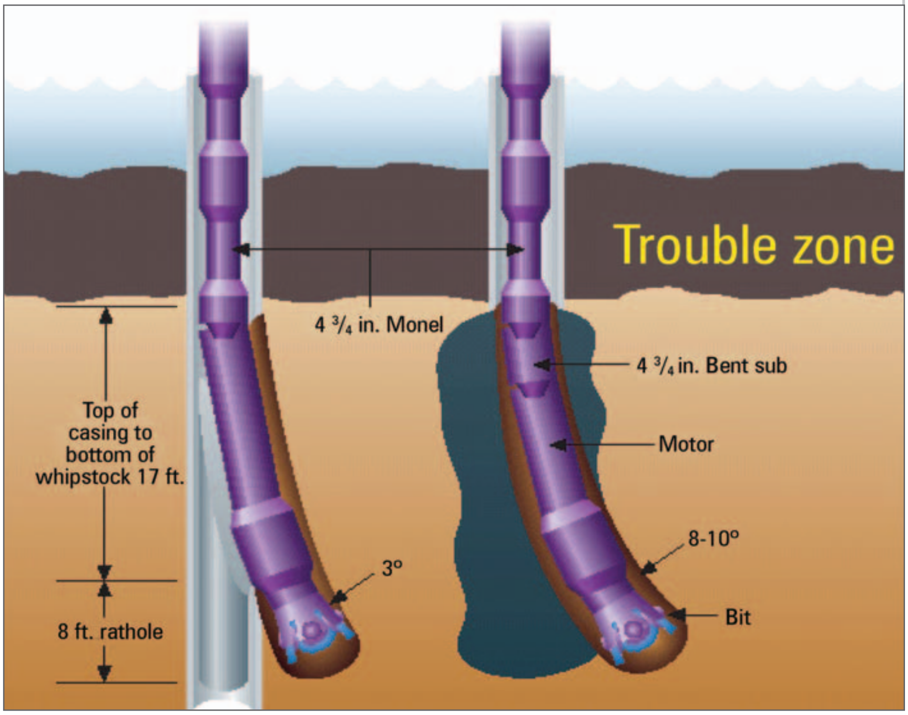
Short-radius drilling: a decade of development

By Charles Ingold, Schlumberger

THE SHORT-RADIUS technique offers many economical and technical benefits. It may allow drilling within the same zone (one-mud system) using one casing only. This may be a great benefit when a depleted sand is located below a pressurized shale. Production can be maximized where lease lines limit displacement. Drainage below a platform can be improved. Collision risks in congested area can be simplified. On a re-entry well, the correlation with straight-hole logs is easier since entry point is close to the wellbore; hence a pilot hole may be avoided. In the case of an existing straight hole abandoned, the only way to drill horizontally may be to use short radius.



Section mill allows kicking off closer to the trouble zone and allows drilling a tighter curve than a whipstock.

REDEFINING SHORT RADIUS

Curves as low as 28°/100 ft should be classified as short radius for a simple reason: The "take off" distance may transform a medium radius into a short radius. Maximum hole size is normally 6 1/8. Short-radius curves should integrate fatigue, ability to rotate and drillstring limits. Pipe rotation is allowed (basically up to a 70-ft curve). The upper limit for a short radius is 40 ft when a motor is used. Pipe rotation is normally not feasible. Some techniques have allowed 30-ft and even just 1-ft radius. The control of the azimuth with these techniques is often poor.

FATIGUE CONSIDERATIONS

In short-radius wells, drill pipe (DP) is a consumable. Above 80°/100 ft, rotation is not practical with 3½-in. DP. At 95°/100 ft, 2 7/8-in. DP will last longer than 3½ in. at 80°/100 ft. Fatigue is a problem especially when pipe rotation is allowed in a corrosive environment. The combination of stress and fatigue (stress fatigue corrosion) is often difficult to model.

Lab tests have showed titanium has fatigue life about 10 times that of steel; it is very resilient to corrosion. As such, Titanium DP should be considered for short-radius wells drilled in a corrosive environment. The added benefit would be the lighter weight of the string located in the lateral

DRILL PIPE DEVELOPMENT

Special DP can be used. They are equipped with stress relief grooves as recuts of thread are unlikely. They have shorter tool joints and an 18° shoulder. The thread and the torque shoulder are optimized to sustain higher strain. The idea is to impede the connection from opening and guarantee a smooth transition of stress to the tube.

TYPES OF WINDOWS ON RE-ENTRY WELLS

Section-milled windows take longer than whipstocks. They allow starting higher, thus reducing BUR. On the same well, there could be a difference of 7° at the equivalent "whipstock rathole" depth.

When a whipstock is used, undercutting may occur as much as 3 ft above the top. This is important to avoid in case of a water zone. Two-trips whipstock require less rathole than one trip. A long rathole increases BUR needed and implies drilling a tighter curve. Two famous "one trip whipstock" have the first two mills undergauge. Consequently the top mill needs to pass the bottom of the whipstock. This means loosing as much as 9 ft of TVD. On a semi-straight hole, 9 ft of TVD lost equates to 11° DLS extra (in a 70-ft curve). For a 40-ft curve 9 ft TVD lost equates to 40° DLS extra.

A whipstock set wrong has a negative impact in the quality of the curve — initial azimuth is important. The milling techniques used can transform a medium radius into a short radius and vice versa. On the average job, this is what happens, with a whipstock:

- The first 60 ft are drilled without reliable azimuth data (unless steering gyro is used).
- The first valid azimuth appears with 45° of drift at the bit.

With section milling (45 ft):

- The first 25 ft are drilled without reliable azimuth data.
- The next 29 ft (25 ft to 54 ft) are drilled with valid azimuth data.

There will be dependable MWD readings sooner. As the DNI passes close to the bottom of the window, tool face will be in gravity mode. The section mill technique will require less gyro surveys than a whipstock.

OPERATIONAL CONSIDERATIONS

The biggest difference in azimuth may happen at the start. Using a "steering type gyro" (especially with whipstock) eliminates this risk. Short-radius motors are less powerful but BHAs are limber.

Minimum DP should be run above the motor on the first BHA to minimize reactive torque. It is better to drill slower until a clean TF is obtained. A large azimuth error may require a cement plug. Short radius is like drag racing — there is no cure for a bad start.

SURVEY PROBLEMS

Having the exact landing azimuth is hard on an SR well. Initial orientation can be off, and the curve may call for a build and turn.

Light magnetic interference may be experienced at the beginning (external interference). The proximity of the DNI to the motor at the landing point (or at high inclination) may cause drillstring interference. Fortunately, a 5° error in azimuth has limited impact on 150-ft curve. The DNI spacing should be optimum on the rest of the well. Better tools have made this technique easier to control.

- The use of "continuous inc" on modern MWD reduces surveying time (no more 5-ft stations)
- Steering gyros are of great help, especially with whipstocks.
- Lateral drain is surveyed just like a long radius.

MOTORS USED

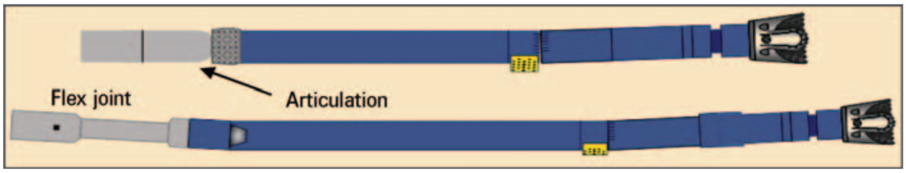
The techniques considered here require a motor. There are motors usable in short-radius wells similar to those used in medium-radius wells. They may be single or double bend and may have a short bearing pack. Some models have a short power section and an articulation on top. These motors are good up to 50º/100 ft. Even though DLS in excess of 50º/100 ft are achievable, the drawback is the limited "pass-through."

For 80º/100 ft DLS, double articulated motors work better — they are easier to run in the hole and do not require any "downsizing."

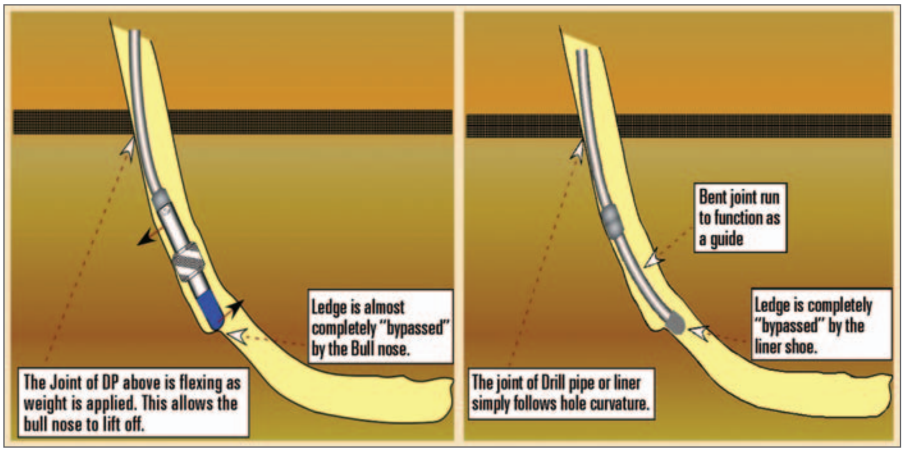
Generally, double articulated motors work great in sliding mode but are unstable in rotary mode. Single articulation motors with adjustable bend work opposite.

DOUBLE ARTICULATED

- Drill the tightest curves without downsizing (just 1/8 in.)



Adjustable bend motors should be limited to 50°/100 ft without downsizing and can be single bend or double bend with short or long power section.



Two solutions exist for a "step" or ledge in the curve: near bit plus bull nose (left) or liner run with a bent joint (right).

- Drill better curves (no hanging). No substitute above 70º/100 ft.
- Poor sidetracking capability.
- Do not respond well to time drilling.
- Unstable in rotary mode.
- Power is limited.
- Very sensitive to calibration.

It all boils down to bit offset. A large bit offset allows time drilling. A small bit offset does not.

SINGLE AND DOUBLE BEND

- Easy to use (no calibration).
- Stable in rotary mode (single bend only).
- Good sidetracking capability.
- Better power with regular power section.
- Hard to run in the hole on high BURs.

ULTRA-SHORT RADIUS

Ultra-short radius is normally drilled with double-articulation motors. Fixed-bend motors usually require a huge casing clearance. The problem with USR is the lack of rotation. Hence the double-articulated motor is the only option to drill the lateral. The curve is too tight for a regular motor to be run. There is no other way but to drill a tortuous lateral (usually not exceeding 500 ft). Mechanical systems using ultra-flexible BHAs and strings are limited as far as azimuth control.

NUMBER OF RUNS

A curve requiring 80º/100 ft can be drilled with two runs. In practice, a third run using a fixed-bend motor in conjunction with a longer power section and a flex joint may result more economical in hard rock.

BITS

Bits used to drill the curve may have to be less aggressive because motors are less powerful. Bits should be short with short gauges. There are bulky tricones unusable in SR curves. The wrong bit can decrease BUR by 10% to 15 %.

COMMON PROBLEMS

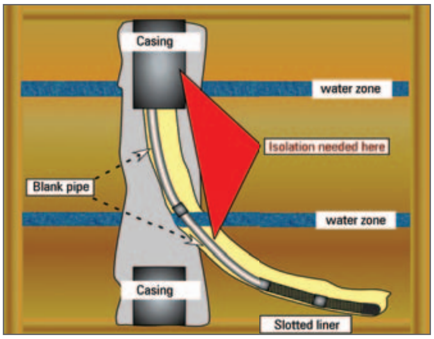
Any trouble in a tight curve is harder to deal with. A joint of DP always breaks within 3 ft below or above a tool joint and most likely in the curve. All of a sudden, running an overshot becomes impossible (even a "short-catch" overshot run on DP may not go through). This is where the use of an articulated overshot may solve this problem, a field-proven technique).

When reaming is needed in the curve, the side forces become excessive. The same solution can be applied on a "hole opener" with the articulation of a motor. Minor downsizing (6-in. bit after a 6 1/8-in. bit) may reduce risks of accidental side tracks.

COMPLETION SOLUTIONS

There may be some stringent completion limits. The size of the liner is often the same size as the DP. (For example, 6 1/8-in. hole drilled with 3½-in. DP and completed with 3½-in. liner). The best well is only as good as the completion. If the liner cannot be run, the well is useless. In the case of liners hanging in the middle of a curve, solutions have been developed (see illustrations).

There may be one or several water zones to isolate, including in the middle of the curve. A water zone can be sealed off with a mechanical system (inflatable packer, cement). It can also be sealed off by injecting a polymer that reacts with water. In practice, these techniques are risky. The packers may fail. The injection of polymer may not work and may cause a sidetrack.



Shutting off water: In this example, the easiest solution is to run two packers, one in casing and one in open hole.

"Hydrocarbon-absorbing packers" have been successfully tested, though not in short-radius wells.

LWD

In short-radius curves, LWD is limited to Gamma Ray in 5 7/8 to 6 1/8 hole size. There are resistivity tools for smaller hole sizes (3 ¾ to 4 ¾) that can take 100º/100 ft. Resistivity tools capable of taking 50º/100 ft would be a nice addition for 6 1/8-in. hole size.

CONCLUSIONS

Many principles are reversed with short radius (short tool joints and short cross overs are better). Tools considered obsolete (section mill, two-trips whipstock) are actually better. DP can be considered a consumable. Titanium DP will be a benefit in corrosive environments and should allow breaking multiple records. (Note: Titanium motors have been used.)

Rotation of composite DP will induce external wear, which may weaken composite material.

• The double-articulation motor is unstable in rotary mode.

• Critical buckling values should be known.

• The completion is often the limiting factor.

• SR seems to be a natural complement to TTRD.

Acknowledgments: Many thanks to Pat Tracy and Warren Askew.

References:

SPE 35049: "A Predictable and Efficient Short Radius Drilling System," W. Askew, P. Tracy, V. Koval, D. Hill-

SPE 39023: "A Successful Short Radius Reentry with Aerated Mud," C. Ingold, J. Salazar, J. Carasquel, J. Vidal, F. Ramirez, B. Gourgues, J. Beltran