Drilling Fluids for Water Well Drilling Applications

Why Drilling Fluids Are Used

Why use mud (drilling fluids)? There are numerous valid technical and economic reasons for using drilling fluids, but the most obvious reason is clear to anyone who has spent time around a rotary drilling rig. Any time you drill a hole in the ground and circulate water into it, you make mud. So why not utilize this slurry of mud to help you drill the hole better?

Modern drilling fluids are much more than just dirty water, but the technology behind how they are formulated is not difficult to understand. Anyone with common sense and a desire to learn can understand and become proficient in the application of drilling fluids as a tool for maximizing the effectiveness of drilling operations.

Contrary to the thinking in some segments of the industry, there is no all-purpose mud, no wonder mud, and no miracle additives. But there is some solid, basic technology behind making muds work for you.

Drilling fluids (muds) can be defined as "the fluid placed or circulated in the drilled hole during the drilling operation." Drilling fluids of various types and quality are used on both cable tool and rotary drilling operations as an aid to accomplishing the driller's objective: to enable the execution of an economical, efficient and professional drilling program.

What Drilling Fluids Should Do

Functions which the drilling fluid should accomplish include:

- Clean drill cuttings off the bit and the bottom of the hole.
- Transport ("float") the cuttings to the surface and remove them from the fluid.
- Provide bore hole stability (keep the sides or "wall" of the hole from caving in).
- Control subsurface pressures (which are greater than the pressure at the surface).
- Cool the bit and lubricate the drill string.
- Prevent excessive loss of fluid into permeable zones in the formation (fluid seepage into permeable rocks).
- Ensure that the required information about the formations penetrated is obtainable (type of rock formation, mineral content, porosity, etc.).
- Provide protection to formation productivity.

Several variables dictate the drilling fluid properties and additives necessary to accomplish these objectives. These include the drilling equipment available, downhole conditions (i.e. temperature, pressure), and the types of formations being drilled. However, even the best quality drilling fluid formulations may not achieve desired results if poor drilling techniques are practiced. For example, rapid movement of the drill pipe (with the pumping equipment on) while spudding through unconsolidated gravel or sand formations can erode the hole and cause cave-ins or washed-out sections. This leads to hole stability problems and difficulty in cleaning the hole.

Unless the owner or project representative is thoroughly experienced in drilling techniques and drilling fluids engineering, he should entrust the drilling to the contractor and qualified drilling fluids engineers. Drilling fluids should be used as a tool to avoid hole trouble and avoid drilling problems, thereby reducing the total cost of drilling and completing a well. Using drilling fluids to get out of trouble after problems occur is usually expensive and is almost always time-consuming.

Drilling Fluid Types and Components

The two main types of drilling fluids commonly used in water well drilling applications are water-based fluids and air. Oddly enough , air is classified as a drilling fluid because it is sometimes used to accomplish some of the objectives outlined above such as cooling the bit, cleaning out the hole, etc.

By themselves, clear water or air are usually inadequate as a drilling fluid for most conditions. Other additives are required to make the drilling fluid accomplish its functions. There are hundreds of additives used in the various drilling industries to enhance the qualities and improve the performance of drilling fluids, but only a few are used in water well drilling applications.

Various combinations of additives are used with both rotary drilling and cable tool drilling methods. The major difference is how the drilling fluid is introduced into the hole. In rotary drilling applications, the water-based fluid or air is pumped continuously down the drill stem, is injected into the bottom of the hole through nozzles in the drill bit, and flows back to the surface through the annular space surrounding the drill stem. This is called conventional; circulation. Reverse circulation means that the direction of the fluid flow is reversed. This is done to accommodate certain downhole conditions. In cable tool drilling applications, the fluid is introduced into the borehole as a slurry and can be put in place with a dump bailer, or dropped dry (in a plastic or paper bag) then churned up by bit action.

Additives used to improve the performance characteristics of water well drilling fluids can be classified in either of two categories:

- Dissolved (they mix with the water or air)
- Non-dissolved (they are suspended in the air or water but do not react or combine with it).

Dissolved Additives	Non-Dissolved Additives
Inorganic phosphates	Native solids (clays, sand, etc.)
Drilling detergents	Bentonite
Foaming agents	Polymers
Soda Ash	Weight materials
	Lost circulation materials

In the ground water drilling industry, environmental, health and safety regulations confine the list of additives to a limited number of economical, easy-to-use items that are acceptable from a safety and environmental standpoint. These are discussed below.

Product	What it Does
Inorganic phosphates	Mud thinners, solids control
Surfactants/detergents	Mud conditioners
Foaming agents	Enhances air drilling
Soda Ash	Water softener
Bentonites	Filtration control, viscosifier, plugging And grouting holes
Organic polymers	Viscosifier, hole stabilizer, hole cleaning

In most cases, these additives are commercially processed, high-quality products developed through research to serve a specific function and to comply with industry specifications (e.g. standards for product quality/purity as set by the API or the ISO).

Additives are used in both water-based and air fluids. Air drilling fluids may consist of dry air only, or may have clear water or other additives injected into the air stream before it is pumped down the drill stem. The most common additives are foaming agents which change the air stream into a foam with a consistency similar to shaving cream.

Drilling Fluid Properties and Testing

Several different physical properties have been defined that measure the relative quality (effectiveness) of a drilling fluid. Both before and during drilling, these properties must be controlled according to downhole conditions and the drilling equipment being used. Several types of testing equipment are available to determine these properties, and testing procedures used must comply with the recommendations of the API as outlined in standard RP-13-B, Field Testing of Drilling Fluids.

The most important properties of drilling fluids are discussed below:

Viscosity (Thickness)

Indicates:	Carrying capacity and gel development.
Affects:	Ability of fluid to carry solids out of the hole, settling rate of solids, hole cleaning.
Test Equipment:	Marsh Funnel (API)
Desirable Limits:	32-38 seconds/quart (water is 26 seconds/quart)

NOTE: Viscosity required depends on:

- Ascending velocity of drilling fluid in annulus
- Cuttings size, shape and density
- Formation stability

Viscosity should be kept as low as possible but still retaining adequate hole cleaning and formation stability.

Weight (Density)

Indicates:	Hydrostatic pressure of fluid column and solids content.
Affects:	Drilling rate, aquifer damage, hold stability.
Test Equipment:	Mud Balance (API)
Desirable Limits:	9.0 lb/gallon maximum (water is 8.33 lb/gal); maximum may be increased to control formation overpressure situations.

Filtration (filter Cake Formation and Water Loss)

Indicates:	Ability of fluid to form a controlled "filter cake" (membrane) on the wall of the hole.
Affects:	Hole stability, occurrence of formation damage, movement of pipe, development time.
Test Equipment:	Filter Press (API)
Desirable Limits:	Very thin wall cake (2/32 inch), rapidly applied, slick, impermeable, soft and easily removable by backflushing.

Sand Content

Indicates:	Percent (by volume) of solid particles which are larger than 200-mesh size.
Affects:	Mud weight, equipment wear, bit footage, formation damage.
Test Equipment:	Sand content set (API)
Desirable Limits:	No more than 2% by volume – preferably 0%.

These and other properties are controlled by the types and concentrations of additives used. For optimum drilling results, it is important to control properties, use an adequate mud pit configuration, and utilize desanding/desilting equipment.

Recordkeeping Pertaining to Drilling Fluids

It is extremely important to the well contractor to know and record the condition of the drilling fluid. The most important properties for record are the fluid" viscosity and weight. Records of the filtration properties and sand content are also extremely beneficial. The suggested frequency for testing these properties is once for each 50 ft. of hole drilled or four hours circulating time, whichever is more frequent. Such records could be important in the event of a problem during construction or development.

Other important things to record include materials added, the time each material is added, and amounts of water used. This information will provide valuable guidelines in planning future wells.

Properties and Functions of Drilling Fluids And How to Control Them

Key to Development problem wells that drive over

FILTRATION PROPERTIES (Wall Cake and Filtrate)

Measures:	Ability of circulating fluid to form a controlled filter cake on the wall of the borehole.
Affects:	Hole stability, freedom of movement of the drill string, formation damage and development time.
Desirable Limits:	Very thin (2/32 inch), rapidly applied, slick, impermeable, soft and easily removed on back flow.
Control:	Maintain high ratio of good quality, active colloidal solids (QUIK-GEL or QUIK-TROL).

VISCOSITY (Thickness)

Measures:	Carrying capacity and gel development.
Affects:	Hole cleaning capability, drilling rate, hole stability and cuttings settling rate, circulating pressure of drilling fluid.
Desirable Limits:	As thin as possible while still retaining formation stability and cuttings lifting capacity; usually 32 to 38 sec/qt (water is 26 sec/qt).
Control:	QUIK-GEL to thicken; water of BARAFOS to thin; QUIK-TROL to thicken and improve gels.

WEIGHT (Density)

Measures:	Hydrostatic pressures (bore hole) and solids content.
Affects:	Drilling rate, aquifer damage, hole stability, transportation and settling rate of cuttings. Unwanted solids accumulation wastes fuel, causes equipment wear, loss of circulation, differential sticking, and other problems.
Desirable Limits:	Under 9.0 lb/gal (water is 8.34 lb/gal).
Control:	BAROID to increase weight; water dilution to decrease weight.

CALCIUM INDICATOR

Measures:	Approximation of hardness of mixing water due to dissolved calcium salts.
Affects:	Mud mixing, filtration control, filter cake formation. Excessively high level of calcium suppresses viscosity and gel development.
Desirable Limits:	Less than 100 ppm calcium.
Control:	Pre-treat mixing water with soda ash (approximately 1 lb/100 gallons).

pH

Measures:	Alkalinity or acidity of mixing water and drilling fluids.
Affects:	How mud is mixed, hole stability and mud properties, corrosivity, viscosity and gel development, filtration control.
Desirable Limits:	8.5 to 9.5 (neutral solutions pH = 7.0)
Control:	Soda Ash (1 to 2 lb/100 gal).

SAND CONTENT

Measures:	Solids content over 200 mesh size particles (abrasive).
Affects:	Mud weight, equipment life, bit footage, drilling rate, formation damage and drilling problems.
Desirable Limits:	Not over 2% by volume.
Control:	Lower viscosity and gels with BARAFOS and/or water. Ensure proper pit design with maximum settling time and suspend pump suction off bottom of pit. Utilize mechanical separation equipment (shakers, desanders).

Mixing & Handling of Drilling Fluids

1.) Why utilize drilling fluids?
   - A.) Maintain borehole stabilization.
   - B.) Cool and lubricate bit and down hole tooling.
   - C.) Transport cuttings.
   - D.) Control formation pressures.

2.) Requirements of Drilling Fluids
   - A.) Pre-treatment of make-up water.
   - B.) Adequate mixing equipment.
   - C.) Monitoring of drilling fluid properties.
   - D.) Maintaining adequate product concentrations.

3.) Make – Up Water : Building the Foundation
   - A.) Common contaminants.
   - B.) Treatment and removal of common contaminants.
   - C.) Order of product addition.

4.) Mixing Requirements of Bentonite and Polymers.
   - A.) Requires shear.
   - B.) Effect of shear on bentonite.
   - C.) Effect of shear on polymers.
   - D.) Dry polymer vs. Liquid polymer

5.) Importance of Proper Mixing.
   - A.) Full utilization of drilling fluid additives.
   - B.) Biggest bang for your buck.
   - C.) Reduces the potential for unyielded product (bentonite & polymer)
   - D.) Problems resulting from unyielded product.

6.) Safe Product Handling
   - A.) Caustic Soda (sodium hydroxide)
   - B.) Hazards associated with a strong base.
   - C.) Consult MSDS sheets for safe handling procedures for all Baroid products.

Mixing & Handling of Drilling Fluids

Why utilize drilling fluids?

- Maintain borehole stabilization.
- Cool and lubricate bit and down hole tooling.
- Remove drill cuttings from the hole.
- Transfer hydraulic horsepower.
- Control formation pressures.

Additional advantages of drilling fluids.

- Limit formation damage due to the drilling process.
- Reduction of filtrate invasion.
- Reduction of development time!!!
- Maximize well productivity!!!

Requirements of Drilling Fluids

- Pre-Treatment of make-up water. Removal of Hardness/Basic Environment – pH range of 8.5 – 9.5
- Adequate mixing equipment.
- Venturi Mixer
- Monitoring of drilling fluid properties. You can't just look at the pit and know what to do!
- Check fluid properties at regular intervals. Mud weight, viscosity, pH and filtrate.
- Maintaining adequate product concentrations.
- Drilling fluid additives are reactive products, which are used up as the drlg. process continues

Make-Up Water: Building the Foundation.

Common Contaminants in Water:

- Calcium (hardness) Upper Limits: 150 PPM
- Chlorides (salt) Upper Limits: 500 PPM
- Chlorine (municipal water) Upper Limits: 150 PPM

Treatment and Removal of Common Contaminants

- Calcium (hardness) – Utilize Soda Ash (sodium carbonate) at 1-2 lbs/100 gallons. Soda Ash will remove calcium and increase pH.
- Chlorides (salt) – If high levels of chlorides are encountered the best solution is to seek out a new water source.
- Chlorine – Water with high levels of chlorine can be aerated and released to the atmosphere. Otherwise another source of water should be found.

A BASIC DRILLING FLUID FORMULATION USED IN WATER WELL DRILLING

- **WATER** – 100 GALLONS (u.s.) – as necessary add Soda Ash (± ½ quart, dry measure) to drop out calcium and correct pH.

- **QUIK-GEL®** - 15 to 25 pounds per 100 gallons for normal drilling conditions, and 30 to 40 pounds for problem situations. Mix thoroughly using a high shear mixer (Venturi jet hopper). Apply slowly and uniformly until completely yielded.

- **EZ-MUD®** - 1 to 1-1/2 quarts liquid measure added uniformly to the pre-yielded QUIK-GEL® slurry.

CONTROL PROPERTIES

- **Weight** – not over 9.3 pounds per gallon for normal drilling conditions. Increase when necessary to control excess down-hole pressures.

- **Viscosity** – sufficient to clean hole with up hole velocities in the annulus not exceeding 120 feet/minute, usually in range of 32 to 38 seconds per quart.

- **Filtration** – 12 – 15 cc produced wall cake not to exceed 2/32 inch.

Volumes usually required are based on 3 times the calculated hole volume at total depth. Solids control is very important in water well drilling, provide a well designed surface pit(s) system, keep the pump suction suspended off-bottom and further enhance the solids control system through the use of desilters (hydro-cyclone) which can eliminate drilled solids down to 15 microns size.

A few thoughts about drilling practices in constructing water wells.

- Drilling fluid is a "tool" to help keep you out of trouble and not to get out of trouble. Use a properly formulated system from the start.

- While drilling, the reactive materials in the system are being used up and their place in the slurry taken by inactive materials (dispersed drilled solids). Maintaining the system quality is necessary or you will wind up with just dirty water.Avoid high mud weights formation pressures are usually less than that of a column of water. Differential pressure (over balance) will result in flow from the bore into the aquifer reducing the efficiency of the well. High mud weights can also result in loss of circulation while drilling.

- Do not over pump the hole, high up hole velocities can erode the annular space and cause formation instability and hole cleaning problems.

- Do not pump too long in one place unless advancing hole. Balance penetration rate and hole cleaning rate.

- Do not swab hole while pulling the drill string. This can develop low pressures below the bit and result in hole collapse.

- It is not good practice to free fall the drill pipe in the fluid filled hole. This can result in excessive shock pressures, fracturing the formation, developing loss of circulation and formation instability.

- Keep the hole full of good quality drilling fluid. This keeps the hole open and stable.