History of Well Construction & Related Matters

The watering place has always been the focal point of life on earth. First animals and then humankind clustered around their source of fresh water. Both animals and humans can exist for weeks without food, but without water life ceases within days. Wells were one of humans' earliest construction activities.

The earliest wells are known from the Neolithic era. Neolithic refers to the time period roughly 7,000-10,000 BC. Well construction seems to date from the time of the adoption of a series of behaviours common to the people of a given region. These behaviours include the widespread use of farming, the keeping of domestic animals, and the use of metal (copper) tools. By the time of the progression in development from the use of copper tools, to bronze tools to the widespread use of iron tools (Iron Age-1000-2000 BC) wells were commonly constructed.

The oldest know well has been found in the archaelogical excavation of the settlement of Atlit Yam in Israel, dated to 8100-7500 BC. .

Wood-lined wells are known from the early Neolithic for example in Germany and Austria. From the Iron Age onwards, wells are common archaeological features, both with wooden shafts and shaft-linings made from wickerwork.

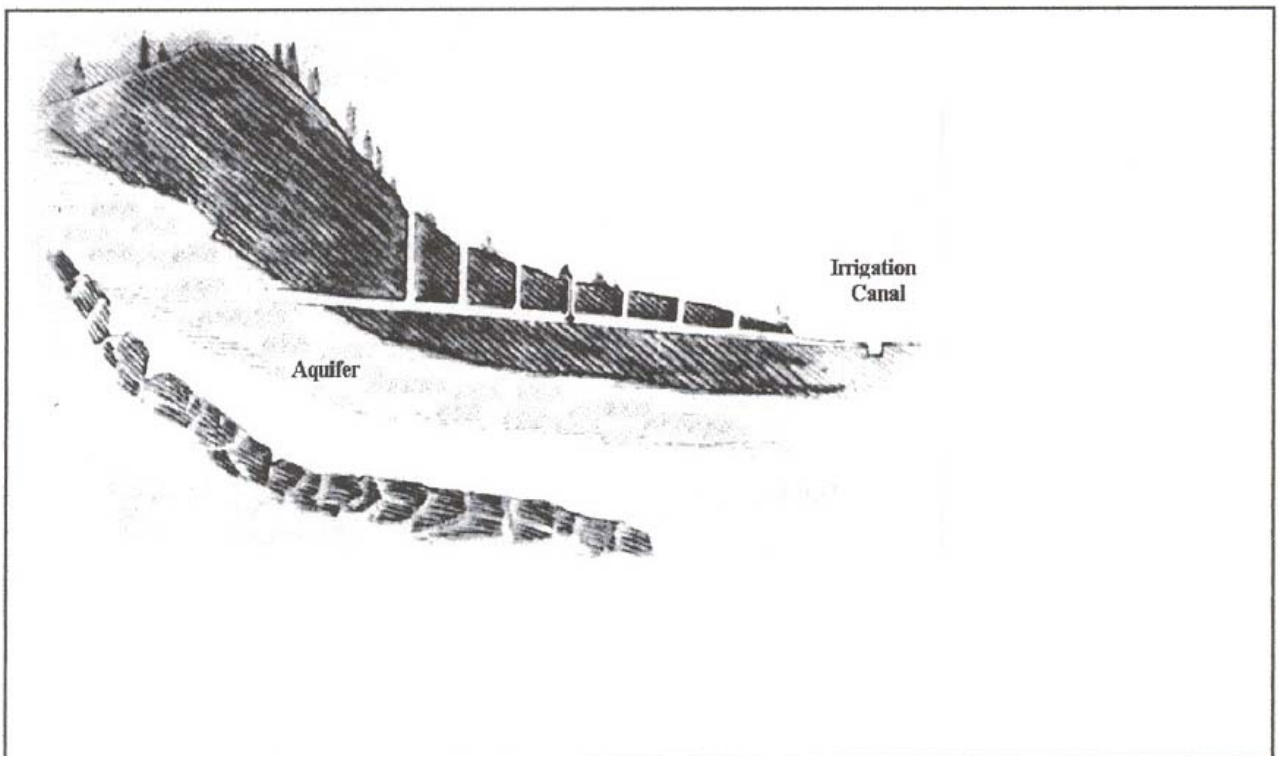
“Persian Works”

Beginning around 2000 BC Iranian people were building tens of thousands of miles of irrigation tunnels or early “collector” type wells.

Collector wells may be of one of two types. The first, is a single or series of near horizontal wells entering the aquifer at one end and gently sloping downward at an angle less than the surface gradient. The tunnel exits the ground at a lower elevation where the water is used for irrigation purposes.

A series of vertical shafts are extended upward to the surface along the tunnels’ journey. These vertical shafts serve several purposes. They provided ventilation in the tunnel during excavation; they provided a more efficient means for the removal of construction debris, and these vertical exit points became a series of vertical wells that can tap into the horizontal tunnel below providing a source of water at intervals over the entire length of the tunnels’ journey from aquifer to exit point.

These Iranian “Ganats” honeycomb certain areas of Iran and are said to total in excess of 100,000 miles made up of 22,000 separate ganats. Ganats originated in Iran (Persia) but were adopted by other lands exposed to the cultural influence of the ancient Persians. Ganats have been found in: Pakistan and Afghanistan (where they are called a karez), western China, North Africa (a foggara), Spain and Sicily. The term “Persian Works” was used by these countries to refer to the underground conduits constructed for irrigation and domestic supply based on “ganats.”



The second type of collector well is relatively commonplace in the US for large scale applications and is spoken about in the section on Well Types.

History of the Hydrologic Cycle

Over the centuries humankind had many explanations of how water came to be on earth and the sources of rivers, lakes and streams. Many of these theories seem truly fanciful to us today, but they represented the best observations and thoughts of their era. When Roman civilization faded, there was literally no original thinking about natural phenomena for about the next 1500 years. Even the great Leonardo da Vinci (1452 - 1519)

maintained the concept of a hydrologic cycle in which underground veins of water rose from the sea to the mountains, where they issued forth as rivers. During this underground passage the salt was filtered out. This concept was identical to some of the concepts put forth by Greeks such as Plato.

The first person to provide a correct written explanation of the origin of rivers and springs and the hydrologic cycle was a Frenchman, Bernard Palissy (1510? - 1590):

" rain water that falls in the winter goes up in summer, to come again in winter. . . And when the winds push these vapors the waters fall on all parts of the land, and when it pleases God that these clouds (which are nothing more than a mass of water) should dissolve, these vapors are turned into rain that falls on the ground." "And these waters, falling on these mountains through the ground and cracks, always descend and do not stop until they find some region blocked by stones or rock very close set and condensed. And they rest on such a bottom and having found some channel or other opening, they flow out as fountains or brooks or rivers according to the size of the opening and receptacles…"

***Discourse Admirables*, Palissy, 1580. Palissy also correctly deduced the origin of artesian pressure in wells and the fact that wells near rivers could be connected to the rivers through "underground veins".**

Unfortunately Palissy wrote in French, rather than Latin, which was the accepted scientific language of the day. Hence, his work was not widely distributed and the incorrect hydrologic concepts of the Greek and Roman philosophers continued to persist.

Biblical Well Producers?

Through the ages Christians have come to believe that there were three men mentioned in the Bible who built wells or extracted water from the ground. Two of the three appear in Genesis, the third in Numbers. The Bible only specifically mentions one of these 3 men as having produced water from the earth. The other two men and their well construction feats are the stuff of legend and folklore.

Jacob was the son of Isaac and the grandson of Abraham. We are told that Jacob was the second born of twin boys and that he was born holding onto the heel of the first born of the twins, Esau. As the boys grew they were always competing for the blessing and affection of their father Isaac.

Esau was said to be a hairy man, and a skilled hunter, often successful in bringing home delicacies for his father. Jacob was a quiet man, who dwelt in tents. Jacob became the favorite of his mother Rebekah.

Because of the great envy Jacob had for Esau, he plotted ways to usurp their father's favor from his older brother. The Bible relates how Jacob was successful in having Esau renounce his birthright in favor of Jacob, and how Jacob later deceived his blind father Isaac by pretending to be Esau so as to gather Isaac's blessing for himself.

Esau plotted to kill Jacob for his treachery. But Rebekah coaxed Jacob to flee to the land of his uncle, Rebekah's brother Laban. Jacob stayed in the land of Laban for 20 years. While thee he took as his wife

Laban's daughter and he prospered. During this time, as his flocks of sheep grew, Jacob purchased land in the village of Shechem, in Samaria.

While the Old Testament makes no specific mention of the well's construction, this well has been known since ancient times as Jacob's (Son of Isaac) well. The well still exists as this internet excerpt from the experiences of a recent tourist tells:

"We enter the arched opening through the cut-stone wall into a courtyard, where tree-blossoms, shrubs, and a variety of flowers greet our vision. A welcomed breeze softens the dry heat of Israel's West Bank in June. In the center of the courtyard a concrete walkway leads to a covered stairway at the opposite end. We descend the circular stone stairs 15-20 feet below ground level to a vaulted room, floored with stone mosaics and decorated in Greek Orthodox style. Looking around the small chamber to the side opposite the stairs, we see it. This is Jacob's Well—Bir Ya'qub—where Jesus encountered a Samaritan woman and discussed the spiritual "water" which quenches forever the soul's deepest thirst (John 4:1-42).

The well bottom has varied in depth through the centuries, from 240 feet deep to the present day 67 ft. The well is fed from underground springs and is therefore moving. Called "living water" by the ancients, Jesus gave this term new meaning." The well is located within the walls of the Greek Orthodox Monastery in the modern city of Nablus (see picture below.

Samaritans, Muslims, Christians and Jews accept the authenticity of this well.

Well construction is often passed down from generation to generation. Multi-generation family well drilling businesses are commonplace throughout the United States. But this practice of multi-generation well constructors may also be part of the Biblical story of Jacob.

Jacob had many sons. But his favorite was Joseph. To show Joseph how much he favored him Jacob had a special robe made for Joseph. Not surprisingly, his male siblings hated Joseph. Their feelings were so strong toward Joseph that the brothers plotted to kill him. One Brother Reuben, intervened saying, "*let us not do this thing and have our brother's blood on our hands."* Instead of killing Joseph the brothers sold him into slavery to a passing caravan bound for Egypt. Joseph was to remain in Egypt all of his years.

While in Egypt Joseph is credited with constructing Joseph's well in Cairo (see picture below).

Some question this assumption however as can be seen from the following excerpt from an Egyptian tourist publication.

"*The Citadel, on account of its age and history, is one of the most important buildings of Cairo, and, because of its commanding position on the Moqattom hills, it is the most prominent.*

The well outside the citadel, called Joseph's well and generally attributed to the Biblical Joseph, was probably sunk around 1183 AD by Sultan Salah el Din (Saladin) whose name was Josef (Joseph), to supply the citadel with water before the aqueduct was built. It is a square shaft with a spiral passage round it, sunk to a depth of 290 feet in the limestone rock. Within the shaft, at a depth of 155 feet, is a platform on which stood a saqiya (water wheel). The saqiya was worked by oxen and brought the water to the surface. The well is not now used."

As with Jacob's well there is no mention in the Bible of the construction of Joseph's well. Whichever Joseph constructed the well in Cairo, Jacob's favorite son or Sultan Saladin it is a noteworthy feat of construction for its time. The spiral passage mentioned above has given the well another name: "the well of the snail."

The book of Numbers tells of Moses act of bringing forth water from the ground for his people. We are told that Moses was divinely instructed to bring forth water for his people by asking for water to be brought forth from the rock through the power of God. Moses unfortunately disobeyed his instructions and struck the rock twice with his staff instead of demonstrating his faith in the power of God by the act of asking. Although water did come forth in abundance, Moses is punished for his disobedience of Divine Instruction. (Numbers 20:11)

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Water is also associated with the older sister of Moses, Miriam.

Thus far, in our narrative we have talked only of dug wells. From this point onward we discuss the history of wells *drilled* by mechanical and technical means rather than dug wells such as those of Jacob and Joseph.

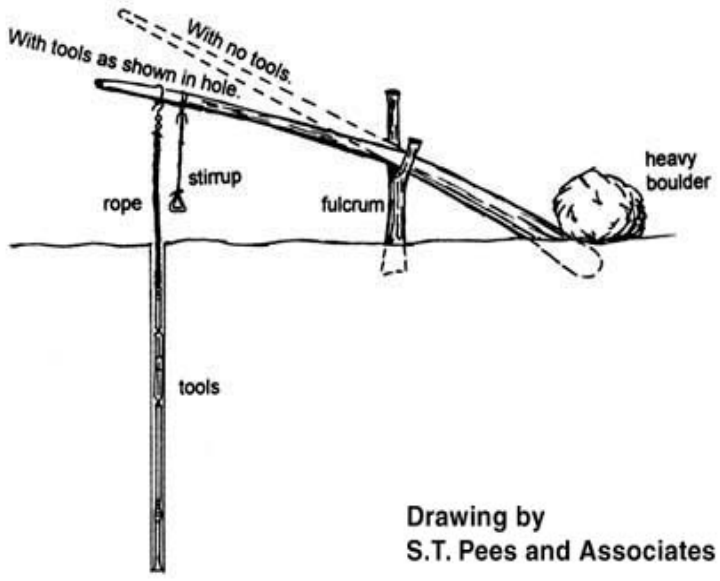
Well Drilling Technology

The Chinese are credited with developing the percussion method of well construction. In continuous use for 4000 years (and counting), the percussion system of drilling began with frameworks constructed of bamboo that allowed for the raising and dropping of a heavy chiseling or crushing tool. Using this system wells were drilled to depths of 3,000 feet, although construction took generations to complete. The cable tool drilling rig as we know it today, directly descended from the bamboo framework percussion drilling techniques of the Chinese people.

The first adequately documented spring-pole well in America was drilled by David and Joseph Ruffner beginning 1806 and completed January 15, 1808, on the bank of the Kanawha River near Charleston, West Virginia.

They reached a total depth of approximately 58 feet of which 40 feet was in bedrock. It was a salt well. This area became the salt manufacturing and distribution center of the United States from 1806 until the 1830's. The Ruffner brothers were the inventive pioneers of drilling in North America. They even cased the well with wooden pipe to prevent weaker salt water from mixing with the brine of their main pay zone.

The drill string used by the brothers was forged by the local blacksmith based on ideas given by the brothers. Their design created a standard for drillers that followed. The brothers then erected a spring pole device and with their new tools ushered in a new era drilling in America. The drillers at the Ruffner Salt Works became so renowned for their drilling skills that they were called to Titusville, Pennsylvania in 1859 to help drill the first US oil well.



A lot of wells were started with the spring-pole. This method required strong legs and considerable time. The outfit was simple: a long pole, a weight to anchor the butt end, a fulcrum, stirrup, manila rope, oak rods, downhole tools including the percussion bit. More tools and other improvements would be added to the drill string as time went on.

The preferred pole wood was hemlock. It was springy and wouldn't crack easily. Ash and hickory were other trees that served well for spring poles. A tree would be selected to give about 30 feet or less of manageable pole and then cut and barked.

The fulcrum or fork was easy to make too. An oak tree would be found with a good limb and then cut to post size. The fork end would consist of a foot of sturdy trunk and a portion of the limb together forming a V. The post of the fulcrum would be firmly set into the ground and the spring-pole would be placed in the fork. The fulcrum would be positioned about a third (or less) distance from the butt end of the pole.

The pole's butt end would be anchored to the ground by boulders or a heavy log in such a way that the butt wouldn't move when the pole was springing. Sometimes wooden structures with a lintel and clamps would serve to secure the butt. All of these essential things could be found and fashioned in the forest, practically at the sites of the earliest oil wells.

The stirrup would hang from the spring-pole very near to the intended position of the borehole, maybe 3 1/2 feet to 4 feet from the working end of the pole. It could be a piece of manila rope looped at the bottom or it could resemble the stirrup on a saddle. The downward

push of the driller's leg in the stirrup would bring the tip of the pole down and allow the bit to smack the rock. Sometimes two stirrups were used so that two men could work together.

The drill string (a vertical series of tools and components) would be fastened about 3 feet from the end of the pole. It would consist of manila rope or oak rods with metal connectors, rope socket, a sinker bar, jars, an auger stem and a bit. Manila rope could entirely replace the oak rods if desired, but the rods continued in common use in America into the 1860's, more or less. The augur stem was a 3 1/2 inch diameter solid iron bar with the box on the bottom into which the pin of the bit is screwed. The stem gives weight and some rigidity to the downhole operation. Additional cable tool drilling devices were put into use in the 1860's and later, but most reflected a background dating to the salt well days and to early water wells.

A high tripod of poles was erected over the borehole and pullies (sheaves) were hung from the apex of the tripod. This allowed the pulling of the drill string when tools needed to be changed or when the hole needed to be bailed out. The latter was done by a bailer tool which retrieved the accumulated cuttings and cavings and thus cleaned the hole prior to resumption of percussion (cable-tool) drilling. Later this tripod would become the derrick and constructed in that familiar manner.

Drilling Machine with Spring-Pole

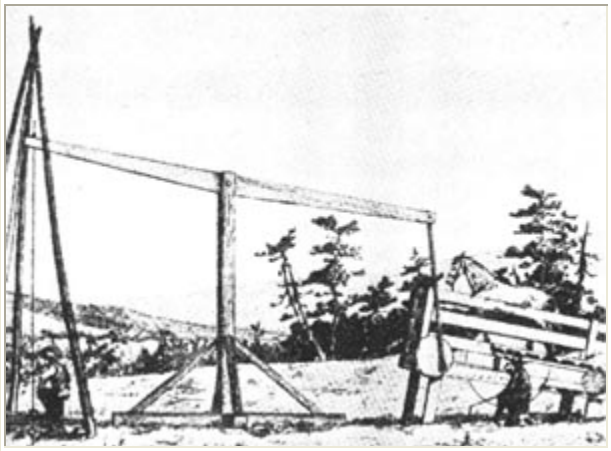
Horsepower Drives Drilling Machine

Treadles and Teeter-Totters

Different arrangements to provide the downstroke were tried out in the early days before steam power became common as a prime-mover. The bit had to forcibly hit the rock. Leg power on a spring pole was only as reliable as the strength and endurance of the man. Therefore, devices to replace sore legs were put into

use, but most of these look rather pathetic although they worked and even became rather elaborate by the 1870's, especially the horse-powered machines.

A walking horse, doomed to spend its shift trodding but going nowhere, provided power. The treadmill ran like an exercise machine. A horse and treadle arrangement served to operate a walking beam rig and could have done the same with a spring-pole. It was a matter of hooking it up right. This means of drilling goes back to the salt days and, after a fashion, even before then.



This horsepowered treadle is rigged to a wooden walking beam rather than a spring pole. This arrangement was in use in the early salt days and also served for drilling shallow water wells. This cable tool rig is considered portable. Ca. 1810.

Competing technologies often exist side by side during transition periods from the old to the newer technology. So spring poles drilling devices existed besides walking beam devices. And so too in the early 1800's when steam power became available, early steam powered drill rigs competed with horse driven drill rigs. The age of steam roughly coincided with the entire 19th century. Steam powered drill rigs began to appear around 1830.

It was at this same time, in 1831, during the salt mine drilling days of the Ruffner Brothers and other that the first metal drilling jars were invented. Billy Morris a spring pole driller patented his invention 10 years later, in 1841. Little is known about Morris except for his invention and that he listed Kanawha County (now in West Virginia) as his address.

Cable tool drillers can thank Morris for his invention and the mechanical advantage is gave cable tool drillers in the prevention of downhole problems with stuck tools.

Jars and the later invention of fishing tools allowed many previously abandoned wells to be reopened, lost tools retrieved, and wells completed.

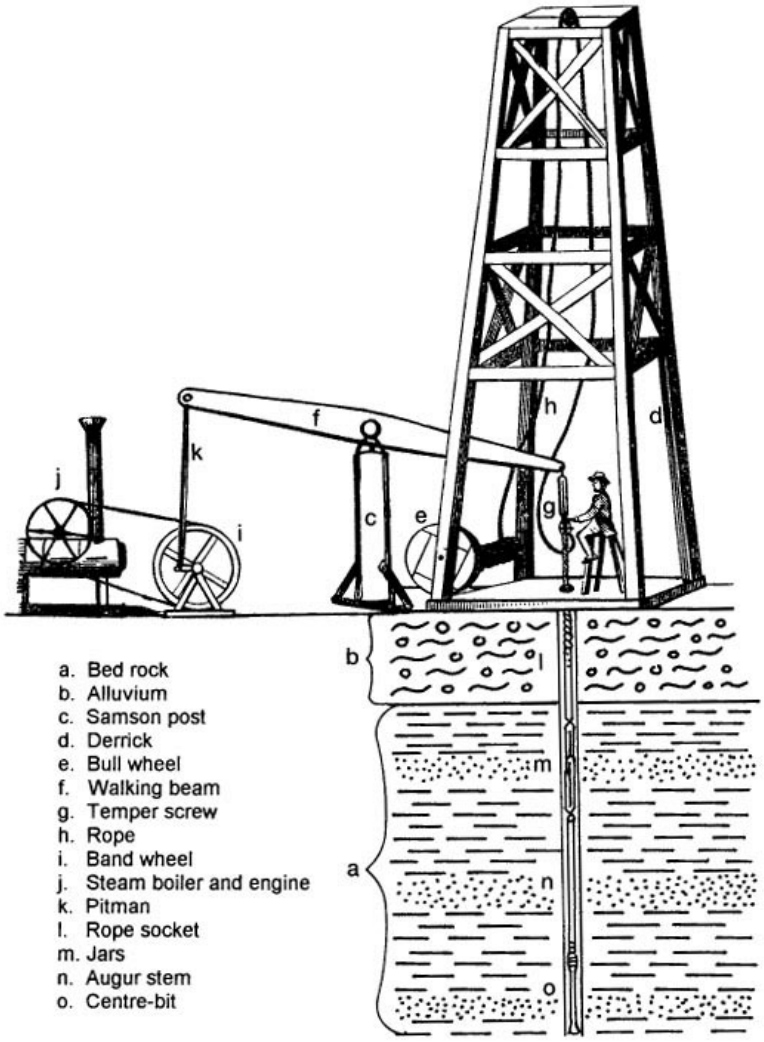
In 1872, a more sophisicated cable-tool device called a horse-driven spudder rig was patented. It used a horse on a treadle but didn't require a spring-pole or permanent walking beam and was considered to be portable. The horse activated a heavy fly wheel, cam, pendulum bar, elbow lever and other apparatus which combined to pull the drilling tools and then allowed them to drop to the bottom.

Walking Beam

The history of the walking beam in America is a little hazy. Apparently it was nearly contemporaneous with the spring pole. The known use of a walking beam dates back to the early salt days of ca.1810 and continued in use through the rest of the 1800's and well into the 1900's even through WW II and, in another form, to the present. The walking beam was part of the standard cable tool rig in the 1870's and later .

The walking beam was securely held up by a samson post (also spelled or mispelled sampson) which was either set deeply into the ground or held by beams which were built into an outside extension of the derrick floor. Different dimensions of this important device were used over the years the walking beam achieved a

manner of standardization when it became a part of the so-called standard derrick or rig.



Drawing modified by S.T. Pees and Associates, 1999

The early samson posts were usually 8 to 10 feet high. The center of the walking beam balances in a saddle on the post and moves freely due to a center pivot. Thus the up and down motion of the walking beam can be achieved as soon as a pitman, bandwheel and power are hooked up (see illustration above). The early walking

beams (before standardization) were 16 to 20 feet long and about one foot thick in the middle.

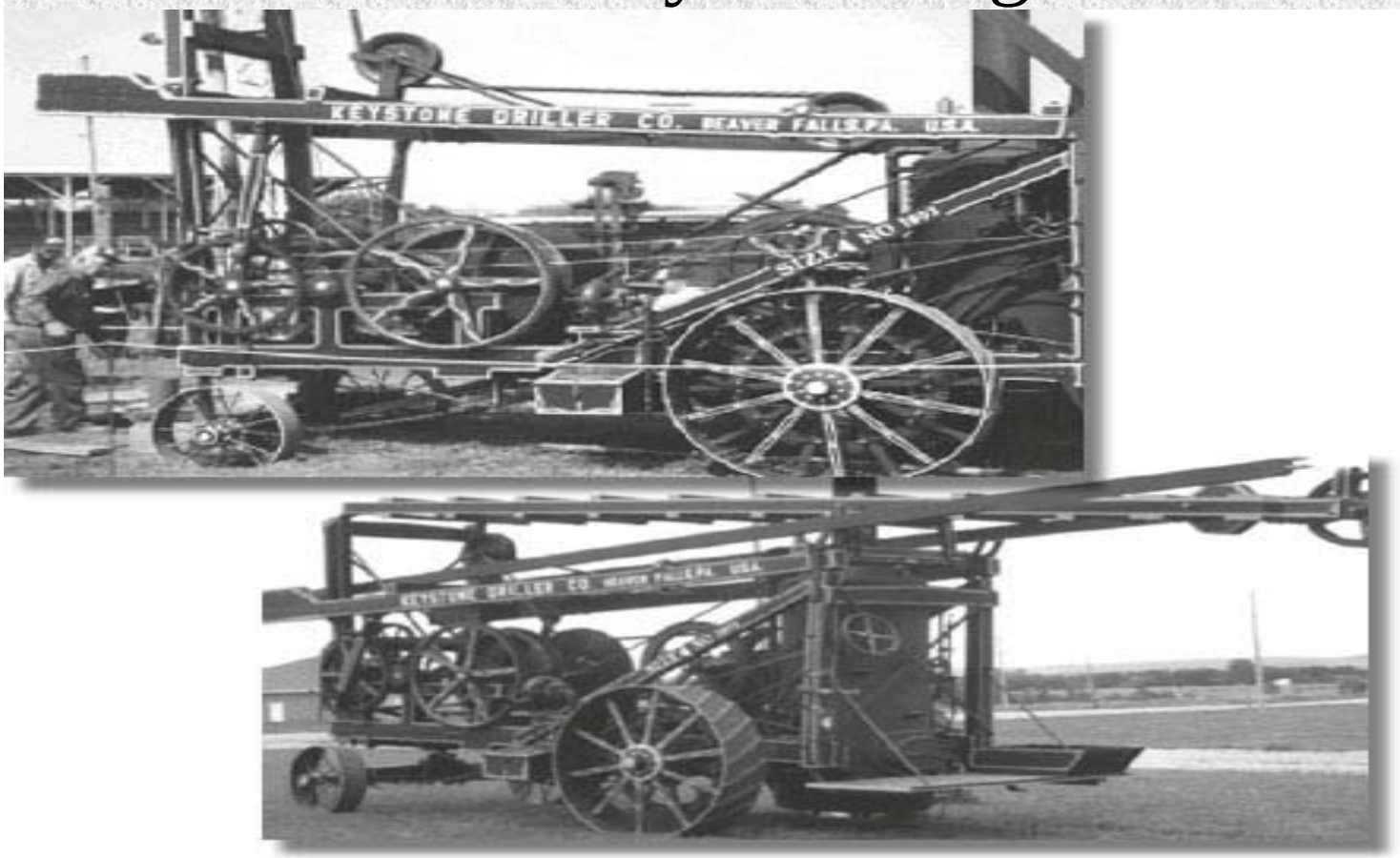
By 1884 the standardization of the wooden drilling rigs (the standard cable tool rig) was clearly achieved and the specifications of a carpenter's rig was in print. The standard rig walking beam was 26 feet long and was 12 inches wide by 26 inches thick in the middle and bevelled to one foot or 14 inches square at each end. The samson post was 13 feet high, 18 inches by 20 inches thick at the base and 18 inches square at the top.

The walking beam concept continued on into the portable spudders and drilling machines of the 1920's, 30's, 40's and 50's.

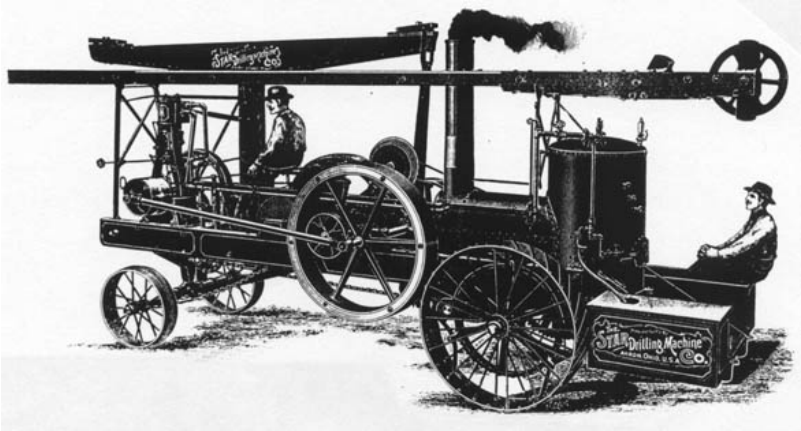
It is interesting to note the struggle which one company underwent in making a portable steam-driven drilling machine. In 1878, the Keystone Driller Co. which later settled in Beaver Falls, Pennsylvania, made a wagon-mounted steam-powered drilling device using a vertical boiler set at the back end of the wagon. This arrangement was not new at that time. However, this company of water well drillers and coal prospectors still clung to the spring pole which they anchored to the ground behind the boiler end of the wagon. That was retrograde progress, and they were also late in the game.

However, within four years, in 1882, they were turning out portable steam drills with walking beams, the common instrument then in use on the standard derricks. The Keystone Driller Co. was beginning to catch up. By the late 1880's and 90's they had become a very important builder of portable cable tool drilling rigs using steam engines.

1903 Keystone Rig



As time went on, more and more engines and boilers for cable tool drilling were sold as separate items (not mounted), and the layout was to have the steam engine fairly close to the derrick and the boiler farther behind. Both the mounted and the separated layouts were in use at the same time.



Star No. 2 or 800 foot drilling machine with traction attachment. It has a T shaped boiler. The vertical steam engine is at the front. The machine has a mast and a walking beam. Circa 1910

THE DRILL STRING
Cable Tools

The cable tools in America date back to the salt well days and, in spite of many improvements, have maintained a remarkable resemblance over the 194 years since the famous Ruffner salt well was put down in 1806-08 on the bank of the Kanawha River near Charleston, West Virginia (the Ruffner brothers were to salt what Drake was to oil). Of course changes occurred

in the tools, but these changes were mainly in the use of metal (steel faces), length (most tools were lengthened), weight, and tapered pins (replacing straight pins). When truck-mounted cable tool rigs replaced the early derricks and portable walking beam rigs, tools underwent a change and finally the switch over to rotary drilling brought in a completely new set of tools, doing away with the old.

Prior to 1859 the force for technological advancement in the drilling industry came first from salt mining and then from the increasing need for water wells as the west was settled. But in 1859, the force for drilling advancements in technology shifted.

Oil wells had been successfully drilled first in Asia ten years before an American well was drilled. Russian engineer F. N. Semyenov drilled the first modern oil well in 1848 on the Aspheron Peninsula in present day Azerbaijan. Also preceding the American drilling of a successful oil well, European wells were drilled in 1854 and the first North American well was drilled in Ontario, Canada in 1858.

But is was the drilling of the first American oil well in Titusville, Pennsylvania in 1859 by Colonel Edwin Drake that sparked the nations' oil fever.

Kerosene had been distilled form oil by Canadian geologist Dr. Abraham Gesner in 1849. By 1858 a kerosene lamp had been developed by Michael Deitz that created a strong demand for crude oil and spelled the end of whale oil for use in lamps in America.

The 20th century brought the internal combustion engine. Steam and internal combustion engines as

sources of power for drilling equipment competed side by side for a time. Eventually internal combustion engines became the sources of power aboard all portable cable tool drilling machines.

Rotary drilling technology became common in the early 20th century aided by Howard Hughes Sr.'s invention in 1908 of the roller cone drill bit.

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