Handbook of Mining Technology

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First Edition, 2012

ISBN 978-81-323-2780-6

Published by:
Orange Apple
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
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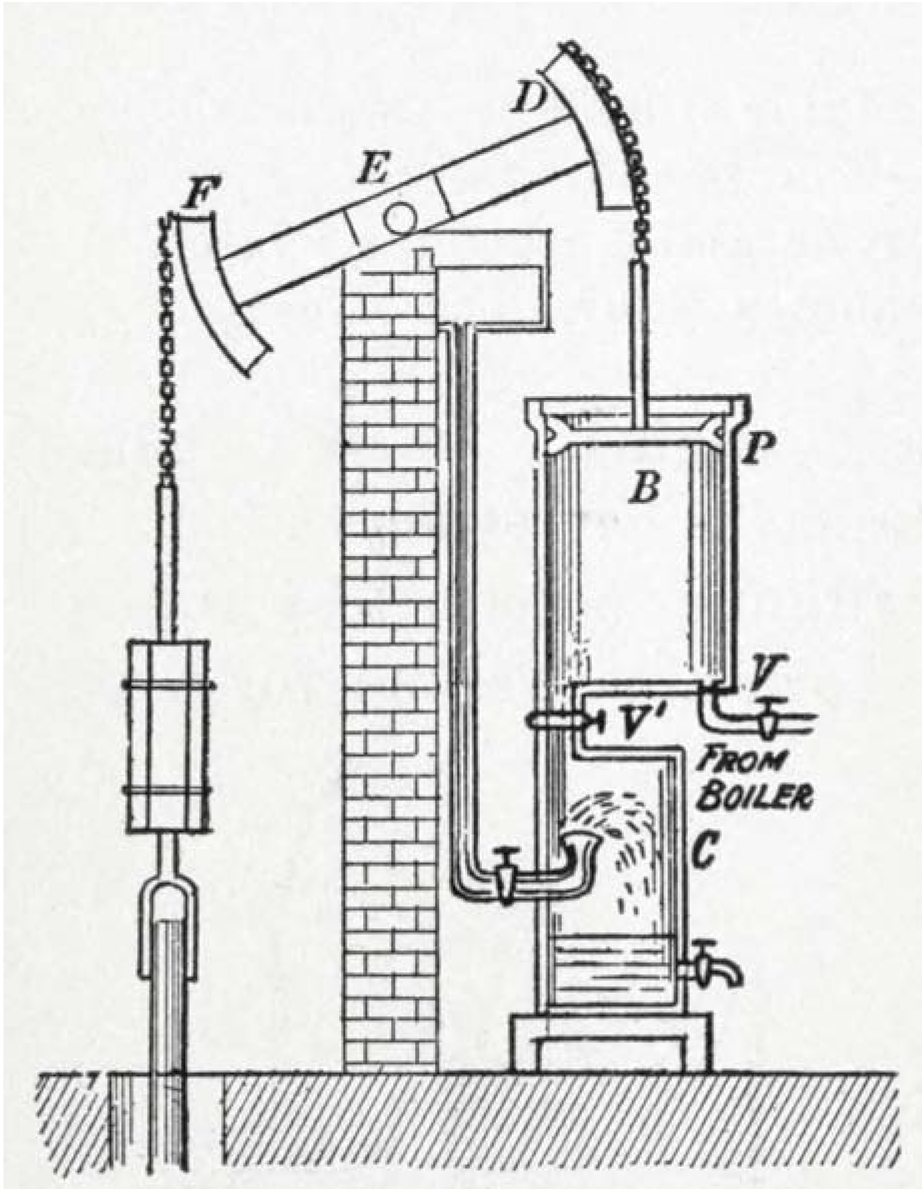
Beam Engine

The remains of a water-powered beam engine at Wanlockhead



A Watt engine: showing entry of steam and water

The cast-iron beam of the 1812 Boulton & Watt engine at Crofton Pumping Station – the oldest working example in the world

A **beam engine** is a type of steam engine where a pivoted overhead beam is used to apply the force from a vertical piston to a vertical connecting rod. This configuration, with the engine directly driving a pump, was first used by Thomas Newcomen around 1705 to remove water from mines in Cornwall. The efficiency of the engines was improved by engineers including James Watt who added a condenser, Jonathan Hornblower and Arthur Woolf who compounded the cylinders, and William McNaught (Glasgow) who devised a method of compounding an existing engine. Beam engines were first used to pump water out of mines or into canals, but could be used to pump water to supplement the flow for a waterwheel powering a mill.

The **rotative beam engine** is a later design of beam engine where the connecting rod drives a flywheel, by means of a crank (or, historically, by means of a sun and planet gear). These beam engines could be used to directly power the line-shafting in a mill. They also could be used to power steam ships.

History

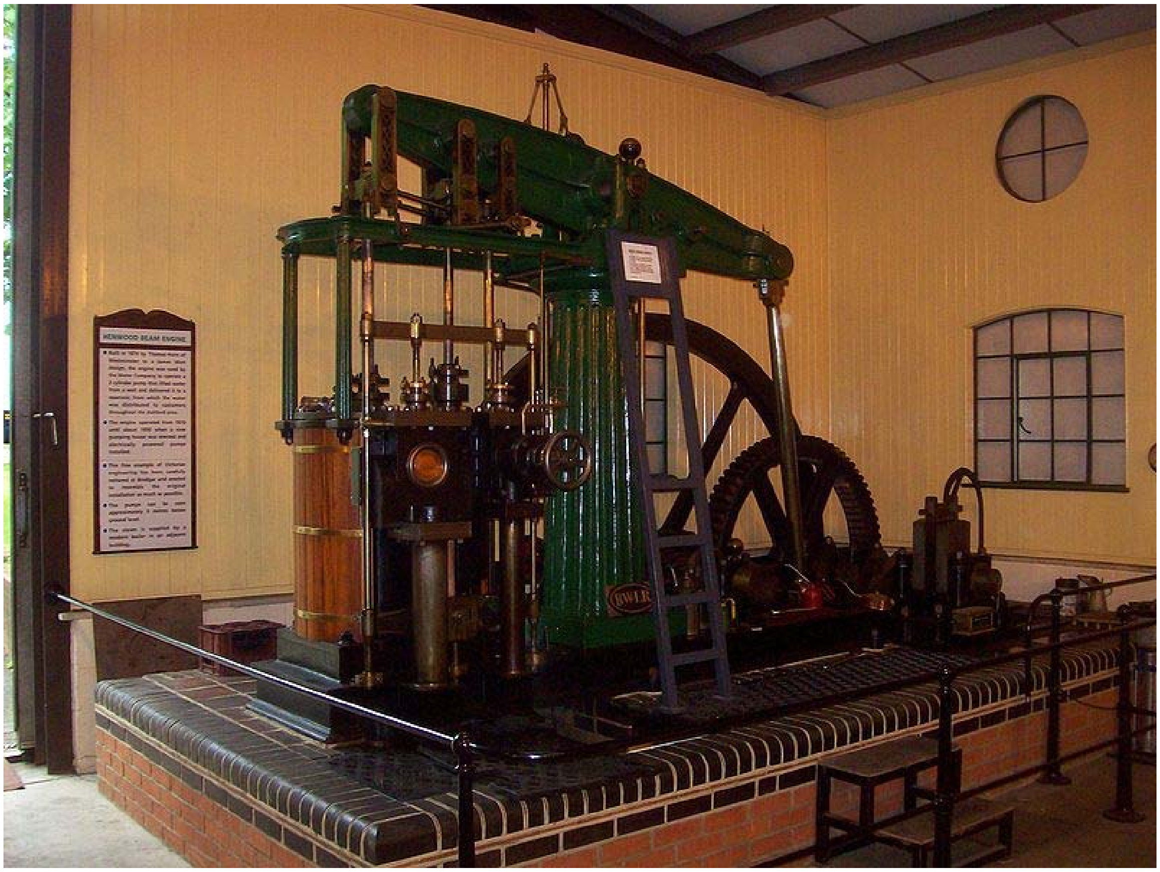
The first beam engines were water-powered, and used to pump water from mines. A 'preserved' example may be seen at Wanlockhead, in Scotland.

Beam engines were extensively used to power pumps on the English canal system when it was expanded by means of locks early in the Industrial Revolution, and also to drain water from mines in the same period, and as winding engines.

The first steam-powered beam engine was developed by Thomas Newcomen. The Newcomen steam engine was adopted by many mines in Cornwall and elsewhere, but it was relatively inefficient and consumed a large quantity of fuel. James Watt resolved the main inefficiencies of the Newcomen engine in his Watt steam engine, and these beam engines were used commercially in much larger numbers.

Watt held patents on key aspects of his engine's design, and it was not until these patents expired that others could develop modifications to improve it. The beam engine was considerably improved and enlarged in the tin- and copper-rich areas of south west England, which enabled the draining of the deep mines that existed there. Consequently the Cornish beam engines became world famous, as they remain the most massive beam engines ever constructed.

Rotative beam engines



A small rotative beam engine, built in 1870 by Thomas Horn to a design by James Watt. The crank is visible at the front, the flywheel part-hidden by the engine. (Originally installed in a waterworks in Ashford, now operational and preserved at the Bredgar and Wormshill Light Railway.)

In a rotative beam engine, the piston is mounted vertically, and the piston rod does not connect directly to the connecting rod, but instead to a rocker or *beam* above both the piston and flywheel. The beam is pivoted in the middle, with the cylinder on one side and the flywheel, which incorporates the crank, on the other. The connecting rod connects to the opposite end of the beam to the piston rod, and then to the flywheel.

Early Watt engines used Watt's patent sun and planet gear, rather than a simple crank, as use of the latter was protected by a patent owned by someone else. Once the patent had expired, the simple crank was employed universally.

Compounding

Compounding involves two or more cylinders; waste low-pressure steam from the first, high-pressure, cylinder is passed to the second cylinder where it expands further and provides more drive. This is the compound effect; the waste steam from this can produce further work if it is then passed into a condenser in the normal way. The first experiment with compounding was conducted by Jonathan Hornblower, who took out a patent in 1781. His first engine was installed at Tincroft Mine, Cornwall. It had two cylinders – one 21-inch (0.53 m) diameter with 6-foot (1.8 m) stroke and one 27-inch (0.69 m) diameter with 8-foot (2.4 m) stroke – placed alongside each other at one end of the beam. The early engines showed little performance gain: the steam pressure was too low, interconnecting pipes were of small diameter and the condenser ineffective.

At this time the laws of thermodynamics were not adequately understood, particularly the concept of absolute zero. Engineers such as Arthur Woolf were trying to tackle an engineering problem with an imperfect understanding of the physics. In particular, their valve gear was cutting-in at the wrong position in the stroke, not allowing for expansive working in the cylinder. Successful Woolf compound engines were produced in 1814, for the Wheal Abraham copper mine and the Wheal Vor tin mine.

McNaught engines

William McNaught of Glasgow, not to be confused with William McNaught of Rochdale (Petrie and McNaught), patented a compound beam engine in 1845. On a beam engine of the standard Boulton & Watt design he placed a high-pressure cylinder, on the opposite side of the beam to the existing single cylinder, where the water pump was normally fitted. This had two important effects: it massively reduced the pressure on the beam, and the connecting steam pipe, being long, acted as an expansive receiver – the element missing in the Woolf design. This modification could be made retrospectively, and engines so modified were said to be "McNaughted". The advantages of a compound engine were not significant at pressures under 60psi, but showed at over 100psi.

Chapter- 2

Bucket-Wheel Excavator

Bucket wheel excavator in Ferropolis, Germany

Bucket-wheel excavators (BWEs) are heavy equipment used in surface mining and civil engineering. The primary function of BWEs is to act as a continuous digging machine in large-scale open pit mining operations. What sets BWEs apart from other large-scale mining equipment, such as bucket chain excavators, is their use of a large wheel consisting of a continuous pattern of buckets used to scoop material as the wheel turns. They are among the largest vehicles ever constructed, and the biggest bucket-wheel excavator ever built, Bagger 293, is the largest terrestrial (land) vehicle in human history according to the Guinness Book of World Records.

History

Bucket-wheel excavator in the open-pit mining Garzweiler

Bucket-wheel excavators have been used in mining for the past century, with some of the first being manufactured in the 1920s. They are used in conjunction with many other pieces of mining machinery (conveyer belts, spreaders, crushing stations, heap-leach systems, etc.) to move and mine massive amounts of overburden (waste). While the overall concepts that go into a BWE have not changed much, their size has grown drastically. BWEs built since the 1990s, such as the Bagger 293, have reached sizes as large as 96 meters (314.9 feet) tall, 225 meters (738.2 feet) long, and as heavy as 14,200 tons (31.3 million lb). The bucket-wheel itself can be over 70 feet in diameter with as many as 20 buckets, each of which can hold over 15 cubic meters of material. BWEs have also advanced with respect to the extreme conditions in which they are now capable of operating. Many BWEs have been designed to operate in climates with temperatures as low as -45°C (-49°F). Developers are now moving their focus toward automation and the use of electrical power.

Structure

A bucket wheel excavator (BWE) consists of a superstructure to which several more components are fixed.

The bucket wheel from which the machines get their name is a large, round wheel with a configuration of scoops which is fixed to a boom and is capable of rotating. Material picked up by the cutting wheel is transferred back along the boom. In early cell-type bucket wheels, the material was transferred through a chute leading from each bucket, while newer cell-less and semi-cell designs use a stationary chute through which all of the buckets discharge.

A discharge boom receives material through the superstructure from the cutting boom and carries it away from the machine, frequently to an external conveyer system.

A counterweight boom balances the cutting boom and is cantilevered either on the lower part of the superstructure (in the case of compact BWEs) or the upper part (in the case of mid-size C-frame BWEs). In the larger BWEs, all three booms are supported by cables running across towers at the top of the superstructure.

Beneath the superstructure lay the movement systems. On older models these would be rails for the machine to travel along, but newer BWEs are frequently equipped with crawlers, which grant them increased flexibility of motion.

To allow it to complete its duties, the superstructure of a BWE is capable of rotating about a vertical axis (slewing). The cutting boom can be tilted up and down (hoisting). The speeds of these operations are on the orders of 30 m/min and 5 m/min, respectively. Slewing is driven by large gears, while hoisting generally makes use of a cable system.

Size

The scale of BWEs varies drastically and is dependent on the intended application. Compact BWEs designed by ThyssenKrupp may have boom lengths as small as 6m, weigh 50 tons, and move 100 fm3/hr of earth. Their larger models reach boom lengths of 80m, weigh 13,000 tons, and move 12,500 fm3/hr. The largest BWE ever constructed is TAKRAF's Bagger 293, which weighs 14,200 tons and is capable of moving 240,000 cubic meters of overburden every day. Excavations of 380,000 cubic meters have been recorded. The BWEs used in the United States tend to be smaller than those constructed in Germany.

Bucket chain excavators

Bucket chain excavators (BCEs) are similar in structure and function to BWEs. However, instead of the buckets being placed in a ring, they are strung out in a manner reminiscent of a trencher. They remove material from below their plane of movement, which is useful if the pit floor is unstable or underwater. TAKRAF's BCEs travel on rails rather than crawlers.

Operation

BWEs are used for continuous overburden removal in surface mining applications. They use their cutting wheels to strip away a section of earth (the working block) dictated by the size of the excavator. Through hoisting, the working block can include area both above and below the level of the machine (the bench level). By slewing, the excavator can reach through a horizontal range.

The overburden is then delivered to the discharge boom, which transfers the cut earth to another machine for transfer to a spreader. This may be a fixed belt conveyer system or a mobile conveyer with crawlers similar to those found on the BWE. Mobile conveyers permanently attached to the excavator takes the burden of directing the material off of the operator. The overburden can also be transferred directly to cross-pit spreader, which reaches across the pit and scatters overburden at the dumping ground.

Automation

Automation of the BWEs requires integrating many sensors and electrical components such as GPS, data acquisition systems, and online monitoring capabilities. The goal of these systems is to take away some of the work from the operators in order to achieve higher mining speeds. Project managers and operators are now able to track crucial data regarding the BWEs and other machinery in the mining operations via the Internet. Sensors can detect how much material is being scooped onto the conveyor belt, and the automation system can then vary the speed on the conveyor belts in order to feed a continuous amount of material. Further development of these types of automation may make it possible to, someday, operate these enormous machines with fewer operators.

Applications

Bucket wheel excavators and bucket chain excavators take jobs that were previously accomplished by rope shovels and draglines. They have been replaced in most applications by hydraulic excavators, but still remain in use for very large-scale operations, where they can be used for the transfer of loose materials or the excavation of soft to semi-hard overburden.

Lignite mining

The primary application of BWEs is the in lignite (brown coal) mining, where they are used for soft rock overburden removal in the absence of blasting. They are useful in this capacity for their ability to continuously deliver large volumes of materials to processors, which is especially important given the continuous demand for lignite.

Because of the great demand for lignite, lignite mining has also been one of the areas of greatest development for BWEs. The additions of automated systems and greater maneuverability, as well as components designed for the specific application, have increased the reliability and efficiency with which BWEs deliver materials.

Materials handling

Bucket wheel technology is used extensively in bulk materials handling. Bucket wheel reclaimers are used to pick up material that has been positioned by a stacker for transport to a processing plant. Stacker/reclaimers, which combine tasks to reduce the number of required machines, also use bucket wheels to carry out their tasks.

In shipyards, bucket wheels are used for the continuous loading and unloading of ships, where they pick up material from the yard for transfer to the delivery system. Bucket chains can be used to unload material from a ship's hold. TAKRAF's continuous ship unloader is capable of removing to 95% of the material from a ship's hold, owing to a flexibly-configured digging attachment.

Heap leaching

An extension of their other uses, BWEs are used in heap leaching processes. Heap leaching entails of constructing stacks of crushed ore, through which a solvent is passed to extract valuable materials. The construction and removal of the heaps are an obvious application of stacking and reclaiming technology.

Manufacturers and market

Current use of bucket-wheel excavators is mainly focused in the area of lignite (brown coal) mining for the production of electricity. Most of these mining operations are located in Germany and East/Southeastern Europe. The manufacturers of BWEs and similar mining systems receive a large amount of business in maintenance and refurbishing projects. Many of the systems set up in the European mining operations need refurbishment and upgrading. One of the main reasons it is favorable to refurbish instead of replace these machines is the cost of the large gears needed to build them. There are few companies willing to manufacture these massive gears in such low quantity for a reasonable price.

Chapter- 3

Dragline Excavator

Dragline excavator with pile driver attachment

A **dragline excavator** is a piece of heavy equipment used in civil engineering and surface mining.

In civil engineering the smaller types are used for road, port construction, and as pile driving rigs. The larger types are used in strip-mining operations to move overburden above coal, and for tar-sand mining. Draglines are amongst the largest mobile equipment ever built on land, and weigh in the vicinity of 2000 metric tonnes, though specimens weighing up to 13,000 metric tonnes have also been constructed.

A dragline bucket system consists of a large bucket which is suspended from a boom (a large truss-like structure) with wire ropes. The bucket is manoeuvred by means of a number of ropes and chains. The hoist rope, powered by large diesel or electric motors, supports the bucket and hoist-coupler assembly from the boom. The dragrope is used to draw the bucket assembly horizontally. By skillful manoeuvre of the hoist and the dragropes the bucket is controlled for various operations. A schematic of a large dragline bucket system is shown below.

History

The dragline was invented in 1904 by John W. Page (as a partner of the firm Page & Schnable Contracting) for use digging the Chicago Canal. By 1912, Page realized that building draglines was more lucrative than contracting so he created the Page Engineering Company to build draglines. Page build its first crude, walking dragline in 1923. These used legs operated by rack and pinion on a separate frame that lifted the crane. The body was then pulled forward by chain on a roller track and then lowered again. Page developed the first diesel engines exclusively for dragline application in 1924. Page also invented the arched dragline bucket, a design still commonly used today by draglines from many other manufacturers, and in the 1960s pioneered an archless bucket design. With its walking mechanism badly behind Monighan, Page updated the mechanism to an eccentric drive in 1935. This much improved mechanism gave a proper elliptical motion and was used until 1988. Page modernized its draglines further with the 700 series in 1954. Page's largest dragline was the Model 757 delivered to the Obed Mine near Hinton, Alberta in 1983. It featured a 75-yard bucket on a 298-foot boom and an operating weight of 4,500 tons. In 1988, Harnischfeger Corporation (P&H Mining Equipment) purchased Page Engineering Company.

In 1907, Monighan's Machine Works of Chicago became interested in manufacturing draglines when local contractor John W. Page placed an order for hoisting machinery to install a dragline. In 1908, Monighan changed its name to the Monighan Machine Company. In 1913, a Monighan engineer named Oscar Martinson invented the first walking mechanism for a dragline. The device, known as the Martinson Tractor, was installed on a Monighan dragline, creating the first walking dragline. This gave Monighan a significant advantage over other draglines and the company prospered. The cam mechanism was further improved in 1925 by eliminating the drag chains for the shoes and changing to a cam wheel running in an oval track. This gave the shoe a proper elliptical motion. The first dragline using the new mechanism was the 3-W available in

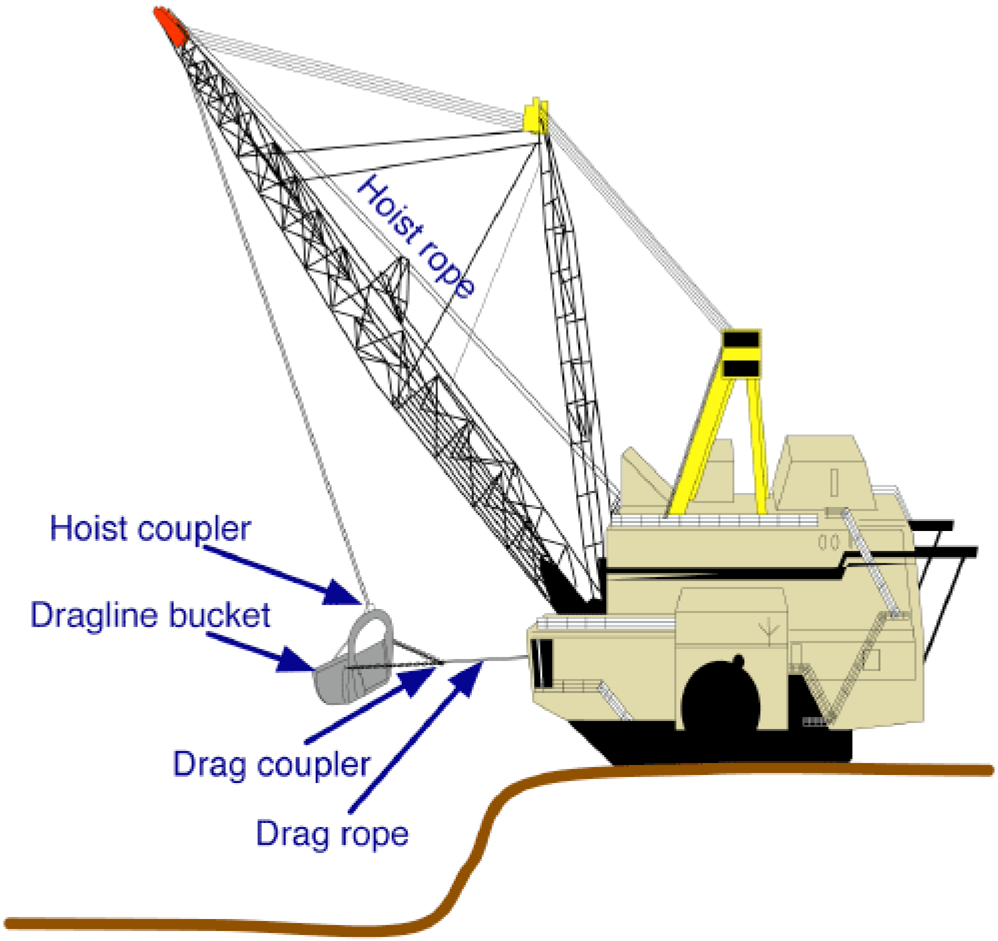
1926. So popular were these machines that the name Monighan became a generic term for dragline. In the early 1930s, Bucyrus-Erie began purchasing shares of Monighan stock with Monighan's approval. Bucyrus purchased a controlling interest and the joint company became known as Bucyrus-Monighan until the formal merger in 1946.

Bucyrus International supplied about two thirds of the steam shovels used on the Panama Canal. In 1910, they entered the dragline market with the purchase of manufacturing rights for the Heyworth-Newman dragline excavator. Their "Class 14" dragline was introduced in 1911 as the first crawler mounted dragline. In 1912 Bucyrus helped pioneer the use of electricity as a power source for large stripping shovels and draglines used in mining. After the merger with Monighan in 1946, Bucyrus began producing much larger machines using the Monighan walking mechanism such as the 800 ton 650-B which used a 15-yard bucket. Bucyrus' largest dragline was Big Muskie built for the Ohio Coal Company in 1969. This machine featured a 220-yard bucket on a 310-foot boom and weighed 14,000 tons. The market for draglines began shrinking rapidly after the boom of the 1960s and 1970s. P&H's acquisition of Page and then Bucyrus' acquisition of Marion has cut the number of worldwide suppliers in half. Today these two companies are the sole remaining manufacturers of large draglines.

In 1914, Harnischfeger Corporation (established as P&H Mining in 1884 by Alonzo Pawling and Henry Harnischfeger) introduced the world's first gasoline engine-powered dragline. An Italian company, Fiorentini, produced dragline excavators from 1919 licensed by Bucyrus. In 1988 Page was acquired by the Harnischfeger Corp., makers of the P&H line of shovels, draglines, and cranes. Besides Bucyrus, P&H is the only surviving company that still makes large draglines.

The Marion Steam Shovel Dredge Company (established in 1880) supplied about one third of the steam shovels used for the Panama Canal. Marion continued making larger power shovels until they built The Captain in 1965 with a 180-yard bucket and a weight of 15,000 tons. In 1939, it built its first walking dragline with a simple single-crank mechanism. The company changed its name to the Marion Power Shovel Company in 1946. Its largest dragline was the 8950 sold to Amax Coal Company in 1973. It featured a 150-cubic yard bucket on a 310-foot boom and weighed 7,300 tons. Marion was acquired by Bucyrus in 1997.

Operation



In a typical cycle of excavation, the bucket is positioned above the material to be excavated. The bucket is then lowered and the dragrope is then drawn so that the bucket is dragged along the surface of the material. The bucket is then lifted by using the hoist rope. A swing operation is then performed to move the bucket to the place where the material is to be dumped. The dragrope is then released causing the bucket to tilt and empty. This is called a dump operation.

The bucket can also be 'thrown' by winding up to the jib and then releasing a clutch on the drag cable. This would then swing the bucket like a pendulum. Once the bucket had passed the vertical, the hoist cable would be released thus throwing the bucket. On smaller draglines, a skilled operator could make the bucket land about one-half the length of the jib further away than if it had just been dropped. On larger draglines, only a few extra metres may be reached.

Draglines have different cutting sequences. The first is the side cast method using offset benches; this involves throwing the overburden sideways onto blasted material to make a bench. The second is a key pass. This pass cuts a key at the toe of the new highwall and also shifts the bench further towards the low-wall. This may also require a chop pass if the wall is blocky. A chop pass involves the bucket being dropped down onto an angled highwall to scale the surface. The next sequence is the slowest operation, the blocks pass. However, this pass moves most of the material. It involves using the key to access to bottom of the material to lift it up to spoil or to an elevated bench level. The final cut if required is a pull back, pulling material back further to the low-wall side.

Draglines in mining

Dragline at the Curragh Coal Mine

A large dragline system used in the open pit mining industry costs approximately US$50-100 million. A typical bucket has a volume ranging from 30 to 60 cubic metres, though extremely large buckets have ranged up to 168 cubic metres. The length of the boom ranges from 45 to 100 metres. In a single cycle it can move up to 450 metric tonnes of material.

Most mining draglines are not diesel-powered like most other mining equipment. Their power consumption is so great that they have a direct connection to the high-voltage grid at voltages of between 6.6 to 22 kV. A typical dragline, with a 55 cubic metre bucket, can use up to 6 megawatts during normal digging operations. Because of this, many (possibly apocryphal) stories have been told about the blackout-causing effects of mining draglines. For instance, there is a long-lived story that, back in the 1970s, if all seven draglines at Peak Downs Mine (a very large BHP coal mine in central Queensland, Australia) turned simultaneously, they would black out all of North Queensland. However even now, if they have been shutdown they are always restarted one at a time due to the immense power requirements of startup.

In all but the smallest of draglines, movement is accomplished by "walking" using feet or pontoons, as caterpillar tracks place too much pressure on the ground, and have great difficulty under the immense weight of the dragline. Maximum speed is only at most a few metres per minute since the feet must be repositioned for each step. If travelling medium distances, (about 30–100 km), a special dragline carrier can be brought in to transport the dragline. Above this distance, disassembly is generally required. But mining draglines due to their reach can work a large area from one position and do not need to constantly move along the face like smaller machines.

Limitations

The primary limitations of draglines are their boom height and boom length, which limits where the dragline can dump the waste material. Another primary limitation is their dig depth, which is limited by the length of rope the dragline can utilize. Inherent with their construction, a dragline is most efficient excavating material below the level of their base. While a dragline can dig above itself, it does so inefficiently and is not suitable to load piled up material (as a rope shovel or wheel loader can).

Despite their limitations, and their extremely high capital cost, draglines remain popular with many mines, due to their reliability, and extremely low waste removal cost.

Examples

The Walking Mechanism on a preserved Bucyrus-Erie 1150 dragline in the UK

The coal mining dragline known as Big Muskie, owned by the Central Ohio Coal Company (a division of American Electric Power), was the world's largest mobile earth-moving machine, weighing nearly 13,000 metric tons and standing nearly 22 stories tall. It operated in Muskingum County, in the U.S. state of Ohio from 1969 to 1991, and was powered by 13,800 volts of electricity. It was scrapped in 1999.

The British firm of Ransomes & Rapier produced a few large (1400-1800 ton) excavators, the largest in Europe at the time (1960s). Power was from internal combustion engines driving electric generators. One, named *SUNDEW*, was used in a quarry from 1957 to 1974. After its working life at the first site in Rutland was finished it walked 13 miles to a new life at Corby; the walk took 9 weeks.

Smaller draglines were also commonly used before hydraulic excavators came into common use, the smaller draglines are now rarely used other than on river and gravel pit works. The small machines were of a mechanical drive with clutches. Firms such as Ruston and Bucyrus made models such as the RB10 which were popular for small building works and drainage work. Several of these can still be seen in the English Fens of Cambridgeshire, Lincolnshire and parts of Norfolk. Ruston's are a company also associated with drainage pumping engines. Electric drive systems were only used on the larger mining machines, most modern machines use a diesel-hydraulic drive, as machines are seldom in one location long enough to justify the cost of installing a substation and supply cables.

Technological Advances

Draglines, unlike most equipment used in earth-moving, have remained relatively unchanged in design and control systems for almost 100 years. Over the last few years, some advances in dragline systems and methodologies have occurred.

Automation

Researchers at CSIRO in Australia have a long-term reaearch project into automating draglines and have moved over 250,000 tonnes of overburden under computer control.

Simulation software

Since draglines are typically large, complicated and very expensive, training new operators can be a tricky process. In the same way that flight simulators have developed to train pilots, mining simulator software has been developed to assist new operators in learning how to control the machines.

UDD

UDD stands for Universal-Dig-Dump. It represents the first fundamental change to draglines for almost a century, since the invention of the 'miracle hitch'. Instead of using two ropes (the hoist rope and the drag rope) to manipulate the bucket, a UDD machine uses three ropes, two hoist and one drag. This allows the dragline operator to have much greater selectivity in when to pick up the bucket, and in how the bucket may be dumped. UDD machines generally have higher productivity than a standard dragline, but often have greater mechanical issues. Within the mining industry, there is still much debate as to whether UDD improvements justify their costs.

Chapter- 4

Dredging

Dredging is an excavation activity or operation usually carried out at least partly underwater, in shallow seas or fresh water areas with the purpose of gathering up bottom sediments and disposing of them at a different location. This technique is often used to keep waterways navigable.

It is also used as a way to replenish sand on some public beaches, where too much sand has been lost because of coastal erosion.

A **dredge** is a device for scraping or sucking the seabed, used for dredging. A **dredger** is a ship or boat equipped with a dredge. The terms are sometimes interchanged.

The process of dredging creates spoils (excess material), which are carried away from the dredged area. Dredging can produce materials for land reclamation or other purposes (usually construction-related), and has also historically played a significant role in gold mining. Dredging can create disturbance in aquatic ecosystems, often with adverse impacts.

Uses

- **Capital**: dredging carried out to create a new harbour, berth or waterway, or to deepen existing facilities in order to allow larger ships access. Because capital works usually involve hard material or high-volume works, the work is usually done using a cutter suction dredge or large trailing suction hopper dredge, but for rock works drilling and blasting along with mechanical excavation may be used.
- **Preparatory**: work and excavation for future bridges, piers or docks/wharves, often connected with foundation work.
- **Maintenance**: dredging to deepen or maintain navigable waterways or channels which are threatened to become silted with the passage of time, due to sedimented sand and mud, possibly making them too shallow for navigation. This is often carried out with a trailing suction hopper dredge. Most dredging is for this purpose, and it may also be done to maintain the holding capacity of reservoirs or lakes.
- **Land reclamation**: dredging to mine sand, clay or rock from the seabed and using it to construct new land elsewhere. This is typically performed by a cutter-

suction dredge or trailing suction hopper dredge. The material may also be used for flood or erosion control.

- **Beach nourishment**: mining sand offshore and placing on a beach to replace sand eroded by storms or wave action. This is done to enhance the recreational and protective function of the beaches, which can be eroded by human activity or by storms. This is typically performed by a cutter-suction dredge or trailing suction hopper dredge.
- **Harvesting materials**: dredging sediment for elements like gold, diamonds or other valuable trace substances.
- **Seabed mining**: a possible future use, recovering natural metal ore nodules from the sea's abyssal plains.
- **Construction materials**: dredging sand and gravels from offshore licensed areas for use in construction industry, principally for use in concrete. Very specialist industry focused in NW Europe using specialized trailing suction hopper dredgers self discharging dry cargo ashore.
- **Anti-eutrophication**: Dredging is an expensive option for the remediation of eutrophied (or de-oxygenated) water bodies. However, as artificially elevated phosphorus levels in the sediment aggravate the eutrophication process, controlled sediment removal is occasionally the only option for the reclamation of still waters.
- **Contaminant remediation**: to reclaim areas affected by chemical spills, storm water surges (with urban runoff), and other soil contaminations. Disposal becomes a proportionally large factor in these operations.
- **Removing trash and debris**: often done in combination with maintenance dredging, this process removes non-natural matter from the bottoms of rivers and canals and harbors.
- **Flood prevention**: this can help to increase channel depth and therefore increase a channel's capacity for carrying water.
- **Peat extraction**: in former times, so-called *dredging poles* or *dredge hauls* were used on the back of small boats to manually dredge the beds of peat-moor waterways before extracting the peat for use as a fuel. This tradition has now become more or less obsolete and the tools used to do this have also changed significantly.

Relevance

Without the many and almost non-stop dredging operations world wide, much of the world's commerce would be impaired, often within a few months, since much of world's goods travel by ship, and need to access harbours or seas via channels. Recreational boating also would be constrained to the smallest vessels. The majority of marine dredging operations (and the disposal of the dredged material) will require that appropriate licences are obtained from the relevant regulatory authorities, and dredging is usually carried out by (or for) harbour companies or corresponding government agencies.

Types of dredging vessels

Suction

The Geopotes 14 lifting its boom on a canal in The Netherlands. (*gēopotēs* is Greek for "that which drinks earth")

These operate by sucking through a long tube, like some vacuum cleaners but on a big scale.

A plain suction dredger has no tool at the end of the suction pipe to disturb the material. This is often the most commonly used form of dredging.

Trailing suction

A trailing suction hopper dredger (TSHD) trails its suction pipe when working, and loads the dredge spoil into one or more hoppers in the vessel. When the hoppers are full, the TSHD sails to a disposal area and either dumps the material through doors in the hull or pumps the material out of the hoppers. Some dredges also self-offload using drag buckets and conveyors. The largest trailing suction hopper dredger in the world is currently Jan De Nul's *Cristobal Colon* (launched July 4, 2008); its sister ship *Leiv Eriksson* is under construction as of the end of 2008 (keel laid August 27, 2008, expected launch July 2009). Main design specs for the *Cristobal Colon* and the *Leiv Eriksson* are: 46,000 cubic meter hopper and a design dredging depth of 155 m. Next largest is *HAM 318* (Van Oord) with its 37,293 cubic meter hopper and a maximum dredging depth of 101 m.

Cutter suction

A cutter-suction dredger's (CSD) suction tube has a cutter head at the suction inlet, to loosen the earth and transport it to the suction mouth. The cutter can also be used for hard surface materials like gravel or rock. The dredged soil is usually sucked up by a wear-resistant centrifugal pump and discharged through a pipe line or to a barge. In recent years, dredgers with more powerful cutters have been built in order to excavate harder rock without blasting.

The two largest cutter suction dredgers in the world are currently (as at August 2009) DEME's *D'Artagnan* (28,200 kW total installed power) and Jan De Nul's *J.F.J. DeNul* (27,240 kW). Jan de Nul has by far the most heavy cutters in the market.

Auger suction

This process functions like a cutter suction dredger, but the cutting tool is a rotating Archimedean screw set at right angles to the suction pipe. The first widely used auger dredges were designed by Mud Cat Dredges in the 1980s which was run by National Car Rental, but is now a Division of Ellicott Dredges. In 1996, IMS introduced a self-propelled version of the auger dredge that allows the system to propel itself without the use of anchors cables. During the 1980s and 1990s auger dredges were primarily used for sludge removal applications from waste water treatment plants. Today, auger dredges are used for a wider variety of applications including river maintenance and sand mining. The most common auger dredge on the global market today is the Versi-Dredge. The turbidity shroud on auger dredge systems creates a strong suction vacuum and creates much less turbity than conical (basket) type cutterheads and that is why they are preferred for environmental type applications. The vacuum created by the shroud and the ability to convey material to the pump faster makes auger dredge systems more productive than similar sized conical (basket) type cutterhead dredges.

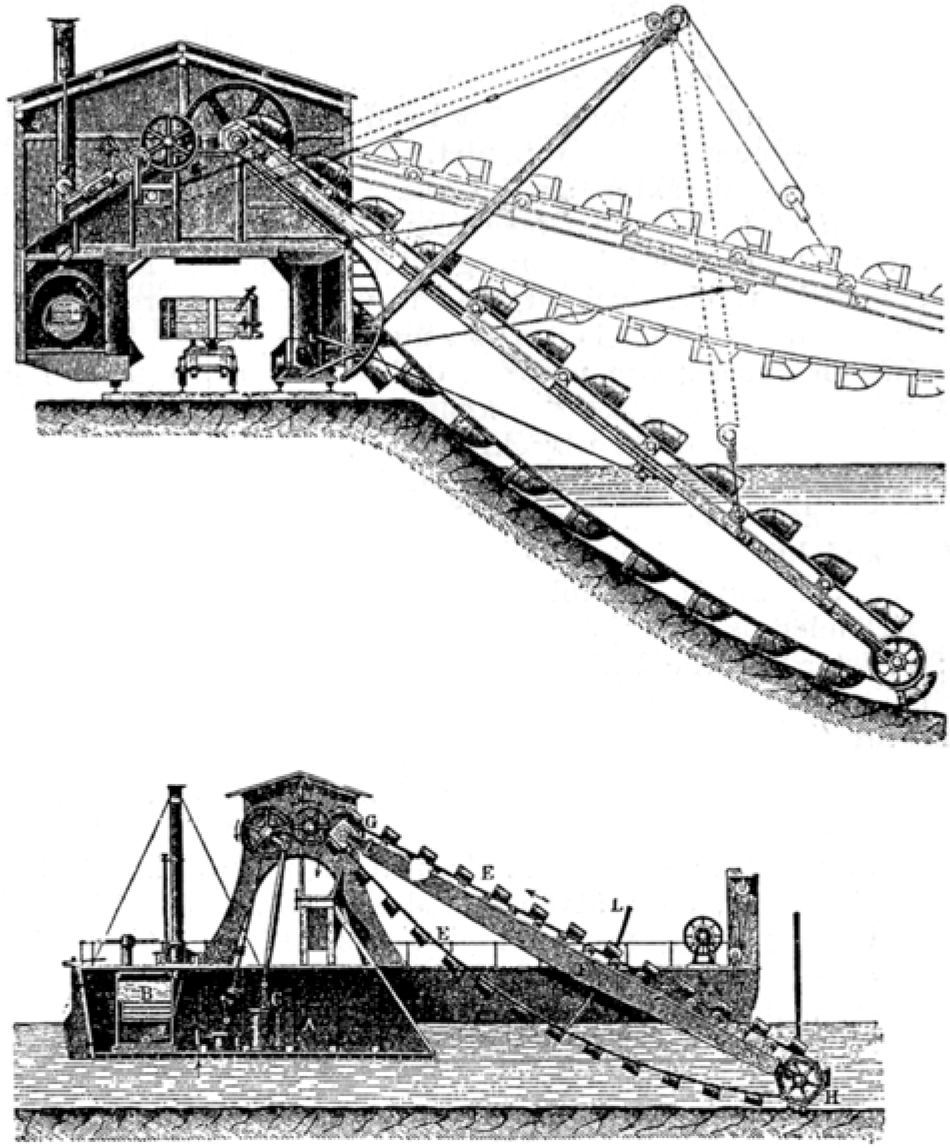
Jet-lift

These use the Venturi effect of a concentrated high-speed stream of water to pull the nearby water, together with bed material, into a pipe.

Air-lift

An airlift is a type of small suction dredge. It is sometimes used like other dredges. At other times, an airlift is used, handheld underwater by a diver. It works by blowing air into the pipe, and that air, being lighter than water, rises inside the pipe, dragging water with it.

Bucket



Bucket dredging

A bucket dredger is equipped with a bucket dredge, which is a device that picks up sediment by mechanical means, often with many circulating buckets attached to a wheel or chain. Some bucket dredgers and grab dredgers are powerful enough to rip out coral to make a shipping channel through coral reefs.

Grab

Grab dredging in process in Port Canaveral, Florida

A grab dredger picks up seabed material with a clam shell grab, which hangs from an onboard crane or a crane ship, or is carried by a hydraulic arm, or is mounted like on a dragline. This technique is often used in excavation of bay mud. Most of these dredges are crane barges with spuds.

Backhoe/dipper

A backhoe/dipper dredge has a backhoe like on some excavators. A crude but usable backhoe dredger can be made by mounting a land-type backhoe excavator on a pontoon. The six largest backhoe dredgers in the world are currently the Vitruvius, the Mimar Sinan, Postnik Jakovlev (Jan De Nul), the Samson (DEME), the Simson and the Goliath (Van Oord). They featured barge-mounted excavators. Small backhoe dredgers can be track-mounted and work from the bank of ditches. A backhoe dredger is equipped with a half-open shell. The shell is filled moving towards the machine. Usually dredges material is loaded in barges. This machine is mainly used in harbors and other shallow water.

Water injection

A water injection dredger uses a small jet to inject water under low pressure (to prevent the sediment from exploding into the surrounding waters) into the seabed to bring the sediment in suspension, which then becomes a turbidity current, which flows away down slope, is moved by a second burst of water from the WID or is carried away in natural currents. Water injection results in a lot of sediment in the water which makes measurement with most hydrographic equipment (for instance: singlebeam echosounders) difficult.

Pneumatic

These dredgers use a chamber with inlets, out of which the water is pumped with the inlets closed. It is usually suspended from a crane on land or from a small pontoon or barge. Its effectiveness depends on depth pressure.

Bed leveler

Steam dredger *Bertha* from 1844

This is a bar or blade which is pulled over the seabed behind any suitable ship or boat. It has an effect similar to that of a bulldozer on land. The chain-operated steam dredger *Bertha*, built in 1844 to a design by Brunel and now the oldest operational steam vessel in Britain, was of this type.

Krabbelaar

This is an early type of dredger which was formerly used in shallow water in the Netherlands. It was a flat-bottomed boat with spikes sticking out of its bottom. As tide current pulled the boat, the spikes scraped seabed material loose, and the tide current washed the material away, hopefully to deeper water. *Krabbelaar* is Dutch for "scratcher".

Snagboat

A snagboat is designed to remove big debris such as dead trees and parts of trees from rivers and canals.

Amphibious

Some of these are any of the above types of dredger, which can operate normally, or by extending legs, also known as spuds, so it stands on the seabed with its hull out of the water. Some forms can go on land.

Some of these are land-type backhoe excavators whose wheels are on long hinged legs so it can drive into shallow water and keep its cab out of water. Some of these may not have a floatable hull and, if so, cannot work in deep water.

- Oliver Evans (1755–1819) in 1804 invented an amphibious dredger which was America's first steam-powered road vehicle.

Submersible

These are usually used to recover useful materials from the seabed. Many of them travel on caterpillar tracks. A unique variant is intended to walk on legs on the seabed.

Fishing

Dredge haul including live clams and empty shells

Fishing dredges are used to collect various species of clams scallops, oysters or crabs from the seabed. These dredges have the form of a scoop made of chain mesh, and are towed by a fishing boat. Careless dredging can be destructive to the seabed. Nowadays some scallop dredging is replaced by collecting via scuba diving.

Police drag

In some police departments a small dredge (sometimes called a *drag*) is used to find and recover objects and bodies from underwater. The bodies may be murder victims, or people who committed suicide by drowning, or victims of accidents. It is sometimes pulled by men walking on the bank.

Disposal of materials

In a "hopper dredger", the dredged materials end up in a large onboard hold called a "hopper." A suction hopper dredger is usually used for maintenance dredging. A hopper dredge usually has doors in its bottom to empty the dredged materials, but some dredges empty their hoppers by splitting the two halves of their hulls on giant hinges. Either way, as the vessel dredges, excess water in the dredged materials is spilled off as the heavier solids settle to the bottom of the hopper. This excess water is returned to the sea to reduce weight and increase the amount of solid material (or slurry) that can be carried in one load. When the hopper is filled with slurry, the dredger stops dredging and goes to a dump site and empties its hopper.

Some hopper dredges are designed so they can also be emptied from above using pumps if dump sites are unavailable or if the dredge material is contaminated. Sometimes the slurry of dredgings and water is pumped straight into pipes which deposit it on nearby land. Other times, it is pumped into barges (also called scows), which deposit it elsewhere while the dredge continues its work.

A number of vessels, notably in the UK and NW Europe de-water the hopper to dry the cargo to enable it to be discharged onto a quayside 'dry'. This is achieved principally using self discharge bucket wheel, drag scraper or excavator via conveyor systems.

When contaminated (toxic) sediments are to be removed, or large volume inland disposal sites are unavailable, dredge slurries are reduced to dry solids via a process known as dewatering. Current dewatering techniques employ either centrifuges, large textile based filters or polymer flocculant/congealant based apparatus.

In many projects, slurry dewatering is performed in large inland settling pits, although this is becoming less and less common as mechanical dewatering techniques continue to improve.

Similarly, many groups (most notable in east Asia) are performing research towards utilizing dewatered sediments for the production of concretes and construction block, although the high organic content (in many cases) of this material is a hindrance toward such ends.

Environmental impacts

Dredging can create disturbance to aquatic ecosystems, often with adverse impacts. In addition, dredge spoils may contain toxic chemicals that may have an adverse effect on the disposal area; furthermore, the process of dredging often dislodges chemicals residing in benthic substrates and injects them into the water column.

The activity of dredging can create the following principal impacts to the environment:

- Release of toxic chemicals (including heavy metals and PCB) from bottom sediments into the water column.
- Short term increases in turbidity, which can affect aquatic species metabolism and interfere with spawning.
- Secondary effects from water column contamination of uptake of heavy metals, DDT and other persistent organic toxins, via food chain uptake and subsequent concentrations of these toxins in higher organisms including humans.
- Secondary impacts to marsh productivity from sedimentation
- Tertiary impacts to avifauna which may prey upon contaminated aquatic organisms
- Secondary impacts to aquatic and benthic organisms' metabolism and mortality
- Possible contamination of dredge spoils sites

The nature of dredging operations and possible environmental impacts cause the industry to be closely regulated and a requirement for comprehensive regional environmental impact assessments with continuous monitoring. The U.S. Clean Water Act requires that any discharge of dredged or fill materials into "waters of the United States," including wetlands, is forbidden unless authorized by a permit issued by the Army Corps of Engineers. As a result of the potential impacts to the environment, dredging is restricted to licenced areas only with vessel activity monitored closely using automatic GPS systems.

Major dredging companies

- Royal Boskalis Westminster (Netherlands)
- Jan De Nul (Belgium)
- Van Oord Dredging and Marine Contractors (Netherlands)
- Gezhouba Group (China CGGC)
- DEME (Belgium)

Chapter- 5

Drilling Rig

Drilling rig, Reverse circulation in western Australia

Drilling rig preparing rock blasting

A **drilling rig** is a machine which creates holes (usually called boreholes) and/or shafts in the ground. Drilling rigs can be massive structures housing equipment used to drill water wells, oil wells, or natural gas extraction wells, or they can be small enough to be moved manually by one person. They sample sub-surface mineral deposits, test rock, soil and groundwater physical properties, and also can be used to install sub-surface fabrications, such as underground utilities, instrumentation, tunnels or wells. Drilling rigs can be mobile equipment mounted on trucks, tracks or trailers, or more permanent land or marine-based structures (such as oil platforms, commonly called 'offshore oil rigs' even if they don't contain a drilling rig). The term "rig" therefore generally refers to the complex of equipment that is used to penetrate the surface of the Earth's crust.

Drilling rigs can be:

- Small and portable, such as those used in mineral exploration drilling, water wells and environmental investigations.
- Huge, capable of drilling through thousands of meters of the Earth's crust. Large "mud pumps" circulate drilling mud (slurry) through the drill bit and up the casing annulus, for cooling and removing the "cuttings" while a well is drilled. Hoists in the rig can lift hundreds of tons of pipe. Other equipment can force acid or sand into reservoirs to facilitate extraction of the oil or natural gas; and in remote locations there can be permanent living accommodation and catering for crews (which may be more than a hundred). Marine rigs may operate many hundreds of miles or kilometres distant from the supply base with infrequent crew rotation.

Petroleum drilling industry

Petroleum drilling rig. Capable of drilling thousands of feet

Modern Oil Driller La Pampa Argentina

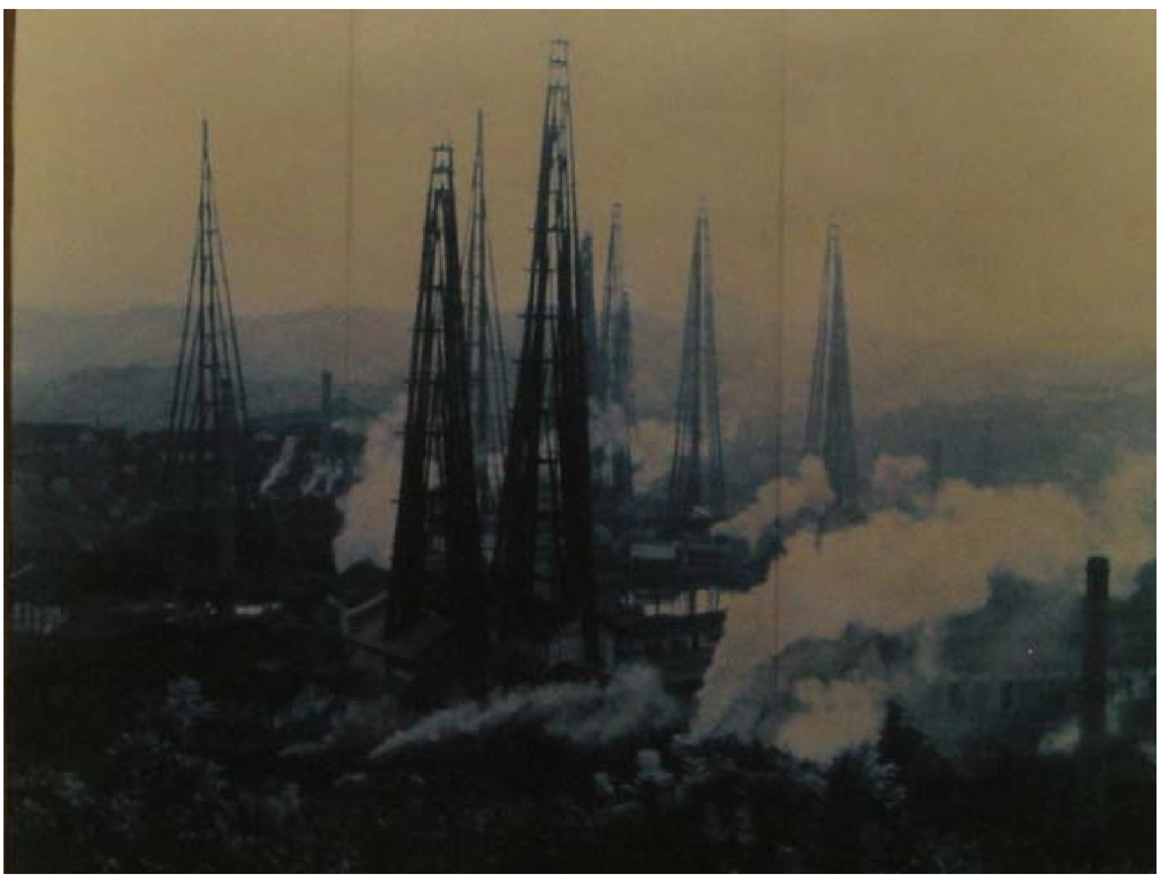
Oil and Natural Gas drilling rigs can be used not only to identify geologic reservoirs but also to create holes that allow the extraction of oil or natural gas from those reservoirs. Primarily in onshore oil and gas fields once a well has been drilled, the drilling rig will be moved off of the well and a service rig (a smaller rig) that is purpose-built for completions will be moved on to the well to get the well on line. This frees up the drilling rig to drill another hole and streamlines the operation as well as allowing for specialization of certain services, i.e., completions vs. drilling.

Water well drilling

New technology uses smaller portable trailer mounted rigs with shorter 10 foot (3.0 m) drill pipe. DIY users and missionary groups use these to drill water wells as they can be operated by 1 or 2 people with a minimal skill level. The shorter drill pipe also allows a much smaller mast, which gives a smaller and lighter rig which is cheaper to ship overseas and can fit in a standard 20 foot (6.1 m) shipping container. Drillcat portable trailer mounted drilling rigs have drill ratings from 300 to 800 feet (91 to 240 m) depending on mud pump flow and pressure ratings. Other more complicated and heavy truck rigs require much more skill to run, and the longer 20 to 30 foot (6.1 to 9.1 m) drill pipe is more difficult to handle safely than the shorter pipe on smaller rigs. Large truck rigs also have a much higher over head to operate. Large truck drills can use over 150 or more gallons of fuel per day, compared to smaller portable drills that use 5 to 20 gallons of fuel per day. The larger truck drills still have there place, but in remote or hard to get places , the newer portable drill technology is a money saver.

History

Antique drilling rig now on display at Western History Museum in Lingle, Wyoming. It was used to drill many water wells in that area—many of those wells are still in use.



Antique drilling Rigs in Zigong, China

Until internal combustion engines were developed in the late 19th century, the main method for drilling rock was muscle power of man or animal. Rods were turned by hand, using clamps attached to the rod. The rope and drop method invented in Zigong, China used a steel rod or piston raised and dropped vertically via a rope. Mechanised versions of this persisted until about 1970, using a cam to rapidly raise and drop what, by then, was a steel cable.

In the 1970s, outside of the oil and gas industry, roller bits using mud circulation were replaced by the first pneumatic reciprocating piston Reverse Circulation (RC) drills, and became essentially obsolete for most shallow drilling, and are now only used in certain situations where rocks preclude other methods. RC drilling proved much faster and more efficient, and continues to improve with better metallurgy, deriving harder, more durable bits, and compressors delivering higher air pressures at higher volumes, enabling deeper and faster penetration. Diamond drilling has remained essentially unchanged since its inception.

Mobile drilling rigs

In early oil exploration, drilling rigs were semi-permanent in nature and the derricks were often built on site and left in place after the completion of the well. In more recent times drilling rigs are expensive custom-built machines that can be moved from well to well. Some light duty drilling rigs are like a mobile crane and are more usually used to drill water wells. Larger land rigs must be broken apart into sections and loads to move to a new place, a process which can often take weeks.

Small mobile drilling rigs are also used to drill or bore piles. Rigs can range from 100 ton continuous flight auger (CFA) rigs to small air powered rigs used to drill holes in quarries, etc. These rigs use the same technology and equipment as the oil drilling rigs, just on a smaller scale.

The drilling mechanisms outlined below differ mechanically in terms of the machinery used, but also in terms of the method by which drill cuttings are removed from the cutting face of the drill and returned to surface.

Drilling rig classification

There are many types and designs of drilling rigs, with many drilling rigs capable of switching or combining different drilling technologies as needed. Drilling rigs can be described using any of the following attributes:

By power used

- Mechanical — the rig uses torque converters, clutches, and transmissions powered by its own engines, often diesel

- Electric — the major items of machinery are driven by electric motors, usually with power generated on-site using internal combustion engines
- Hydraulic — the rig primarily uses hydraulic power
- Pneumatic — the rig is primarily powered by pressurized air
- Steam — the rig uses steam-powered engines and pumps (obsolete after middle of 20th Century)

By pipe used

- Cable — a cable is used to raise and drop the drill bit
- Conventional — uses metal or plastic drill pipe of varying types
- Coil tubing — uses a giant coil of tube and a downhole drilling motor

By height

(All rigs drill with only a single pipe. Rigs are differentiated by how many connected pipe they are able to "stand" in the derrick when needing to temporarily remove the drill pipe from the hole. Typically this is done when changing a drill bit or when "logging" the well.)

- Single — can pull only single drill pipes. The presence or absence of vertical pipe racking "fingers" varies from rig to rig.
- Double — can hold a stand of pipe in the derrick consisting of two connected drill pipes, called a "double stand".
- Triple — can hold a stand of pipe in the derrick consisting of three connected drill pipes, called a "triple stand".

By method of rotation or drilling method

- No-rotation includes direct push rigs and most service rigs
- Rotary table — rotation is achieved by turning a square or hexagonal pipe (the "Kelly") at drill floor level.
- Top drive — rotation and circulation is done at the top of the drill string, on a motor that moves in a track along the derrick.
- Sonic — uses primarily vibratory energy to advance the drill string
- Hammer — uses rotation and percussive force

By position of derrick

- Conventional — derrick is vertical
- Slant — derrick is slanted at a 45 degree angle to facilitate horizontal drilling

Drill types

There are a variety of drill mechanisms which can be used to sink a borehole into the ground. Each has its advantages and disadvantages, in terms of the depth to which it can drill, the type of sample returned, the costs involved and penetration rates achieved. There are two basic types of drills: drills which produce rock chips, and drills which produce core samples.

Auger drilling

Auger drilling is done with a helical screw which is driven into the ground with rotation; the earth is lifted up the borehole by the blade of the screw. Hollow stem auger drilling is used for environmental drilling, geotechnical drilling, soil engineering and geochemistry reconnaissance work in exploration for mineral deposits. Solid flight augers/bucket augers are used in construction drilling. In some cases, mine shafts are dug with auger drills. Small augers can be mounted on the back of a utility truck, with large augers used for sinking piles for bridge foundations.

Auger drilling is restricted to generally soft unconsolidated material or weak weathered rock. It is cheap and fast.

Cable tool water well drilling rig in Kimball, West Virginia. These slow rigs have mostly been replaced by rotary drilling rigs in the U.S.

Percussion rotary air blast drilling (RAB)

RAB drilling is used most frequently in the mineral exploration industry. (This tool is also known as a Down-the-hole drill.) The drill uses a pneumatic reciprocating piston-driven "hammer" to energetically drive a heavy drill bit into the rock. The drill bit is hollow, solid steel and has ~20 mm thick tungsten rods protruding from the steel matrix as "buttons". The tungsten buttons are the cutting face of the bit.

The cuttings are blown up the outside of the rods and collected at surface. Air or a combination of air and foam lift the cuttings.

RAB drilling is used primarily for mineral exploration, water bore drilling and blast-hole drilling in mines, as well as for other applications such as engineering, etc. RAB produces lower quality samples because the cuttings are blown up the outside of the rods and can be contaminated from contact with other rocks. RAB drilling at extreme depth, if it encounters water, may rapidly clog the outside of the hole with debris, precluding removal of drill cuttings from the hole. This can be counteracted, however, with the use of "stabilisers" also known as "reamers", which are large cylindrical pieces of steel attached to the drill string, and made to perfectly fit the size of the hole being drilled. These have sets of rollers on the side, usually with tungsten buttons, that constantly break down cuttings being pushed upwards.

The use of high-powered air compressors, which push 900-1150 cfm of air at 300-350 psi down the hole also ensures drilling of a deeper hole up to ~1250 m due to higher air pressure which pushes all rock cuttings and any water to the surface. This, of course, is all dependent on the density and weight of the rock being drilled, and on how worn the drill bit is.

Air core drilling

Air core drilling and related methods use hardened steel or tungsten blades to bore a hole into unconsolidated ground. The drill bit has three blades arranged around the bit head, which cut the unconsolidated ground. The rods are hollow and contain an inner tube which sits inside the hollow outer rod barrel. The drill cuttings are removed by injection of compressed air into the hole via the annular area between the innertube and the drill rod. The cuttings are then blown back to surface up the inner tube where they pass through the sample separating system and are collected if needed. Drilling continues with the addition of rods to the top of the drill string. Air core drilling can occasionally produce small chunks of cored rock.

This method of drilling is used to drill the weathered regolith, as the drill rig and steel or tungsten blades cannot penetrate fresh rock. Where possible, air core drilling is preferred over RAB drilling as it provides a more representative sample. Air core drilling can achieve depths approaching 300 meters in good conditions. As the cuttings are removed inside the rods and are less prone to contamination compared to conventional drilling where the cuttings pass to the surface via outside return between the outside of the drill rod and the walls of the hole. This method is more costly and slower than RAB.

Cable tool drilling

SpeedStar cable tool drilling rig, Ballston Spa, New York

Cable tool rigs are a traditional way of drilling water wells. The majority of large diameter water supply wells, especially deep wells completed in bedrock aquifers, were completed using this drilling method. Although this drilling method has largely been supplanted in recent years by other, faster drilling techniques, it is still the most practicable drilling method for large diameter, deep bedrock wells, and in widespread use for small rural water supply wells. The impact of the drill bit fractures the rock and in many shale rock situations increases the water flow into a well over rotary.

Also known as ballistic well drilling and sometimes called "spudders", these rigs raise and drop a drill string with a heavy carbide tipped drilling bit that chisels through the rock by finely pulverizing the subsurface materials. The drill string is composed of the upper drill rods, a set of "jars" (inter-locking "sliders" that help transmit additional energy to the drill bit and assist in removing the bit if it is stuck) and the drill bit. During the drilling process, the drill string is periodically removed from the borehole and a bailer is lowered to collect the drill cuttings (rock fragments, soil, etc.). The bailer is a bucket-like tool with a trapdoor in the base. If the borehole is dry, water is added so that the drill cuttings will flow into the bailer. When lifted, the trapdoor closes and the cuttings are then raised and removed. Since the drill string must be raised and lowered to advance the boring, the casing (larger diameter outer piping) is typically used to hold back upper soil materials and stabilize the borehole.

Cable tool rigs are simpler and cheaper than similarly sized rotary rigs, although loud and very slow to operate. The world record cable tool well was drilled in New York to a depth of almost 12,000 feet. The common Bucyrus Erie 22 can drill down to about 1,100 feet. Since cable tool drilling does not use air to eject the drilling chips like a rotary, instead using a cable strung bailer, technically there is no limitation on depth.

Cable tool rigs now are nearly obsolete in the United States. They are mostly used in Africa or Third-World countries. Being slow, cable tool rig drilling means increased wages for drillers. In the United States drilling wages would average around US$200 per day per man, while in Africa it is only US$6 per day per man, so a slow drilling machine can still be used in undeveloped countries with depressed wages. A cable tool rig can drill 25 feet to 60 feet of hard rock a day. A newer rotary top head rig equipped with down-the-hole (DTH) hammer can drill 500 feet or more per day, depending on size and formation hardness.

Reverse circulation (RC) drilling

Reverse Circulation (RC) rig, outside Newman, Western Australia

Track mounted Reverse Circulation rig (side view).

RC drilling is similar to air core drilling, in that the drill cuttings are returned to surface inside the rods. The drilling mechanism is a pneumatic reciprocating piston known as a "hammer" driving a tungsten-steel drill bit. RC drilling utilises much larger rigs and machinery and depths of up to 500 metres are routinely achieved. RC drilling ideally produces dry rock chips, as large air compressors dry the rock out ahead of the advancing drill bit. RC drilling is slower and costlier but achieves better penetration than RAB or air core drilling; it is cheaper than diamond coring and is thus preferred for most mineral exploration work.

Reverse circulation is achieved by blowing air down the rods, the differential pressure creating air lift of the water and cuttings up the "inner tube", which is inside each rod. It reaches the "bell" at the top of the hole, then moves through a sample hose which is attached to the top of the "cyclone". The drill cuttings travel around the inside of the cyclone until they fall through an opening at the bottom and are collected in a sample bag.

The most commonly used RC drill bits are 5-8 inches (13–20 cm) in diameter and have round metal 'buttons' that protrude from the bit, which are required to drill through shale and abrasive rock. As the buttons wear down, drilling becomes slower and the rod string can potentially become bogged in the hole. This is a problem as trying to recover the rods may take hours and in some cases weeks. The rods and drill bits themselves are very expensive, often resulting in great cost to drilling companies when equipment is lost down the bore hole. Most companies will regularly re-grind the buttons on their drill bits in order to prevent this, and to speed up progress. Usually, when something is lost (breaks off) in the hole, it is not the drill string, but rather from the bit, hammer, or stabiliser to the bottom of the drill string (bit). This is usually caused by a blunt bit getting stuck in fresh rock, over-stressed metal, or a fresh drill bit getting stuck in a part of the hole that is too small, owing to having used a bit that has worn to smaller than the desired hole diameter.

Although RC drilling is air-powered, water is also used, to reduce dust, keep the drill bit cool, and assist in pushing cutting back upwards, but also when "collaring" a new hole. A mud called "Liqui-Pol" is mixed with water and pumped into the rod string, down the hole. This helps to bring up the sample to the surface by making the sand stick together. Occasionally, "Super-Foam" (a.k.a. "Quik-Foam") is also used, to bring all the very fine cuttings to the surface, and to clean the hole. When the drill reaches hard rock, a "collar" is put down the hole around the rods, which is normally PVC piping. Occasionally the collar may be made from metal casing. Collaring a hole is needed to stop the walls from caving in and bogging the rod string at the top of the hole. Collars may be up to 60 metres deep, depending on the ground, although if drilling through hard rock a collar may not be necessary.

Reverse circulation rig setups usually consist of a support vehicle, an auxiliary vehicle, as well as the rig itself. The support vehicle, normally a truck, holds diesel and water tanks for resupplying the rig. It also holds other supplies needed for maintenance on the rig. The auxiliary is a vehicle, carrying an auxiliary engine and a booster engine. These engines are connected to the rig by high pressure air hoses. Although RC rigs have their own booster and compressor to generate air pressure, extra power is needed which usually isn't supplied by the rig due to lack of space for these large engines. Instead, the engines are mounted on the auxiliary vehicle. Compressors on an RC rig have an output of around 1000 cfm at 500 psi (500 $L \cdot s^{-1}$ at 3.4 MPa). Alternatively, stand-alone air compressors which have an output of 900-1150cfm at 300-350 psi each are used in sets of 2, 3, or 4, which are all routed to the rig through a multi-valve manifold.

Diamond core drilling

Multi-combination drilling rig (capable of both diamond and reverse circulation drilling). Rig is currently set up for diamond drilling.

Diamond core drilling (exploration diamond drilling) utilizes an annular diamond-impregnated drill bit attached to the end of hollow drill rods to cut a cylindrical core of solid rock. The diamonds used are fine to microfine industrial grade diamonds. They are set within a matrix of varying hardness, from brass to high-grade steel. Matrix hardness, diamond size and dosing can be varied according to the rock which must be cut. Holes within the bit allow water to be delivered to the cutting face. This provides three essential functions — lubrication, cooling, and removal of drill cuttings from the hole.

Diamond drilling is much slower than reverse circulation (RC) drilling due to the hardness of the ground being drilled. Drilling of 1200 to 1800 metres is common and at these depths, ground is mainly hard rock. Diamond rigs need to drill slowly to lengthen the life of drill bits and rods, which are very expensive.

Core samples are retrieved via the use of a "lifter tube", a hollow tube lowered inside the rod string by a winch cable until it stops inside the core barrel. As the core is drilled, the core barrel slides over the core as it is cut. An "overshot" attached to the end of the winch cable is lowered inside the rod string and locks on to the "backend", located on the top end of the core barrel. The winch is retracted, pulling the core barrel to the surface. The core does not drop out of the inside of the core barrel when lifted because either a split ring core lifter or basket retainer allow the core to move into, but not back out of the tube.

Diamond core drill bits

Once the core barrel is removed from the hole, the core sample is then removed from the core barrel and catalogued. The Driller's offsider screws the rod apart using tube clamps, then each part of the rod is taken and the core is shaken out into core trays. The core is washed, measured and broken into smaller pieces using a hammer or sawn through to make it fit into the sample trays. Once catalogued, the core trays are retrieved by geologists who then analyse the core and determine if the drill site is a good location to expand future mining operations.

Diamond rigs can also be part of a multi-combination rig. Multi-combination rigs are a dual setup rig capable of operating in either a reverse circulation (RC) and diamond drilling role (though not at the same time). This is a common scenario where exploration drilling is being performed in a very isolated location. The rig is first set up to drill as an RC rig and once the desired metres are drilled, the rig is set up for diamond drilling. This way the deeper metres of the hole can be drilled without moving the rig and waiting for a diamond rig to set up on the pad.

Direct push rigs

Direct push technology includes several types of drilling rigs and drilling equipment which advances a drill string by pushing or hammering without rotating the drill string. While this does not meet the proper definition of drilling, it does achieve the same result — a borehole. Direct push rigs include both cone penetration testing (CPT) rigs and direct push sampling rigs such as a PowerProbe or Geoprobe. Direct push rigs typically are limited to drilling in unconsolidated soil materials and very soft rock.

CPT rigs advance specialized testing equipment (such as electronic cones), and soil samplers using large hydraulic rams. Most CPT rigs are heavily ballasted (20 metric tons is typical) as a counter force against the pushing force of the hydraulic rams which are often rated up to 20 kN. Alternatively, small, light CPT rigs and offshore CPT rigs will use anchors such as screwed-in ground anchors to create the reactive force. In ideal conditions, CPT rigs can achieve production rates of up to 250–300 meters per day.

Direct push drilling rigs use hydraulic cylinders and a hydraulic hammer in advancing a hollow core sampler to gather soil and groundwater samples. The speed and depth of penetration is largely dependent on the soil type, the size of the sampler, and the weight and power the rig. Direct push techniques are generally limited to shallow soil sample recovery in unconsolidated soil materials. The advantage of direct push technology is that in the right soil type it can produce a large number of high quality samples quickly and cheaply, generally from 50 to 75 meters per day. Rather than hammering, direct push can also be combined with sonic (vibratory) methods to increase drill efficiency.

Hydraulic rotary drilling

Oil well drilling utilises tri-cone roller, carbide embedded, fixed-cutter diamond, or diamond-impregnated drill bits to wear away at the cutting face. This is preferred because there is no need to return intact samples to surface for assay as the objective is to reach a formation containing oil or natural gas. Sizable machinery is used, enabling depths of several kilometres to be penetrated. Rotating hollow drill pipes carry down bentonite and barite infused drilling muds to lubricate, cool, and clean the drilling bit, control downhole pressures, stabilize the wall of the borehole and remove drill cuttings. The mud travels back to the surface around the outside of the drill pipe, called the annulus. Examining rock chips extracted from the mud is known as mud logging. Another form of well logging is electronic and is frequently employed to evaluate the existence of possible oil and gas deposits in the borehole. This can take place while the well is being drilled, using Measurement While Drilling tools, or after drilling, by lowering measurement tools into the newly drilled hole.

The rotary system of drilling was in general use in Texas in the early 1900s. It is a modification of one invented by Fauvelle in 1845, and used in the early years of the oil industry in some of the oil-producing countries in Europe. Originally pressurized water was used instead of mud, and was almost useless in hard rock before the diamond cutting bit. The main breakthrough for rotary drilling came in 1901, when Anthony Francis Lucas combined the use of a steam-driven rig and of mud instead of water in the Spindletop discovery well.

The drilling and production of oil and gas can pose a safety risk and a hazard to the environment from the ignition of the entrained gas causing dangerous fires and also from the risk of oil leakage polluting water, land and groundwater. For these reasons, redundant safety systems and highly trained personnel are required by law in all countries with significant production.

Sonic (vibratory) drilling

A sonic drill head works by sending high frequency resonant vibrations down the drill string to the drill bit, while the operator controls these frequencies to suit the specific conditions of the soil/rock geology. Vibrations may also be generated within the drill head. The frequency is generally between 50 and 120 hertz (cycles per second) and can be varied by the operator.

Resonance magnifies the amplitude of the drill bit, which fluidizes the soil particles at the bit face, allowing for fast and easy penetration through most geological formations. An internal spring system isolates these vibrational forces from the rest of the drill rig.

Limits of the technology

An oil rig

Drill technology has advanced steadily since the 19th century. However, there are several basic limiting factors which will determine the depth to which a bore hole can be sunk.

All holes must maintain outer diameter; the diameter of the hole must remain wider than the diameter of the rods or the rods cannot turn in the hole and progress cannot continue. Friction caused by the drilling operation will tend to reduce the outside diameter of the drill bit. This applies to all drilling methods, except that in diamond core drilling the use of thinner rods and casing may permit the hole to continue. Casing is simply a hollow sheath which protects the hole against collapse during drilling, and is made of metal or PVC. Often diamond holes will start off at a large diameter and when outside diameter is lost, thinner rods put down inside casing to continue, until finally the hole becomes too narrow. Alternatively, the hole can be reamed; this is the usual practice in oil well drilling where the hole size is maintained down to the next casing point.

For percussion techniques, the main limitation is air pressure. Air must be delivered to the piston at sufficient pressure to activate the reciprocating action, and in turn drive the head into the rock with sufficient strength to fracture and pulverise it. With depth, volume is added to the in-rod string, requiring larger compressors to achieve operational pressures. Secondly, groundwater is ubiquitous, and increases in pressure with depth in the ground. The air inside the rod string must be pressurised enough to overcome this water pressure at the bit face. Then, the air must be able to carry the rock fragments to surface. This is why depths in excess of 500 m for reverse circulation drilling are rarely achieved, because the cost is prohibitive and approaches the threshold at which diamond core drilling is more economic.

Diamond drilling can routinely achieve depths in excess of 1200 m. In cases where money is no issue, extreme depths have been achieved, because there is no requirement to overcome water pressure. However, circulation must be maintained to return the drill cuttings to surface, and more importantly to maintain cooling and lubrication of the cutting surface.

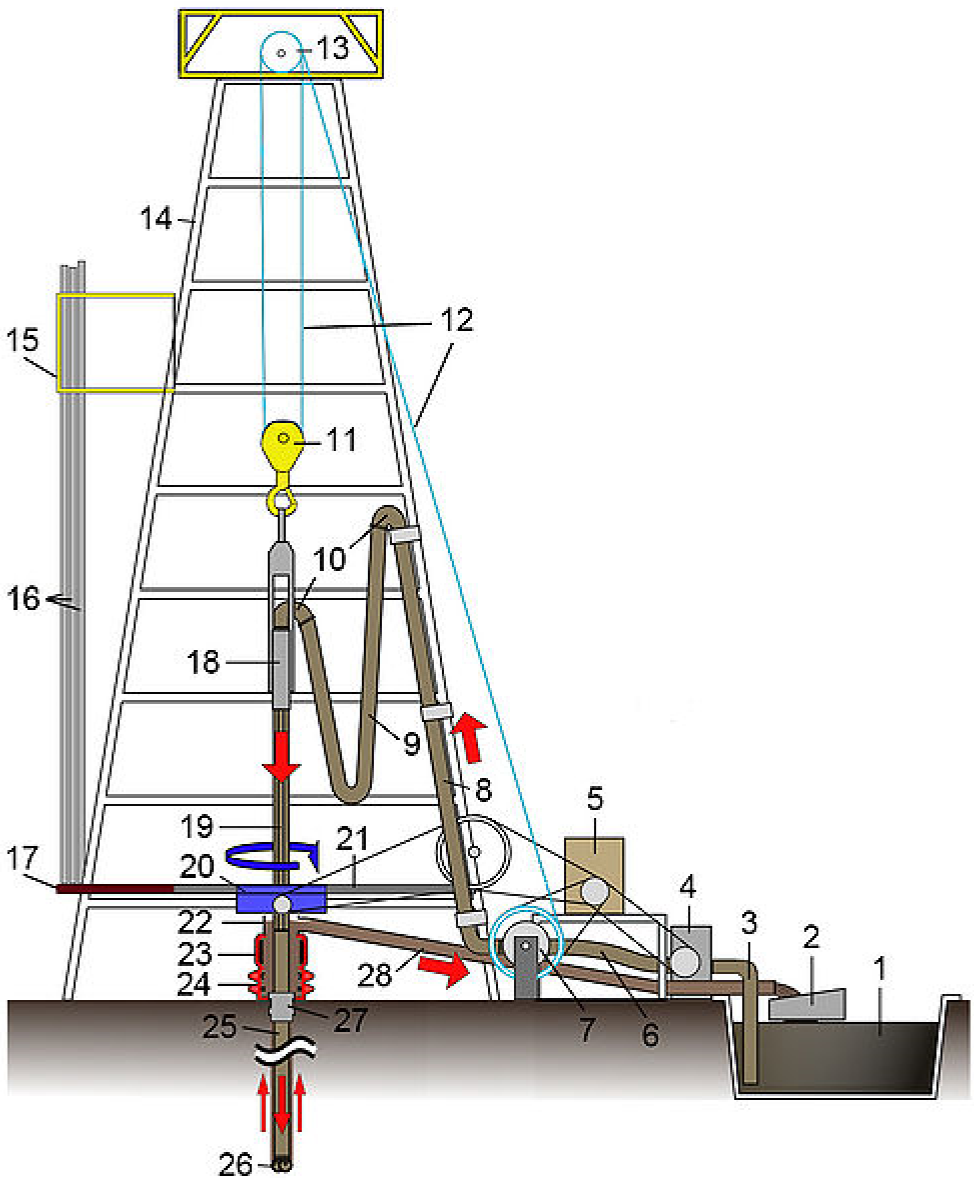
Without sufficient lubrication and cooling, the matrix of the drill bit will soften. While diamond is the hardest substance known, at 10 on the Mohs hardness scale, it must remain firmly in the matrix to achieve cutting. Weight on bit, the force exerted on the cutting face of the bit by the drill rods in the hole above the bit, must also be monitored.

A unique drilling operation in deep ocean water was named Project Mohole.

Causes of deviation

Most drill holes deviate from the vertical. This is because of the torque of the turning bit working against the cutting face, because of the flexibility of the steel rods and especially the screw joints, because of reaction to foliation and structure within the rock, and because of refraction as the bit moves into different rock layers of varying resistance. Additionally, inclined holes will tend to deviate upwards because the drill rods will lie against the bottom of the bore, causing the drill bit to be slightly inclined from true. It is because of deviation that drill holes must be surveyed if deviation will impact the usefulness of the information returned. Sometimes the surface location can be offset laterally to take advantage of the expected deviation tendency, so the bottom of the hole will end up near the desired location. Oil well drilling commonly uses a process of controlled deviation called directional drilling (e.g., when several wells are drilled from one surface location).

Rig equipment



Simple diagram of a drilling rig and its basic operation

The equipment associated with a rig is to some extent dependent on the type of rig but (#23 & #24) are devices installed at the wellhead to prevent fluids and gases from unintentionally escaping from the borehole. #23 is the annular (often referred to as the "Hydril", which is one manufacturer) and #24 is the pipe rams and blind rams. In the place of #24 Variable bore rams or VBR's can be used, they offer the same pressure and sealing capacity found in standard pipe rams, while offering the versatility of sealing on various sizes of drill pipe, production tubing and casing without changing standard pipe rams. Normally VBR's are used when utilizing a tapered drill string (when different size drill pipe is used in the complete drill string).

- Centrifuge: an industrial version of the device that separates fine silt and sand from the drilling fluid.
- Solids control: solids control equipments for preparing drilling mud for the drilling rig.
- Chain tongs: wrench with a section of chain, that wraps around whatever is being tightened or loosened. Similar to a pipe wrench.
- Degasser: a device that separates air and/or gas from the drilling fluid.
- Desander / desilter: contains a set of hydrocyclones that separate sand and silt from the drilling fluid.
- Drawworks: (#7) is the mechanical section that contains the spool, whose main function is to reel in/out the drill line to raise/lower the traveling block (#11).
- Drill bit: (#26) device attached to the end of the drill string that breaks apart the rock being drilled. It contains jets through which the drilling fluid exits.
- Drill pipe: (#16) joints of hollow tubing used to connect the surface equipment to the bottom hole assembly (BHA) and acts as a conduit for the drilling fluid. In the diagram, these are "stands" of drill pipe which are 2 or 3 joints of drill pipe connected together and "stood" in the derrick vertically, usually to save time while Tripping pipe.
- Elevators: a gripping device that is used to latch to the drill pipe or casing to facilitate the lowering or lifting (of pipe or casing) into or out of the borehole.
- Mud motor: a hydraulically powered device positioned just above the drill bit used to spin the bit independently from the rest of the drill string.
- Mud pump: (#4) reciprocal type of pump used to circulate drilling fluid through the system.
- Mud tanks: (#1) often called mud pits, provides a reserve store of drilling fluid until it is required down the wellbore.
- Rotary table: (#20) rotates the drill string along with the attached tools and bit.
- Shale shaker: (#2) separates drill cuttings from the drilling fluid before it is pumped back down the borehole.

Chapter- 6

Excavator

A typical modern excavator: a CAT 325C, fitted with quick coupler and tilting bucket.

Excavators are heavy construction equipment consisting of a boom, bucket and cab on a rotating platform (known as the "house"). The house sits atop an undercarriage with tracks or wheels. All movement and functions of the excavator are accomplished through the use of hydraulic fluid, be it with rams or motors. Their design is a natural progression from the steam shovel.

Terminology

Excavators are also called **diggers** , a **JCB** (which is a proprietary name) or **360-degree excavators** sometimes abbreviated simply to **360**. Tracked excavators are sometimes called "trackhoes" by analogy to the backhoe. In the UK, wheeled excavators are sometimes known as "rubber ducks." In Japan, the alias **Yumbo** (ユンボ *Yunbo*[?]) is sometimes used for excavators, after the 1961 Mitsubishi Yumbo Y35.

Usage

Excavators are used in many ways:

- Digging of trenches, holes, foundations
- Material handling
- Brush cutting with hydraulic attachments
- Forestry work
- Demolition
- General grading/landscaping
- Heavy lift, e.g. lifting and placing of pipes
- Mining, especially, but not only open-pit mining
- River dredging
- Driving piles, in conjunction with a Pile Driver

Link-Belt excavator trenching

An old excavator under the Northwest (now Terex) name at the Pageant of Steam grounds

Excavator demolishing a house. Note the hydraulic thumb

Configurations

Excavators come in a wide variety of sizes. The smaller ones are called mini or compact excavators. Caterpillar's smallest mini-excavator weighs 3,549 pounds (1,610 kg) and has 19 hp; their largest model weighs 187,360 pounds (84,990 kg) and has 513 hp. The largest excavator available is the Bucyrus RH400, it weighs in excess of 2,160,510 pounds (979,990 kg), has 4500 hp and has a bucket size of about 52.0 m³.

Engines in excavators drive hydraulic pumps; there are usually 3 pumps: the two main pumps are for supplying oil at high pressure (up to 5000 psi) for the rams, slew motor, track motors, and accessories, and the third is a lower pressure (700 psi) pump for Pilot Control, this circuit used for the control of the spool valves, this allows for a reduced effort required when operating the controls.

The two main sections of an excavator are the undercarriage and the house. The undercarriage includes the blade (if fitted), tracks, track frame, and final drives, which have a hydraulic motor and gearing providing the drive to the individual tracks, and the house includes the operator cab, counterweight, engine, fuel and hydraulic oil tanks. The house attaches to the undercarriage by way of a center pin, allowing the machine to slew 360° unhindered.

The main boom attaches to the house, and can be one of 3 different configurations:

- Most are mono booms: these have no movement apart from straight up and down.
- Some others have a knuckle boom which can also move left and right in line with the machine.
- The other option is a hinge at the base of the boom allowing it to hydraulically pivot up to 180° independent to the house, however this is generally available only to compact excavators.

Attached to the end of the boom is the stick (or dipper arm). The stick provides the digging force needed to pull the bucket through the ground. The stick length is optional depending whether reach (longer stick) or break-out power (shorter stick) is required.

On the end of the stick is usually a bucket. A wide, large capacity (Mud) bucket with a straight cutting edge is used for cleanup and levelling or where the material to be dug is soft, and teeth are not required. A general purpose (GP) bucket is generally smaller, stronger, and has hardened side cutters and teeth used to break through hard ground and rocks. Buckets have numerous shapes and sizes for various applications. There are also many other attachments which are available to be attached to the excavator for boring, ripping, crushing, cutting, lifting, etc.

Before the 1990s, all excavators had a long or conventional counterweight that hung off the rear of the machine to provide more digging force and lifting capacity. This became a nuisance when working in confined areas. In 1993 Yanmar launched the world's first Zero Tail Swing excavator, which allows the counterweight to stay inside the width of the tracks as it slews, thus being safer and more user friendly when used in a confined space. This type of machine is now widely used throughout the world.

Excavator attachments

In recent years, hydraulic excavator capabilities have expanded far beyond excavation tasks with buckets. With the advent of hydraulic powered attachments such as a breaker, a grapple or an auger, the excavator is frequently used in many applications other than excavation. Many excavators feature a quick coupler for simplified attachment mounting, increasing the machine's utilization on the jobsite. Excavators are usually employed together with loaders and bulldozers. Most wheeled, compact and some medium sized (11 to 18 tonne) excavators have a backfill (or dozer) blade. This is a horizontal bulldozer-like blade attached to the undercarriage and is used for levelling & pushing removed material back into a hole.

Notable manufacturers

- Benati
- Bobcat Company
- Case CE
- Caterpillar Inc.
- CNH Global
- Doosan Infracore (formerly Daewoo Heavy Industries & Machinery) - including Solar brand
- Hitachi Construction Machinery
- Hidromek
- Hydrema
- Hyundai Heavy Industries
- John Deere
- J. C. Bamford (JCB)
- Komatsu Limited
- LBX (Link-Belt) Excavators
- ThyssenKrupp
- Kobelco
- Kubota
- Liebherr
- LiuGong
- Manitowoc Cranes
- Mitsubishi Heavy Industries
- New Holland
- Orenstein & Koppel (O&K)
- Poclain
- Sandvik Mining and Construction
- ST Kinetics
- Terex Corporation
- Volvo Construction Equipment

Chapter- 7

Steam Shovel

A derelict steam shovel in Alaska; major components visible include boiler, water tank, winch, main engine, boom, dipper stick, crowd engine, wheels and bucket.

A **steam shovel** is a large steam-powered excavating machine designed for lifting and moving material such as rock and soil. It is the earliest type of power shovel or excavator. They played a major role in public works in the 19th and early 20th century, being key to the construction of railroads and the Panama Canal. The development of simpler, cheaper diesel-powered shovels caused steam shovels to fall out of use in the 1930s.

Origins and development

A Marion steam shovel excavating the Panama Canal in 1908

A steam shovel excavating for the San Diego and Arizona Railway line, circa 1919

A Link-Belt steam shovel crane, circa 1890

The steam shovel was invented by William Otis, who received a patent for his design in 1839.

The first machines were known as 'partial-swing', since the dipper arm could not rotate through 360 degrees. They were built on a railway chassis, on which the boiler and movement engines were mounted. The shovel arm and driving engines were mounted at one end of the chassis, which accounts for the limited swing. Bogies with flanged wheels were fitted, and power was taken to the wheels by a chain drive to the axles. Temporary rail tracks were laid by workers where the shovel was expected to work, and repositioned as required.

Steam shovels became more popular in the latter half of the nineteenth century. Originally configured with chain hoists, the advent of steel cable in the 1870s allowed for easier rigging to the winches.

Later machines were supplied with caterpillar tracks, obviating the need for rails.

The full-swing, revolving shovel was developed in England in 1884, and became the preferred format for these machines.

Expanding railway networks (in the US and the UK) fostered a demand for steam shovels. The extensive mileage of railways, and corresponding volume of material to be moved, forced the technological leap. As a result, steam shovels became commonplace.

During the 1930s steam shovels lost out to the simpler, cheaper diesel-powered excavating shovels that were the forerunners of those still in use today. Open-pit mines were electrified at this time. Only after the Second World War, with the advent of robust high-pressure hydraulic hoses, did the more versatile hydraulic backhoe shovels take pre-eminence over the cable-hoisting winch shovels.

Many steam shovels remained at work on the railways of developing nations until diesel engines supplanted them. Most have since been scrapped.

History (US)

American manufacturers included the Marion Steam Shovel Company, which was founded in 1884, Erie, P and H, and Bucyrus-Erie Shovel Companies.

The booming cities in North America used shovels to dig foundations and basements for the early skyscrapers.

The Panama Canal

The only Bucyrus model 50-B remaining from the Panama Canal, now in the Nederland, Colorado Mining Museum, USA

Perhaps the most famous application of steam shovels is the digging of the Panama Canal across the Isthmus of Panama. One hundred and two shovels worked in that decade-long dig. Of these, seventy-seven were built by Bucyrus ; the remainder were Marion shovels. These machines 'moved mountains' in their labours. The shovel crews would race to see who could move the most dirt.

Mining

Steam shovels assisted mining operations: the iron mines of Minnesota, the copper mines of Chile and Montana, placer mines of the Klondike – all had earth-moving equipment. But it was with the burgeoning open-pit mines – first in Bingham Canyon, Utah – that shovels came into their own. The shovels systematically removed hillsides. As a result, steam shovels were used around the world from Australia to Russia to coal mines in China. Shovels were also used for construction, road and quarry work.

Later history (US)

Steam shovels came into their own in the 1920s with the publicly-funded road building programmes around North America. Thousands of miles of State Highways were built in this time period, together with new factories, such as Henry Ford's River Rouge Plant, and many docks, ports, buildings, and grain elevators.

Preservation

Most steam shovels have been scrapped, although a few reside in industrial museums and private collections.

The Le Roy Marion

The world's largest steam shovel surviving intact is a 1906-built Marion machine, located in the small American town of Le Roy, New York. It was listed on the National Register of Historic Places in 2008.

Ruston Proctor Steam Navvy No 306

This machine was originally used at a chalk pit at Arlesey, in Bedfordshire, England. After the pit was closed, the steam navvy was simply abandoned and 'lost' as the pit became flooded with water. By the mid-1970s, the area had become a local beauty spot, known as *The Blue Lagoon* (from chemicals from the quarry colouring the water), and after long periods of drought, the top of the rusty navvy could be seen protruding from the water. Ruston & Hornsby expert Ray Hooley heard of its existence, and organised the difficult task of rescuing it from the water-filled pit. Hooley arranged for its complete restoration to working order by apprentices at the Ruston-Bucyrus works. Subsequently it passed into the care of the Museum of Lincolnshire Life, although it is not known whether it remains in operational condition.

The navvy was recovered with hundreds of hours labour and free help from many organisations but today (2010) this Lincolnshire industrial monument stands unprotected with water allowed to pour down the boiler chimney. Many Lincolnshire residents and Ruston engineers wish to see this icon rescued.

Operation

A steam shovel comprises:

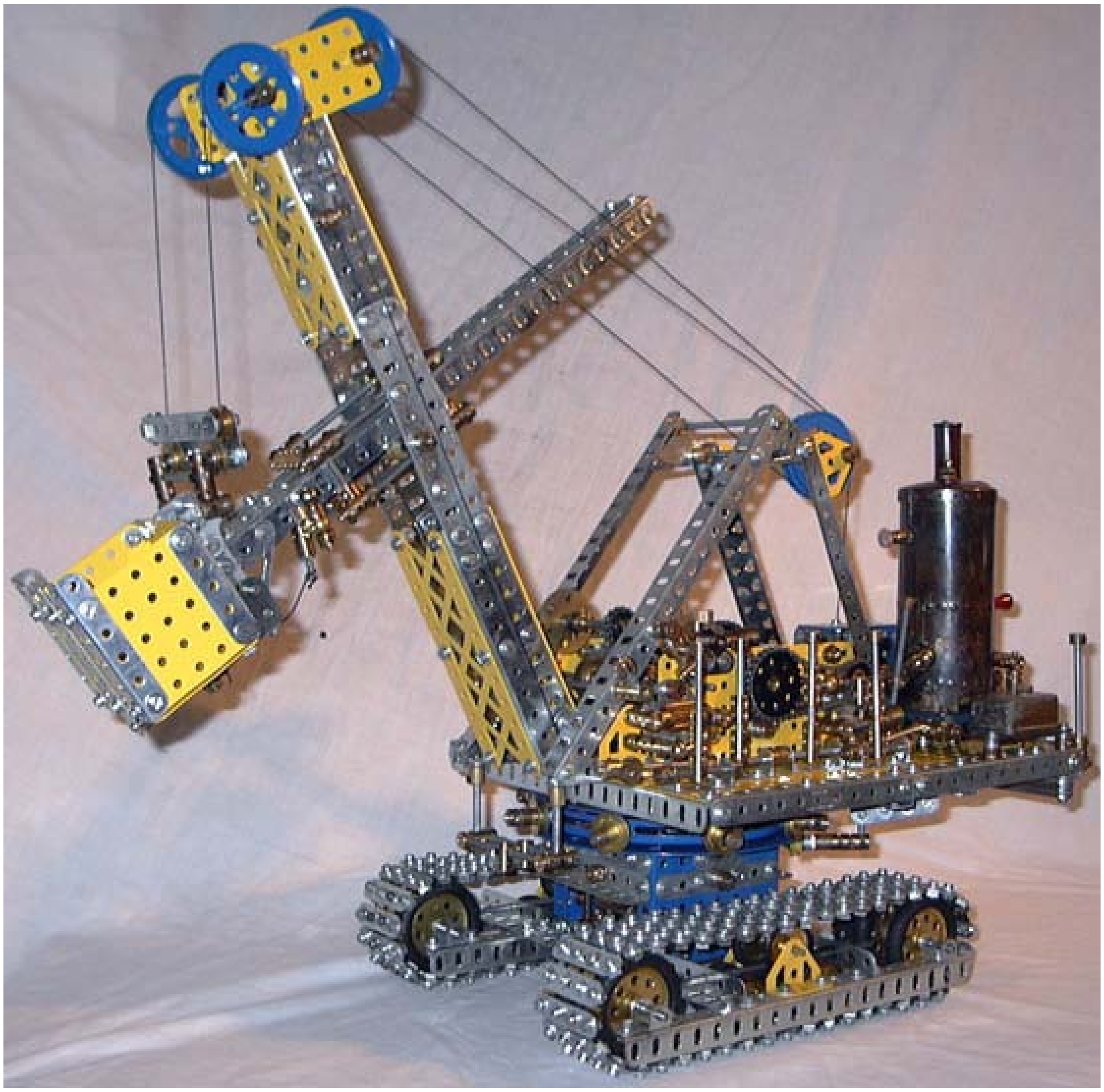
- a bucket
- boom and 'dipper stick'
- boiler
- water tank and coal bunker
- steam engines and winches
- operator's controls
- a rotating platform on a truck, on which everything is mounted
- wheels (or sometimes caterpillar tracks or railroad wheels)
- a house (on the platform) to contain and protect 'the works'

The shovel has several individual operations: it can raise or luff the boom, rotate the house, or extend the dipper stick with the boom or crowd engine, and raise or lower the dipper stick.

When digging at a rock face, the operator simultaneously raises and extends the dipper stick to fill the bucket with material. When the bucket is full, the shovel is rotated to load a railway car or motor truck. The locking pin on the bucket flap is released and the load drops away. The operator lowers the dipper stick, the bucket mouth self-closes, the pin relocks automatically and the process repeats.

Steam shovels usually had a three-man crew: engineer, fireman and ground man. There was much jockeying to do to move shovels: rails and timber blocks to move; cables and block purchases to attach; chains and slings to rig; and so on. On soft ground, shovels used timber mats to help steady and level the ground. The early models were not self-propelled, rather they would use the boom to manoeuvre themselves.

Steam shovel manufacturers



Model of a steam shovel built from Meccano and powered by a restored 1929 Meccano steam engine. (Model details here)

North American manufacturers:

- Ball Engine Co.
- Bucyrus
- Erie
- Marion Steam Shovel Dredge Company
- Moore Speedcrane *(later Manitowoc Cranes)*
- Northwest Shovels
- Vulcan Iron Works

European manufacturers:

- Demag *(Germany)*
- Fiorentini *(Italy)*
- Lubecker
- Menck
- Newton & Chambers *(UK)*
- Orenstein and Koppel GmbH *(Germany)*
- Ruston & Hornsby *(UK)*

Power shovels

Large, multi-ton mining shovels still use the cable-lift shovel arrangement.

In the 1950s and 1960s Marion Shovel built massive stripping shovels for coal operations in the Eastern US. Shovels of note were the Marion 360, the Marion 5900, and the Marion 6360 – with a 180-cubic-yard (140 m^3) bucket – while Bucyrus constructed one of the most famous monsters: the Big Brutus, the largest power shovel ever built and the largest still in existence. The *GEM of Egypt* (GEM standing for "Giant Excavating Machine" and Egypt referring to the Egypt Valley in Belmont County, eastern Ohio where it was first put to use), which operated from 1967 to 1988, was of comparable size; it has since been dismantled.

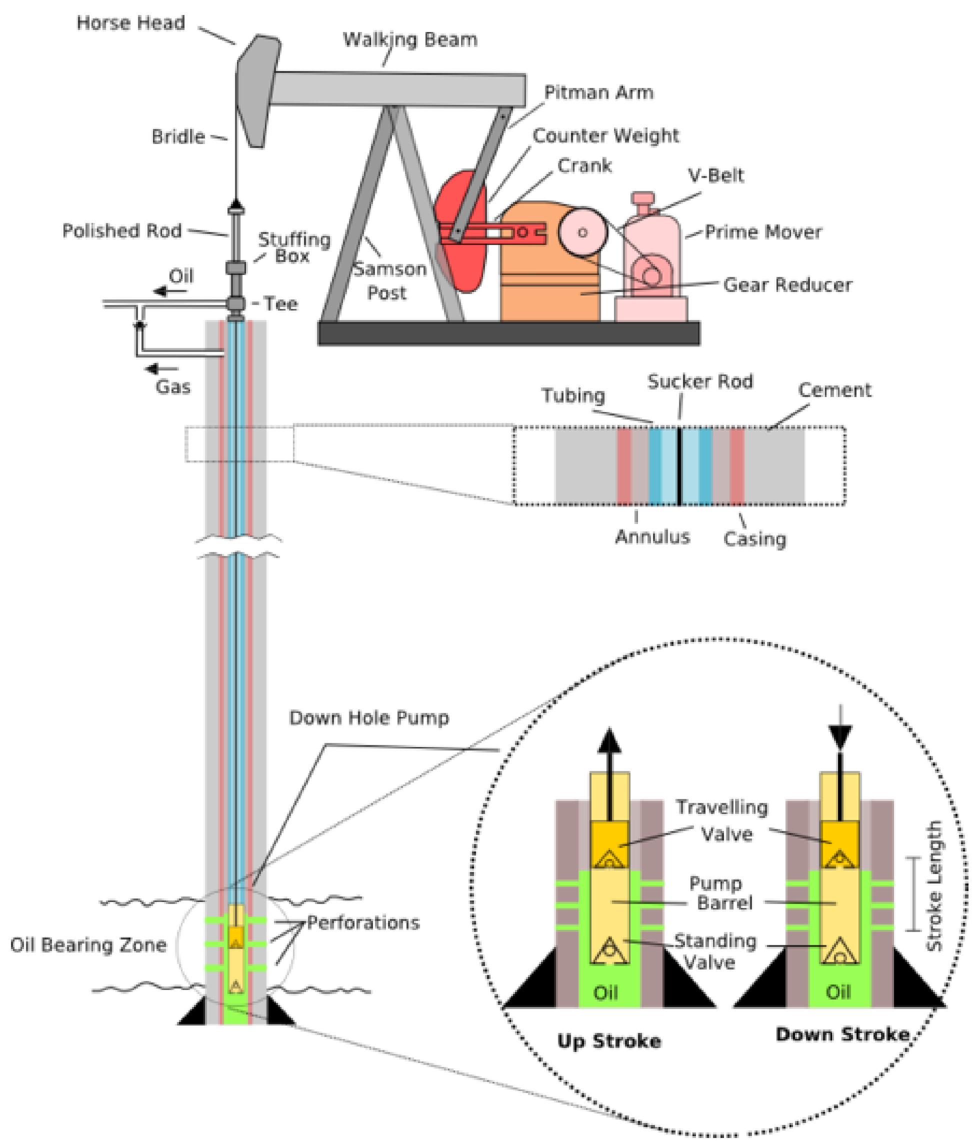
Although these big machines are still called *steam shovels*, they are more correctly known as *power shovels* since they use electricity to wind their winches.

Power shovel/dragline manufacturers

- Bucyrus International
- Insley Manufacturing Co.
- Komatsu
- Lima Locomotive Works
- Link Belt
- Marion Power Shovel
- P&H Mining Equipment
- Priestman Bros *(UK)*
- Ransomes & Rapier *(UK)*
- Ruston-Bucyrus *(UK)*

Chapter- 8

Pumpjack



A diagram of a pumpjack

A **pumpjack** (also known as **nodding donkey**, pumping unit, **horsehead pump**, **beam pump**, sucker rod pump (SRP), grasshopper pump, **thirsty bird** and **jack pump**) is the overground drive for a reciprocating piston pump installed in an oil well.

It is used to mechanically lift liquid out of the well if there is not enough bottom hole pressure for the liquid to flow all the way to the surface. The arrangement is commonly used for onshore wells producing relatively little oil. Pumpjacks are common in many oil-rich areas, dotting the countryside and occasionally serving as local landmarks.

Depending on the size of the pump, it generally produces 5 to 40 litres of liquid at each stroke. Often this is an emulsion of crude oil and water. The size of the pump is also determined by the depth and weight of the oil to be removed, with deeper extraction requiring more power to move the heavier lengths of sucker rods.

A pumpjack converts the rotary mechanism of the motor to a vertical reciprocating motion to drive the pump shaft, and is exhibited in the characteristic nodding motion. The engineering term for this type of mechanism is a walking beam. It was often employed in stationary and marine steam engine designs in the 18th and 19th centuries.

Above ground

Pumpjacks, such as this one located south of Midland, TX, are a common sight in West Texas.

Pumpjacks are powered by a "prime mover". This is commonly an electric motor, but combustion engines are used in isolated locations without economic access to electricity. The most common "off-grid" pumpjack engines run on casing gas produced from the well, but pumpjacks have been run on many types of fuel, such as propane (LPG) and diesel. In harsh climates such motors and engines may be housed inside a shack to protect them from the elements.

A nodding donkey-type pumpjack (painted to resemble a toucan) in the United States

A pumpjack in southern Alberta operating on natural gas. Location: 4-31-5-4 W4M

A field of pumpjacks along Interstate 20 in Texas

The prime mover of the pumpjack runs a set of pulleys to the transmission which in turn drives a pair of cranks, generally with counterweights on them to assist the motor in lifting the heavy string of rods. The cranks in turn raise and lower one end of an I-beam which is free to move on an A-frame. On the other end of the beam, there is a curved metal box called a Horse Head or Donkeys Head, named so due to its appearance. A cable made of steel (or, occasionally, fiberglass) called a bridle, connects the horse head to the polished rod, a piston that passes through the stuffing box. The polished rod has a very close fit to the stuffing box, letting it move in and out of the tubing without fluid escaping. (The tubing is a pipe that runs to the bottom of the well through which the liquid is produced.) The bridle follows the curve of the horse head as it lowers and raises to create an almost completely vertical stroke. The polished rod is connected to a long string of rods called sucker rods, which run through the tubing all the way to the down-hole pump, usually positioned near the bottom of the well.

Down-hole

A pump jack in California, USA

At the bottom of the tubing is the "down-hole pump". This pump consists of two ball check valves: a stationary valve at bottom called the "standing valve", and a valve on the piston connected to the bottom of the sucker rods that travels up and down as the rods reciprocate, known as the "traveling valve". Reservoir fluid enters from the formation into the bottom of the borehole through perforations that have been made through the casing and cement (the casing is a larger metal pipe that runs the length of the well, which has cement placed between it and the earth; the tubing, pump and sucker rods are all inside the casing). When the rods at the pump end are traveling up, the traveling valve is closed and the standing valve is open (due to the drop in pressure in the pump barrel). Consequently, the pump barrel fills with the fluid from the formation as the traveling piston lifts the previous contents of the barrel upwards. When the rods begin pushing down, the traveling valve opens and the standing valve closes (due to an increase in pressure in the pump barrel). The traveling valve drops through the fluid in the barrel (which had been sucked in during the upstroke). The piston then reaches the end of its stroke and begins its path upwards again, repeating the process.

Often, gas is produced through the same perforations as the oil. This can be problematic if gas enters the pump, because it can result in "gas locking", where insufficient pressure builds up in the pump barrel to open the valves (due to compression of the gas) and little or nothing is pumped. To preclude this, the inlet for the pump can be placed below the perforations. As the gas-laden fluid enters the well bore through the perforations, the gas bubbles up the annulus (the space between the casing and the tubing) while the liquid moves down to the standing valve inlet. Once at the surface, the gas is collected through piping connected to the annulus.

There are hundreds of pumpjacks on Lost Hills Oil Field near route 46 in California.

A pumpjack on display in New Mexico.

Double pumpjacks pumping from the same oil well

Water well pump jacks

Pumpjacks can also be used to drive what would now be considered "old fashioned" hand-pumped water wells. The scale of the technology is much smaller than for an oil well, and can typically fit on top of an existing hand-pumped well head. The technology is very simple, typically using a parallel-bar double-cam lift driven from a very low horsepower electric motor.

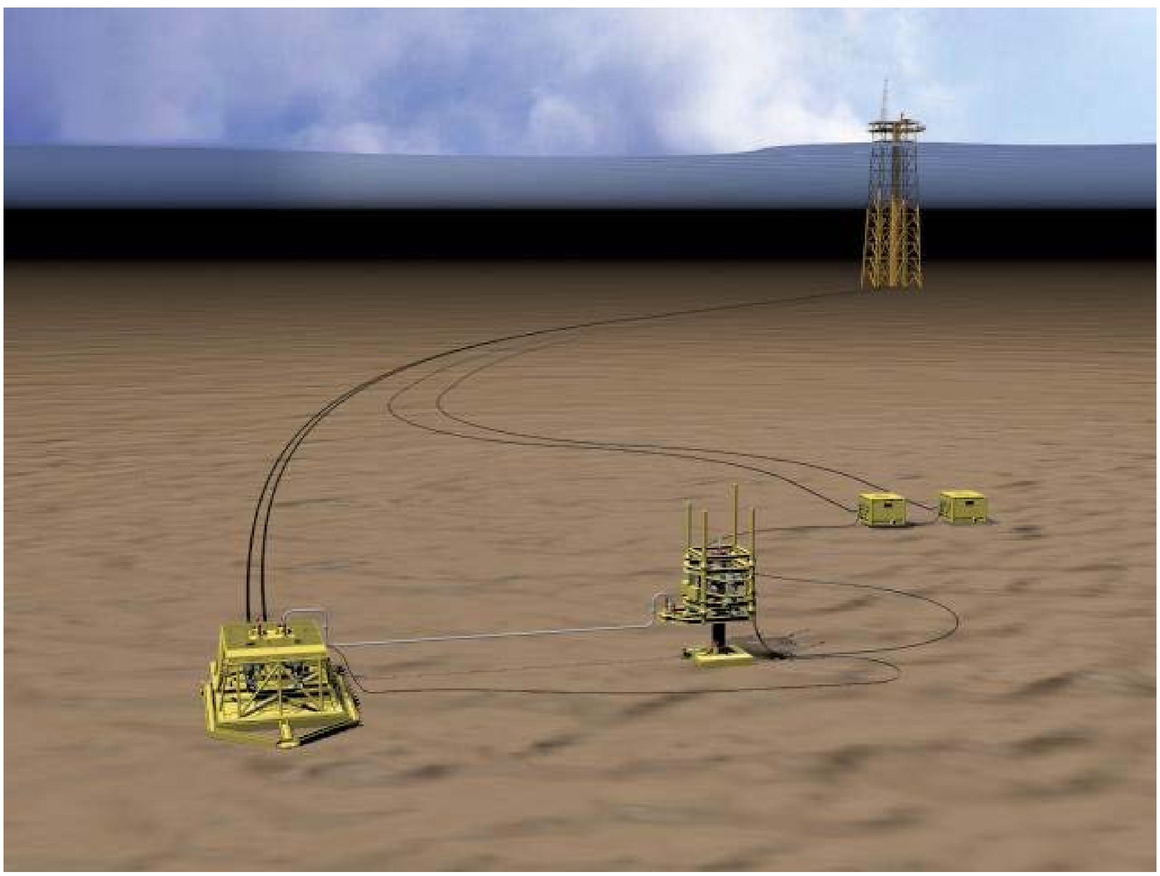
Although the flow rate for a water well pumpjack is very low compared to a modern jet pump and the lifted water is not pressurized, the water well pumpjack does at least have the option of falling back to hand pumping in an emergency, by simply hand-rotating the pumpjack cam to its lowest position, and attaching a manual handle to the top of the wellhead rod.

Chapter- 9

Subsea (Technology)

Subsea is a general term frequently used to refer to equipment, technology, and methods employed in marine biology, undersea geology, offshore oil and gas developments, underwater mining, and offshore wind power industries.

Oil and gas



Typical basic Subsea Oil or Gas Development

Oil and gas fields reside beneath many inland waters and offshore areas around the world, and in the oil and gas industry the term *subsea* relates to the exploration, drilling and development of oil and gas fields in underwater locations.

Under water oil field facilities are generically referred to using a *subsea* prefix, such as *subsea well*, *subsea field*, *subsea project*, and *subsea development*.

Subsea oil field developments are usually split into *Shallow water* and *Deepwater* categories to distinguish between the different facilities and approaches that are needed.

The term *shallow water* or *shelf* is used for shallow water depths where bottom-founded facilities like jackup drilling rigs and fixed offshore structures can be used, and where saturation diving is feasible.

Deepwater is a term often used to refer to offshore projects located in water depths greater than around 600 feet, where floating drilling vessels and floating oil platforms are used, and unmanned underwater vehicles are required as manned diving is not practical.

Subsea completions can be traced back to 1943 with the Lake Erie completion at a 35-ft water depth. The well had a land-type christmas tree that required diver intervention for installation, maintenance, and flow line connections.

Shell completed its first subsea well in the Gulf of Mexico in 1961

The first known subsea ultra-high pressure waterjet system capable of operating below 5,000 ft was developed in 2010 by Jet Edge and Chukar Waterjet. It was used to blast away hydrates that were clogging a containment system at the Gulf oil spill site.

Systems

Subsea production systems can range in complexity from a single satellite well with a flowline linked to a fixed platform, FPSO or an onshore installation, to several wells on a template or clustered around a manifold, and transferring to a fixed or floating facility, or directly to an onshore installation.

Subsea production systems can be used to develop reservoirs, or parts of reservoirs, which require drilling of the wells from more than one location. Deep water conditions, or even ultradeep water conditions, can also inherently dictate development of a field by means of a subsea production system, since traditional surface facilities such as on a steel-piled jacket, might be either technically unfeasible or uneconomical due to the water depth.

The development of subsea oil and gas fields requires specialized equipment. The equipment must be reliable enough to safe guard the environment, and make the exploitation of the subsea hydrocarbons economically feasible. The deployment of such equipment requires specialized and expensive vessels, which need to be equipped with diving equipment for relatively shallow equipment work (i.e. a few hundred feet water depth maximum), and robotic equipment for deeper water depths. Any requirement to repair or intervene with installed subsea equipment is thus normally very expensive. This type of expense can result in economic failure of the subsea development.

Subsea technology in offshore oil and gas production is a highly specialized field of application with particular demands on engineering and simulation. Most of the new oil fields are located in deepwater and are generally referred to as deepwater systems. Development of these fields sets strict requirements for verification of the various systems' functions and their compliance with current requirements and specifications. This is because of the high costs and time involved in changing a pre-existing system due to the specialized vessels with advanced onboard equipment. A full scale test (System Integration Test – SIT) does not provide satisfactory verification of deepwater systems because the test, for practical reasons, cannot be performed under conditions identical to those under which the system will later operate. The oil industry has therefore adopted modern data technology as a tool for virtual testing of deepwater systems that enables detection of costly faults at an early phase of the project. By using modern simulation tools models of deepwater systems can be set up and used to verify the system's functions, and dynamic properties, against various requirements specifications. This includes the model-based development of innovative high-tech plants and system solutions for the exploitation and production of energy resources in an environmentally friendly way as well as the analysis and evaluation of the dynamic behavior of components and systems used for the production and distribution of oil and gas. Another part is the real-time virtual test of systems for subsea production, subsea drilling, supply above sea level, seismography, subsea construction equipment and subsea process measurement and control equipment.

Offshore wind power

The power transmission infrastructure for offshore wind power utilizes a variety of subsea technologies for the installation and maintenance of submarine power transmission cables and other electrical energy equipment. In addition, the monopile foundations of fixed-bottom wind turbines and the anchoring and cable structures of floating wind turbines are regularly inspected with a variety of shipborne subsea technology.

Underwater mining

Recent technological advancements have given rise to the use of remotely operated vehicles (ROVs) to collect mineral samples from prospective mine sites. Using drills and other cutting tools, the ROVs obtain samples to be analyzed for desired minerals. Once a site has been located, a mining ship or station is set up to mine the area.

Remotely operated vehicles

Remotely operated vehicles require high intensity lighting.

Remotely Operated Vehicles (ROVs) are robotic pieces of equipment operated from afar to perform tasks on the sea floor. ROVs are available in a wide variety of function capabilities and complexities from simple "eyeball" camera devices, to multi-appendage machines that require multiple operators to operate or "fly" the equipment.

Organizations

A number of professional societies and trade bodies are involved with the subsea industry around the world. Such groups include

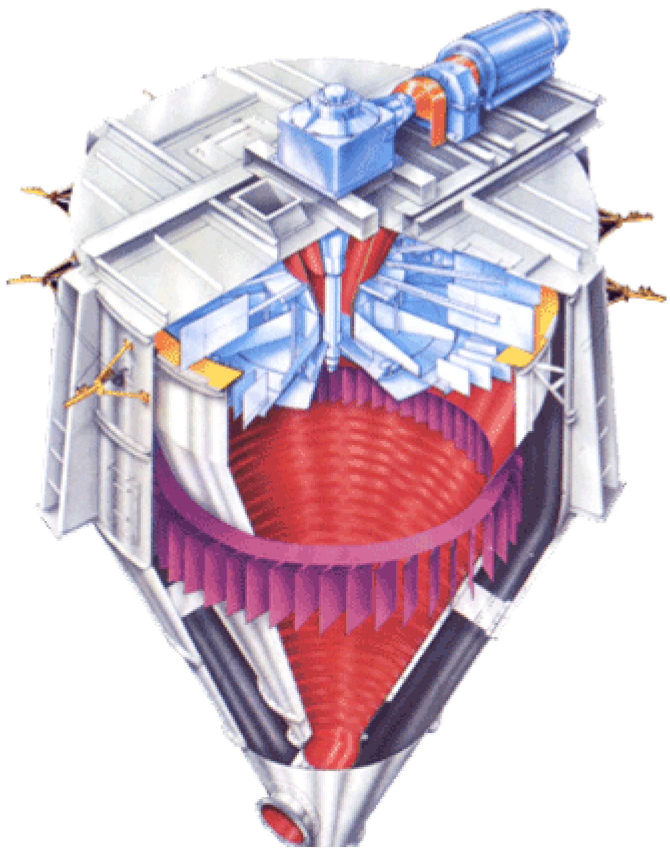
- Society for Underwater Technology
- Subsea Project Awards
- Subsea UK
- Subsea Valley The largest subsea technology business cluster.
- Society of Petroleum Engineers
- American Petroleum Institute (API)
- American Society of Mechanical Engineers (ASME)
- National Association of Corrosion Engineers (NACE).

Government agencies administer regulations in their territorial waters around the world. Examples of such government agencies are the Minerals Management Service (MMS, US), Norwegian Petroleum Directorate (NPD, Norway), and Health & Safety Executive (HSE, UK). The MMS administers the mineral resources in the US (using Code of Federal Regulations (CFR)) and provides management of all the US subsea mineral and renewable energy resources.

Chapter- 10

Other Mining Technologies

Air classifier



Air Classifier

An **air classifier** is an industrial machine which sorts materials by a combination of size, shape, and density. It works by injecting the material stream to be sorted into a chamber which contains a column of rising air. Inside the separation chamber, air drag on the objects supplies an upward force which counteracts the force of gravity and lifts the material to be sorted up into the air. Due to the dependence of air drag on object size and shape, the objects in the moving air column are sorted vertically and can be separated in this manner.

Air classifiers are commonly employed in industrial processes where a large volume of mixed materials with differing physical characteristics need to be sorted quickly and efficiently. One such example is in recycling centers, where various types of metal, paper, and plastics arrive mixed together and need to be sorted before further processing can take place.

Selected patents

- US patent 1629594, Stebbins, Albert H., "Air Classifier", issued 1927-05-24
- US patent 3734287, Jager, Heinz, "Air Classifier Assembly", issued 1973-05-22, assigned to WEDAG Westfalia Dinnendahl Groppel Aktiengesellschaft
- US patent 4869786, Hanke, Ernst W., "Air Classifying Process and Air Classifier", issued 1989-09-26, assigned to Pfeiffer, Christian

Winding engine

Steam engine in mine "Królowa Luiza"

A **winding engine** is a stationary engine used to control a cable, for example to power a mining hoist at a pit head. Electric hoist controllers have replaced proper winding engines in modern mining, but use electric motors that are also traditionally referred to as *winding engines*.

Most proper winding engines have been stationary steam engines. They differ from most other stationary steam engines in that, like a steam locomotive, they need to be able to stop frequently and also reverse. This requires more complex valve gear and other controls than are needed on engines used in mills or to drive pumps.

Wheel tractor-scraper

A twin engined Terex TS-14b scraper in Hudson, Ohio.

In civil engineering, a **wheel tractor-scraper** is a piece of heavy equipment used for earthmoving.

The rear part has a vertically moveable hopper (also known as the bowl) with a sharp horizontal front edge. The hopper can be hydraulically lowered and raised. When the hopper is lowered, the front edge cuts into the soil or clay like a plane or cheese slicer and fills the hopper. When the hopper is full (8 to 34 m^3 or 10 to 44 cu yd) heaped, depending on type) it is raised, and closed with a vertical blade (known as the apron). The scraper can transport its load to the fill area where the blade is raised, the back panel of the hopper, or the ejector, is hydraulically pushed forward and the load tumbles out. Then the empty scraper returns to the cut site and repeats the cycle.

Elevating scraper by Caterpillar

On the *elevating scraper* the hopper is filled by a type of conveyor belt with cutting edges.

Scrapers can be very efficient on short hauls where the cut and fill areas are close together and have sufficient length to fill the hopper. The heavier scraper types have two engines ('tandem powered'), one driving the front wheels, one driving the rear wheels, with engines up to 400 kW (536 hp). Two scrapers can work together in a push-pull fashion but this requires a long cut area.

A Caterpillar towed scraper parked up

Self propelled scrapers were invented by R. G. LeTourneau in the 1930s. His company called them Tournahoppers.

Wellhead

A **wellhead** is a general term used to describe the component at the surface of an oil or gas well that provides the structural and pressure-containing interface for the drilling and production equipment.

Wellhead gas storage, Etzel Germany

The primary purpose of a wellhead is to provide the suspension point and pressure seals for the casing strings that run from the bottom of the hole sections to the surface pressure control equipment.

While drilling the oil well, surface pressure control is provided by a blowout preventer (BOP). If the pressure is not contained during drilling operations by the column of drilling fluid, casings, wellhead, and BOP, a well blowout could occur.

Once the well has been drilled, it is *completed* to provide an interface with the reservoir rock and a tubular conduit for the well fluids. The surface pressure control is provided by a christmas tree, which is installed on top of the wellhead, with isolation valves and choke equipment to control the flow of well fluids during production.

Wellheads are typically welded onto the first string of casing, which has been cemented in place during drilling operations, to form an integral structure of the well. In exploration wells that are later abandoned, the wellhead may be recovered for refurbishment and re-use.

Offshore, where a wellhead is located on the production platform it is called a *surface wellhead*, and if located beneath the water then it is referred to as a subsea wellhead or mudline wellhead.

Functions

A wellhead serves numerous functions, some of which are:

1. Provide a means of casing suspension. (Casing is the permanently installed pipe used to line the well hole for pressure containment and collapse prevention during the drilling phase).
2. Provides a means of tubing suspension. (Tubing is removable pipe installed in the well through which well fluids pass).
3. Provides a means of pressure sealing and isolation between casing at surface when many casing strings are used.
4. Provides pressure monitoring and pumping access to annuli between the different casing/tubing strings.
5. Provides a means of attaching a blowout preventer during drilling.
6. Provides a means of attaching a christmas tree for production operations.
7. Provides a reliable means of well access.
8. Provides a means of attaching a well pump.

Components

The primary components of a wellhead system are:

- casing head
- casing spools
- casing hangers
- packoffs (isolation) seals
- bowl protectors / wear bushings
- test plugs
- mudline suspension systems
- tubing heads
- tubing hangers
- tubing head adapters

Design specification

The oil industry specifications for wellhead systems (materials, dimensions, test procedures and pressure ratings etc.) are :

1. API 6A Specification for Wellhead and Christmas Tree Equipment
2. ISO 10423 Wellhead and Christmas Tree Equipment

Trommel

An operating trommel processing mixed waste

Example: Komptech mobile trommel MAGNUM

Portable trommel screening topsoil

A **trommel** (from the German word for drum, "Trommel") is a screened cylinder used to separate materials by size - for example, separating the biodegradable fraction of mixed municipal waste or separating different sizes of crushed stone.

Portable trommels (also called portable trommel screens) are often used in the production of organic products from various types of waste.

For example, excavation contractors may screen their site debris into two fractions; a saleable topsoil for farms, nurseries and site-work, as well as cleaned rock for aggregates or landscaping work. This allows the contractor to resell their waste, instead of incurring the cost of sending it for disposal.

The same principle applies to the production of compost, sand/gravel, lumber mill by-products and municipal waste.

Safety lamp

Modern flame safety lamp used in mines, manufactured by Koehler

A **safety lamp** is any of several types of lamp, which are designed to be safe to use in coal mines. These lamps are designed to operate in air that may contain coal dust, methane, or firedamp, all of which are potentially flammable or explosive. The use of open lamps, rather than the safety lamps that were then available, was one cause of the Naomi Mine explosion and the Darr Mine Disaster in Pennsylvania in December 1907.

First safety lamps

The first safety lamp was invented by William Reid Clanny, an Irish physician, who announced his discovery on May 20, 1813 at the Royal Society of Arts in London, but it was not tried out in a colliery until 1815. Within months of this demonstration, two improved designs had been announced: one by George Stephenson, which later became the Geordie lamp, and the Davy lamp, invented by Sir Humphry Davy. Most later lamps are constructed on the principle discovered by Davy, that a flame enveloped in wire gauze of a certain fineness does not ignite firedamp.

Both the Davy and Stephenson lamps were fragile. The gauze in the Davy quickly rusted in the moist air of a coal pit, and so became unsafe, while the glass in the Stephenson was easily broken, and could then allow the flame to ignite firedamp in the atmosphere. Later designs, the Gray, Mueseler, Marsaut, and other lamps, tried to overcome these problems by using multiple gauze cylinders, but the glass remained a problem until toughened glass became available.

Also, the light that all these gave was poor and this was not solved until the introduction of electric lighting in mines around 1900. But it took until 1930 for the introduction of battery-powered helmet lamps to finally solve the problem.

Early illumination

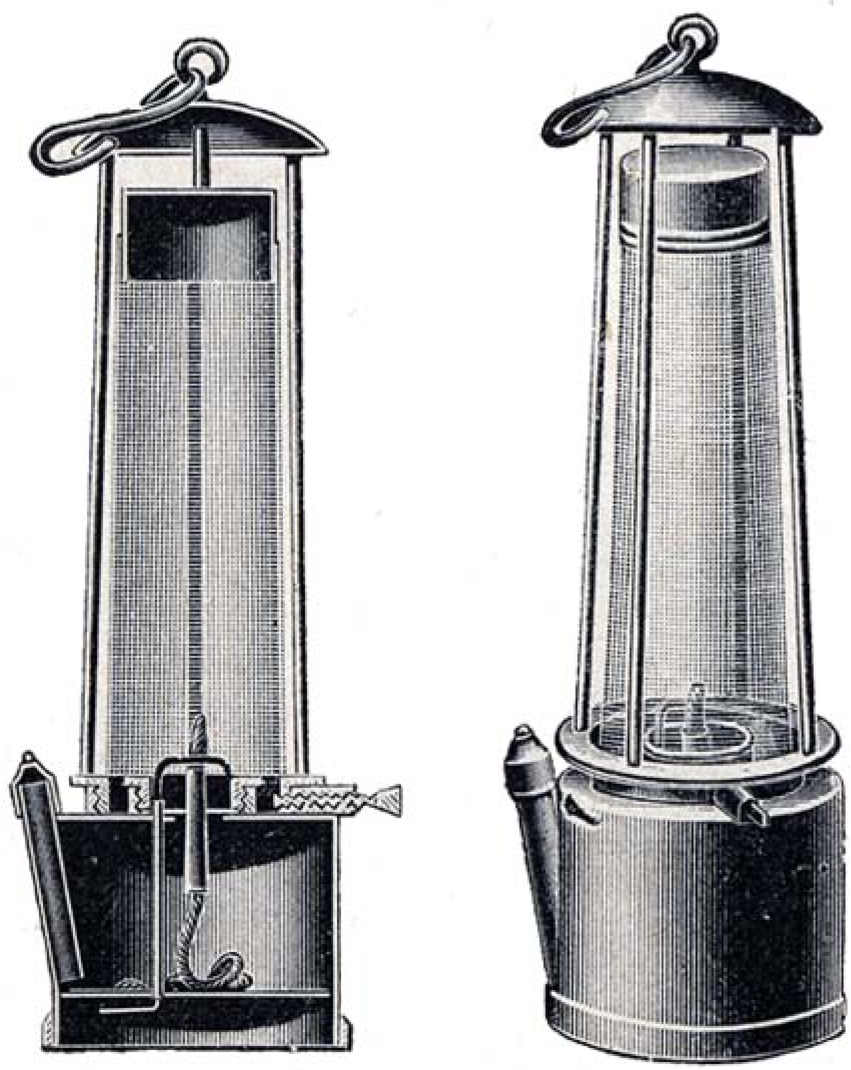


Fig. 192. Davysche Sicherheitslampe

A Davy lamp, an early example of a safety lamp

Prior to the invention of these safety lamps, miners used candles with open flames or phosphorescent sources of light and later flint or steel mills designed by 'Spedding.' Later, barometers were used to tell them if atmospheric pressure was low (in which case more methane seeped out of the coal seams into the mine galleries).

The use of small mammals or birds was used much later at the end of the Victorian age to warn of the presence of the deadly carbon monoxide present after underground fires or explosions, the so-called afterdamp. The method was introduced by the noted physiologist and disaster investigator, John Scott Haldane after the Laxey lead mine disaster. Such animals are much more susceptible to the gas, and will die before a human, so giving an early warning of the problem. There were numerous deaths caused by carbon monoxide from a small fire near one of the shaft bottoms. An alternative method of removing a different gas, known as firedamp (methane) involved igniting the gas deliberately to cause explosions, thus evacuating the mines of the majority of explosive or easily flammable material present.

The lack of good lighting was a prime cause of a painful eye affliction (nystagmus).

Modern lamps

Nowadays, safety lamps are mainly electric, and traditionally mounted on miners' helmets (such as the wheat lamp) or the Oldham headlamp, sealed to prevent gas penetrating the casing and being ignited by electrical sparks.

Although its use as a light source was superseded by electric lighting, the flame safety lamp has continued to be used in mines to detect methane and blackdamp, although many modern mines now also use sophisticated electronic gas detectors for this purpose.

As a new light source, LED has many advantages for safety lamps, including longer burn time and less energy required. Combined with new battery technologies, such as the lithium battery, it gives much better performance in safety lamp applications. It is replacing conventional safety lamps.

Movement and Surveying Radar

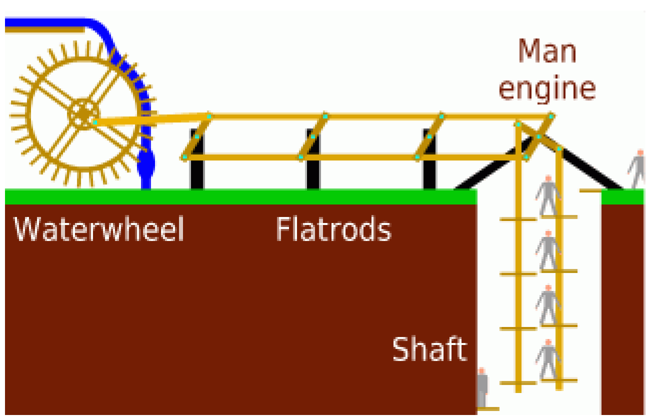
In open pit mining operations, people and equipment are constantly at the base of a steep, man-made slope (the highwall or pit-wall). Instances where this slope fails resulting in a rock or earthfall can result in loss of life, injuries and damage or destruction of equipment. It has been found that, over the last few hours preceding a slope failure, there is nearly always a small movement, or alteration in the movement pattern in the rock face of that section.

The system is intended to monitor mine slopes to detect this movement and generate a warning of impending failure (slope stability), so that personnel and equipment may be removed prior to the failure. The radar element provides very accurate, real-time, all weather slope movement measurements with sub millimetre detection ability, and is able to provide an alarm if the detected movement reaches a predetermined level, thereby permitting evacuation of the unstable area, and enhancing safety.

All radar measurements are fully geo-referenced to an accuracy that allows easy integration with standard digital terrain mapping (DTM) tools.

A second function of the Movement and Surveying Radar is to determine the absolute range to the electromagnetic reflective centroid of an area on a body of material or geographical feature. This functionality, combined with the accurately surveyed position of the measurement origin of the Movement and Surveying Radar and the positioning system's angular measurement information, may be used to generate survey data of geographical features such as mine walls and rubble dumps. The survey data collected may be used for applications such as the calculation of material removal volumes.

A Movement and Surveying Radar combines simultaneously the execution of slope stability and surveying measurements, which together with high-speed external data links makes it a near real-time tool for mining safety, planning and productivity improvement.



The operation of a double-acting man engine

A **man engine** is a mechanism of reciprocating ladders and stationary platforms installed in mines to assist the miners' journeys to and from the working levels. It was invented in Germany in the 19th century and was a prominent feature of tin and copper mines in Cornwall until the beginning of the twentieth.

Operation

An underground section of the man engine at the Dolcoath Mine, Cornwall

In the Cornish examples the motive power was provided by waterwheels, or one of the mine's beam engines. Originally operating without a flywheel, this offered a reciprocating motion of, typically, twelve to fifteen feet (three to five metres). The engine would be linked to a series of beams – known as "rods" – fastened together and reaching to the bottom of the mineshaft. Small platforms would be attached to the rods at the same distance apart as the engine stroke. Fixed platforms were built onto the shaft walls, spaced to coincide with the top and bottom positions of each of the moving platforms. In a common variation a pair of rods was used, with one on its upstroke as the other descended. The miner hopped from one to the other, rather than waiting at a fixed rest, as they changed direction. Counterweights – large boxes filled with stones attached through "see-sawing" horizontal beams – were installed in order to avoid the full weight of the shaft and men bearing on the engine beam. In the deepest mines, which could sink to more than 350 fathoms (640 metres), extra counterweights were provided in side-shafts at regular intervals.

To go up or down, the miner would step onto the travelling platform and allow himself to be carried to the next fixed platform, where he would step off and wait. At the end of the next stroke the next moving platform would line up and he could step onto it and repeat the process. Although the footholds were often small, grab handles were fitted above each one. Miners may ascend and descend at the same time: the pause at the changeover point is made long enough for two men to change places.

Safety

Twin-rod engine installed at the Kongens Gruve, Kongsberg, Norway

The miners took to these devices without hesitation as their pay was not calculated until they had reached their underground workplace. Contemporary safety studies concluded that, although intrinsically dangerous, the use of a man engine was in practice safer than climbing long ladders: it was less risky to be carried up at the end of a hard shift than to climb a ladder and risk falling because of exhaustion. In some mines, particularly in Germany, wedges or collars placed just above close-fitting rollers, or chains, were installed to limit any drop should a breakage occur.

Levant mine accident

In the afternoon of 20 October 1919 an accident occurred on the man engine at the Levant Mine, St Just, Cornwall. More than 100 miners were on the engine being drawn to the surface when a metal bracket at the top of the rod broke. The heavy timbers crashed down the shaft, carrying the side platforms with them, and thirty-one men lost their lives. The man engine was not replaced and the lowest levels of the mine were abandoned.

History

The earliest known examples of this device were from the first half of the nineteenth century in the silver mining area of the Harz mountains, Germany, where they were driven by cranks connected to water wheels, although bucket hoists using the same method of operation had been used in Swedish iron mines since the 17th century. They appear to have evolved from an informal modification to the beam pumps, where the miners used spikes stuck into the wooden pump rods to get themselves carried up the shaft. As beam pumps were universal in deep mines, it was a then simple development to make proper platforms to carry the miners. The first formal engine was installed in 1833 at a mine at Clausthal, Lower Saxony, where inspector Wilhelm Albert and manager Georg Dörell (1793–1854) fastened foot platforms and hand-holds to adjacent, reciprocating pump rods, using a waterwheel-driven pump put out of use when a new drainage adit was made at a lower level. The 1837 man engine at the Samson Pit in Sankt Andreasberg in the same region is still in use, although converted from water to electric power in 1922.

The device was introduced to Cornwall in 1842, following the award of a premium for the best design, by the Royal Cornwall Polytechnic Society. The winner, Michael Loam, built one for the proprietors of the Tresavean Mine, in Lanner near Redruth. He used a double-rod design, driven by a waterwheel. The miners' journey time (in either direction) was reduced from about an hour to twenty-four minutes and output per shift increased by one fifth. More than a dozen examples were installed in Cornish mines by the end of the century, but these were usually of the single-rod type, which was perceived as safer in use.

When cable operated winding gear became available the man engines continued in use, particularly in cases where the mineshaft was not truly vertical and winding engines drawing suspended cages could not be used: with the provision of a few well-place rollers, and “fend offs” mounted on trunnions, the rods could reach the bottom of a shaft even at a substantial deviation from the vertical. Economics also played a part: the rods needed for pumping could be used for this extra function at little increased cost. Even when skips or “kibbles” were used in such shafts, (running on “skipways”) the tipping motion would make them impractical for carrying men.