The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Water Floods and Improving Oil Flow

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Topic: Supply/Production
Tags: abqaiq, aramco, samotlor, tech talk, water flood [list all tags]

This is part of Heading Out's Sunday tech talk series.

I am going to insert a topic here before going on to Carbonates, as I had mentioned doing in the last post, because it will help to explain a developing problem that comes when extracting oil from rocks such as chalk. And, because I used this example in my original post, let me again start by creating an analogy.

The oil business is one of great complexity and there are some challenges even in trying to explain some of the basic reasons why, when price goes up, producers can't just turn a tap and pull more oil out of the underground reservoir.

I was trying to think of a way of explaining it, and offer the following, in the hope that not too many of those who know reality will be offended at the simplification.

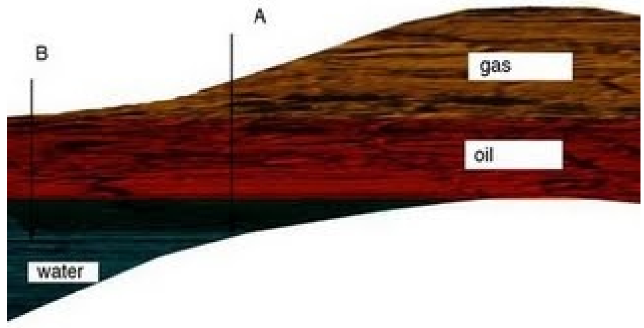
Way back at the beginning of the current Elizabethan era it used to be fun, after dinner, to float cream on top of coffee. I still do it when the cream is of the right sort, and it gives the coffee a different taste. Putting the cream over the coffee is a bit of a challenge, you start by using the back of a spoon, and when you get better pour it down the side of the cup.

So now we have quarter of an inch of cream floating, unmixed, on top of the coffee. This can be very simply considered to be the oil floating on an underground pool of water in the porous rock underground. Now take a straw, put it into the cream and try and remove it without sucking up any coffee. If you suck gently you might be able to get a lot of the cream up, especially if you bend the straw to run across the top of the cup. But if you suck too hard then you not only pull the coffee into the straw and can't get any more cream from that particular place, but you also mix up the cream around that point into the coffee, and you lose the chance to recover that cream later. Separating the cream from the much larger amount of coffee beneath it is not really an option (though as you will see it is needed with oil and water).

Oil is somewhat the same, in that, if you try pulling it out of the ground too fast, you can cause changes in the flow pattern that drop the total amount you can get out from any one well, and the immediately surrounding rock, pretty severely. I will return to this topic of fluid control in a later post (and yes I know, there is an alcoholic version of this example, but it would be (grin) socially highly irresponsible to encourage folk to try doing this with different layers of liquor - especially since I can't remember which colors you have to use and which liquor you have to float on which to get them to stay separate. Research may be needed.)

So, if we can't just change the differential pressure between the well and the surrounding rock to get more of the oil out, then how can we do it?

Given the volumes of space that the oil occupies, and the distances and rock it must pass through to get to the well, it would be easier if the oil continued to flow out of the well by itself. But if the natural driving forces that I mentioned last time (the pressure difference and the gas and water pressures) have all played their part then the next step is often to pump another fluid back into the ground to fill the space left by the oil and thus to recreate, or better to keep up the pressure in the oil, so that there is still a differential pressure that is pushing the oil out. So let's go back to the section of the rock that contains the oil, and which I have used before:



Simplified sketch of an oil bearing layer in the ground.

There are two ways to inject fluid to keep up the oil pressure. One is to pump in a gas, under pressure, into the rock just over where the oil is, and this will move the oil to the well. If you have that sort of imagination it is similar in effect to going from the small toy water pistol that I could just about hit my baby brother with when he was really close, and still a child, to now having one of those more modern Super Soaker water guns that pump air under pressure behind the water. Now you put out more water faster, and can hit that obnoxious kid over on the next block.

However when this is tried in an oil well, while the gas works, you have to get it from somewhere, and it also turns out not to work as well as pumping in water below the oil. And so pumping water into the ground is often used, after the initial pressure has dropped, to keep some pressure in the well and help with what is known as secondary recovery (the initial flow being called primary).

In developing the large Saudi oil fields Aramco decided to speed the process up by combining the water flood with the initial extraction since, in this way they could keep a higher pressure in the rock, and the oil would thus flow out faster (the Super Soaker approach). The idea, as I recall, originated in what was then the Soviet Union, water injection being used at Samotlor, for example, in the 1970's, for which I will quote from John Grace's "Russian Oil Supply", later.

It I possible, though it depends on individual project economics to also include a surfactant with the water (think detergent) so that the oil can be more efficiently driven ahead of what is known as a water flood.

When the technology was first developed pre-existing wells were used to pump water into the ground in a relatively localized operation so that, for example in the illustration above, I might use four wells surrounding well A to inject water so that locally I could raise the pressure, so that A would continue to produce.

However, with larger fields this tends to be less efficient, and so what is now more common in larger fields, is to start at the edge of the field , say at B, and inject water along the edge of the field. This not only increases the pressure in the overlying oil, but also, as the water level rises, it helps “sweep” the oil from the edge of the field up towards the center. Thus, over time, the oil would pass the well at A, and a new well would be drilled closer to the crest of the field, while A would then become a water injection well.

Now there are two problems (this being a simple explanation) with this way of increasing production. The first is shown with a simple mathematical calculation. Let us say the original well at A was drilled through 100 ft on oil bearing rock. At a given differential pressure the well produced some 100 barrels a day. Now we inject water under the oil, and this replaces the oil as it is removed. So, after a while the bottom of the oil layer in the well has risen by, say 25 ft. With the layer under that now being water. If we maintain the same differential pressure across the well, we will see a 25% drop in production, because we are now only drawing oil from the 75 ft of rock that still has oil in it. We will also see additional water coming out of the well with the oil.

Initially this might not be much of a problem – but over time this “water cut” can become very significant. Here is that quote from John Grace:

> Water cut also played a major role (in the collapse of Samotlor production). The water injected into the ground with such fervor in the seventies had to be pumped back to the surface in the eighties. Water climbed from 24% of the fluid lifted by Samotlor’s wells in 1980, to 68% by 1985 – an extraordinarily quick rise. The field was drowning in water, all of which required pumping, and processing to recover any oil.

The current water cut at Samotlor is around 90%.

Saudi Aramco, as I mentioned, also extensively uses water flood to assist production. Some of the most productive regions have been the Ain Dar/Shedgum portions, which are to the north end of the main field. These are the regions that have been producing at around 30% water cut, and are some of the oldest of the producing regions of the Kingdom, with a current water injection rate of 2 mbd It is thus interesting to see look at the new water pumping stations that are being installed. The new construction for the Qurayyah Seawater Treatment Plant to be used to supply seawater for the Khurais expansion that has been put in and will provide the fields with 4.5 million barrels of water, to help in pressure maintenance and production. The overall water capacity of the plant has, however, grown to 14 mbd. Of this flow some 2.5 million will now go to the Ain Dar/Shedgum fields.

(Note I will try and remember to update a sort of “worked example” of all this with Abqaiq that I have previously posted next time) to help make this perhaps a little more real.