Mud, mud, glorious mud*

Posted by Heading Out on August 9, 2009 - 10:35am
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This is one of a continuing series of posts that I am making to describe some of the technology that is used in the production of fossil and other fuels. Last week's post on tri-cone and diamond drilling bit can be found here. That post, plus tech talks I have done in years past can accessed through this tech talk link. They can also be accessed by clicking on "Tech Talk" in the rectangle at the top of The Oil Drum home page.

In my post last week, I wrote about physically breaking the rock, either by pressing a series of small teeth set in rings around the perimeter of cones that rotate around the bottom of the borehole, or dragging diamonds that are attached to the bottom of the drill string. There can be different numbers of cones and in the picture you can see a bit with four. In this particular case we had added a nozzle set through the center to jet under the teeth as they cut into the rock. The reason for this is that if you wash out the crushed zone of rock under the bit, as it is formed, then you don’t re-crush and compact it and the bit can penetrate into the rock more easily and faster.

Experimental jets on a quadracone bit.

The jets both remove the crushed material and keep the bit cool, which is important if it is to remain sharp. (Removing the crushed material can increase penetration rates by a factor of 5, but that is another story).

The cones are mounted with their largest diameter running around the outside of the hole, and thus each cone will have the greatest number of teeth along that edge. We call the outside edge of the hole the **gage**, and the cones, bearings and mounts combine to form the **drill bit**.

Now if we just turned the bit round and round in the hole, it would start to drill into the rock, but after a short while the chips and crushed rock would fill up all the space between the bit and the solid rock, and the bit could go no further. We have to get the crushed rock out of the way, and preferably before it is crushed by the following bit tooth since that would also waste energy. And thus we have today's topic.

When the old miner was hand steeling, he could either blow the chips out of the hole with his breath, or wash them out with a squirt of water. On a more sophisticated level this still holds true, but with some differences. In very short holes, or special circumstances, compressed air can be used to blow the chips that have been cut from the rock (hence the name **cuttings**) up out of the hole. However as the hole gets deeper this becomes less practical and some form of liquid must be used. Again it could be water, but there are several reasons why this is not usually the case.

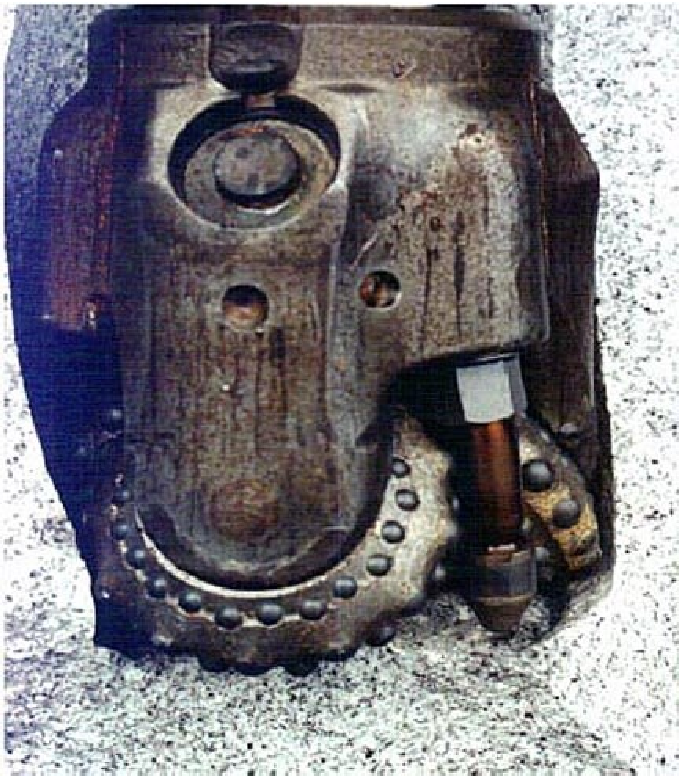
Firstly the rock is much denser than water, and so if the water flows back up the hole (usually in the space between the drill pipe and the rock wall, a gap often called **the annulus**), and the fluid is not moving fast enough, then the cuttings will settle back down the hole, blocking the gap and sticking the drill pipe in the ground. For this reason the water is usually mixed with very small particles of different types of material that will increase the density of the fluid so that it will help lift the cuttings all the way from the bit to the surface. This can be as far as 3 miles up or more (15,000 ft or so) and so it's important to choose the right density for these additional particles. Usually the particles that are added to the water are made from finely ground clays, and this makes a mud, and the fluid has thus now, regardless of what is in it, become known as a **drilling mud**. The mud has to be thick enough to help carry the individual chips to the surface, but, it also has to keep them held in suspension when the flow stops while another length of drill pipe is being added to the string.

The mud, however, has a few additional things that it must do as it is pumped down to the bit, through the inside of the drill pipe, and then **circulates** back up the outside carrying the cuttings to the surface. This circulation is sometimes reversed (i.e. **reverse circulation**) so that the mud flows back up the inside of the drill pipe, but this is not common.

The first thing that it must do (as mentioned above) is keep the bit cool. As the bit rotates, and the cones turn on their axes there is a lot of friction generated under the thrust being used to push the bit into the rock. Some of this friction will generate heat (in the same way as happens if you press your palms hard together and rub them back and forth). Because the bit is in a confined hole, without the mud there is nowhere for that heat to go, and so it would otherwise build up, until it got hot enough that the bearings failed, and the bit fell apart at the bottom of the hole. (This is not a good thing to happen, since how can you drill through the parts of a broken bit with a new one?) So the mud flow also serves to keep the bit cool enough to keep working.

But there is also a lot of heat that comes from the rock. This is because of something called the **geothermal gradient**. This is one of the last, almost untapped, sources of energy that we have. While it varies around the world, the numbers where I come from are these: At 500 ft below the ground the rock temperature is 60 degrees F. For every 60 ft you go further down, the rock temperature goes up a degree. So that if you are 1100 ft down, then the temperature is 1100 - 500 = 600 (extra depth)/60 = 10 extra degrees + 60 = 70 degrees F. And at 8,000 ft (a deep gold mine) it will be ((8000-500)/60) +60 = 185 degrees--which is why they refrigerate the air in mines that go that deep. And this rock temperature in deeper wells can also damage the bit. So the mud flow has to also take account of the depth and the rock temperature.

To keep the bit cool and carry away the cuttings the mud flow has to be quite fast. But there is a small problem that arises (and is not always fixed). As the hole gets deeper the weight of the mud in the hole will press down on the chips that are being formed by the bit. It will try and press them back down against the rock, (it is called **chip hold-down**). To stop that happening the mud has to be formed into a stream of fluid that can be pointed at the rock and (just as you move dirt with the pressure from a garden hose) will push under the chips and lift them into the circulating mud flow, as it then flows back up the annulus. To do this the mud feeds from the center of the bit out through a set of **jet nozzles** that point the streams down onto the rock. The deeper the bit is drilling, the closer the nozzles have to be to the rock, in order to reach through the surrounding mud liquid with enough power to lift the chips and get them moving when it reaches the rock.



Flowdril bit showing how close the nozzle is to the rock, just above the button teeth on the bit. In this case the jet is cutting a groove at the hole gage, which also improves penetration rate.

The third thing that the mud has to do is to act as a seal around the wall of the hole, where the bit drills through the different rock layers. As the hole gets deeper some of the rocks it will go through are very permeable. In other words the mud can flow into them, or water can come out of them. We don't want that to happen. If the mud flows into the rock, then it is lost, and the circulation of mud stops (its called **lost circulation**). Without the mud, the cuttings settle back down to the bottom of the hole, and the bit is stuck again. So to prevent that the clay particles are made large enough, so that if the mud starts to flow into the rock, the particles cannot enter the very small gaps in the rock. Instead they are filtered out and are left on the edge of the hole. As the water flows into the rock, leaving the clay behind, the clay builds up and forms a layer of clay along the rock wall. This seals the rock from the mud in the well, and stops the fluid from leaking out of the well.

To do all these things, with different temperatures in the well, different chemistries in the different rock being drilled through, and different fluids flowing into the hole, requires that the mud be very carefully selected for each job. And sometimes that chemistry may be such that simple water cannot be used as the carrier fluid. There is a shale in Texas, for example, called the Gumbo shale, that turns from a hard rock to mud (like a Louisiana gumbo); when it gets wet. So if you are drilling through it, either the water has to be treated with chemicals so that it stops being able to wet things, or you use a different base fluid, and change to perhaps an oil. There are a number of patents that deal with different additives to the mud, of which I have cited, for example, just one.

So making mud, and using it properly can be an ongoing job on an oil rig.

Again, if there are questions, or comments, let me know, since I tried to make this relatively simple, and may have gone too far for some of those involved.

* The hippopotamus song by Flanders and Swann