A few years ago, I received a call from a contractor asking for help mitigating a situation with a governmental transport agency in regards to monitoring downhole pressures as they were drilling under a six-lane highway crossing. They were asked to provide details on the drilling fluid they were using and the recommended annular pressure while drilling. In order to do this, one must look at the functions of the drilling fluids, the properties of the drilling fluids (like viscosity and solids content), the volume of fluids being pumped, and the rate or speed of drilling.

During the drilling process, a contractor circulates drilling fluids through the bore. The drilling fluids have several functions that keep the hole open and stable in order to pull the pipe through with ease. The primary functions of a drilling fluid are:

- Keep the tooling, sonde and any other instrumentation cool
- Lubricate the hole
- Clean the hole by suspending and transporting cuttings to the surface
- Hold the hole open via a filter cake and positive hydrostatic pressure (control fluid loss)
- Reduce torque, especially associated with sticky soil
- Control subsurface pressure

A bentonite-based drilling fluid is typically chosen for HDD bores, since it is able to provide all the functions listed above. The concentration of the bentonite fluid is determined by the soil. The coarser the soil, the more bentonite is required to ensure minimum fluid loss. The amount of bentonite used can be decreased by adding in polymers to help reduce the fluid loss while keeping the concentration of bentonite down.

You may be wondering what this has to do with fluid volumes and downhole pressure? The answer is quite a bit, based on the properties of the fluid being used. The contractor needs to look at the primary properties of the fluid, which are:

- Viscosity
- Gel strength, or the ability of the fluid to suspend cuttings
- Protection against fluid loss

The higher the viscosity of the fluid, the higher the pump pressure required and the higher the downhole pressure. As the fluid is designed to suspend and transport cuttings, the amount of fresh fluid being pumped will directly affect the solids content of the fluids being displaced out of the hole. Lastly, the pressure of the drilling fluid, encapsulated by the filter cake against the formation, helps hold the hole open. The filter cake controls the fluid loss with positive pressure; however, it must be controlled in order to not exceed downhole pressure.

**FLUID VOLUME**

There is a simple formula that can be used to calculate soil volumes in a given bore path:

\[
\text{volume of soil} = \left( \frac{\text{bit or reamer size in inches}^2 \times 24.5}{24.5} \right) \times \text{gallons of soil per linear foot}.
\]

Using a 5-inch bit as an example:

\[
5^2 \times 24.5 = 122.5 \text{ gallons of soil per linear foot}.
\]

**DOWNHOLE PRESSURES**

This now brings us to downhole pressures. The calculations of recommended downhole pressures are only as good as the geotechnical report the contractor has. Often the engineering documents will recommend an annular pressure not to be exceeded. There is also software available that can produce this data. It is common that the available geotechnical soil reports were taken from the entry pit and the exit pit or nearby, but not necessarily along the entire planned bore path. Therefore, there can be unknown ground formations along the bore that the contractor may be unaware of unless he or she has drilled in the same area before.

A quick way to calculate downhole pressures is:

\[
\text{mud weight in pounds} \times 0.052 \text{ psi/ft.} \times \text{depth in feet} = \text{hydrostatic pressure}.
\]

In this equation, 0.052 is a unit conversion factor. It means that hydrostatic pressure (P), the result of the equation, is expressed in units of psi.

At a depth of 60 feet, with clean mud being an estimated 8.5 lbs./gal., the estimated pressure would be:

\[
8.5 \times 0.052 \times 60 = 26.6 \text{ psi}.
\]

The contractor mentioned at the beginning of this column wanted some assistance to maintain downhole pressure in order to not cause formation damage while drilling under the roadway. The reality is that, in order to do this, the contractor needs to fully understand and ensure the following: the drilling fluid’s functions and properties match the soil type; flow rate requirements are understood; and the speed of the drill is known and monitored, all while keeping circulation constant.

A small- to medium-sized HDD driller has some options to understand the downhole pressure while drilling. On critical pullbacks, there is special instrumentation that can be installed between the reamer and the pullback string. This instrumentation can provide real-time annular pressure readings. The speed of the drilling and volume of fluids can be regulated to keep pressure consistent and below a pre-determined value. Another option is for the driller to continuously measure the mud weight of the fluid returns at the exit pit. The weight of the returns can be an indicator of the downhole pressure. The higher the mud weight, the higher the annular pressure. Spending the time to understand the fluids required, the volume and speed of drilling, and the resultant annular pressure can make the difference between success and failure. This knowledge results in bores completed on time and on budget. Keep on turning to the right!

There are many nuances to any drilling project. It is always good to get these down on paper to make sure you don’t forget them. Boost your odds for success. Utilize drilling fluids as a tool to avoid trouble instead of an aid to get you out of trouble! now.