Turning an Oil Well and Down-Hole Motors

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Topic: Supply/Production
Tags: downhole motors, drill bits, horizontal wells, rospo mare, tech talk, turbines [list all tags]

This is part of the series of tech talk posts on how to get fossil fuels out of the ground that appear here most Sundays. In this post, I talk about several innovations in drilling, including **down-hole motors**. Among other things, down-hole motors made it possible to turn tighter corners with the drill bit, enabling horizontal wells.

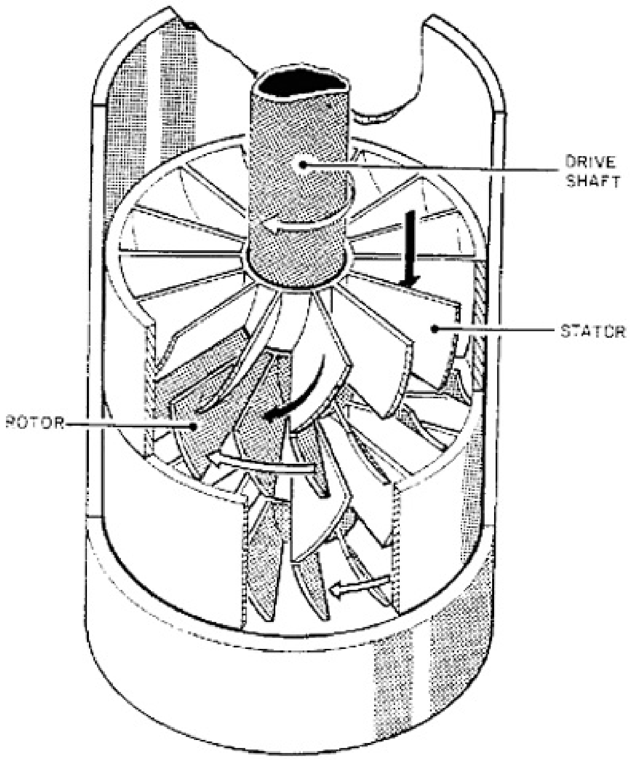
The last post in this series dealt with directional drilling, where I had mentioned the need to go back in time to the period where the then Soviet Government was developing the Volga-Ural basin in the Soviet Union, back in the 1950's. And I quote from John Grace's "Russian Oil Supply."

> In the Volga-Ural basin, however, particularly after recognition of the enormous potential of the deeper Devonian strata, drilling targets were further below the Earth's surface. Moreover, the older, more lithified rock of the Volga-Ural basin was harder. This required higher drilling torque, which in turn demanded superior strength drill-string steel. The Soviet steel industry was basically unable to provide high-strength drill string in volumes necessary to develop the basin.
>
> Engineers responded with **turbo-drilling**, which does not depend on rotating the drill string. Instead, immediately above the bit, they placed a turbo drilling motor, which itself did the work of turning the bit. This obviated the necessity of twisting the pipe and thereby reduced the required quality of steel.
>
> Turbo drilling radically increased the productivity, Combined with the growing number of rigs available, the total number of feet of development drilling conducted per year nationwide jumped from 1.9 million feet in 1949 to 7.1 million feet by 1950 and 12.1 million feet by 1960.

They were also developing waterflood techniques in the basin at the same time, and we have discussed that in previous posts.

The idea of putting a motor directly behind the drilling bit was not new, the first Russian turbine drill having been designed in the mid 19th century; however, it required a number of stages before the design could turn out enough power. And the first patent for an American downhole turbine was granted in 1873.

For those who are not familiar with a turbine drilling motor, essentially it consists of a set of fixed turning vanes at the top of the motor (the stator vanes) which direct the flow of mud going down the hole to flow onto a second set of vanes (the rotor vanes) which are pushed around by the flow, causing the drive shaft to which they are connected to rotate.



Single stage of a turbine motor, showing the stator and rotor vanes (Baker Hughes)

By combining a series of these stages together into a multi-stage turbine considerable torque, and speed, can be passed to the drilling bit which is attached to the rotating drive shaft.

Connection of a turbine drive to a drilling bit (Boraisegypt)

Putting the motor at the bottom end of the drill string had a couple of other advantages. One is that it allows the hole to **make angle**, i.e. to turn in a tighter radius than if the whole pipe were rotating. While conventional rotary rigs can build angle at only 10 degrees per 100 ft, with a down hole motor the angle can build at 13-15 deg per 100 ft. The Russian idea took a while to catch on in the West and to his credit, a guy in Houston called Bill Maurer, had a fair bit to do with that. Time and technology have however moved on a bit since then, and Bill's company was acquired by Noble Drilling Corp so I can't pass on links to the firm.

With the advent of down-hole motors there is no need to have the complexity of joining 30-ft lengths of drill pipe together to deliver power to the end of the bit. This had always been constrained by the steel strength and joint limitations. Now that could be designed out, and the power could be delivered to the bit hydraulically through the mud, since this could be used to drive the motor.

Later motors have included positive displacement designs, such as the progressing cavity motors which Dyna-drill illustrates with an animated figure at their web site.

For those interested in relative performance, and the gains that technology can bring there is a case study available of a well drilled with a down-hole motor and PDC bits with a rate of penetration (ROP) of 93.5 ft/hr.

Turbine motors work best at higher speeds, but to create the chips and achieve effective drilling with conventional tri-cones, rotation speeds had historically been slow. And the problem remained of creating the high thrusts across the bit that were required for this type of drilling, when the motor turned faster.

One answer came in response to a second problem. As the rocks that have to be drilled became harder, so the forces used to cut through them also went up, causing a materials problem. The materials used to make the drill bits were either wearing out, or teeth were being broken out as the bits pushed through the rock.

Worn out bit (Stavanger Oil Museum)

Drill with inserts knocked out (Stavanger Oil Museum)

Until now, we had tried to break the rock in compression by pushing the tooth into the rock. But if, instead, we dragged the bit across the rock without trying to chip it, in the same way as a metal-cutting bit on a lathe peels off a layer of metal, maybe we could lower the forces on the bit.

And if we used a diamond tool to do this, then while each diamond insert would only remove a very small amount of rock, we could impregnate a whole bit face with small diamonds (much cheaper than the single stone you buy for the intended, since they are much smaller, and more common). These diamonds can be dragged over the rock face and slice off very thin layers, but can do so when moved at a very fast speed. Putting the two together meant that a new drilling concept could be developed, and a new drilling bit.

Diamond drilling bit (Stavanger Oil Museum)

The next development came about with the development of larger polycrystalline diamond compacts (PDC's or PCD's depending on your level of technical correctness). By making these larger diamond coated discs and setting them on the drill bit it was easier to circulate the mud so that it kept the diamonds cool.

Used PDC bit (Stavanger Oil Museum)

This is important since, if you get the temperature of the inserts above about 3-400 degrees, the diamond starts to soften a bit and wears faster. In this regard the design of these bits is still not perfect, but it has become better.

The lower force required to drive these bits into the rock, and the ultimately faster ROP that they allowed meant that it became easier to consider turning the well, not only to some angle downwards to intersect an oil reservoir not directly below the rig, but that one could also turn the well so that it could be turned to the point that it was drilling a horizontal well.

And this had a lot of advantages – once the technique was developed. The first horizontal well that I know of was drilled at Rospo Mare in 1982, and it achieved a much higher initial and sustained production than vertical and slant wells in that reservoir. It was a technique also being developed for coal bed methane recovery, something still in development.

But I'll leave that development, and more until next time.

The list of talks is getting longer, and as we are also getting a little more complicated, it might be more useful for those just finding this series go to the tech talk series, and read the posts in order, starting with my August 6, 2009 post (found on sheet 2). Because this is a relatively informal it is also prone to the occasional short cut, which may not leave things as clear as I would like. So please ask, if I need to give more detail, or if you know more feel free to comment.