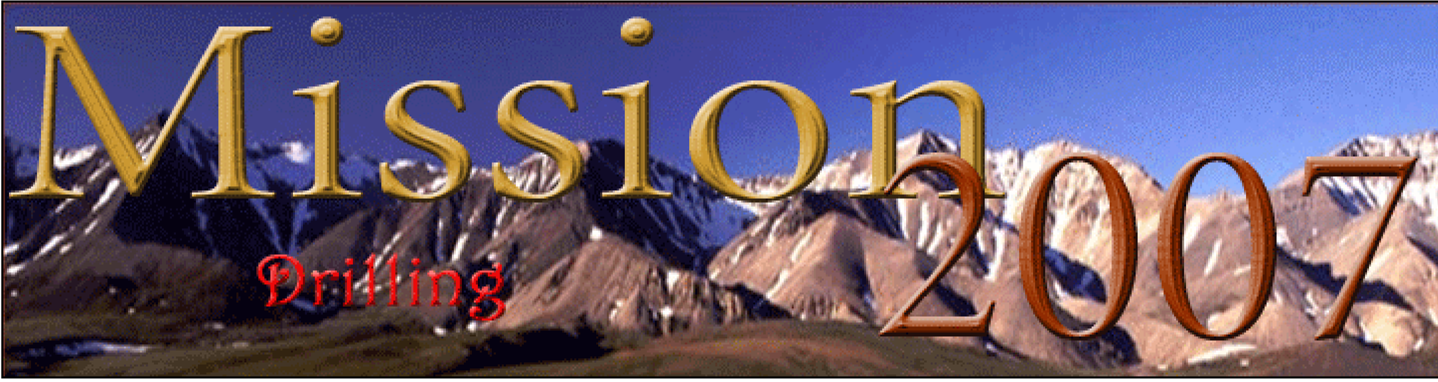

Production Technology

Vertical Drilling

The oldest method of drilling is to drill a vertical well. In this method, a wellbore is drilled with as little deviance as possible directly towards the reservoir; once it penetrates and goes through the reservoir, the well is stopped and the drill string removed. At this point cement is poured down the well to prevent hydrocarbons from flowing down the well once it is perforated. Then the well is perforated, and the pressure in the formation forces the oil out of the rock and up the pipe.

Directional Drilling

Directional drilling is a relatively new technology which allows a well to be drilled along a predetermined path which is not vertical. A directional well has the added benefits of being able to thread through a horizontal strata, in order to obtain the most pipe-to-formation surface area. Directional drilling is useful for a number of reasons, including

•sidetracking
•offshore development drilling
•drilling to avoid geological problems
•horizontal drilling
•controlling vertical holes
•increasing oil pressure due to penetration
•drilling beneath inaccessible locations
•drilling to reach oil in reservoirs which would be unreachable by vertical wells.

Directional drilling must be approached carefully. It is not as risky as it used to be due to special tools to help the well deviate in a controlled manner and new technology to keep track of the directional of the well once it has deviated. Often the target of the well is very precise and must not be missed. There is a possibility of drilling many different wells from the same well bore, which dramatically decreases pad size and increases possible production from the well.

Horizontal drilling has the added advantage of being able to thread back and forth through a horizontal reservoir to increase the formation penetration. The horizontal technique combined with multilateral wells allow several formations to be penetrated horizontally at once.
Recommendation: Directional Drilling with other necessary components added as necessary.

Rigs

Drill rigs vary dramatically depending on the depth and the type of formation they are drilling through. Since this information is not offered in the absolute for the ANWR region, it is only possible to speculate on the best rigs for the job. Companies being looked at to supply possible rigs include Anadarko and Schlumberger.

Exploration Drilling

After seismic exploration has taken place, one must go in and drill to to find the the true dimensions of the well. Directional drilling with coring is the best way to do this, making a minimum of holes and still determining the dimensions of the well. This can be drilled from a fairly mobile, lightweight rig. We are still researching exploration drilling techniques.

Rig Components

Drill Bits break down into categories:

Roller cone bits have one, two or three cones that have teeth sticking out of them. The cones roll across the bottom of the hole and the teeth press against the formation with enough pressure to exceed the compressive strength of the rock. They're made for rougher drilling conditions and less expensive; they aren't ideal for small holes, but they are very sensitive to the porosity of the rock they are drilling through (drilling faster or slower depending on the pore pressure) giving the drilling crew a good idea of changes in pressure in the wellbore. Roller cone bits with steel teeth are called mill tooth bits; they withstand high drilling stresses while tungsten carbide bits can drill for long distances without wearing out. Tungsten bits are more expensive; tungsten carbide insert bits have teeth coated with diamond, which give them an even longer life.

Fixed cutter bits have no moving parts, and therefore only the cutting surfaces become dull. Diamond fixed cutter drill bits produce small rock cuttings called rock flour; they drill through the hardest formations, though slowly, and are also extremely expensive. These bits are only used in formations which have high compressive strength or are very abrasive and would destroy other bits before they made much progress. PDC bits drill with a diamond disk mounted on a tungsten carbide stud; they have the capability to drill very fast (100 feet an hour) and are very costly. They can be built with either steel or molded tungsten carbide bodies (matrix body). These bits are made in many different shapes and can be made to drill directionally; the shape also affects how many cutters can be mounted on the bit. Fishtail bits are of very old design and only suitable for drilling in very soft formations.

The drill bits will need to be replaced as they become dull. The drill will be equipped with a jet to direct flow of drilling fluid to clean cuttings from the bottom of the hole and allow them to rise to the top of the well bore. There is an optimal speed for the bit, which allows it to clear away most rock and still maintain a high RPM).

There are many different types of drill bits to choose from and since the exact type of strata to be drilled through in ANWR is unknown, it is almost impossible to select drill bits. Instead, drill bits have been listed to accommodate as many different types of strata as possible. Roller cone bits would be good for exploration drilling; because they are so attentive to the porosity of the hole, it is a good indicator to the drilling crew if there is danger of a blowout. For longer drilling operations in harder formations, PDC bits appear to clearly be the best choice.

Drilling Power

The torque needed to drill the bit may be given by a top drive motor, suspended by the traveling block above the drill pipe in the derrick; it turns the drill string. This motor is electrical. New technology includes instead downhole equipment, where the torque provided to turn the bit is initiated at the bottom of the hole. The drill bit can be driven by a mud motor, which rotates the bit through the pressure of the drilling mud. This has obvious benefits, like not needing an additional outside power source. The drill collar is placed behind the drill bit in order to give it enough weight to be pressed against the formation while drilling. Drilling fluid is forced down the drill string and is expelled out the jets, lubricating and cooling the drill bit while at the same time carrying the rock cuttings away from the bit, exposing fresh formation to be drilled. The drilling mud performs many crucial functions and also has substantial environmental impact.

Drilling Mud

The drilling mud is essential to safe, efficient and economic oil well drilling. Drilling mud is depended upon for:
- Control formation pore pressures to assure proper well control
- Minimize drilling damage to the reservoir
- Stabilize the wellbore so that the hole diameter remains equal to bit diameter, or at least minimizes hole enlargement
- Remove cuttings from under the bit while drilling
- Carry drilled cuttings to the surface while circulating
- Suspend the cuttings to prevent them falling back down the hole when pumping stops
- Release the drilled solids at the surface so that clean mud can be returned downhole
- Keep bit cool
- Provide necessary lubrication to the bit and drill string
- Allow circulation and pipe movement without causing formations to fracture
- Absorb contaminants from downhole formations and handle the difference between surface and downhole temperatures, all without causing serious degradation of mud properties.

(Drilling Tech, 146)

There are approximately six types of mud: dispersed mud, non-dispersed mud, solids free brines, oil mud and invert oil emulsion mud, air mud, and aerated and foamed mud. Dispersed mud means that the clay (cuttings from the well) is dispersed throughout the fluid. This is achieved by adding alkalis to water which increase its polarity; the more polar the water, the more reactive clays will disperse throughout the mud. Montmorillonite may be added to the mud to give it useful properties; this is commercially known as bentonite. The addition of this causes the mud to become viscous, and may help maintain hole stability. Non-dispersed muds rely on the opposite of this effect by using little water and attracting many clay particles to the same electrical charge, enabling the polymer to wrap itself around the clay cuttings, essentially dissolving the cuttings with the mud as the solvent. These are described as encapsulating polymer muds. It is now possible to tailor synthetic muds to specific drilling situations, depending on variables such as: increasing the viscosity of the fluid, increasing the gellation properties, decreasing fluid loss into the formation, and acting as a surfactant, to allow oil and water to mix together in an emulsion. Solid free brines are used when working within the reservoir to minimize damage to the formation. They can be formulated with densities of up to 1.07psi/foot. The brine is unlikely to damage the formation because it won't plug the reservoir with irremovable solids or by causing reactions with formation fluids or solids. This makes solids-free brines useful during completion or workover operations.
Oil mud and oil emulsion mud, water is present less then 10% by volume; the continuous phase is the oil.

These are mostly no longer used as some of them are toxic, carcinogenic, and flammable, which are undesirable for safety, environmental and health reasons. It is possible to use compressed air instead of mud, but requires specific conditions, namely a formation which can remain stable without hydrostatic mud pressure to support it and there can be no danger of a fluid influx into the well. Aerated and foamed mud is essentially drilling mud injected with air, which in turn lightens the fluid column. This mud is restricted to about 2800 feet as the pressure below these depths cannot be sustained by the mud density. Its lifting capacity is greater than that of regular drilling mud, but will not survive immersions in oil or salt water.

The basic physical properties of mud which should be monitored by the drilling crew are densities, fluid loss, and sand content. As of yet it is hard to make an estimate of how much mud will be needed in order to maintain the wells, because there is still a vary vague idea of how many wells need to be drilled. However, the mud can be reused many times and we are currently working on a way to dispose of it efficiently and safely.

Drilling process

Once an area has been picked and appropriately cleared, the well is spudded by driving a conductor pipe into the ground with a pile driver. This pipe must then be cleaned of rubble using a small drill head which breaks up the rubble and forces it to the surface. The initial size may vary, but the pilot hole may be approximately 12-1/4" in diameter; this may get bigger. Our team is currently researching how to drill to great depths using the smallest holes possible. This pilot hole will later be re-drilled with a larger bit. Slowly a drill bit of approximately 24" inches in diameter (again, we are still researching this and believe it is possible to achieve much smaller hole diameters) will be forced into the ground by the pressure of the drill collars, which weigh approximately 6,000 lbs each. Mud is pumped down the drillstring to clear the the cuttings as the bit begins to cut into the rock; it needs to be moving at an annular velocity of approximately 100 feet per minute to efficiently clean the well pipe (minimum 50 fpm). The amount of mud needed may be calculated by initially subtracting (D2-d2) and multiplying by 0.0408 where D equals the diameter of the hole and d equals the diameter of the drill pipe yielding the gallons per foot. Multiply this quantity by the minimum annular velocity, 50 fpm, and it yields the number of gallons of mud needed per minute. It is as yet undecided how big the hole needs to be and how many holes need to be drilled, so only rough estimates may be made. The mud may be reused.

The drainpipe, held up by the derrick or mast, lowers the bit into the ground. When enough drill collars have been applied to give the bit the weight it needs, a crossover pipe is added to the end and then the drill string is solely added to the drainpipe. During this initial phase there may be much mud loss. When the drill reaches the required depth, the cuttings are cleaned out and the the first casing is installed and cemented into the well bore. It is important to cement the pipes in formations which are strong enough to withstand the pressures of drilling. The process is again repeated until the bit reaches the desired depth. There is instrumentation for determining how much the well deviated from its path and it is still being looked into. If a directional well is being drilled, a whipstock or a jet will be used to create the deviation in the desired direction.

Jetting is when a particularly pressurized stream of mud is shot out in the direction the bit should go, essentially eroding the rock in the needed direction. However, this only works in soft formations. The whipstock is tool which is attached to the end of the drillstring and fed into the wellbore head of the drill bit. Its wide, flat edge prevents the bit from following the path it normally would have taken and instead forces the bit to deviate to the side.

Another essential part of equipment for the drilling process is the blow out preventer, which monitors the downhole pressures and uses a system of valves to close access to the hole incase a pocket of natural gas or highly pressurized fluid is hit. It is important to pick a blow out preventer which will be able to handle the pressures which may be encountered along the drilling path.

Once the hole has been drilled, perhaps with several deviated wells traveling horizontally through reservoirs, it becomes necessary to complete the well. First, tubing is run down the well so that the hydrocarbons are not flowing directly up the casing. We will used coiled tubing in the well completion, and we are looking into using it more instrumentally in drilling as well. Coiled tubing is faster and less expensive because unlike regular tubing, it can be fed into the hole faster and does not need to be connected through joints, which takes time to complete. Once each ending of the wellbore is left open or blocked off with cement. When it is left open, it is called and open-ended perforation and the pressure in the formation must be such that the oil will rise in the hole and not sink into the formation below it. Sometimes the pressure is not enough and in order to prevent the loss of hydrocarbons, the finished well will be sealed with cement. When the company is ready to start producing, it will send a few charges down the well, and detonate them, perforating the tubing and allowing the hydrocarbons to flow into the tube.

Once the drill has been perforated and starts producing, a Christmas tree is installed on top. This device allows the operator to control the amount of production or shut down the well entirely if needful, or to direct the flow of the oil once it reaches the surface. Usually, once the Christmas tree is installed the well is complete.

Enhanced Recovery

The initial drilling process will only allow as much oil out of the well as the pressure forces out. The easiest way to stimulate a flagging pressure is by means of pumps to keep the tubing pressure less than the formation pressure. However, soon this no longer becomes feasible and at this point only 5-10% of the oil may have been recovered. Therefore secondary methods have been developed to increase the oil production from reservoirs; these usually involve flooding the reservoir with water and using the water to create pressure, driving the oil before it and up the pipe. This water flooding method may increase oil production by approximately 45% of the original oil concentration. In order to make the well extract the greatest amount of oil, tertiary (enhanced recovery methods) may be used. If the viscosity of the crude oil could be reduced, it would not need high pressures to push it up the drill pipe; therefore by adding solvents or by forcing steam into the well, the now “thinned” oil will flow up the pipe. This method may remove approximately 60% of the reservoir’s initial concentration. Technology is being developed which would utilize microbial recovery systems, limiting the amount of chemicals used.