Drilling Fluids, Inc.

GEO PetroDrill
OIL BASE MUD SYSTEM

Introduction

The concept of water-in-oil (invert) drilling fluid technology provides fluid systems that are economical, fast drilling, and non-damaging to either the reservoir or the environment. The PetroDrill system is specifically formulated to satisfy these requirements. The highly concentrated chemical components allow formulation for a variety of temperature and pressure conditions.

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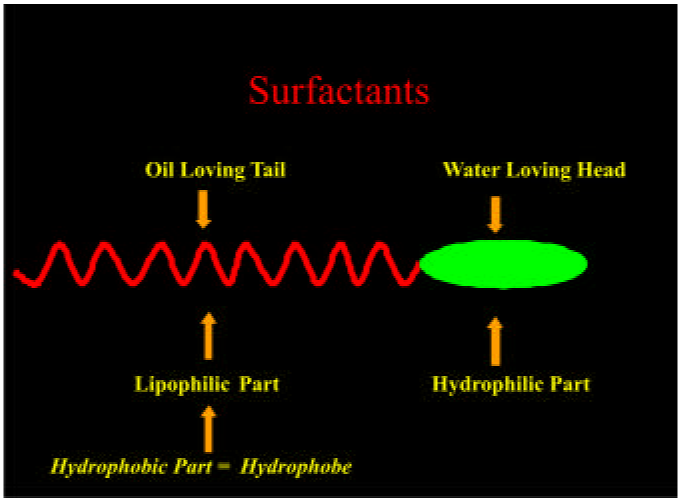
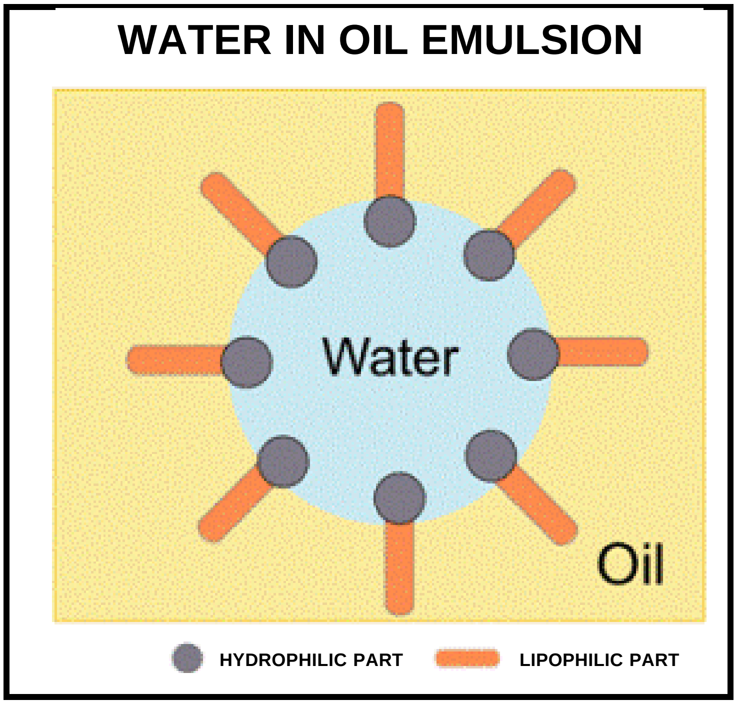
The oil external phase and thin wall cake virtually eliminate differential sticking while providing the lowest possible torque and drag values. The base oil and amine emulsifiers combine to provide corrosion protection for the drill string and casing in the presence of corrosive or saline environments. The PetroDrill system can be formulated to be stable to temperatures in excess of 450°F and pressures greater than 20,000 psi. The internal phase is typically formulated with Calcium Chloride but can also be formulated with Sodium Chloride. These salts, in a wide range of concentrations, provide a flexible activity range to prevent shale hydration or hole enlargement. Calcium Chloride is used in preference over Sodium Chloride because of the greater water phase salinity, higher activity, and higher density. Drilling performance is enhanced by the water free filtrate which does not allow formation clays to swell. “Wiper trips” (also called “short” or “drag” trips) which are necessary when using water base mud to drill through high clay content (swelling formations) can be eliminated. This can produce significant savings in rig time and cost.



EXTERNAL PHASE

The external phase of a water base fluid or an oil-in-water emulsion fluid is water. The water comes in contact with the well bore and producing formations. Materials added, such as Barite, become water wet. Clays yield by hydration with water, both when added as a viscosifier and when the mud or filtrate contact clays in the drilled formations.

An invert emulsion has oil as the external phase and water as the internal phase. Objects which come in contact with the mud become oil wet. The oil comes in contact with the well bore and producing formations. Clays do not yield unless specially treated to be organophillic (oil loving).



A continuous external phase of oil must be maintained to prevent water wetting of solids. This is particularly true in weighted muds. Water wetting of Barite in the system can cause catastrophic settling of solids which cannot be stirred back into suspension. Therefore, the oil to water ratio must be maintained at greater than 55/45 in all cases.

The oil used in the external phase will govern many of the properties by which the drilling fluid will be evaluated. The component chemicals used to formulate PetroDrill systems are compatible with a broad range of oils. The diverse properties of the various oils provide exceptional flexibility with respect to flow properties, gel structure, toxicity, temperature stability, filtration values and cost effectiveness.

LVT 200, a very low aromatic, "low toxicity", low viscosity oil is available for use in oil base drilling fluids. It is from this oil that most PetroDrill systems are prepared. When properly applied, the PetroDrill systems are suitable for use offshore and in sensitive land base areas. Cost and availability may dictate the use of diesel or other oils as the external phase. Emulsifiers specific to the base oil properties are used.

Internal Phase

INTERNAL PHASE

The internal phase of PetroDrill is salt water. The water phase controls, to a great extent, the rheological and filtration properties of the fluid. By varying the oil/water ratio the viscosity and rheological properties of the mud can be controlled. By varying the salinity of the water phase, the "activity" of the fluid may be altered with respect to shale hydration and well bore stability.

In most drilling operations a "balanced" activity is recommended, so that water vapors do not transfer from the mud to the well bore or vice versa. Except in critical conditions, a simple daily check of the hardness of the cuttings at the shaker is sufficient. In highly deviated holes or troublesome shales, a hygrometer should be used to monitor the "activity" of the fluid and cuttings. The hygrometer measures the relative humidity produced by the fluid and cuttings. Fresh water has an "activity" of 1.0, saturated Sodium Chloride Brine 0.75, and saturated Calcium Chloride Brine 0.30. An activity of 0.60 will

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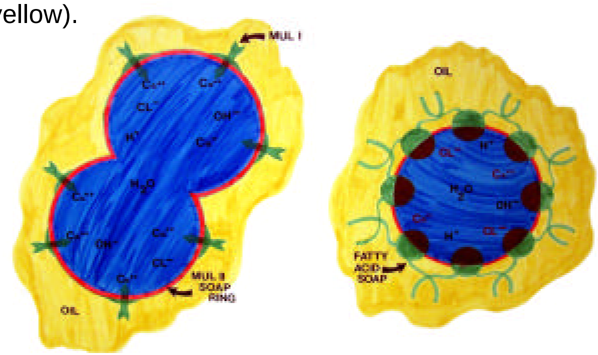
Water droplets (blue) with emulsifiers (green) forming a soap ring (red) to create an internal phase in the oil (yellow).



Water droplet shearing into two droplets.

satisfy most shales encountered.

A saturated $CaCl_2$ brine is not recommended as it is just that, saturated. It will be difficult to solubilize the various additives that must go into the water phase.

Once the formation activity has been balanced by the mud, further increases in salinity can only make the fluid more costly to build and expensive to maintain. Therefore, increases above this balance are not recommended.

Further, where possible it is recommended that the salt additions be made with brine fluids at either a pre-adjusted chloride level or at saturation. For NaCl, only brine water can be used. Crystalline Sodium Chloride (sack) can be added to a finished emulsion. However, the NaCl will drop out in the continuous oil phase without penetrating the oil water interface if high levels of Calcium Chloride are present or the NaCl is near saturation. Powdered Calcium Chloride can be added if necessary. Do not mix NaCl and $CaCl_2$.

Advantages

ADVANTAGES OF USING THE PetroDrill SYSTEM

Protection of Producing Sands
A properly maintained invert emulsion mud will produce an all oil filtrate. This effectively prevents the swelling of formation clays which can reduce permeability within the sand.

Protection of Soluble Formations
The oil external phase permits soluble formations such as Salt, Potash, and Gypsum to be drilled without detrimental effects to the formations or the mud system.

Prevention of Stuck Pipe
The lubricity of PetroDrill produces an extremely low coefficient of friction. The ultra-thin all-oil filtrate reduces the contact area in potential differential sticking areas. Clay swelling is virtually eliminated avoiding one of the major causes of tight hole, the need for frequent trips, and a contributing factor in stuck pipe situations.

High Temperature Application
The PetroDrill system is not adversely affected by temperature as the emulsion is stable in excess of 450°F. In HTHP applications the stable rheology and gel strengths allow operations to proceed at minimum values between fracture gradient and pore pressure.

Torque and Drag Reduction
The excellent lubricity coefficient, thin filter cake, and inert nature of the PetroDrill system will reduce torque and drag in deep and deviated holes. Directional sets and slides can be accomplished in minimum times.

Corrosion Protection
The oil external phase and amine derivative emulsifiers combine to provide maximum drill pipe and casing protection from such corrosives as oxygen, hydrogen sulfide, chloride salts, carbon dioxide, and organic acids. The PetroDrill systems are excellent packer fluids because they are not susceptible to temperature degradation nor are they miscible with corrosive formation waters.

DRILLING PRACTICES TO REDUCE THE COST OF PetroDrill MUD

<u>Avoid all losses of fluid.</u>

1. Use a mud saver sub or Kelly Cock valve, pipe wiper, and mud box to prevent spills onto the rig floor during trips.
2. Install a flared bell nipple (pitcher nipple) or catch pan large enough to extend beyond the edge of the rotary table to divert mud falling past the rotary, back into the pits.
3. A pan should be provided for racked drill pipe to drain back into the pit system.
4. Utilize a "slugging" tank (pill pit). Properly prepared and implemented slugs (pills) will eliminate pulling wet pipe on trips.
5. Run pipe into and out of the open hole slowly, base upon calculated maximum surge and swab pressures. Oil base muds produce gauge holes, increasing the possibility of excessive surge and swab pressures. Oil base muds remain thin at higher temperatures which increases their tendency to seep or to be lost due to surge pressures.
6. Before filling mud tanks with oil base mud, be sure all clean-out doors and valves are well sealed with oil-compatible material.
7. All valves and rubber components that come in contact with the mud system should be oil compatible. Compare aniline number on base oil to aniline number for rubber products.

<u>Reduce maintenance costs by preventing surface contamination.</u>

1. Be sure that rig personnel understand the effects of water contamination to the oil mud system. An 80/20 oil/water ratio will require 4 barrels of oil for every barrel of water that enters the mud system. A 90/10 oil/water ratio will require 9 barrels of oil for every barrel of water that enters the system. Additional weight material and chemicals will also be required to re-establish good fluid properties.
2. If significant rain is to be expected, the mud pits should be covered. 1" of rain falling in a 1000 barrel system with 8' deep pits is approximately a 10 barrel addition.

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Reduce maintenance costs by preventing surface contamination.

1. All water lines that come in contact with the mud system should be locked out or plugged.
2. "Dump-and-dilute" is not economical because of the cost of oil base mud. A centrifuge in Barite recovery mode is also uneconomical. It is important to maximize the cuttings removal by using linear motion, high "G" force, shakers equipped with fine screens. A mud cleaner down stream is also beneficial in removing sand and silt. A centrifuge should be used in low mud weight systems to keep the density down to the desired level.
3. Wash solids control screens with make-up oil, not water. If oil is impractical then utilize a pressure washer.

Reduce maintenance cost by preventing the waste of chemicals.

1. Oil muds are shear dependant fluids. Every effort should be made to provide maximum agitation to shear water droplets and disperse component chemicals. Venturi hoppers, guns and agitators are recommended.
2. Where practical, all chemicals, water, and oil should be added through the hopper.
3. Do not add Barite and water at the same time! Add oil to maintain flow properties while adding Barite. If needed, a small amount of MUL Treat may be added to preferentially oil wet the weight material and enhance dispersion during large additions.
4. Be sure the mud system has adequate suspension characteristics to prevent settling of solid chemical components. Most oil muds are shear thinning and temperature sensitive. Higher rheological properties at the suction as opposed to the flow line are normal and necessary. If at all in question these properties should be confirmed at the appropriate pressure and temperature.
5. Chemical and liquid additions should be determined base on a complete mud check. Make all additions slowly, over a full circulation, to avoid "spotty" or uneven mud properties. When testing the mud, make sure the sample is representative of the entire system. Do not rely solely on electrical stability readings for emulsion stability.

PetroDrill MUD SYSTEM DISPLACEMENT TECHNIQUES

Rig Equipment Consideration

1. A kelly cock valve or saver sub should be installed to prevent waste during connections.
2. Where rain is expected, pits should be covered.
3. All water lines that come in contact with the mud system should be plugged or tagged out.
4. Use a pipe wiper during trips.
5. Flare the bell nipple (pitcher nipple) or install a catch pan large enough to extend beyond the edge of the rotary table to divert mud falling past the rotary, back into the pits.
6. All centrifugal pumps should be lubricated with grease rather than water to prevent water from entering the system through a damaged packing. Centrifugals with mechanical seals are preferred and very cost effective over time.
7. Use make up oil or a wash-down gun to clean shaker screens.
8. A pan should be provided for racked drill pipe to drain back into the pit system. This will make the floor a cleaner and safer place to work, as well as reducing waste on trips.
9. High speed linear motion shakers and mud cleaners should be used. Sole reliance on dilution of solids to maintain mud weight is not practical or economical.
10. A centrifuge should be utilized to maintain minimum mud weights where applicable. In a weighted system, running a centrifuge for Barite recovery is not normally cost effective.
11. Vacuum recovery system is recommended to clean cellars and any spilled oil mud. A compatible mud bucket with vacuum hook-ups will minimize losses on unpreventable wet trips., i.e. coring operations or plugged jets

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DISPLACEMENT TO PetroDrill **OIL BASE MUD**

<u>Recommended Procedures</u>

Prior to change over from water base mud to oil base mud:

1. Mud pits must be cleaned and free of water. Be sure clean-out doors, valves, and gates are sealed!

2. Make sure all rubber parts that come in contact with the mud are oil proof. (Annular Preventer rubber, pump heads, valve seats, etc.)

3. Prepare the spacer to be used.

   a. Cased Hole: Pump 500 linear feet (in the interval with the largest hydraulic diameter) of water followed by 500 linear feet of oil followed by PetroDrill oil base mud.

   b. Open hole: Utilize some fresh water followed by oil with 2 ppb MUL TREAT added, followed by oil mud. If well conditions preclude the use of fresh water, 500 linear feel of minimum viscosity mud should be pumped ahead of the Oil/MUL TREAT spacer and oil mud.

4. **Do not change over to oil mud until the fluid can be circulated and conditioned after displacement. (Do not leave fresh oil mud static down hole.)**

5. Spacer design should be carefully considered. High viscosity sweeping spacers as well as low viscosity turbulent flow scrubbing spacers may be used.

6. Displace in plug or laminar flow. Do not displace in turbulent flow.

7. Displace the hole in one continuous circulation.

8. Slowly rotate the drill string to prevent channeling.

9. Use rig mud scales or emulsion stability meter to differentiate between the returning spacer and oil mud.

10. Plan a cutoff point in terms of density or stability at which the returns will be kept. Monitor volumes pumped and compare to theoretical.

11. Plan ahead what spacers to keep and what to discard. A small water spacer can be detrimental to Oil Base Mud.

12. Often water base wall cake is stripped from the well bore and removed from the hole by the oil base mud. Care should be taken that no mud is lost over blinded shale shaker screens. Some sloughing shale may accompany the old wall cake out of the hole.

13. Run a complete mud check and several spot checks to ascertain the condition of the entire mud system. Treat accordingly.

Displacement from Oil Base Mud

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DISPLACEMENT OF PetroDrill OIL BASE MUD FROM THE HOLE

Recommended Procedures

1. Prepare carefully to displace oil mud from the well after use. Storage and trucking or pumps should be sufficient to handle the anticipated volumes and flow rates.

2. Separate the fluids with a spacer of at least 500 feet in the interval with the largest hydraulic diameter. Spacer design should be carefully considered. Geo Drilling Fluids has specifically designed spacer programs to minimize oil mud contamination while maximizing the tubular cleansing in addition to leaving the tubulars water wet. High viscosity sweeping spacers as well as low viscosity turbulent flow scrubbing spacers may be used.

3. Displace in plug or laminar flow. Do not displace in turbulent flow.

4. Displace the hole in one continuous circulation.

5. Slowly rotate and reciprocate the drill string to prevent channeling.

6. Use rig mud scales or emulsion stability meter to differentiate between the returning spacer and oil mud.

7. Plan a cutoff point in terms of density or stability at which the returns will be kept. If the GEO Drilling Fluids spacer program is utilized the contamination of fluid will be very minimal. Monitor volumes pumped and compare to theoretical.

8. Plan ahead what spacers to keep and what to discard. Saving water, brine, or water base mud will reduce the value of the returned oil mud. If changing over to lease crude, adding crude oil to the saved oil mud will make it unsuitable for use as a non-fluorescing, non-toxic mud system.

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Spacer Program

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Oil Base Mud Recommended Spacer Program for Changeovers

The mixing of the spacers and the changeover are to be supervised by a GEO Drilling Fluids engineer. Spacers are designed to be a minimum of 500 linear feet and can be adjusted for hole size or pumping limitations. Surface to bit volumes and strokes should be calculated along with annular volume and bottoms up strokes. Once changeover has begun the mud engineer will monitor returns and spot changeover. Pumping procedures, volumes, and strokes should be checked against Drill Site Manager (DSM) to ensure success. Once changeover has begun, stopping pumps is not an option. Stopping pumps will disturb the integrity of the changeover.

-- Base Oil will be pumped ahead of Spacer I to thin the existing mud.

Spacer I:

1. WWS (Solvent) or equivalent
2. Lease Water
3. Caustic Soda

*Designed for removal of oil mud from tubulars.

High Viscosity / High Density Spacer:

1. Water
2. Sodium Formate (250º)
3. GeoZan
4. Barite (recommended ~2 ppg over system mud weight)

*Designed to clean debris from well bore.

Spacer II:

1. WW100 (Surfactant) or equivalent
2. Lease Water
3. Caustic Soda

*Designed to water wet casing and tubulars.

Pumping Program:
In low angle wells (< 20º) pump all spacers at maximum rate for laminar flow. Increase the pump rate to maximum allowable when high density/ high viscosity spacer clears liner or minimum sized casing. In high angle wells (>20º) pump all spacers at maximum rates—if possible achieve turbulent flow.