The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Tech Talk - Improving Horizontal Well Flow at Berri and Ghawar

Posted by Heading Out on April 30, 2012 - 7:06pm
Topic: Supply/Production
Tags: acidizing, berri, ct, ghawar, rotating jets, saudi arabia, tractor [list all tags]

The very size of oil reservoirs in Saudi Arabia means that as the dominant method of water flooding is used to sweep oil to the producing wells, not all the oil in place migrates as hoped. Some remains in place and this makes up a very significant volume of possibly lost production. This is particularly true in reservoirs such as the Hanifa and Hadriya reservoirs at Berri, where water flooding since 1975 has largely obscured the field. Recognizing this problem, Aramco has increasingly used sophisticated mathematical models of various reservoirs to help locate these remaining pools, searching for oil volumes that could be successfully recovered.

As the models were increasingly able to divide the reservoir into smaller and smaller fractions over time, the presence of these pools became increasingly apparent. Definite proof of their existence then came through drilling. Here again, the change in technology in the use of horizontal wells has allowed the recovery of volumes of stranded oil from thin layers that would have been more difficult to recover had technology not advanced. The first test of this was at Berri where the field modeling was changed from a 14-layer to a 128-layer model, revealing accessible "lost" oil. Five wells were drilled into the region and all yielded oil for a total of 17.4 million barrels by 2007, when the wells were still producing. This capability has extended the life of the Berri field, capturing much of the oil that would otherwise have been lost.

One of the problems, however, in changing to the use of the horizontal wells has been that the well diameter is reduced and as a result the ability to do remedial work on those wells as required was limited at first. The three techniques that are now being aggressively used in these cases include acidizing, advanced hydraulic fracturing, and hydrojetting. And since this latter is an area in which I “wrote the book” and controlled crack growth demonstrations led to the only time I was picketed by a union, I thought I would spend today's post explaining a couple of these developments with fluid treatments, which aren't often as simple to apply as they may appear. Next time I'll finish up with some thoughts on improving hydraulic fracturing, and the possible benefits of using carbon dioxide as the fracking medium rather than other fluids.

The problem of scale in the pumping of fluids into the reservoirs and the flow of oil out is that the quantities dealt with are significantly larger than in most other countries. Flow levels are required to reach over 10,000 bd, both in oil recovery and in the relatively precise location of water injection to sustain reservoir pressures. This led Aramco to adopt horizontal well technology, not only for the recovery of oil, but also in the injection wells that are used to inject the seawater.

Horizontal wells in carbonate are prone to well damage around the borehole due to the drilling process, and this initially limits the flow of fluid through this annulus, or requires a higher driving pressure to inject the water into the formation. In one example, it took an injection pressure of 2,350 psi to drive 13,000 bd through an exposed horizontal open hole section some 8,900 ft long. In order to improve the performance of the well, it was to be treated with an acid bath to remove damaged sections of the wall, and also to eat wormholes into the formation. Where the wells are draining gas, it is not that difficult to bullhead the acid into the well where the acid is injected to allow the well to fill for a couple of hours before being removed. This can be successful in wells where the use of coiled tubing (CT) is limited and flow rates would otherwise not be as high as needed for an effective cleaning. But this requires considerable volumes of acid, and in filling the entire open hole there is the risk of differential attack along the walls, providing an undesired result. The alternative was to use the smaller diameter of a coiled tubing rig and to feed this first to the back of the hole, and then inject acid as the coiled tubing was pulled out of hole (POOH). However, it is sometimes a little difficult to feed the smaller pipe down the open hole all the way to the back because the diameter limits the rate at which acid can be injected. Thus, there was a debate as to which method would be the best to use.

Aramco has used two ways to get around this problem. The first was to use a down-hole tractor to overcome the frictional forces that were otherwise stalling the placement of the CT by overwhelming the driving force before the tool could reach the back of the hole. The tractor has a small series of wheels that are recessed within the tool while it is fed down the well to the point where it is deployed.

Figure 1. Down-hole coiled tubing tractor (Welltec)

> When the CT Well Tractor is initially powered up, the wheel sections are hydraulically extended out of the tool body and activated automatically. Each wheel contains its own independent hydraulic motor, which drives the wheels and provides the forward motion of the CT Well Tractor. . . . . . The modular structure of the drive sections makes it possible to change the traction by reducing or increasing the number of wheels needed to drive the toolstring. The CT Well Tractor 318 can provide a pull of 3,500 lbs, which doubles in tandem configuration. This can further be increased to 10,000 lbs by stacking three CT Well Tractors.

The first major test of this was in the 8,900 horizontal section water injection well I referred to above. That section of the well was divided into 16 sections, each of which was treated as follows:

> 1. First, the treatment interval has to be washed with plain 20 wt% HCl for filter-cake clean up and provide initial wormholes. The main additives to the plain acid are a corrosion inhibitor, surfactant, and friction reducer. Plain acid was used at 10 gal/ft, including additives, resulting in a total acid volume of 77,000 gallons.
>
> 2. Plain acid was followed by 20 wt% diesel emulsified acid at 20 gal/ft with a total of 154,000 gallons for the 16 treatment stages. The higher concentration of retarded acid is meant to provide deeper wormholes.
>
> 3. To achieve better acid diversion at the end of each pumping stage, viscoelastic surfactant-based (VES) water will be used at 10 gal/ft at a total volume of 7,500 gallons.

4. Finally, water over-flush of 10,000 gallons is to be pumped following the previous 16 treatment stages to break micelles formed by VES. The over-flush contained brine water mixed with 3 vol% of mutual solvent.

The total treatment fluid to be injected in this job is 248,500 gallons; this large acid job is considered one of the biggest stimulation jobs for any well in the Ghawar field.

There were a couple of glitches with running the tool, in that the well had washouts that took a "flying leap" for the tractor to get past and it was not able to reach the last 3,000 ft of the well, which was bullheaded. Nevertheless, after the treatment the flow injection rate for the well was increased from 13,000 barrels of water per day (BWPD) to 28,000 BWPD.

In a consequent test of a multilateral water injection well, some 362,700 gallons of treatment fluid were used to acidize a dual lateral horizontal water injection well with a total horizontal interval of 10,335 feet. Prior to the treatment the well required an injection pressure of 2,100 psi to inject 15,000 BWPD into the formation. After the treatment the two laterals were able to inject 30,000 BWPD at 700 psi driving pressure, and at 2,100 psi the wells became capable of delivering 80,000 BWPD. This saved the cost of adding two additional wells in the neighborhood.

The use of these large volumes of acid carries burdens with it, and in much the same way as the chemical industry has moved to the use of self-rotating high-pressure jets to clean heat exchanger tube bundles and other tubulars, so this tool also became available for use downhole. I am going to use one of StoneAge illustrations to show how these work, since they pioneered a lot of the development of these tools for the industry. (You should also know that I have done a small amount of consulting for this company).

Figure 2. StoneAge "Gopher" showing the nozzle array at the front of the tool (StoneAgeTools)

In normal jet cleaning operations, the head would be fixed and the jets would clean only where they impacted along the walls of the tube. But by housing a bearing within the body of the tool, the front head can rotate, and if the jets are turned so that their axes lie slightly offset and angled to the central axis of the head, then the force of water leaving the orifices becomes high enough to rotate the tool (quite fast), spinning the jets across the surrounding surface.

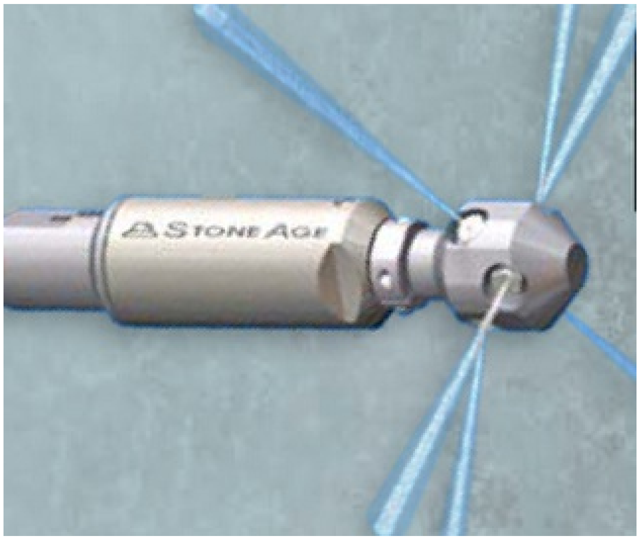

Figure 3. Representation of the jets from the Gopher, showing that they are slightly offset so as to cause the head to rotate, and the jets will sweep the entire surface of the tubular (or hole completion) as the tool advances/retreats. (StoneAgetools)

The technique that works for clearing the horizontal sections for water injection obviously also can be used to clean producing oilwells to enhance their productivity. Because the zones that are now being developed are much smaller, as these are often the trapped oil left after a water flood with very tight geometric constraints where the acid must be applied, bullheading is still being successfully used. However, it is in the placement precision of the rotary tools and the total coverage of the interval in which the benefit is becoming apparent. The tool is obviously somewhat more complex than that used on the surface, but operates under the same idea of jet thrust, causing the head to rotate.

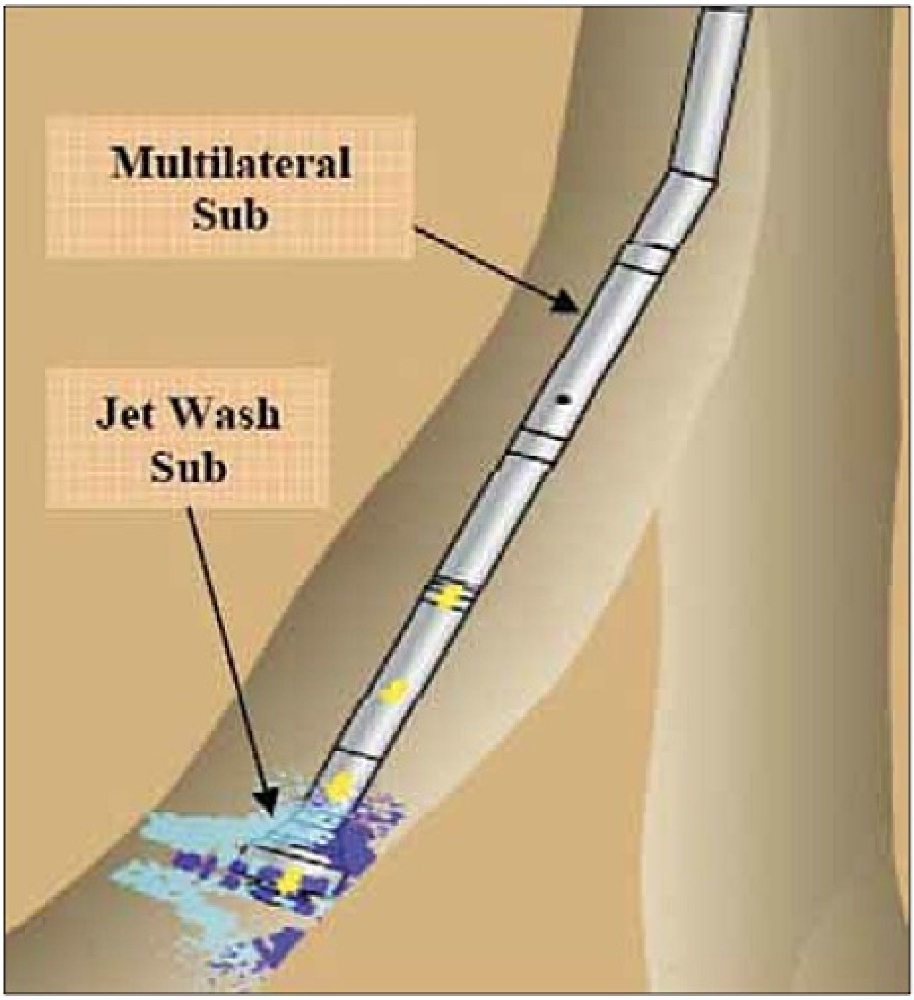

Figure 4. Downhole high-pressure rotating tool for acidizing holes ([Al-Buali et al](#))

Note that because the orifices are larger for this tool, the jet pressure drop across the nozzles required to make it rotate was 1,900 psi, at which pressure the tool was delivering 1.5 barrels/minute of treatment fluid. This dual-lateral well had been shut-in because of formation damage and after treatment, produced at 11,000 bd.

The equally significant number is that the amount of treatment fluid required was reduced by 70%, and that at a 7,000 ft interval, only required 42,000 gal of 20% nitrified hydrochloric acid.

As the main reservoirs in Ghawar are filling with water, it is through techniques like these that the oil left behind can continue to be recovered at a significant rate. But each of those reserve pools in itself is not that large a volume.