# Drilling Technologies

**Fritz Gunkel**
**ARCO/BP Shared Services Drilling**

BP and ARCO have been working our drilling together for a number of years on the North Slope. The purpose of my talk is to provide a description of directional drilling and the impacts that advances in this technology have made on the North Slope over the last 20 years

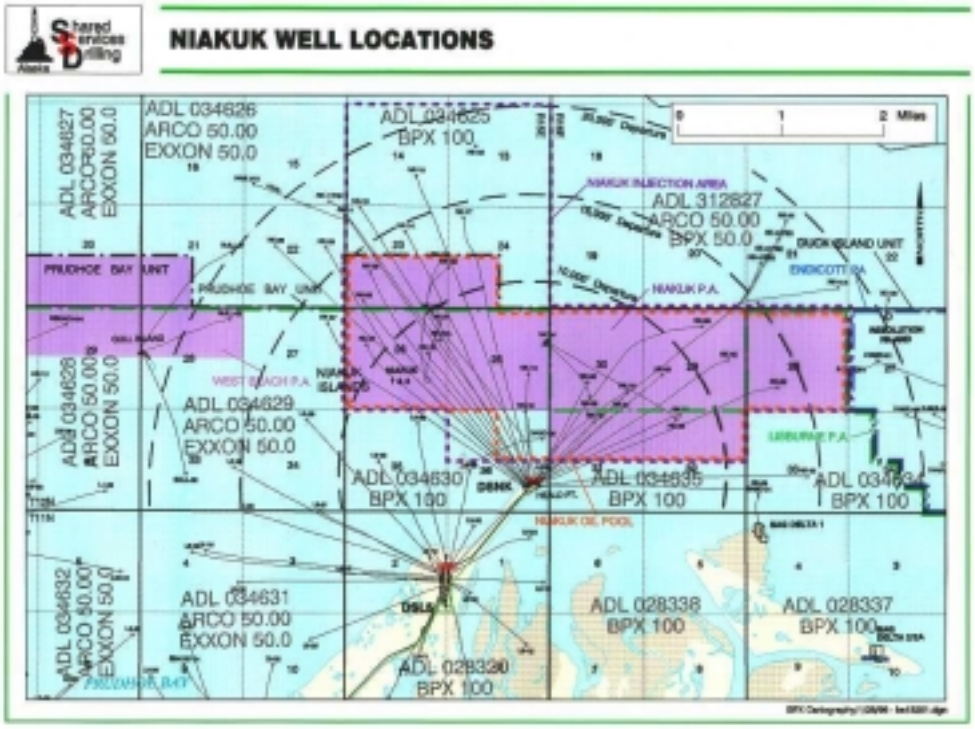
First some contrasts attributable to directional drilling technology: In 1980, in Prudhoe Bay, we considered the minimum economic thickness of oil saturated sand to be 100 feet. So, sand thicknesses less than the equivalent of an eight-story building were uneconomic to develop. We encountered reserves at drill site 18 in 1985 of less than that and plugged the well back. Today we drill horizontal wells a mile long in pays no thicker than from the bottom of that door to the top of that doorjamb.

In 1980, we thought the closest we could put two wells together was from that wall to that wall (approximately 120 ft.). We thought that for a number of reasons. The first had little to do with directional drilling. We thought that the impact of frost subsidence would be so severe that the two wells would impact each other. But we were also concerned about running into the other well while we were directional drilling. Today in an area the size of this room, we would line up 12 wells from there to there, and we would line up another 12 between you and I. As a result, where we used to have 60 acre well pads, we now have a five acre development that will include room for 35 wells, production facilities, and all the storage capacity and housing for the people. Now you've already heard that one reason for the reduced space required is the elimination of the reserve. The other reason for the reduction is directional drilling.

The last contrast I would like to draw for you is that in 1980 we thought we were doing pretty well to drill a well with an inclination from vertical of 45 degrees through the reservoir, and to push it out 5000 feet. Today we can do the equivalent of spotting a well here, drilling that well out under the Cook Inlet, over to the airport, riding the well down through the walkway and out to the airplane at Gate B-2. We can put it right there. There are eight rigs on the North Slope doing that kind of work right now. That is the progress that has been made in this area.

So how did the technology of directional drilling start? It started ages ago, actually in California off of Signal Hill as oil men looked longingly out into the ocean trying to figure out how they could get from here to there. The quest was to reach the offshore oil from onshore. This started with guys making wooden and later steel wedges and jamming them into the hole, to nudge the bit in roughly in the direction they wanted it to go. From those simple beginnings, directional-drilling technology has evolved at a dramatic pace. The technology has benefited from advancements in navigation from aerospace, from advancements in metallurgies, and from many other scientific fields.

This morning you saw some pictures of well pads on the North Slope, and I'd like to give you feel for what is underneath those well pads.




Without looking at the fine detail here, this is one of our well pads, our Niakuk pad, way out on the edge of one of the natural peninsulas on the North Slope. In 1988 I was asked as a drilling engineer, to describe how far we could drill a well from this well area. The question was “what is the maximum we will ever reach?” At that time, we thought the maximum was roughly about 10,000 to 12,000 feet sideways. But, in the last few years we’ve drilled wells that traveled laterally over 20,000 feet from its surface location. It is technically feasible to reach out 35,000 feet from the surface location under the right geologic conditions. At a place called Wytch Farm in the south of England 35,000-foot departures have been achieved by BP-Amoco.

The objective for directional drilling is to be able to reach out and touch oil and gas where we were not able to touch it before. Under each of the well pads on the North Slope you will find one and only one vertical well - every other well is deviated in some respect. Most of the wells on each pad reach laterally to access oil not located near the vertical projection of the pad footprint.

Let me offer a quick look at the technology. It is an interesting combination of some pretty, simple, pragmatic things that work in the rough and tumble world of downhole drilling, and some highly technical pieces of equipment that really were taken from the aerospace industry. There are some basic tools in directional drilling: (1) a steerable motor; (2) a “measurement while drilling tool”; and (3) a directional drilling plan.

A steerable drilling assembly is made up of just a couple of key components. The only component that rotates in this assembly is the bit on the bottom. It is turned by a reverse Moyno pump, that is just a shaft that turns in an elliptical stator. Pumping drilling mud through this device turns the shaft. The motor assembly is bent, and we are able to control which way it is oriented. The bent motor assembly puts a lateral load on the well bore, and we’re able to carve our way along. It used to be that in the length of this room we might be able to turn the well bore three degrees. Today, using the right equipment,

we can start on this end of the room, start down this way, and by the time we get to that wall we're headed in the opposite direction. And amazingly, some of the same pipe, that we used to think would be permanently ruined by doing that, works just fine.

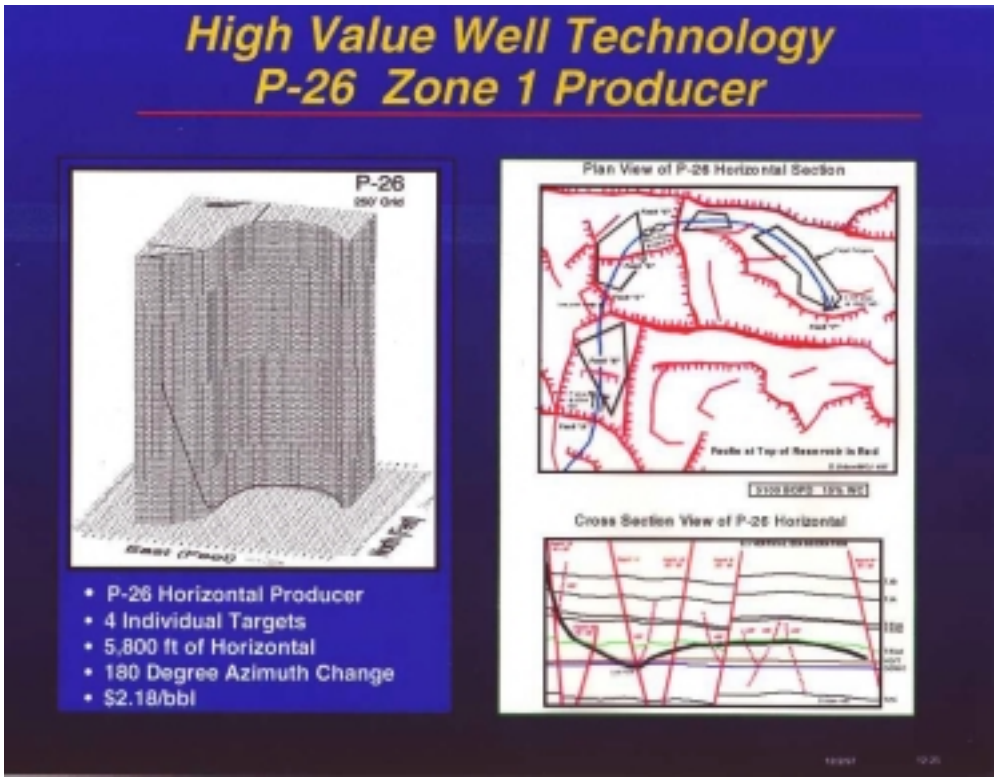
The other key pieces to this are the real high tech components. These are the downhole tools that read the chemical and mechanical properties of the reservoir. They tell us what the density, porosity, and the water saturation of the reservoir are; all important things to know. Are you in a sweet spot or not? When you are following ten feet of pay, you are susceptible to the hills and valleys that exist even in a flat depositional environment. These tools help us find our way.

Also today, we use more of our old wells to access reserves than we create new wells. Blair talked this morning about the cementing of surface pipes. We eliminate the need to make that investment in many of our replacement wells today because we use wells that were drilled 10 years ago as our starting point. We ensure the mechanical integrity of that well, and then we abandon the old zone and drill a new well from that existing one. Many times we don't take any of the plumbing out of the well at all - we leave the well with the original tubing string in place. We plug back the old unneeded section, we mill a window in the existing casing, and we deviate out into new reserves.

This is been a solution to a few problems. Old wells down in the pay zone are susceptible to corrosion, and instead of going down and fixing those old wells, we just replace them. It also has reduced our costs of development significantly in situations where you get a lot less oil recovery from each well. A redrill of an existing well can cost as little as one tenth of what the original well cost in 1980.

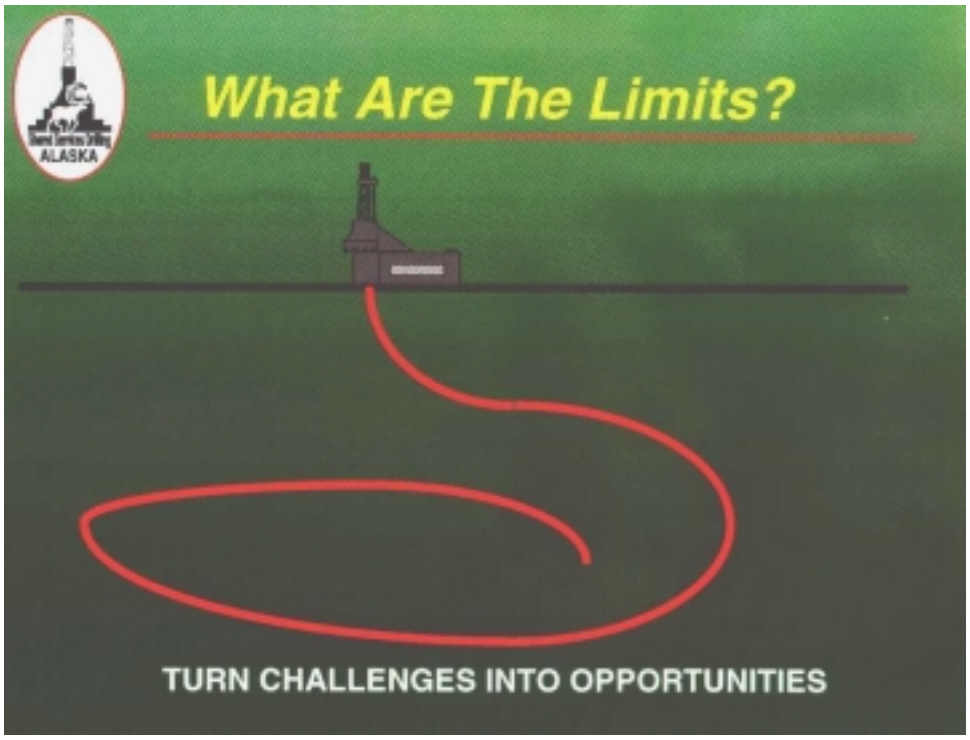
Now a little on directional planning when I was just starting out was pretty easy stuff. Today it is much harder. Planning is done in three dimensions, where we literally lay out the trajectory of the well bore according to the various horizons where we want to be. Frequently we want to porpoise up and down in the reservoir so that we cross the permeability barriers, and we have to be sure that we are allowing flow across vertical permeability barriers

I'll show you a three dimensional picture of one of many of the wells of this type that we have drilled.




Here is an example of a well drilled on P-Pad. Steve Taylor showed you a picture of P-Pad showing development on ten-foot centers this morning. Here is an attempt to depict this three-dimensional well in two dimensional space. You can see that we've deviated it, and then we drilled a little fishhook at the bottom. This little fishhook is about 5000 feet long. Why did we do that? Because as you can see, we had four accumulations of oil against faults, and we wanted to be able to access those accumulations of oil. No single one of these accumulations of oil would have merited drilling a well here - no one accumulation of oil would have supported a million plus dollars of investment. But because we were able to access it like this, we were able to make this well an economic venture. Directional drilling has allowed us to continue developing the depleting reservoir by allowing access to smaller accumulations of oil with greater accuracy and at lower cost.

So what are the limits here?




Somebody drew this picture about a year and a half ago as a joke, then we drilled two wells that look much like this. We actually have thrown a well bore lasso around a production well, and then herded oil into the center by injecting miscible injectant along this horizontal column with the producer in the middle. We'll sweep the maximum amount of oil out of the reservoir.

A relatively recent development in directional drilling as is multilateral wells.


Multilateral wells use the same main well, and then drill multiple branches to a variety of locations out from that main well. So imagine today where you might drill two or three of these branches into the reservoir, all from the same surface system using the same plumbing on top to gather it together. This may be the way that we end up developing some of the shallow sands on the North Slope. We plan to drill a few wells in the Schrader Bluff this year testing our ability to deliver the goods.

This morning seemed to be a morning of quotes, and I have a quote of my own. As an ARCO guy working in BP's office, I found a quote from that famous British drilling engineer, Robin Hood. "Smaller targets require better aim". That is the name of our game on the North Slope.

Thank you very much