E&P - Drilling to the max.
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Modern drilling technology is now allowing field operators to create production wells with immense exposure to pay zones, writes Gordon Cope. But will maximum reservoir contact (MRC) wells turn out to be a boon, or a curse?

In the last several years, an exciting new drilling technology has been hailed as a way to rejuvenate production in everything from offshore fields in the North Sea, heavy oil in Venezuela and mega giant projects in the Middle East.

Maximum reservoir contact (MRC) wells - also known as horizontal, multi-lateral wells (see also p16) - are essentially horizontal production wells with several lateral offshoots. While a conventional, single horizontal well might be in contact with the reservoir for a total of 2,000 ft, an MRC well typically has a total reservoir contact greater than 10,000 ft.

The goal of an MRC well is to increase production of a field, yet do it at a lesser overall cost. A single horizontal well, for instance, might have to penetrate 3,000 ft of non-productive overburden before it is then drilled horizontally through 2,000 ft of pay. An MRC well, on the other hand, only penetrates the overburden once before splitting off several times in the pay zone. 'If you can get 2,000 ft of contact in five wells and 10,000 ft of contact in (an MRC well), then you only have to drill one well,' says Guy Arrington, Manager of Drilling & Measurements for Schlumberger Canada.

The arithmetic might be simple, but the execution requires a complex series of steps. Each well is custom-designed to take into account the properties of the reservoir, hole stability, potential formation damage, interference with offset wells and comparative economics with alternative production methods (such as fraccing). The drilling itself requires advanced equipment owned and operated by only a handful of service companies around the world. If done correctly, production (when compared to a single, horizontal well), can increase by 200-600%. When done incorrectly, however, it can lead to sanding in, watering and permanent loss of portions of the reserves.

Knowing when to drill MRC wells and when to eschew them is the province of experts like Dr Kenny Adegbesan. The Calgary-based reservoir engineer is a horizontal well specialist with KADE Technologies. In addition to teaching horizontal well engineering at the University of Calgary, he has consulted with oil companies around the world. In his opinion, several factors make reservoirs good candidates for horizontal, multilateral wells.

'A thin reservoir is a positive factor, because you have tremendous economic leverage (when comparing horizontal wells to vertical). With the quality of geo-steering, you could manage down to 3 metres (of reservoir thickness) without hitting the reservoir cap or aquifer.' Carbonate reservoirs have their advantages, because if the reservoir is damaged during drilling, one can do an acid frac to repair permeability.

On the other hand, there are many types of reservoir in which MRC wells are not recommended. 'If a reservoir is very stratified (alternating shale and sand, for instance), then vertical permeability is low and there is little advantage to a horizontal well,' explains Adegbesan. Oddly, thicker reservoirs are also less attractive. 'A thick pay zone means good contact in a vertical well, so a horizontal well is not as economically advantageous.' Lithological stability of the reservoir is also very important. 'With a vertical well, you normally cement and perf, but it's too expensive for a long horizontal well. Sandstone (under openhole conditions) can break off and sand in a well.'

However, most geological provinces have good candidates for MRC wells, however. Saudi Arabia, in addition to having the world's largest reserves of conventional oil, also has many attributes amenable to horizontal, multilateral wells. 'They have good permeability compared to North American fields,' comments Adegbesan. 'Many fields are well consolidated, which creates good stability, and they have a relatively low stratification problem.'

Shaybah field

Saudi Aramco first began to explore the value of MRC wells at Shaybah, a 14bn barrel field located in eastern Saudi Arabia. The field, discovered in 1968, contains 42 deg API oil in low permeability carbonates and has a large overlying gas cap and underlying aquifer. In order to mitigate gas encroachment and to achieve high production rates in a low permeability formation, single horizontal wells were drilled in the mid-1990s and the field put into production. After a comprehensive study of the field and its production, a decision was made to drill an MRC well in 2001.

In a paper presented to the Society of Petroleum Engineers in 2003*, Nansen Saleri, Manager of Saudi Aramco's Reservoir Management Department; Salam Salamy, a Senior Petroleum Engineer; and Saud Otaibi, General Supervisor of the Gas Reservoir Management Division, outlined the process. Starting in 2002, a main wellbore (also known as a motherbore), was drilled to the target formation, where special 'geo-steering' equipment was employed to continue penetration into the reservoir.

While horizontal drilling with a downhole motor has become relatively common in the oil industry, there are only a handful of service companies worldwide, including Baker Hughes, Sperry-Sun and Schlumberger, that possess the suite of tools and software to drill MRC wells. 'Motors are old technologies, and still the most common,' says Arrington. 'Rotary steerable systems (RSS) are the next generation.'

RSS tools are similar to standard drilling systems in that the drill bit is rotated by the drillstring, which gives a smoother, cleaner wellbore with less torque and drag. It differs from a conventional system in the manner in which the drillbit is aimed, however. Schlumberger's system, for instance, uses three exterior pads sitting directly behind the drillbit to deviate the direction of drilling by applying directed pressure against the rock. It does so using an internal valve that controls the flow of mud to pad actuators. As the bit rotates through each revolution, the pads are extended and retracted in sequence to provide consistent pressure against one side of the wellbore. The bit can thus be deflected in a smooth, continuous arc.

Obviously, for the MRC well to be productive, it must remain within the confines of the pay zone. Too high, and the wellbore is exposed to the gas cap, which can cause slugging in the production stream. Too low, and it runs afoul of the underlying aquifer. Too wayward, and it penetrates into unproductive lateral rock. Keeping it just right means knowing not only where it is at all times, but what it is in, as well.

The where is controlled by a location unit positioned as close as possible to the drill bit. The most advanced units, generically known as measurement while drilling (MWD), contain direction and deviation sensors mounted on bearings within the drill collar. This allows the sensors to remain stationary so that they can take tilt and azimuth measurements while the drillstring is rotating.

The what is supplied by logging while drilling (LWD) devices. The LWD suite includes most of the conventional wireline logs, including resistivity, density-neutron and sonic devices. They can be used to provide comprehensive geological and petrophysical evaluation, allowing the operator to identify approaching formation contacts by distinguishing lithological changes in four directions (up, down, left and right). Thus, a drill bit that is approaching a shale layer overlying the carbonate reservoir is able to distinguish the fact, and the driller can alter course. It can also be used to steer the drill bit toward higher porosity.

Such information, of course, is of dubious merit after the fact. The bottom hole assembly (BHA) is thus invariably equipped with either mud pulse telemetry or e-pulse (low-frequency electromagnetic waves that pulse through the rock) communication systems. As the drill bit advances, the systems allow MWD and LWD information to be transmitted uphole in real time, as well as new commands to be transmitted downhole to the tool.

At Shaybah, MWD and LWD information was sent by satellite communication from the rig site to offices in Dharan, Saudi Arabia. The live link allowed real-time, 24/7 well geo-navigation. No major problems were encountered during drilling or post-drilling, and by the end of 2003, nine MRC wells were completed and placed onstream. Initial studies show that all the wells experienced significant gains in productivity and reductions in unit development costs.

In their paper, Saleri et al noted that, at Shaybah, a conventional horizontal well with 3,280 ft completion produces 2,000 b/d of oil. An MRC well with 25,584 ft pay zone exposure produced 12,000 b/d. The initial cost of drilling the conventional horizontal well amounted to $1 per b/d output. The comparable cost of the MRC well amounted to 38 cents. Saudi Aramco's successful experience has since been applied to the Abqaiq and Ghawar fields.

A quibble with Yibal

As previously reported in Petroleum Review**, however, MRC wells have their detractors. Matt Simmons, President of Houston-based, private investment banker Simmons and Co, took issue, in part, with modern technologies during an evaluation of Middle East reserves and production life. In a February 2004 review presented to the Center for Strategic and International Studies in Washington, DC, Simmons expressed a pessimistic interpretation regarding the prospects of Ghawar, Saudi Arabia's (and the world's) largest oil field.

As part of his thesis, he pointed to Saudi Aramco's increased use of MRC wells, declaring that, although the wells can maintain and even increase production, they rarely augment total yield, and in fact may hasten decline.

As an example of what can go wrong, Simmons pointed to the Yibal field in Oman. First drilled in 1962, Yibal was produced using a standard system of water injection and pressure maintenance through vertical wells. The field began to experience problems after 1990, however, when horizontal wells were introduced. Production at first rose, peaking at approximately 250,000 b/d in 1997, then began to decline at a rate of 12% per year.

By 2003, Oman officials noted, the field was producing in the range of 90,000 b/d. About 90% of the liquid coming out of the ground at Yibal is water, and the remaining 10% oil. (It was speculated that the high volume of water comes in part from the water injected into the ground as part of its horizontal drilling technique. Regardless, the water adds considerably to the costs of extracting the oil). 'Instead of creating easy supply growth, the technology revolution created monstrous decline rates,' said Simmons.

Saudi Aramco officials were quick to refute the charges, asserting that their estimates of reserves and petroleum engineering practices were sound.

In a recent interview with the Oil & Gas Journal, company officials noted that Shaybah's current production of 560,000 b/d (with a water cut of approximately 10%) was achieved with 70 wells less than the original estimate of 170 wells, thanks largely to MRC technology. Furthermore, the output could be expanded to 1mn b/d with little risk of negative impact to the reservoir.

But the question of Oman's Yibal field lingers - What reservoirs make bad candidates for MRC? Part of the problem, says Adegbesan, could be related to the amount of energy

coming from the oil or aquifer. 'If you drill into a new field and the initial oil pressure is high, is it due to the oil, or the aquifer? If initial assumptions overstate oil energy, the field can water out earlier than expected.' Another problem could relate to production history. Yibal was produced with vertical wells for decades before horizontal wells were introduced. Generally, layers of high permeability deplete first, leaving residue oil in areas of lower permeability. Later, if a decision is made to drill horizontal wells into the areas of lower permeability to recover the residue oil, water that has displaced oil in the depleted high permeability zones may enter the new wells.

The future

So far, the number of horizontal, multilateral well completions has been relatively low, but, where proper preparation has been done, MRC drilling has proven itself to be cost-efficient and safe. Drilling experts expect usage to expand in the coming decade, first in areas where production drilling costs are relatively high. 'In the North Sea, for instance, you can drill from one platform and save costs,' says Adegbesan.

Regions that are already adopting MRC will also become more comfortable with the technology. 'Early on, there were a number of mistakes made,' says Adegbesan. 'In the Middle East, as we get more and more experience, we will know better how to manage them.'

Finally, economics will play a huge roll in their expanded use. Adegbesan notes that completion of multilateral wells can range from a simple open hole to sophisticated production modules that allow each lateral to be independently produced. 'The higher up you go, the more expensive it gets, but in the future, we will have advances in drilling and production that will make it cheaper, and you'll have more multilateral wells. We will also see advances in geological sciences and seismic as they relate to reservoirs.'

*'The expanding role of the drill bit in shaping the subsurface', Nansen Saleri, Salam Salamy, Saud Otaibi, SPE 84923.

** 'A tale of two planets', **Julian Darley**, Petroleum Review, April 2004.

Intelligent completion specialist WellDynamics recently installed the first SmartWell(R) completion in Saudi Arabia - in a trilateral maximum reservoir contact (MRC) well in the Shaybah field for Saudi Aramco. The SmartWell technology provides inflow control from each lateral branch, resulting in more efficient clean-up, stimulation and production control for the life of the well. The Shaybah 119 completion is a three-lateral SmartWell completion, employing hydraulically actuated interval control valves with Accupulse(TM) to allow selective variable choking of each of the laterals, without costly intervention.

Dr Nansen G Saleri, Manager of Reservoir Management at Saudi Aramco, said: 'Advanced well completion is one of our technology focus areas and we firmly believe

that SmartWell technology will contribute to our goals of improved reservoir management with maximum recovery while reducing well count.'.

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