



# Advanced Construction Vehicles

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First Edition, 2012

ISBN 978-81-323-2703-5

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*Published by:*

**Orange Apple**

4735/22 Prakashdeep Bldg,

Ansari Road, Darya Ganj,

Delhi - 110002

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## Chapter- 1

# Aerial Work Platform



A tracked AWP at a building site

An **aerial device** or **elevating work platform** is a mechanical device used to provide temporary access for people or equipment to inaccessible areas, usually at height. These two distinct types of mechanized access platforms may also be known as a "cherry picker" or a "scissor lift".

They are generally used for temporary, flexible access purposes such as maintenance and construction work or by firefighters for emergency access, which distinguishes them from permanent access equipment such as elevators. They are designed to lift limited weights (usually less than a ton, although some have a higher safe working load (SWL)),

distinguishing them from most types of cranes. They are usually capable of being fully operated (including setup) by a single person.

Regardless of the task they are used for, aerial work platforms may provide additional features beyond transport and access, including being equipped with electrical outlets or compressed air connectors for power tools. They may also be equipped with specialist equipment, such as carrying frames for window glass.

## Lifting mechanisms

There are several distinct types of aerial work platforms, which all have specific features which make them more or less desirable for different applications. The key difference is in the drive mechanism which propels the working platform to the desired location. Most are powered by either hydraulics or possibly pneumatics. The different techniques also reflect in the pricing and availability of each type.



Articulated lift being demonstrated

## Aerial Device

**Aerial devices** were once exclusively operated by hydraulic pistons, powered by diesel or gasoline motors on the base unit. Lightweight electrically-powered units are gaining popularity for window-cleaning or other maintenance operations, especially indoors and in isolated courtyards, where heavier hydraulic equipment cannot be used. Aerial devices are the closest in appearance to a crane- consisting of a number of jointed sections, which can be controlled to extend the lift in a number of different directions, which can often include 'up and over' applications.



'Spider' set up outside a building.

This type of AWP is the most likely of the types to be known as a 'cherry picker', owing to its origins, where it was designed for use in orchards (though not just cherry orchards). It lets the picker standing in the transport basket pick fruit high in a tree with relative ease (with the jointed design ensuring minimum damage to the tree). The term 'cherry picker' has become generic, and is commonly used to describe articulated lifts (and more rarely all AWPs).

This type of AWP is now widely used for maintenance and construction of all types, including extensively in the power and telecommunications industries to service overhead lines, and in arboriculture to provide an independent work platform on difficult or dangerous trees. A specialist type of the articulated lift is the type of fire apparatus used by firefighters worldwide as a vehicle to provide high level or difficult access. These types of platforms often have additional features such as a piped water supply and water cannon to aid firefighters in their task.

Some articulated lifts are limited to only the distance accessible by the length of each boom arm, however, by the use of telescoping sections, the range can be vastly increased. Some large hydraulic platforms mounted on a lorry can reach heights of over 100 metres.

The majority of articulated lifts require a wide supportive base to operate safely, and most models have extending legs/struts to help accomplish this. These legs can be manual or hydraulic (usually depending on size and price of the machine). Some AWPS are classified as 'spiders' due to the appearance of these legs. Spiders are also available in especially compact form, to fit through doorways for use inside buildings.



Large scissor lift extended

## Scissor Lift

A **scissor lift** is a type of platform which can usually only move vertically. The mechanism to achieve this is the use of linked, folding supports in a criss-cross 'X' pattern, known as a pantograph. The upward motion is achieved by the application of

pressure to the outside of the lowest set of supports, elongating the crossing pattern, and propelling the work platform vertically. The Platform may also have an extending 'bridge' to allow closer access to the work area (because of the inherent limits of vertical only movement).

The contraction of the scissor action can be hydraulic, pneumatic or mechanical (via a leadscrew or rack and pinion system). Depending on the power system employed on the lift, it may require no power to enter 'descent' mode, but rather a simple release of hydraulic or pneumatic pressure. This is the main reason that these methods of powering the lifts are preferred, as it allows a fail-safe option of returning the platform to the ground by release of a manual valve. Scissor Lift Manufacturers include Genie Industries, JLG industries, Skyjack, and Haulette. Scissor Lifts have been around for many years, one of the first companies to influence the scissor lift rental industry is ABC Rentals headquartered in Boynton Beach, Florida with several locations in Florida, Including Miami, West Palm Beach, Pompano Beach, Vero Beach, and Ft. Myers.

### **"Hotel Lift"**

There are a number of smaller lifts which use mechanical devices such as rack and pinion or screw threads to extend. These often have juxtaposed sections which move past each other in order to create the movement, usually in a vertical direction only. This lifts usually have limited capability in terms of weight and extension, and are most often used for internal maintenance tasks such as changing lightbulbs.

## **Motive mechanisms**

AWPs, by their nature, are designed for temporary works and therefore frequently require transportation between sites, or simply around a single site (often as part of the same job). For this reason, they are almost all designed for easy movement.

### **Unpowered**

These usually smaller units have no motive drive and require external force to move them. Dependent on size and whether they are wheeled or otherwise supported, this may be possible by hand, or may require a vehicle for towing or transport. Small non-powered AWP's can be light enough to be transported in a pickup truck bed, and can usually be moved through a standard doorway.

### **Self propelled**

These units are able to drive themselves (on wheels or tracks) around a site (they usually require to be transported to a site, for reasons of safety and economy). In some instances, these units will be able to move whilst the job is in progress, although this is not possible on units which require secure outriggers, and therefore most common on the scissor lift types. The power can be almost any form of standard mechanical drive system, including

electric or gasoline powered, or in some cases, a hybrid (especially where it may be used both inside and outside).



Telescoping articulated platform mounted on firefighting appliance. These provide more flexibility than ladder engines.

### **Vehicle mounted**

Some units are mounted on a vehicle, usually a truck or it can be mounted on a flat back pick up van known as a **Self Drive**), though other vehicles are possible, such as railway cars. This vehicle provides mobility, and may also help stabilize the unit - though outrigger stabilizers are still typical, especially as vehicle-mounted AWP's are amongst the largest of their kind. The vehicle may also increase functionality by serving as mobile workshop or store.

### **Control**

The power assisted drive (if fitted) and lift functions of an AWP are controlled by an operator, who can be situated either on the work platform itself, or at a control panel at the base of the unit. Some models are fitted with a panel at both locations or with a remote control, giving operator a choice of position. A control panel at the base can also

function as a safety feature if for any reason the operator is at height and becomes unable to operate his controls. Even models not fitted with a control panel at the base are usually fitted with an emergency switch of some sort, which allows manual lowering of the lift (usually by the release of hydraulic or pneumatic pressure) in the event of an emergency or power failure.

Controls vary by model, but are frequently either buttons or a joystick. The type and complexity of these will depend on the functions the platform is able to perform. The controls can control features such as:

- Vertical movement
- Lateral movement
- Rotational movement (cardinal direction)
- Platform / basket movement – Normally, the system automatically levels the platform regardless of boom position, but some allow overrides, tilting up to 90 degrees for work in difficult locations.
- Ground movement (in self propelled models)

## Safety



Aerial work platforms in use

The majority of manufacturers and operators have strict safety criteria for the operation of AWP. In some countries, a licence and/or insurance is required to operate some types of AWP. Most protocols advocate training every operator, whether mandated or not. Most operators also prescribe a range of pre-usage checks on the unit itself, and manufacturers recommend regular maintenance schedules.

Work platforms are fitted with safety or guard rails around the platform itself to contain operators and passengers. This is supplemented in most models by a restraining point, designed to secure a harness or fall arrestor. Some work platforms also have a lip around the floor of the platform itself to avoid tools or supplies being accidentally kicked off the platform. Some protocols require all equipment to be attached to the structure by its own lanyard.

Extreme caution must be taken when using AWP in the vicinity of overhead power lines as electrocution may result if the lift comes in contact with energized wiring. Non-conductive materials, such as fiberglass, may be used to reduce this hazard.

AWPs often come equipped with a variety of tilt sensors. The most commonly activated sensor (especially with two people on a lift), will cause the machine to refuse to raise the platform beyond a certain height. Sensors within the machine detect that weight on the platform is off balance to such a point as to risk a possible tip-over if the platform is raised further. Another sensor will refuse to extend the platform if the machine is on a significant incline. Some models of AWP additionally feature counterweights, which extend in order to offset the danger of tipping the machine inherent in extending items like booms or bridges. Some lifts are also fitted with sensors which will prevent operation if the weight on the platform exceeds the safe working load.

As with most dangerous mechanical devices, all AWP are fitted with an emergency stop button or buttons for use in the event of a malfunction or danger. Best practice dictates fitting of emergency stop buttons on the platform and at the base as a minimum. Other safety features include automatic self checking of the AWP working parts, including a voltmeter, which detects if the lift has insufficient power to complete its tasks (which will result in it refusing to operate for safety). Some AWP provide manual lowering levers at the base of the machine, allowing operators to lower the platform to the ground in the event of a power or control failure or deliberate use of the machine (e.g. by unauthorized persons).

## **Business model**

AWP are often bought by equipment rental companies, who then rent them out to construction companies or individuals needing these specialised machines. The market for these machines is known to be marked by especially strong boom and bust cycles, and after a great demand in the 1990s (with up to 70,000 AWP sold per year in the US) the market crashed in the early 2000s, leading to a strong contraction amongst the manufacturers.

## Chapter- 2

# Dump Truck

A **dump truck** (or, UK, dumper truck) is a truck used for transporting loose material (such as sand, gravel, or dirt) for construction. A typical dump truck is equipped with a hydraulically operated open-box bed hinged at the rear, the front of which can be lifted up to allow the contents to be deposited on the ground behind the truck at the site of delivery. In the UK and Australia the term applies to off-road construction plant only, and the road vehicle is known as a **tipper**, **tipper lorry** (UK) or **tip truck** (AU).



A Kenworth K-100 dump truck



Isuzu NPR 300 *Tipper*

## Types of dump trucks



An Ashok Leyland Comet dump truck, this is a good example of a very basic 2 x 4 dump truck used for payloads of 10 tonnes or less

The dump truck was first conceived in Saint John, New Brunswick when Robert T. Mawhinney attached a dump box to a flat bed truck in 1920. The lifting device was a winch attached to a cable that fed over sheave (pulley) mounted on a mast behind the cab. The cable was connected to the lower front end of the wooden dump box which was attached by a pivot at the back of the truck frame. The operator turned a crank to raise and lower the box. Today, virtually all dump trucks operate by hydraulics and they come in a variety of configurations each designed to accomplish a specific task in the construction material supply chain.

## Standard dump truck



Another kind of 8x4 dump truck: three rear axles (two powered, one lift).

A *standard dump truck* is a truck chassis with a dump body mounted to the frame. The bed is raised by a hydraulic ram mounted under the front of the dumper body between the frames, and the back of the bed is hinged at the back to the truck. The tailgate can be configured to swing on hinges or it can be configured in the "High Lift Tailgate" format wherein pneumatic rams lift the gate open and up above the dump body.

In the United States, a standard dump truck has one front axle, and one or more rear axles which typically have dual wheels on each side. Rear axles are either powered or unpowered. Most unpowered rear axles can be raised off the pavement, to minimize wear and tear when the truck is unloaded or lightly loaded, and lowered to become load-bearing when the truck needs the extra support. These are referred to as lift axles or drop axles. Lift axles can be steerable or non-steerable; steerable lift axles are always configured with single wheels on each side, instead of dual wheels. Lift axles positioned in front of the powered axles are called *pushers*; lift axles positioned behind the powered axles are called *tags*. A *trailing tag* is a special type of tag mounted on an arm that extends 12' to 15' behind the truck frame to extend the overall *outer bridge* length of the vehicle.

Common configurations for a standard dump truck include the *six wheeler* which has one powered rear axle, the *ten wheeler* with two powered rear axles, the *tri-axle* with one lift

axle and two powered axles, and the *quad* with two lift axles and two powered axles.. The largest of the standard dump trucks is commonly called a "centipede" and has seven axles. The rear two axles are powered, the front axle is the steering axle, and the remaining four are lift axles. The intermediate axles are present to support the weigh over the length of the chassis and sometimes to provide additional braking power. In the European Union, the dump truck configurations are 2, 3 and 4 axles. The 4 axle *eight wheeler* has 2 axles at the front and 2 at the rear and is limited to 32 tonnes gross weight in most EU countries.

The short wheelbase of a standard dump truck makes it more maneuverable than the higher capacity semi-trailer dump trucks.

### **Articulated dump truck**



Articulated dump truck or dumper

An *articulated dump truck*, or "Yuke" in the construction world, has a hinge between the cab and the dump box, but is distinct from semi trailer trucks in that the cab is a permanent fixture, not a separable vehicle. Steering is accomplished via hydraulic rams that pivot the entire cab, rather than rack and pinion steering on the front axle. This vehicle is highly adaptable to rough terrain. In line with its use in rough terrain, longer distances and overly flat surfaces tend to cause driveline troubles, and failures. Articulated trucks are often referred to as the modern scraper, in the sense that they carry a much higher maintenance burden than most trucks.

## Transfer dump truck



Example of a transfer truck and trailer

A *transfer dump* is a standard dump truck which pulls a separate trailer which can also be loaded with aggregate (gravel, sand, asphalt, klinkers, snow, wood chips, triple mix, etc.)

The second aggregate container, (B box) on the trailer, is powered by either an electric, pneumatic motor or hydraulic line,. It rolls on small wheels, riding on rails from the trailer's frame, into the empty main dump (A) box. This maximizes payload capacity without sacrificing the maneuverability of the standard dump truck. Transfer dumps are typically seen in the western United States because of the peculiar weight restrictions on western highways.

Another configuration seen is called a Triple Transfer Train, which consists of a B and C box. These are common on Nevada and Utah Highways but not in California. Depending on the axle arrangement, a Triple Transfer can haul up to 129,000 kilograms with a special permit in certain US states. The Triple Transfer usually costs a contractor about \$105 an hour while a A/B config usually runs about \$85 per hour (2007 stats).

Transfer dump trucks typically haul between 26 and 27 tons of aggregate per load, each truck is capable of 3-5 loads per day, generally speaking.

## Truck and pup



Tandem dump truck

A *truck and pup* is very similar to a transfer dump. It consists of a standard dump truck pulling a dump trailer. The pup trailer, unlike the transfer, has its own hydraulic ram and is capable of self-unloading.

## Superdump truck



Example of a Superdump body and trailing axle

A *Superdump* is a straight dump truck equipped with a trailing axle, a liftable, load-bearing axle rated as high as 13,000 pounds. Trailing 11 to 13 feet (4.0 m) behind the rear tandem, the trailing axle stretches the outer "bridge" measurement—the distance between the first and last axles—to the maximum overall length allowed. This increases the gross weight allowed under the federal bridge formula, which sets standards for truck size and weight. Depending on the vehicle length and axle configuration, Superdumps can be rated as high as 80,000 pounds GVW and carry 26 tons of payload or more. When the truck is empty or ready to offload, the trailing axle toggles up off the road surface on two hydraulic arms to clear the rear of the vehicle. Truck owners call their trailing axle-equipped trucks Superdumps because they far exceed the payload, productivity, and return on investment of a conventional dump truck. The Superdump and trailing axle concept was developed by Strong Industries of Houston, Texas.

### **Semi trailer end dump truck**

A *semi end dump* is a tractor-trailer combination wherein the trailer itself contains the hydraulic hoist. A typical semi end dump has a 3-axle tractor pulling a 2-axle semi-trailer. The key advantage of a semi end dump is rapid unloading. A key disadvantage is that they are very unstable when raised in the dumping position limiting their use in many applications where the dumping location is uneven or off level.

### **Semi trailer bottom dump truck**



Bottom dump trailer

A semi bottom dump (or "belly dump") is a 3-axle tractor pulling a 2-axle trailer with a clam shell type dump gate in the belly of the trailer. The key advantage of a semi bottom dump is its ability to lay material in a wind row (a linear heap). In addition, a semi bottom dump is maneuverable in reverse, unlike the double and triple trailer configurations described below. These trailers may be found either of the windrow type shown in the photo, or may be of the 'cross spread' type with the gates opening front to rear instead of left and right. The cross spread gates will actually spread gravel fairly

evenly the width of the trailer. by comparison, the windrow gates leave a pile in the middle. The cross spreads jam and do not work well with larger materials. Likewise they are not suitable for use where spreading is not desired such as when hot asphalt paving material is being dumped into a paving machine.

### **Double and triple trailer bottom dump truck**

*Double and triple bottom dumps* consist of a 2-axle tractor pulling one single-axle semi-trailer and an additional full trailer (or two full trailers in the case of triples). These dump trucks allow the driver to lay material in windrows without leaving the cab or stopping the truck. The main disadvantage is the difficulty in backing double and triple units.

The specific type of dump truck used in any specific country is likely to be closely keyed to the weight and axle limitations of that jurisdiction. Rock, dirt and other types of materials commonly hauled in trucks of this type are quite heavy, and almost any style of truck can be easily overloaded. Because of that, this type of truck is frequently configured to take advantage of local weight limitations to maximize the cargo. For example, within the United States, the maximum weight limit of 40 tons throughout the country, except for specific bridges with lower limits. Individual states, in some instances, are allowed to authorize trucks up to 52.5 tons. Most states that do so require that the trucks be very long, to spread the weight over more distance. It is in this context that double and triple bottoms are found within the US.

### **Side dump truck**



Side Dump Industries Train Set

A *side dump truck* (S.D.T) consists of a 3-axle tractor pulling a 2-axle semi-trailer. It has hydraulic rams which tilt the dump body onto its side, spilling the material to either the left or right side of the trailer. The key advantages of the side dump are that it allows rapid unloading and can carry more weight in western United States. In addition, it is almost immune to upset (tipping over) while dumping unlike the semi end dumps which are very prone to tipping over. It is, however, highly likely that a side dump trailer will tip over if dumping is stopped prematurely. Also, when dumping loose materials or cobble sized stone, the side dump can become stuck if the pile becomes wide enough to cover too much of the trailer's wheels. Trailers that dump at the appropriate angle (50° for example) avoid the problem of the dumped load fouling the path of the trailer wheels by dumping their loads further to the side of the truck, in some cases leaving sufficient clearance to walk between the dumped load and the trailer.

### **Off-road dump truck**



Liebherr T 282B haul truck



Hitachi haul truck



Logan Lake Mining Dump Truck

Off-road dump trucks more closely resemble heavy construction equipment or engineering vehicles than they do highway dump trucks. Off-road dump trucks are used strictly off-road for mining and heavy dirt hauling jobs. There are two primary forms: rigid frame and articulating frame.

The term 'dump' truck is not generally used by the mining industry, or by the manufacturers that build these machines. The more appropriate U.S. term for this strictly off road vehicle is "haul truck" and the equivalent European term is 'dumper'. The classifications bottom and side for example, describes how loaded material is discharged from the dump body. In the case of the haul truck illustrated, a Liebherr T 282B, the load is discharged to the rear, designating this particular vehicle as an end dump.

Bottom dump normally describes a trailer that discharges its load by opening two clam shell doors under the load space. In some instances, one tractor may pull several trailers (road train). They are manufactured by Kador Engineering, Kress Corporation, Maxter-Atlas and Rimpull. This large capacity truck is used for the transportation of coal from a loading device (shovel) directly to a power station or bulk storage area.

The current largest off road haul trucks are the Liebherr T 282B, the Bucyrus MT6300AC and the Caterpillar 797F, which each have payload capacities of up to 400 short tons (363 t). Most haul trucks employ diesel/electric powertrains, using the diesel engine to drive an AC alternator or DC generator that sends electric power to electric motors at each rear wheel. The Caterpillar 797 is unique in this class because it employs a diesel engine to power a mechanical powertrain typical of most road going vehicles. Other major manufacturers of haul trucks include Hitachi, Komatsu, DAC, Terex and Belaz.

## **Winter service vehicles**

Many winter service vehicle units are based on dump trucks, to allow the placement of ballast to weigh the truck down or to hold sodium or calcium chloride salts for spreading on snow and ice covered surfaces.

## **Dangers**

### **Collisions**

Dump trucks are normally built for some amount of off-road or construction site driving; as the driver is protected by the chassis and height of the driver's seat, bumpers are either placed high or omitted for added ground clearance. The disadvantage is that in a collision with a standard car, the entire motor section or luggage compartment goes under the truck. Thus the passengers in the car could be more severely injured than would be common in a collision with another car. Several countries have made rules that new trucks should have bumpers approximately 40 cm (20 in) above ground in order to protect other drivers better. There are also rules about how long the load or construction

of the truck can go beyond the rear bumper to prevent cars that rear-end the truck from going under it.

## **Tipping**

Another safety consideration is the leveling of the truck before unloading. If the truck is not parked on relatively horizontal ground, the sudden change of weight and balance due to lifting of the skip and dumping of the material can cause the truck to slide, or even—in some light dump trucks—to turn over.

## **Back-up accidents**

Because of their size and the difficulty of maintaining visual contact with on-foot workers, dump trucks in car parks can be a threat, especially when backing up. Mirrors and back-up alarms provide some level of protection, and having a spotter working with the driver also decreases back-up injuries and fatalities.

## Chapter- 3

# Backhoe



Rear view of a JCB 3CX showing the backhoe being employed to remove a tree stump. Note the stabilisers deployed to avoid the vehicle tipping sideways when the arm is extended.

A **backhoe**, also called a **rear actor** or **back actor**, is a piece of excavating equipment or digger consisting of a digging bucket on the end of a two-part articulated arm. They are typically mounted on the back of a tractor or front loader. The section of the arm closest to the vehicle is known as the boom, and the section which carries the bucket is known as the **dipper** or dipperstick (the terms "boom" and "dipper" having been used previously on steam shovels). The boom is attached to the vehicle through a pivot known as the kingpost, which allows the arm to slew left and right, usually through a total of around 200 degrees. Modern backhoes are powered by hydraulics.

## Characteristics



A skid loader with its bucket replaced by backhoe attachment



Kobelco Excavator in shovel configuration

Most backhoes are at their strongest curling the bucket, with the dipper arm next most powerful, and boom movements the least powerful.

Similar attachments for skid loaders are still called backhoes even though they are mounted on the front. This is because the name refers to the action of the shovel, not its location on the vehicle: a backhoe digs by drawing earth backwards, rather than lifting it with a forward motion like a bulldozer or a man shoveling.

A **backhoe loader** is a tractor-like vehicle with an arm and bucket mounted on the back and a front loader mounted on the front. This type of vehicle is often known colloquially as a **JCB** in Europe (after its inventor) and simply a Backhoe or a Tractor Loader Backhoe (TLB) in North America. In North American terms, a Backhoe includes both a front bucket and a rear hoe, on a chassis originally derived from farm tractors. A dedicated hoe on its own chassis is more properly referred to as an excavator.

Backhoes can be designed and manufactured from the start as such, or can be the result of a farm tractor equipped with a Front End Loader (FEL) and rear hoe. Though similar

looking, the designed backhoes are much stronger, with the farm variation more suitable for light work. The farm variation also requires that the operator switch seats from sitting in front of the backhoe controls to the tractor seat in order to reposition the equipment while digging, and this often slows down the digging process.

With the advent of hydraulic powered attachments such as a tiltrotator, breaker, a grapple or an auger, the backhoe is frequently used in many applications other than excavation and with the tiltrotator attachment, serves as an effective tool carrier. Many backhoes feature quick coupler (quick-attach) mounting systems for simplified attachment mounting, dramatically increasing the machine's utilization on the job site. Backhoes are usually employed together with loaders and bulldozers. Excavators that use a backhoe are sometimes called "trackhoes" by people who do not realize the name is due to the action of the bucket, not its location on a backhoe loader.

Backhoes are general purpose tools, and are being displaced to some extent by multiple specialist tools like the excavator and the speciality Front End Loader, especially with the rise of the mini-excavator. On many jobsites which would have previously seen a backhoe used, a skidsteer (colloquially often called a Bobcat after the most well known manufacturer and inventor of the category) and a mini excavator will be used in conjunction to fill the backhoes role. However, backhoes still are in general use.

Sometimes a backhoe bucket is reversed to work in a power shovel configuration. This is generally when loading from a large stockpile, for picking up or filling material next to walls, to increase the reach of the machine, or working around obstacles such as pipes.

## Thumb

The backhoe's scoop may have a metal bar called a "thumb" hinged to the scoop. It grips against the scoop like a man's thumb to pick up objects. When not needed some sorts can lie back against the backhoe arm.

## Origins

The British company JCB developed the early hoes. Their first tractor equipped with both a hoe and a front-mounted loading bucket was completed in 1953 and set the standard pattern for future designs of backhoe loader. Because of the long-time predominance of this marque in the United Kingdom and Ireland, it has become a genericized trademark there, and all backhoe-equipped diggers are commonly called **JCBs**, while the term "hoe" is almost unknown to the general public in this context. The founder of the JCB company, Joseph Cyril Bamford, holds the honour of being the only non-American in the US construction industry's Hall of fame.

The American company Hy-Dynamic, a division of Bucyrus-Erie, introduced the second purpose-built American-made backhoe loader in 1959, the Dynahoe Model A. It offered a 14,000 lb. operating weight, 14 foot dig depth, and was powered by either a 65 hp

Continental flat-head "Red Seal" 6 cylinder gasoline engine, or starting in 1961, a Detroit Diesel 353 diesel engine. The gasoline engine was phased out in 1964, with only diesel powered units produced from that point on. The company marketed the Dynahoe as the only purpose-built backhoe-loader, previously all American backhoes were merely farm tractors fitted with front loader and rear backhoe attachments. The Dynahoe was built very robust from the ground up with heavy excavation in mind. Production of the Dynahoe continued into the early 1990s culminating in the model Dynahoe 200-4, with a 36,000 lb. operating weight, 4 wheel drive, and a 20 foot dig depth. Production ceased with demand wavering in favor of more modern and versatile excavator type machines becoming more cost effective, and productive. Many of the original Dynahoe Model A's are still in use to this day. The first, and much more popular Case Corporation introduced their backhoes in 1957. The design of the Case backhoes, from the straight arm boom assembly, to the "Extendahoe" design, which can extend the dipper from four to eight feet longer, are all registered with the U.S. Patent Office, along with the chassis design.

## Backhoe fade

**Backhoe fade** or **JCB fade** is a humorous term coined by the telecommunications industry, referring to the accidental severing of a cable by a backhoe or similar construction activity.

The term comes from the sudden and initially inexplicable loss of signal ("fading") experienced when a cable is accidentally dug up and damaged. Depending on the particular cable destroyed, service may be interrupted to just a few customers or, for a large fiber optic cable, millions of customers across an entire continent.

## Notable manufacturers

-  Case CE (Subsidiary of  CNH)
-  Caterpillar Inc.
-  Cukurova
-  Deere & Company
-  Ford Motor Company
-  Hitachi Construction Machinery (Europe) (Subsidiary of  Hitachi Construction Machinery)
-  Hydrema
-  JCB
-  Komatsu
-  Kubota
-  LiuGong
-  Massey Ferguson (Subsidiary of  AGCO)
-  Terex
-  Volvo Construction Equipment (Subsidiary of  Volvo)

## Chapter- 4

# Backhoe Loader



The archetypal backhoe loader, a restored JCB 3C MkII, showing the conventional arrangement of front loader (left) and backhoe (right)



A typical European backhoe-loader; these usually have a side-shift rather than stabilizer legs.



A backhoe with a snow plow attachment clearing snow



A worker attaches a lifting cable to a concrete sewer pipe section. Note the retracted stabilizers on this Case backhoe



Pipe transported using a lifting cable

A **backhoe loader**, also called a **loader backhoe**, **digger**, or colloquially shortened to **backhoe**, is a heavy equipment vehicle that consists of a tractor fitted with a shovel/bucket on the front and a small backhoe on the back. Due to its (relatively) small size and versatility, backhoe loaders are very common in urban engineering and small construction projects (such as building a small house, fixing urban roads, etc.).

## History

The backhoe loader was invented in the UK in 1953 by Joseph Cyril Bamford, founder of J. C. Bamford (JCB), by equipping a farm tractor with both a backhoe and a front-mounted loading bucket. Although based on a tractor, a backhoe loader is almost never called a *tractor* when both the loader and the backhoe are permanently attached. Backhoe loaders are also not generally used for towing and usually do not have a power take-off (PTO). When the backhoe is permanently attached, the machine usually has a seat that can swivel to the rear to face the hoe controls. Removable backhoe attachments almost always have a separate seat on the attachment itself.

In Britain and Ireland they are commonly referred to simply as JCBs due to the company being the inventor and major supplier. In the United States, they are often referred to as "Backhoes", although the term 'backhoe' only refers to one component.

In 1970, Hy-Dynamic now a division of Bucyrus-Erie, manufacturer of the Dynahoe was the first company to incorporate a four wheel drive system into their backhoe loaders, allowing these models to go over almost any terrain with little difficulty.

## Use

Backhoe loaders are very common and can be used for a wide variety of tasks: construction, small demolitions, light transportation of building materials, powering building equipment, digging holes/excavation, landscaping, breaking asphalt, and paving roads. The backhoe bucket can also be replaced with powered attachments such as a breaker, grapple, auger, or a stump grinder. Enhanced articulation of attachments can be achieved with intermediate attachments such as the tiltrotator. Many backhoes feature quick coupler (quick-attach) mounting systems and auxiliary hydraulic circuits for simplified attachment mounting, increasing the machine's utilization on the job site. Some loader buckets have a retractable bottom or "clamshell", enabling it to empty its load more quickly and efficiently. Retractable-bottom loader buckets are also often used for grading and scraping. The front assembly may be a removable attachment or permanently mounted. Often the bucket can be replaced with other devices or tools. The backhoe loader must be equipped with a tool coupler in order to mount different attachments to the loader. A tool coupler consists of two hydraulic cylinders on the end of the loader arm assembly which can expand and retract allowing different tools to be attached to the unit. Advanced couplers like the tiltrotator allow for greater articulation of attachments and makes the backhoe an effective tool carrier.

Because the design is intrinsically top-heavy and the swinging weight of the backhoe could cause the vehicle to tip, most backhoe loaders use hydraulic outriggers only at the back when digging and lower the loader bucket for additional stability. This means that the bucket must be raised and the outriggers retracted when the vehicle needs to change positions, reducing efficiency. For this reason many companies offer miniature tracked excavators, which sacrifice the loader function for increased digging efficiency.

Their relatively small frame and precise control make backhoe-loaders very useful and common in urban engineering projects such as construction and repairs in areas too small for larger equipment. Their versatility and compact size makes them one of the most popular urban construction vehicles. For larger projects, a tracked excavator is generally used.

In recent years, small compact tractors from manufacturers such as Kubota have become very popular with private homeowners. Subcompact tractors, the size between a compact tractor and lawn tractor, are also often sold in backhoe loader setup, sometimes with a belly-mounted mower also included. These tractors offer private homeowners the ability to perform minor excavation projects.

## Trivia

- The cutting of network cables during road repairs is now so common that network engineers often refer to "Backhoe fade" or "JCB fade" as a likely cause of communications problems.
- The second American made backhoe loader was introduced by the Hy-Dynamic company of Lake Bluff, Ill. in 1959. Named the Dynahoe, the machines were marketed as rugged, purpose-built, heavy-duty loader backhoes, built with productivity and low maintenance in mind.
- The term "*Loader/Backhoe*" became famous in the USA when J.I. Case Company rolled the first backhoe loader off the assembly line in 1967. Today, the Case backhoe loader is synonymous to the term, and is perhaps the most recognizable model in the United States of America.

## Manufacturers

- Bharat Earth Movers Limited
- Case Corporation
- Caterpillar Inc.
- Fiat
- Hitachi, Ltd.
- Hydrema
- Hidromek
- J. C. Bamford (JCB)
- John Deere Tractors
- Komatsu LTD
- New Holland Ag
- Terex
- Venieri
- Volvo Construction Equipment

## Chapter- 5

# Bulldozer



A Caterpillar D10N bulldozer equipped with a single shank ripper

A **bulldozer** is a crawler (Continuous tracked tractor) equipped with a substantial metal plate (known as a blade) used to push large quantities of soil, sand, rubble, etc., during construction work and typically equipped at the rear with a claw-like device (known as a ripper) to loosen densely-compacted materials. The term "bulldozer" is often used to mean any heavy equipment (sometimes a loader and sometimes an excavator), but precisely, the term refers only to a tractor (usually tracked) fitted with a dozer blade. That is the meaning used here.

# History



A Liebherr bulldozer with a multi-shank ripper



Caterpillar D9 "cable-rig" bulldozer in the museum at Sinsheim, Germany

The first bulldozers were adapted from Holt farm tractors that were used to plough fields. Their versatility in soft ground for logging and road building led directly to their becoming the armoured tank in World War I.

In 1923, a young farmer named James Cummings and a draftsman named J. Earl McLeod made the first designs for a bulldozer. A replica is on display at the city park in Morrowville, Kansas where the two built the first bulldozer.

By the 1920s, tracked vehicles became common, particularly the Caterpillar 60. To dig canals, raise earth dams, and do other earth moving jobs, these tractors were equipped with a large thick metal plate in front. This metal plate (it got its curved shape later) is called a "blade". The blade peels layers of soil and pushes it forward as the tractor advances. In some early models the driver sat on top in the open without a cabin. There are three main types of bulldozer blades: a U-blade for pushing and carrying dirt relatively long distances, a straight blade for "knocking down" and spreading piles of dirt, and a brush rake for removing brush and roots. These attachments (home-built or built by small equipment manufacturers of attachments for wheeled and crawler tractors and trucks) appeared by 1929. Widespread acceptance of the bull-grader does not seem to appear before the mid-1930s. The addition of power down-force provided by hydraulic cylinders instead of just the weight of the blade made them the preferred excavation

machine for large and small contractors alike by the 1940s, by which time the term "bulldozer" referred to the entire machine and not just the attachment.

Over the years, bulldozers got bigger and more powerful in response to the demand for equipment suited for ever larger earthworks. Firms like Caterpillar, Komatsu, Case, JCB, Liebherr, LiuGong, Terex, Fiat-Allis, John Deere and International Harvester manufactured large tracked-type earthmoving machines.

Bulldozers grew more sophisticated as time passed. Important improvements include drivetrains analogous to (in automobiles) an automatic transmission instead of a manual transmission, blades controlled by hydraulic cylinders instead of early models' cable winch/brake, and automatic grade control. Hydraulic cylinders enabled more precise manipulation of the blade and automated controls.

Bulldozers can be equipped with a rear attachment.

The most common attachment is a ripper to loosen densely-compacted soils. A large bulldozer usually has only one shank on the ripper, and a small bulldozer usually has multiple shanks. Each shank has a replaceable tooth on its end.

A less common attachment is a stumpbuster, which is a single spike that protrudes horizontally and can be raised to get it (mostly) out of the way. A stumpbuster is used to split a tree stump. A bulldozer with a stumpbuster is used for landclearing operations, and probably has a brush-rake blade.

A more recent innovation is the outfitting of bulldozers with GPS technology, such as manufactured by Topcon Positioning Systems, Inc., Trimble Inc, or Leica Geosystems for precise grade control and (potentially) "stakeless" construction. As a response to the many, -and often varying claims about these systems, The Kellogg Report published in 2010 a detailed comparison of all the manufacturers' systems, evaluating more than 200 features for dozers alone.

The best known maker of bulldozers is probably Caterpillar in the USA, which earned its reputation by making tough, durable, reliable machines. Komatsu, JCB and John Deere are present-day competitors. Although these machines began as modified farm tractors, they became the mainstay for big civil construction projects, and found their way into use by military construction units worldwide. The best known model, the Caterpillar D9, was also used to clear mines and demolish enemy structures.

## **History of the word**

- 19th century: term used in engineering for a horizontal forging press.
- 1886: "bulldozer" meant a large-caliber pistol and the person who wielded it.
- Around 1880: In the USA, a "bull-dose" was a large and efficient dose of any sort of medicine or punishment. 'Bull-dosing' meant a severe whipping or coercion, or other intimidation such as at gunpoint.

- Late 19th century: "bulldozing" meant using big force to push over or through any obstacle.
- 1930s: applied to the vehicle.

These appeared as early as 1929, but were known as "bull grader" blades, and the term "bulldozer blade" did not appear to come into widespread use until the mid 1930s, and now refers to the whole machine not just the attachment. In contemporary usage, "bulldozer" is often shortened to "dozer".

## Description

Most often, bulldozers are large and powerful tracked heavy equipment. The tracks give them excellent ground hold and mobility through very rough terrain. Wide tracks help distribute the bulldozer's weight over a large area (decreasing pressure), thus preventing it from sinking in sandy or muddy ground. Extra wide tracks are known as 'swamp tracks'. Bulldozers have excellent ground hold and a *torque divider* designed to convert the engine's power into improved dragging ability. The Caterpillar D9, for example, can easily tow tanks that weigh more than 70 tons. Because of these attributes, bulldozers are used to clear areas of obstacles, shrubbery, burnt vehicles, and remains of structures.

Sometimes a bulldozer is used to push another piece of earthmoving equipment known as a "scraper". The towed Fresno Scraper, invented in 1883 by James Porteous, was the first design to enable this to be done economically, removing the soil from the *cut* and depositing it elsewhere on shallow ground (*fill*). Many dozer blades have a reinforced center section with this purpose in mind, and are called "bull blades."

The bulldozer's primary tools are the **blade** and the **ripper**.

## Blade



Degelman Blade Degelman Industries Ltd.

The bulldozer blade is a heavy metal plate on the front of the tractor, used to push objects, and shoving sand, soil and debris. Dozer blades usually come in three varieties:

1. A Straight Blade ("S-Blade") which is short and has no lateral curve, no side wings, and can be used for fine grading.
2. A Universal Blade ("U-Blade") which is tall and very curved, and has large side wings to carry more material.
3. A "S-U" combination blade which is shorter, has less curvature, and smaller side wings. This blade is typically used for pushing piles of large rocks, such as at a quarry.

In military use, dozer blades are fixed on combat engineering vehicles and can optionally be fitted on other vehicles, such as artillery tractors like the Type 73 or M8 Tractor. Dozer blades can also be mounted on Main battle tanks, where it can be used to clear antitank obstacles, mines, and dig improvised shelters. Combat applications for dozer blades include clearing battlefield obstacles and preparing fire positions.

## Ripper



Multi-shank ripper

The **ripper** is the long claw-like device on the back of the bulldozer. Rippers can come as a single (single shank/giant ripper) or in groups of two or more (multi shank rippers). Usually, a single shank is preferred for heavy ripping. The ripper shank is fitted with a replaceable tungsten steel alloy tip.

Ripping rock lets the ground surface rock be broken into small rubble easy to handle and transport, which can then be removed so grading can take place. Agricultural ripping lets rocky or very hard earth (such as podzol hardpan) be broken up so otherwise unploughable land can be farmed. For example, much of the best land in the California wine country consists of old lava flows. With heavy bulldozers the lava is shattered, allowing agriculture. Also, hard earth can be ripped and broken up to allow planting of orchards where trees could not otherwise grow.

## Modifications

Bulldozers have been further modified over time to evolve into new machines which can work in ways that the original bulldozer cannot.

One example is that loader tractors were created by removing the blade and substituting a large volume bucket and hydraulic arms which can raise and lower the bucket, thus making it useful for scooping up earth and loading it into trucks, these are often known as a Drott.

Other modifications to the original bulldozer include making it smaller to let it operate in small work areas where movement is limited, such as in mining. A very small bulldozer is sometimes called a **calldozer**.

Some lightweight form of bulldozer are commonly used in snow removal and as a tool for preparing winter sports areas for ski and snowboard sports.

Nevertheless, the original earthmoving bulldozers are still irreplaceable as their tasks are concentrated in deforestation, earthmoving, ground levelling, and road carving. Heavy bulldozers are mainly employed to level the terrain to prepare it for construction. The construction, however, is mainly done by small bulldozers and loader tractors.

### Armored bulldozers



An armored Caterpillar D9R Bulldozer used by Israel Defense forces

Some bulldozers, especially bulldozers in military usage, have been fitted with armor to protect the driver from enemy fire, enabling the bulldozer to operate in battle zones. The best-known use of an armored bulldozer is probably the use by the Israeli Defence Forces (IDF) of the IDF Caterpillar D9, for earth moving, clearing terrain obstacles, opening routes, detonating explosive charges and demolishing structures whilst under fire. The extensive use of armored bulldozers during the Second Intifada drew controversy and criticism from human rights organizations while military experts saw it as a key factor in reducing IDF casualties.

Some bulldozers have been fitted with armor by non-government civilian operators to prevent bystanders or police from interfering with the work performed by the bulldozer, as in the case of strikes or demolition of condemned buildings. This has also been done by civilians with a dispute with the authorities, such as Marvin Heemeyer, who outfitted his Komatsu D355A bulldozer with homemade composite armor to then demolish government buildings.

## **Uses**

Bulldozers can be found on a wide range of small scale and large construction sites, mines and quarries, military bases, heavy industry factories, and large governmental and public Engineering projects as well as farming.

## Chapter- 6

# 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 built 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

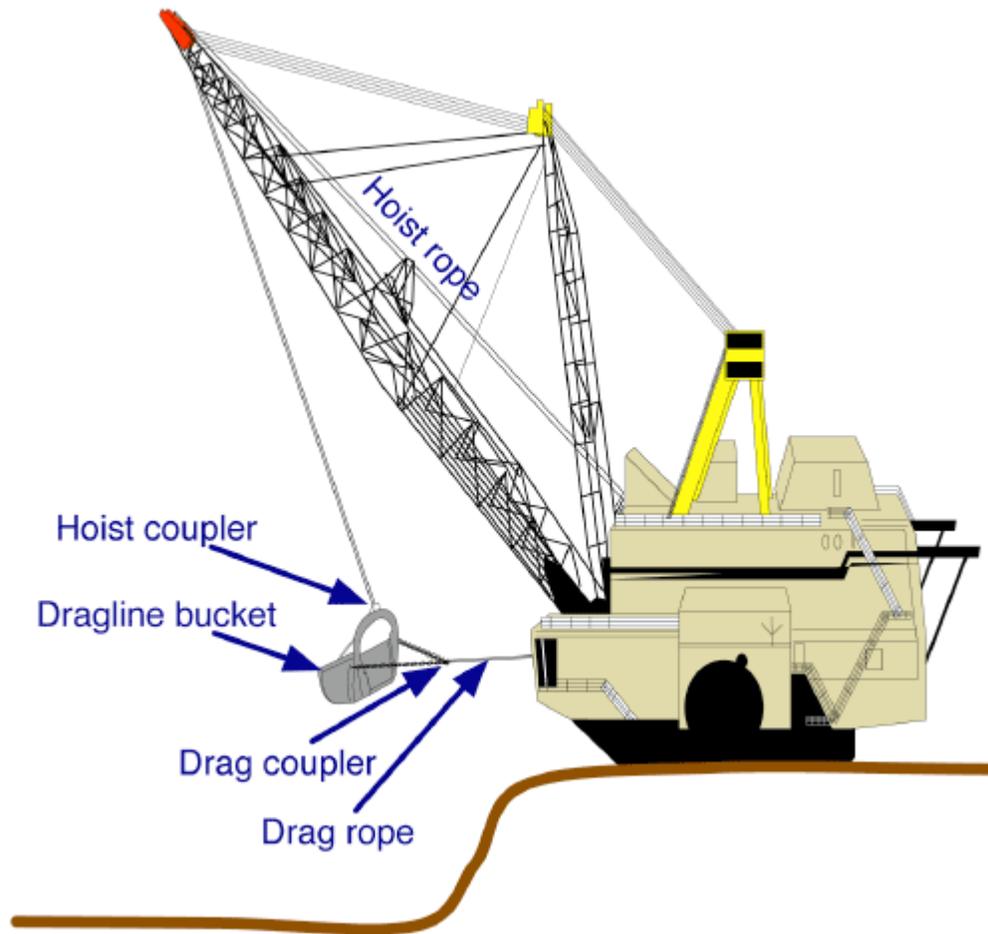
1926. So popular were these machines that the name Monighan became a generic term for dragline. In the early 1930s, Bucyrus-Erie began purchasing shares of Monighan stock with Monighan's approval. Bucyrus purchased a controlling interest and the joint company became known as Bucyrus-Monighan until the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

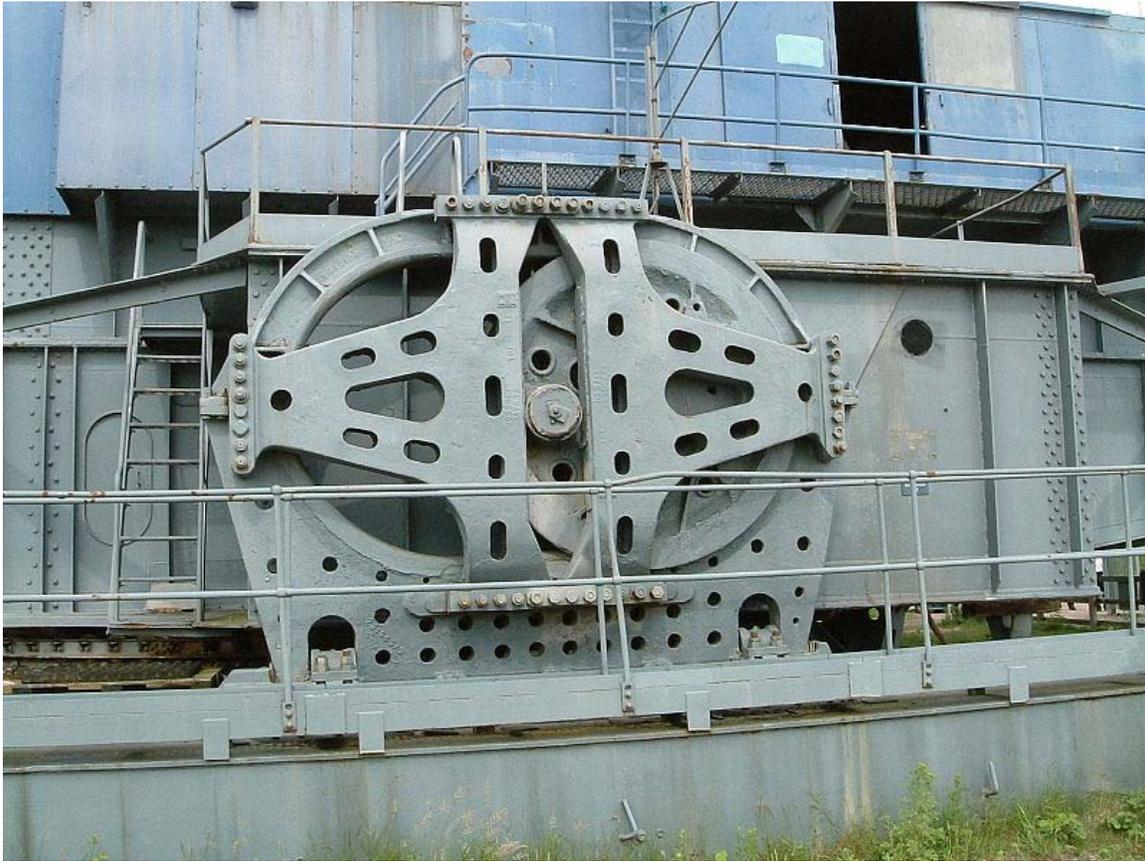
In all but the smallest of draglines, movement is accomplished by "walking" using feet or pontoons, as caterpillar tracks place too much pressure on the ground, and have great difficulty under the immense weight of the dragline. Maximum speed is only at most a few metres per minute since the feet must 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 research 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- 7

# Drilling Rig



Drilling rig, Reverse circulation in western Australia



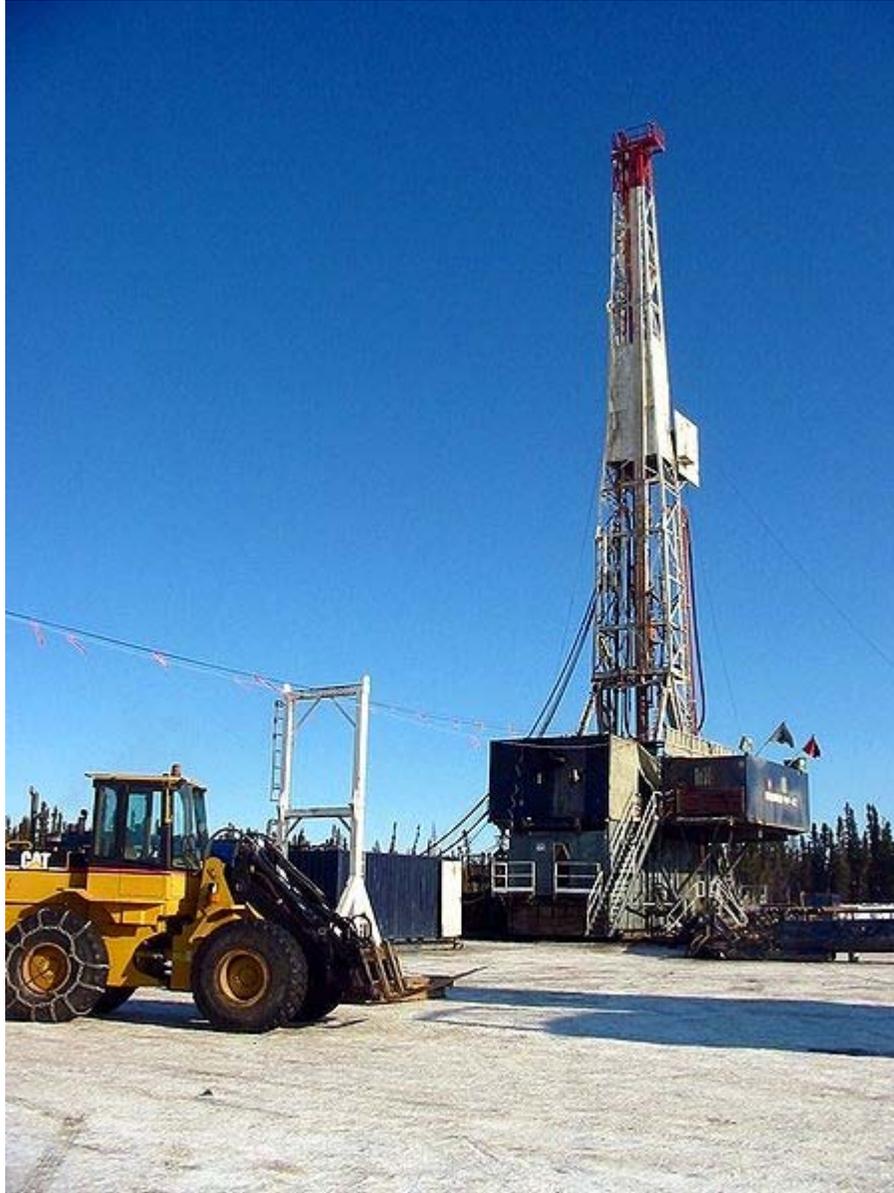
Drilling rig preparing rock blasting

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**

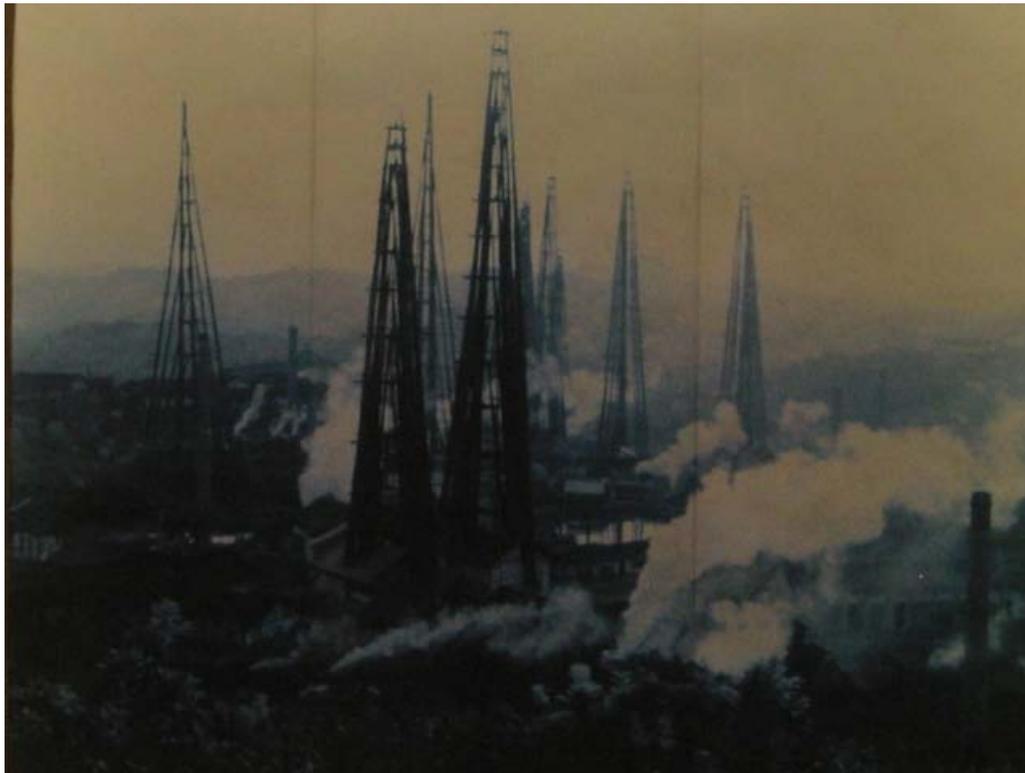
New technology uses smaller portable trailer mounted rigs with shorter 10 foot (3.0 m) drill pipe. DIY users and missionary groups use these to drill water wells as they can be operated by 1 or 2 people with a minimal skill level. The shorter drill pipe also allows a much smaller mast, which gives a 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 ( $500 \text{ L}\cdot\text{s}^{-1}$  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.

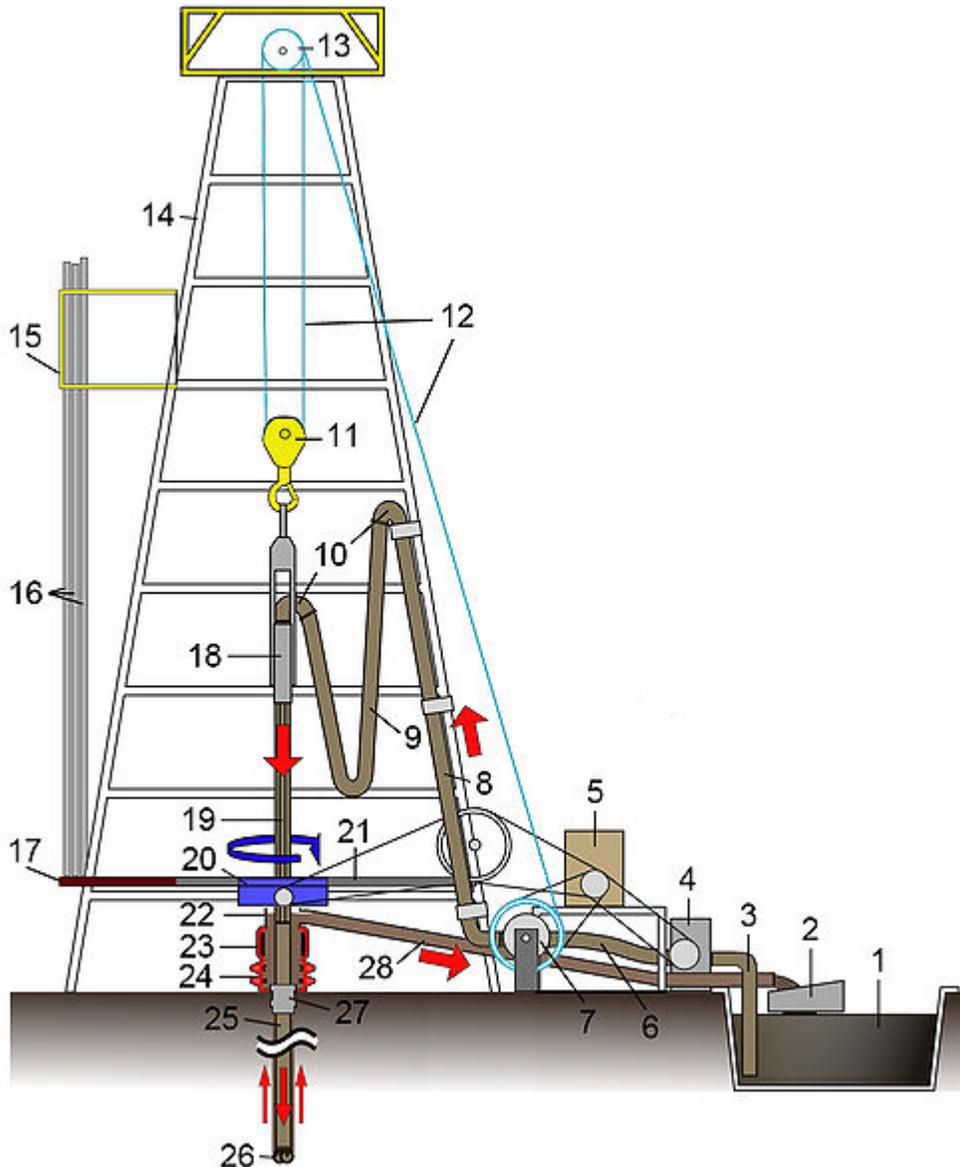
A unique drilling operation in deep ocean water was named Project Mohole.

## **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

Drilling rigs typically include at least some of the following items: Drilling rig (petroleum) for a more detailed description.

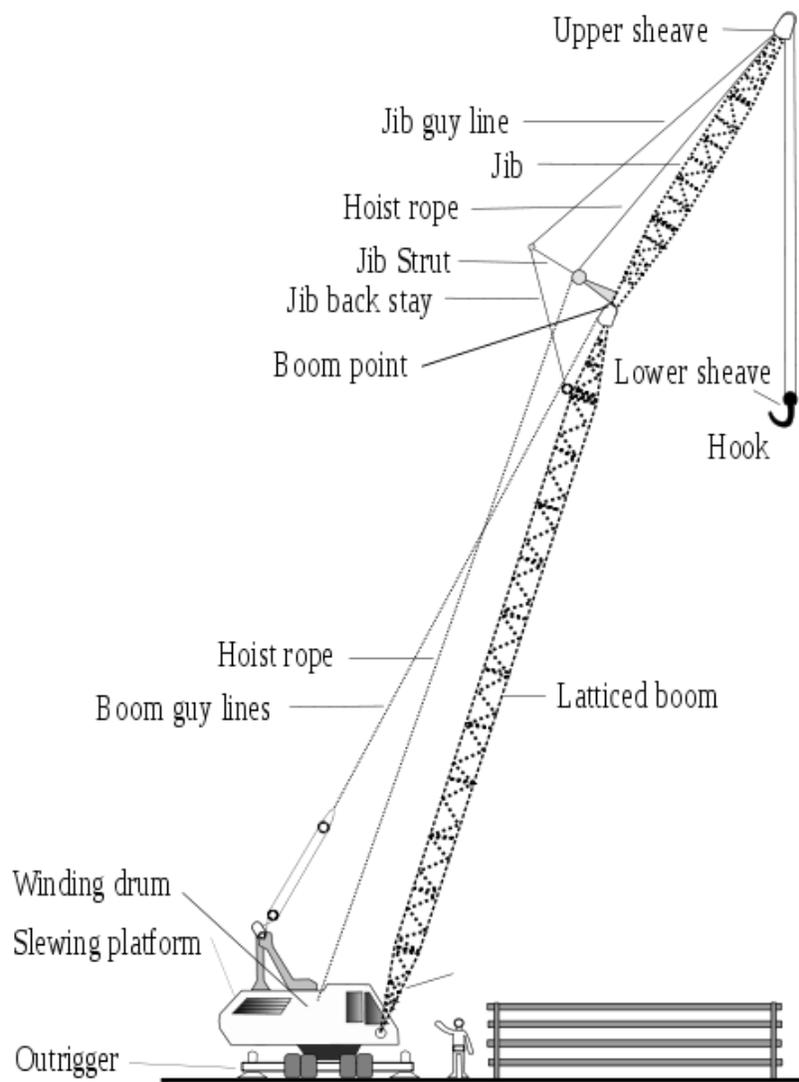
- Blowout preventers: (BOPs)

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- 8

# Crane



A modern crawler type derrick crane with outriggers. The latticed boom is fitted with a jib.



An old manual crane with a pivoted boom. The incline of the boom is controlled by means of chains, sprockets and gears.

A **crane** is a lifting machine, generally equipped with a winder (also called a wire rope drum), wire ropes or chains and sheaves, that can be used both to lift and lower materials and to move them horizontally. It uses one or more simple machines to create mechanical advantage and thus move loads beyond the normal capability of a human. Cranes are commonly employed in the transport industry for the loading and unloading of freight, in the construction industry for the movement of materials and in the manufacturing industry for the assembling of heavy equipment.

## Overview



Gantry cranes for handling containerized cargo



Mini - crane generally used for constructing building  
Two different types of cranes

The first construction cranes were invented by the Ancient Greeks and were powered by men or beasts of burden, such as donkeys. These cranes were used for the construction of tall buildings. Larger cranes were later developed, employing the use of human treadwheels, permitting the lifting of heavier weights. In the High Middle Ages, harbour cranes were introduced to load and unload ships and assist with their construction – some were built into stone towers for extra strength and stability. The earliest cranes were constructed from wood, but cast iron and steel took over with the coming of the Industrial Revolution.

For many centuries, power was supplied by the physical exertion of men or animals, although hoists in watermills and windmills could be driven by the harnessed natural power. The first 'mechanical' power was provided by steam engines, the earliest steam crane being introduced in the 18th or 19th century, with many remaining in use well into the late 20th century. Modern cranes usually use internal combustion engines or electric motors and hydraulic systems to provide a much greater lifting capability than was

previously possible, although manual cranes are still utilised where the provision of power would be uneconomic.

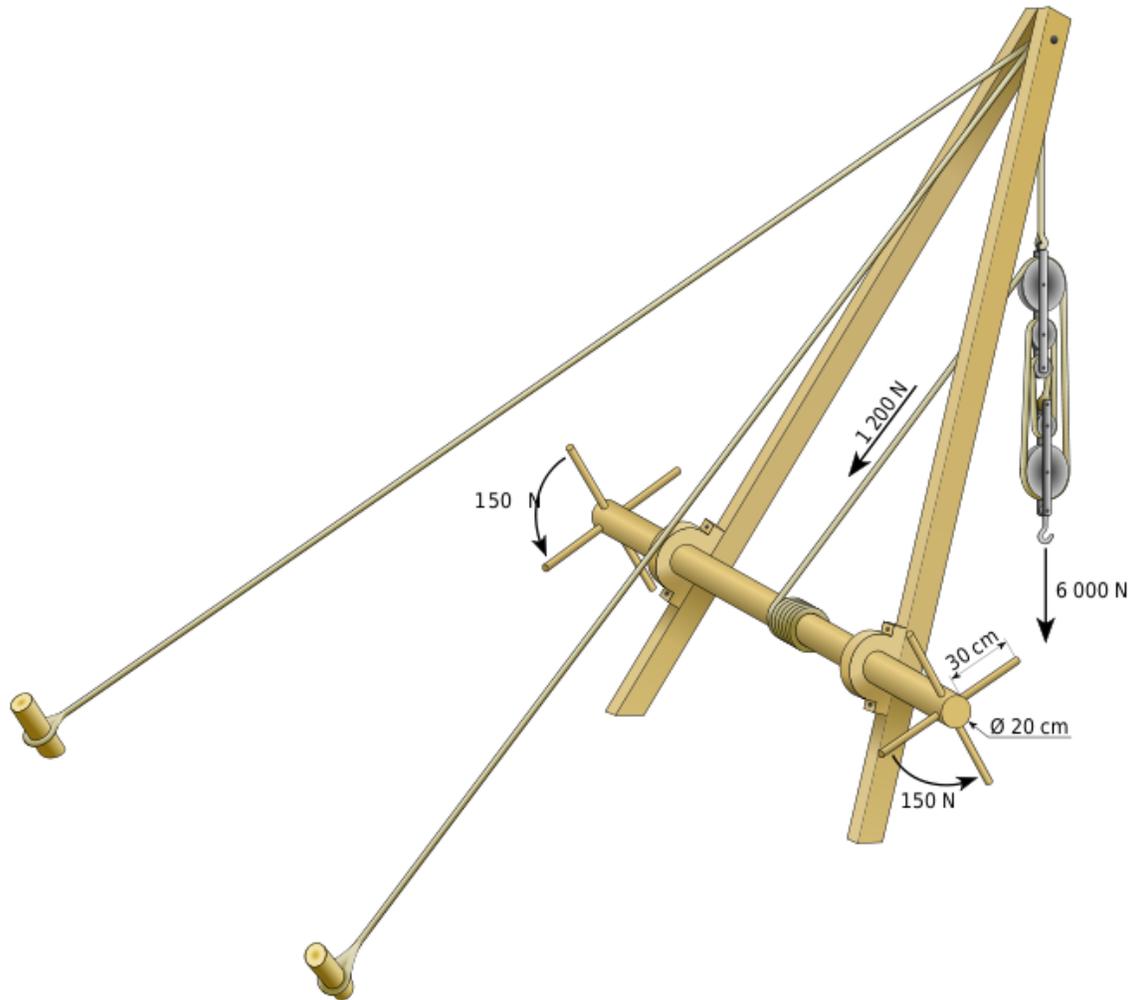
Cranes exist in an enormous variety of forms – each tailored to a specific use. Sizes range from the smallest jib cranes, used inside workshops, to the tallest tower cranes, used for constructing high buildings. For a while, mini - cranes are also used for constructing high buildings, in order to facilitate constructions by reaching tight spaces. Finally, we can find larger floating cranes, generally used to build oil rigs and salvage sunken ships.

## History

### Ancient Greece



Greco-Roman *Trispastos* ("Three-pulley-crane"), the simplest crane type (150 kg load)



Greco-Roman *Pentaspastos* ("Five-pulley-crane"), a medium-sized variant (ca. 450 kg load)

The crane for lifting heavy loads was invented by the Ancient Greeks in the late 6th century BC. The archaeological record shows that no later than c.515 BC distinctive cuttings for both lifting tongs and lewis irons begin to appear on stone blocks of Greek temples. Since these holes point at the use of a lifting device, and since they are to be found either above the center of gravity of the block, or in pairs equidistant from a point over the center of gravity, they are regarded by archaeologists as the positive evidence required for the existence of the crane.

The introduction of the winch and pulley hoist soon lead to a widespread replacement of ramps as the main means of vertical motion. For the next two hundred years, Greek building sites witnessed a sharp drop in the weights handled, as the new lifting technique made the use of several smaller stones more practical than of fewer larger ones. In contrast to the archaic period with its tendency to ever-increasing block sizes, Greek temples of the classical age like the Parthenon invariably featured stone blocks weighing

less than 15-20 metric tons. Also, the practice of erecting large monolithic columns was practically abandoned in favour of using several column drums.

Although the exact circumstances of the shift from the ramp to the crane technology remain unclear, it has been argued that the volatile social and political conditions of Greece were more suitable to the employment of small, professional construction teams than of large bodies of unskilled labour, making the crane more preferable to the Greek polis than the more labour-intensive ramp which had been the norm in the autocratic societies of Egypt or Assyria.

The first unequivocal literary evidence for the existence of the compound pulley system appears in the *Mechanical Problems* (*Mech.* 18, 853a32-853b13) attributed to Aristotle (384-322 BC), but perhaps composed at a slightly later date. Around the same time, block sizes at Greek temples began to match their archaic predecessors again, indicating that the more sophisticated compound pulley must have found its way to Greek construction sites by then.

## **Ancient Rome**



Reconstruction of a 10.4m high Roman *Polyspastos* powered by a treadwheel at Bonn, Germany

The heyday of the crane in ancient times came during the Roman Empire, when construction activity soared and buildings reached enormous dimensions. The Romans adopted the Greek crane and developed it further. We are relatively well informed about their lifting techniques, thanks to rather lengthy accounts by the engineers Vitruvius (*De Architectura* 10.2, 1-10) and Heron of Alexandria (*Mechanica* 3.2-5). There are also two surviving reliefs of Roman treadwheel cranes, with the Haterii tombstone from the late first century AD being particularly detailed.

The simplest Roman crane, the *trispastos*, consisted of a single-beam jib, a winch, a rope, and a block containing three pulleys. Having thus a mechanical advantage of 3:1, it has been calculated that a single man working the winch could raise 150 kg (3 pulleys x 50 kg = 150), assuming that 50 kg represent the maximum effort a man can exert over a longer time period. Heavier crane types featured five pulleys (*pentaspastos*) or, in case of the largest one, a set of three by five pulleys (*Polyspastos*) and came with two, three or four masts, depending on the maximum load. The *polyspastos*, when worked by four men at both sides of the winch, could already lift 3000 kg (3 ropes x 5 pulleys x 4 men x 50 kg = 3000 kg). In case the winch was replaced by a treadwheel, the maximum load even doubled to 6000 kg at only half the crew, since the treadwheel possesses a much bigger mechanical advantage due to its larger diameter. This meant that, in comparison to the construction of the Egyptian Pyramids, where about 50 men were needed to move a 2.5 ton stone block up the ramp (50 kg per person), the lifting capability of the Roman *polyspastos* proved to be 60 times higher (3000 kg per person).

However, numerous extant Roman buildings which feature much heavier stone blocks than those handled by the *polyspastos* indicate that the overall lifting capability of the Romans went far beyond that of any single crane. At the temple of Jupiter at Baalbek, for instance, the architrave blocks weigh up to 60 tons each, and one corner cornice block even over 100 tons, all of them raised to a height of about 19 m. In Rome, the capital block of Trajan's Column weighs 53.3 tons, which had to be lifted to a height of about 34 m.

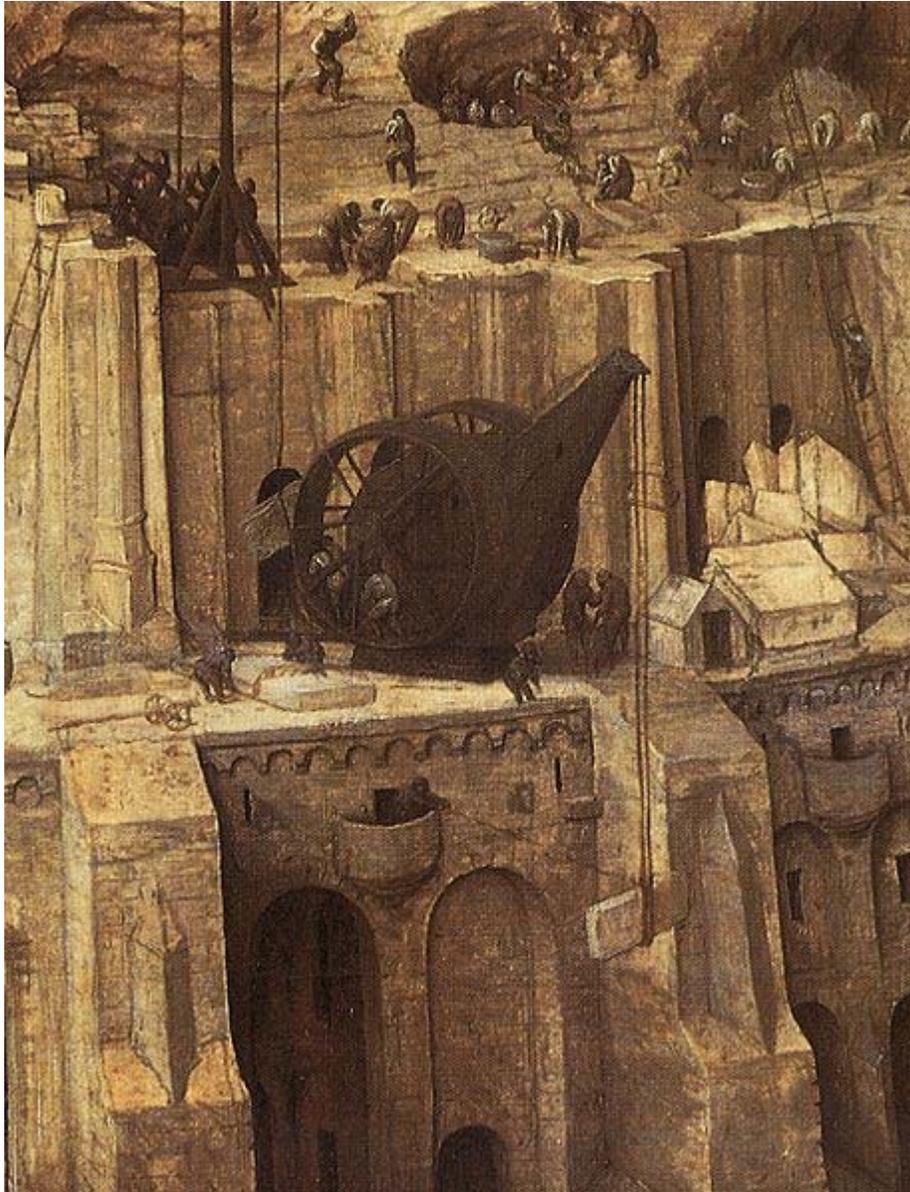
It is assumed that Roman engineers lifted these extraordinary weights by two measures: First, as suggested by Heron, a lifting tower was set up, whose four masts were arranged in the shape of a quadrangle with parallel sides, not unlike a siege tower, but with the column in the middle of the structure (*Mechanica* 3.5). Second, a multitude of capstans were placed on the ground around the tower, for, although having a lower leverage ratio than treadwheels, capstans could be set up in higher numbers and run by more men (and, moreover, by draught animals). This use of multiple capstans is also described by Ammianus Marcellinus (17.4.15) in connection with the lifting of the Lateranense obelisk in the Circus Maximus (ca. 357 AD). The maximum lifting capability of a single capstan can be established by the number of lewis iron holes bored into the monolith. In case of the Baalbek architrave blocks, which weigh between 55 and 60 tons, eight extant holes suggest an allowance of 7.5 ton per lewis iron, that is per capstan. Lifting such heavy weights in a concerted action required a great amount of coordination between the work groups applying the force to the capstans.

## Middle Ages



Medieval port crane for mounting masts and lifting heavy cargo in the former Hanse town of Gdańsk

During the High Middle Ages, the treadwheel crane was reintroduced on a large scale after the technology had fallen into disuse in western Europe with the demise of the Western Roman Empire. The earliest reference to a treadwheel (*magna rota*) reappears in archival literature in France about 1225, followed by an illuminated depiction in a manuscript of probably also French origin dating to 1240. In navigation, the earliest uses of harbor cranes are documented for Utrecht in 1244, Antwerp in 1263, Brugge in 1288 and Hamburg in 1291, while in England the treadwheel is not recorded before 1331.



Double treadwheel crane in Pieter Bruegel's *The Tower of Babel*

Generally, vertical transport could be done more safely and inexpensively by cranes than by customary methods. Typical areas of application were harbors, mines, and, in particular, building sites where the treadwheel crane played a pivotal role in the construction of the lofty Gothic cathedrals. Nevertheless, both archival and pictorial sources of the time suggest that newly introduced machines like treadwheels or wheelbarrows did not completely replace more labor-intensive methods like ladders, hods and handbarrows. Rather, old and new machinery continued to coexist on medieval construction sites and harbors.

Apart from treadwheels, medieval depictions also show cranes to be powered manually by windlasses with radiating spokes, cranks and by the 15th century also by windlasses

shaped like a ship's wheel. To smooth out irregularities of impulse and get over 'dead-spots' in the lifting process flywheels are known to be in use as early as 1123.

The exact process by which the treadwheel crane was reintroduced is not recorded, although its return to construction sites has undoubtedly to be viewed in close connection with the simultaneous rise of Gothic architecture. The reappearance of the treadwheel crane may have resulted from a technological development of the windlass from which the treadwheel structurally and mechanically evolved. Alternatively, the medieval treadwheel may represent a deliberate reinvention of its Roman counterpart drawn from Vitruvius' *De architectura* which was available in many monastic libraries. Its reintroduction may have been inspired, as well, by the observation of the labor-saving qualities of the waterwheel with which early treadwheels shared many structural similarities.

### Structure and placement



Single treadwheel crane working from top of the building

The medieval treadwheel was a large wooden wheel turning around a central shaft with a treadway wide enough for two workers walking side by side. While the earlier 'compass-

arm' wheel had spokes directly driven into the central shaft, the more advanced 'clasp-arm' type featured arms arranged as chords to the wheel rim, giving the possibility of using a thinner shaft and providing thus a greater mechanical advantage.

Contrary to a popularly held belief, cranes on medieval building sites were neither placed on the extremely lightweight scaffolding used at the time nor on the thin walls of the Gothic churches which were incapable of supporting the weight of both hoisting machine and load. Rather, cranes were placed in the initial stages of construction on the ground, often within the building. When a new floor was completed, and massive tie beams of the roof connected the walls, the crane was dismantled and reassembled on the roof beams from where it was moved from bay to bay during construction of the vaults. Thus, the crane 'grew' and 'wandered' with the building with the result that today all extant construction cranes in England are found in church towers above the vaulting and below the roof, where they remained after building construction for bringing material for repairs aloft.

Less frequently, medieval illuminations also show cranes mounted on the outside of walls with the stand of the machine secured to putlogs.

### **Mechanics and operation**



Tower crane at the inland harbour of Trier from 1413.

In contrast to modern cranes, medieval cranes and hoists - much like their counterparts in Greece and Rome - were primarily capable of a vertical lift, and not used to move loads

for a considerable distance horizontally as well. Accordingly, lifting work was organized at the workplace in a different way than today. In building construction, for example, it is assumed that the crane lifted the stone blocks either from the bottom directly into place, or from a place opposite the centre of the wall from where it could deliver the blocks for two teams working at each end of the wall. Additionally, the crane master who usually gave orders at the treadwheel workers from outside the crane was able to manipulate the movement laterally by a small rope attached to the load. Slewing cranes which allowed a rotation of the load and were thus particularly suited for dockside work appeared as early as 1340. While ashlar blocks were directly lifted by sling, lewis or devil's clamp (German *Teufelskralle*), other objects were placed before in containers like pallets, baskets, wooden boxes or barrels.

It is noteworthy that medieval cranes rarely featured ratchets or brakes to forestall the load from running backward. This curious absence is explained by the high friction force exercised by medieval treadwheels which normally prevented the wheel from accelerating beyond control.

## Harbor usage



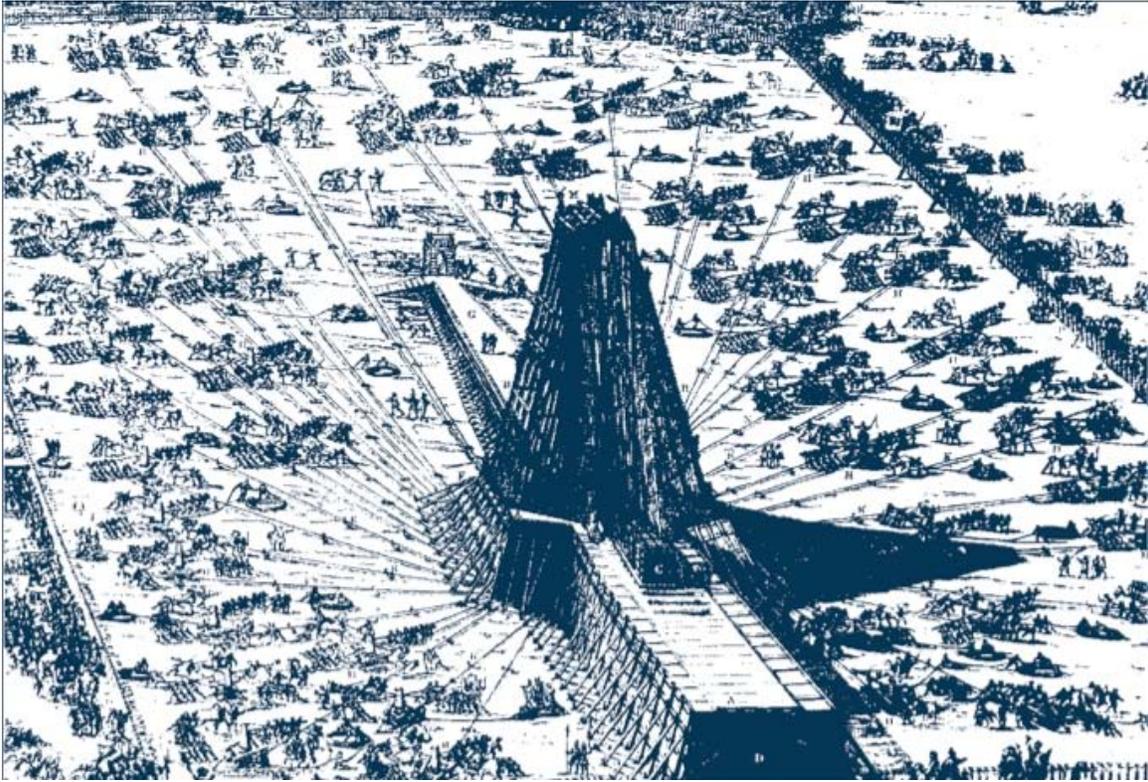
Beyond the modern warship stands a crane constructed in 1742, used for mounting masts to large sailing vessels. Copenhagen, Denmark

According to the "present state of knowledge" unknown in antiquity, stationary harbor cranes are considered a new development of the Middle Ages. The typical harbor crane was a pivoting structure equipped with double treadwheels. These cranes were placed docksides for the loading and unloading of cargo where they replaced or complemented older lifting methods like see-saws, winches and yards.

Two different types of harbor cranes can be identified with a varying geographical distribution: While gantry cranes which pivoted on a central vertical axle were commonly found at the Flemish and Dutch coastside, German sea and inland harbors typically featured tower cranes where the windlass and treadwheels were situated in a solid tower with only jib arm and roof rotating. Interestingly, dockside cranes were not adopted in the Mediterranean region and the highly developed Italian ports where authorities continued to rely on the more labor-intensive method of unloading goods by ramps beyond the Middle Ages.

Unlike construction cranes where the work speed was determined by the relatively slow progress of the masons, harbor cranes usually featured double treadwheels to speed up loading. The two treadwheels whose diameter is estimated to be 4 m or larger were attached to each side of the axle and rotated together. Their capacity was 2–3 tons which apparently corresponded to the customary size of marine cargo. Today, according to one survey, fifteen treadwheel harbor cranes from pre-industrial times are still extant throughout Europe. Some harbour cranes were specialised at mounting masts to newly built sailing ships, such as in Gdańsk, Cologne and Bremen. Beside these stationary cranes, floating cranes which could be flexibly deployed in the whole port basin came into use by the 14th century.

## Renaissance



Erection of the Vatican obelisk in 1586 by means of a lifting tower

A lifting tower similar to that of the ancient Romans was used to great effect by the Renaissance architect Domenico Fontana in 1586 to relocate the 361 t heavy Vatican obelisk in Rome. From his report, it becomes obvious that the coordination of the lift between the various pulling teams required a considerable amount of concentration and discipline, since, if the force was not applied evenly, the excessive stress on the ropes would make them rupture.

### Early modern age

Cranes were used domestically in the 17th and 18th century. The chimney or fireplace crane was used to swing pots and kettles over the fire and the height was adjusted by a trammel.

## Mechanical principles



Broken crane in Sermetal Shipyard, former Ishikawajima do Brasil - Rio de Janeiro. The cause of the accident was a lack of maintenance and misuse of the equipment.



Cranes can mount many different utensils depending on load (left). Cranes can be remote-controlled from the ground, allowing much more precise control, but without the view that a position atop the crane provides (right).



The stability of a mobile construction crane can be jeopardized when outriggers sink into soft soil, which can result in the crane tipping over.

There are three major considerations in the design of cranes. First, the crane must be able to lift the weight of the load; second, the crane must not topple; third, the crane must not rupture.

### **Lifting capacity**

Cranes illustrate the use of one or more simple machines to create mechanical advantage.

- The lever. A balance crane contains a horizontal beam (the *lever*) pivoted about a point called the *fulcrum*. The principle of the lever allows a heavy load attached to the shorter end of the beam to be lifted by a smaller force applied in the opposite direction to the longer end of the beam. The ratio of the load's weight to the applied force is equal to the ratio of the lengths of the longer arm and the shorter arm, and is called the mechanical advantage.
- The pulley. A jib crane contains a tilted strut (the *jib*) that supports a fixed pulley block. Cables are wrapped multiple times round the fixed block and round another block attached to the load. When the free end of the cable is pulled by hand or by a winding machine, the pulley system delivers a force to the load that is equal to the applied force multiplied by the number of lengths of cable passing between the two blocks. This number is the mechanical advantage.
- The hydraulic cylinder. This can be used directly to lift the load or indirectly to move the jib or beam that carries another lifting device.

Cranes, like all machines, obey the principle of conservation of energy. This means that the energy delivered to the load cannot exceed the energy put into the machine. For example, if a pulley system multiplies the applied force by ten, then the load moves only one tenth as far as the applied force. Since energy is proportional to force multiplied by distance, the output energy is kept roughly equal to the input energy (in practice slightly less, because some energy is lost to friction and other inefficiencies).

The same principle can operate in reverse. In case of some problem, the combination of heavy load and great height can accelerate small objects to tremendous speed. Such projectiles can result in severe damage to nearby structures and people. Cranes can also get in chain reactions; the rupture of one crane may in turn take out nearby cranes. Cranes need to be watched carefully.

## Types

### Mobile

The most basic type of mobile crane consists of a truss or telescopic boom mounted on a mobile platform - be it on road, rail or water.

### Truck-mounted crane



Truck-mounted crane

A crane mounted on a truck carrier provides the mobility for this type of crane.

Generally, these cranes are able to travel on highways, eliminating the need for special equipment to transport the crane. When working on the jobsite, outriggers are extended horizontally from the chassis then vertically to level and stabilize the crane while stationary and hoisting. Many truck cranes have slow-travelling capability (a few miles per hour) while suspending a load. Great care must be taken not to swing the load sideways from the direction of travel, as most anti-tipping stability then lies in the

stiffness of the chassis suspension. Most cranes of this type also have moving counterweights for stabilization beyond that provided by the outriggers. Loads suspended directly aft are the most stable, since most of the weight of the crane acts as a counterweight. Factory-calculated charts (or electronic safeguards) are used by crane operators to determine the maximum safe loads for stationary (outriggered) work as well as (on-rubber) loads and travelling speeds.

Truck cranes range in lifting capacity from about 14.5 short tons (12.9 long tons; 13.2 t) to about 1,300 short tons (1,161 long tons; 1,179 t).

### **Sidelift crane**



Sidelift crane

A sidelifter crane is a road-going truck or semi-trailer, able to hoist and transport ISO standard containers. Container lift is done with parallel crane-like hoists, which can lift a container from the ground or from a railway vehicle.

## Rough terrain crane



Rough terrain crane

A crane mounted on an undercarriage with four rubber tires that is designed for pick-and-carry operations and for off-road and "rough terrain" applications. Outriggers are used to level and stabilize the crane for hoisting.

These telescopic cranes are single-engine machines, with the same engine powering the undercarriage and the crane, similar to a crawler crane. In a rough terrain crane, the engine is usually mounted in the undercarriage rather than in the upper, as with crawler crane.

## All terrain crane



## All terrain crane

A mobile crane with the necessary equipment to travel at speed on public roads, and on rough terrain at the job site using all-wheel and crab steering. AT's combine the roadability of Truck-mounted Cranes and the manoeuvrability of Rough Terrain Cranes.

AT's have 2-9 axles and are designed for lifting loads up to 1,200 tonnes (1,323 ST; 1,181 LT).

## Crawler crane



Crawler crane

A crawler is a crane mounted on an undercarriage with a set of tracks (also called crawlers) that provide stability and mobility. Crawler cranes range in lifting capacity from about 40 to 3,500 short tons (35.7 to 3,125.0 long tons; 36.3 to 3,175.1 t).

Crawler cranes have both advantages and disadvantages depending on their use. Their main advantage is that they can move around on site and perform each lift with little set-up, since the crane is stable on its tracks with no outriggers. In addition, a crawler crane is capable of traveling with a load. The main disadvantage is that they are very heavy, and cannot easily be moved from one job site to another without significant expense. Typically a large crawler must be disassembled and moved by trucks, rail cars or ships to its next location.

## Railroad crane



Rail Crane

A railroad crane has flanged wheels for use on railroads. The simplest form is a crane mounted on a flatcar. More capable devices are purpose-built.

Different types of crane are used for maintenance work, recovery operations and freight loading in goods yards.

## Floating crane



Floating crane

Floating cranes are used mainly in bridge building and port construction, but they are also used for occasional loading and unloading of especially heavy or awkward loads on and off ships. Some floating cranes are mounted on a pontoon, others are specialized crane barges with a lifting capacity exceeding 10,000 short tons (8,929 long tons; 9,072 t) and have been used to transport entire bridge sections. Floating cranes have also been used to salvage sunken ships.

Crane vessels are often used in offshore construction. The largest revolving cranes can be found on SSCV Thialf, which has two cranes with a capacity of 7,100 tonnes (7,826 ST; 6,988 LT) each.

## Aerial crane



Aerial crane

Aerial crane or 'Sky cranes' usually are helicopters designed to lift large loads. Helicopters are able to travel to and lift in areas that are difficult to reach by conventional cranes. Helicopter cranes are most commonly used to lift units/loads onto shopping centers and highrises. They can lift anything within their lifting capacity, (cars, boats, swimming pools, etc.). They also perform disaster relief after natural disasters for clean-up, and during wild-fires they are able to carry huge buckets of water to extinguish fires.

Some aerial cranes, mostly concepts, have also used lighter-than air aircraft, such as airships.

## Fixed

Exchanging mobility for the ability to carry greater loads and reach greater heights due to increased stability, these types of cranes are characterised that they, or at least their main structure does not move during the period of use. However, many can still be assembled and disassembled.

## Tower crane



Tower crane



Tower crane cabin



A tower crane rotates on its axis before lowering the lifting hook.

Tower cranes are a modern form of balance crane that consist of the same basic parts. Fixed to the ground on a concrete slab (and sometimes attached to the sides of structures as well), tower cranes often give the best combination of height and lifting capacity and are used in the construction of tall buildings. The base is then attached to the mast which gives the crane its height. Further the mast is attached to the slewing unit (gear and motor) that allows the crane to rotate. On top of the slewing unit there are three main parts which are: the long horizontal jib (working arm), shorter counter-jib, and the operators cab.

The long horizontal jib is the part of the crane that carries the load. The counter-jib carries a counterweight, usually of concrete blocks, while the jib suspends the load to and from the center of the crane. The crane operator either sits in a cab at the top of the tower or controls the crane by radio remote control from the ground. In the first case the operator's cab is most usually located at the top of the tower attached to the turntable, but can be mounted on the jib, or partway down the tower. The lifting hook is operated by the crane operator using electric motors to manipulate wire rope cables through a system of sheaves. The hook is located on the long horizontal arm to lift the load which also contains its motor.

In order to hook and unhook the loads, the operator usually works in conjunction with a signaller (known as a 'dogger', 'rigger' or 'swamper'). They are most often in radio contact, and always use hand signals. The rigger or dogger directs the schedule of lifts for the crane, and is responsible for the safety of the rigging and loads. A tower crane is usually assembled by a telescopic jib (mobile) crane of greater reach and in the case of tower cranes that have risen while constructing very tall skyscrapers, a smaller crane (or derrick) will often be lifted to the roof of the completed tower to dismantle the tower crane afterwards.

The average fee to rent a 150-foot (46 m) crane is \$60,000 for assembly and disassembly and an additional \$15,000 per month. It is often claimed that a large fraction of the tower cranes in the world are in use in Dubai. The exact percentage remains an open question.

## Self-erecting crane



Self-erecting crane

Generally a type of tower crane, these cranes, also called self-assembling or "Kangaroo" cranes, lift themselves off the ground using jacks, allowing the next section of the tower to be inserted at ground level or lifted into place by the partially erected crane itself. They can thus be assembled without outside help, or can grow together with the building or structure they are erecting.

## Telescopic crane



Telescopic crane

A telescopic crane has a boom that consists of a number of tubes fitted one inside the other. A hydraulic or other powered mechanism extends or retracts the tubes to increase or decrease the total length of the boom. These types of booms are often used for short term construction projects, rescue jobs, lifting boats in and out of the water, etc. The relative compactness of telescopic booms make them adaptable for many mobile applications.

Note that while telescopic cranes are not *automatically* mobile cranes, many of them are. These are often truck-mounted.

## Hammerhead crane



Hammerhead crane

The "hammerhead", or giant cantilever, crane is a fixed-jib crane consisting of a steel-braced tower on which revolves a large, horizontal, double cantilever; the forward part of this cantilever or jib carries the lifting trolley, the jib is extended backwards in order to form a support for the machinery and counter-balancing weight. In addition to the motions of lifting and revolving, there is provided a so-called "racking" motion, by which the lifting trolley, with the load suspended, can be moved in and out along the jib without altering the level of the load. Such horizontal movement of the load is a marked feature of later crane design. These cranes are generally constructed in large sizes, up to 350 tons.

The design of *hammerkran* evolved first in Germany around the turn of the 19th century and was adopted and developed for use in British shipyards to support the battleship construction program from 1904 to 1914. The ability of the hammerhead crane to lift heavy weights was useful for installing large pieces of battleships such as armour plate and gun barrels. Giant cantilever cranes were also installed in naval shipyards in Japan and in the USA. The British Government also installed a giant cantilever crane at the Singapore Naval Base (1938) and later a copy of the crane was installed at Garden Island Naval Dockyard in Sydney (1951). These cranes provided repair support for the battle fleet operating far from Great Britain.

The principal engineering firm for giant cantilever cranes in the British Empire was Sir William Arrol & Co Ltd building 14. Of around 60 built across the world few remain; 7 in England and Scotland of about 15 worldwide.

The Titan Clydebank is one of the 4 Scottish cranes on the Clydebank and preserved as a tourist attraction.

### **Level luffing crane**



Level luffing crane

Normally a crane with a hinged jib will tend to have its hook also move up and down as the jib moves (or *luffs*). A level luffing crane is a crane of this common design, but with an extra mechanism to keep the hook level when luffing.

## **Gantry crane**



Gantry crane

A gantry crane has a hoist in a fixed machinery house or on a trolley that runs horizontally along rails, usually fitted on a single beam (mono-girder) or two beams (twin-girder). The crane frame is supported on a gantry system with equalized beams and wheels that run on the gantry rail, usually perpendicular to the trolley travel direction. These cranes come in all sizes, and some can move very heavy loads, particularly the extremely large examples used in shipyards or industrial installations. A special version is the container crane (or "Portainer" crane, named by the first manufacturer), designed for loading and unloading ship-borne containers at a port.

## **Overhead crane**

Also known as a 'suspended crane', an overhead crane works very similar to a gantry crane but instead of the whole crane moving, only the hoist/trolley assembly moves in one direction along one or two fixed beams, often mounted along the side walls or on elevated columns in the assembly area of factory. Some of these cranes can lift very heavy loads.



Overhead crane being used in typical machine shop. The hoist is operated via a wired pushbutton station to move system and the load in any direction



Deck crane



Bulk-handling crane

### **Deck crane**

Located on the ships and boats, these are used for cargo operations or boat unloading and retrieval where no shore unloading facilities are available. Most are diesel-hydraulic or electric-hydraulic.

## Jib crane



Jib crane

A jib crane is a type of crane where a horizontal member (*jib* or *boom*), supporting a moveable hoist, is fixed to a wall or to a floor-mounted pillar. Jib cranes are used in industrial premises and on military vehicles. The jib may swing through an arc, to give additional lateral movement, or be fixed. Similar cranes, often known simply as hoists, were fitted on the top floor of warehouse buildings to enable goods to be lifted to all floors.

A loader crane (also called a *knuckle-boom crane* or *articulating crane*) is a hydraulically-powered articulated arm fitted to a truck or trailer, and is used for

loading/unloading the vehicle. The numerous jointed sections can be folded into a small space when the crane is not in use. One or more of the sections may be telescopic. Often the crane will have a degree of automation and be able to unload or stow itself without an operator's instruction.

Unlike most cranes, the operator must move around the vehicle to be able to view his load; hence modern cranes may be fitted with a portable cabled or radio-linked control system to supplement the crane-mounted hydraulic control levers.

In the UK and Canada, this type of crane is often known colloquially as a "Hiab", partly because this manufacturer invented the loader crane and was first into the UK market, and partly because the distinctive name was displayed prominently on the boom arm.

A **rolloader** crane is a loader crane mounted on a chassis with wheels. This chassis can ride on the trailer. Because the crane can move on the trailer, it can be a light crane, so the trailer is allowed to transport more goods.

### **Stacker crane**

A crane with a forklift type mechanism used in automated (computer controlled) warehouses (known as an automated storage and retrieval system (AS/RS)). The crane moves on a track in an aisle of the warehouse. The fork can be raised or lowered to any of the levels of a storage rack and can be extended into the rack to store and retrieve product. The product can in some cases be as large as an automobile. Stacker cranes are often used in the large freezer warehouses of frozen food manufacturers. This automation avoids requiring forklift drivers to work in below freezing temperatures every day.

## Similar machines



Shooting a film from crane

The generally-accepted definition of a crane is a machine for lifting and moving heavy objects by means of ropes or cables suspended from a movable arm. As such, a lifting machine that does not use cables, or else provides only vertical and not horizontal movement, cannot strictly be called a 'crane'.

Types of crane-like lifting machine include:

- Block and tackle

- Capstan (nautical)
- Hoist (device)
- Winch
- Windlass

More technically-advanced types of such lifting machines are often known as 'cranes', regardless of the official definition of the term.

## Special examples

- Finnieston Crane (aka the *Stobcross Crane*)
  - Category A -listed example of a 'hammerhead' (cantilever) crane in Glasgow's former docks
  - 50 m (164 ft) tall, 175 tonnes (193 ST; 172 LT) capacity, built 1926
- Taisun
  - double bridge crane at Yantai, China.
  - 20,000 tonnes (22,046 ST; 19,684 LT) capacity, World Record Holder
  - 133 m (436 ft) tall, 120 m (394 ft) span, lift-height 80 m (262 ft)
- Kockums Crane
  - shipyard crane formerly at Kockums, Sweden.
  - 138 m (453 ft) tall, 1,500 tonnes (1,653 ST; 1,476 LT) capacity, since moved to Ulsan, South Korea
- Samson and Goliath (cranes)
  - two gantry cranes at the Harland & Wolff shipyard in Belfast
  - *Goliath* is 96 m (315 ft) tall, *Samson* is 106 m (348 ft)
  - span 140 m (459 ft), lift-height 70 m (230 ft), capacity 840 tonnes (926 ST; 827 LT) each (1,600 tonnes / 1,764 short tons; 1,575 long tons combined)
- Breakwater Crane Railway
  - self-propelled steam crane that formerly ran the length of the breakwater at Douglas.
  - ran on 10 feet (3.05 m) gauge track, the broadest in the British Isles