Drilling of Wells

Water Well Drilling

Well drilling is the process of drilling a hole in the ground for the extraction of a natural resource such as ground water natural gas, or petroleum. Drilling for the exploration of the nature of the material underground (for instance in search of metallic ore) is best described as borehole drilling, or 'drilling'.

The earliest wells were water wells, shallow pits dug by hand in regions where the water table approached the surface, possibly with masonry walls lining the interior to prevent collapse. Modern drilling techniques utilize long drill shafts, producing holes much narrower and deeper than could be produced by digging.

Well drilling can be done either manually or mechanically and the nature of required equipment varies from extremely simple and cheap to very sophisticated.

Managed Pressure Drilling (MPD) is defined by the International Association of Drilling Contractors (IADC) as “an adaptive drilling process used to more precisely control the annular pressure profile throughout the wellbore." The objectives of MPD are “to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly."

Drill Bits in Mechanical Drilling

Depending on the soil condition, different drill bits are used. There are three main categories: soft, medium and hard formation bits. Soft formation rock bits are used in unconsolidated sands, clays, soft limestones, red beds and shale, etc. Medium formation bits are used in calcites, dolomites, limestones, and hard shale. Hard formation bits are used in hard shale, calcites, mudstones, cherty lime stones and hard and abrasive formations.

Historically there were two types of drill bits used in oil or natural gas drilling rigs, a drag bit and a rock bit:

Drag Bits

A drag bit is a drill bit usually designed for use in soft formations such as sand, clay, or some soft rock. However, they will not work well in coarse gravel or hard rock formations. Uses include drilling water wells, mining, geothermal, environmental and exploration drilling. Whenever possible, they should be used to drill pilot holes because they produce cuttings that are easiest to log.

TORQUATO DRAG BITS are designed for a variety of applications including seismic exploration, soil sampling, mining and construction.

STEP-TYPE DRAG BITS are very effective in drilling soft and unconsolidated material. They are available in a full range of sizes from 3-7/8” thru 12-1/4”.

The design of TORQUATO STEP-TYPE DRAG BITS provides for fast drilling penetration and requires only moderate drilling weight for proper operation. A large center flushing hole is incorporated into our design for efficient removal of cuttings.

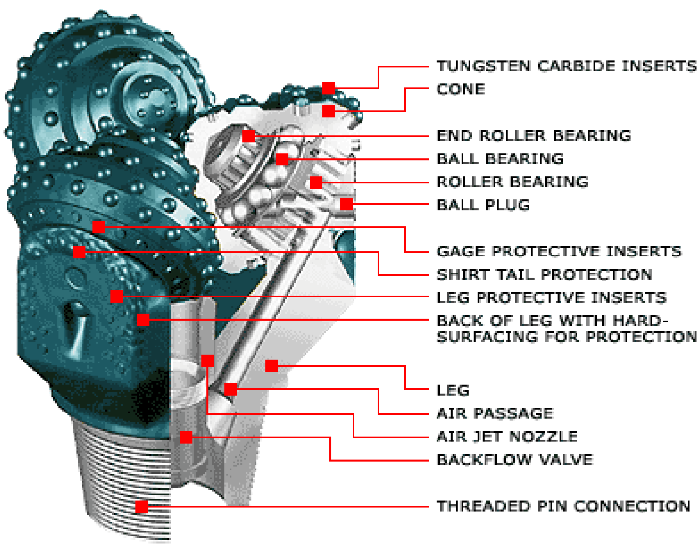
CHEVRON-TYPE DRAG BITS are recommended for drilling in slightly harder and more consolidated materials. Best suited for abrasive conditions, TORQUATO CHEVRON-TYPE DRAG BITS are also available in a full range of sizes up to 8”.

The clean design, use of premium tungsten carbide and rugged construction of these fine drilling tools ensures effective performance in a variety of ground conditions.

Rock Bits

Three Cone Rock bits produced by UralBMT are sophisticated products made from high quality materials (steel forging, carbide, and others). These Three Cone Rock bits are designed for a multitude of drilling applications including: Gas and Oil production, Mining and Mineral Exploration, Water Well production, Construction, Horizontal and Directional, Geotech, Environmental, and a variety of other industrial uses.

A typical **Three Cone Rock** bit consists of three cones and three leg sections with journals. Hard surfacing is applied to leading edge of **Leg** and **Shirttail** area, and load areas of journal. **Leg** and **Gage** protective flat tungsten carbide inserts are available in the majority of UralBMT rock bits.



Each of the three cones is subjected to detailed processes of carburizing and specialized machine operations.

Bearing structures are available as Open Bearing or Sealed Bearing. Open Bearing configuration can be made up of different combinations of Roller, Ball, and Friction assemblies (examples: Roller Ball Roller, Roller Ball Friction, etc...). The Sealed Bearing configurations are available in either Sealed Journal or Sealed Roller.

Each bit is attached to a drill string using a standard Threaded Pin Connection. These **Connections** are in compliance with established IADC and API specifications.

Cutting structures for **Three Cone Rock** bits are available in either **milled steel teeth** or teeth made from **tungsten carbide (TCI)**. Rock formations and desired rates of penetration determine types of required cutting structure. UralBMT rock bit cutting structures are in accordance with IADC specifications.

Three Cone Rock bits are offered with a standard variety of air and fluid circulation types including Air Jet Nozzles, and Air Passage to the bearing. A Backflow Valve is available in the majority of the air circulation bits, and prevents pieces of formation from entering the drill string once the air to the bit has been shut down.

Each bit is marked on Pin Connection with a serial number, bit type, manufacturing date, and UralBMT trademark.

UralBMT's three cone rock bits are available in sizes from 2 15/16" (74.6mm) to 11 5/8" (295.3mm).

The original patent for the rotary rock bit was issued to Howard Hughes, Sr. for his dual cone roller bit in 1909. It consisted of two interlocking wheels. Walter Benona Sharp worked very closely with Hughes in developing the rock bit. The success of this bit led to the founding of the Sharp-Hughes Tool Company.

In 1933 two Hughes engineers, one of whom was Ralph Neuhaus, invented the tricone bit, which has three wheels. The Hughes patent for the tricone bit lasted until 1951, after which time other companies started making similar bits. However, Hughes' market share was still 40% of the world's drill bit market in 2000. The superior wear performance of PDC bits gradually eroded the dominance of roller cone bits and early in this century PDC drill bit revenues overtook those of roller cone bits.

In today's modern industry the two main types of drill bits are now classed as PDC (polycrystalline Diamond Compact) and Roller Cone; although the tri-cone dominates, bi-cone and mono cone bits do exist. Natural and synthetic diamonds are used in coring bits, as well as for very hard rock drilling with mud motors and turbines. Drag bit type bits are used for mining and construction and also for oil and gas work over wells.

The technology of both bit types has advanced significantly to provide improved durability and rate of penetration of the rock. This has been driven by the economics of the industry, and by the change from the empirical approach of Hughes in the 1930s, to today's time domain Finite Element codes for both the hydraulic and cutter placement software.

A very simple manual method to drill water wells, meant to be applied by very poor villagers in developing countries, who quickly learn how to drill their wells themselves. The Baptist drilling rig can be built in any ordinary arc welding workshop and materials for a basic version costs about 150 US Dollars (2006 prices). In suitable conditions, boreholes over 100 m deep have been drilled with this method.

History

The method was developed by Terry Waller, a North American Baptist missionary, in Africa and Bolivia. It applies some of the same principles used in mechanized commercial well drilling, but does so using the simplest, most available and cheapest possible materials.

Social / Development Context

Rural people in developing countries often cannot afford to have specialists drill or dig wells for them. This method was developed to provide poor people with a way to help themselves with their water supply.

A Baptist drilling rig, fit to drill holes up to 30 m deep, can be built in Nicaragua for about US$ 150. This includes all essential non-common tools to operate it. Its core element, the drill bits, can be made in about any arc-welding workshop, using only scrap steel and materials that can be found in virtually any hardware store.

Once the well is drilled, it is cased with cheap PVC tube. Fitting it with a slab of concrete as a sanitary seal and a simple PVC piston pump (also built by the users themselves) will cost about 2.5 dollars per meter well depth.

Having built their own well and pump, users become independent from external help forever.

Suitable Conditions

A hybrid between sludging and percussion drilling, this method permits to drill through all kinds of loose alluvial soils, sands, silts and clays, as well as “soft” rocks, like light conglomerates, consolidated volcanic ashes, some calcareous rocks and weathered materials. It will not, however, penetrate hard igneous rock or boulders (e.g. in ancient river beds).

Technical Specifications

Like in sludging, the drilling process is continuous: the drill bit is normally not removed from the borehole until it is finished and the broken-up material is pumped to the surface in the drilling liquid (mud). But instead of using a hand as a valve on top of the drill pipe (sludging), the drill bit itself doubles as a foot-valve. The operator's hand does not have to reach the end of the drill pipe and drill stem extensions can be several meters long.

Percussion action is performed by lifting the drill stem with a rope over a pulley, attached to a simple derrick, made with whatever available wood or bamboo poles.

The borehole diameter is kept as small as possible in order to remove a minimum of material and hence advance rapidly.

The main drill tool consists of a length of pipe with a bit/valve.

No temporary casing is used. The borehole being kept full of mud and the "caking" of mud into any unstable sand layers, as a consequence of the percussion action and friction of the smooth lateral edges of the bit, is normally sufficient to stabilize it. Drilling mud is evacuated from the borehole after casing the well by pouring or injecting water into the casing (backwashing).

This technique adapts best to sand, loam and light rock. The standard drill bits also work through sticky and even consolidated clays. Nevertheless, best results in varying conditions are obtained with an array of different bits:

- Moveable point bits for general purpose and clay-holding soils: the moving stem of the heavy dart helps to keep the foot valve clean.
- Fixed point bits for sandy and rocky layers, where there is no risk for sticky material to obstruct the foot valve.
- Open-ended (hollow) bits without a foot valve (pure sludging) for layers of pure clay or gravel. In these conditions the presence of a foot valve may slow down progress, since clay has to be pounded into suspension and stones have to be ground to small pieces in order to enter the drilling tool through the foot valve.

Reaming

If required, the upper part of the well can be reamed and cased with larger diameter pipe (3 or 5 inches), to accommodate larger pumps. A shallow (large diameter) rope pump, for example, may require a wider well and submersible pumps commonly need at least 4". Note that there is no need to enlarge the entire depth of the borehole: reaming until slightly below the lowest expected water table (the pump's water intake) is sufficient.

A **blowout** is the uncontrolled release of formation fluid from a well, typically for petroleum production, after pressure control systems have failed.

Cause of Blowouts

A blowout is caused when a combination of well control systems fail – primarily drilling mud hydrostatics and blow-out preventers (BOPs) – and formation pore pressure is greater than the wellbore pressure at depth.

When such an incident occurs, formation fluids begin to flow into the wellbore and up the annulus and/or inside the drill pie, and is commonly called a **kick**. If the well is not shut in, a kick can quickly escalate into a blowout when the formation fluids reach the surface, especially when the fluid is a gas which rapidly expands as it flows up the wellbore and accelerates to near the speed of sound. Blowouts can cause significant damage to drilling rigs, injuries or fatalities to rig personnel, and significant damage to the environment if hydrocarbons are spilled.

Prior to the development of blow-out preventers, blowouts were common during drilling operations, and were referred to as gushers.

Formation Kick

A kick can be the result of improper mud density control, an unexpected over pressured (shallow) gas pocket, or may be a result of the loss of drilling fluids to a formation called a *thief zone*. If the well is a development well (and not a wildcat), these thief zones should already be known to the driller and the proper loss control materials would have been used. However, unexpected fluid losses can occur if a formation is fractured somewhere in the open-hole section, causing rapid loss ofhydrostatic pressure and possibly allowing flow of formation fluids into the wellbore. (See "Underground Blowout" discussion in next section.) Shallow over pressured gas pockets are generally unpredictable and usually cause the more violent kicks because of rapid gas expansion almost immediately.

The primary means of detecting a kick is a relative change in the circulation rate back up to the surface into the mud pits. The drilling crew or mud engineer keeps track of the level in the mud pits, and a increase in this level would indicate that a higher pressure zone has been encountered at the bit. Conversely, a drop in this level would indicate lost circulation to a formation (which might allow influx of formation fluids from other zones if the hydrostatic head at depth is reduced from less than a full column of mud). The rate of mud returns also can be closely monitored to match the rate that it is being pumped down the drill pipe. If the rate of returns is slower than expected, it means that a certain amount of the mud is being lost to a thief zone, but this is not necessarily yet a kick (and may never become one). In the case of a higher pressure zone, an increase in mud returns would be noticed as the formation influx pushes the drilling mud toward the surface at a higher rate.

The first response to detecting a kick would be to isolate the wellbore from the surface by activating the BOPs and closing in the well. Then the drilling crew would attempt to circulate in a heavier *kill fluid* to increase the hydrostatic pressure (sometimes with the assistance of a well control company). In the process, the influx fluids will be slowly circulated out in a controlled manner, taking care not to allow any gas to accelerate up the wellbore too quickly by controlling casing pressure with chokes on a predetermined schedule. In a simple kill, once the kill-weight mud has reached the bit the casing pressure is manipulated to keep drill pipe pressure constant (assuming a constant pumping rate); this will ensure holding a constant adequate bottom hole pressure. The casing pressure will gradually increase as the contaminant slug approaches the surface if the influx is gas, which will be expanding as it moves up the annulus and overall pressure at its depth is gradually decreasing. This effect will be minor if the influx fluid is mainly salt water. And with an oil-based drilling fluid it can be masked in the early stages of controlling a kick because gas influx may dissolve into the oil under pressure at depth, only to come out of solution and expand rather rapidly as the influx nears the surface. Once all the contaminant has been circulated out, the casing pressure should have reached zero.

Sometimes, however, companies drill under balanced for better, faster penetration rates and thus they "drill for kicks" as it is economically sounder to take time to kill a kick than to drill overbalanced (which causes slower penetration rates). Under these circumstances, always with qualified personnel on the rig, calling in a "well control" specialist may not be necessary.

Blowout

When all the controls described above fail, a blowout occurs. Blowouts are dangerous since they can eject the drill string out of the well, and the force of the escaping fluid can be strong enough to damage the drilling rig. Blowouts often ignite due to the presence of an ignition source, from sparks from rocks being ejected along with flammable fluids, or simply from heat generated by friction. (Rarely the flowing gas will contain poisonous hydrogen sulfide and the oil operator might decide to ignite the stream to convert this to less hazardous substances.) A well control company will then need to extinguish the well fire and/or cap the well, and replace the casing head and hangars.

Sometimes, blowouts can be so forceful that they cannot be directly brought under control from the surface, particularly if there is so much energy in the flowing zone that it does not deplete significantly over the course of a blowout. In such cases, other wells (called relief wells) may be drilled to intersect the well or pocket, in order to allow kill-weight fluids to be introduced at depth. (Contrary to what might be inferred from the term, such wells generally are not used to help relieve pressure using multiple outlets from the blowout zone.)

An "underground blowout" is a special situation where fluids from high pressure zones flow uncontrolled to lower pressure zones within the open-hole portion of the wellbore. Usually they come up the wellbore to shallower formations (typically near the last casing shoe) that have been fractured from the overall effect of hydrostatic mud head plus casing pressure imposed at the time of the initial kick. Underground blowouts can be very difficult to bring under control although there is no outward flow at the drill site itself. However, if left unchecked, in time the fluids may find their way to the surface elsewhere in the vicinity (possibly "cratering" the rig), or may pressurize other zones, leading to problems when drilling subsequent wells.

Under balanced drilling, or UBD, is a procedure used to drill oil and gas wells where the pressure in the wellbore is kept lower than the fluid pressure in the formation being drilled. As the well is being drilled, formation fluid flows into the wellbore and up to the surface. This is the opposite of the usual situation, where the wellbore is kept at a pressure above the formation to prevent formation fluid entering the well. In such a conventional "overbalanced" well, the invasion of fluid is considered a kick, and if the well is not shut-in it can lead to a blowout, a dangerous situation. In under balanced drilling, however, there is a "rotating head" at the surface - essentially a seal that diverts produced fluids to a separator while allowing the drill string to continue rotating.

If the formation pressure is relatively high, using a lower density mud will reduce the well bore pressure below the pore pressure of the formation. More commonly, inert gas is injected into the drilling mud to reduce its equivalent density and hence its hydrostatic force throughout the well depth. This gas is commonly nitrogen, as it is non-combustible and readily available, but air, reduced oxygen air, processed flue gas and natural gas have all been used in this fashion.

Advantages

Under balanced wells have several advantages over conventional drilling including eliminated formation damage. In a conventional well, drilling mud is forced into the formation in a process called invasion, which frequently causes formation damage - a decrease in the ability of the formation to transmit oil into the wellbore at a given pressure and flow rate. It may or may not be repairable. In under balanced drilling, if the under balanced state is maintained until the well becomes productive, invasion does not occur and formation damage can be completely avoided.

Increased Rate of Penetration (ROP): With less pressure at the bottom of the wellbore, it is easier for the drill bit to cut and remove rock.

Reduction of Lost Circulation.: Lost circulation is when drilling mud flows into the formation uncontrollably. Large amounts of mud can be lost before a proper mud cake forms, or the loss can continue indefinitely. If the well is drilled under balanced, mud will not enter the formation and the problem can be avoided.

Differential sticking is eliminated. Differential sticking is when the drill pipe is pressed against the wellbore wall so that part of its circumference will see only reservoir pressure, while the rest will continue to be pushed by wellbore pressure. As a result the pipe becomes stuck to the wall, and can require thousands of pounds of force to remove, which may prove impossible. Because the reservoir pressure is greater than the wellbore pressure in UBD, the pipe is pushed away from the walls, eliminating differential sticking.

Disadvantages

Under balanced drilling is usually more expensive than conventional drilling, and has safety issues of its own. This is true when combustible and corrosive gasses like processed flue gas and oxygen are injected into the drilling mud to lower its density. Drilling under balanced may be pointless from a formation damage standpoint if the under balanced condition can not be maintained - which can be difficult when the drillstring needs to be removed to change a bit, or if the flow must stop in order to allow mud pulse telemetry to be sent. Information is frequently needed from the bottom of the well (knowledge of bottom hole pressure is very important in under balanced drilling, as is information for geosteering if it is a deviated well). When gas is injected into drilling mud, standard mud pulse telemetry becomes impossible. "Killing" the well (making it overbalanced) may be necessary to send information, inducing formation damage. Underbalanced drilling also increases the chances of the wellbore collapsing in on itself.

