Testing times for HDD

George Dugan of CETCO looks at 'cup testing' as a common-sense approach to horizontal directional drilling fluids

UNLIKE the people working in waterwell drilling, horizontal directional drilling (HDD) contractors frequently move around to different areas and are often drilling into unfamiliar turf.

Complicating matters is the fact that most HDD contractors do not have the luxury of geological information derived from geotechnical drilling and soil sampling. It is therefore up to the contractor to choose a drilling fluid for the prevailing soil conditions and ensure it will meet all the functions required of it.

A simple 'cup test' is a great, non-scientific, yet accurate way of finding answers to these questions because if it happens in a cup, it will happen down the hole.

SOIL IDENTIFICATION

Soil identification is the first step in matching drilling fluids to soil conditions; the process is simplified by separating soil into two categories: fine/reactive and coarse/non-reactive.

Fine or reactive soils are basically clay and/or shale. Clay has a particle size ranging up to 2 microns in diameter (in comparison, the human hair can be up to 120 microns in diameter) and is considered reactive because, when hydrated, it tends to swell, stick and ball up around bits and reamers. Take a clear cup or container of water and add clay/reactive soil to it, stir and note how the clay thickens the water, sticks to the stirring implement, and then swells up as it absorbs water. If these problems occur in the cup, they will occur down the hole, causing excessive torque, reduced penetration rates, frac-outs and stuck product lines.

Using a waterbottle for cup testing

Coarse/non-reactive soils, on the other hand, can be anything from rock to sand, and when they are mixed with water the material quickly settles to the bottom. Often, material such as red soil may look like reactive red clay, yet, when mixed with water, the solids immediately sink to the bottom of the container, leaving a red tint.

When drilling in coarse soils, such as sand, fluid loss is a big issue. If left unchecked, it will cause borehole instability and stuck pipes. If heavy solids are allowed to settle, they can pack off around the drill stem, causing frac-outs, lost circulation and (you guessed it) stuck pipes. Two key factors that enable a drilling fluid to keep a hole open in coarse soils, such as sand, are an impermeable filter cake and a means of evenly applying positive pressure against the cake (controlling the hydrostatic head created by drilling fluid in the hole).

REACTIVE SOILS

Along with determining whether soil conditions are fine/reactive or coarse/non-reactive, it is important to observe and understand how and why various soil conditions behave the way they do. For example, clay has to hydrate (absorb water) in order to swell and stick. One can watch reactive clays in action by sprinkling granular bentonite (sodium bentonite, clay-based cat litter will work for this demo) into a cup of water, and noting how quickly the clay reacts and swells as it hydrates.

One of the most common methods of dealing with reactive soils is by encapsulating clay with a polymer film that delays the hydration/reactivity. Synthetic polymers are most frequently used as clay inhibitors, although other polymers such as polyanionic cellulose polymers (PAC) and some natural, biodegradable polymers also work well in this respect. By thoroughly mixing synthetic polymer into a glass of water, and then sprinkling in granular bentonite or reactive soils while stirring, one can see how polymer coats the clay particles and prevents them from sticking, as well as delaying the swelling process.

Another thing to note in this cup test is that all of the clay settles to the bottom, which is why polymer and water alone do not perform all of the functions required of a drilling fluid: bentonite is needed to provide the necessary gel strength to carry clay drill cuttings out of the hole.

Other products and additives for reactive soils, such as dispersants (thinners), clay flocculants and even drilling detergents can be cup-tested in a similar fashion. This is a good way to determine how a drilling-fluid mix will work with reactive soils – and a much better approach than finding out the hard way.

COARSE/NON-REACTIVE SOILS

One of the most important functions of a HDD fluid is gel strength, which can be raised by increasing the amount of bentonite in a drilling fluid or using a gel, strength-enhancing polymer. The problem with increasing the amount of bentonite in a drilling fluid is that it also raises the viscosity (resistance to flow), making it harder to move returns out of the borehole. ➔

Minimal fluid loss = borehole stability

Fluid loss with sand

Bentonite and PAC polymer drilling fluid. MINIMAL fluid loss | *Water of drilling fluid with poor fluid loss. HIGH fluid loss*

DRILLING FLUIDS

Mixing clay with water *Polymer and water*

Inhibiting clay with PHPA polymer

Clay will hydrate, causing sticking and swelling

Polymer coats clay particles and delays hydration

Bentonite settling due to calcium in water

➔ High-viscosity drilling fluids also dramatically reduce mud-pump efficiency, which increases the chance of out-running the drilling fluid during back-reaming. By taking a cup of drilling fluid, stirring in soil collected from the entry or exit pit, and then letting it sit, it is possible to determine whether the gel strength of a drilling fluid is adequate. If it settles in the cup, it will settle down the hole, and there is a good chance that you are going to get stuck, frac-out or a stretched product line.

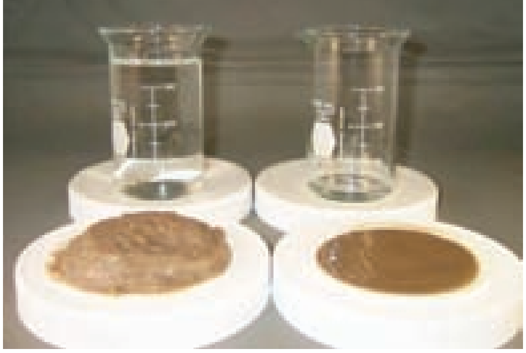
Fluid loss can be measured by using a filter press, which uses 7kg/cm^2 (100lbs/in^2) of pressure for 30min to force drilling fluid through a filter membrane. The clear water forced through the filter is then measured and recorded in millilitres, and the residual filter cake can also be analysed. A drilling fluid with good fluid-loss characteristics can yield fluid-loss readings below 10ml, and it will have a thin filter cake with a rubber-like texture.

A fluid with bad fluid-loss characteristics (such as high-yield bentonite mixed into hard water without pre-treating with soda ash) can yield fluid-loss readings in excess of 25ml, with a filter cake that is thick, yet porous and very soft.

It is easy to see how fluid loss effects borehole stability: by pouring water into a half-full glass of dry sand and noting how the water quickly saturates through the sand. If a person inserts their finger through the middle of the sand and then removes it, the sand quickly fills in the hole because there is no fluid-loss control to create borehole stability. Conducting the same cup test by pouring a good bentonite drilling fluid over a half-cup of dry sand will result in just a thin, wet layer at the top of the sand and dry sand below.

This effect is caused by bentonite platelets shingling off to seal the sand and/or the formation, creating a low permeability filter cake. If one inserts a finger through the middle of the sand and then removes it using something like a turkey baster to evacuate the drilling fluid, you will find a perfect hole in the sand – borehole stability through good fluid-loss control.

In the field, contractors can get a cup sample of coarse soil from the entry and/or exit pit, add drilling fluid to it, and gain a rough idea of the kind of fluid-loss control that the fluid will



Thick filter cake (poor rheology). HIGH fluid loss

Thin but strong filter cake. LOW fluid loss

Filter press results

have on the soils to be encountered. If the fluid permeates the coarse soils deeply, instead of leaving just a thin, wet line at the top of the material, additional fluid-loss control will be needed, and PAC polymer will dramatically improve borehole stability with a minimal increase in viscosity.

MONITORING PROGRESS/RESULTS

Water makes up 95-99% of a HDD fluid and bad water leads to a bad drilling fluid. Minerals, such as calcium, which contribute to water hardness, are not only detrimental to sodium bentonite but also to most of the polymers and additives used in HDD fluids.

One can take a cup of bentonite drilling fluid mixed with untreated, hard water to see how a clear layer of water will form at the top of the cup in a short amount of time (or in the top of a mix tank after the mixers have been shut off).

This is caused by minerals such as calcium, which short-circuit the negative electrical charge on the surface of the bentonite platelets (which would normally keep the platelets apart and create gel strength), causing the bentonite platelets to clump together. This is known as flocculation. If clear water is present on the top of a bentonite drilling fluid, then that fluid will not maintain borehole stability or suspend drill cuttings adequately. And the risk of failing to properly complete the bore is extremely high.

Cup testing can be used to identify soil conditions and determine whether the drilling fluid is capable of controlling down-hole conditions. But it is also a good idea to use the test to monitor for changes in soil conditions or, at least, to closely observe the return flow during drilling and back-reaming.

For example, when drilling in sand, one may encounter zones consisting of heavier pea gravel or rocks that may require an increase in gel strength. If an unexpected zone of clay is encountered, changes to the drilling fluid returns are usually the first warning sign, and proper measures can be taken to avoid problems.

Constantly monitoring drilling-fluid returns can also help to identify other problems, such as outrunning the fluid. Drilling fluid and drill cuttings are mixed by the drill bit or reamer into what must be a flowable mixture that is capable of being pumped out of the borehole.

Reamer pull-back speed is determined primarily by the amount of drilling fluid that can be delivered to the reamer; if the reamer is pulled back too fast in relation to the drilling fluid that is delivered to it, the returns become too thick and no longer flow, with disaster close at hand.

In conclusion, cup testing is a great way of identifying soil conditions, matching drilling fluids to them, and monitoring success. It is also a good way of visualising what is going to happen downhole. Cup testing does not require expensive or extravagant testing equipment (although it is not a replacement for drilling-fluids testing equipment). Clear, plastic cups and plastic spoons are cheap, and available at almost any grocery or department store. Or one can simply cut the top off an empty, plastic waterbottle and stir the material with a stick.

Remember: if it happens in a cup, it will happen down the hole.

George Dugan is regional manager at Illinois-based CETCO