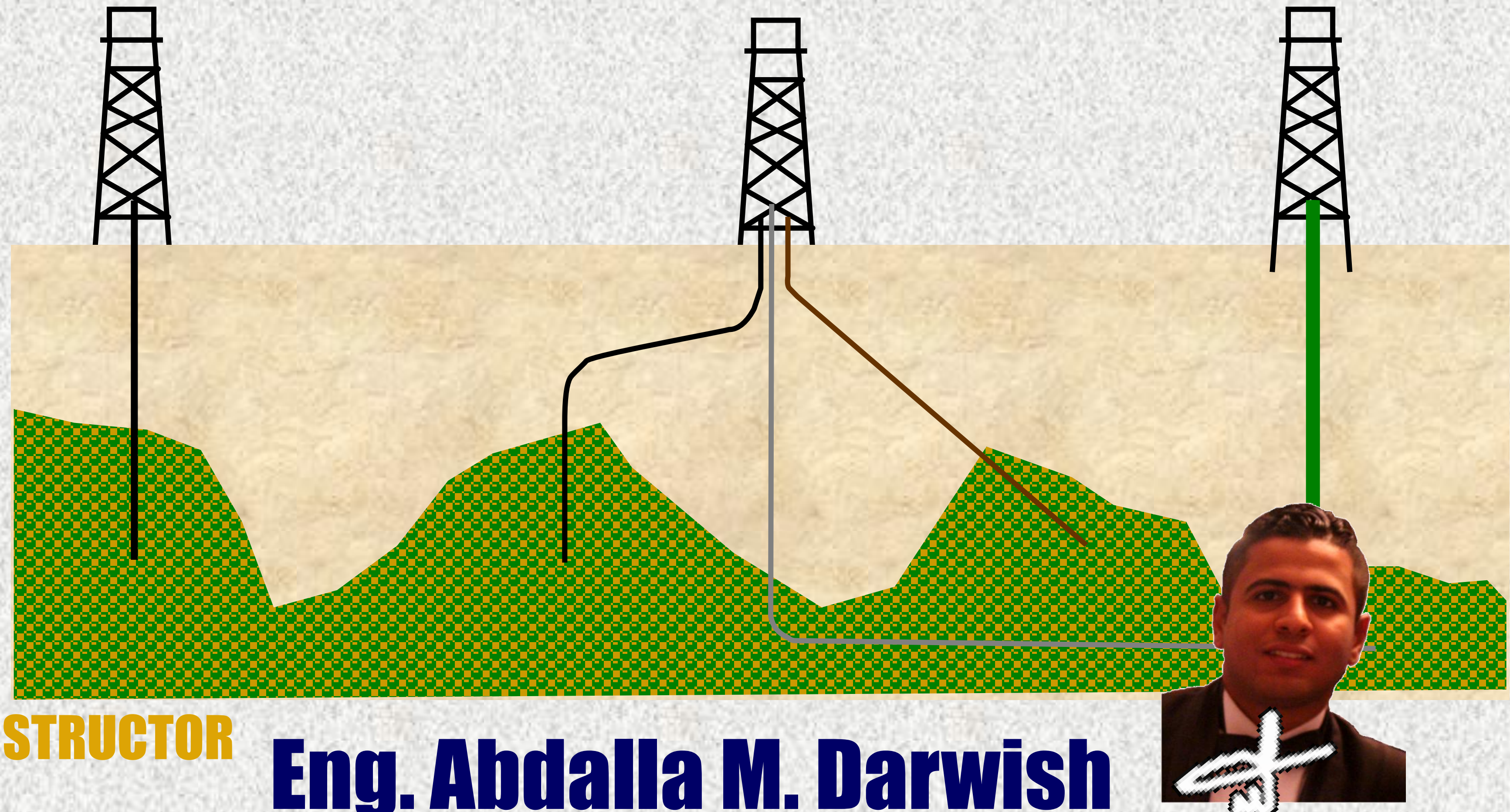
Drilling and Completion
SEC.4

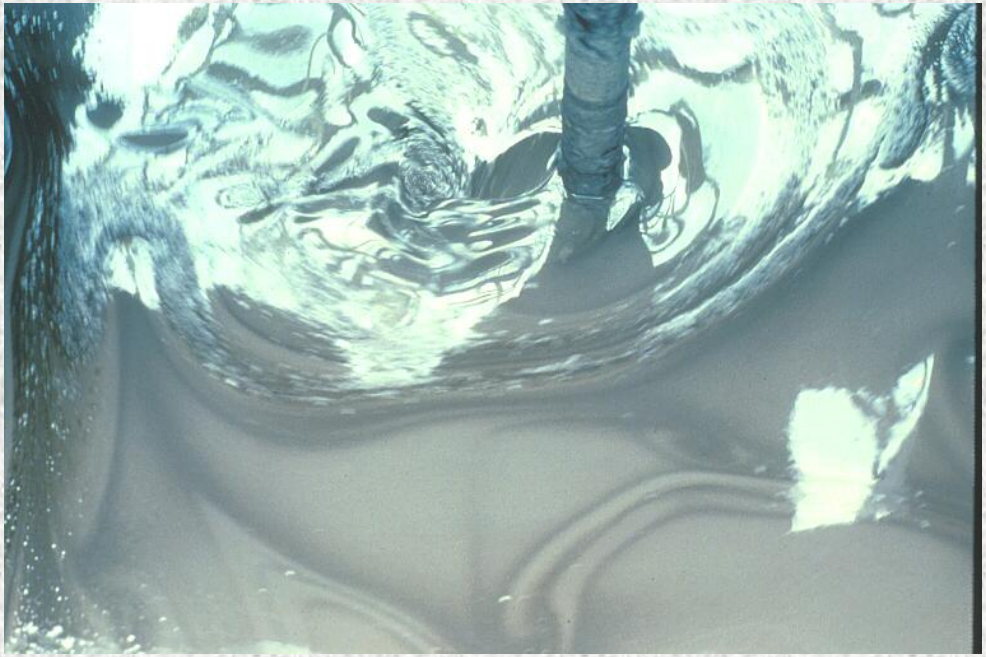


INSTRUCTOR

Eng. Abdalla M. Darwish

What is Drilling fluid?

- Drilling fluid or drilling mud as many people call it is a vitality in a rotary drilling process. The term “drilling fluid” includes air, gas, water and mud. “Mud” refers to the liquid that contains solids and water or oil.
- The mud is made up with clay and other additives that give it desirable properties.

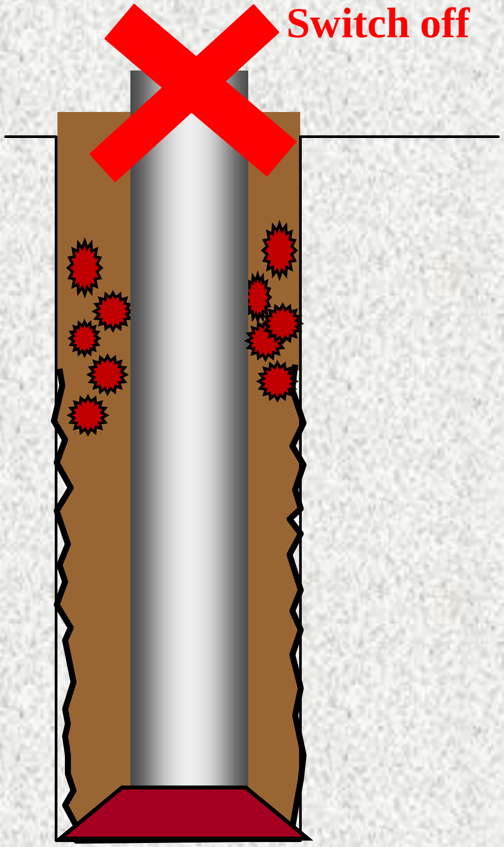


Functions of a Drilling Fluid

- Hole Cleaning
- Pressure Control
- Suspend Solids
- Minimize Formation Damage
- Isolate Fluids from Formation
- Cooling and Lubrication
- Power Downhole Tools
- Environment
- Maximum Hole Information
- Corrosion
- Support Part of DS
- Cost

Suspension of Solids

- Whenever the pumps are switched off solids will start to settle. This can result in:
  - Bridging off of the wellbore
  - Stuck pipe
  - Hole fill
  - Loss of Hydrostatic
- A gel structure is required to suspend the cuttings under zero shear conditions:
  - The gel structure is caused by time dependant attractive forces which develop in the fluid.
  - The longer the fluid is static the stronger these forces become
  - The gel structure should be easily broken
  - The gel properties are especially important for deviated and horizontal wells as the distance solids have to settle is very small



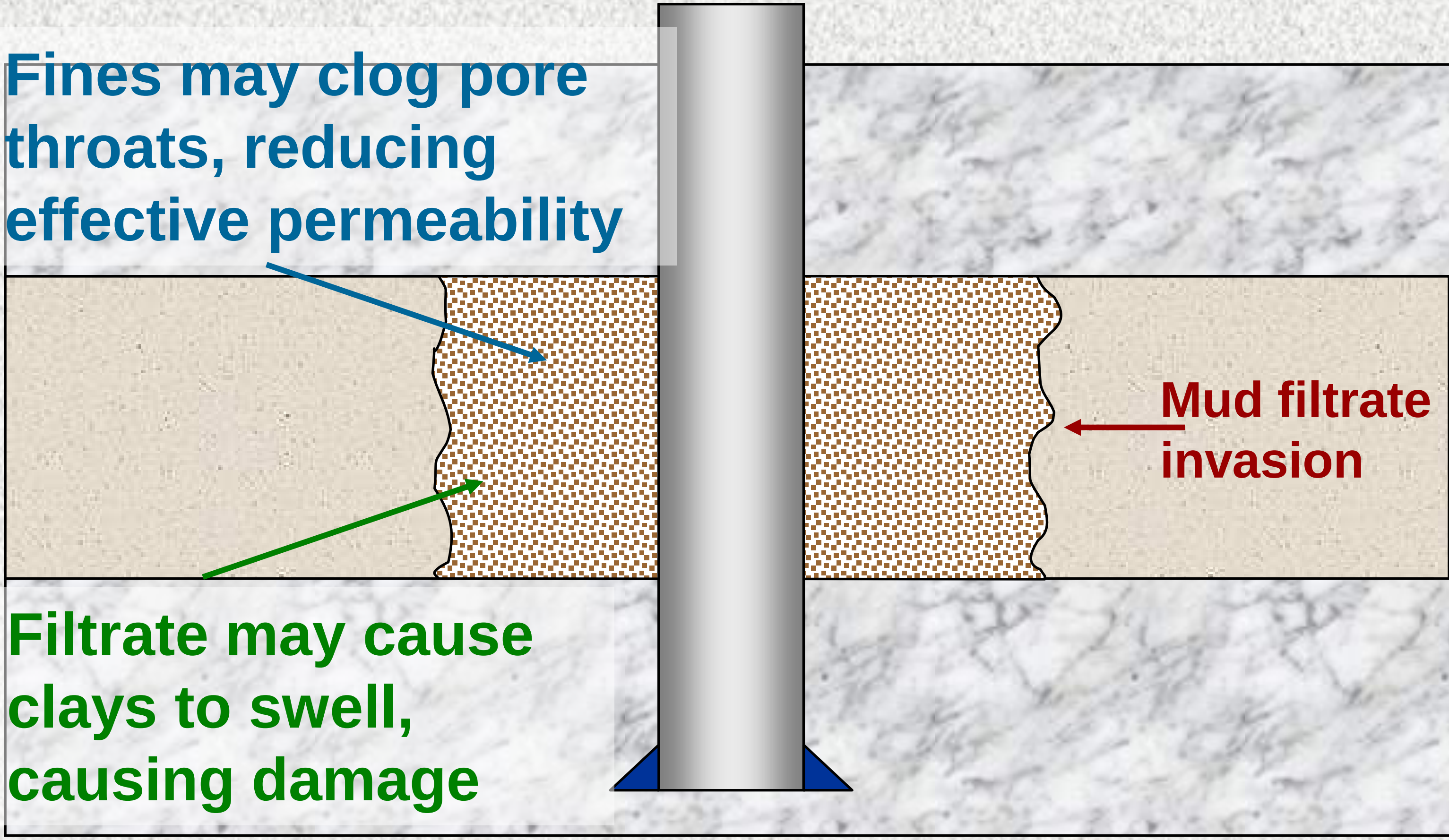
Minimize Formation Damage

- Damage to the formation while drilling to the reservoir:
  - Formation swelling (Normally clay and Salt formations)
  - Washouts (Clay and Salt formations or any unconsolidated formation)

    This can result in:
    - Difficult directional control
    - Poor zonal isolation
    - Excess mud and cement costs
    - Poor Hole Cleaning
    - Stuck Pipe
    - Difficult fishing jobs

- Damage to the reservoir will result in loss of production or the need for remedial treatment

Minimize Formation Damage



√ Function of drilling fluid

Types and importance of different drilling fluid

Drilling Mud Composition

Clay Chemistry and Structure

Mud Chemistry

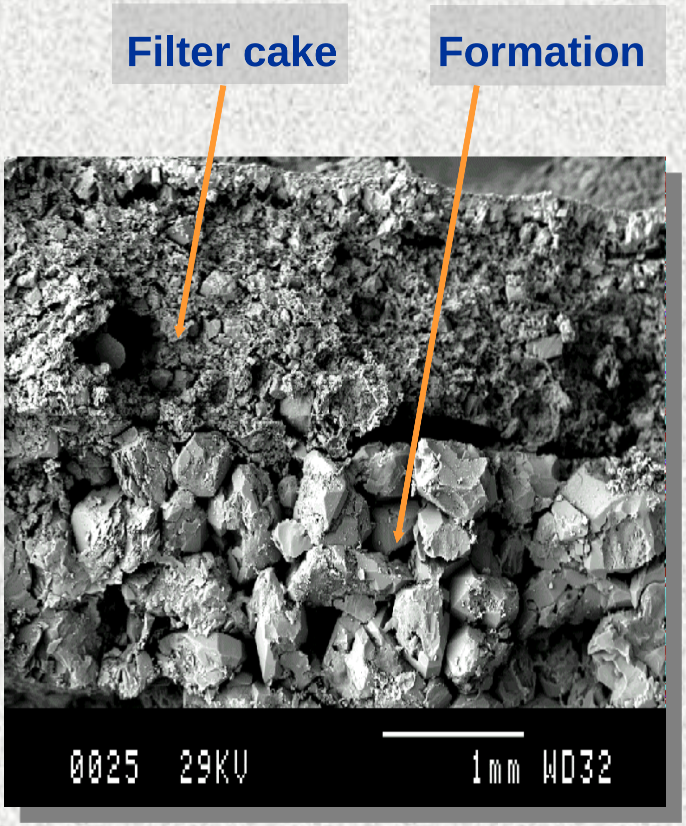
Mud Rehology

Mud Testing

Calculation

Minimize Formation Damage

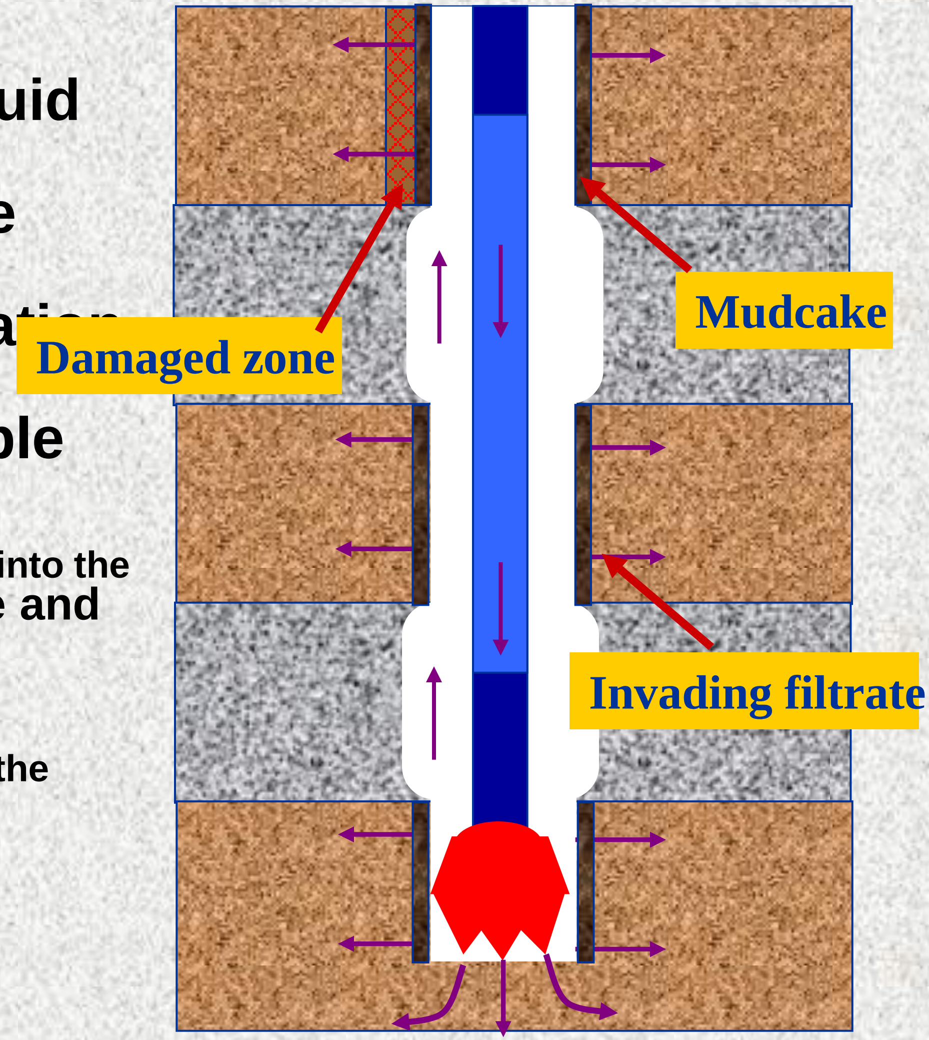
- Mud composition & reservoir characteristics influence the degree of damage. Depth of damage is influenced by
  - Mud formulation
  - Time in open hole
  - Mud overbalance
- Depth of damage is often less than the total depth of invasion due to depletion of damaging species
- Filter cake should prevent extensive damage to formation during drilling



RDF (STARDRILL) Filter Cake

Isolate the Fluid From the Formation

- The differential pressure forces fluid into the wellbore, resulting in whole mud or filtrate entering the formation. Either, or both, of these is undesirable because:
  - The loss of whole mud into the wellbore is expensive and damaging
  - The loss of filtrate into the wellbore may cause formation damage



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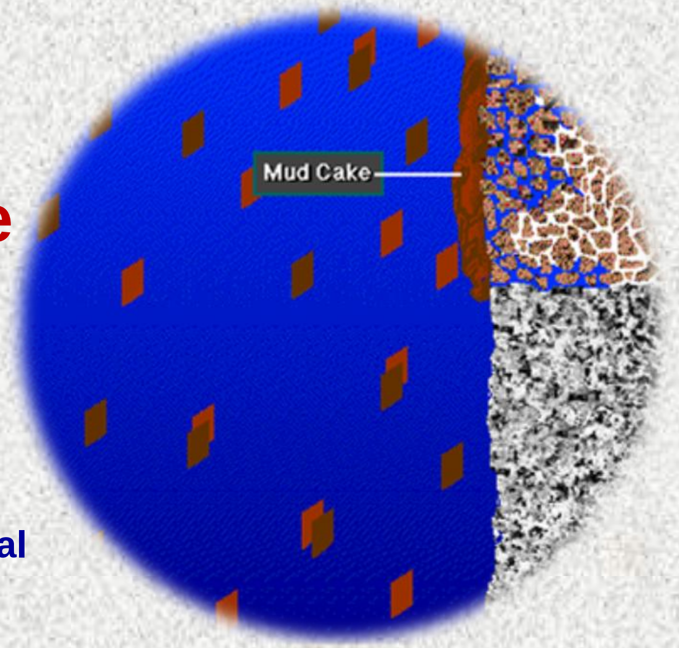
Isolate the Fluid From the Formation

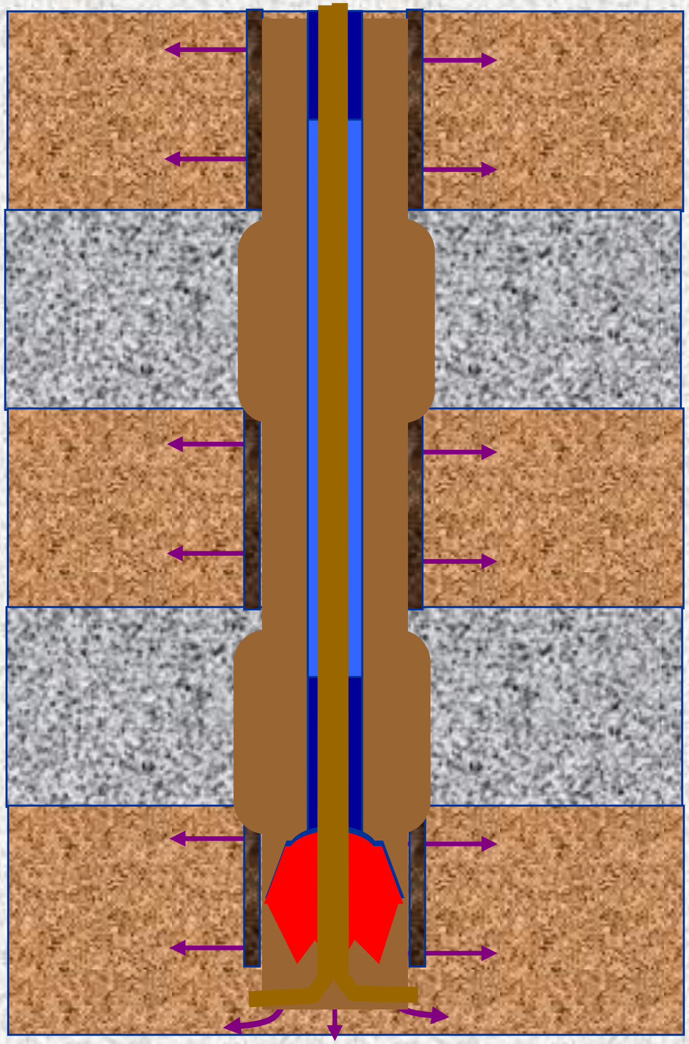
- The flow of fluid is affected by the formation of a filter cake
- The filter cake reduces the flow of fluid into the formation.

  Special additives are added to improve the cake quality:
  - Bridging material
  - Plate like material
  - Plugging material
- The filter cake should be thin with a low permeability
  - This avoids reducing the effective hole diameter
  - It also reduces the chance of differential sticking



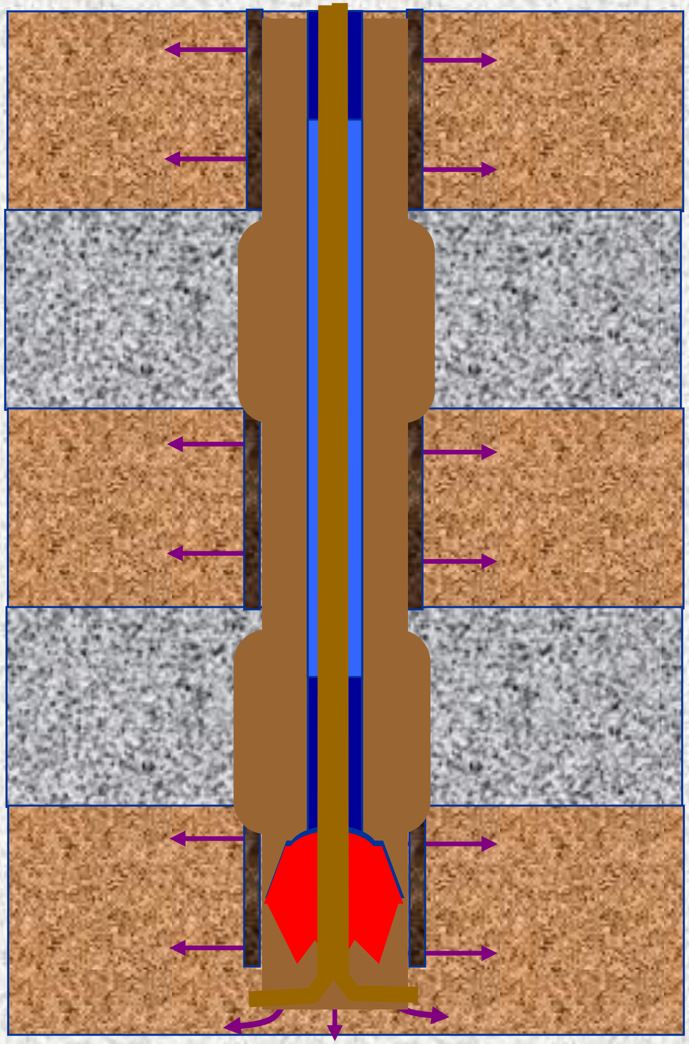
Cooling and Lubrication

- The drilling fluid removes heat from the bit which is then dispersed at the surface
  – Fluid formulations are not changed to improve this function
  – Very occasionally the temperature of the fluid exceeds the flash point. In this case it is necessary to improve surface cooling



Cooling and Lubrication

- Extra lubrication may be required between the drill string and the casing or wellbore, especially in directional wells
  - Liquid additives are used, or Oil based mud
  - Solid additives are sometimes used such as glass beads, plastic beads, graphite or nut plug
  - Drill pipe rubbers are sometimes added to reduce wear between the casing and drill pipe



√ Function of drilling fluid

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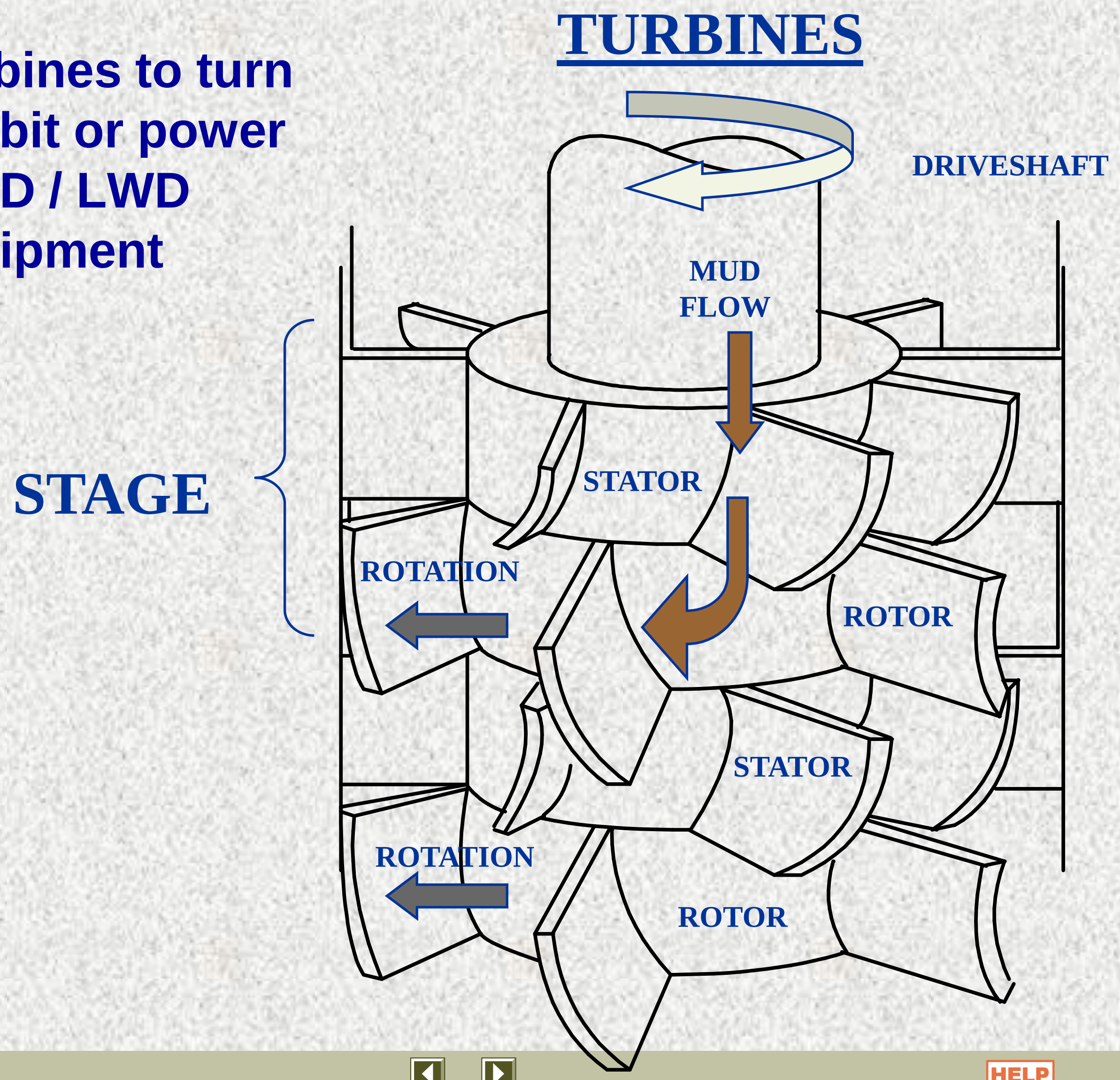
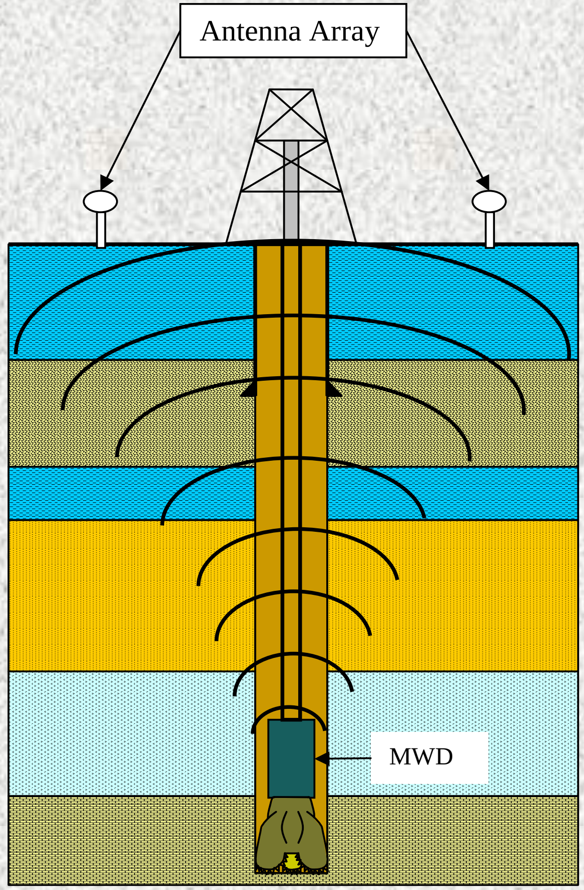
Power Downhole motors

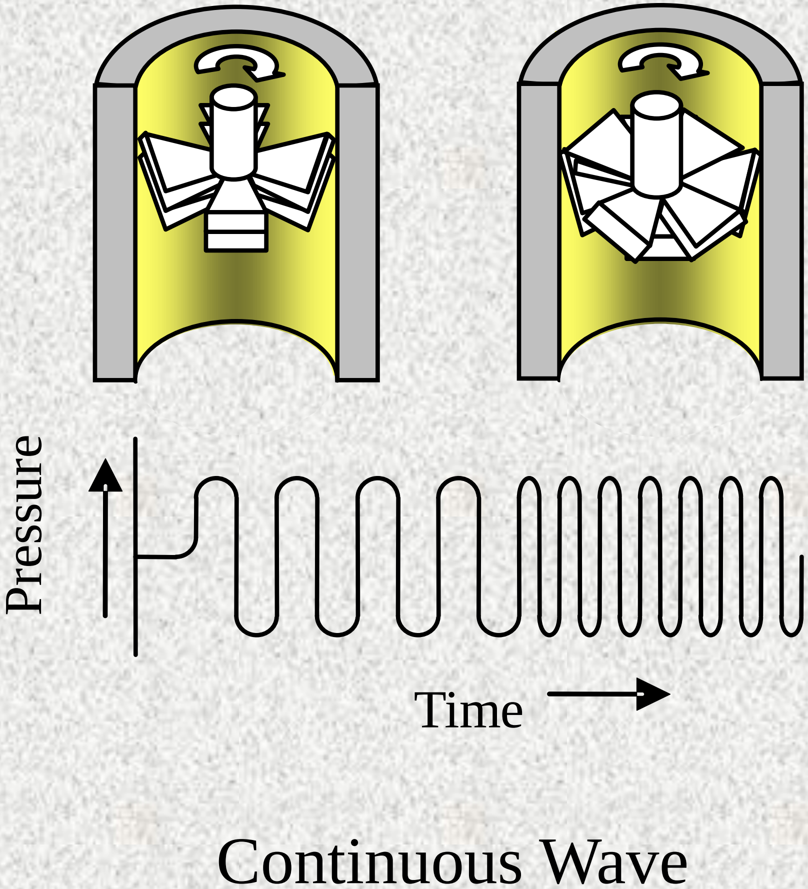
– Turbines to turn the bit or power MWD / LWD equipment



Transfer information from measurement equipment to the surface

- This is done with a pressure pulse





√ Function of drilling fluid

Types and importance of different drilling fluid

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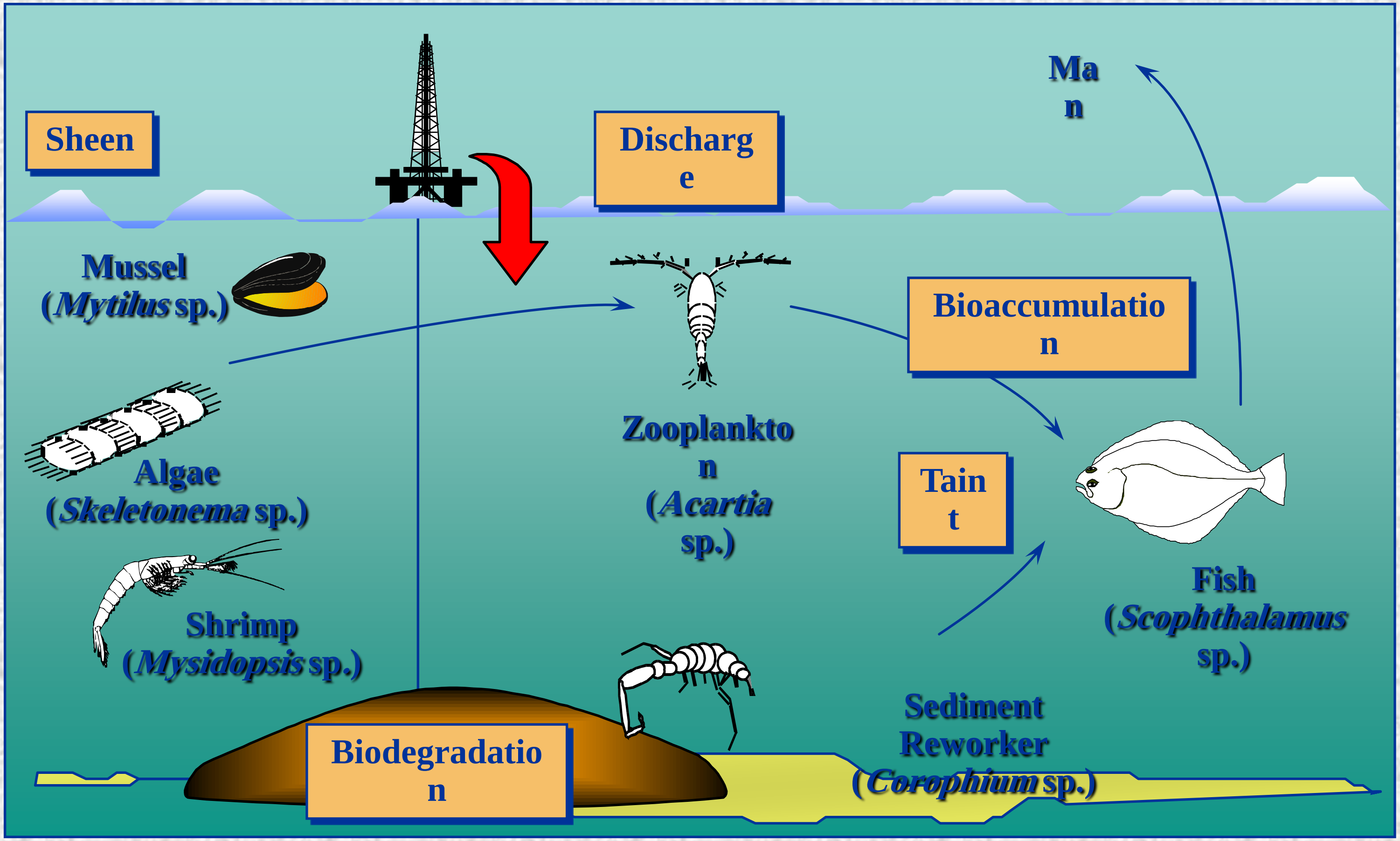
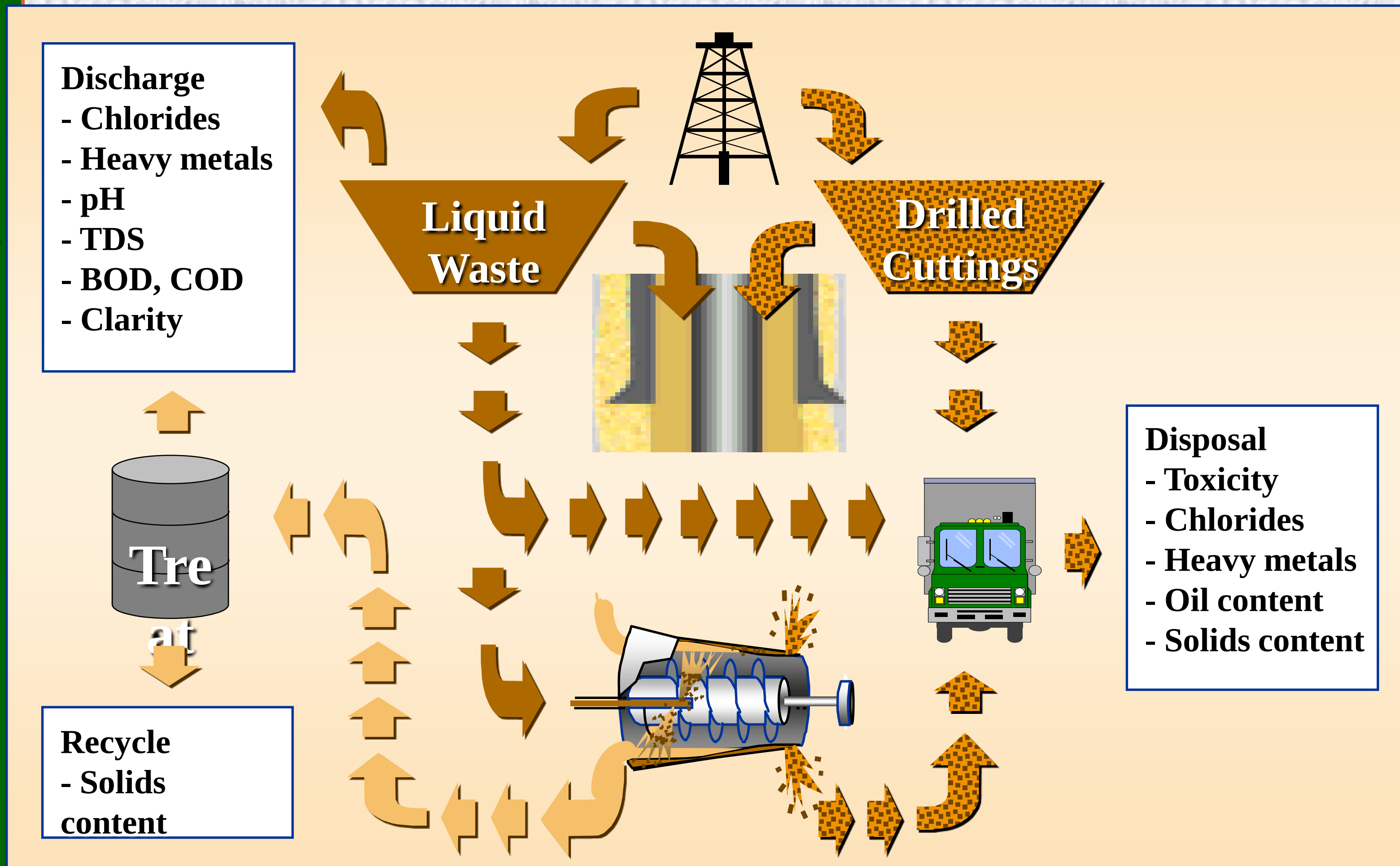
Environmental Impact - Offshore



Environmental Impact - Land



√ Function of drilling fluid

Types and importance of different drilling fluid

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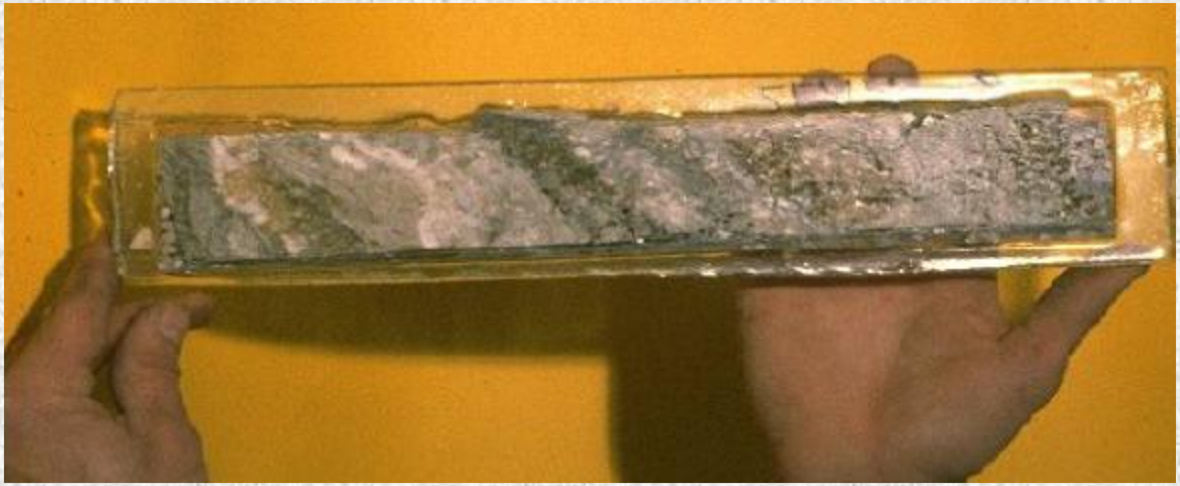
Secure Maximum Hole Information

- The operator will always require the following information:

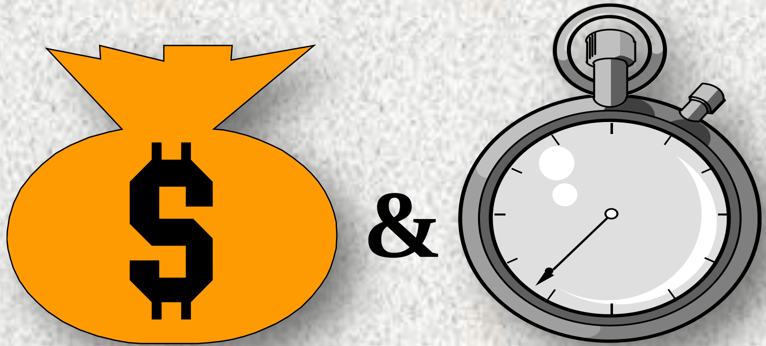
- Rock type being drilled
  - The cuttings should not dissolve or disintegrate
- Analyses of gases
  - The gases should separate easily from the mud
- The fluid should have a defined resistivity
  - Formation resistivity measurements need to be



Control Corrosion

- The :
  - Drill string fluid should be non corrosive to the Casing and Surface equipment
- Corrosion can lead to:
  - Wash outs
  - Twist off
  - Pump failure
  - Surface Leaks

Corrosion leads to loss of

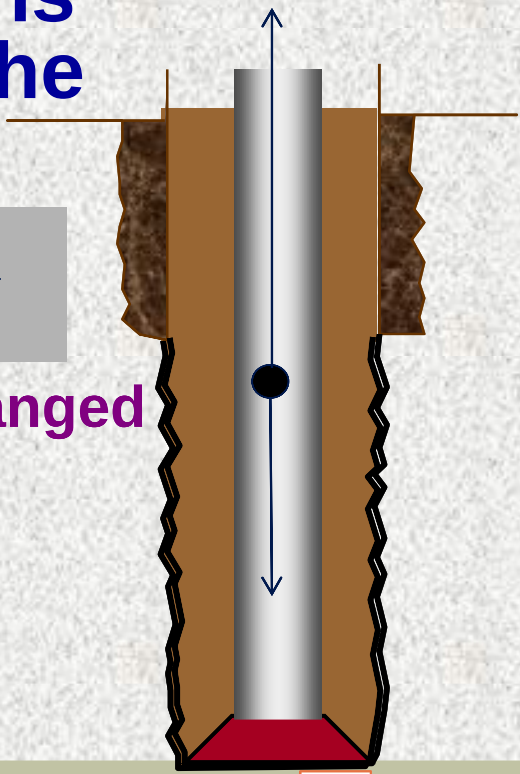


Support Part of the Tubular Weight

- Aids in supporting part of the weight of the drill string and casing
- The degree of buoyancy is directly proportional to the density of the fluid.

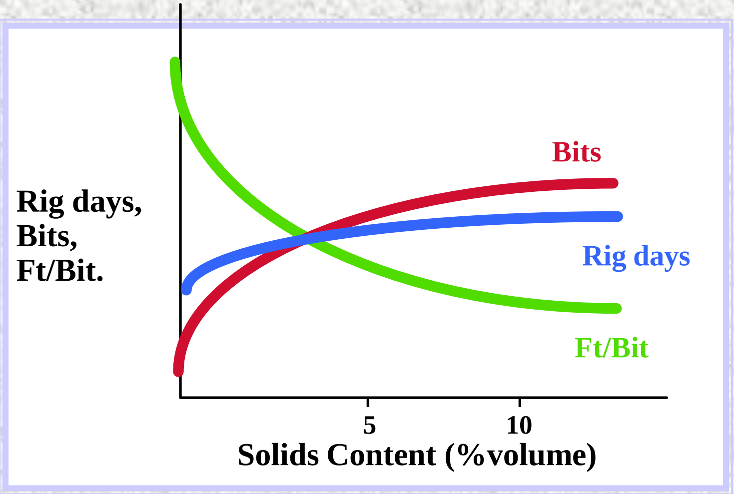
$$\text{Buoyancy factor} = \frac{65.4 - \text{mud weight, ppg}}{65.4}$$

  - The fluid density is never changed increase the buoyancy



Maximize Penetration Rates

- The fluid properties greatly influence penetration rates by:
  - Removing cuttings from below the bit and wellbore
  - Reducing the cushioning effect of solids between the bit teeth and the formation
  - Reducing the hydrostatic differential
  - Increasing the jet velocity



√ Function of drilling fluid

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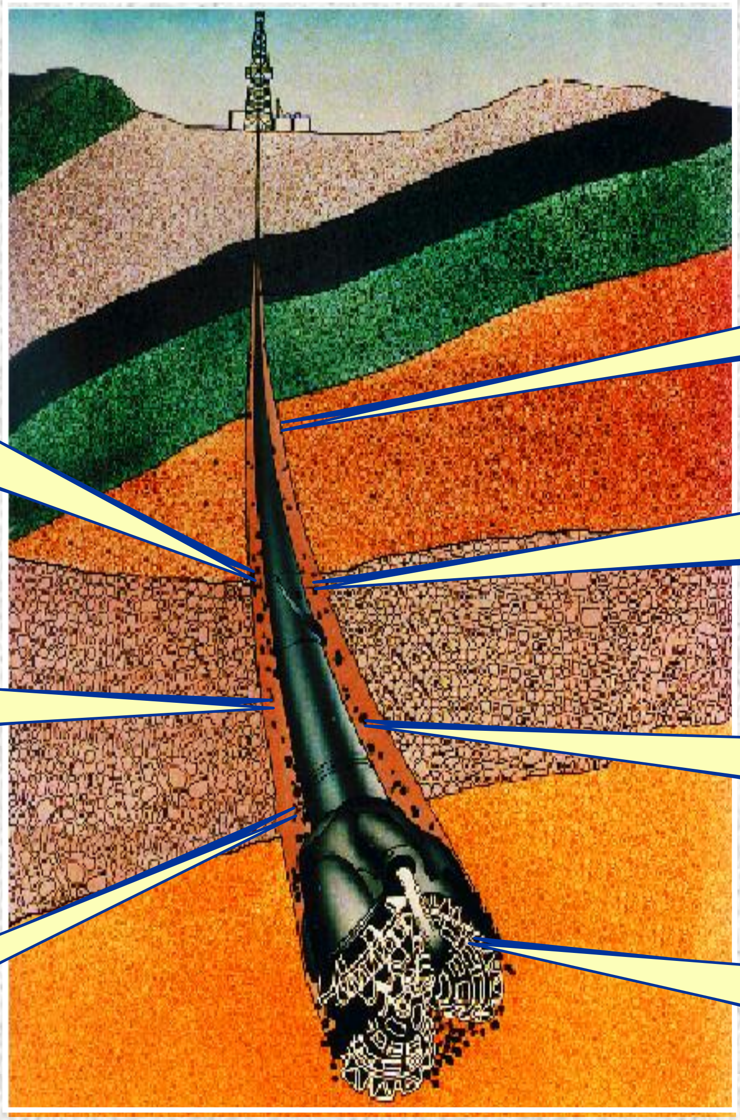
Well Cost

Well Cost ($)	=	Daily Cost (days x $/day)	+	Footage Cost (ft x $/ft)	+	Once off and Other Costs ($)
DFS Cost ($)	=	Fluids Engineering (days x $/day)	+	Drilling Fluid (ft x $/ft)	+	Completion Fluid ($)

– *DFS direct cost is relatively small (5 to 10% of well cost)*

– *Greatest savings achieved by improving Drilling Efficiency*

Key Drilling Fluid Issues



Minimise loss of fluid to the formation

Control formation pressure

Lubricate the drill string

Maintain borehole stability

Suspend barite under static and dynamic conditions

Remove drilling cuttings from the hole

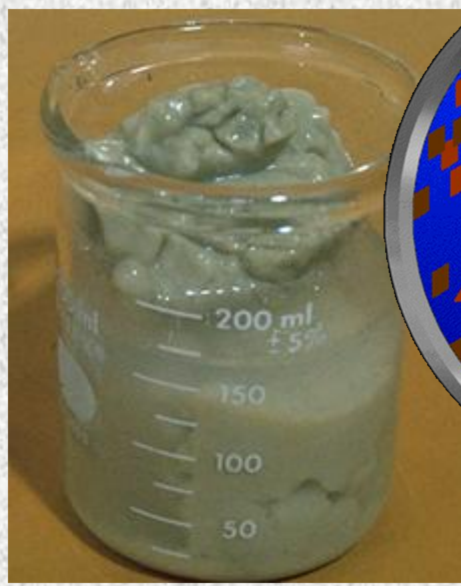
Provide hydraulic horse power to the bit

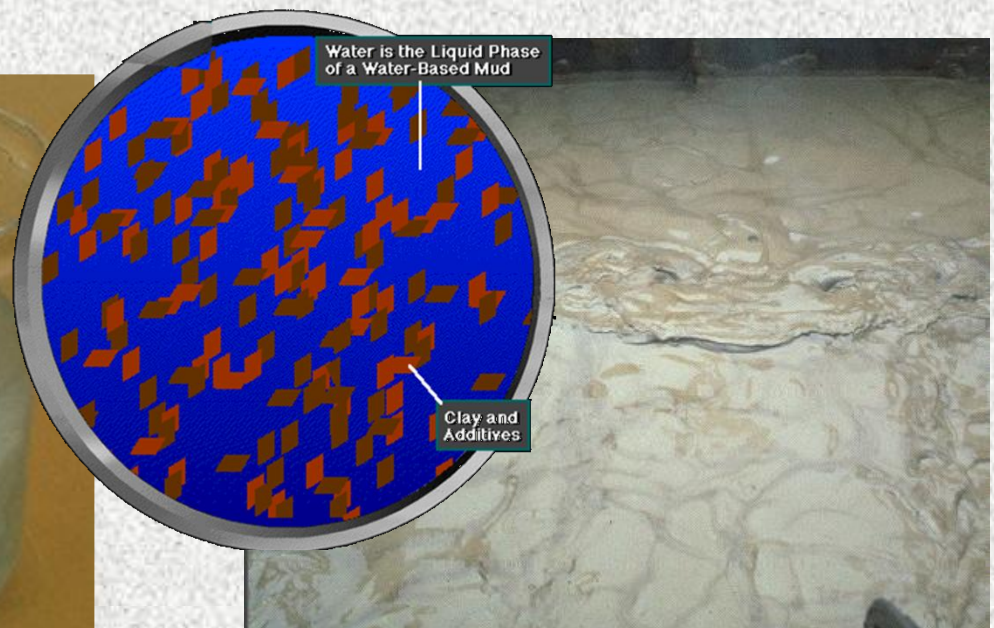
Drilling fluid

- Liquid
  - Water Base Mud
    - Non-inhibitive
    - Inhibitive
      - Polymer
  - Oil base mud
    - Diesel
    - Mineral
    - Non-petroleum HCS
- Gas
  - Air
  - NG
  - N2
  - Exhaust gas
- Liquid+ Gas
  - Mist
  - Foam
  - Aerated mud

Liquid (WBM)

Often, water is the base of drilling mud. Water makes up the liquid part or phase of a water-based mud. Crew members put clay and special additives into the water to make a mud with the properties needed to do its job well. For example, clays give it thickness or viscosity. The water in the mud may be fresh water, sea water or concentrated brine (salt water).





Function of drilling fluid

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Liquid (WBM)

- INHIBITIVE FLUIDS
- Inhibitive fluids are fluids which do not cause appreciable formation alteration. When swelling and hydration of clays and shale are expected, inhibitive water-base muds can be applied. Sub-classified into
  - Calcium-based Muds
  - Salt-based Muds
  - Potassium-based Muds

INHIBITIVE FLUIDS

Calcium-Based Muds

- Calcium-based muds are primarily used to drill intervals of highly reactive shales. Calcium muds are best suited to penetrate horizons that contain gypsum and hydrite.
- Calcium-based muds are highly resistant to contamination. They tolerate solids well, but a high concentration of low-gravity solids will cause unstable rheological properties.
- The principal calcium-based muds are:
  - Lime Muds
  - Lime/MOR-REX Muds
  - Gyp Muds

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INHIBITIVE FLUIDS

Calcium-Based Muds (Lime Muds)

A type of water-base mud that is saturated with lime, $Ca(OH)_2$, and has excess, undissolved lime solids maintained in reserve. It can be low lime, intermidate or high.

Additive	Concentration, lb/bbl	Function
Bentonite	22-26	Viscosity, Filtration control
Lignosulfonate	2-6	Deflocculant
Lime	2-10	Inhibition, Alkalinity Control
Caustic Soda/ Caustic Potash	PH 10.5-12.5	Alkalinity control, Inhibition
Lignite	2-4	Filtration control
Starch	3-4	Filtration Control
PAC	0.25-1.5	Filtration Control

INHIBITIVE FLUIDS

Calcium-Based Muds (Lime/MOR-REX Muds)

Lime/MOR-REX Muds are similar to the lime muds previously discussed; however, lignosulfonate is not required. Instead, a polysaccharide deflocculant (MOR-REX) is used to counteract rheological problems associated with lime muds.

Additive	Concentration, lb/bbl	Function
Bentonite	10-30	Viscosity, Filtration control
MOR-REX	2-6	Deflocculant, limitation 250 ºF, Alkalinity control
Lime	2-10	Viscosity, filtration control
Caustic Soda/ Caustic Potash	PH 11.5-12.5	Alkalinity control, Inhibition
Lignite	2-10	Filtration control
Starch	2-6	Filtration Control
PAC	0.25-1.5	Filtration Control
Gilsonite	2-8	Hole stabilizer and filtration control

INHIBITIVE FLUIDS

Calcium-Based Muds (Gyp Muds)

Originally, gyp muds were used for drilling massive sections of anhydrite. Lack of an effective deflocculant confined their use to low-density muds that normally possessed high viscosity and high gel strengths, until the introduction of chrome lignosulfonate as a deflocculant.

Additive	Concentration, lb/bbl	Function
Bentonite	20-24	Viscosity, Filtration control
Lignosulfonate	4-8	Deflocculant
Gypsum	4-8	Inhibition, Alkalinity Control
Caustic Soda/ Caustic Potash	PH 9.5-11.0	Alkalinity control, Inhibition
Lignite	2-4	Filtration control
Starch	2-6	Filtration Control
PAC	0.25-1.5	Filtration Control
Barite	As required	Weighting agent
DESCO	2-3	Deflocculant

INHIBITIVE FLUIDS

Salt-Based Muds

- salt-based muds are muds containing varying amounts of predominantly sodium chloride ranging from 10,000 mg/L NaCl up to saturation 315,000 mg/L NaCl.
- Salt acts as a contaminant in freshwater mud systems. Even when encountered in small amounts, salt contamination can cause an increase in viscosity, gel strengths, and fluid loss. As salt concentrations increase to greater than 10,000 mg/L, mud properties become increasingly more difficult to control.

- The principal salt-based muds are:
  - Saturated salt mud
  - Saltwater mud
  - Brackish water mud

Function of drilling fluid

√ Types and importance of different drilling fluid

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INHIBITIVE FLUIDS

Salt-Based Muds (Saturated salt Muds)

Saturated Salt Muds are used to prevent excessive hole enlargement while drilling massive salt beds.They can also be used to reduce dispersion and hydration of shales and clays. The chloride content of saturated salt muds is 192,000 mg/L (315,000 mg/L NaCl) at saturation.

Additive	Concentration, lb/bbl	Function
Rehydrated Bentonite	10-25	Viscosity, Filtration control
Caustic Soda	PH 9.0-11.0	Alkalinity control, Inhibition
Soda Ash	1-3	Calcium removal
Starch	4-6	Filtration Control
PAC	0.25-1.5	Filtration Control
Salt (Nacl)	125	Weigh Material, inhibition

Function of drilling fluid

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INHIBITIVE FLUIDS

Salt-Based Muds (salt Water Muds)

Saltwater muds are often prepared from fresh water or bentonite-water muds. The are most often the result of using field brine or seawater as make up wate or incorporating salt that is encountered while drilling. These muds may range from approximately 25,000 mg/L salt (Nacl) up to 315,000 (nearly saturation).

Additive	Concentration, lb/bbl	Function
Rehydrated Bentonite	15-25	Viscosity, Filtration control
Caustic Soda/ Caustic Potash	0.5-1.5	Alkalinity control, Inhibition
Lignite	2-4	Filtration Control
Starch	3-6	Filtration Control
PAC	0.5-1.0	Filtration Control
Lignosulfonate	3-6	Deflocculant

INHIBITIVE FLUIDS

Salt-Based Muds (Brackish Water Muds)

In many areas, because of economics or lack of sufficient fresh water, brackish water from bay water, inland canales or swamps often is used as the makeup water for drilling fluids. These muds generally are termed brackish-water if their salt content is between 10,000 to 25,000 mg/L.

Additive	Concentration, lb/bbl	Function
Rehydrated Bentonite	15-25	Viscosity, Filtration control
Caustic Soda/ Caustic Potash	0.5-1.5	Alkalinity control, Inhibition
Lignite	2-4	Filtration Control
Starch	3-6	Filtration Control
PAC	0.5-1.0	Filtration Control
Lignosulfonate	3-6	Deflocculant

INHIBITIVE FLUIDS

Potassium-Based Muds

- Potassium-based muds are used in areas where inhibition is required to limit chemical alteration of shales, To drill water sensitive and sloughing shale, to stabilize shale and prevent swelling . Potassium performance is based on cationic exchange of potassium for sodium or calcium ions on smectites and interlayered clays. The potassium ion compared to calcium ion or other inhibitive ions, fits more closely into the clay lattice structure, thereby greatly reducing hydration of clays.

- The principal salt-based muds are:
  - KCl-Polymer (KCl-PHPA)
  - KOH-Lignite Muds
  - KOH-Lime Muds
  - KCl-Cationic Polymer Muds

Function of drilling fluid

√ Types and importance of different drilling fluid

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INHIBITIVE FLUIDS

Potassium-Based Muds (KCL polymer Muds)

They were developed to provide wellbore stability and minimize cuttings dispersion. When properly formulated, benefits such as low formation damage and high return permeability encourage their use for drilling water-sensitive formations. Potassium chloride (KCl) muds not only use a wide variety of potassium chloride concentrations from 3 to 15 wt%, but also a wide variety of types and concentrations of polymers.

Additive	Concentration, lb/bbl	Function
Prehydrate Bentonite	5-15	Viscosity, Filtration control
Lignosulfonate	3-6	Deflocculant
Potassium Chloride	5-60	Inhibition source of K+ ion
Caustic Potash	PH 9.5-11.0	Alkalinity control, Inhibition
Lignite	2-4	Filtration control
Starch	3-6	Filtration Control
PAC	0.5-1.0	Filtration Control

INHIBITIVE FLUIDS

Potassium-Based Muds (KOH-Lignite Muds)

In areas where high chloride ions may be objectionable (logging, environmental considerations, etc.) KOH-lignite systems should be considered. Potassium lignite muds offer inhibition and are flexible enough to be tailored to meet desired drilling requirements. Polymers can be used for viscosity and fluid loss control. Lignosulfonates are added if additional deflocculation is needed.

Additive	Concentration, lb/bbl	Function
Bentonite	15-25	Viscosity, Filtration control
Caustic Potash	0.5-1.5	Alkalinity control, Inhibition
Lignite	5-8	Filtration control
Barite	As needed for density	Filtration Control and viscosity
PAC/CMC	0.5-1.0	Filtration Control and viscosity

Function of drilling fluid

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INHIBITIVE FLUIDS

Potassium-Based Muds (KCl - Cationic Polymer Muds)

- **One of the most recent advances in drilling fluid technology has been the development of cationic muds, which use a cationic (positively charged) polymer along with a potassium salt to inhibit reactive shales. KCl-Cationic Polymer muds are generally considered to be the most inhibitive water-based muds**

Function of drilling fluid

√ Types and importance of different drilling fluid

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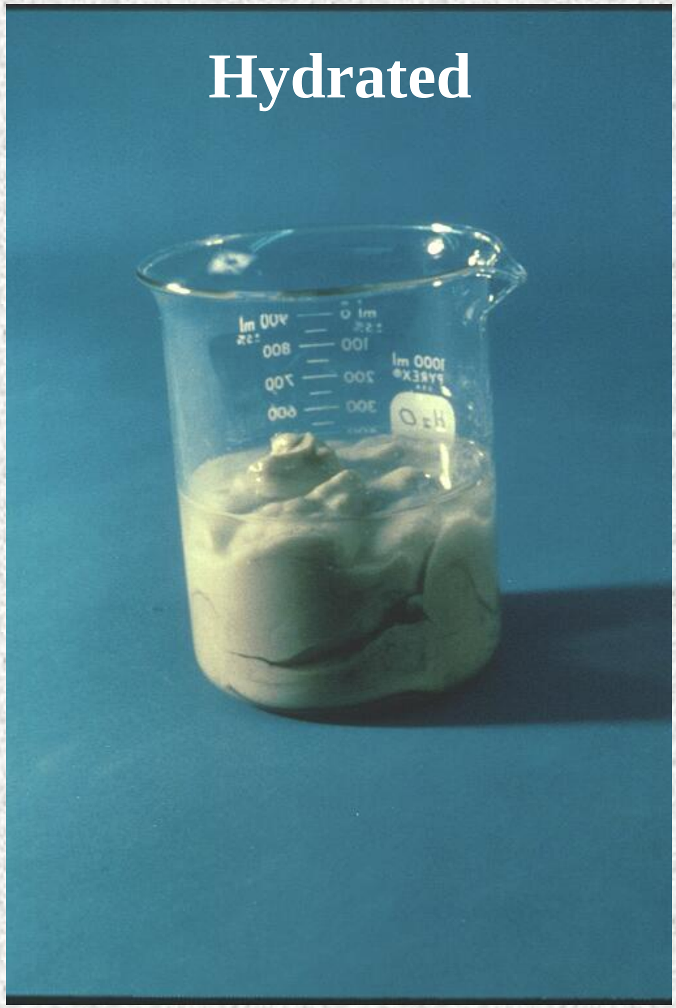
Liquid (WBM)

- Non-INHIBITIVE FLUIDS
- The term noninhibited refers to the lack of specific ions such as potassium, calcium, or chloride that would inhibit the ability of the formation to absorb water. It is simple and inexpensive. It is Sub-classified into
  - Clear Water
  - Native Muds
  - Bentonite-Water Muds
  - Lignite/Lignosulfonate (Deflocculated) Muds



NON-INHIBITIVE FLUIDS

Clear water

Spud Muds are used during drilling to:

- clean the hole;
- prevent sloughing of the surface hole;
- provide a viscous sweep to clean gravel/sand from the borehole;
- form a filter cake to prevent seepage to the formation.

Formulation:

- Water: (Fresh, brackish, salt)
- Caustic: 8.5 to 10.5 pH in fresh-water muds 10.5 to 11.5 pH in salt-water muds
- Clay: 10 to 35 lb/bbl, depending on mud weight Fresh water-Sodium bentonite. Salt water-Attapulgite or prehydrated bentonite

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NON-INHIBITIVE FLUIDS

Native Mud

- In some areas, drilled formations contain mud-making claystones or shales. When water is pumped down the hole during drilling, it returns with the native solids dispersed in it.
- Viscosity builds with continued drilling and circulation. The result is a viscous native mud. Dilution may be needed to keep the mud from becoming excessively viscous. On the other hand, small quantities of bentonite may be added to increase viscosity and improve filtration control. Caustic soda or lime is usually added for corrosion control.

NON-INHIBITIVE FLUIDS

Bentonite-Water Muds

- Bentonite dispersed in fresh water produces a mud with good cuttings lifting capacity, good drilling rate, and usually adequate filtration control.
- These bentonite-water muds are commonly used as spud muds for drilling surface hole; however, they are sometimes used for drilling deeper.
- Water quality is important in formulating a bentonite-water mud. Chlorides (Cl-) and hardness (Ca++and Mg++) in the makeup water interfere with the hydration of the bentonite. Calcium ion concentration should not exceed 150 mg/L. If greater than 150 mg/L, it should be treated out with soda ash. Treatment with 0.1 lb of soda ash per barrel of water will remove approximately 100 mg/L of calcium ion

Function of drilling fluid

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NON-INHIBITIVE FLUIDS

Lignite-Lignosulfonate Muds

Lignite-Lignosulfonate Muds can be used to drill a variety of formations. They can be weighted up to 18 or 19 lb/gal, provided low-gravity solids (bentonite and drill solids) are in the proper range.

Additive	Concentration, lb/bbl	Function
Bentonite	10-25	Viscosity, Filtration control
Lignosulfonate	0.25-8	Deflocculant, filtration control
Caustic Soda/Caustic potash	For PH 9.5-10.5	Alkalinity control
Soda Ash	0.25-1	Calcium Ion removal
Lignite	1-4	Filtration Control
Barite	As needed for density	Weighting agent
Low visocsity PAC/CMC	0.25-1.0	Filtration control
Gilsonite	2-8	Filtration control

Liquid (WBM)

- Polymer FLUIDS
- Polymer fluids generally contain only minor amounts of bentonite to build viscosity. Primary viscosification is provided by high molecular weight polymers such as PHPA, PAC, XC polymer, etc. Polymers fluids also reduce cuttings dispersion and stabilize the wellbore through encapsulation. It can be:
  - Non-Dispersed Polymer Muds
  - High-Temperature Deflocculated Polymer Muds

Function of drilling fluid

√ Types and importance of different drilling fluid

Drilling Mud Composition

Clay Chemistry and Structure

Mud Chemistry

Mud Rehology

Mud Testing

Calculation

Polymer fluids

Non-Dispersed Polymer Muds

- In many areas clear water cannot be used as a drilling fluid because of its effect on formations and the lack of sufficient viscosity to properly clean the hole. In these circumstances Non-Dispersed Polymer Muds may be used to closely simulate the drilling characteristics of clear water.
- Non-dispersed Polymer muds have found their best application in areas where formations are hard and penetration rates are slow.
- The principal Non-dispersed polymer muds are:
  - BEN-EX Muds
  - Low-Solids PAC/CMC Muds
  - Low-Solids PHPA Muds

Function of drilling fluid

√ Types and importance of different drilling fluid

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Polymer fluids

Non-Dispersed Polymer Muds-BEN-EX (Bentonite Extender) Muds

BEN-EX is a powdered water-dispersible polymer packaged in 2-lb bags. It is used to increase the yield of bentonite and to flocculate drilled solids. The addition of 0.05 lb/bbl BEN-EX will approximately double the yield of bentonite. This is an advantage because fewer solids are used to produce the same viscosity.

Additive	Concentration, lb/bbl	Function
Bentonite	10-14	Viscosity, Filtration control
BEN-EX	0.05-0.1	Bentonite Extender
Sodium Polyacrylate	0.25-0.5	Selective flocculant
Soda Ash	0.25-0.75	Calcium Ion removal
Barite	As needed for density	Weighting agent

Function of drilling fluid

√ Types and importance of different drilling fluid

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Polymer fluids

Non-Dispersed Polymer Muds- Low-solids PAC/CMC muds

- **Low-solids PAC/CMC muds use cellulose-based polymers rather than sodium polyacrylate polymers.The cellulosic polymers have greater tolerance to calcium and salt than do the acrylate polymers.**

Additive	Concentration, lb/bbl	Function
Bentonite	5-10	Viscosity, Filtration control
Caustic Soda	For PH 9.0-9.5	Alkalinity
Regular PAC/CMC	0.25-0.5	Filtration control
Soda Ash	0.25-0. 5	Calcium Ion removal
Barite	As needed for density	Weighting agent

Function of drilling fluid

√ Types and importance of different drilling fluid

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Polymer fluids

Non-Dispersed Polymer Muds- Low-Solids PHPA Muds

- **Low-Solids PHPA Muds (partially hydrolyzed polyacrylamide) are used to inhibit shale. These acrylate/acrylamide polymers absorb onto clay surfaces. Thus, because PHPA is a long-chemical molecule, it can effectively link a number of clay platelets together creating viscosity with a minimum concentration of low-gravity solids.**

Additive	Concentration, lb/bbl	Function
Bentonite	10-14	Viscosity, Filtration control
Caustic Soda/Caustic Potash	For PH 9.0-9.5	Alkalinity
PHPA	1.0	Solids Encapsulation, Borehole Stability
Soda Ash	0.25-0.75	Treat out Ca++
SPA	0.25-0.5	Filtration control

Polymer fluids

High-Temperature Deflocculated Polymer Muds

- They were developed to extend the temperature stability of conventional polymer muds. They are designed to tolerate, in addition to contaminants the inclusion of inhibiting ions such as KCl or NaCl. These muds are required to provide stability along the same lines as an oil mud yet still be economical. If the high-temperature deflocculated polymer mud can be used in place of an oil-base mud, then it becomes very attractive for reasons of environmental and safety considerations.

- The principal Non-dispersed polymer muds are:
  - THERMA-DRIL
  - PYRO-DRILL
  - DURATHERM
  - POLYTEMP

Function of drilling fluid
√ Types and importance of different drilling fluid
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Polymer fluids

High-Temperature Deflocculated Polymer Muds-(PYRO-DRILL)

- **PYRO-DRIL is a high-temperature mud system sold by Milpark. This system uses a MILTEMP, a sulfonated, styrene maleic anhydride, as a high-temperature deflocculant. PYRO-TROL is an acrylamide-acrylmido methyl propane sulfonic acid. This material is used as a high-temperature filtration control agent. PYRO-VIS is a sugar beet extract and is used to provide carrying capacity without addition of bentonite. KEM-SEAL, an acrylate-acrylamide compound, provides filtration control in saltwater brines.**

Additive	Concentration, lb/bbl	Function
PYRO-VIS	As needed	Supplemental viscosifier
MIL-TEMP	1-2	Deflocculant
PYRO-TROL	1-3	Filtration control
KEM-SEAL	0.5-2	Filtration Control
CHEMTROL X	2-6	Filtration control

Function of drilling fluid

√ Types and importance of different drilling fluid

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Polymer fluids

High-Temperature Deflocculated Polymer Muds- (THERMA-DRIL)

- **THERMA-DRIL is a high-temperature polymer drilling fluid system sold by Baroid. This mud system utilizes prehydrated bentonite for suspension and some filtration control. THERMA-THIN, a liquid polyacrylate/terpolymer, is used as a deflocculant and to control high-temperature gelation. THERMA-CHECK, a vinyl-sulfonate co-polymer, is used to control filtrate up to 425°F.**

Additive	Concentration, lb/bbl	Function
Bentonite	8-10	Viscosity, Filtration control
Therma-Thin	1-4	Deflocculant
Therma-Check	2-8	Filtration control
Caustic Soda	For Ph 9-10	Alkalinity Control
Oxygen Scavenger	1-2	corrosion control, temperature stability

Polymer fluids

High-Temperature Deflocculated Polymer Muds- (DURATHERM)

- **DURATHERM is a high-temperature mud system sold by M-I Drilling Fluids. This mud system uses small concentrations of bentonite for suspension. XP-20, a modified chrome lignite containing potassium, is used as a fluid loss additive and viscosity stabilizer. XP-20 is used primarily in fresh water systems. MELANEX-T, a melanin polymer derivative, is used as a high-temperature deflocculant to reduce viscosity and high-temperature gelation. RESINEX, a resin polymer, is used for HTHP filtration control**

Additive	Concentration, lb/bbl	Function
PYRO-VIS	As needed	Supplemental viscosifier
MIL-TEMP	1-2	Deflocculant
PYRO-TROL	1-3	Filtration control
KEM-SEAL	0.5-2	Filtration Control
CHEMTROL X	2-6	Filtration control

Function of drilling fluid

√ Types and importance of different drilling fluid

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Polymer fluids

High-Temperature Deflocculated Polymer Muds-(POLYTEMP)

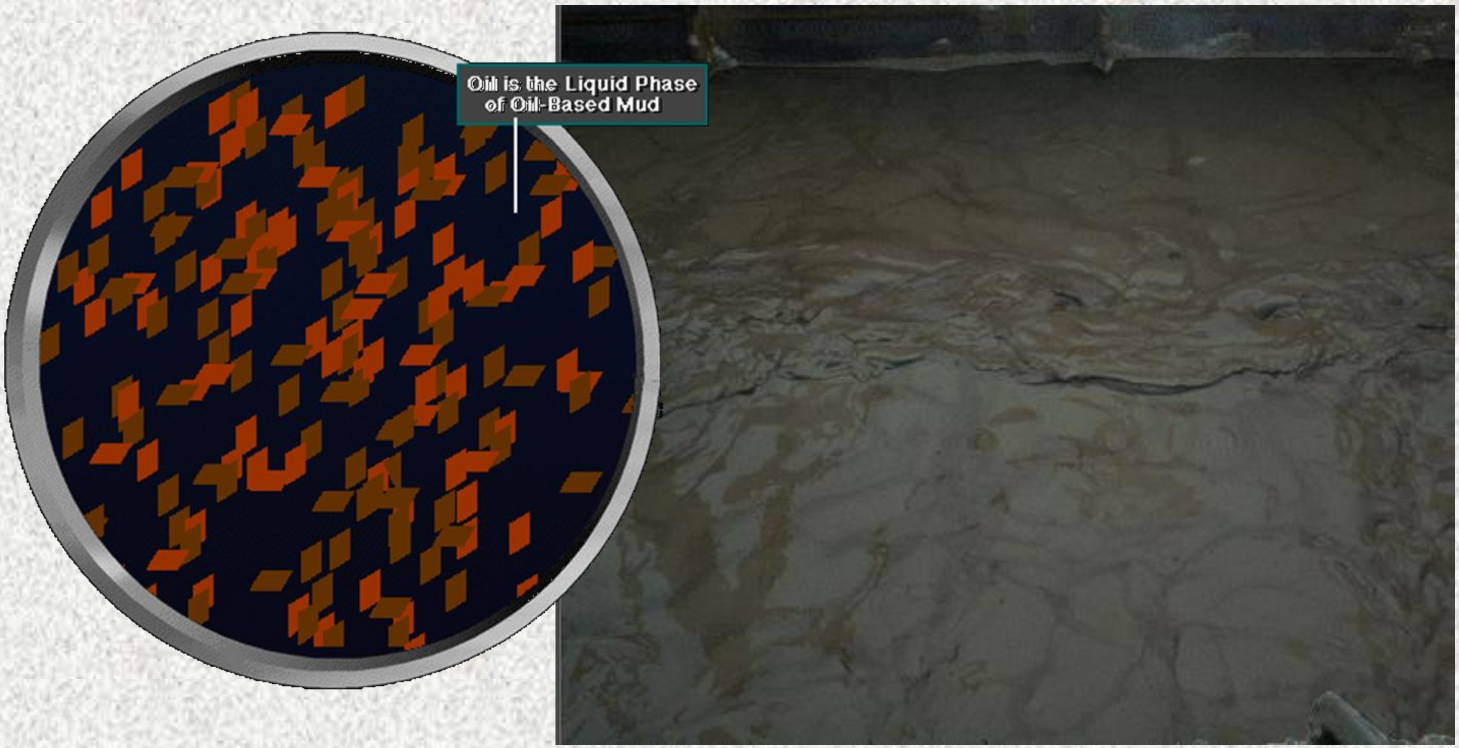
- **The IDF POLY TEMP mud system uses POLY TEMP, a vinyl sulphonate-vinyl amide co-polymer of low to medium molecular weight, to reduce filtrate. Bentonite is used for suspension. POLY TEMP can be used in a seawater or freshwater system. IDF HITEMP, a resin compound, is used to aid in HTHP filtrate control.**

Additive	Concentration, lb/bbl	Function
Bentonite	8-10	Viscosity, filter cake
Hi-Temp II	4.0-8.0	Fluid loss control
PTS-200	4.0-8.0	Temperature Stabilizer
PolyTemp	2.0-4.0	Fluid Loss Control
Idsperse XT	1.0-4.0	Deflocculant

Liquid (OBM)

- Oil Based Mud

At times, down hole drilling conditions require the crew to add oil to the mud, or in some cases, crew members use oil instead of water as the base of the mud. This is called oil-based mud.



Function of drilling fluid

√ Types and importance of different drilling fluid

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Liquid (OBM)

- Oil based mud has many advantages: It can stabilize the formation and reduce downhole drilling problems. However, it is harder for the crew to work with because it can create slippery conditions and environmental precautions must be used. From an environmental standpoint, mud with oil is more difficult to handle because the oil clings to the drill cuttings. The oil must be cleaned off the cuttings before they're disposed of.

Function of drilling fluid

√ Types and importance of different drilling fluid

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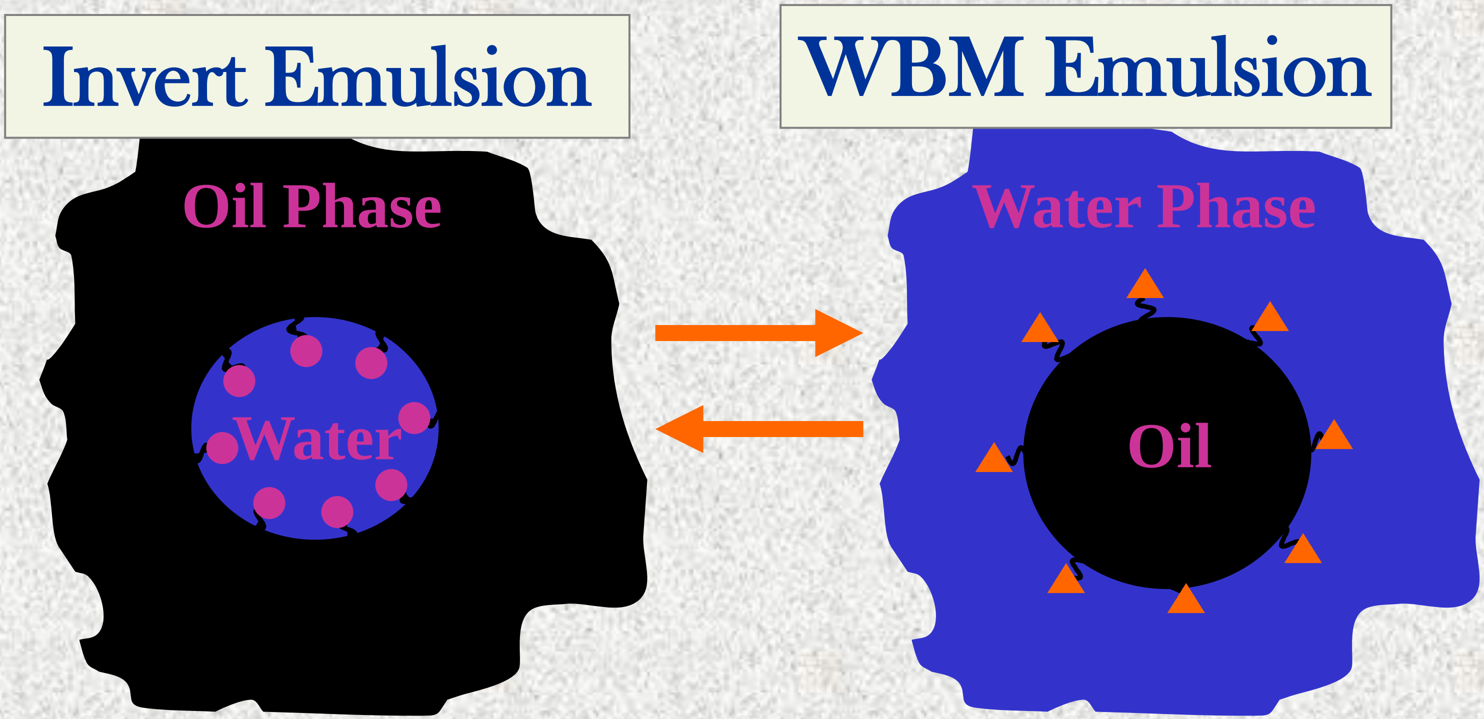
Liquid (OBM)

- There are two basic classifications of oil-based fluids;
  - Invert emulsions
  - Conventional all-oil muds.
- The amount of water present will describe the type of oil base fluid.
- The oil used in these types of oil base fluids can range from crude oil, refined oils such as diesel or mineral oils, or the non-petroleum organic fluids that are currently available..

Emulsions



Oil External Phase

Oil wet solids & surfaces

Desirable for Drilling

Water External Phase

Water-wet solids & surfaces

Cementing / Stimulation

Emulsifiers

SURFACTANTS - ***Surface Active Agents.***

- **Act by Reducing the Interfacial Tension Between Two Liquids or Between a Liquid and a Solid.**

  ❶ **Emulsifiers**

  ❷ **Soaps**

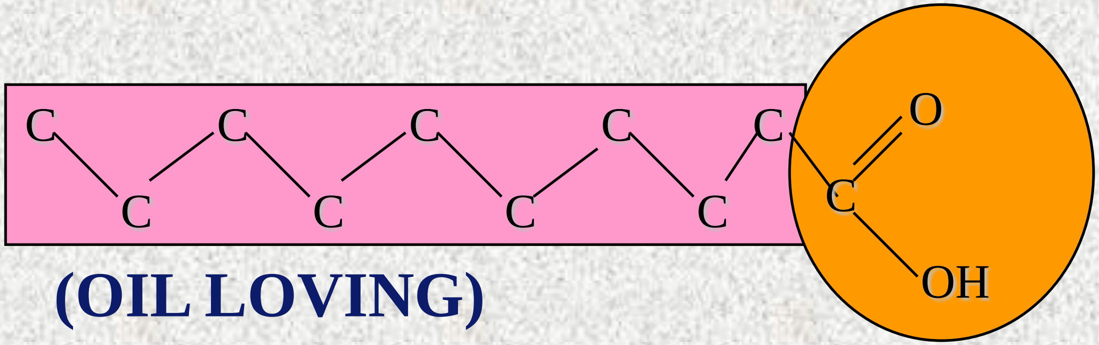
  ❸ **Wetting Agents**

Emulsifiers

SURFACTANTS - *Surface Active Agents*

Have a hydrophilic polar head and an organophilic non-polar tail.

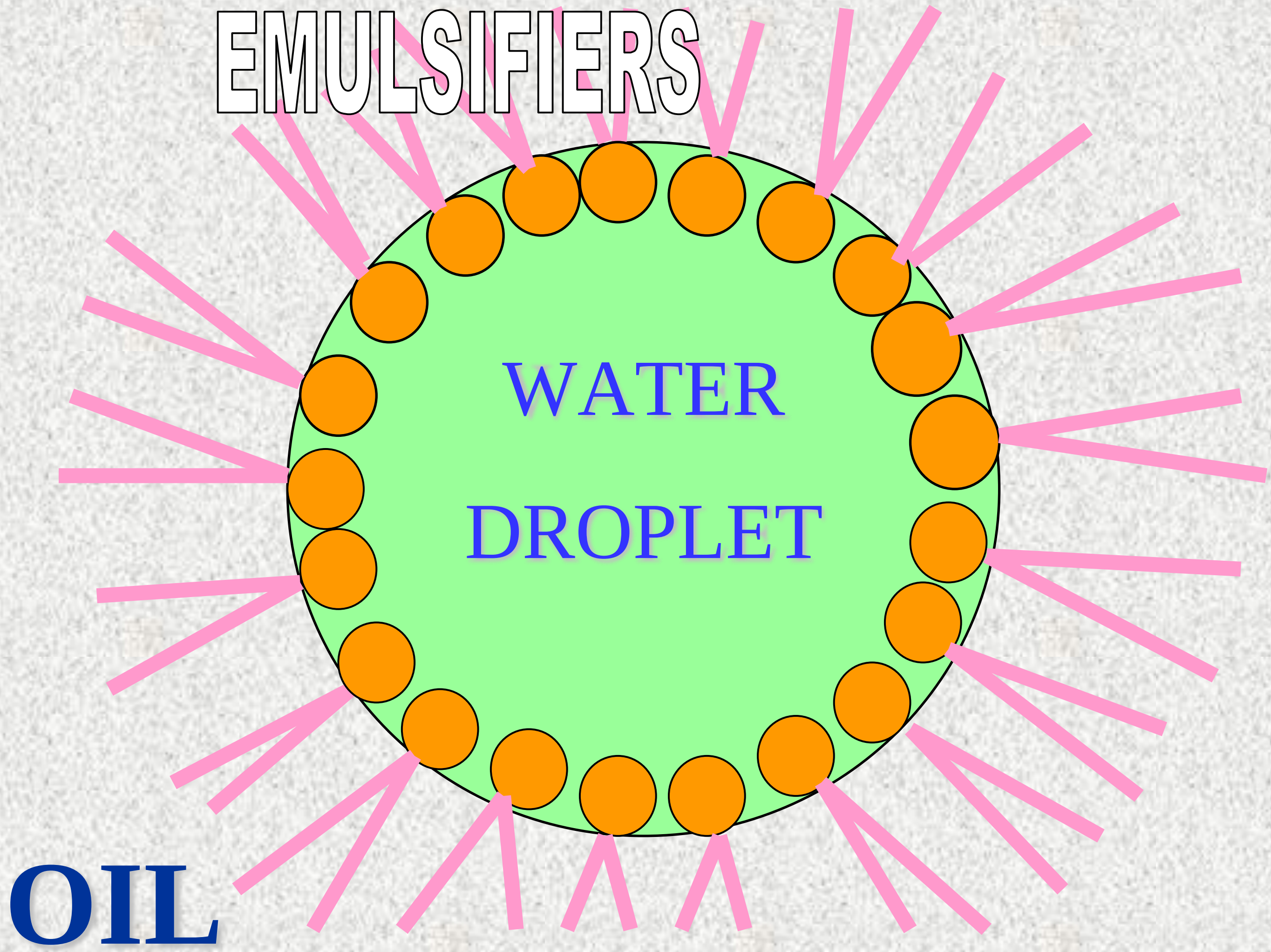
HYDROPHILIC HEAD (WATER LOVING)



(OIL LOVING)

ORGANOPHILIC TAIL

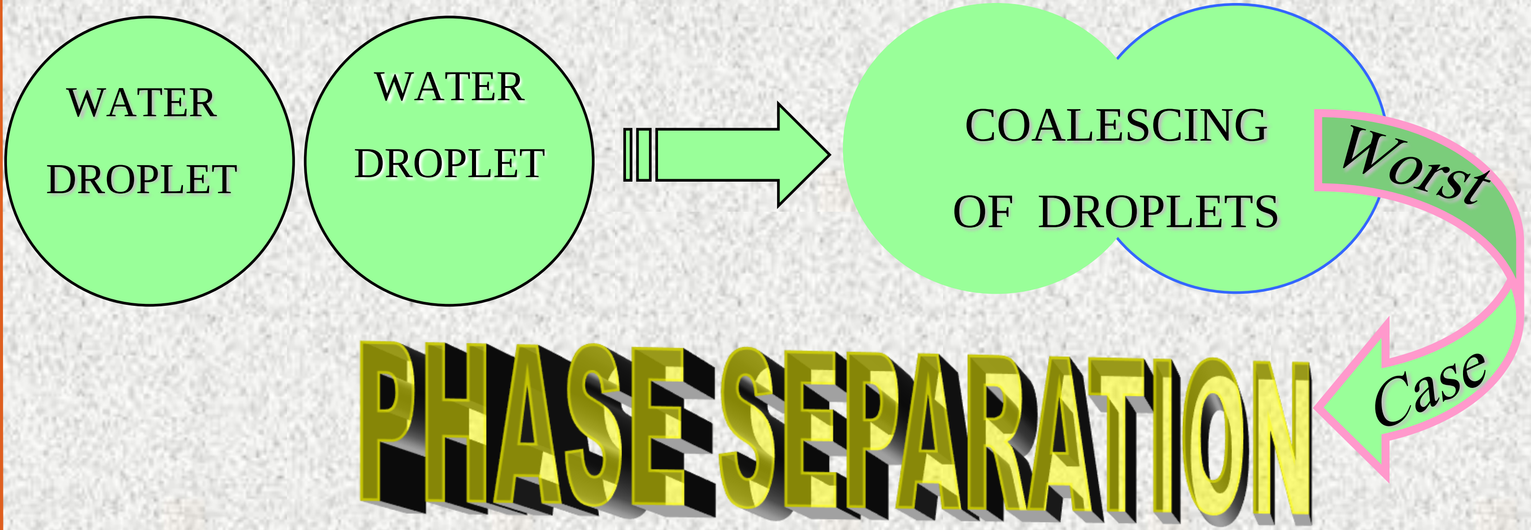
Emulsifiers



Emulsifiers

INSUFFICIENT

EMULSIFIER CONCENTRATION



Function of drilling fluid

√ Types and importance of different drilling fluid

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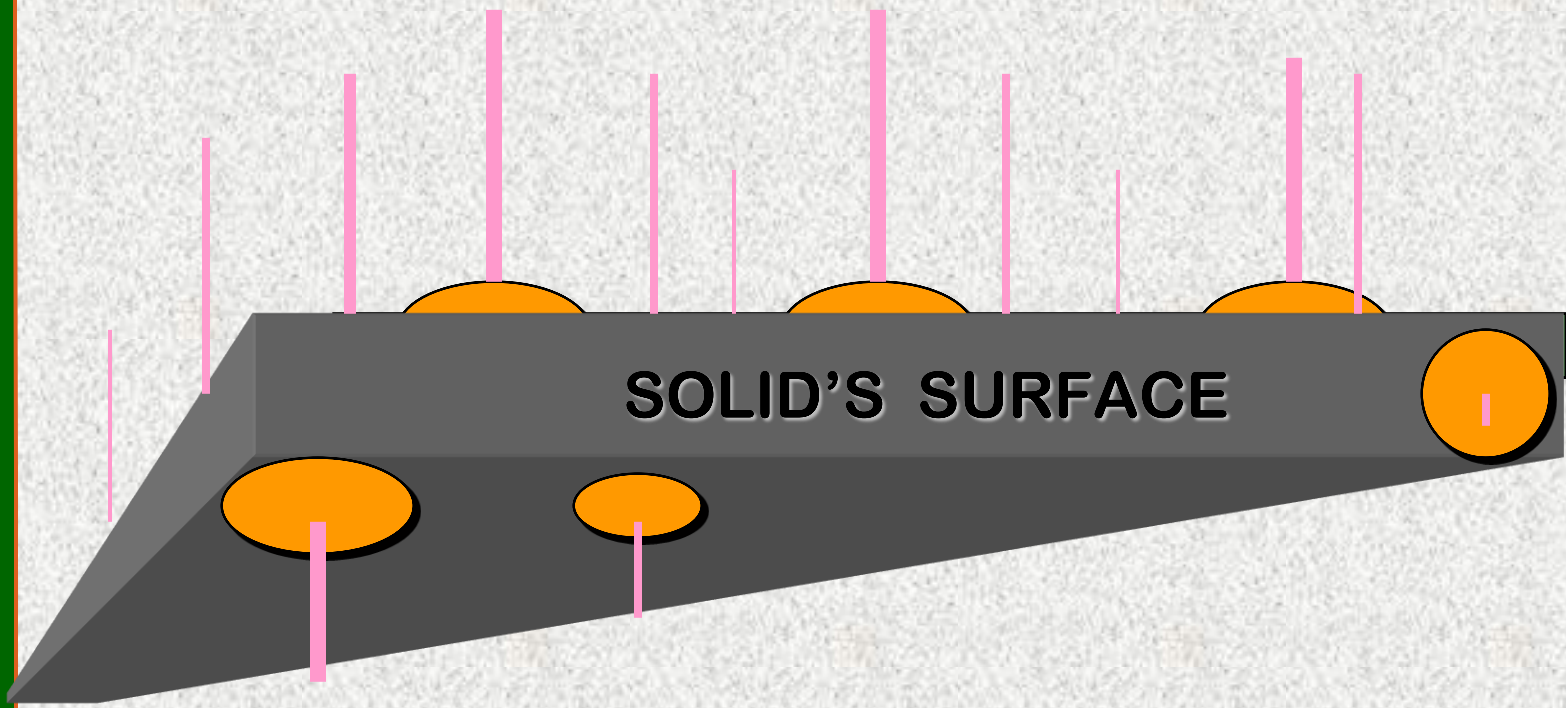
Emulsifiers

OIL WETTING AGENTS

- Designed to Oil Wet solids



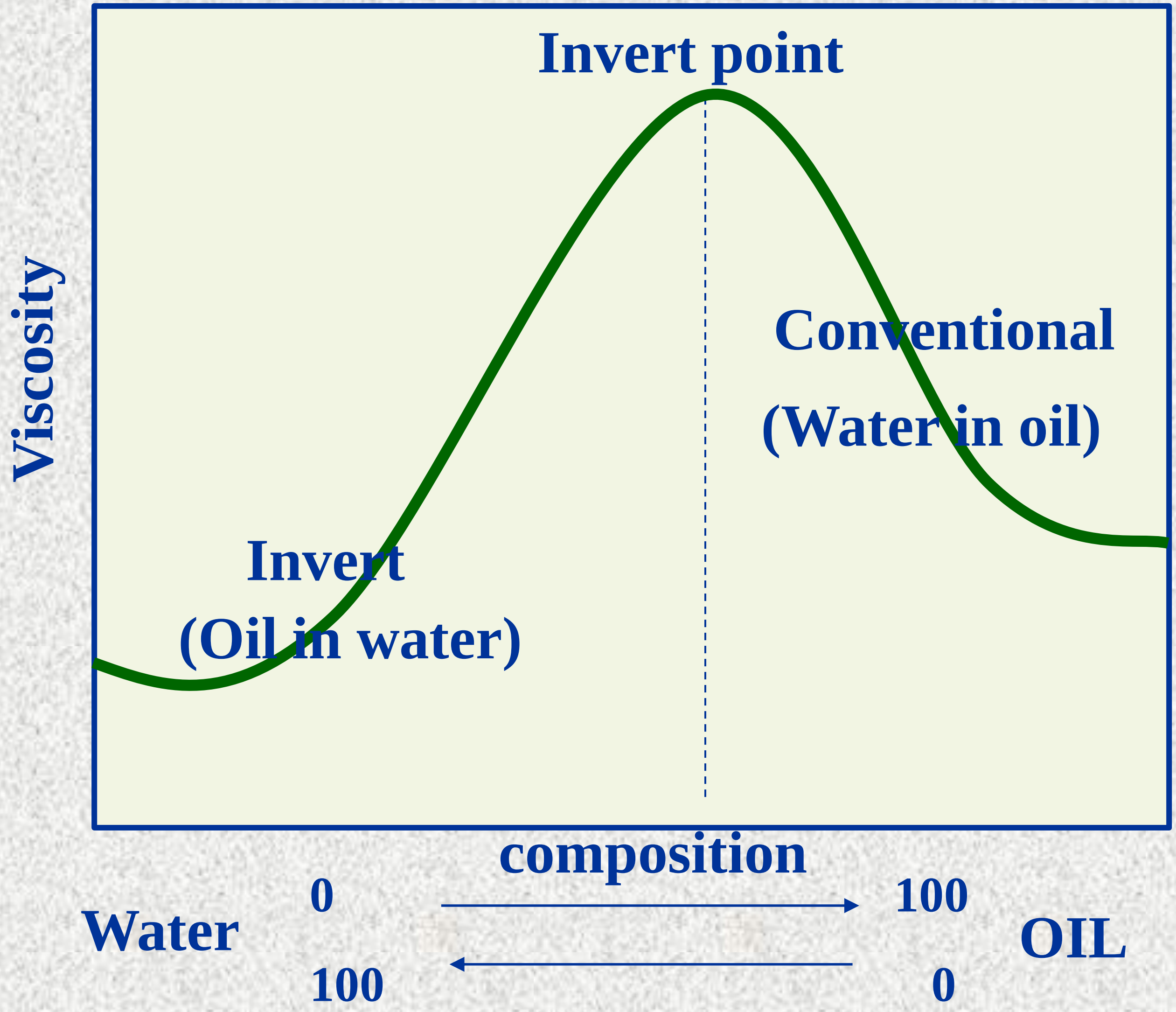
Conventional all-oil mud

- Conventional all-oil muds have oil as the external phase but they are designed to be free of water when formulated or in use. Since water is not present, asphaltic type materials are required to control the fluid loss and viscosity. Since there is no water added to this system during the formulation and water additions are avoided if possible while drilling, there is only a minimum requirement for emulsifiers.
- All-oil muds can withstand small quantities of water; however, if the water becomes a contaminating effect, the mud should be converted to an invert emulsion. If the water is not quickly emulsified, the solids in the mud can become water wet and will cause stability problems.
- Water may represent at most 2 to 5 % to recognize a conventional type

Invert emulsions

- Invert emulsions are oil muds that are formulated to contain moderate to high concentrations of water. Water is an integral part of the invert emulsion and can contain a salt such as calcium or sodium chloride. An invert emulsion can contain as much as 60% of the liquid phase as water. Special emulsifiers are added to tightly emulsify the water as the internal phase and prevent the water from breaking out and coalescing into larger water droplets. These water droplets, if not tightly emulsified, can water wet the already oil wet solids and seriously affect the emulsion stability.
- Invert emulsions are usually tightly emulsified, low fluid loss oil muds. An improvement in drilling rates has been seen when the fluid loss control of the system is relaxed, thus the name "relaxed" invert emulsion.

Invert Vs Conventional



Function of drilling fluid

√ Types and importance of different drilling fluid

Drilling Mud Composition

Clay Chemistry and Structure

Mud Chemistry

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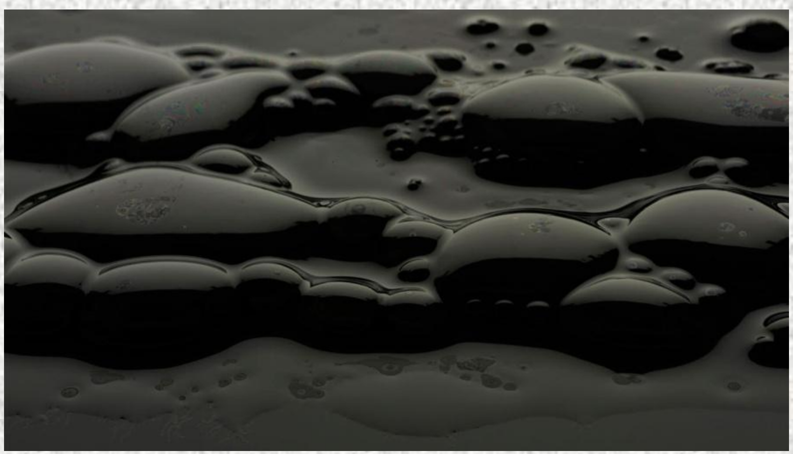
The types of base oils used

- Refined Oils- the refined oils are those such as diesel or kerosene which is the most commonly used oil to formulate and maintain oil-based muds.

The types of base oils used

- Crude Oils - crude oil can be used in place of diesel as the base oil in areas where diesel may not be available in sufficient quantities to formulate and maintain an oil-based mud system.



The types of base oils used

- Mineral Oils - the mineral oils have lower aromatic content than diesel and are considered less toxic than diesel.

Function of drilling fluid
√ Types and importance of different drilling fluid
Drilling Mud Composition
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Mud Testing
Calculation

The types of base oils used

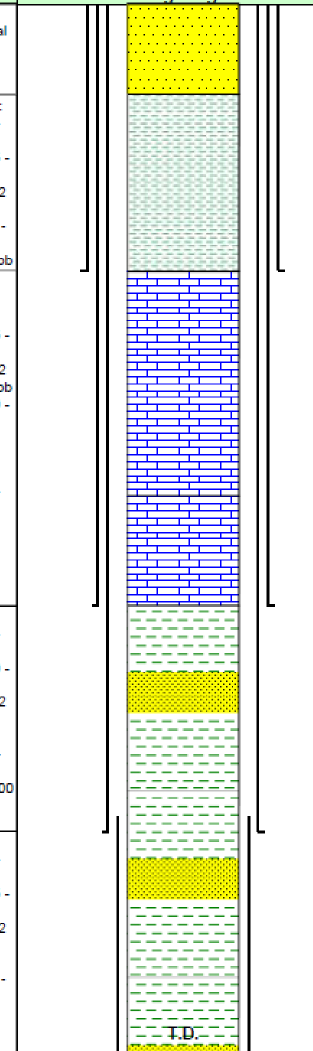
- Synthetic Fluids - The base fluids in synthetic muds are non-petroleum organic compounds that act like petroleum-derived oils in drilling operations but appear to biodegrade readily in the ocean. Like most OBMs, synthetic muds are invert emulsions, with the synthetic fluid serving as the external, or continuous, phase and a brine serving as the internal phase.

- Function of drilling fluid
- √ Types and importance of different drilling fluid
- Drilling Mud Composition
- Clay Chemistry and Structure
- Mud Chemistry
- Mud Rehology
- Mud Testing
- Calculation

Mud Drilling Program

Depth MD m	Formation	Drilling Hazard, Solution	Mud Type, Mud Specs
100.00 200.00 300.00 400.00	Moghra	Interval Size: 26.00 in Drilling Hazard: Seepage Losses	Spud Mud: Mud weight: - lb/gal A.L.A.P PV: - cP A.L.A.P
500.00 600.00 700.00 800.00 900.00 1,000.00 1,100.00 1,200.00	Dabaa	Interval Size: 26.00 in	KCl / Polymer Mud: Mud weight: 8.80 - 10.00 lb/gal Funnel Viscosity: 55 - 70 sec/Qrt YP: 30 - 35 lb/100ft2 pH: 9.00 - 9.50 API Fluid Loss: 5.0 - 7.0 ml/30min KCl: 18.00 - 25.00 ppb
1,300.00 1,400.00 1,500.00 1,600.00 1,700.00 1,800.00 1,900.00 2,000.00 2,100.00	Apollonia	Interval Size: 17.50 in	Gel/Polymer Mud: Funnel Viscosity: 45 - 60 sec/Qrt YP: 20 - 25 lb/100ft2 MBT: 5.00 - 10.00 ppb API Fluid Loss: 10.0 - 15.0 ml/30min pH: 9.50 - 10.00 PV: - cP A.L.A.P Mud weight: 8.80 - 9.60 lb/gal 13.375" CSG @ 2,555.00 m
2,200.00 2,300.00 2,400.00 2,500.00 2,600.00	Khoman		
2,700.00 2,800.00 2,900.00 3,000.00 3,100.00 3,200.00 3,300.00 3,400.00 3,500.00	Abu Roash	Interval Size: 12.25 in	OBM: Mud weight: 9.00 - 12.70 lb/gal Funnel Viscosity: 50 - 80 sec/Qrt YP: 20 - 30 lb/100ft2 HTHP: 6.0 - 8.0 ml/30min CaCl2 % wt: 28.0 - 30.0 % wt Emulsion Stability: 600 - 800 V
3,600.00 3,700.00 3,800.00 3,900.00 4,000.00 4,100.00 4,200.00 4,300.00 4,400.00 4,500.00		Interval Size: 8.50 in	DRILL IN: Mud weight: 9.50 - 12.70 lb/gal Funnel Viscosity: 45 - 55 sec/Qrt YP: 15 - 20 lb/100ft2 PV: - cP A.L.A.P API Fluid Loss: 5.0 - 7.0 ml/30min pH: 9.50 - 10.00 7.000" CSG @

Lithology, Casing Diagram



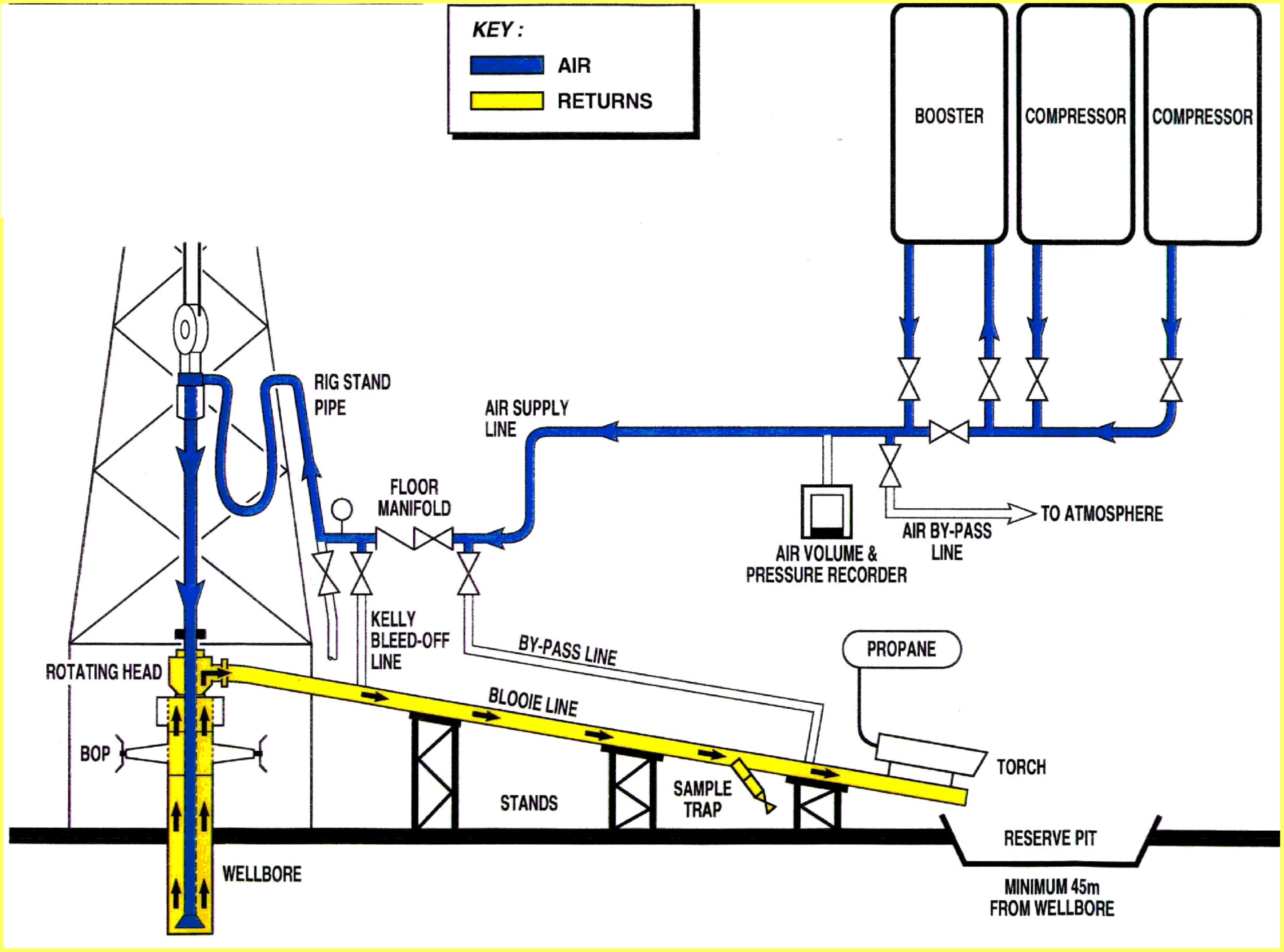
Sand | Shale | Limestone | Sandy Shale

GAS

- **Air drilling**

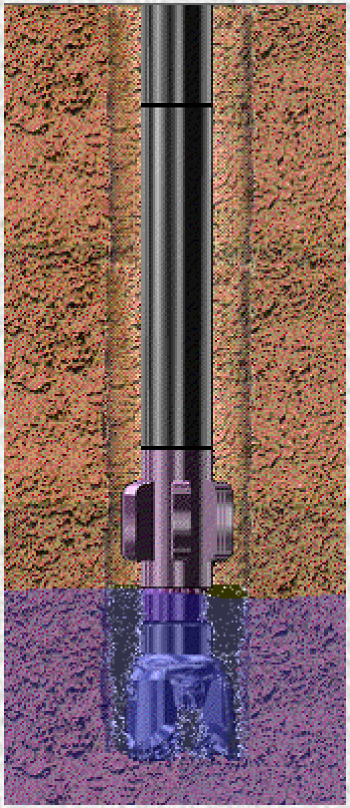
Compressed air is used as the sole circulating medium.No fluid (Water / Soap) injection means the annular returns are "Dust".Cuttings are carried to surface by High Annular Velocity and routed to a pit through a Blooie-Line.

Air Drilling Layout



GAS

- Drilling with air or gas can prevent formation damage and can overcome severe lost circulation problems. And it allows the bit to drill very fast. No fluid system to clean up or Disposal at the surface
- Down hole conditions have to be just right for air or gas to be usable. For example, the bit cannot drill through formations containing large amounts of water. The water mixes with the cuttings and the air or gas and clogs up the hole. Influxes will wet cuttings resulting in mud rings in the annulus, restricting hole cleaning. Chance of downhole fire if these is no eliminated.



Function of drilling fluid

√ Types and importance of different drilling fluid

Drilling Mud Composition

Clay Chemistry and Structure

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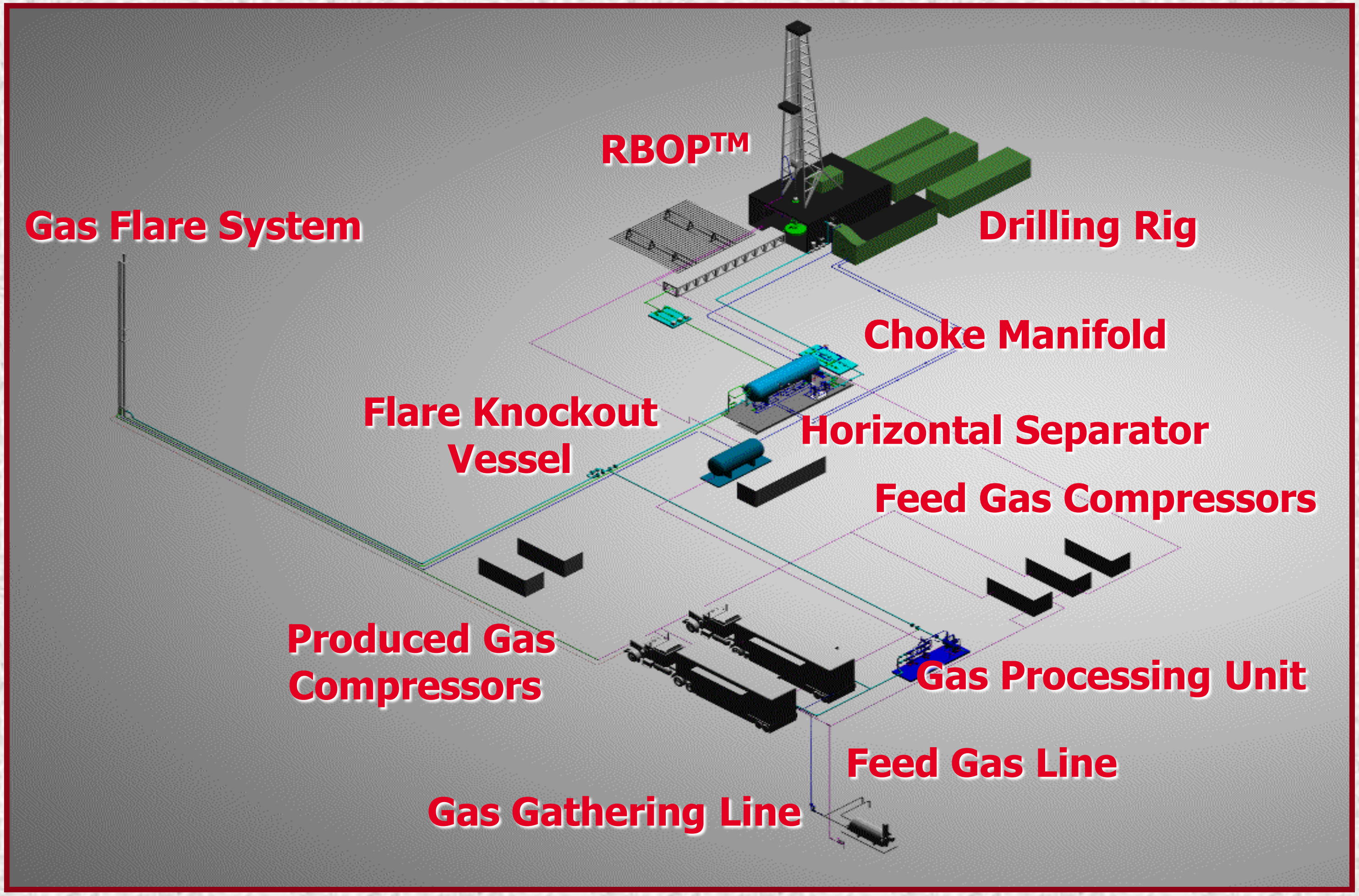
Calculation

GAS

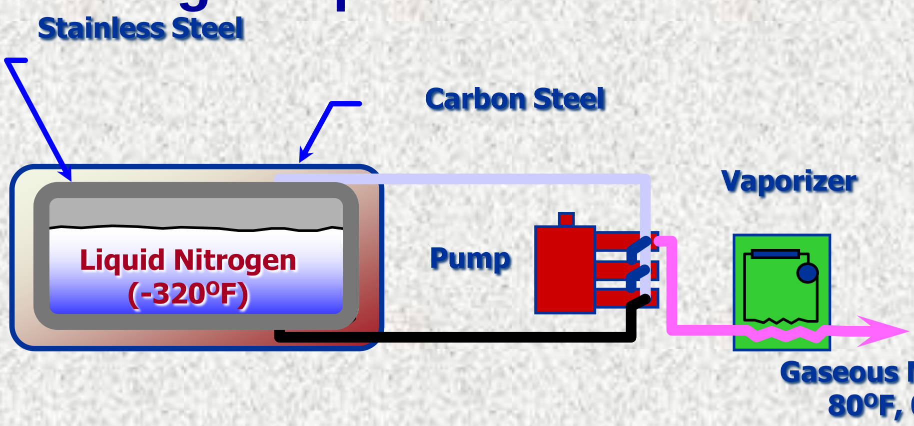
- Natural gas drilling
- If a source of high-pressure natural gas at the correct volumes is available, drilling with natural gas is a very good option. The use of air hammers with gas drilling is another option that can be used to increase ROP. This is an option used in tight gas reservoirs.
- Natural gas is also non-toxic and non-corrosive if sweetened correctly. Natural gas has greater solubility in hydrocarbons when compared to nitrogen, which may resultin the potential for greater disengagement problems and asphaltene precipitation.

Natural gas system



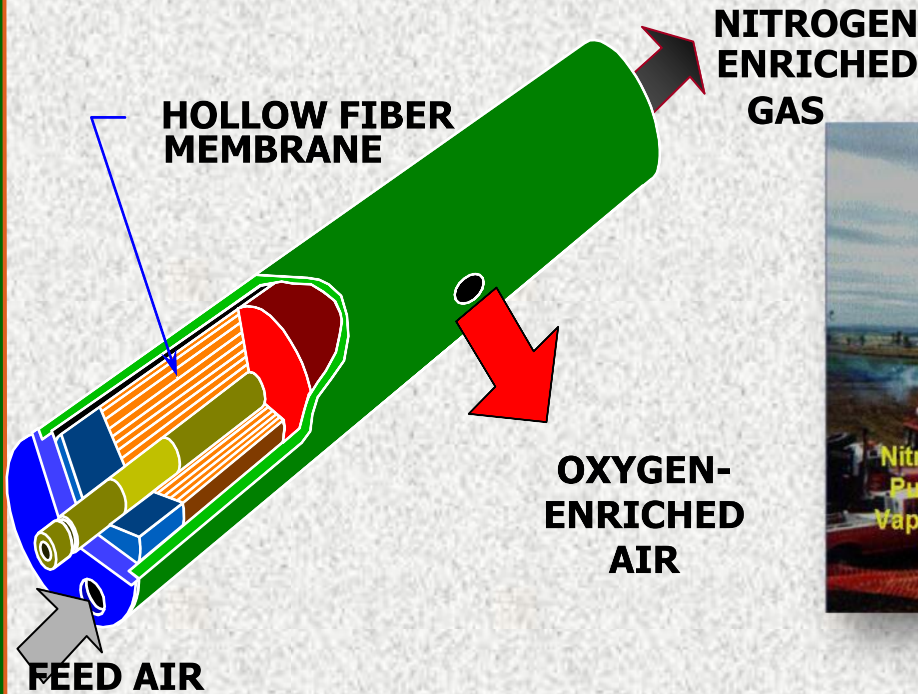
GAS

- Cryogenic nitrogen is produced by extraction from the air through fractional distillation. In this process the air is liquefied and the liquid is then separated though the following factors;
  - Liquid air boils at -317°F
  - Liquid nitrogen boils at -320°F
  - Liquid oxygen boils at -297°F.
- Oxygen starts to evaporate leaving Nitrogen rich liquid. By repeating the boiling and condensing processes high purity of liquid nitrogen up to 99.98 % can be obtained.



GAS

- **Membrane Nitrogen:** Nitrogen gas is generated by introducing compressed air into hollow membrane fibers, which preferentially separate oxygen and other rich gases from the air leaving high purity nitrogen at around 95%. The remaining 5% is normally oxygen.

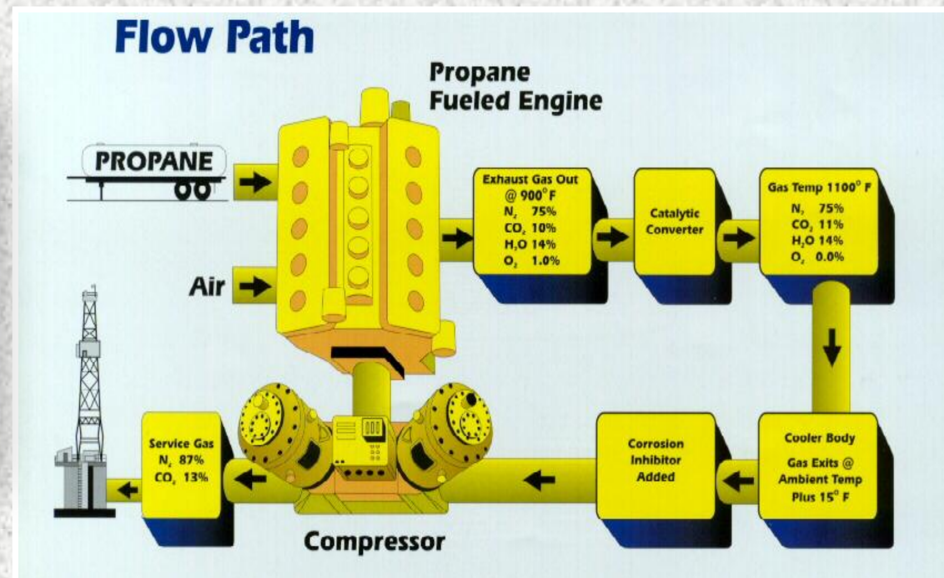


N2 surface Equipment

1. Primary compressors
2. Compressor - extra
3. Nitrogen Unit
4. Booster

GAS

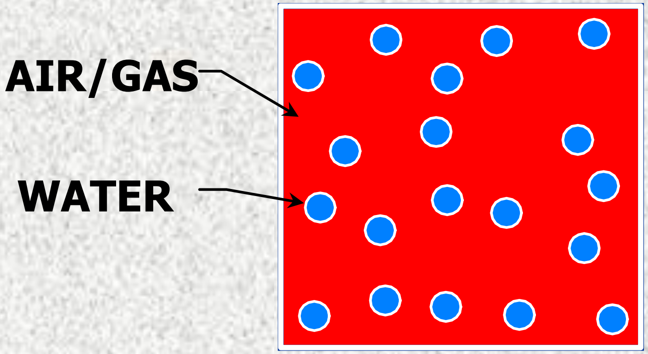
- The exhaust gas from a diesel engine is usually composed of approximately 83% nitrogen, 10% carbon dioxide, 3% oxygen, 2% carbon monoxide and 2% other gases. To date, there are no recorded cases of underbalanced drilling operations using diesel generated exhaust gas.



Exhaust Gas System

Liquid and GAS

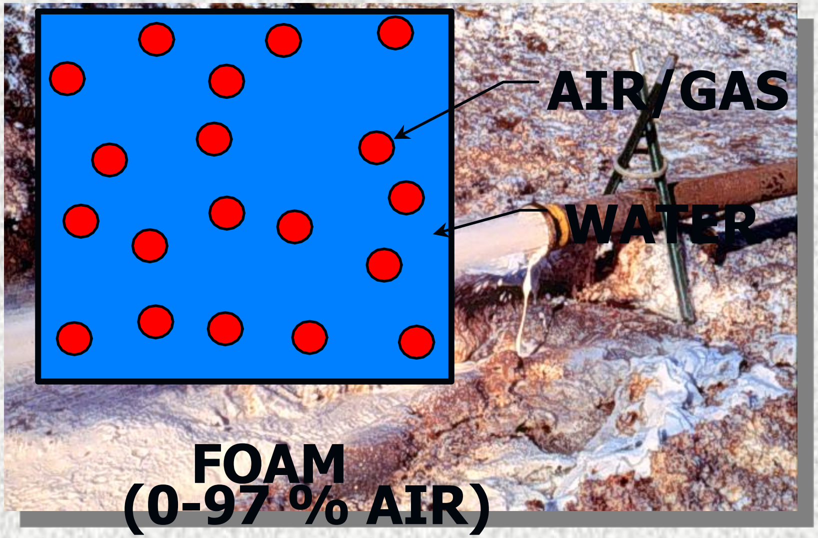
- **Mist Drilling**
- **Air Drilling with the addition of liquids usually water, soap and chemical inhibitors. Mixture of water and soap is added to the air stream at surface at a controlled rate to improve annular hole cleaning. Misting can use many different mediums (water, surfactant, etc.). When Misting the Annular Pressure increases so the ROP will typically drop vs Dusting applications. Additional Air Volume can help improve ROP. Typicall done because the formation makes water or to prevent downhole fires**



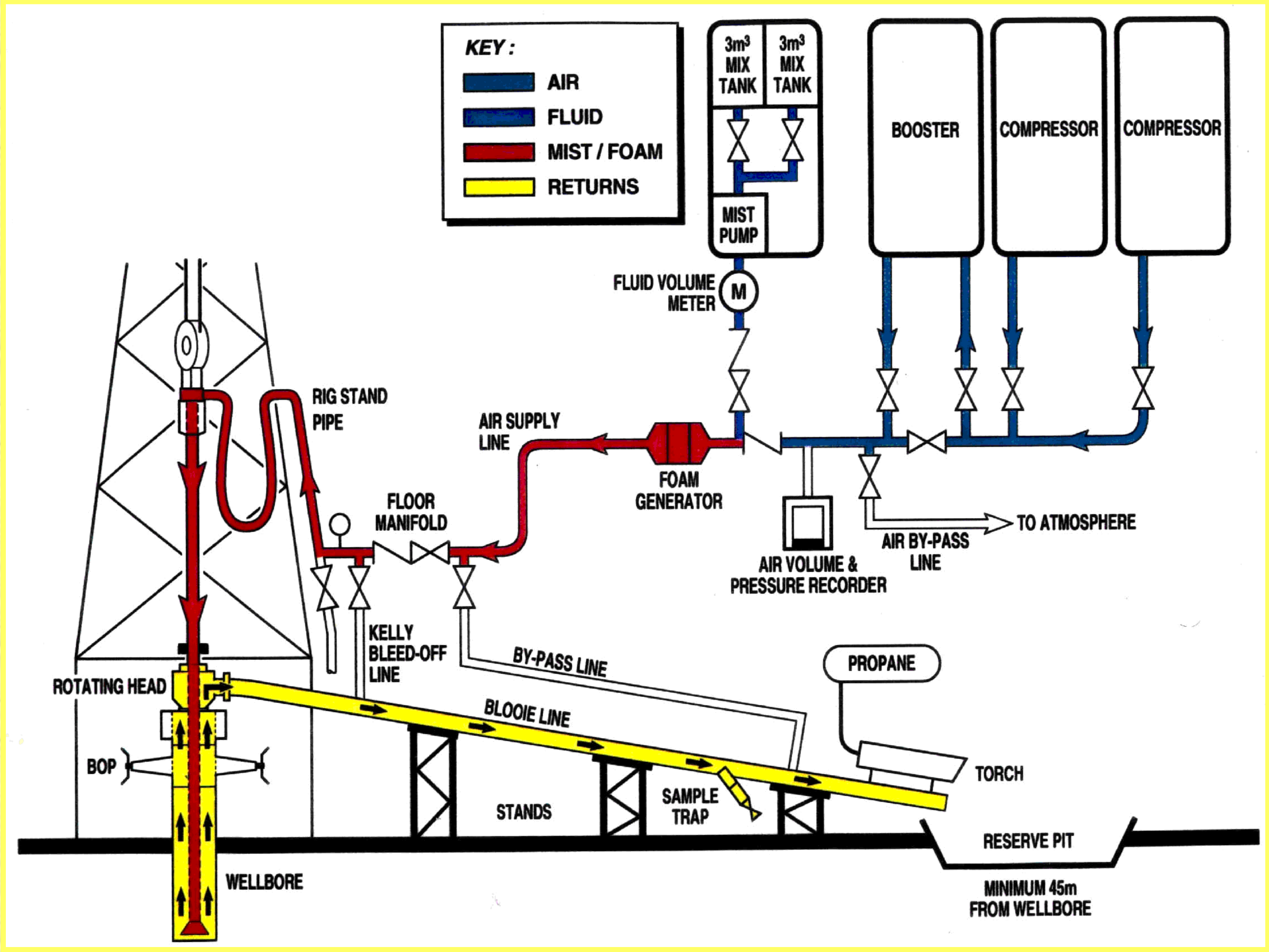
MIST
(97-100 % AIR)

Liquid and GAS

- Foaming drilling
- Adding surfactant to a fluid and mixing the fluid system with a gas generates foam. If small amounts of water are present in the formations being drilled, special equipment can inject a foam agent into the air stream. The foam helps separate the cuttings and remove water from a hole.



Mist or foam drilling layout



Function of drilling fluid

√ Types and importance of different drilling fluid

Drilling Mud Composition

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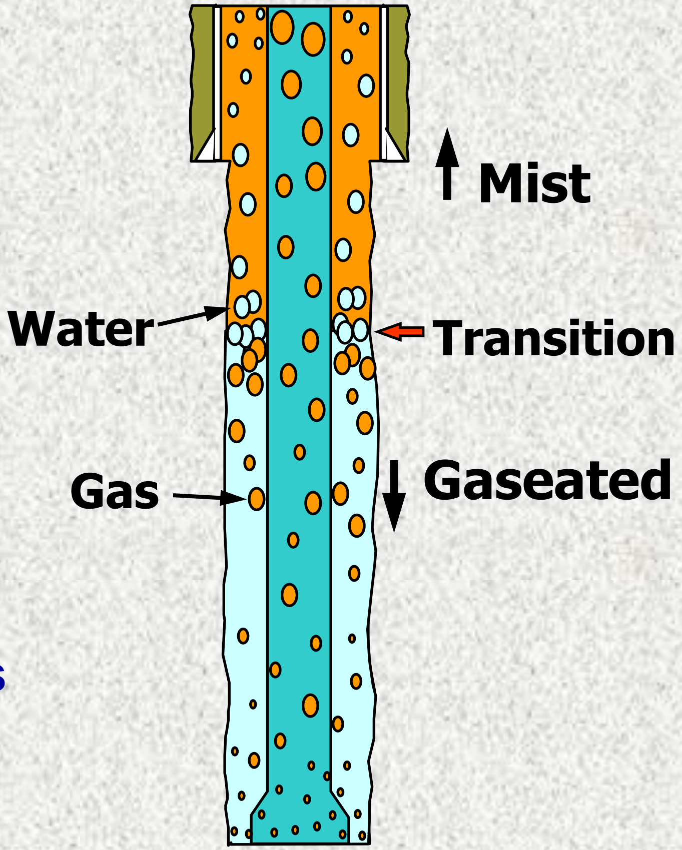
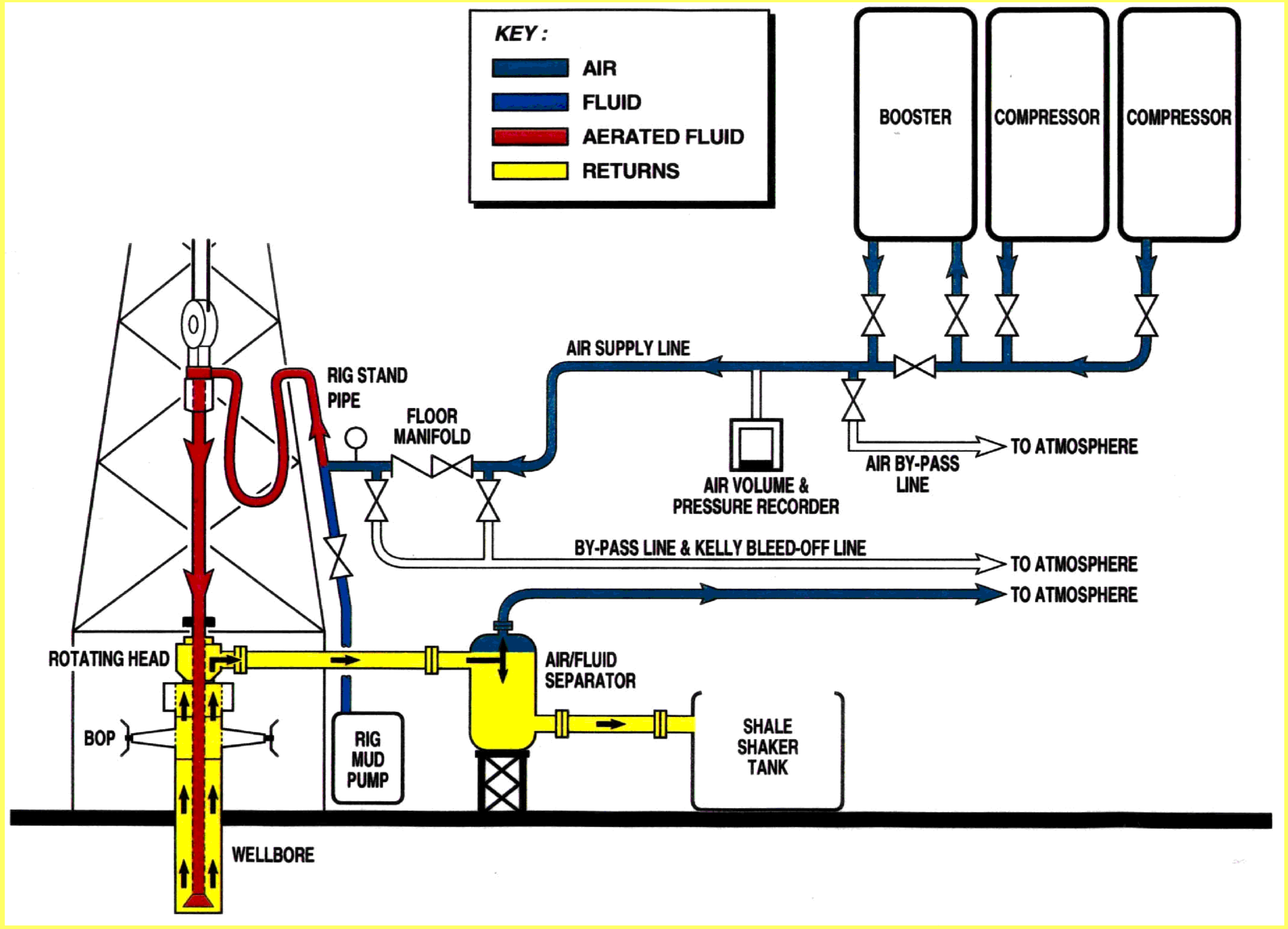
Liquid and GAS

- Aerated Drilling
- In some cases, the rig operator may use aerated mud, which like foam drilling, helps prevent clogging of the well bore. Aerated drilling uses both mud and air pumped into the standpipe at the same time.
- In a gaseated or aerated system, the gas is injected into the system. The gas is compressed at the bottom of the hole and expands as it goes up. It may change the phase and convert into a mist if there is enough air and it is allowed to expand.



Aerated fluid layout



Typical Composition OF WBM

- Water (continuous) phase
- Reactive commercial clay solids
- Reactive formation (drilled) solids
- Inert formation (drilled) solids
- Inert commercial solids
- Soluble chemicals

Composition: Water phase

- Definition: The continuous (liquid) phase of the drilling fluid (mud)
- Can be fresh water, brackish water, sea water, saturated salt water, or another type of brine fluid
- Can be hard water containing a high concentration of calcium or magnesium

Composition: Fresh water

- Usually available only on land locations
- Advantages:
  – Commercial clays hydrate more
  – Most chemicals are more soluble
- Disadvantages:
  – Formation clays hydrate more, which can result in hole problems and damage to the producing zone

Composition: Brackish water

- Usually in a marine environment
- Slightly salty
- Higher calcium and magnesium than fresh water

Composition: Sea water

- Chlorides and hardness varies
  - Chlorides in Gulf of Mexico 15,000 - 30,000 mg/l
  - Calcium in Gulf of Mexico 400 ± mg/l
  - Magnesium in Gulf of Mexico 1200± mg/l
  - Hardness in North Sea much higher

Composition: Saturated salt water

- Used primarily to drill through large salt formations
- Salt must be added to achieve saturation
- Prevents hole enlargement due to leaching or dissolving salt from the formation
- Leaching could result in hole problems and expensive mud and cement costs

Composition: Brine water

- Usually used for clay (shale) inhibition
  - Potassium chloride (KCl)
  - Calcium Chloride $CaCl_2$
  - Formates (Na^+, K^+)
  - Bromides

Function of drilling fluid

Types and importance of different drilling fluid

√ Drilling Mud Composition

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Calculation

Composition: Reactive Commercial Clay solids

That's clay which has low gravity and used to provide viscosity and yield point for the mud and decreasing water loss

Function of drilling fluid

Types and importance of different drilling fluid

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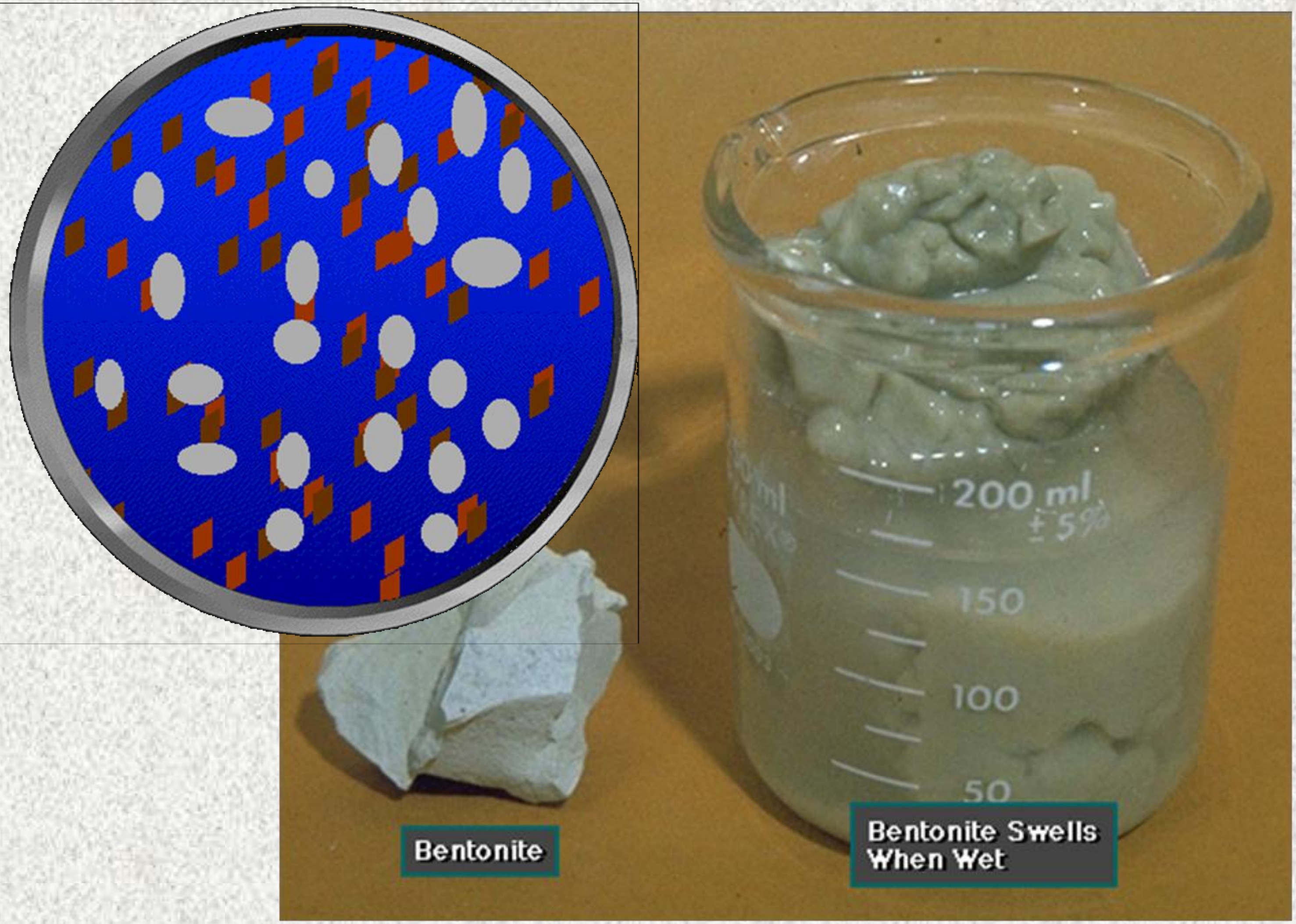
Calculation

Composition: Reactive Commercial Clay solids

- S.G. = 2.6, Density = 21.67 ppg
- Commercial clays
  - Sodium Montmorillonite or bentonite
    - M-I GEL
  - Attapulgite
    - SALT GEL

Composition: Reactive Commercial Clay



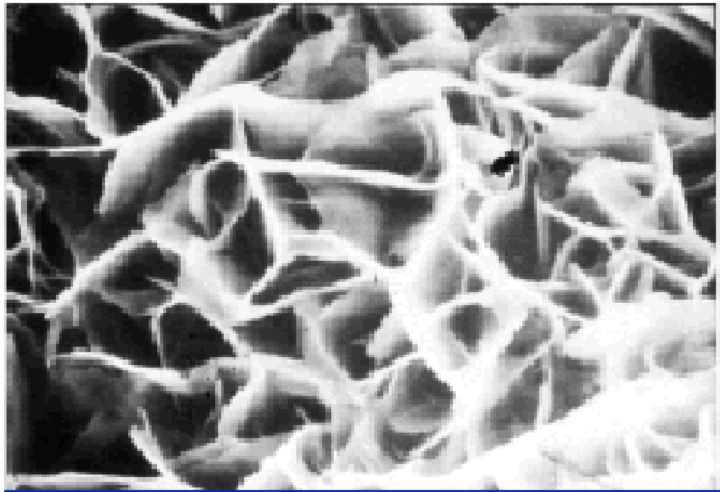
Composition:
Reactive Formation clay solids

- They are produced from drilling and can change mud properties such as:
  - S.G. = 2.6, Density = 21.67 ppg
  - Montmorillonite (swelling clay)
  - Illite (non-swelling clay)
  - Kaolinite (non-swelling clay)
  - Chlorite (non-swelling clay)
  - Gumbo Shale (combination of above clays)

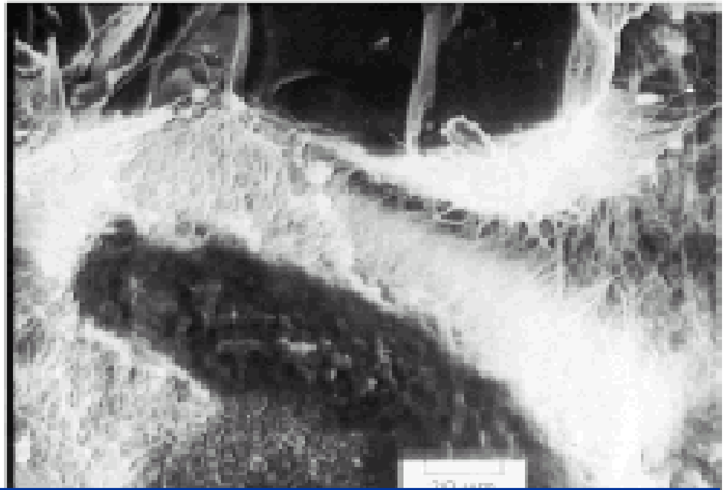
Migratory Silt and Clay

Feldspar (Microcline)

Kaolinite



Chlorite



Illite

Function of drilling fluid

Types and importance of different drilling fluid

√ Drilling Mud Composition

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Mud Testing

Calculation

Composition: Commercial Inert solids

- That's used usually as weighting materials when it has high gravity such as
  - Barite (barium sulfate)
  - S.G. = 4.2, Density = 35 ppg
  - (M-I BAR)
    - Used to increase mud density up to maximum of 22 ppg±

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Composition: Commercial Inert solids

- Hematite (iron oxide)
  - S.G. = 5.0, Density = 41.67 ppg
  - Fer-Ox
    - Used to increase mud density up to maximum of 25 ppg ±

Composition: Commercial Inert solids

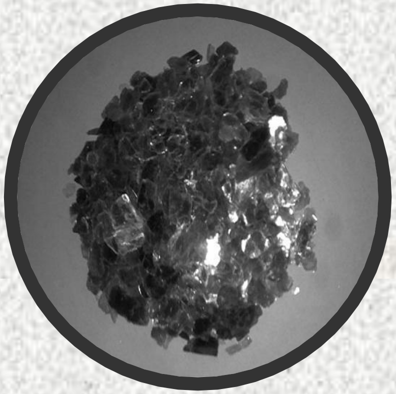
- Calcium Carbonate
  - S.G. = 2.8, Density = 23.34 ppg
  - Acid soluble
  - Lo-Wate
    - Used to increase fluid density up to maximum of 14.0 ppg ±
    - Used as bridging agent in drill-in, oil and synthetic fluids

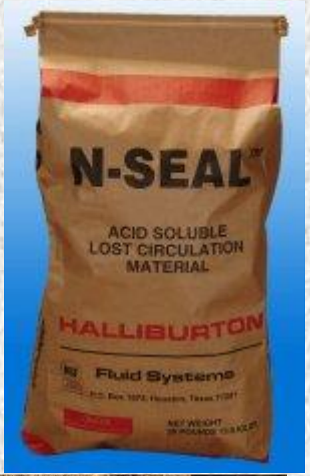
Ground Calcium Carbonate

Composition: Commercial Inert solids

- Lost Circulation Material
  - Material used to bridge off (seal) formations where whole mud is being lost to the formation
  - Nut shells (mostly pecan & walnut)
  - Mica
  - Fiber (wood, paper, plastic, etc.)

Composition: Commercial Inert solids





Composition: Formation Inert solids

- They are produced from drilling and can change mud properties such as
  - S.G. = 2.6 ±, Density = 21.67 ppg ±
  - Sand
  - Limestone
  - Dolomite

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Composition: Formation Inert solids

Composition: Soluble chemicals

- That's used to control PH, density, viscosity, fluid loss and gel strength
  - Caustic Soda (NaOH) pH 13.3
  - Caustic Potash (KOH) pH 13.3
  - Lime [$Ca(OH)_2$] pH 12.4
  - Soda Ash (Na_2CO_3) pH 11 - 11.5
  - Sodium Bicarb ($NaHCO_3$) pH 8.4
  - Zinc Oxide (ZnO)

Composition: Soluble chemicals

Composition: Soluble chemicals

- Lignosulfonate (organic acid)
- Spersene (chrome lignosulfonate)
- Spersene CF (chrome-free lignosulfonate)
- Chemical de-flocculant (mud thinner) adds anionic (negative) charges to the mud.

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Composition: Soluble chemicals

- Lignite (organic acid)
- Tannathin (lignite)
- XP-20 (chrome lignite)
- Chemical de-flocculant (mud thinner) adds anionic (negative) charges to the mud.
- Neutralizes positive sites on the clays causing them to repel each other.

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Functional Category	function	Typical chemicals
Weighting Materials	Increase density (weight) of mud, balancing formation pressure, preventing a blowout	Barite, hematite, calcite. ihmenite
Viscosifiers	Increase viscosity of mud to suspend cuttings and weighting agent in mud	Bentonite or attapulgite clay, carboxymethyl cellulose, & other polymers
Thinners, dispersants, & temperature stability agents	Deflocculate clays to optimize viscosity and gel strength of mud	Tannins,polyphosphates, lignite, ligrosulfonates
Flocculants	Increase viscosity and gel strength of clays or clarify or de-water low-solids muds	Inorganic salts, hydrated lime, gypsum, sodium carbonate and bicarbonate, sodium tetraphosphate, acrylamide-based polymers
Filtrate reducers	Decrease fluid loss to the formation through the filter cake on the wellbore wall	Bentonite clay, lignite, Na-carboxymethyl cellulose, polyacrylate, pregelatinized starch

Functional Category	function	Typical chemicals
Alkalinity, PH control additives	Alkalinity, pH control additives Optimize pH and alkalinity of mud, controlling mud properties	Lime (CaO), caustic soda (NaOH), soda ash (Na2CO3), sodium bicarbonate (NaHCO3), & other acids and bases
Lost Circulation Material	Plug leaks in the welbore wall, preventing loss of whole drilling mud to the formation	Nut shells, natural fibrous materials, inorganic solids, and other inert insoluble solids
lubricants	Reduce torque and drag on the drill string	Oils, synthetic liquids, graphite, surfactants, glycols, glycerin
Shale control material	Control hydration of shales that causes swelling and dispersion of shale, collapsing the wellbore wall	Soluble calcium and potassium salts, other inorganic salts, and organics such as glycols
Emulsifiers & surfactants	Facilitate formation of stable dispersion of insoluble liquids in water phase of mud	Anionic, cationic, or nonionic detergents, soaps, organic acids, and water-based detergents

Functional Category	function	Typical chemicals
Bactericides	Prevent biodegradation of organic additives	Glutaraldehyde and other aldehydes
Defoamers	Reduce mud foaming	Alcohols, silicones, aluminum stearate ($C_{54}H_{105}AlO_6$), alkyl phosphates
Pipe-freeing agents	Prevent pipe from sticking to wellbore wall or free stuck pipe	Detergents, soaps, oils, surfactants
Calcium reducers	Counteract effects of calcium from seawater, cement, formation anhydrites, and gypsum on mud properties	Sodium carbonate and bicarbonate (Na_2CO_3 & $NaHCO_3$) , sodium hydroxide (NaOH), polyphosphates
Corrosion inhibitors	Prevent corrosion of drill string by formation acids and acid gases	Amines, phosphates, specialty mixtures
Temperature stability agents	Increase stability of mud dispersions, emulsions and rheological properties at high temperatures	Acrylic or sulfonated polymers or copolymers, lignite, lignosulfonate, tannins

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Viscosifer-Bentonite

Function of drilling fluid

Types and importance of different drilling fluid

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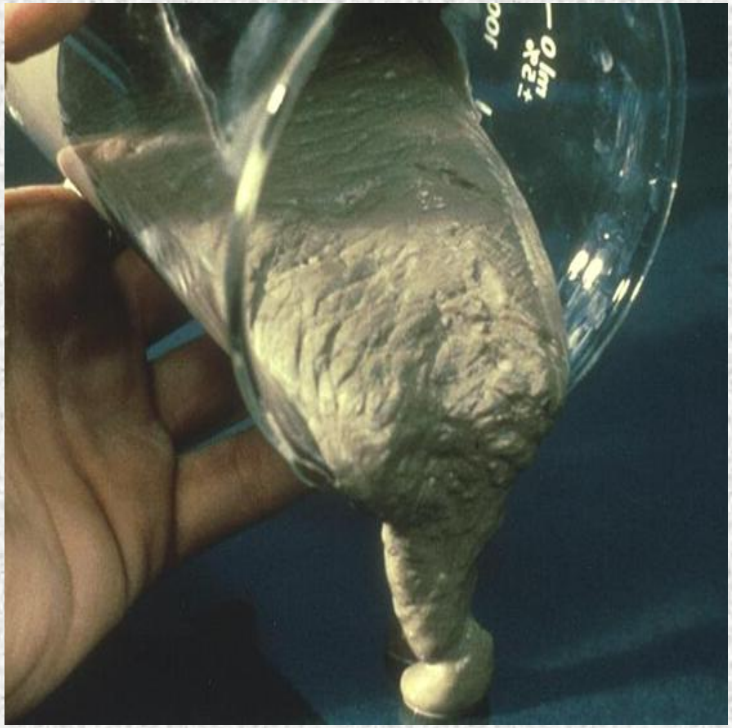
Lost Circulation Material

Lost Circulation Material

Thinners & dispersants



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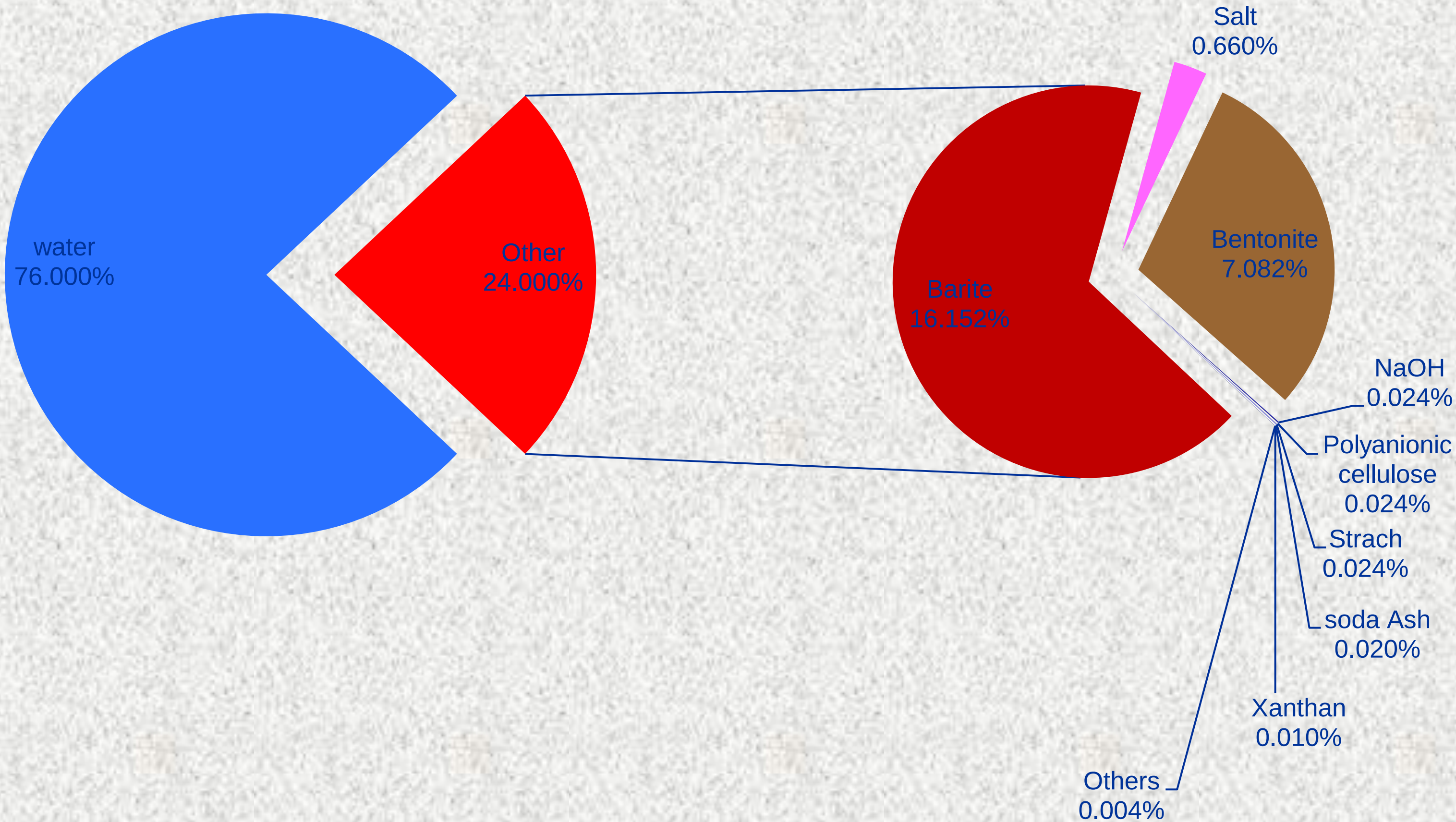
Water Base Mud Composition



Oil Base Mud Additives

- **Primary Emulsifier** - calcium soaps are the primary emulsifier in oil muds. These are made in the mud by the reaction of lime and long chain (C-16 to C-22) fatty acids. Soap emulsions are very strong emulsifying agents but take some reaction time before emulsion is actual formed. Wetting agents prevent solids from becoming water wet while the emulsion is forming. Emulsifiers surround the water droplets and prevent their coalescence.

Oil Base Mud Additives

- **Secondary emulsifiers** - very powerful oil wetting chemicals. Generally these products do not form emulsions as well as the primary emulsifiers, but this oil wet solids before the emulsion is formed. Used to readily emulsify any water intrusions quickly. Typically, these additives are polyamides or imidazolines

Oil Base Mud Additives

- **Organophilic lignites** - used as high temperature fluid loss additives. They also will aid in the emulsification of water especially at high temperatures. A lignite is treated with an amine to make it oil dispersible. It controls fluid loss by plugging and can be used at high concentrations without causing excessive viscosities (20 lb/bbl +/-).

Oil Base Mud Additives

- **Asphaltic fluid loss additives** - generally consist of gilsonite or asphalt derivatives. Gilsonite has high temperature stability (400°F) whereas asphalt is not as temperature stable (350°F). High concentrations can cause excessive viscosity and gelation of the mud. Treatment level will not usually exceed 15 lb/bbl

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Oil Base Mud Additives

- **Organophilic gellants** - viscosity builders that are made from bentonite, hectorite or attapulgite treated with an amine to make them oil dispersible. Bentonite is most commonly used and is compatible with diesel and mineral oils up to 350°F. For temperatures above 350°F, especially in mineral oil formulations, the hectorite based clay should be used. Organophilic attapulgite is used to improve the suspension properties of packer fluids without appreciably increasing the viscosity.

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Oil Base Mud Additives

- **Wetting agents** - supplemental additives to quickly and effectively oil wet solids that become water wet. Drill solids and weighting agents will naturally water wet and the wetting agents will strip off the water and replace it with an oil layer.

Oil Base Mud Additives

- **Polymeric viscosifiers** - additives that increase the viscosity of oil muds in the presence of organophilic bentonite, especially when the organophilic bentonite performance is reduced by high temperatures; they work up to 400°F. A high molecular weight sulfonated polystyrene becomes effective only when the temperature exceeds 250°F.

Oil Base Mud Additives

- **Rheological modifiers** - low molecular weight fatty acid. Provides increase in viscosity at low shear rates (3 and 6 rpm). Barite can "sag" or slide down the hole, especially on deviated wells; these additives will minimize or eliminate this "sag". Increases in total mud viscosity are avoided when using these additives..

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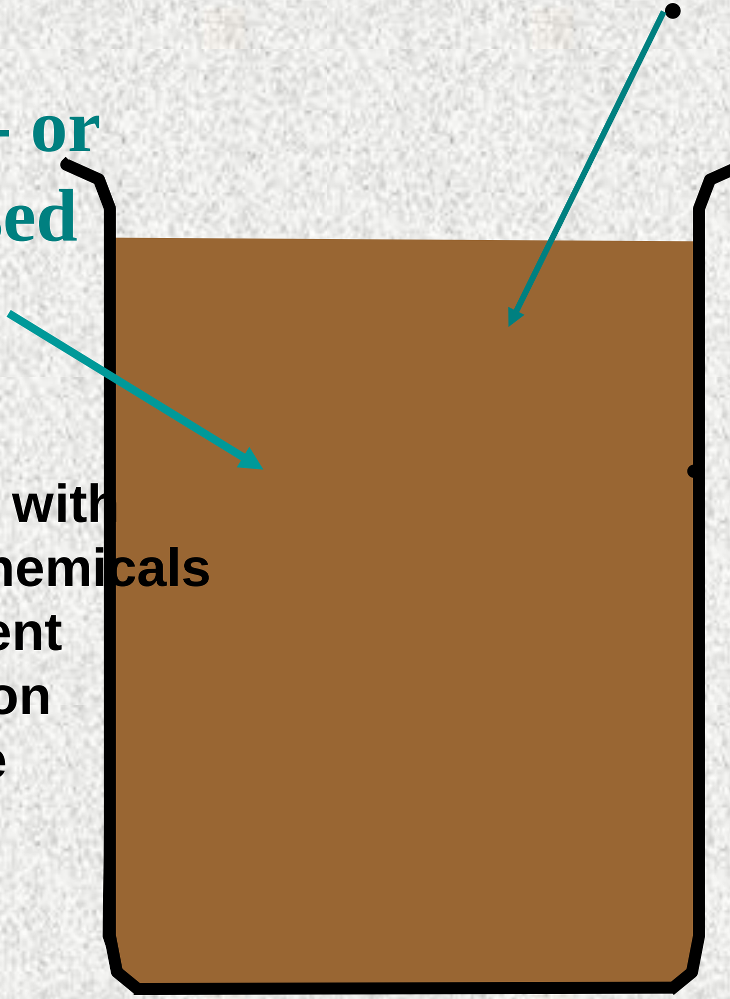
Oil Base Mud Additives

- **Weighting Agents** - used to increase the density of the oil mud. The most commonly used weighting agent is barite. A mud weight of around of 21.0 lb/gal is the highest achievable with barite. Hematite, with a S.G. of 5.0 can also be used to increase the density of the oil mud. A mud weight of around 24.0 lb/gal can be achieved with hematite. For the same mud weight, the solids content of the oil mud weighted with hematite will have a lower solids content than weighted with barite because of the higher S.G. of the hematite.

Preparation of Drilling Mud

- Water- or oil-based fluid

- Thickened with polymers to lift formation cuttings from well



- Treated with other chemicals to prevent formation damage

- Weighted with clays and other materials to increase density for well control

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Mixing Procedures

1. Add the required quantity of base oil to the mixing tank.
2. Add the primary emulsifier and secondary emulsifier as required.
3. Add filtration control additives if required.
4. Add lime as required.
5. Add required amount of water to the above mixture. If brine is to be used, then add brine after the lime additions.
6. Add organophilic viscosifier as required.
7. Add calcium chloride powder if brine is not used. If calcium chloride powder is not available, then mix the calcium chloride flakes into the water and add as a brine.
8. Mix above for several hours to ensure a good emulsion is formed.
9. Add weighting material as required for the desired density.

Rheology

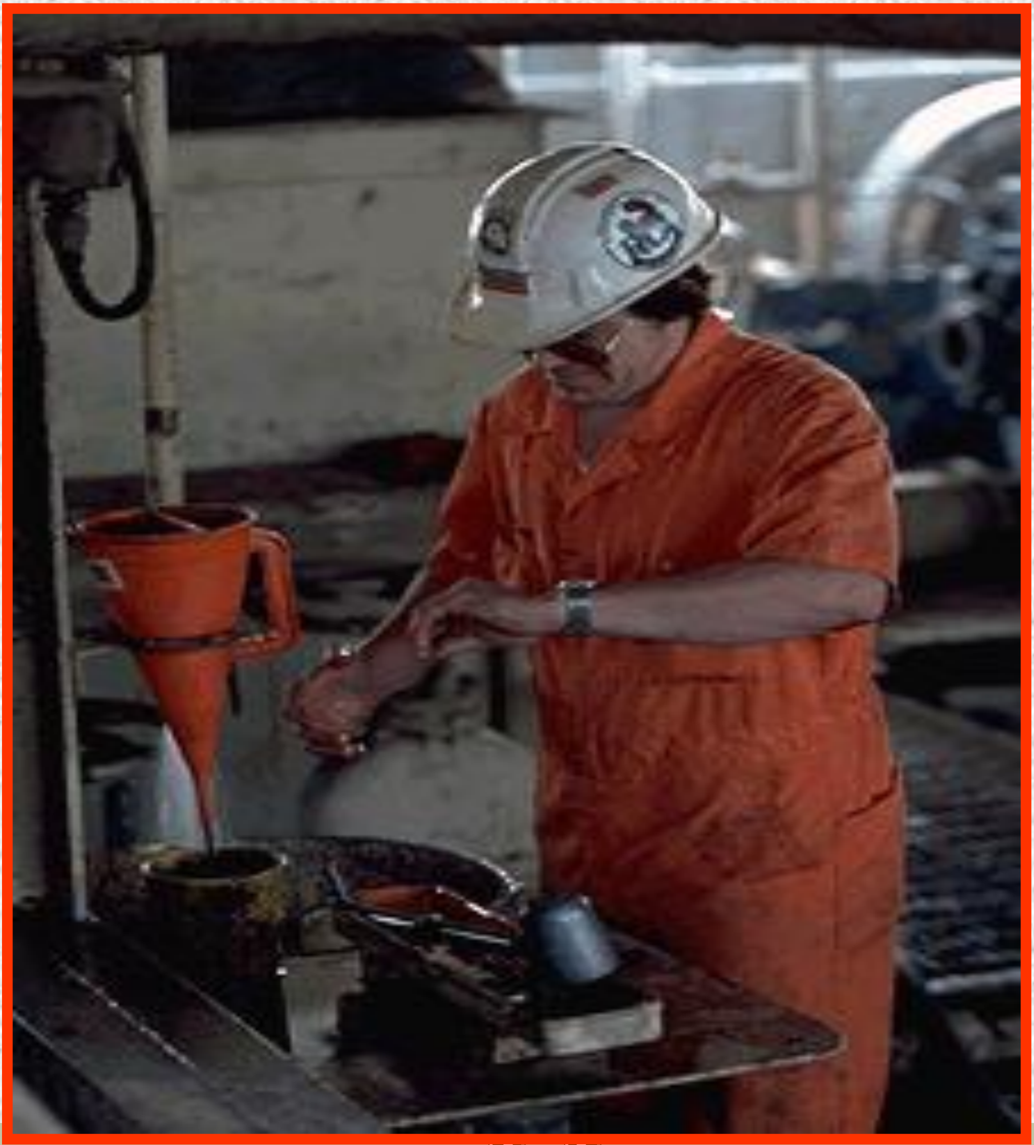
Rheology is the study of how matter deforms and flows

VISCOSITY

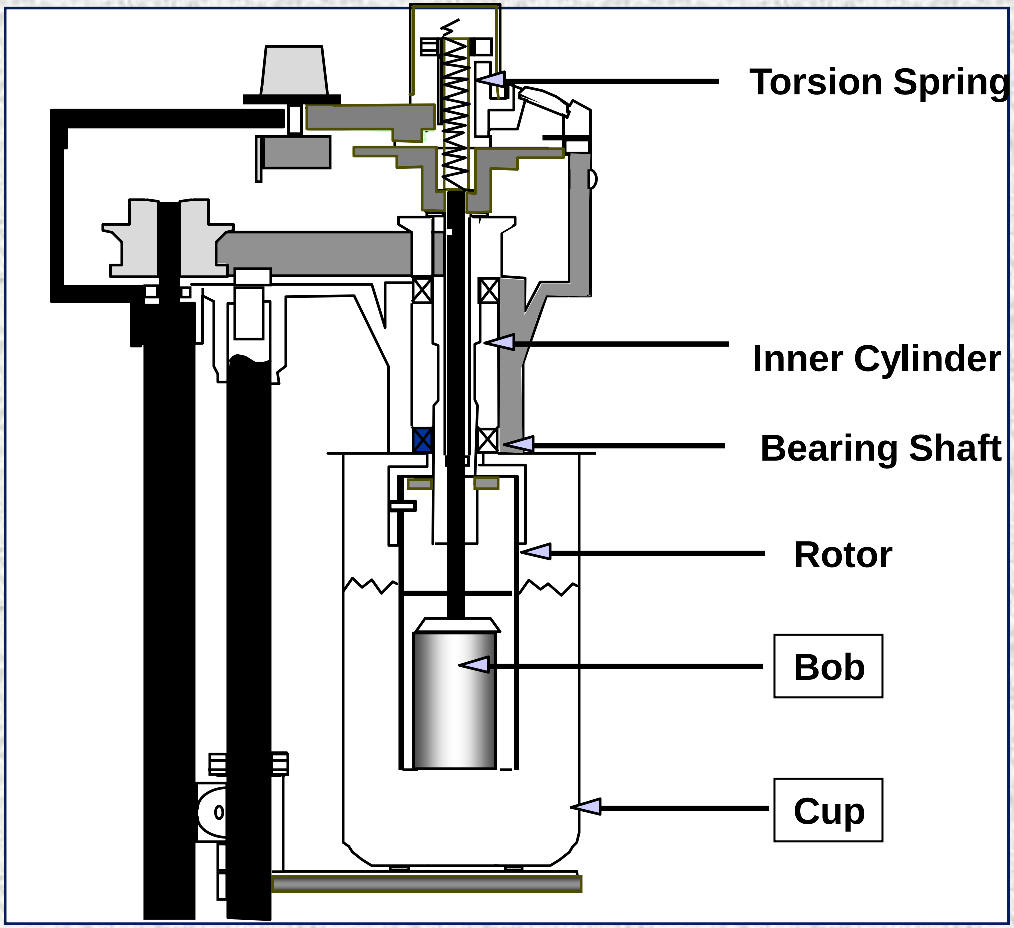
Viscosity

Resistance to flow of a fluid

FUNNEL VISCOSITY



Measurement - Rotational Viscometer



Viscosity

- 100 centipoise (cp) = 1 poise
- Centipoise is the dimension used to express:
  - Plastic viscosity
  - Apparent viscosity
  - Effective viscosity

Apparent Viscosity

Apparent Viscosity (μa) - Apparent viscosity, measured by the VG meter, is the viscosity that a drilling fluid has at 600 RPM (1022 sec-1).

$$AV = \frac{\Theta 600}{2}$$

AV = Apparent Viscosity, centipoise

Effective Viscosity

Effective Viscosity (μe) - The effective viscosity from a VG meter is the viscosity of the drilling fluid at that particular RPM.

$$EV = \frac{300 \times \text{Dial Reading}}{\text{RPM}}$$

EV = Effective Viscosity, centipoise

Viscosity

The dimensions of lb/100 sq ft are used for expressing:

- **Yield point**
- **Initial gel**
- **10-minute gel**

Viscosity

$$\frac{\text{Shear Stress}}{\text{Shear Rate}}$$

$$\frac{\text{Force}}{\text{Velocity}}$$

or

$$\frac{\text{Dial Reading}}{\text{RPM}}$$

SHEAR STRESS

- Internal force that resists flow
- System pressure loss (circulating pressure on the rig)
- Simulated by the dial reading on a V G meter

$$\text{Stress} = \frac{\textbf{Force}}{\textbf{Area}}$$

or

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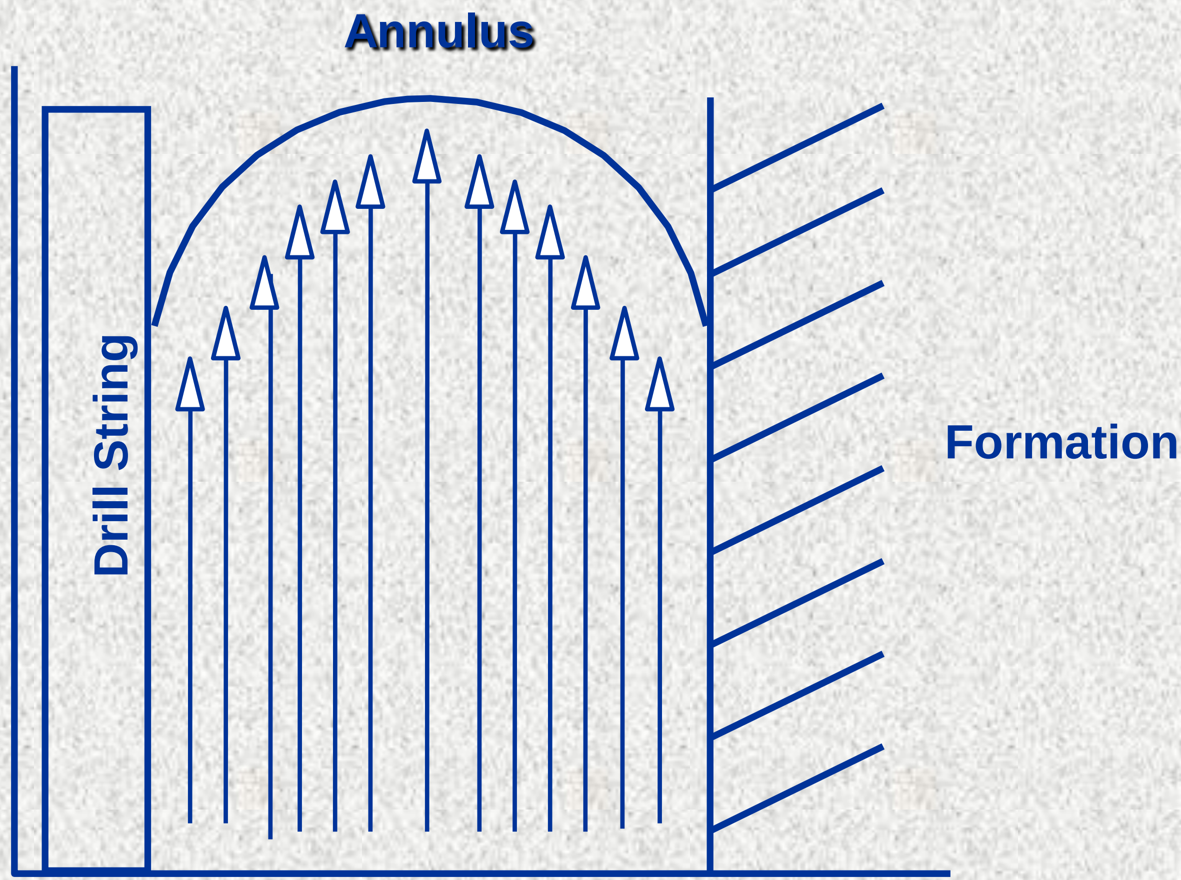
SHEAR RATE

The velocity at which one layer of fluid moves past another



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SHEAR RATE

$$\text{Shear rate} = \frac{\textbf{Velocity (cm/sec)}}{\textbf{Distance (cm)}}$$

Shear rate= Sec^{-1}

1 Sec^{-1}=1.703*RPM (on VG meter)

SHEAR RATE

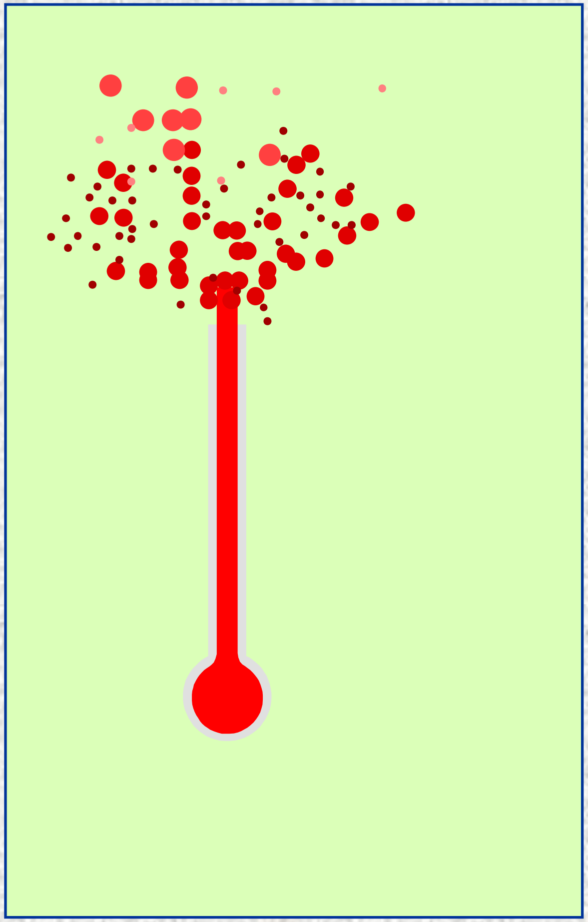
- The bulk (average) velocity at which a fluid is moving
- Annular velocity in the circulating system is an example of bulk velocity
- Velocity is the RPM on a VG meter

Factors Influenced by Mud Rheology

- Hole cleaning
- Suspension of solids
- Hole stability
- Solids control
- Equivalent circulating densities
- Surge / swab pressures

Effect of Temperature & Pressure

- Temperature reduces viscosity
- Pressure increases viscosity
- High temperature
  - Breakdown of polymers
  - Gelation of solids



Plastic Viscosity

Resistance to flow due to mechanical friction

$$PV = \theta_{600} - \theta_{300}$$

Affected by:

- Solids concentration
- Size and shape of the solids
- Viscosity of the fluid phase

Plastic Viscosity Increased by:

Hydratable Drill Solids

- Clays, shales

Inert Drill Solids

- Sand, limestone, etc.

Colloidal Matter

- Starch, CMC

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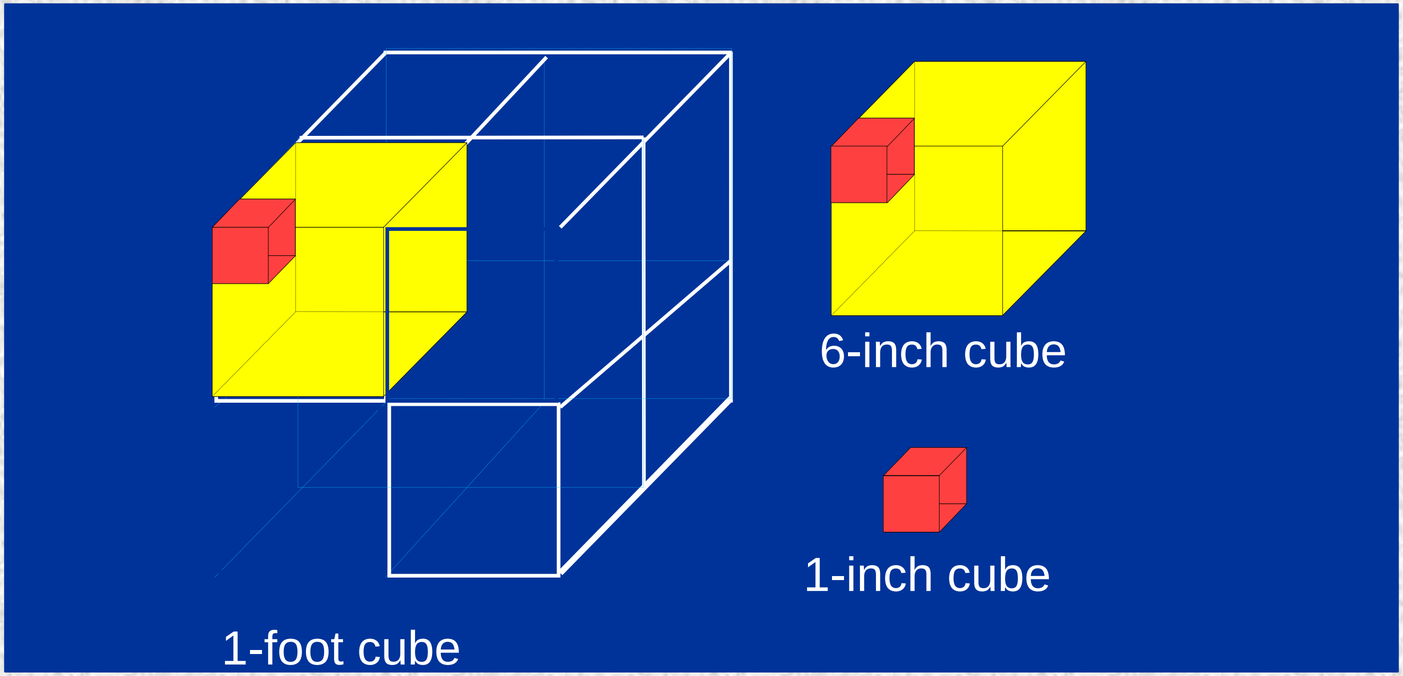
Plastic Viscosity Increased by:

- Particles breaking, thus increasing surface area and more friction
- Weight material to increase density

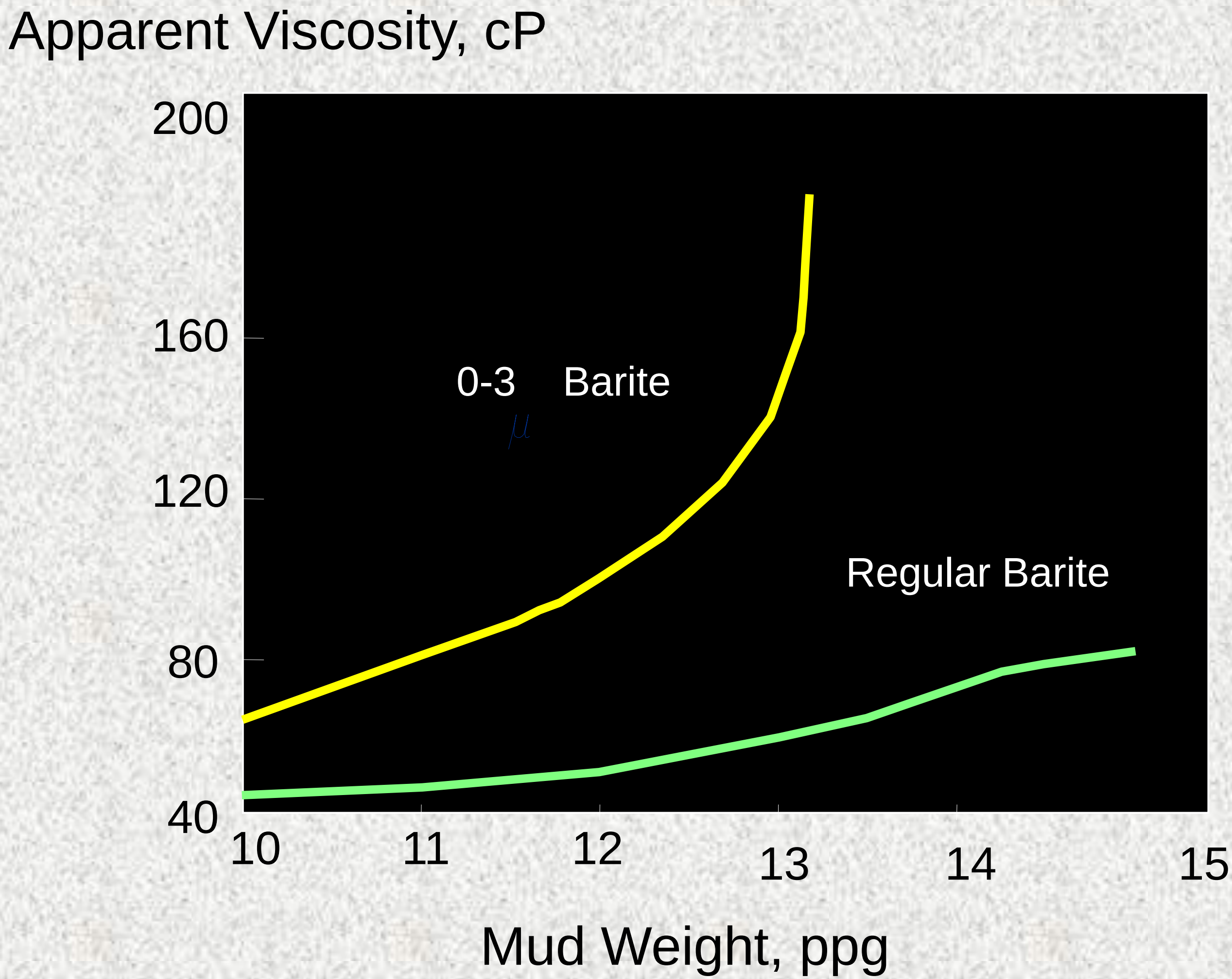
Area Increase by Breaking of Solids



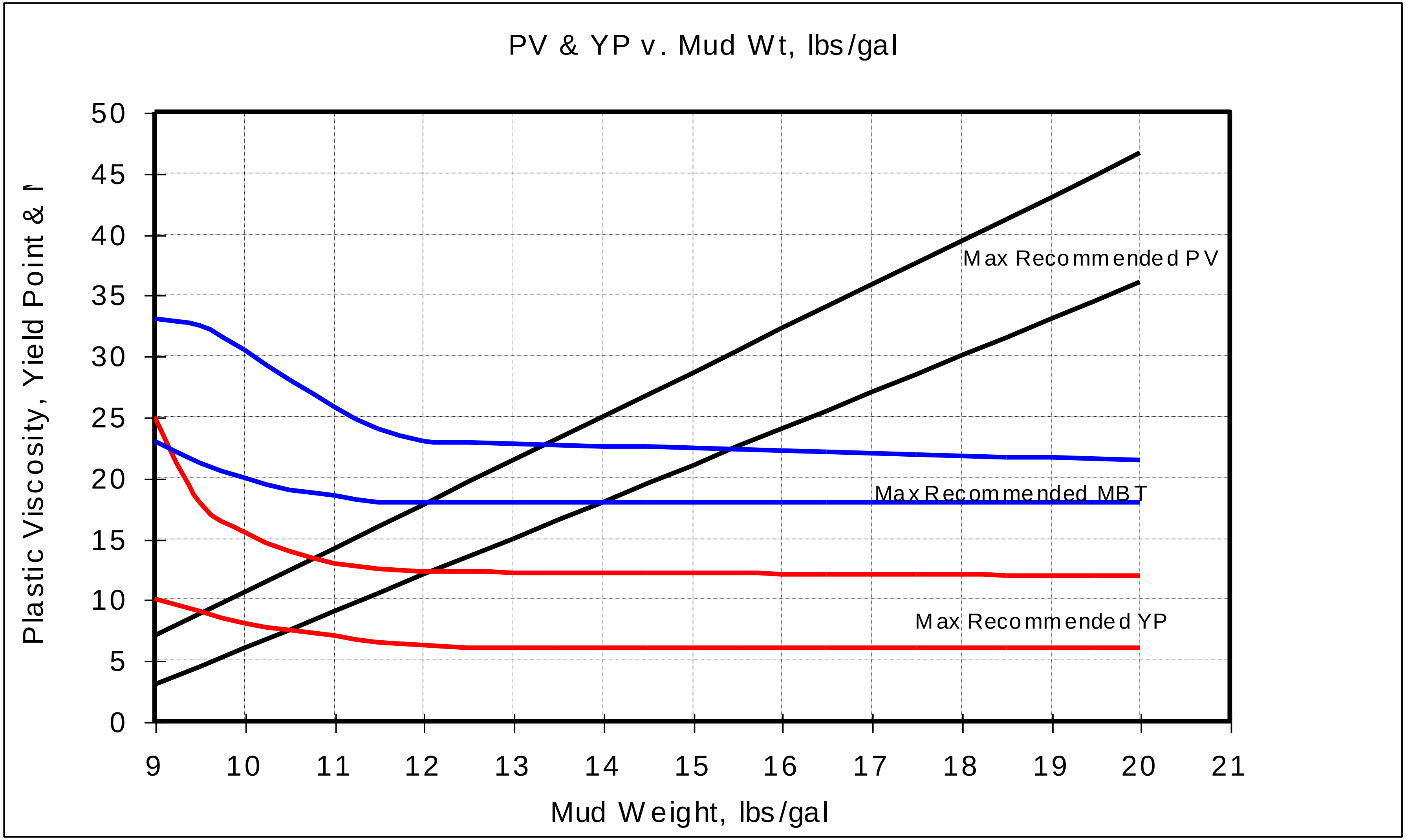
VOLUME			SURFACE AREA		
1 cu ft	=	1728 cu in	1 cu ft	=	864 sq in
8 6-in cubes	=	1728 cu in	8 6-in cubes	=	1728 sq in
1728 1-in cubes	=	1728 cu in	1728 1-in cubes	=	10,368 sq in

10,368 - 864 = 9504 sq in increase

Effect of Particle Size on Viscosity



PV, YP vs Mud Wt. ppg

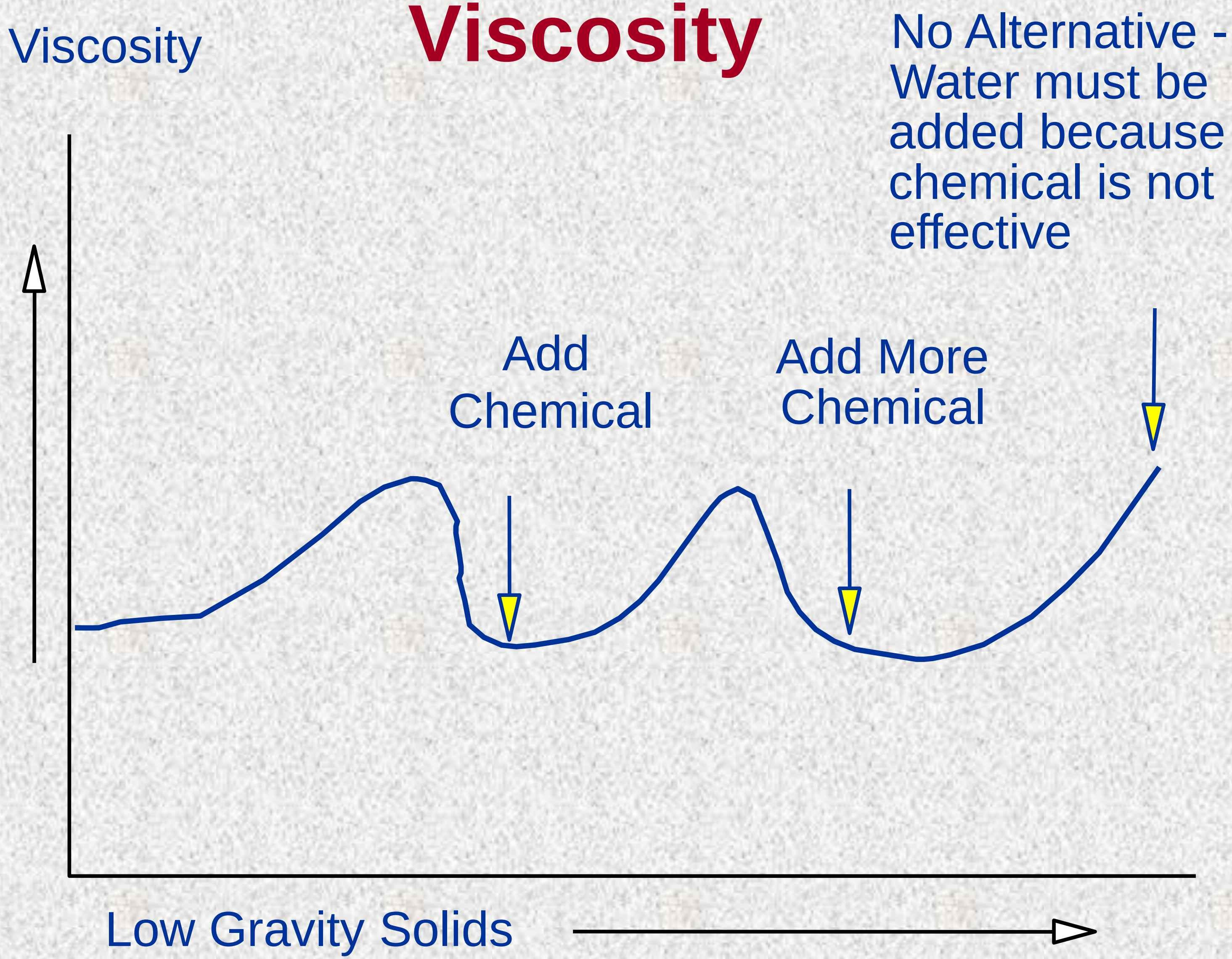


Plastic Viscosity Decreased by:

Removal of Solids

- Shale shaker
- Desanders, desilters, and centrifuges
- Lowering of gel strength allows larger particles to settle out
- Dilution of solids with water

How Solids Affect Mud Viscosity



Yield Point

Resistance to flow due to dispersion or attraction between solids

$$YP = \theta_{300} - PV$$

Affected by:

- Type of solids and associated charges
- Concentration of these solids
- Dissolved salts

Yield Point Increased by:

- Hydratable drilled clay and shale increasing reactive solids content
- Insufficient concentration of deflocculants

Yield Point Increased by:

- Over-treatment with Soda Ash or Sodium Bicarbonate results in carbonate/bicarbonate contamination
- Adding inert solids (like barite) crowds reactive solids closer together resulting in an increase of attractive forces

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Yield Point Increased by:

- Contaminants
  - Salt, cement, anhydrite, acid gases, etc. neutralizes charges of clay particles causing flocculation
- Fracturing clay particles causes residual forces to be left on particle edges resulting in flocculation

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Yield Point Decreased by:

- Neutralizing broken bond valences on the edges of clay particles by adsorbing negative ions from lignite, lignosulfonate, phosphates, etc.
- Removing the contaminating ion (calcium or magnesium) causing the flocculation by precipitating the ion with soda ash, sodium bicarbonate or phosphates.

Yield Point Decreased by:

- The addition of water will minimize flocculation, but is not the solution.
- Flocculation is a chemistry problem and must be treated with a chemical.
- Large additions of water also reduces the mud weight. This may require large additions of weight material, which could be very expensive.

Interpretation of VG Values

Increasing YP with little or no change in PV indicates a chemistry problem, which can be reduced by adding chemical deflocculants only

Increasing PV with little or no change in the YP indicated a solids problem, which can be reduced by the adding water or proper use of solids control equipment

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Interpretation of VG Values

Simultaneous Large Increases in Both YP and PV usually indicates an increase in the reactive clay content of the mud.

This should be treated with additions of both water and chemical de-flocculants.

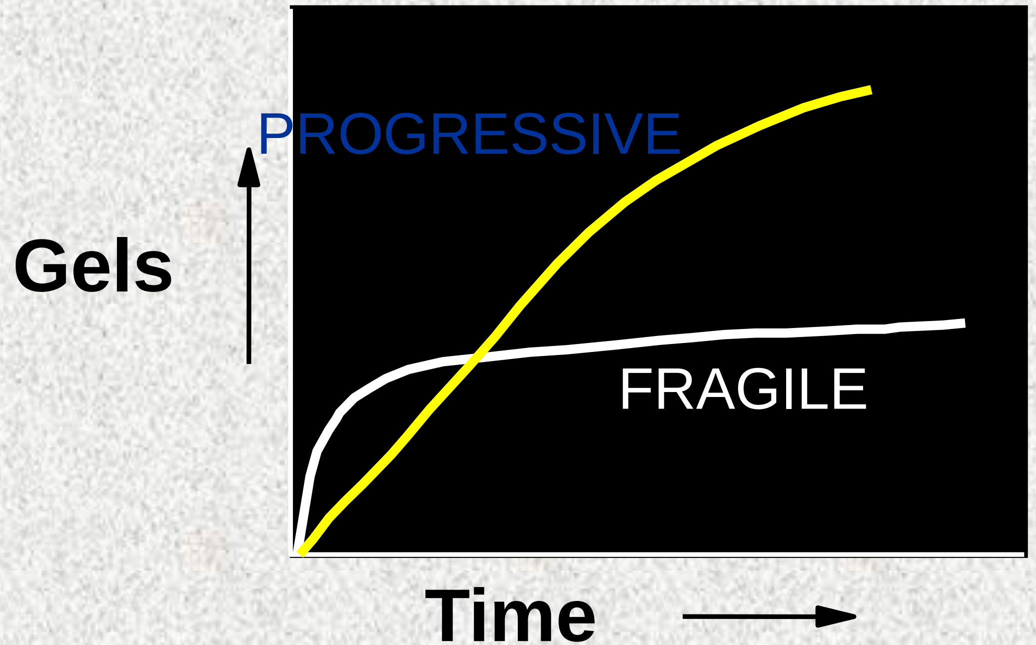
Gel Strength

1. Gel structure develops when the mud is static as reactive clay particles slowly slowly move about (Browning Motion), seeking out other reactive clay particles and linking up with each other in a positive-to-negative manner with respect to each other to form a gel structure.

2. Gel strength is a function of time, temperature, concentration and strength of attractive particles.

Gel Strength

Gel Strengths decrease the settling rate of cuttings when circulation is interrupted



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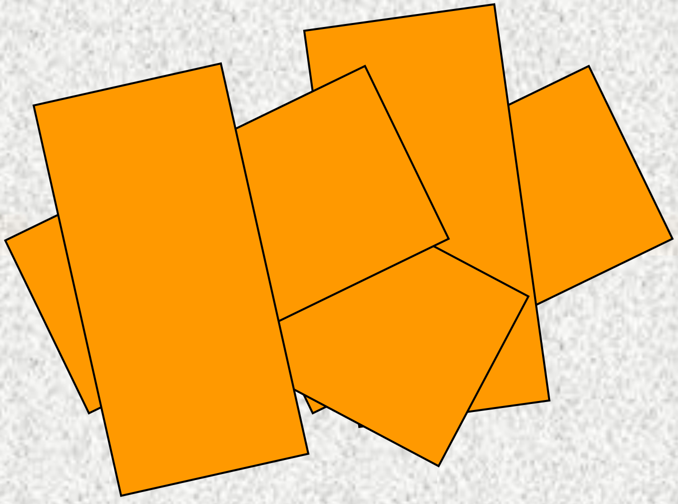
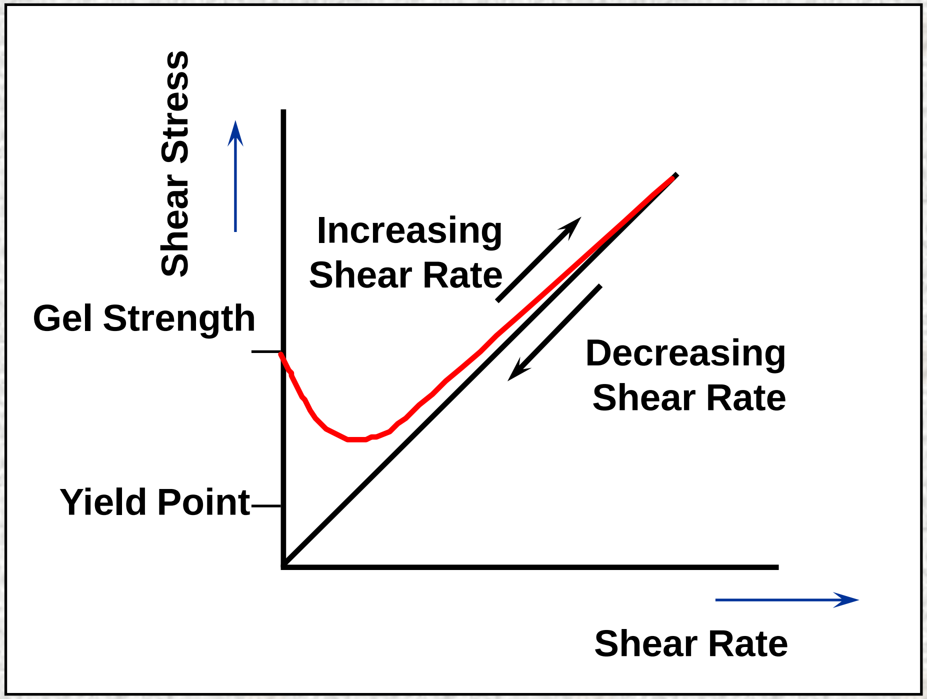
Problems Attributed to High Viscosity and Gel Strengths

- More pump pressure to break circulation
- Lost circulation by pressure surges
- Swabbing of shale and formation fluids into wellbore
- Abrasive sand being carried in mud

Thixotropy



- Due to the clay platelets arranging themselves in positions of free energy.
- With time a greater force than the YP is required to get the fluid moving again
- Gel Strength (lbs/100ft^2)
- Yield Point (lbs/100 ft^2)



Types of Fluids

1. Newtonian

2. Non-Newtonian

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Newtonian Fluids

Shear stress is directly proportional to shear rate,

i.e., viscosity (shear stress/shear rate) is constant regardless of shear rate.

Yield Point = 0

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Newtonian Fluids

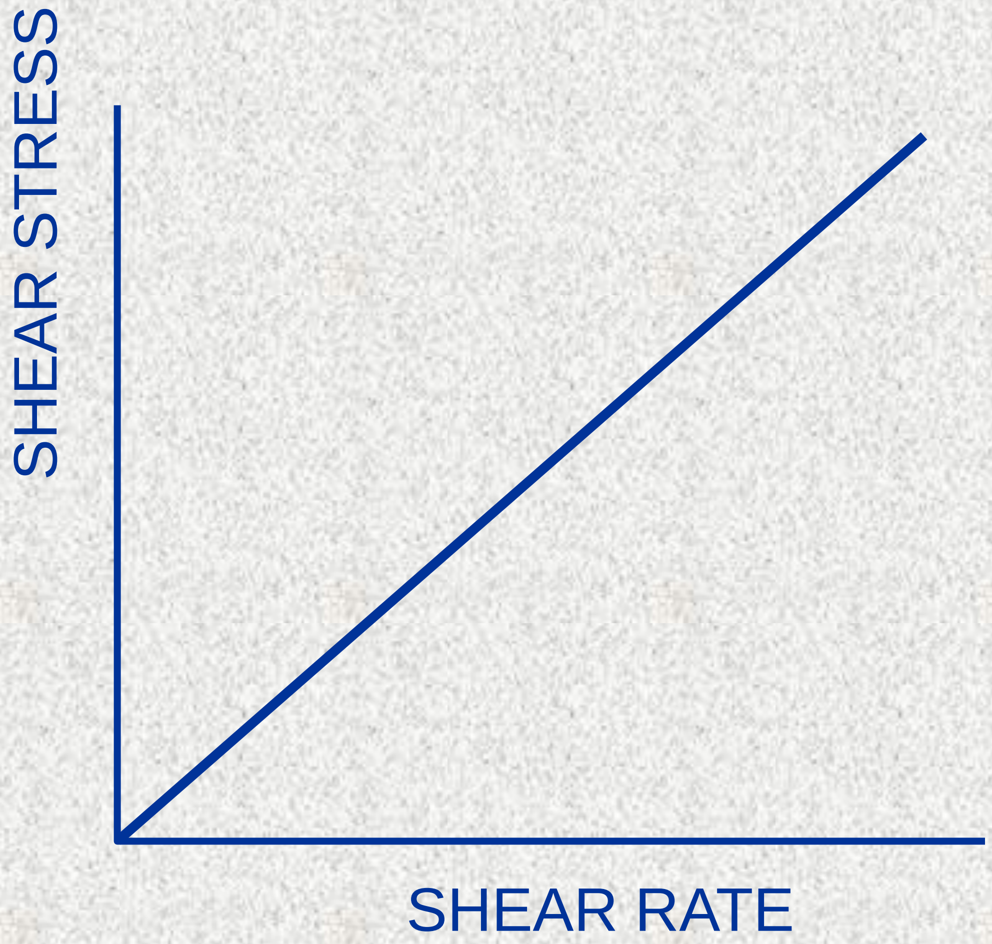
If the 600 dial reading is twice the 300 dial reading, the fluid is Newtonian

NEWTONIAN

600 DR = 80

300 DR = 40

Newtonian Fluid Fluids



Non-Newtonian Fluids

- Viscosity depends on the rate of shear
- Does not exhibit a linear relationship
- Shear thinning (as the shear rate is increased, the shear stress increases at a lower rate than that of the shear rate, making it less than a proportional increase)
- When in laminar flow they are thinner at high shear rates than at low shear rates

Non-Newtonian Fluids

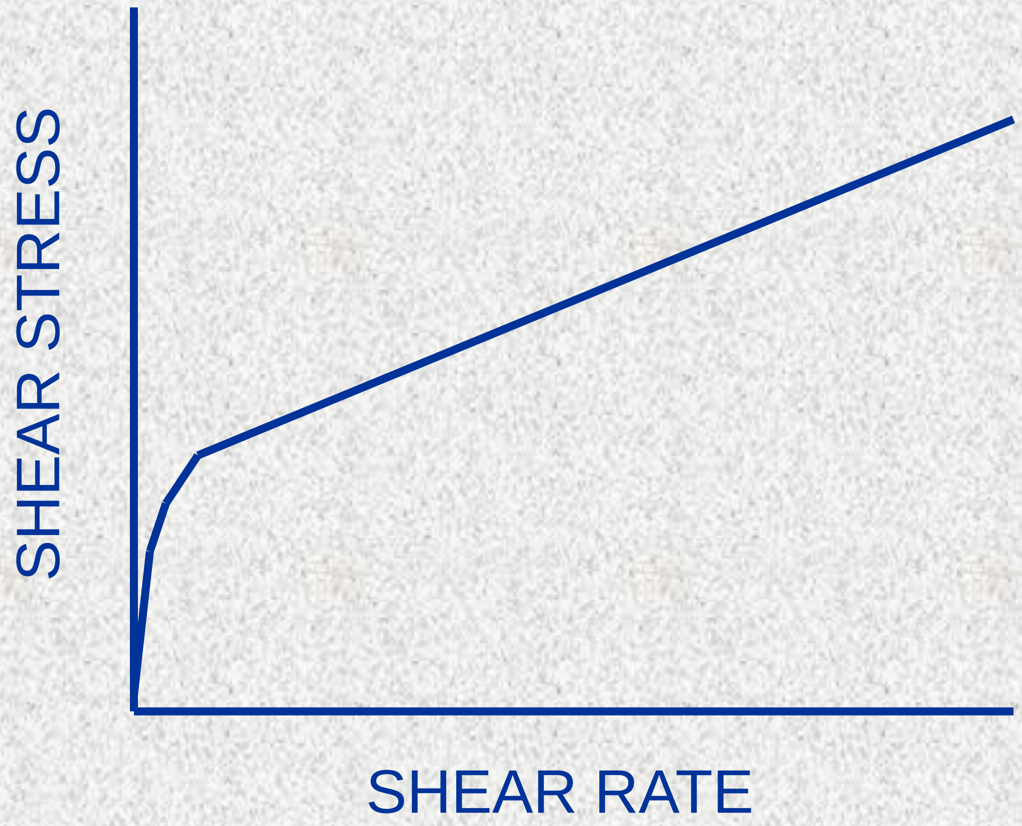
If the 600 dial reading is less than twice the 300 dial reading, the fluid is shear thinning or Non-Newtonian

NON-NEWTONIAN

600 DR = 68

300 DR = 40

Non-Newtonian Fluids

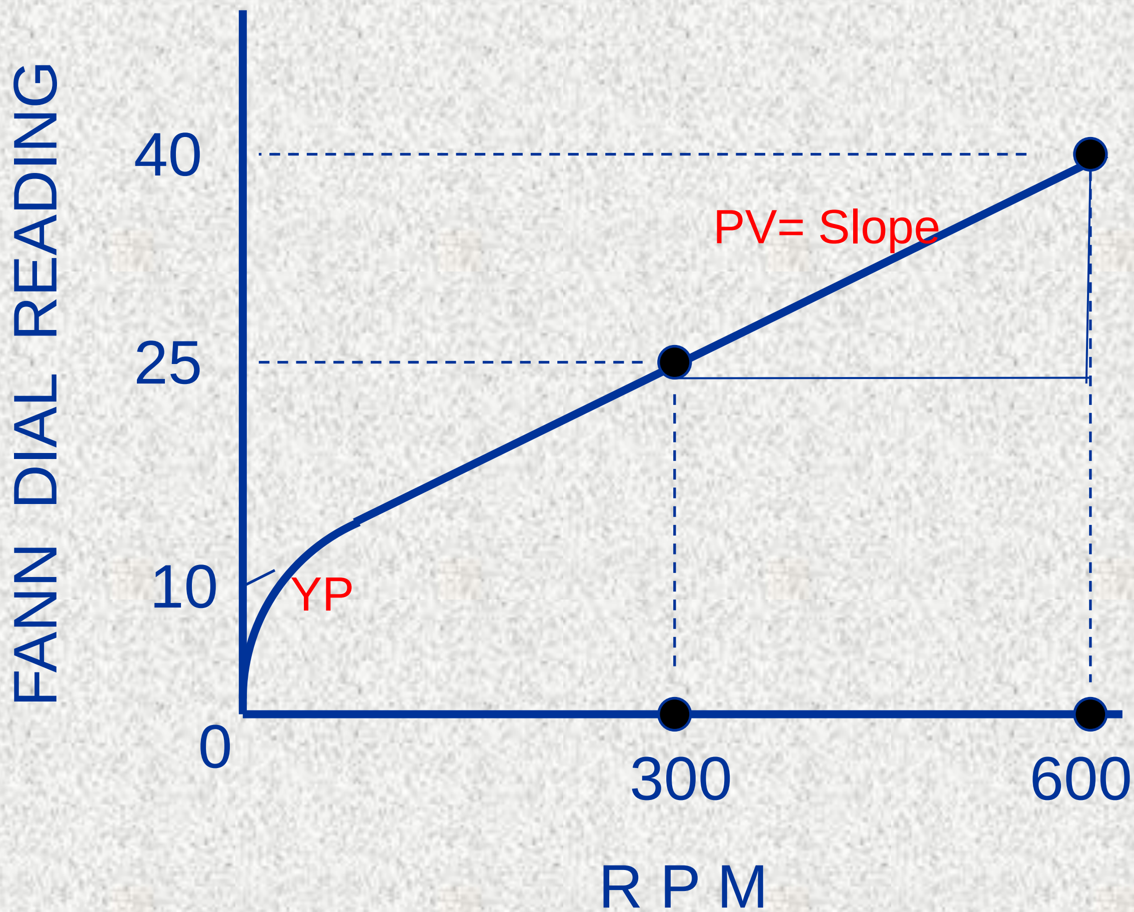


Rheological Models

Bingham Plastic

Power Law

Bingham Plastic Model



600θ = 40
300θ = 25
PV = 15
YP = 10

Function of drilling fluid

Types and importance of different drilling fluid

Drilling Mud Composition

Clay Chemistry and Structure

Mud Chemistry

√ Mud Rehology

Mud Testing

Calculation

Bingham Plastic Equation

$$F = YP + PV\frac{R}{300}$$

PV = Plastic Viscosity

YP = Yield Point

R = RPM Rotary Speed

F = Dial Reading at Speed R

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Bingham Fluids

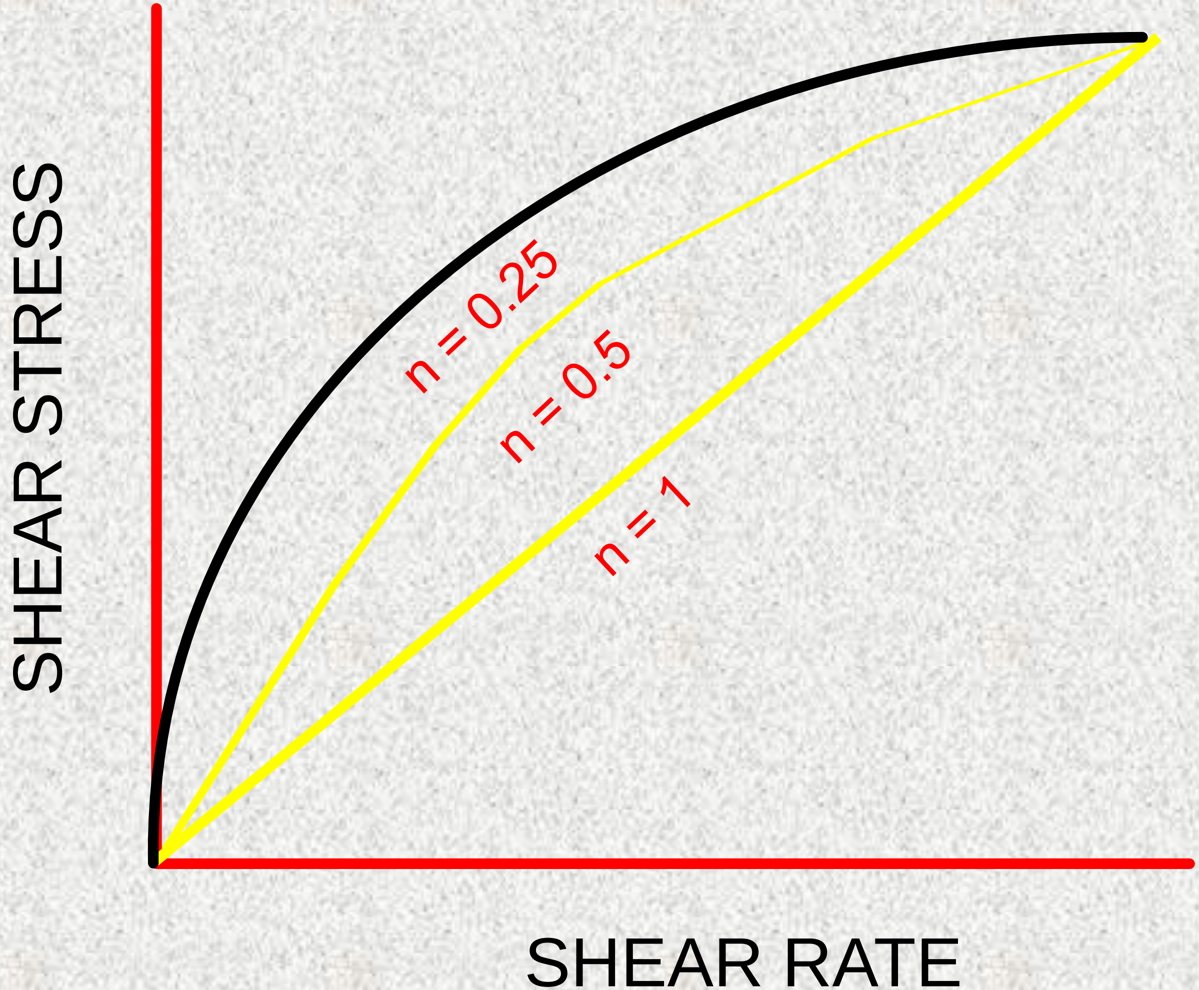
- Bingham Plastic Fluids: These fluids yield a straight-line relationship between shear stress and shear rate that does not pass through the origin. A finite shear stress is required to initiate flow. The value of this shear stress is called the “Yield Point”

Pseudo plastic and dilatant fluid behavior

- **PseudoPlastic: When the shear stress/shear rate plot of such fluids is made on logarithmic scale, a straight line is obtained. The effective viscosity of a pseudoplastic fluid decreases with increasing shear rates.**

- **Dilatant Fluids: The behavior of dilatant fluids is characterized by the flow curve. The effective viscosity of a dilatant fluid increases with increasing shear rate. This is not a desirablecharacteristic for drilling fluids and such fluids are rarely encountered**

Power Law Model



k

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Power Law Equation

$$F = K\,(RPM)^n$$

F	=	Shear Stress, dial units
RPM	=	Shear Rate, pump speed
K	=	Consistency Index
n	=	Power Law Index

n Value

- Power law index
- Indicates the shear thinning ability of a fluid
- As “n” decreases, the fluid becomes more shear thinning

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n Value for Drill Pipe

$$n_p = 3.32 \log (R_{600} / R_{300})$$

n Value for Annulus

$$n_a = .657 \log (R_{100} / R_{3})$$

What Causes n to Increase

- Removal of reactive solids
- Addition of chemical thinners
- (i.e., anything that will reduce the Yield Point)

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What Causes n to Decrease

- Addition of reactive solids
- Chemical contamination
- (I.e., anything that will increase the Yield Point)

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K Value

- Consistency Index
- Indicates a system's viscosity at low shear rates (1 reciprocal second)
- Influenced by viscosifier and solids concentration

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K Value for Drill Pipe

$$K_p = \frac{5.11\ R300}{511^{n_p}}$$

K Value for Annulus

$$K_a = \frac{5.11\ R_3}{5.11^{n_a}}$$

What Causes K to Increase

- Addition of both reactive and non-reactive solids
- Chemical contamination
- (i.e., anything that will result in an increase in viscosity)

What Causes K to Decrease

- Removal of reactive and non-reactive solids
- Addition of chemical deflocculants
- (i.e., anything that will result in a reduction in viscosity)

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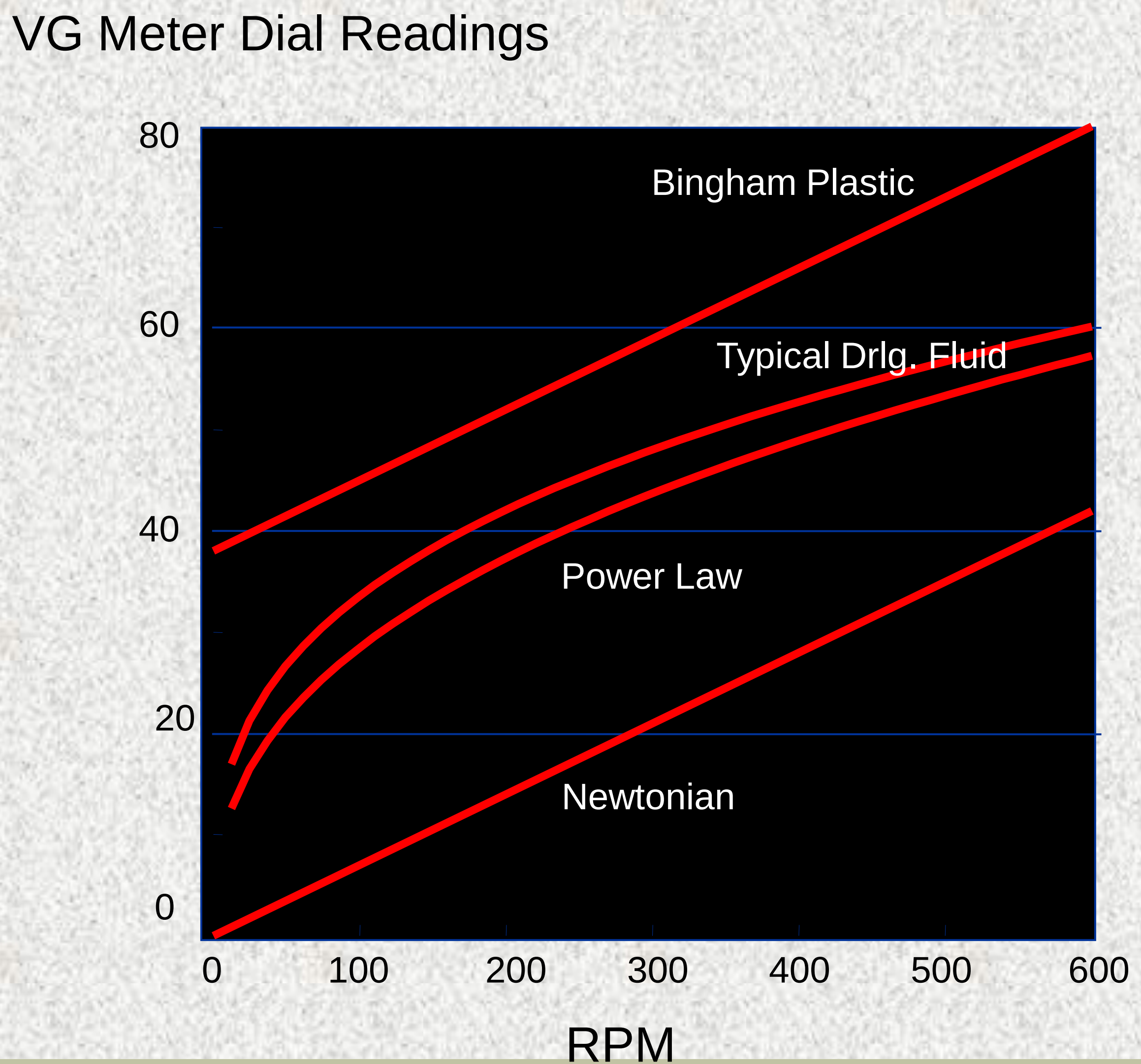
Rheological Models



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Flow Regime Determination

- Reynold's number
- Wellbore geometry
- Fluid properties

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Reynold's Number

Function of:

- Mud weight
- Hole geometry
- Flow rate
- Fluid viscosity

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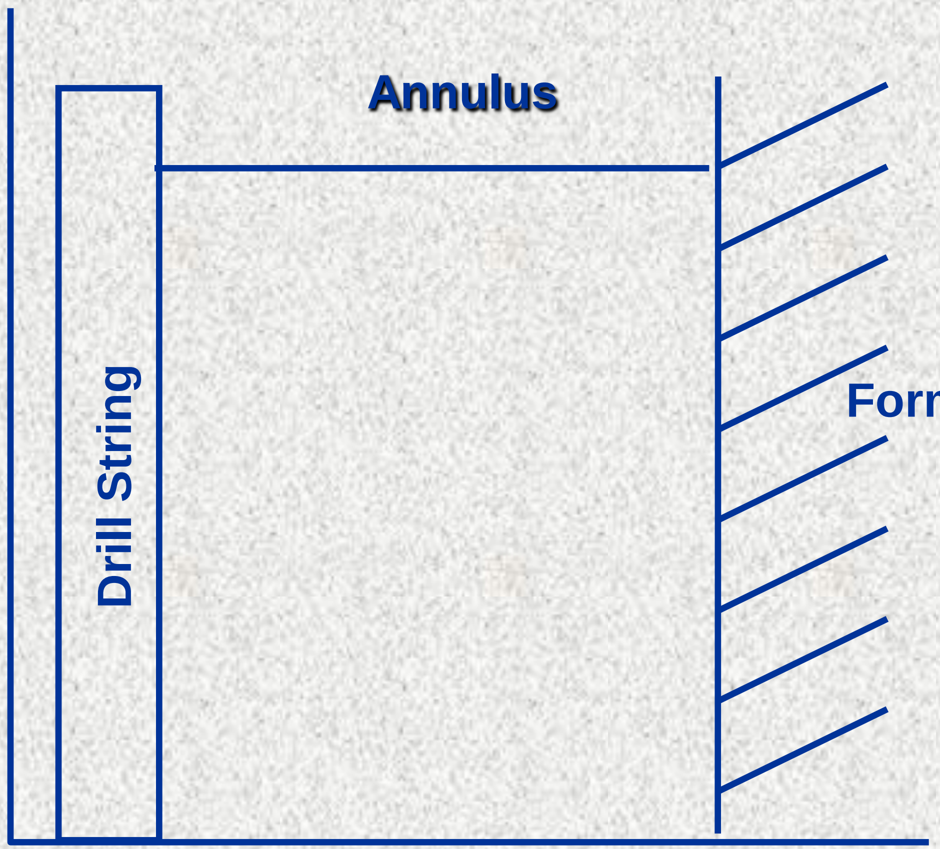
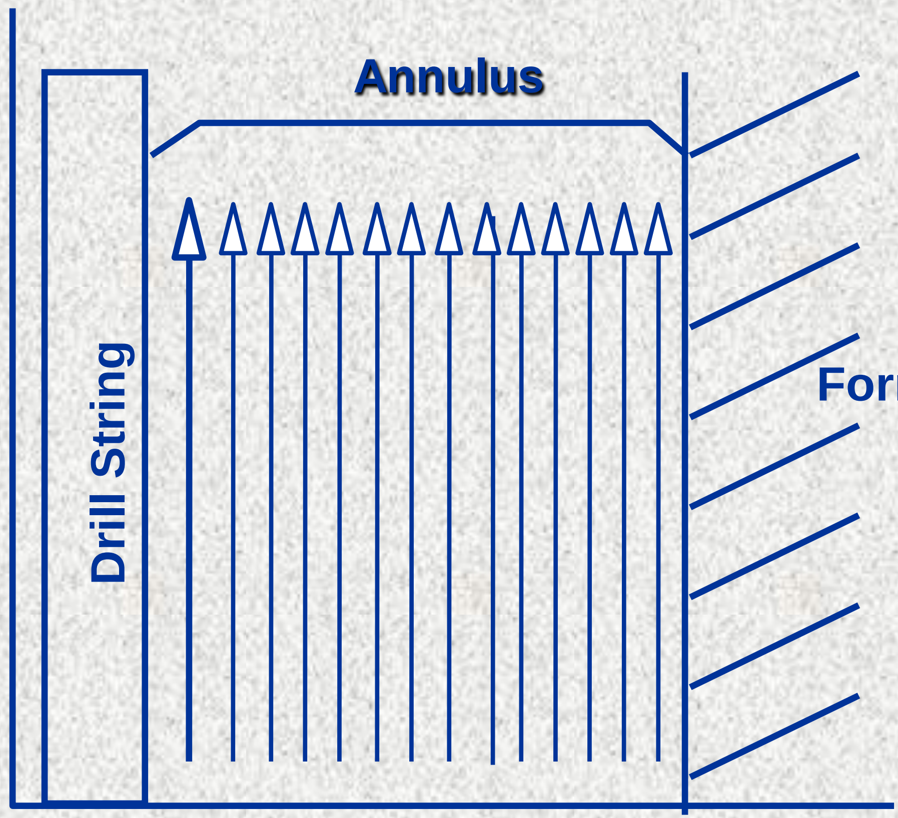
$$R_N = \frac{928\ DV\ (MW)}{\mu}$$

D	=	Hydraulic diameter, in
V	=	Velocity, ft/sec
MW	=	Mud weight, lb/gal
μ	=	Viscosity, cp

Stage 1: No Flow



Stage 2: Plug Flow



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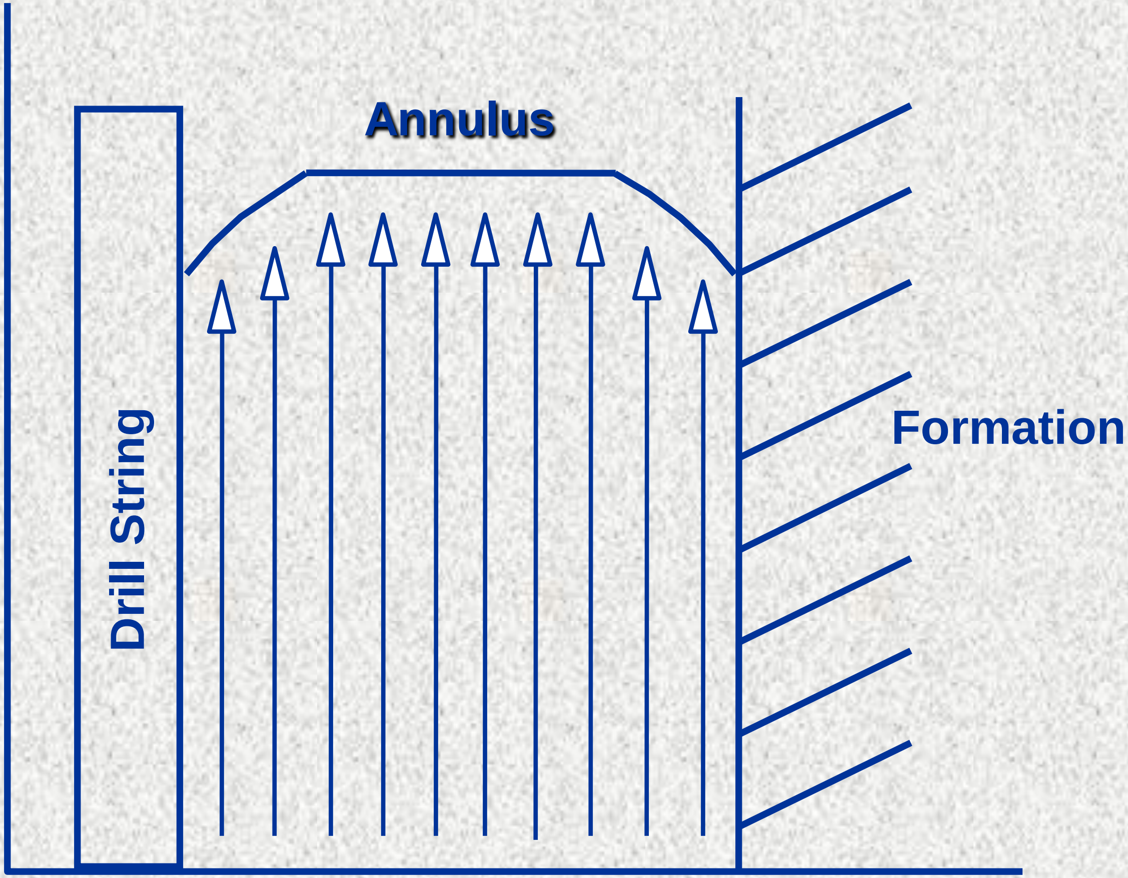
Stage 3: Transition

(Plug to Laminar)



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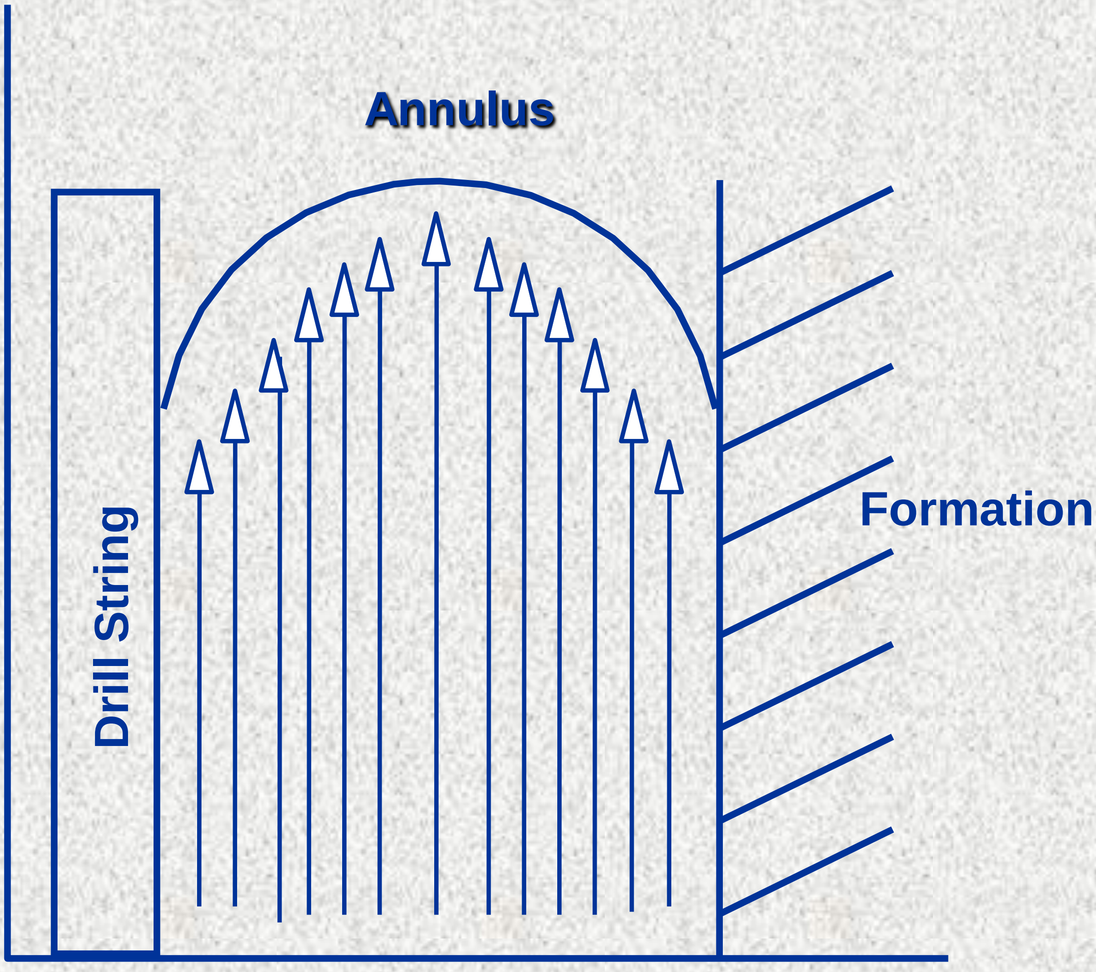
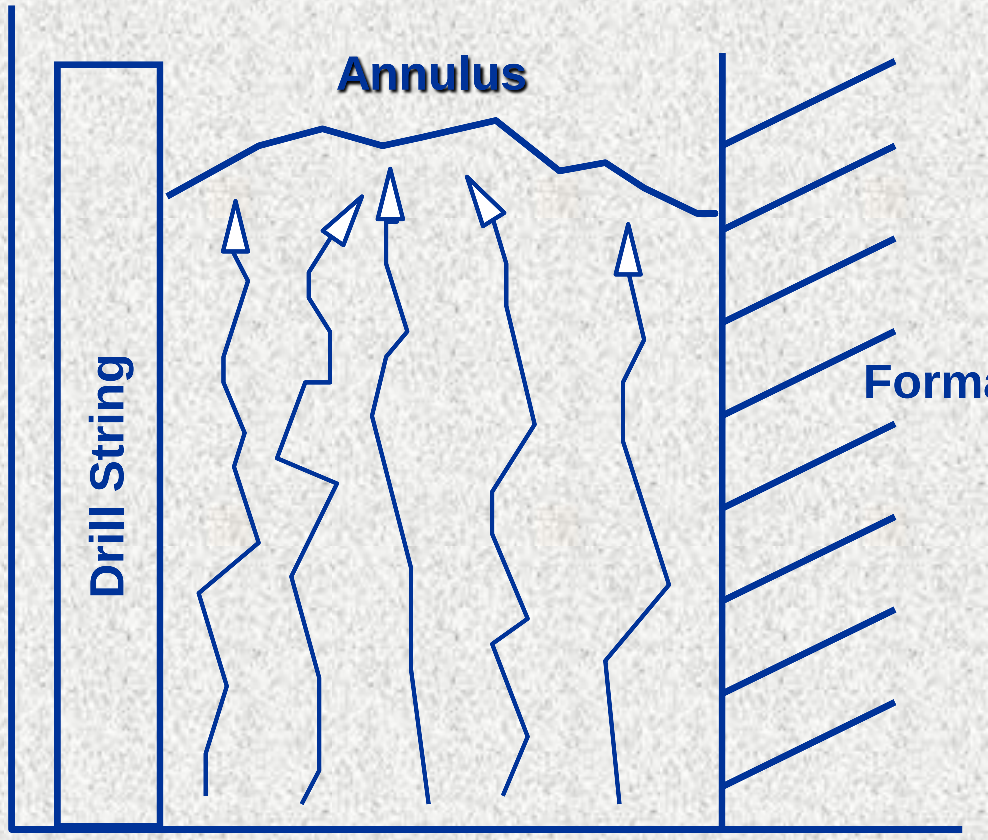
Stage 4: Laminar (Streamline) Flow



Stage 5: Transition (Laminar to Turbulent)



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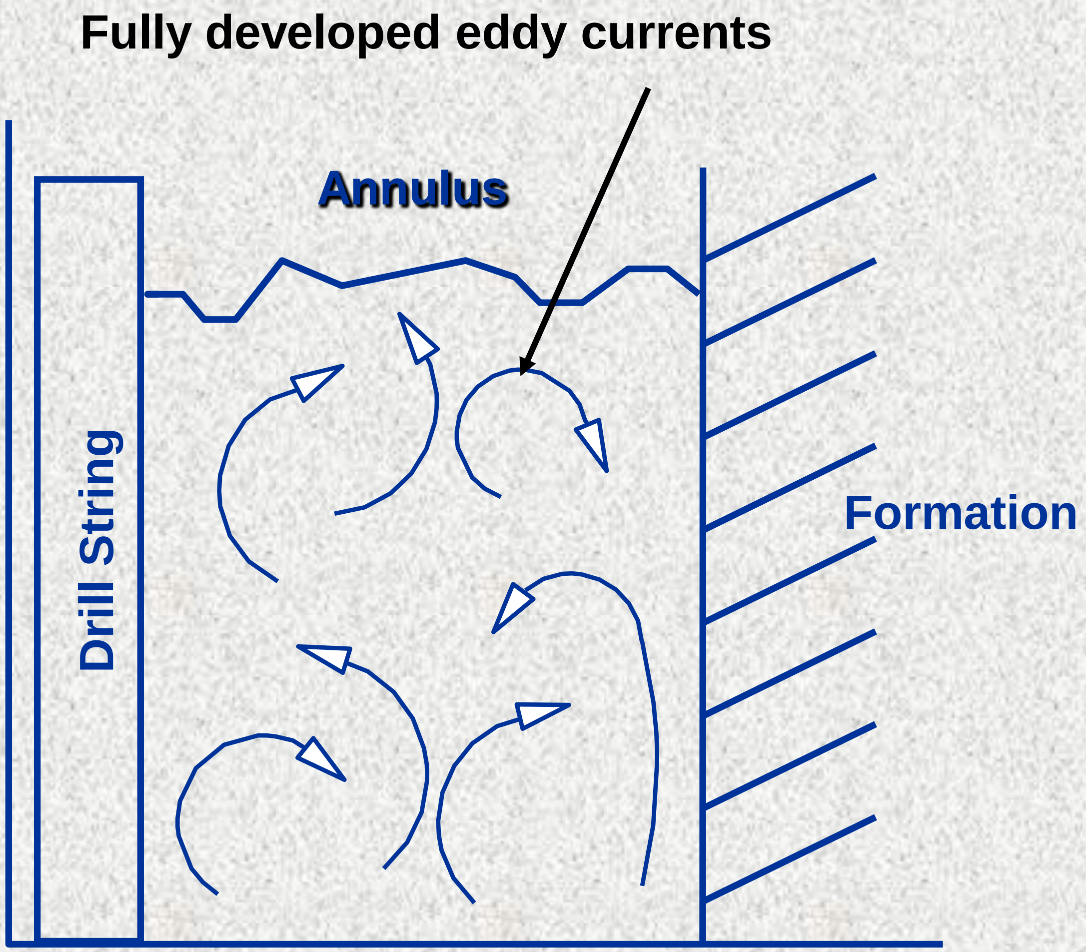
Stage 6: Turbulent Flow



Reynold's Number

< 2100	Laminar
2100 - 4100	Transitional
> 4100	Turbulent

Normally we assume turbulent flow when the Reynolds Number > 2100

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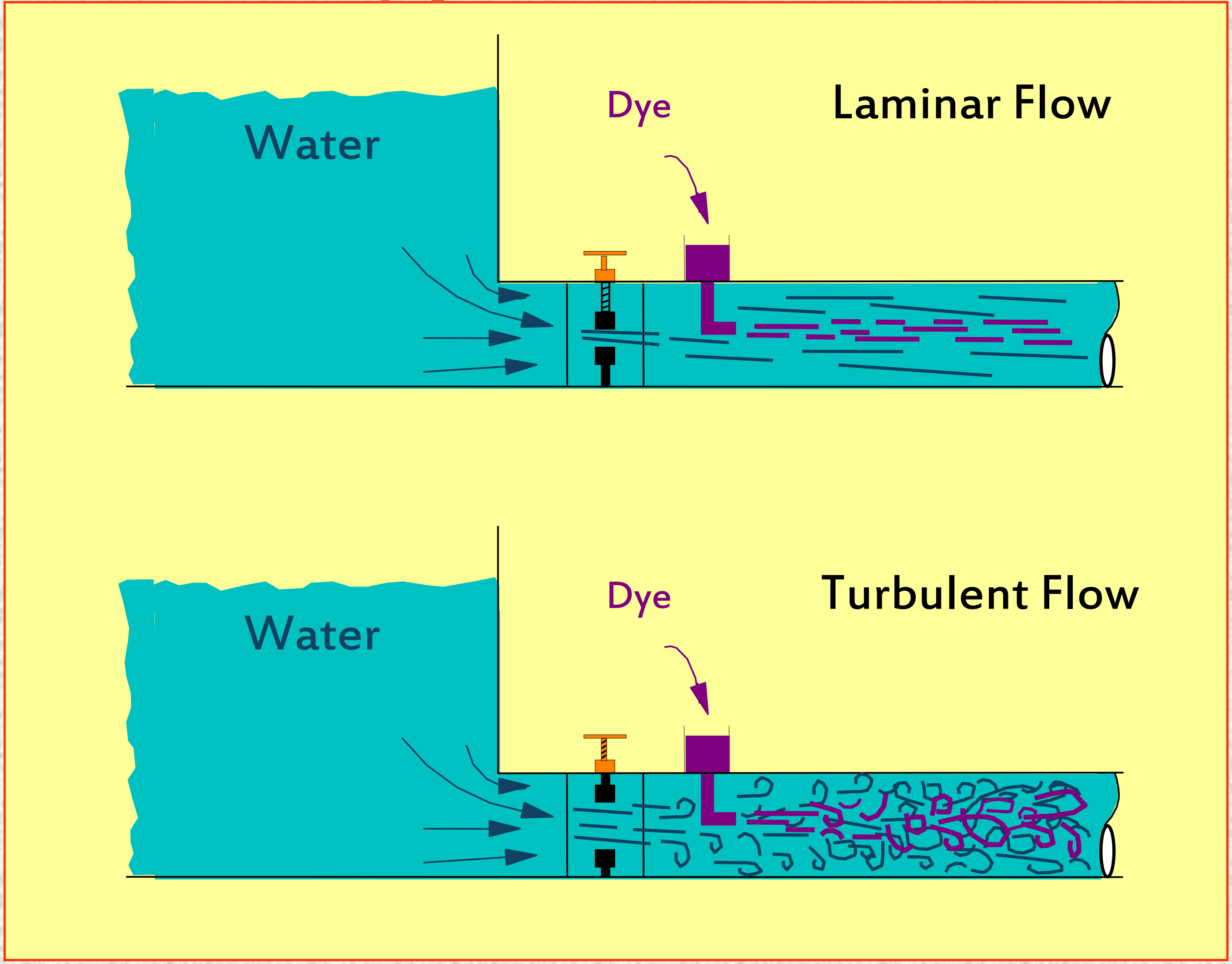
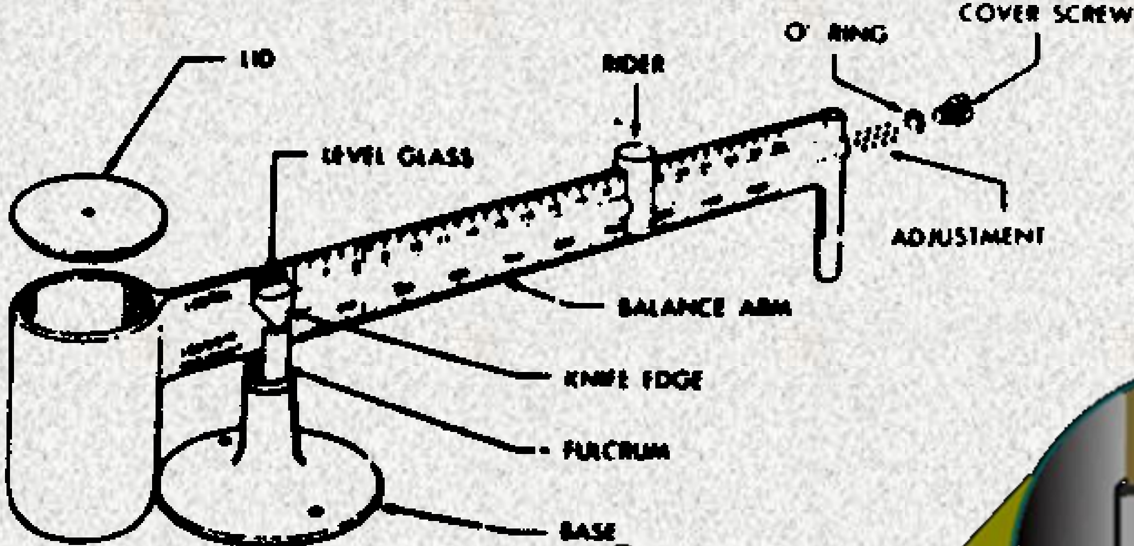
Type of Flow

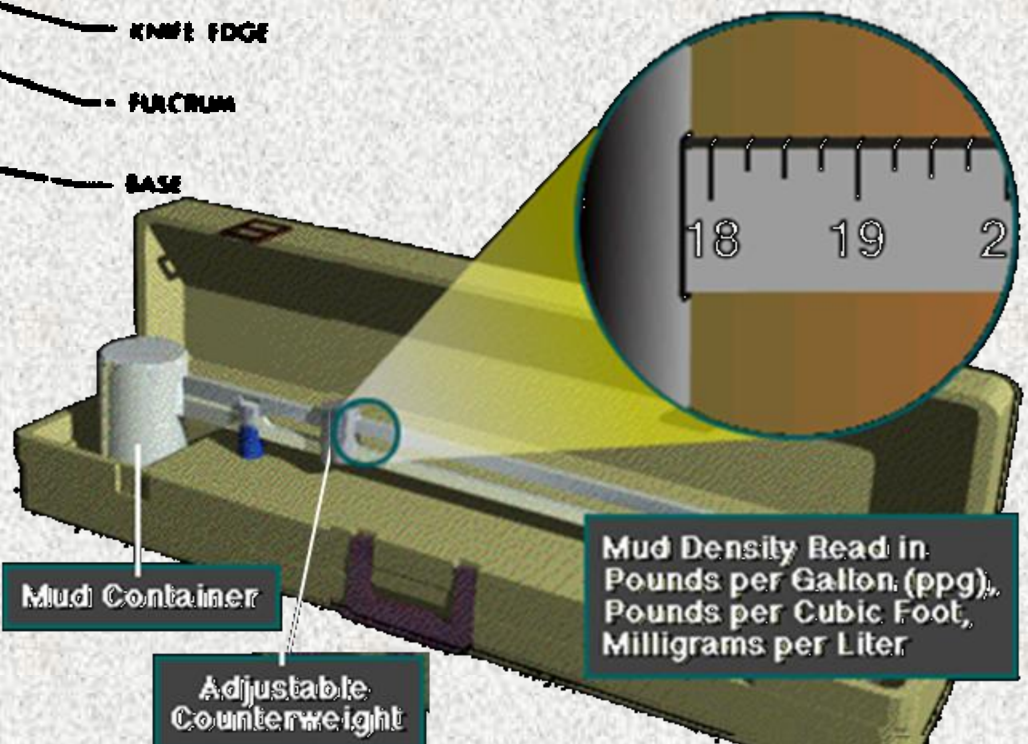


Mud Balance Test

- To determine mud density, the mud engineer or helper uses a mud balance.
- The person weighing the mud puts a small amount of mud in the mud container at left on the balance. He then slides the adjustable counterweight to the right or left until the arm balances on the fork room.
- The person then reads the mud density at the point on the arm next to the counterweight. In many areas, mud density is read in pounds per gallon but can also be reported in pounds per cubic foot, milligrams per liter, and other units. Mud density is usually called mud weight by the rig crew

Mud Balance Tests





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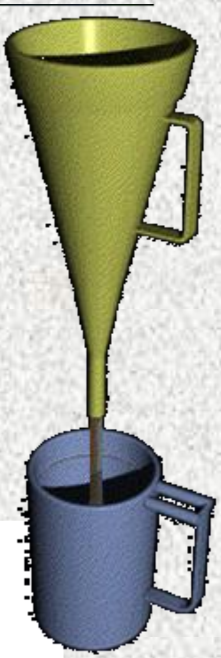
Marsh funnel Test

- One measure of a mud's viscosity is its funnel viscosity.
- That is how many seconds does it take exactly one quart of mud to flow out of a special funnel called a Marsh Funnel. A Marsh Funnel has a hole in the bottom that's the standard size.
- The mud engineer or helper pours one quart of mud into the funnel and records the time that it takes to run out into a pitcher or beaker.

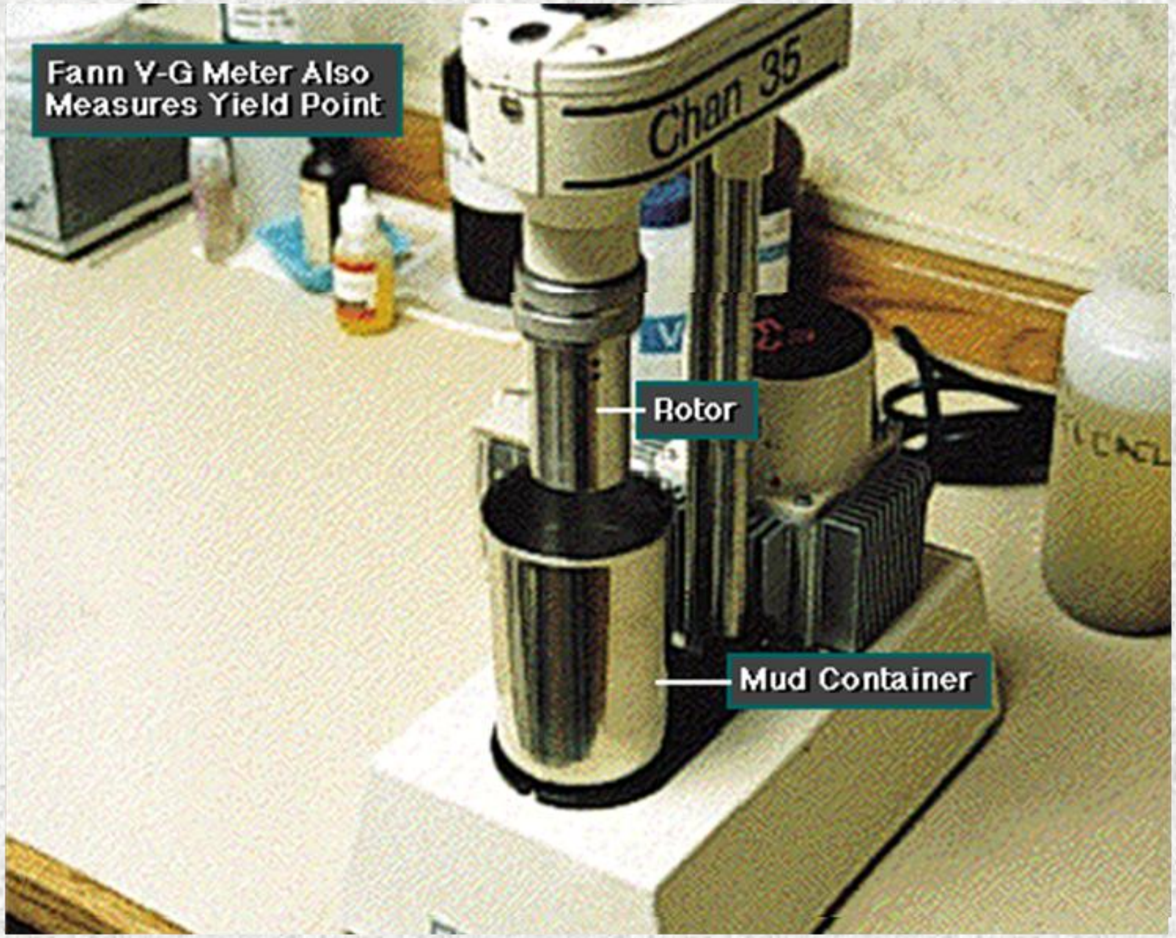
Marsh funnel Test



Rotational Viscometer

- This device also measures mud's viscosity. It is a more scientific viscosity measure than the Marsh Funnel.
- The Fann V-G Meter works by spinning a rotor or bob in a sample of mud at two different speeds. In addition, a Fann V-G Meter is used to determine a mud's yield point, which is a measure of the mud's resistance to flow. Combined with a timer, the Meter also measures the mud's gel strength. Gel strength is the mud's ability to temporarily solidify or gel when it's not flowing.

Rotational Viscometer



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Mud filtration

- that's process of loss of FILTRATE to a porous and permeable formation which Occurs when the hydrostatic pressure of the mud exceeds the formation pressure, and there are adequate solids in the mud to form a filter cake which is formed on the face of the wellbore, and many times forms inside the formation, depending upon the characteristics of the formation and its composition determined by solids in mud

Mud filtration

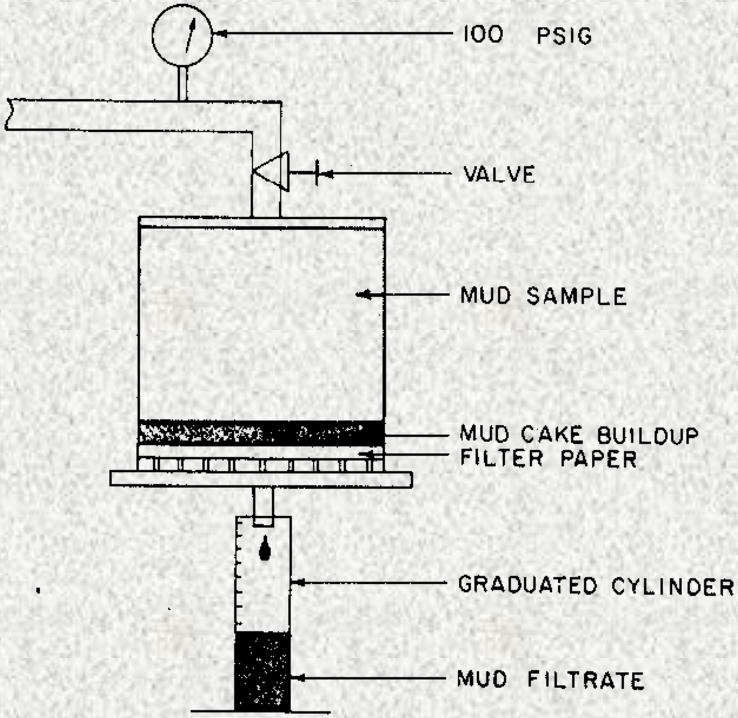
- Factors affecting filtration :-

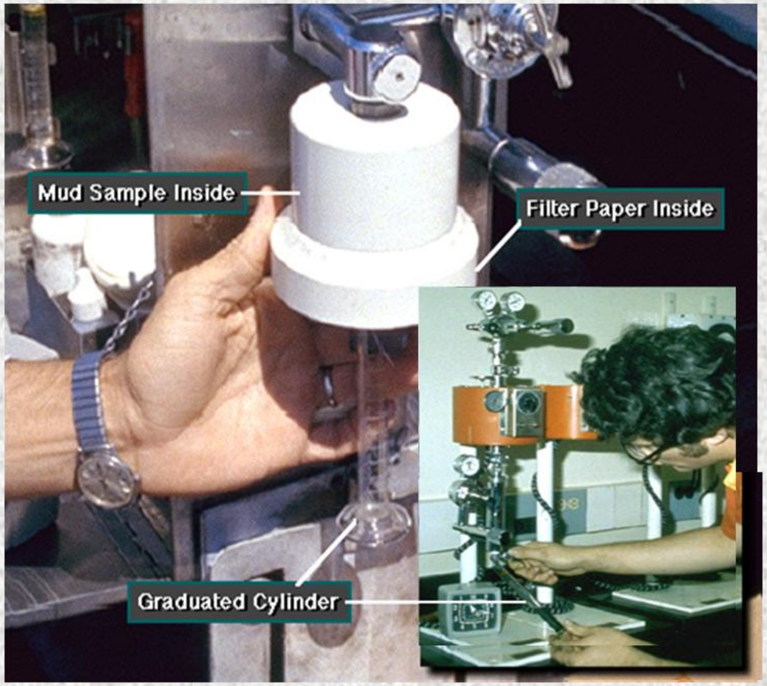
1. TIME
2. TEMPERATURE
3. PRESSURE
4. SOLIDS (type , hydration , Deflocculation and dispersion)
5. Porosity ,permeability and sorting

Filter Press

- This is a Filter Press. Inside the white container is a piece of porous paper called filter paper. Also inside the container is a mud sample.
- The mud engineer puts the mud sample under 100 pounds per square inch of pressure for 30 minutes. The pressure forces the liquid part of the mud, the filtrate, through the filter paper and into the graduated cylinder. By measuring the amount of the filtrate, the mud engineer can get an indication of the amount of filtrate that will be lost to down hole formations and the amount of solids or wall cake build up on the wall of the hole.

Filter Press





Chloride Test

- Mud engineers may run other drilling mud tests. One common test is for salt or chloride in the mud filtrate. By adding Potassium Chromate and other chemicals, the engineer can determine if the hole has penetrated a salt formation. It can also determine whether salt water has entered the well bore, which may be a sign of a kick.

Chloride Test