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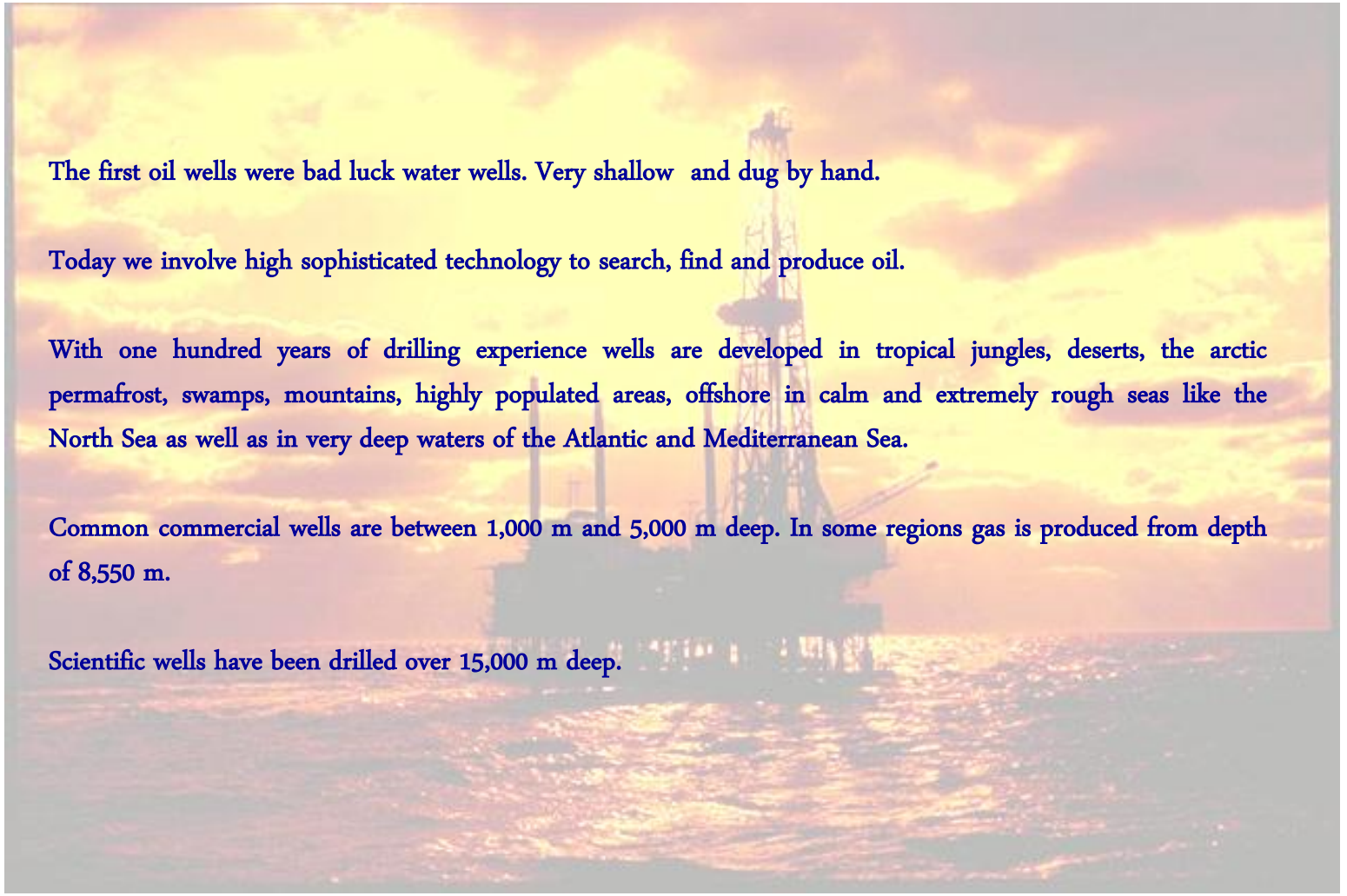
Drilling a well



The first oil wells were bad luck water wells. Very shallow and dug by hand.

Today we involve high sophisticated technology to search, find and produce oil.

With one hundred years of drilling experience wells are developed in tropical jungles, deserts, the arctic permafrost, swamps, mountains, highly populated areas, offshore in calm and extremely rough seas like the North Sea as well as in very deep waters of the Atlantic and Mediterranean Sea.

Common commercial wells are between 1,000 m and 5,000 m deep. In some regions gas is produced from depth of 8,550 m.

Scientific wells have been drilled over 15,000 m deep.

Titusville

1859, Titusville

Todays oil industry actually began in 1859.

A part-time railroad conductor named Edwin L. Drake came to Titusville, Pennsylvania where oil was known to be in salt mines.
In spring of 1859, he built the derrick and started to drill. It was slow going.
In three month he had drilled about 69 feet (23 m!).
Then, the drill bit dropped into an underground crevice and abruptly slid down another 6 inches (15 cm). The next morning oil was floating on top of water in the pipe.

The technique used was called cable tool drilling.

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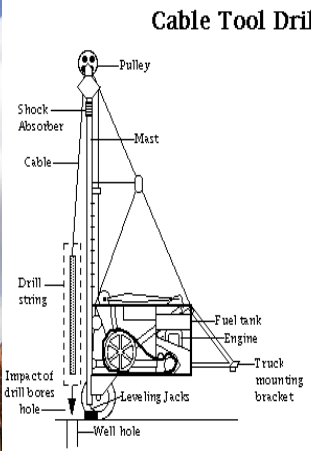
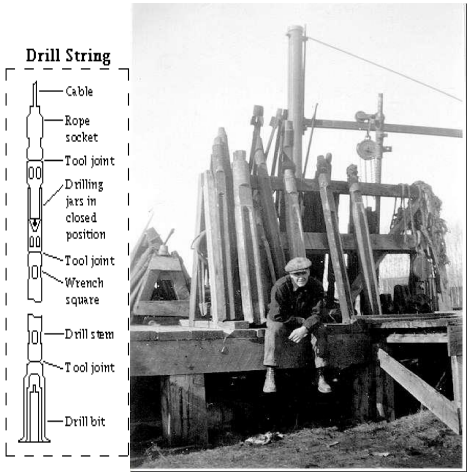
The Cable tool

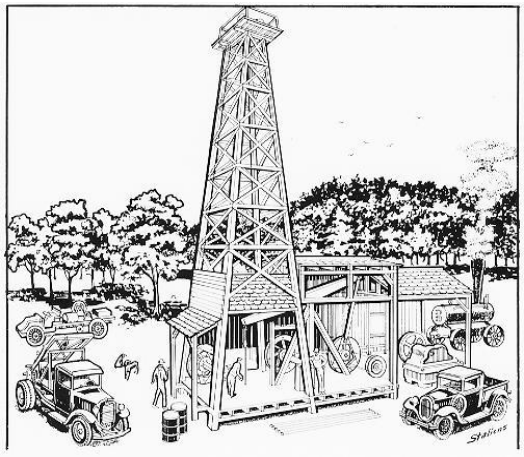
Cable tool chisel



Cable tool rig



Cable tool rig tools



Rig site with steam engine winch house

The first wells were not really drilled but hammered. A bit was jarred on the rock and pulled out of the well with a cable. The chiseled off rock debris, called cuttings were pulled out with a baler. Progress was very slow, not even 100 m per month, but it was very simple and cheap. The last well lowered with this technique was in New York in 1956.

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Rotary drilling

Drilling crew on the rotary table, Spindeltop 1926

Texas 2002, RB
Spindeltop museum 2002

With the turn of the 20th century rotary drilling became the standard. It allowed much faster progress, one could control the well pressure and drilling of even deviated wells was possible.

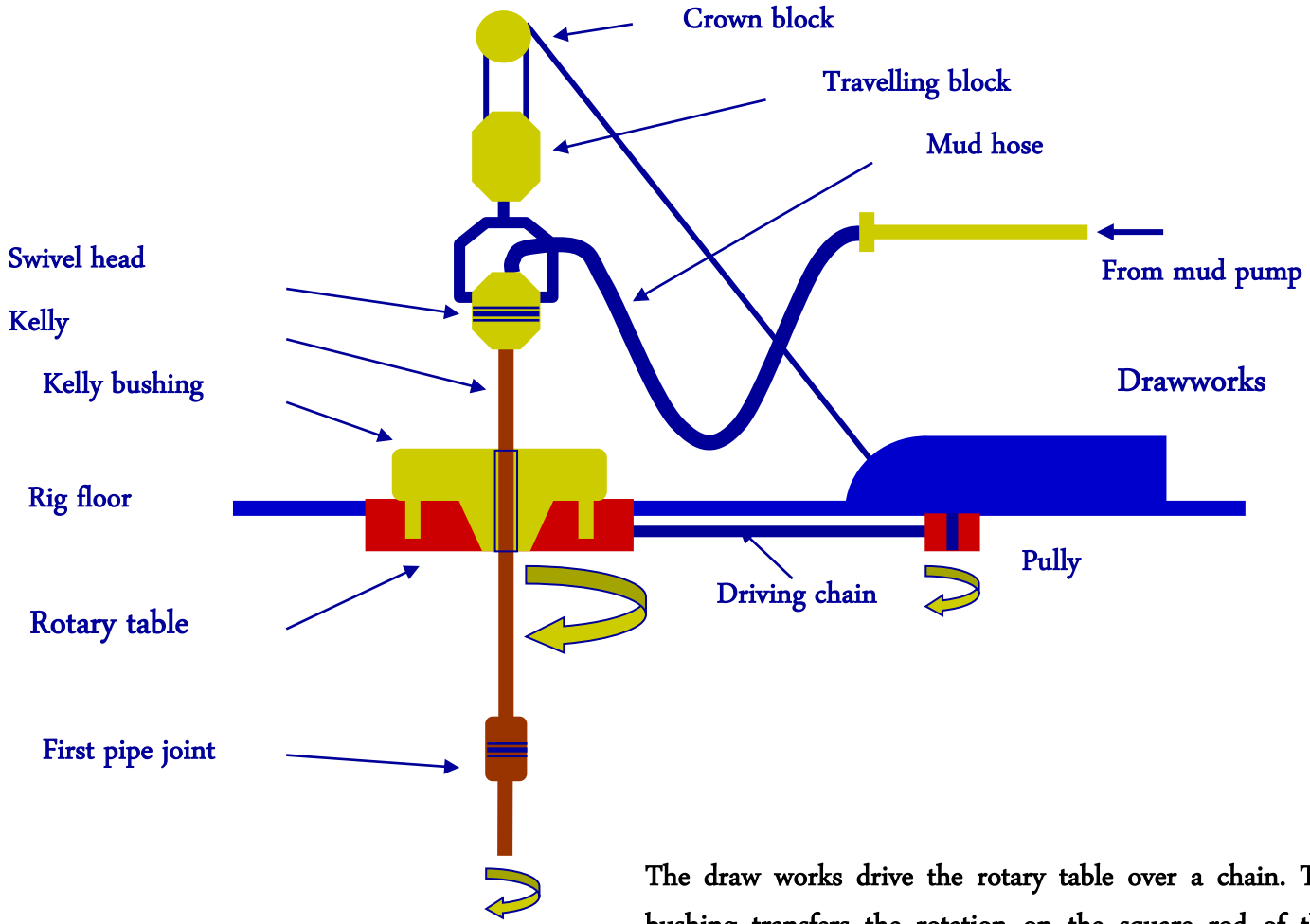
Spindeltop, a hill close to Beaumont/Texas, is regarded as the first well drilled with the rotary technique.

1020 feet, 335 m, were reached in only 75 days!

Today's rotary drilling technique would not need more than a few days to reach that depth.

Endress+Hauser

Rotary



The draw works drive the rotary table over a chain. The kelly bushing transfers the rotation on the square rod of the kelly. Mud is pumped through the kelly into the drill pipe.

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Rotary drilling, BHA

The bottom hole assembly, BHA, is made up of different sections.

Drill pipe (DP) makes up most of the BHA. It is a thin walled pipe made of very elastic steel. Drill pipe can only support tensional forces and hangs in the derrick. It never pushes on the bit.

The weight for the bit is provided by the drill collars (DC).

They are heavy antimagnetic stainless steel pipes with only a small inner opening.

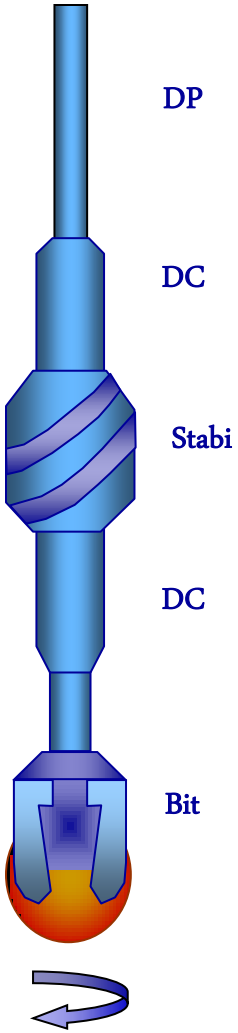
Stabilisers keep the bit centred in the well. There are only a few used.

The bit is at the end of the BHA. Usually a roller cone bit, it has three wheels with chisel type surface.

These chisels are made of hardened or carbon tungsten steel.

The chisels roll with the weight of the drill collars (not of the drill pipe).

The entire BHA is hollow to allow circulation of drilling mud.



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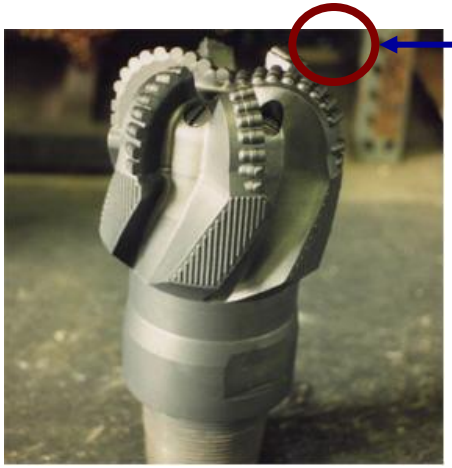
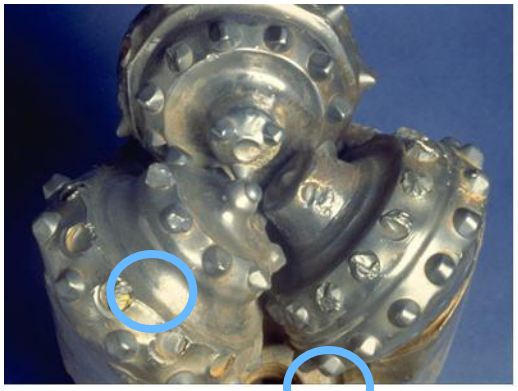
The drilling bit





Mud nozzles

PCD bit

Poly Christaline Diamont

Roller cone bit

most commonly used bit.

(this one has been used and teeth are broken off)

Various bits for different rocks work as a chisel and hammer the rock to cuttings by rotation and weight approx. 25 tons.

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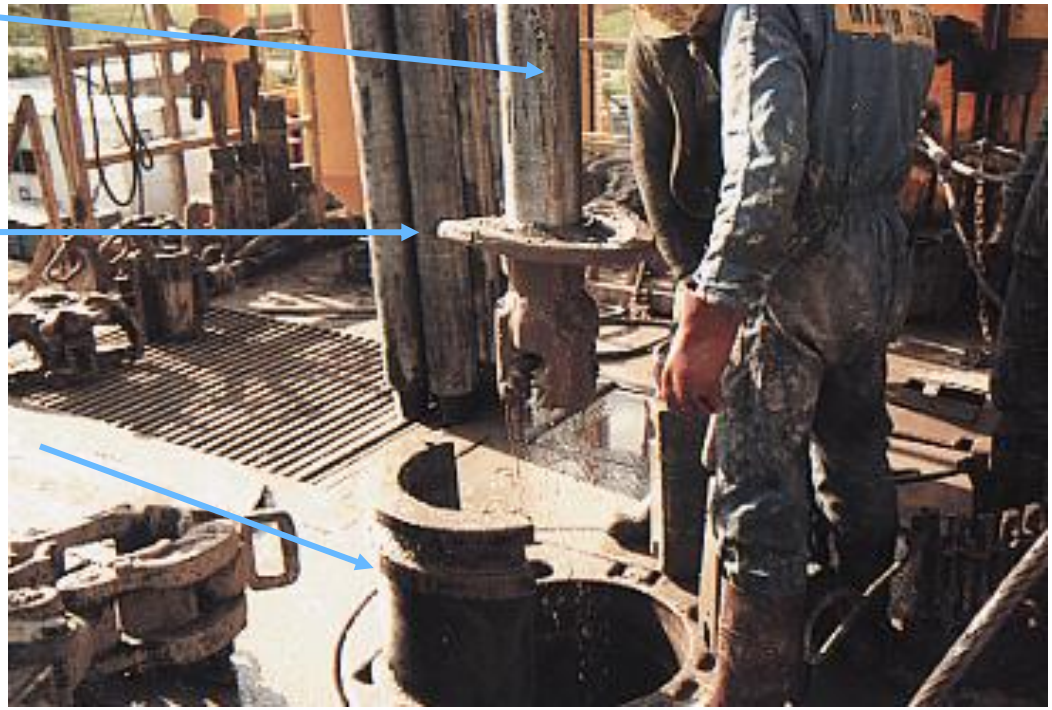
Rotary table

Drill collar with wiper

Bit

Rotary table



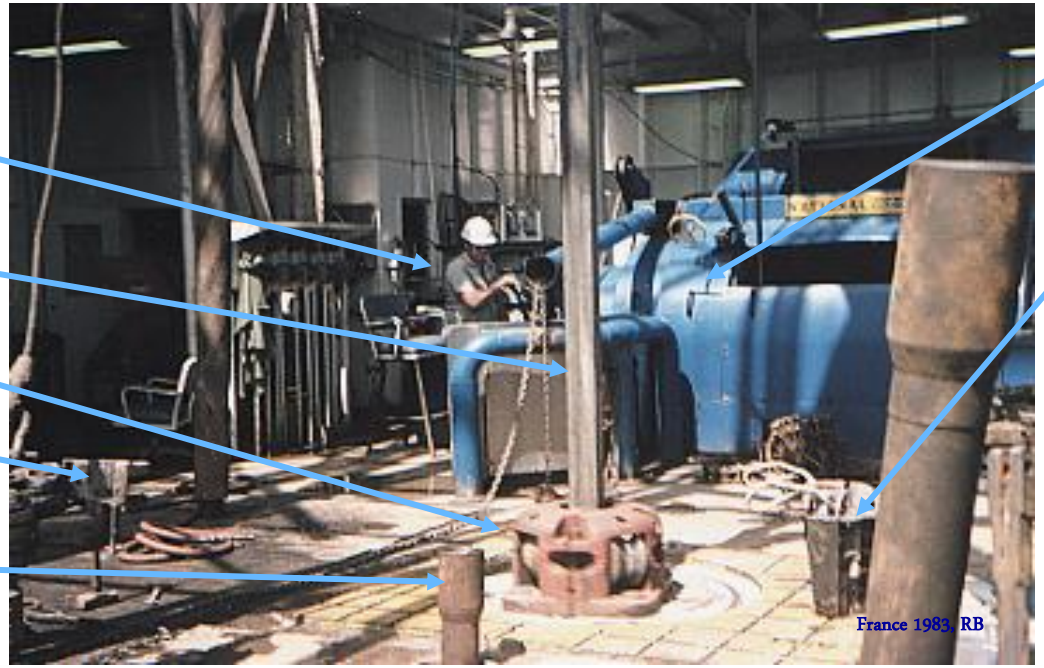
Rough necks

France 1983, RB

A bit comes out of the well, the rotary table is open

Endress+Hauser

The rig floor



Drilling mud is pumped into the drill string through the kelly. The kelly is square shaped thus it can transfer the torque and rotation of the rotary table to the string and bit. The next pipe to be connected already waits in the mouse hole.

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BHA, bottom hole assembly

Drill pipe

Valve sub

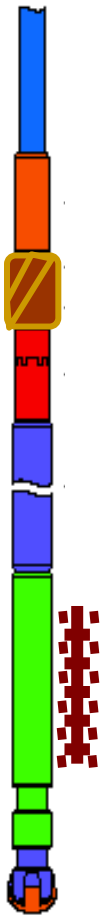
Stabiliser

Jars to hammer a bit free

Drill collars for weight on bit

Down hole motor to drive the bit

Bit



Today's sophisticated drilling is mostly done with turbines close to the bit. This technique allows to drill horizontal over many km.

Jars, like downhole hammers, triggered by pull and push to hammer - or jar - a BHA free when stuck.

A turbine is driven by mud flow. Over a gearbox it rotates the bit with approx. 150 rpm.

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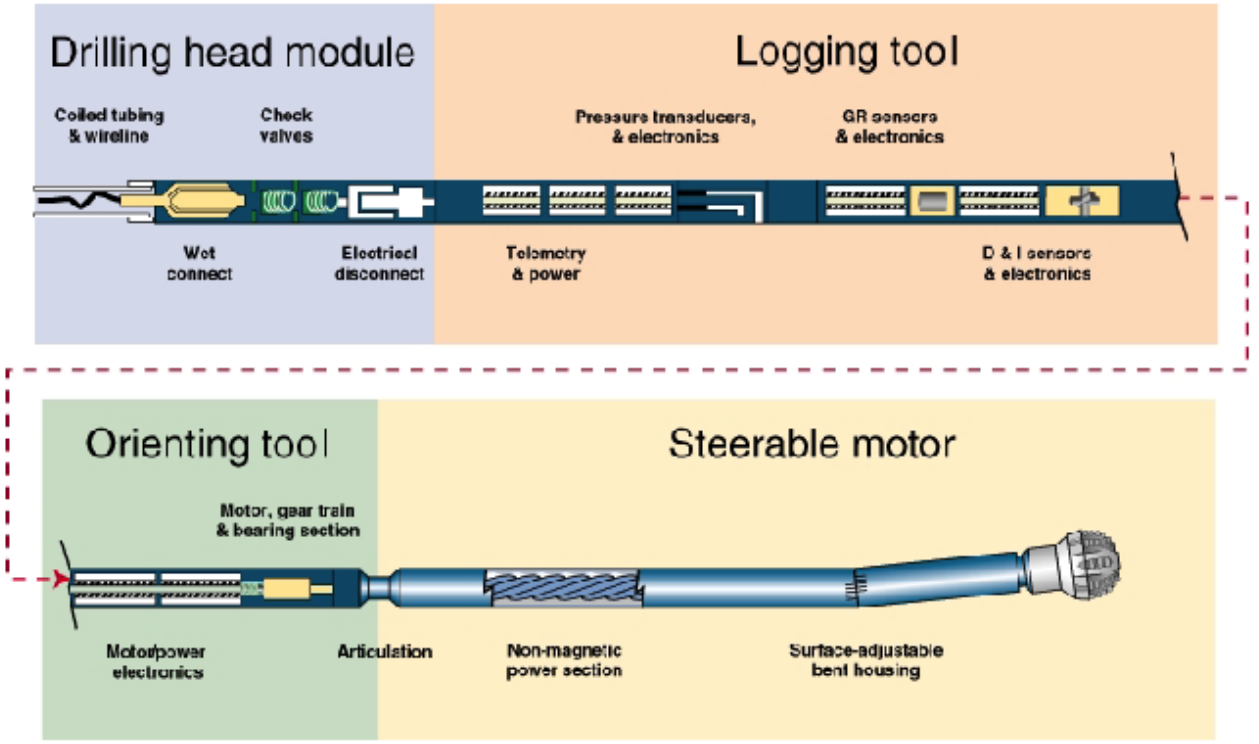
Coil tubing drilling



With the development of highly deviated (not vertical) and even horizontal wells the need for a device to push instruments down to the end of the well became necessary since lowering instruments on cable or wireline no longer works. Soon this new technology was further developed to even drill very small holes.

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Horizontal drilling

For better efficiency and more cost effective production the wells are “kicked off” and drilled horizontally through the reservoir. This way not only a few meters but many hundred and even thousand meters can produce oil and gas.

Endress+Hauser

Make up drill pipe

France 1983, RB

The depth of several thousand meters is reached by joining pipe sections of 10 m each. With heavy tongs the joints are made up and a defined torque is applied to each - several ton/m.

A dangerous job for the rough necks.

Endress+Hauser

Drill pipe and stands in the derrick

The stands are placed for future use in the derrick. Congo 1985, RB

During drilling one by one the pipes are connected to the drill string as they dig down through the formation.

Pulling out, e.g. to change the bit usually 3 drill pipes of approx. 10 m each make up a stand. Smaller rigs have only two or even a single pipe, giant rigs have 4.

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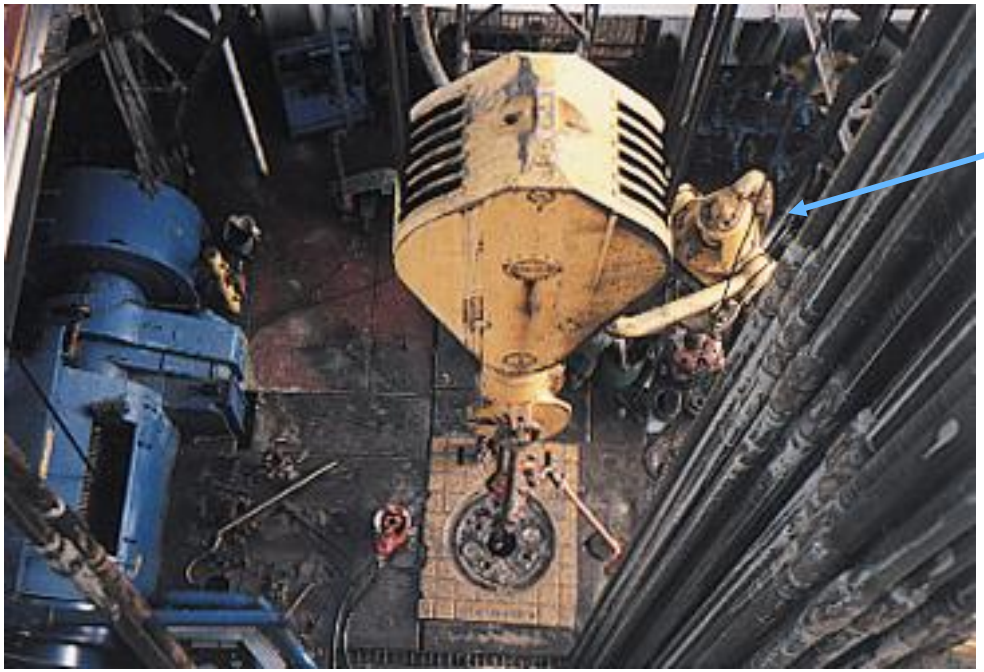
Travelling block



Congo 1985, RB

The drill string is hanging in the elevator. The elevator is attached to the travelling block. The draw works, left in blue, are capable of pulling several hundred tons.

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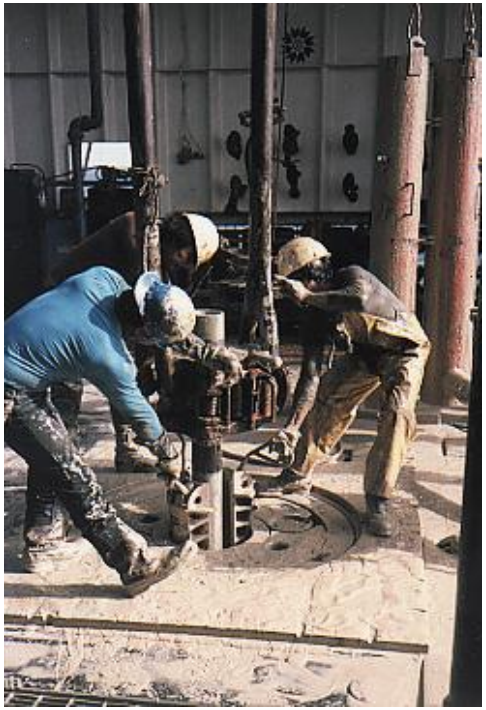
At the rotary table

A conical thread makes a tight and strong joint with only 5 turns.
The chain for speed the turning, many fingers were lost this way already.



Jack-up Trident 9, Congo 1985, RB

Pulling out:
The elevator is closed around the top pipe joint and lifts up.
The rough necks pull out the slips, on which the pipe was resting while the elevator lifted the last stand away.

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Pipe deck

Congo, High Island 5, Sedco Forex 1985, RB

Stored on the pipe deck are drill collars, drill pipe, tubing, and various casings as well as a lot of odds and ends needed

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Bit size, casing

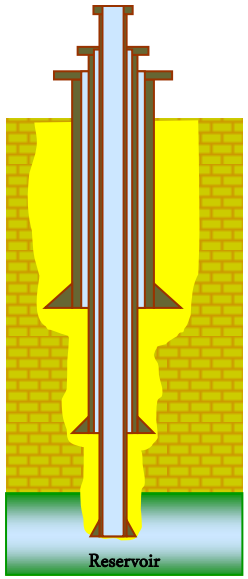
A standard well is drilled in 3 sections:

Surface,

intermediate

and reservoir or final.

Surface hole 100 - 1000 m	17 1/2" Bit size 13 3/8" Casing
Intermediate hole 1000 - 3000 m	12 1/4" Bit size 9 5/8" Casing
Final reservoir hole 1000 - 4000 m	8 1/2" Bit size 7" Casing



Starting the surface hole with a bit as big as 32" the final section can go as small as <3 3/4".

Once a section is drilled the open hole has to be supported by a casing which is a straight steel pipe made up of individual sections some 10 m long.

The casing withstands the pressure of the formation and seals off various formation layers.

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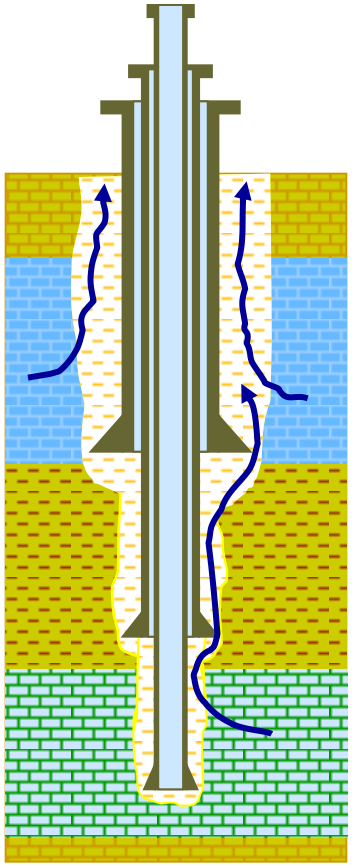
Cementing



Fresh water zone

Shale, cap rock

Petroleum reservoir

Once a casing section is run, the annulus between casing and formation needs to be sealed off to establish a hydraulic seal.

Pure cement together with additives e.g. retarder or accelerator is pumped down hole and circulated behind the casing.

The cement prevents hydraulic communication between various horizons and between subsurface and surface.

Without proper cementation of the casing, petroleum from the reservoir will find its way to surface and contaminate fresh water zone on the way.

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Well logging

Libya 1986, RB making up logging tools

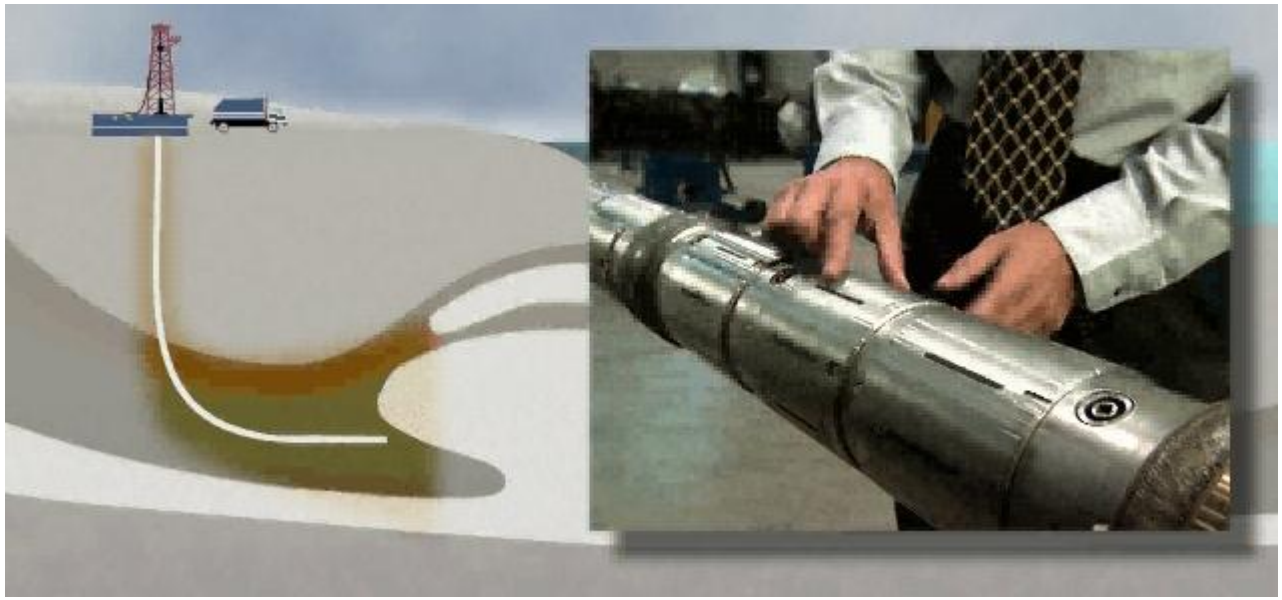
To get a clear picture of the down hole formation and well condition, logging tools are descended on electrical cable - wireline - before the well is cemented.

Density, porosity, resistivity, conductivity, radiation, sonic velocity, rock pressure, formation deviation and orientation are measured. Fractures and formation samples (cores) are taken.

The tool above - high resolution formation imager - gives with 250 electrodes on each pad an electrical picture of the reservoir indication oil/water, tilt and orientation of structure and size of rock fractures.

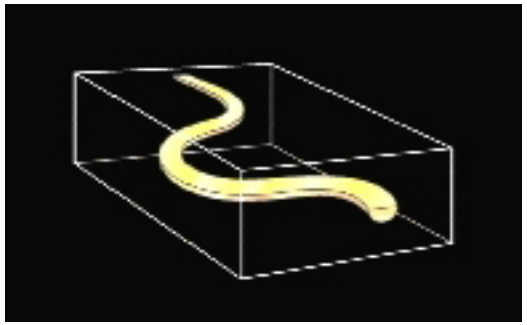
Endress+Hauser

MWD



MWD: Measurement while drilling

Directional sensors at the bit give real time info about the drilling direction.
An adjustable bit allows constant change of directions.
This way even reservoirs in bend channels can be followed.



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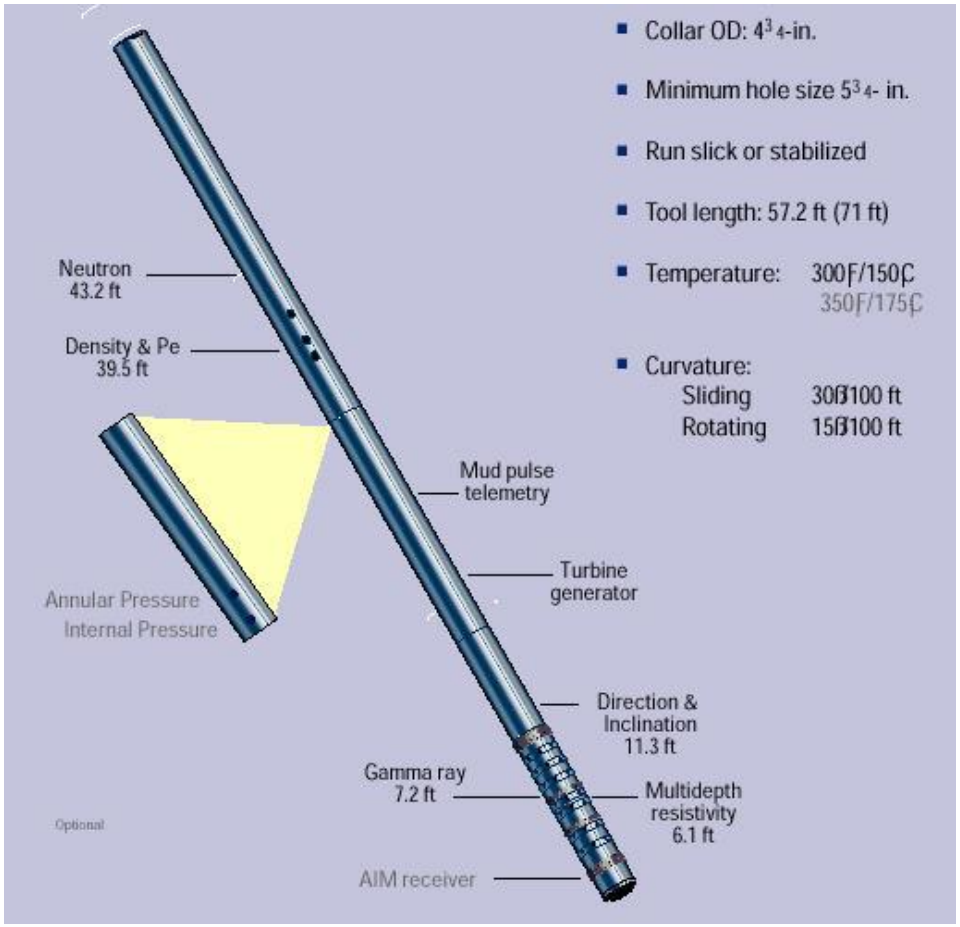
MWD



MWD
Measurement While Drilling:

To be able to log the formation before the mud filtrate changes the original - virgin formation condition and to closely observe the drilling progress in situ.

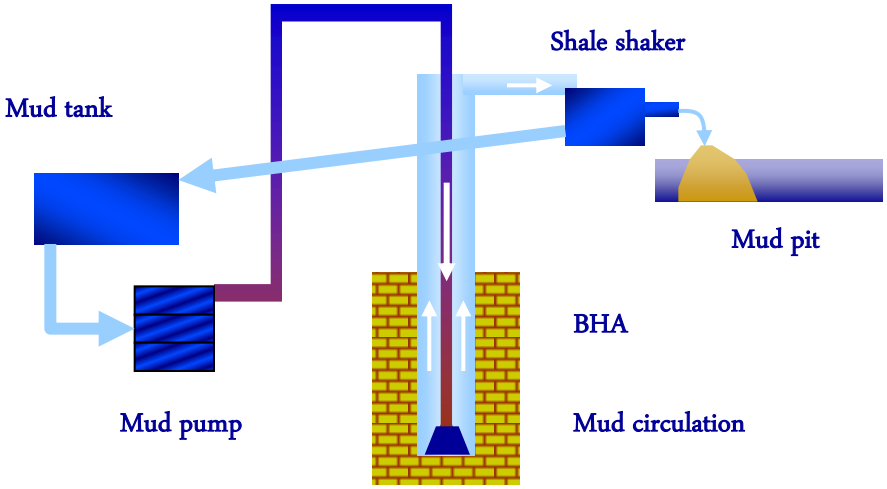
MWD gives real time data to surface.

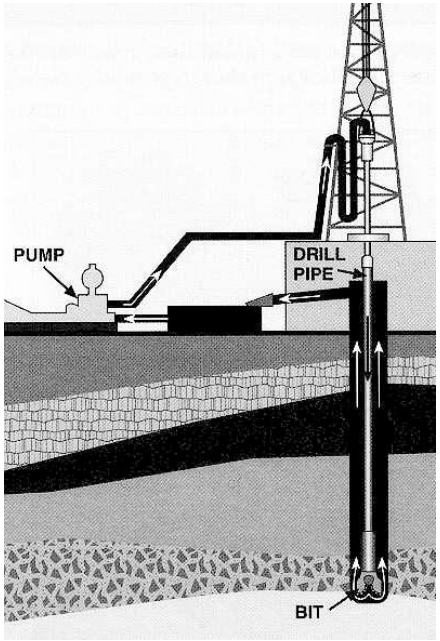
At low baud rates, mud pulses are created (by temporary blocking of the turbine) and detected at surface. Main data is stored in memory.

Formation density, porosity, radiation, conductivity and well deviation and inclination are measured.

Endress+Hauser

Drilling mud





One important purpose of drilling mud is to transport the remains of the cut away formation, called cuttings, from the bit to surface.

The shale shaker filters out the cuttings which drop into the mud pit for disposal.

The mud is collected and treated in several storage tanks.

Triplex piston mud pumps pump the mud through the BHA into the well to circulate back to surface in the annulus carrying the cuttings with it.

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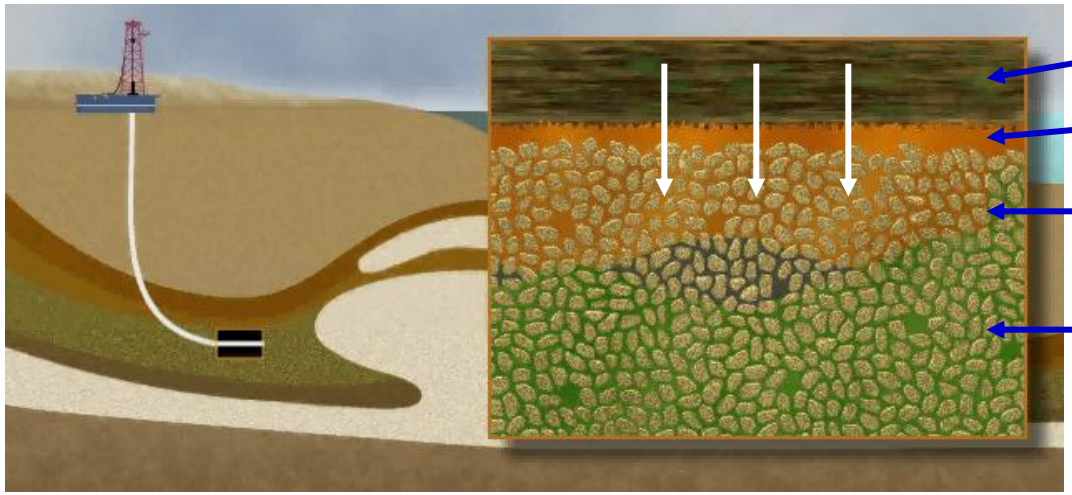
Drilling mud

Invasion of mud filtrate



<u>Mud controls the well pressure!</u>

At no time is an open hole not filled with mud right to the top.

The mud density is always adjusted to guaranty the hydrostatic mud pressure to be higher than the expected formation pressure.

The positive pressure difference forces the mud to squeeze and filtrate into the rock. Mud cake is filtered out and filtrate penetrates the formation, pushing the hydrocarbons away. The mud cake, 5 to 15 mm thick, seals off the well, prevents further invasion and acts as lubricant for the drill string.

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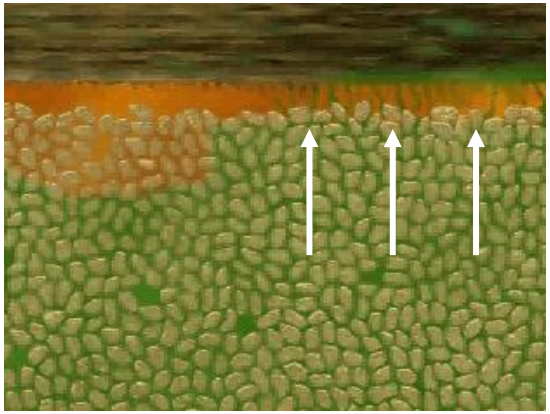
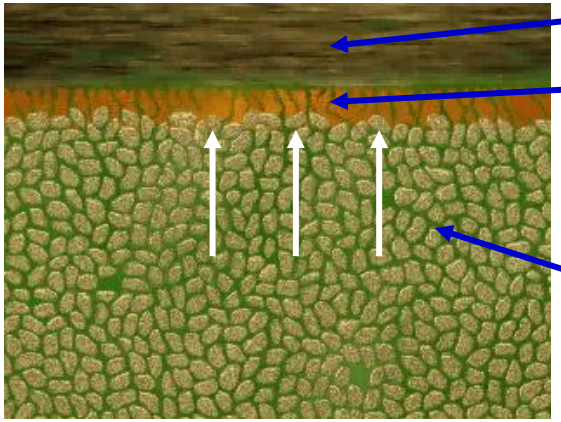
Under balanced mud





Mud pressure is reduced and oil from the formation penetrates back to the bore hole.

Oil pushes the mud cake way and dilutes into the well.

<u>Mud pressure is too low!</u>

Now there is a high risk of a blow-out!

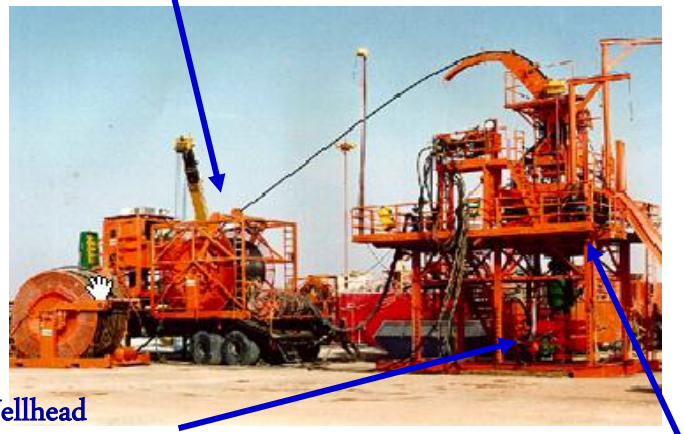
Quick action is required to increase the mud density back to a safe level - or a very fast car to take pictures from a safe distance.

Endress+Hauser

Coil tubing

Tubing on coil

Control unit



Wellhead

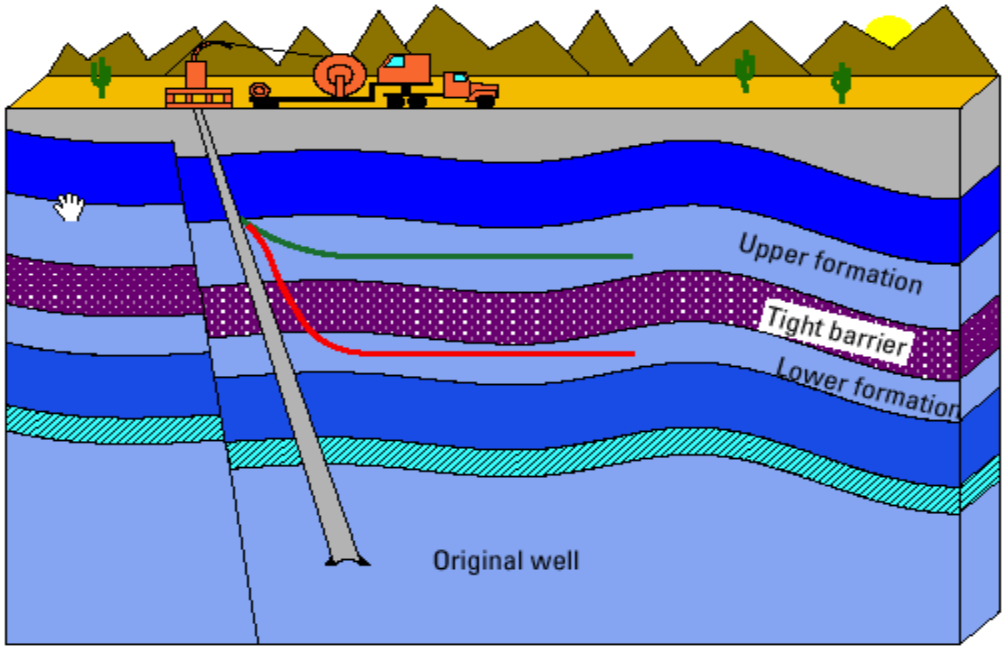
Snabbing unit to seal off the well while running in tubing.

For work over and logging operations in horizontal wells a steel pipe of 1" or 1 1/8" diameter and over 5,000 m long, coming off a huge coil is pushed into the well.

Logging tools can be connected to the end as well as little drilling bits to drill side tracks off on old or original well.

Endress+Hauser

Coil tubing drilling, two laterals



Coil tubing opened a whole lot of opportunities e.g. side tracking one or more wells out of an existing one.

Multilateral wells can produce petroleum from several horizons and make the original investment pay off a lot more.

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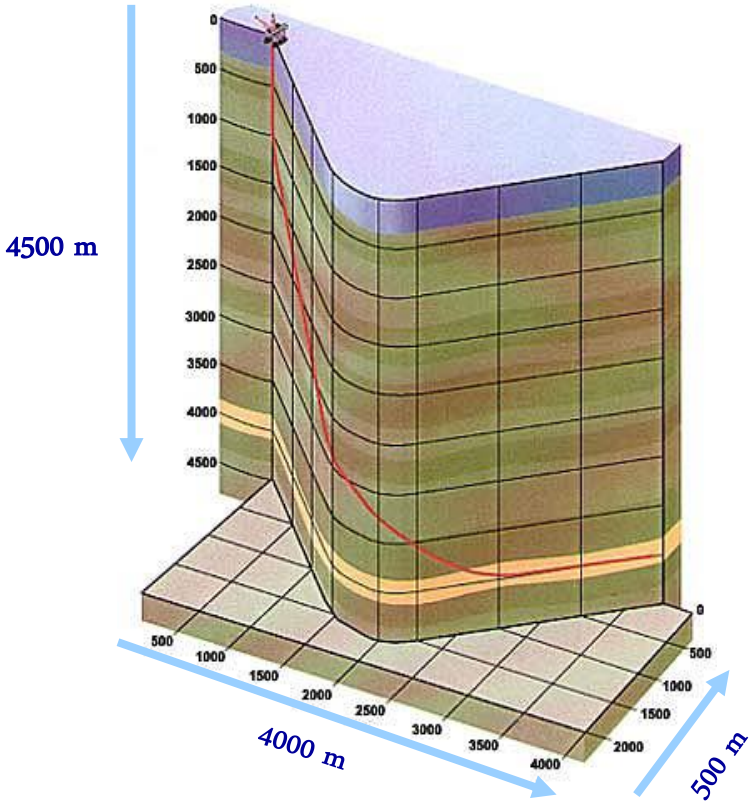
An extreme well



The world's longest three dimensional well drilled from a floater.
Courtesy of Statoil, Norway

Once down to the reservoir depth at about 3,800 - 4,000 metres below ground, the well direction flattens out into a horizontal section extending more than 1,200 metres.

Measuring 6,920 metres in all, this "three-dimensional" route means best penetration of the reservoir at a favourable angle to drain this part of the formation effectively.

Transocean Arctic drilling rig.

The well is the longest 3D type to be drilled from a mobile rig - Transocean Arctic needed 69 days for the job.

This demanding job called for very good planning and close collaboration between people familiar with the reservoir and the drilling specialists.

Endress+Hauser

Titusville story

Today's oil industry actually began almost 150 years ago – in 1859. In those days, an oily fuel for lamps and lubricants was made by melting the fat of whales. But whale oil had become expensive. A company called the Pennsylvania Rock Oil Company became interested in digging for natural oil. Oily rocks had been encountered in Pennsylvania by people drilling for salt. At first, this "rock oil" had been used as a medicine, but if enough of it could be found, perhaps it might be a cheaper substitute for whale oil.

Digging huge pits, however, was a time-consuming, expensive operation, so the Pennsylvania Rock Oil Company came up with the idea of drilling for oil. Not everyone was convinced, however. One banker who was asked to lend some of the money for the venture remarked, "Oil coming out of the ground, pumping oil out of the earth as you pump water? Nonsense!"

But the Pennsylvania Rock Oil Company was convinced that drilling for oil – rather than digging for it – was the way to go. They hired a part-time railroad conductor named Edwin L. Drake to go to Titusville, Pennsylvania and see if he couldn't drill for oil. (Some books call him "Colonel" Drake, but he invented that title only to impress the local townspeople.)

Drake spent almost a year – from 1858 to 1859 – getting the money and building the equipment (including a steam engine) he needed to drill. In the spring of 1859, he built the derrick and started to drill. It was slow going. The investors became nervous, and late that summer, they sent a letter to Drake directing that he cease operations, pay off his debts, and give up. The letter was slow in arriving at Titusville. Before he got it, Drake had drilled about 69 feet (20m). Then, the drill dropped into an underground crevice and abruptly slid down another 6 inches. Work stopped, but the next day one of the Drakes employees went out to check the drill rig. He peered down into the pipe that had been left in the hole. There, floating on top of water in the pipe, was oil. Drake had struck oil. A new industry was born.

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