Horizontal Drilling

By Lynn Helms

Explanation

Horizontal drilling is the process of drilling a well from the surface to a subsurface location just above the target oil or gas reservoir called the "kickoff point", then deviating the well bore from the vertical plane around a curve to intersect the reservoir at the "entry point" with a near-horizontal inclination, and remaining within the reservoir until the desired bottom hole location is reached.

Purpose

Most oil and gas reservoirs are much more extensive in their horizontal dimensions than in their vertical (thickness) dimension. By drilling a well which intersects such a reservoir parallel to its plane of more extensive dimension, horizontal drilling exposes significantly more reservoir rock to the well bore than would be the case with a conventional vertical well penetrating the reservoir perpendicular to its plane of more extensive dimension (fig. 1).

The achievement of desired technical objectives via horizontal drilling comes at a price. A horizontal well can cost up to 300 percent more to drill and complete for production than a vertical well directed to the same target horizon. Due to its higher cost, horizontal drilling is currently restricted to situations where vertical wells would not be as financially successful. In an oil reservoir which has good matrix permeability in all directions, no gas cap and no water drive, drilling of horizontal wells would likely be financial folly, since a vertical well program could achieve a similar recovery of oil at lower cost. But when low matrix permeability exists in the reservoir rock (especially in the horizontal plane), or when coning of gas or water can be expected to interfere with full recovery, horizontal drilling becomes a financially viable or even preferred option producing 2.5 to 7 times the rate and reserves of vertical wells. The higher producing rate translates financially to a higher rate of return on investment for the horizontal project than would be achieved by a vertical project.

Methodology

The initial vertical portion of a horizontal well, unless very short, is typically drilled using the same rotary drilling technique that is used to drill most vertical wells, wherein the entire drill string is rotated at the surface. The drill string consists of many joints of steel alloy drill pipe, drill collars, and the drill bit itself.

From the kickoff point to the entry point the curved section of a horizontal well is drilled using a hydraulic motor mounted directly above the bit and powered by the drilling fluid. The drill bit can be rotated by the hydraulic motor without rotating the drill pipe from the motor to the surface. Steering of the hole is accomplished through the employment of a slightly bent or "steerable" downhole motor (fig. 2). By orienting the bend in the motor and drilling forward without rotating the pipe, known as slide drilling, the hole can be steered around a curve from horizontal to vertical and/or to the left or right. The curved section typically has a radius of 300-500 feet. To return to drilling straight ahead, the pipe is rotated slowly while the downhole motor also continues to rotate the bit.

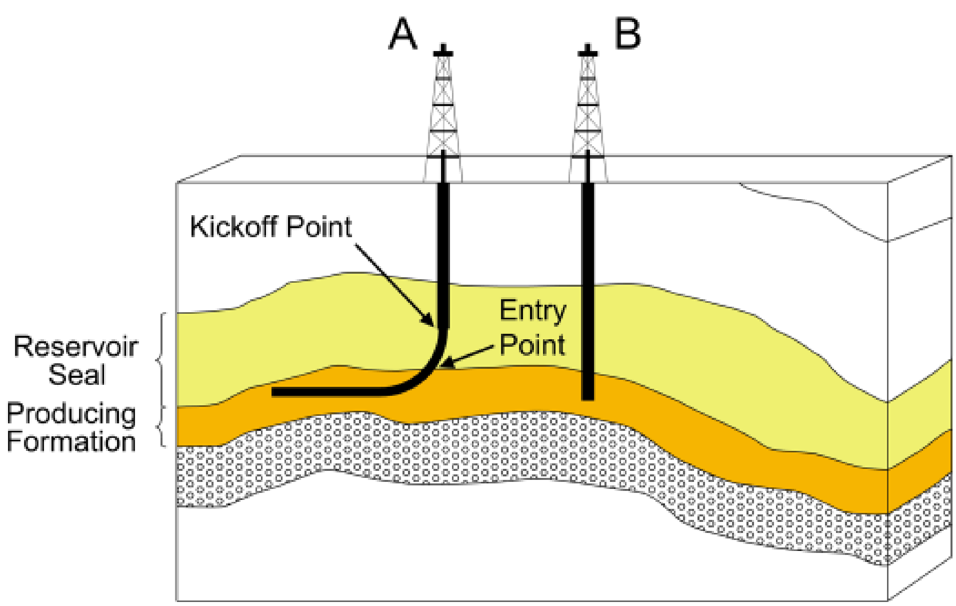

Figure 1. Greater length of producing formation exposed to the wellbore in a horizontal well (A) than in a vertical well (B). Source: Energy Information Administration, Office of Oil and Gas.

Downhole instrument packages that transmit various sensor readings to operators at the surface are included in the drill string near the bit. At a minimum, sensors provide the azimuth (direction versus north) and inclination (angle relative to vertical) of the drilling assembly. Modern downhole instrumentation allows the directional drilling crew to calculate the position (x, y, and z coordinates) of the drill bit at all times. Additional downhole sensors can be, and often are, included in the drill string.

These sensors may provide information on the downhole environment (for example, bottom hole temperature and pressure, weight on the bit, bit rotation speed, and rotational torque). They may also provide any of several measures of physical characteristics of the surrounding rock such as natural radioactivity and electrical resistance, similar to those obtained by conventional wire line well logging methods, but in this case obtained in real time while drilling ahead. The downhole instruments, whatever their composition, are referred to as a measurement-while-drilling (MWD) package. The information is transmitted to the surface via small fluctuations in the pressure of the drilling fluid inside the drill pipe.

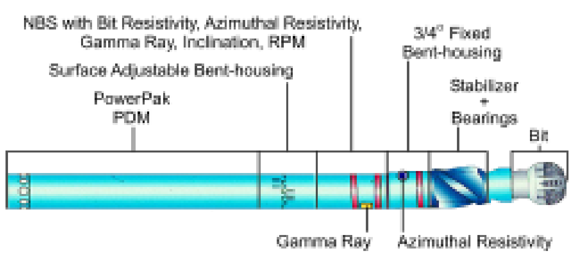

Figure 2. Geosteering Tool.

History

The concept of non-straight line, relatively short-radius drilling, dates back at least to September 8, 1891, when the first U.S. patent for the use of flexible shafts to rotate drilling bits was issued to John Smalley Campbell (Patent Number 459,152). While the prime application described in the patent was dental, the patent also carefully covered use of his flexible shafts at much larger and heavier physical scales "... such, for example, as those used in engineer's shops for drilling holes in boiler-plates or other like heavy work. The flexible shafts or cables ordinarily employed are not capable of being bent to and working at a curve of very short radius ..."

The first recorded true horizontal oil well, drilled near Texon, Texas, was completed in 1929. Another was drilled in 1944 in the Franklin Heavy Oil Field, Venango County, Pennsylvania, at a depth of 500 feet. China tried horizontal drilling as early as 1957, and later the Soviet Union also tried the technique. Generally, however, little practical application occurred until the early 1980s, when the advent of improved downhole drilling motors and the invention of downhole telemetry equipment, made the technology commercially viable.

Tests which indicated that commercial horizontal drilling success could be achieved were carried out between 1980 and 1983 by the French firm Elf Aquitaine in four horizontal wells drilled in southwestern France and offshore Italy. Early production well drilling using horizontal techniques was subsequently undertaken by British Petroleum in Alaska's Prudhoe Bay Field, in a successful attempt to minimize unwanted water and gas production.

Taking a cue from these initial successes, the first generation of modern horizontal drilling expanded rapidly into naturally fractured formations such as Texas' Austin Chalk and North Dakota's upper Bakken shale.

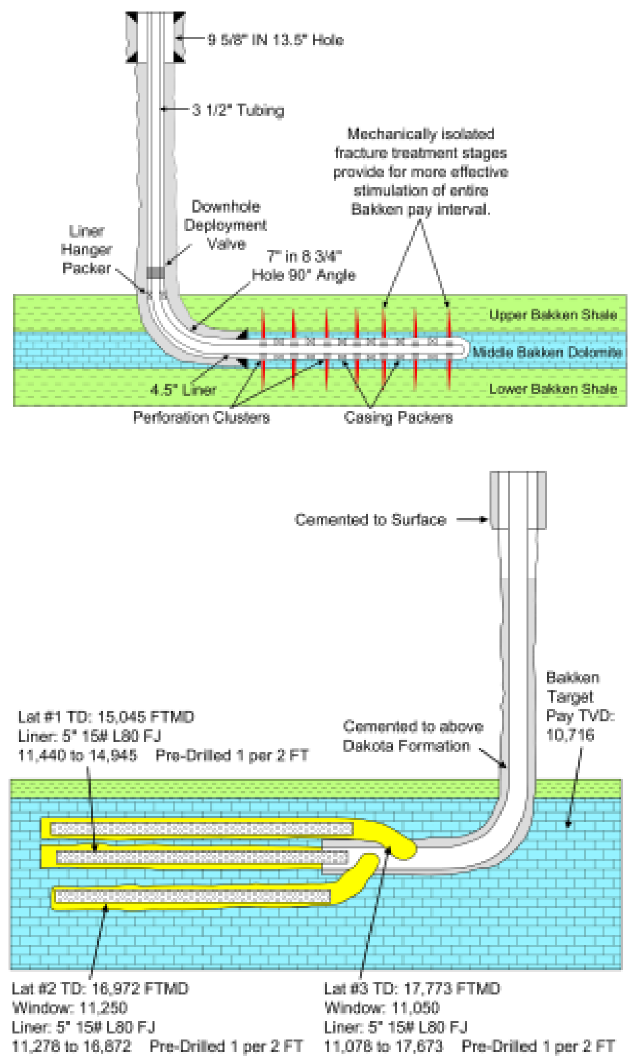

Figure 3. Third generation horizontal well configurations

ABBREVIATIONS:

FNL - Feet from north line	TD - total depth
FSL - feet from south line	BH - bottom hole
FEL - feet from east line	BHL - bottom hole location
FWL - feet from west line	TVD - total vertical depth
FTMD - feet mesasured depth	FJ - flush joint

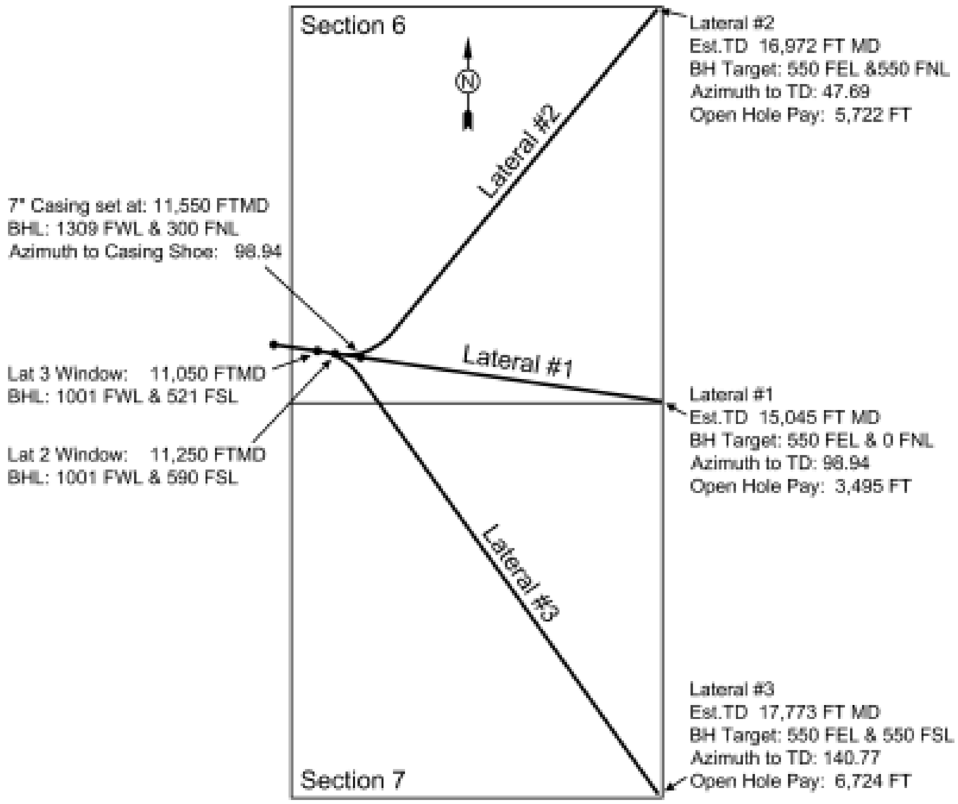

Figure 4. Preliminary directional drilling plan.

The second generation of horizontal drilling is a result of the attainable horizontal displacement, particularly for medium- and long-radius wells, growing significantly. As operators and the drilling and service contractors have devised, tested, and refined their procedures, and as improved equipment has been designed and implemented, routinely achievable horizontal displacements rapidly climbed from 400 to over 8,000 feet. Second generation applications of horizontal drilling technology have included the drilling of stratigraphic traps, heterogeneous reservoirs, coal beds (to produce their methane content), and older fields (to boost their recovery factors), and fluid injection wells to boost both production rates and recovery factors. North Dakota examples of second generation horizontal drilling applications are the Cedar Hills-Red River and Wiley-Madison enhanced oil recovery projects, Nesson Anticline and Bowman County re-development drilling projects, and the Billings Nose-Birdbear drilling.

The third and current generation of horizontal drilling is a result of attaining much longer, deeper and more accurate placement of multiple horizontal well bores to exploit fractured source rocks (where it is coupled with new hydraulic fracturing technology) and heat injection wells (Canadian oil sands steam assisted gravity drainage) intended to boost both production rates and recovery factors. The present middle Bakken play in North Dakota and eastern Montana is an example of third generation horizontal drilling applications (figs. 3 and 4).

Ancillary Benefits

First, operators are often able to develop a reservoir with a significantly smaller number of wells, since each horizontal well can drain a larger rock volume than a vertical well could. The aggregate surface "footprint" of an oil or gas operation can be reduced by use of horizontal wells.

Second, use of a horizontal well may reverse or significantly delay the onset of production problems that engender low production rates, low recovery efficiencies, and/or premature well abandonment. This can significantly enhance oil and gas recovery as well as return on investment and total return.

Third, having the well cased into the producing formation during drilling of the horizontal section allows the operators to use lower density drilling mud. They can even allow the well to produce during drilling operations, preventing much of the formation damage that normally occurs when mud density must be high enough to keep well bore pressure greater than formation pressures.

Special Regulatory Considerations

Permitting and spacing processes use setbacks from the spacing unit boundaries to protect correlative rights and prevent waste. Consideration must be given to the different drainage patterns of horizontal wells and the small tool errors inherent in horizontal drilling that can be magnified over very long distances.

Regulatory inspection and oversight must be increased significantly. This is accomplished through more frequent drilling rig visits and requiring certified well bore surveys.

The geometry of horizontal well bores greatly impacts collection and dissemination of data such as cores, bottomhole pressures, gas oil ratios, and well logs.

The significantly larger well spacing and greater distance between wells impact oil transportation and measurement as well as gas gathering and flaring.