

Handbook of  
Engineering and Construction  
Vehicles



Niki Poirier  
Jacelyn Alfred

First Edition, 2012

ISBN 978-81-323-0908-6

© All rights reserved.

*Published by:*

**Academic Studio**

4735/22 Prakashdeep Bldg,

Ansari Road, Darya Ganj,

Delhi - 110002

Email: [info@wtbooks.com](mailto:info@wtbooks.com)

# Table of Contents

Chapter 1 - Skid Loader & Skidder

Chapter 2 - Winter Service Vehicle

Chapter 3 - Concrete Mixer

Chapter 4 - Excavator

Chapter 5 - Grader & Harvester (Forestry)

Chapter 6 - Forklift Truck

Chapter 7 - Loader (Equipment)

Chapter 8 - Road Roller

Chapter 9 - Tractor

Chapter 10 - Aerial Work Platform

Chapter 11 - Dump Truck

Chapter 12 - Backhoe

Chapter 13 - Backhoe Loader

Chapter 14 - Bulldozer

Chapter 15 - Dragline Excavator

Chapter 16 - Drilling Rig

## Chapter- 1

# Skid Loader & Skidder

## Skid loader



A Gehl skid loader

A **skid loader** or **skid steer loader** is a small rigid frame, engine-powered machine with lift arms used to attach a wide variety of labor-saving tools or attachments. Though sometimes they are equipped with tracks, skid-steer loaders are typically four-wheel drive vehicles with the left-side drive wheels independent of the right-side drive wheels. By having each side independent of the other, wheel speed and direction of rotation of the wheels determine the direction the loader will turn.

Skid steer loaders are capable of zero-radius, "pirouette" turning, which makes them extremely maneuverable and valuable for applications that require a compact, agile loader.

Unlike in a conventional front loader, the lift arms in these machines are alongside the driver with the pivot points behind the driver's shoulders. Because of the operator's proximity to moving booms, early skid loaders were not as safe as conventional front loaders, particularly during entry and exit of the operator. Modern skid loaders have fully-enclosed cabs and other features to protect the operator. Like other front loaders, it can push material from one location to another, carry material in its bucket or load material into a truck or trailer.

### **Operation**



A John Deere 280 skid loader moving mulch

A Skid Steer loader can sometimes be used in place of a large excavator by digging a hole from the inside. The skid loader first digs a ramp leading to the edge of the desired excavation. It then uses the ramp to carry material out of the hole. The skid loader reshapes the ramp making it steeper and longer as the excavation deepens. This method is particularly useful for digging under a structure where overhead clearance does not allow for the boom of a large excavator, such as digging a basement under an existing house.

The conventional bucket of many skid loaders can be replaced with a variety of specialized buckets or attachments, many powered by the loader's hydraulic system.

These include backhoe, hydraulic breaker, pallet forks, angle broom, sweeper, auger, mower, snow blower, stump grinder, tree spade, trencher, dumping hopper, ripper, tillers, grapple, tilt, roller, snow blade, wheel saw, cement mixer, and wood chipper machine.

## ***History***



Bobcat skid loader clearing snow with snowblower attachment

The first three-wheeled, front-end loader was invented by brothers Cyril and Louis Keller (manufacturer) in Rothsay, Minnesota, in 1957. The Kellers built the loader to help a farmer mechanize the process of cleaning turkey manure from his barn. The light and compact machine, with its rear caster wheel, was able to turn around within its own length, while performing the same tasks as a conventional front-end loader.

The Melroe brothers, of Melroe Manufacturing Company in Gwinner, N.D., purchased the rights to the Keller loader in 1958 and hired the Kellers to continue refining their invention. As a result of this partnership, the M-200 Melroe self-propelled loader was introduced at the end of 1958. It featured two independent front-drive wheels and a rear caster wheel, a 12.9-hp engine and a 750-lb. lift capacity. Two years later they replaced the caster wheel with a rear axle and introduced the M-400, the first four-wheel, skid-steer loader. It quickly became the Melroe Bobcat. The term "Bobcat" is sometimes used as a generic term for skid-steer loaders. The M-440 was powered by a 15.5-hp engine and had an 1100-lb. rated operating capacity. Skid-steer development continued into the mid-1960s with the M600 loader.

Many manufacturers have their own versions of the skidloader (often referred to as a Skidsteer in the Construction Industry), including: LiuGong, Volvo, John Deere, Case, JLG, JCB, New Holland, Gehl Company, Mustang, ASV, Caterpillar, Bobcat, Komatsu, Hyundai, and more.

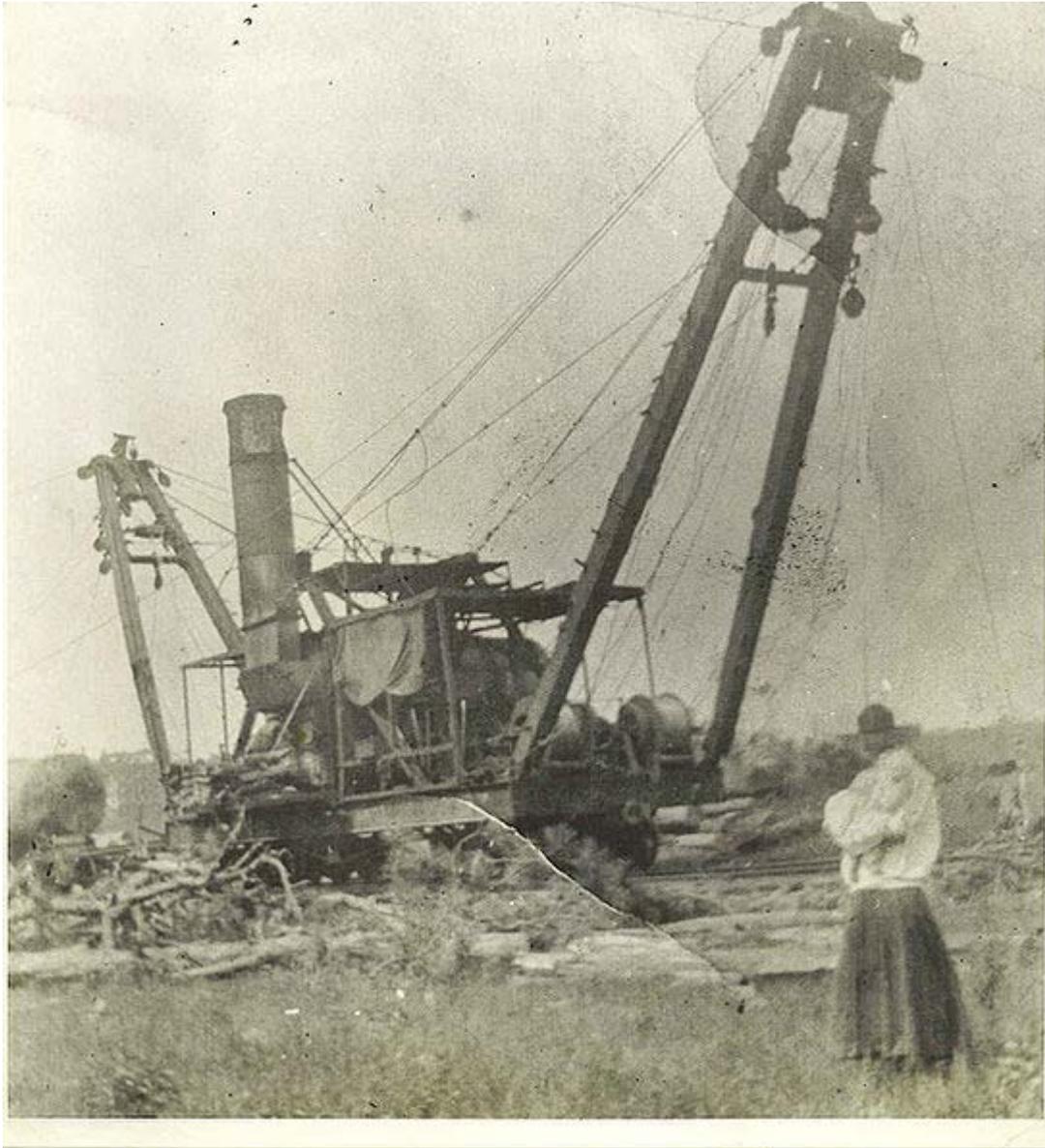
## Skidder



A slip tongue log skidder used in the 19th and early 20th centuries.

A **skidder** is any type of heavy vehicle used in a logging operation for pulling cut trees out of a forest in a process called "skidding", in which the logs are transported from the cutting site to a landing. Here they are loaded onto trucks (or in times past, railroad cars or flumes), and sent to the mill. One exception is that in the early days of logging, when distances to the timberline from the mill were shorter, the landing stage was omitted altogether, and the "skidder" would have been used as the main road vehicle, in place of the trucks, railroad, or flume. Modern forms of skidders can pull trees with a cable/winch, just like the old steam donkeys, or a grapple or a *clam-bunk*.

## History



Clyde Skidder at Marathon Logging Camp ~1921

Early skidders were pulled by a team of horses or mules. The driver would straddle the cart over felled logs, where dangling tongs would be positioned to raise the end of the log off the ground. The team pulled the tongue forward, allowing the log to "skid" along between the rolling wheels. These were known as "slip-tongue wheels" Starting in the early 1920s, animals were gradually replaced by gasoline-powered crawlers, although some small operations continue to use them. In other places, steel "arches" were used behind the crawlers. Similar in function to the slip-tongue wheels, arches were used to reduce friction by raising up one end of the load, which was dangled from a cable which in turn ran down the back of the arch, & was raised or lowered by the crawler's winch.

Another piece similar to the arch was the "bummer", which was simply a small trailer to be towed behind a crawler, on top of which one end of the log load would rest.

The early mechanical skidders were steam powered. They traveled on railroads, known as "dummylines" and the felled trees were dragged or "skidded" to the railroad where they were later loaded onto rail cars. Some were just steam donkeys, others were more complicated. One popular brand was the Clyde Skidder, built by Clyde Ironworks in Duluth, Minnesota. The Clyde skidder illustrated was photographed at the Marathon Lumber Company logging operations near Newton, Mississippi in the early 1920s. Although these machines appear to be large and cumbersome, they were true workhorses of their day. The Clyde was capable of retrieving logs from four different points at the same time. Each cable, or lead, was approximately 1000 feet in length. Once the logs were attached and a clearance signal was sent for retrieval, they could be skidded at a speed of 1000 feet per minute. Working conditions around these machines were very dangerous. The largest of these was the Lidgerwood skidder, which not only brought logs to the landing from the cutting site, but loaded them onto railroad cars as well, making it both a skidder & loader.

### ***Modern equivalents***

Contemporary skidders are tracked or four wheel drive tractors with a turbocharged diesel engine, winch and steel, funnel-shaped guards on the rear to protect the wheels. They have articulated steering and usually a small, adjustable, push-blade on the front. The operator/logger is protected from falling or flying debris (or parted cables, or rolling over) by a steel enclosure. They are one of the few logging machines that is capable of thinning or selective logging in larger timber. Forwarders can haul small short pieces out, but if mature timber is to be thinned, a skidder is one of the few options for taking out some trees while leaving others. While selective logging can be done badly in a host of ways, taking some trees while leaving some may be a preferred alternative to taking all the trees.

The skidder can also be used for pulling tree stumps, pushing over small trees, and preliminary grading of a logging path known as a "skid road".

A positive thing about the skidder is that while wood is being yarded (pulled), tree particles and seeds are cultivated into the soil.

One disadvantage of skidder logging in thinning operations is the damage to remaining trees as branches and trunks are dragged against them, tearing away the protective bark of living trees. Another concern is the deep furrows sometimes made by skidders in the topsoil, especially when using tires with chains, which alter surface runoff patterns and increases the costs of forest rehabilitation and reforestation.

## Versions

### Cable skidders



Caterpillar 528 cable skidder in Apiary, Oregon.

On a cable skidder, the cable is reeled out and attached to a pull of cut timber, then the winch pulls the load toward the skidder. The winch or grapple holds the trees while the skidder drags them to a landing area. Cable skidders are less popular than in the past. They are more labor intensive than grapple skidders because someone (the operator or a second person) must drag the winch line out to the logs and hook them up. This is helpful where it is not possible to drive the machine close to the log (such as in steep hills).

## Grapple skidders



Modern dual function grapple skidder

Alternately, some skidders have a hydraulic grapple bucket instead of a winch, and the bucket- attached to the skidder by a boom- grabs and lifts the timber.

There are three types of 'fixed boom' grapple skidders: a single function boom type with two hydraulic cylinders, only allowing the boom to lower in one position. The dual function booms, (such as the one pictured) which has four cylinders, which allows for adjusting the boom in two different places. The third type that permits the grapple boom to be swung from side to side allowing spread out trees to be grabbed at once.

In some areas, loggers have combined a hydraulic claw on the side the blade of their grapple skidders, making it possible to pile logs in some cases. (More commonly seen on cable skidders) This also permits hauling back bark and tops when returning from a "landing" to a cut block.

## Chapter- 2

# Winter Service Vehicle



A winter service vehicle clearing roads near Toronto, Ontario, Canada

A **winter service vehicle (WSV)**, or **snow removal vehicle**, is used to clear thoroughfares of ice and snow. Winter service vehicles are usually based on dump truck chassis, with adaptations allowing them to carry specially designed snow removal equipment. Many authorities also use smaller vehicles on sidewalks, footpaths, and cycleways. Road maintenance agencies and contractors in temperate or polar areas often own several winter service vehicles, using them to keep the roads clear of snow and ice and safe for driving during winter. Airports use winter service vehicles to keep both aircraft surfaces, and runways and taxiways free of snow and ice, which, besides endangering aircraft takeoff and landing, can interfere with the aerodynamics of the craft.

The earliest winter service vehicles were snow rollers, designed to maintain a smooth, even road surface for sleds, although horse-drawn snowplows and gritting vehicles are

recorded in use as early as 1862. The increase in motor car traffic and aviation in the early 20th century led to the development and popularisation of large motorised winter service vehicles. Sometimes the grit caused erosion which created potholes.

## **History**



An early horse-drawn snowplow at the Rosstag Burggen, a historical reenactment of life in 19th century Germany.

Although snow removal dates back to at least the Middle Ages, early attempts merely involved using a shovel or broom to remove snow from walkways and roads. Before motorised transport, snow removal was seen as less of a concern; unpaved roads in rural areas were dangerous and bumpy, and snow and ice made the surface far smoother. Most farmers could simply replace their wagons with sleds, allowing the transport of heavy materials such as timber with relative ease. Early communities in the northern regions of the United States and Canada even used animal-drawn snow rollers, the earliest winter service vehicles, to compress the snow covering roads. The compression increased the life of the snow and eased passage for sleds. Some communities even employed snow wardens to spread or "pave" snow onto exposed areas such as bridges, to allow sleds to use these routes.

However, with the increase in paved roads and the increasing size of cities, snow-paving fell out of favour, as the resultant slippery surfaces posed a danger to pedestrians and traffic. The earliest patents for snowplows date back to 1840, but there are no records of their actual use until 1862, when the city of Milwaukee began operating horse-drawn carts fitted with snowplows. The horse-drawn snowplow quickly spread to other cities, especially those in areas prone to heavy snowfall.



A Unimog snow blower from 1955.

The first motorised snowplows were developed in 1913, based on truck and tractor bodies. These machines allowed the mechanisation of the snow clearing process, reducing the labor required for snow removal and increasing the speed and efficiency of the process. The expansion of the aviation industry also acted as a catalyst for the development of winter service vehicles during the early 20th century. Even a light dusting of snow or ice could cause an aeroplane to crash, so airports erected snow fences around airfields to prevent snowdrifts, and began to maintain fleets of vehicles to clear runways in heavy weather.

With the popularisation of the motor car, it was found that plowing alone was insufficient for removing all snow and ice from the roadway, leading to the development of gritting vehicles, which used sodium chloride to accelerate the melting of the snow. Early attempts at gritting were resisted, as the salt used encouraged rusting, causing damage to the metal structures of bridges and the shoes of pedestrians. However, as the number of motoring accidents increased, the protests subsided and by the end of the 1920s, many cities in the United States used salt and sand to clear the roads and increase road safety. As environmental awareness increased through the 1960s and 1970s, gritting once again came under criticism due to its environmental impact, leading to the development of alternative de-icing chemicals and more efficient spreading systems.

## Design



The cab of a winter service vehicle in Boston, Massachusetts, showing the plow-frame, amber lightbar, and retroreflectors

Winter service vehicles are usually based on dump truck chassis, which are then converted into winter service vehicles either by the manufacturer or an aftermarket third-party. A typical modification involves the replacement of steel components of the vehicle with corrosion resistant aluminium or fibreglass, waterproofing any exposed electronic components, replacement of the stock hopper with a specially designed gritting body, the addition of a plow frame, reinforcement of the wheels, bumpers to support the heavy blade, and the addition of extra headlamps, a light bar, and retroreflectors for visibility.

Other common changes include the replacement of the stock tires with rain tires or mud and snow tires and the shortening of the vehicle's wheelbase to improve maneuverability. For smaller applications smaller trucks are used. In Canada pickup trucks are used with snow removal operations with a blade mounted in front and optional de-icing equipment installed in the rear. Underbody scrapers are also used by some agencies and are mounted between axles, distributing plowing stresses on the chassis more evenly.



Truck using underbody scraper, notice high contrast cab paint and sand hopper stripe, Deschutes County Oregon

In most countries, winter service vehicles usually have amber light bars, which are activated to indicate that the vehicle is operating below the local speed limit or otherwise poses a danger to other traffic, either by straddling lanes or by spreading grit or de-icer. In some areas, such as the Canadian province of Ontario, winter service vehicles use the blue flashing lights associated with emergency service vehicles, rather than the amber or orange used elsewhere. Many agencies also paint their vehicles in high-contrast orange or yellow to allow the vehicles to be seen more clearly in whiteout conditions.

Some winter service vehicles, especially those designed for use on footpaths or pedestrian zones, are built on a far smaller chassis using small tractors or custom made vehicles. These vehicles are often multi-purpose, and can be fitted with other equipment such as brushes, lawnmowers or cranes—as these operations are generally unable to run during heavy snowfalls, there is generally little overlap between the different uses, reducing the size of the fleet required by the agency or contractor.



A HMMWV with plow, serving with the United States Army 27th Engineer Battalion in Kosovo.

Modern winter service vehicles will usually also have a satellite navigation system connected to a weather forecast feed, allowing the driver to choose the best areas to treat and to avoid areas in which rain is likely, which can wash away the grit used—the most advanced can even adapt to changing conditions, ensuring optimal gritter and plow settings. Most run on wheels, often with snow chains or studded tires, but some are mounted on caterpillar tracks, with the tracks themselves adapted to throw the snow towards the side of the road. Off-road winter service vehicles mounted on caterpillar tracks are known as snowcats. Snowcats are commonly fitted with snowplows or snow groomers, and are used by ski resorts to smooth and maintain pistes and snowmobile runs, although they can also be used as a replacement for chairlifts.

Military winter service vehicles are heavily armoured to allow for their use in combat zones, especially in Arctic and mountain warfare, and often based on combat bulldozers or HMMWVs. Military winter service vehicles have been used by the United Nations, Kosovo Force, and the U.S. Army in Central Europe during the Kosovo War, while during the Cold War, the Royal Marines and Royal Corps of Signals deployed a number of tracked vehicles in Norway to patrol the NATO border with the Soviet Union.

## **Operation**



A salt barn near Lake Michigan, used for storing grit and providing limited accommodation for gritter drivers during winter storms.

Winter service vehicles are operated by both government agencies and by private subcontractors. Public works in areas which regularly receive snowfall usually maintain a fleet of their own vehicles or pay retainers to contractors for priority access to vehicles in winter, while cities where snow is a less regular occurrence may simply hire the vehicles as needed. Winter service vehicles in the United Kingdom are the only road-going vehicles entitled to use red diesel. Though the vehicles still use public highways, they are used to keep the road network operational, and forcing them to pay extra tax to do so would discourage private contractors from assisting with snow removal on public roads. Winter service vehicle drivers in the United States must hold a Class A or Class B commercial driver's license. Although some agencies in some areas, such as the U.S. state of Minnesota, allow winter service vehicle drivers to operate without any extra training, most provide supplemental lessons to drivers to teach them the most effective and safe methods of snow removal. Many require that trainee drivers ride-along with more experienced drivers, and some even operate specially designed driving simulators, which can safely replicate dangerous winter driving conditions. Other organisations require that all staff have a recognised additional licence or certificate—the United Kingdom Highways Agency for example requires that all staff have both a City & Guilds qualification and a supplemental Winter Maintenance Licence.



A brine tank at a service depot in Germany.

Winter service vehicle drivers usually work part time, before and during inclement weather only, with drivers working a 12 to 16 hour shift. Main roads are typically gritted in advance, to reduce the disruption to the network. Salt barns are provided at regular intervals for drivers to collect more grit, and bedding is provided at road maintenance depots for drivers to use between shifts in heavy or prolonged storms.

Weather conditions typically vary greatly depending on altitude; hot countries can experience heavy snowfall in mountainous regions yet receive very little in low-lying areas, increasing the accident rate among drivers inexperienced in winter driving. In addition, road surface temperatures can fall rapidly at higher altitudes, precipitating rapid frost formation. As a result, gritting and plowing runs are often prioritised in favour of clearing these mountain roads, especially at the start and end of the snow season. The hazardous roads through mountain passes pose additional problems for the large winter service vehicles. The heavy metal frame and bulky grit makes hill climbing demanding for the vehicle, so vehicles have extremely high torque transmission systems to provide enough power to make the climb. Furthermore, because the tight hairpin turns found on mountain slopes are difficult for long vehicles to navigate, winter service vehicles for use in mountainous areas are shortened, usually from six wheels to four.

## ***Equipment***

### **De-icer**



A de-icing vehicle treating an American Airlines MD-80 at Syracuse Hancock International Airport, New York

De-icers spray heated de-icing fluid, often propylene glycol or ethylene glycol, onto icy surfaces such as the bodies of aircraft and road surfaces. These prevent ice from forming on the body of the aircraft while on the ground. Ice makes the surface of the wings rougher, reducing the amount of lift they provide while increasing drag. The ice also increases the weight of the aircraft and can affect its balance.

Aircraft de-icing vehicles usually consist of a large tanker truck, containing the concentrated de-icing fluid, with a water feed to dilute the fluid according to the ambient temperature. The vehicle also normally has a cherry picker crane, allowing the operator to spray the entire aircraft in as little time as possible; an entire Boeing 737 can be treated in under 10 minutes by a single de-icing vehicle.

Some road contractors also choose to use de-icers as an alternative to gritters; the vehicle carries a tank of brine, which is sprayed on the road surface. Brine acts faster than solid salt and does not require compression by passing traffic to become effective. The brine is also more environmentally friendly, as less salt is required to treat the same length of road. Airport runways are also de-iced by sprayers fitted with long spraying arms. These arms are wide enough to cross the entire runway, and allow de-icing of the entire airstrip to take place in a single pass, reducing the length of time that the runway is unavailable.

## Front-end loader



Loader removing snow in Jyväskylä, Finland.

Front-end loaders are commonly used to remove snow especially from sidewalks, parking lots, and other areas too small for using snowplows and other heavy equipment. They are sometimes used as snowplows with a snowplow attachment but commonly have a bucket or snowbasket, which can also be used to load snow into the rear compartment of a snowplow or dump truck.

In Canada front end loaders with large box like front end attachment are used to clear snow in parking lots in malls and other institutions.

## Gritter

A **gritter**, also known as a **sander**, salt spreader or salt truck, is found on most winter service vehicles. Indeed, the gritter is so commonly seen on winter service vehicles that the terms are sometimes used synonymously. Gritters are used to spread grit, a mixture of sand and rock salt, onto roads. The grit is stored in the large hopper on the rear of the vehicle, with a wire mesh over the top to prevent foreign objects from entering the spreading mechanism and hence becoming jammed. The salt is generally spread across the roadway by an impeller, attached by a hydraulic drive system to a small onboard engine. However, until the 1970s, the grit was often spread manually using shovels by

men riding on the back of the truck, and some older spreading mechanisms still require grit be manually loaded into the impeller from the hopper.



The hopper and impeller of a gritter in Germany

Salt reduces the melting point of ice by freezing-point depression, causing it to melt at lower temperatures and run off to the edge of the road, while sand increases traction by increasing friction between car tires and roadways. The amount of salt dropped varies with the condition of the road; to prevent the formation of light ice, approximately 10 grams per square metre (2 lb/1000 ft<sup>2</sup>) is dropped, while thick snow can require up to 40 g/m<sup>2</sup> (8 lb/1000 ft<sup>2</sup>) of salt, independent of the volume of sand dropped. The grit is sometimes mixed with molasses to help adhesion to the road surface. However, the sweet molasses often attracts livestock, who lick the road. The grit is sometimes heated as it is passed out of the nozzle; this helps melt the ice and improves the solubility of the salt. Quieter rural roads may be considered too minor to grit, so grit bins are often provided, containing a mixture of sand and salt for drivers and pedestrians to shovel onto the road themselves. Different types of grit substrate can cause problems for some gritting machines with 'blocking' where sand/grit or salt is damp and clumps together, in these cases an auger or some form of vibrator has to be employed to enable continuous flow of substrate.

Gritters are among the winter service vehicles also used in airports, to keep runways free of ice. However, the salt normally used to clear roads can damage the airframe of aircraft and interferes with the sensitive navigation equipment. As a result, airport gritters spread less dangerous potassium acetate or urea onto the runways instead, as these do not corrode the aircraft or the airside equipment.

## Materials



Salt being spread manually from a gritter by workers in Milwaukee, Wisconsin

Gritters cannot use sea-salt, as it is too fine and dissolves too quickly, so all salt used in gritting comes from salt mines, a non-renewable source. Additionally, high concentrations of salt in soil kill plants, so it is in the interest of operators to limit gritting to an absolute minimum. As a result, road maintenance agencies have advanced networks of ice prediction stations, to prevent unnecessary gritting which not only wastes salt, but can damage the environment and disrupt traffic. The salt dropped is eventually washed away and lost, so it cannot be reused or collected after gritting runs, although the insoluble sand can be collected and recycled by street sweeping vehicles and mixed with new salt crystals to be reused in later batches of grit. As a result, operators must regularly purchase large quantities of rock salt.

In some areas of the world, including Berlin, dropping salt is prohibited altogether, except on the highest-risk roads; plain sand, without any melting agents, is spread instead. Although this protects the environment, it is more labour-intensive, as more gritting runs are needed; and as the sand is insoluble, it tends to accumulate at the sides of the road, making it more difficult for buses to pull in at bus stops. Other areas use alternative chemicals which are less harmful to the environment and cause less corrosion damage to metallic structures. The U.S. state of Oregon uses magnesium chloride, a

relatively cheap chemical similar in molecular structure to sodium chloride, but less reactive, while New Zealand uses calcium magnesium acetate, which avoids the environmentally harmful chloride ion altogether. Urea is sometimes used to grit suspension bridges, as it does not react with iron or steel at all, but urea is less effective than salt, and can cost up to 7 times weight-for-weight. Most grit is mixed with hydrous sodium ferrocyanide which, while harmless in its natural form, can undergo photodissociation in strong sunlight to produce the extremely toxic chemical hydrogen cyanide. Although sunlight is generally not intense enough to cause this in polar and temperate regions, salt deposits must be kept as far as possible from waterways to avert the possibility of cyanide-tainted run-off entering fisheries or farms. Gritting vehicles are also dangerous to overtake; as grit is scattered across the entire roadway, loose pieces can damage the paintwork and windows of passing cars. Loose salt does not provide sufficient traction for motorcycles, which can lead to skidding, especially around corners.

Gritters can also be used in hot weather, when temperatures are high enough to melt the bitumen used in asphalt. The grit is dropped to provide a protective layer between the road surface and the tires of passing vehicles, which would otherwise damage the road surface by "plucking out" the bitumen-coated aggregate from the road surface.

### **Snow blower**



A Zaugg snow blower fitted with snow chains

Snow blowers, also known as rotating snowplows or snow cutters, can be used in place of snowplows on winter service vehicles. A snow blower consists of a rapidly spinning

blade which cuts through the snow, forcing it out of a funnel attached to the top of the blower. Snow blowers typically clear much faster than plows, with some clearing in excess of 5000 tonnes of snow per hour, and can cut through far deeper snow drifts than a snowplow can. In addition, snow blowers can remove snow from the roadway completely, rather than piling it at the side of the road, making passage easier for other road users and preventing the windrow from blocking driveways.

## Snow groomer



An Austrian snowcat with grooming blade hauling a roller

A snow groomer is a machine designed to smooth and compact the snow, rather than removing it altogether. Early snow groomers were used by residents of rural areas to compress the snow close to their homes, and consisted of a heavy roller hauled by oxen which compacted the snow to make a smooth surface for sledging. With the invention of the motor car, snow groomers were replaced by snowplows and snow blowers on public thoroughfares, but remained in use at ski resorts, where they are used to maintain smooth, safe trails for various wintersports, including skiing, snowboarding and snowmobiling. Snow groomers remained unchanged throughout the 20th century, with most consisting of heavy roller which could be attached to a tractor or snowcat and then hauled across the area to be groomed. The development of more advanced electronic systems in the 1980s allowed manufacturers to produce snow groomers which could work on and replicate a much wider range of terrains, with the most modern even able to produce half-pipes and

ramps for snowboarding. Snow groomers are also used in conjunction with snow cannons, to ensure that the snow produced is spread evenly across the resort. However, snow groomers have a detrimental effect on the environment within the resort. Grooming removes nutrients and minerals from the soil underneath the snow and the regular pressure from the grooming vehicle increases the infiltration rate of the soil while decreasing the field capacity. This increases the rate at which water can soak through the soil, making it more prone to erosion.

## Snow melter



Snow melters working at JFK Airport, New York

A snow melting vehicle works by scooping snow into a melting pit located in a large tank at the rear of the vehicle. Around the melting pit is a smaller tank full of boiling water, heated by a powerful burner. The gases from the burner are bubbled through the water, causing some of the water to spill over into the melting pit, melting the snow instantly. The meltwater is discharged into the storm drains.

As they have to carry the large water tank and fuel for the burner, snow melting machines tend to be much larger and heavier than most winter service vehicles, at around 18 metres (59 ft), with the largest being hauled by semi-trailer tractor units. In addition, the complicated melting process means that snow melting vehicles have a much lower capacity than the equivalent plow or blower vehicle; the largest snow melter can remove

500 tons of snow per hour, compared to the 5000 tons per hour capacity of any large snow blower. However, snow melters are in some ways more environmentally friendly than gritters, as they do not spray hazardous materials, and pollutants from the road surface can be separated from the meltwater and disposed of safely. In addition, as the snow is melted on board, the costs of removing the collected snow from the site is removed. On the other hand, snow melting can require large amounts of energy, which has its own costs and environmental impact.

## Snowplow



A German snowplow with a hopper for carrying grit

Many winter service vehicles can be fitted with snowplows, to clear roads which are blocked by deep snow. In most cases, the plows are mounted on hydraulically-actuated arms, allowing them to be raised, lowered, and angled to better move snow. Most winter service vehicles include either permanently fixed plows or plow frames: 75% of the UK's Highways Agency vehicles include a plow frame to which a blade can be attached. Winter service vehicles with both a plow frame and a gritting body are known as "all purpose vehicles", and while these are more efficient than using dedicated vehicles, the weight of the hopper often decreases the range of the vehicle. Therefore, most operators will keep at least a few dedicated plowing vehicles in store for heavy storms. In the event that specially designed winter service vehicles are not available for plowing, other service or construction vehicles can be used instead: among those used by various authorities are graders, bulldozers, skid loaders, pickup trucks and rubbish trucks. Front-end loaders can also be used to plow snow. Either a snowplow attachment can be mounted on the loader's

arm in place of the bucket, or the bucket or snowbasket can be used to load snow into the rear compartment of a snowplow or dump truck, which then hauls it away. Snowplows are dangerous to overtake; often, the oncoming lane may not be completely free of snow. In addition, the plow blade causes considerable spray of snow on both sides, which can obscure the vision of other road users.

### **Snow sweeper**



Sand sweeper in Helsinki, Finland

A snow sweeper uses brushes to remove thin layers of snow from the pavement surface. Snow sweepers are used after plowing to remove any remaining material missed by the larger vehicles in areas with very low snow-tolerance, such as airport runways and racing tracks, as the flexible brushes follow the terrain better than the rigid blades of snowplows and snow blowers. These brushes also allow the vehicle to be used on the tactile tiles found at traffic lights and tram stops, without damaging the delicate surface. Unlike other winter service vehicles, snow sweepers do not compress the snow, leaving a rough, high friction, surface behind them. This makes snow sweepers the most efficient method of snow removal for snow depths below 10 centimetres (4 in). Snow deeper than this however can clog the brushes, and most snow sweepers cannot be used to clear snow deeper than 15 centimetres (6 in). A more advanced version of the snow sweeper is the jet sweeper, which adds an air-blower just behind the brushes, in order to blow the swept snow clear of the pavement and prevent the loosened snow from settling.

## Surface friction tester



A NASA surface friction tester at Langley Air Force Base - the extra wheel is clearly visible at the rear.

The surface friction tester is a small fifth wheel attached to a hydraulic system mounted on the rear axle of the vehicle, used to measure road slipperiness. The wheel, allowed to roll freely, is slightly turned relative to the ground so that it partially slides. Sensors attached to the axis of the wheel calculate the friction between the wheel and the pavement by measuring the torque produced by the rotation of the wheel. Surface friction testers are used at airports and on major roadways before ice formation or after snow removal. The vehicle can relay the surface friction data back to the control centre, allowing gritting and clearing to be planned so that the vehicles are deployed most efficiently. Surface friction testers often include a water spraying system, to simulate the effects of rain on the road surface before the rain occurs. The sensors are usually mounted to small compact or estate cars or to a small trailer, rather than the large trucks used for other winter service equipment, as the surface friction tester works best when attached to a lightweight vehicle.

## Chapter- 3

# Concrete Mixer



This portable concrete/mortar mixer has wheels and a towing tongue so that it can be towed by a motor vehicle and moved around the worksite by hand, and its rotation is powered by mains electricity. The lever allows the concrete/mortar to be tipped into a wheelbarrow.

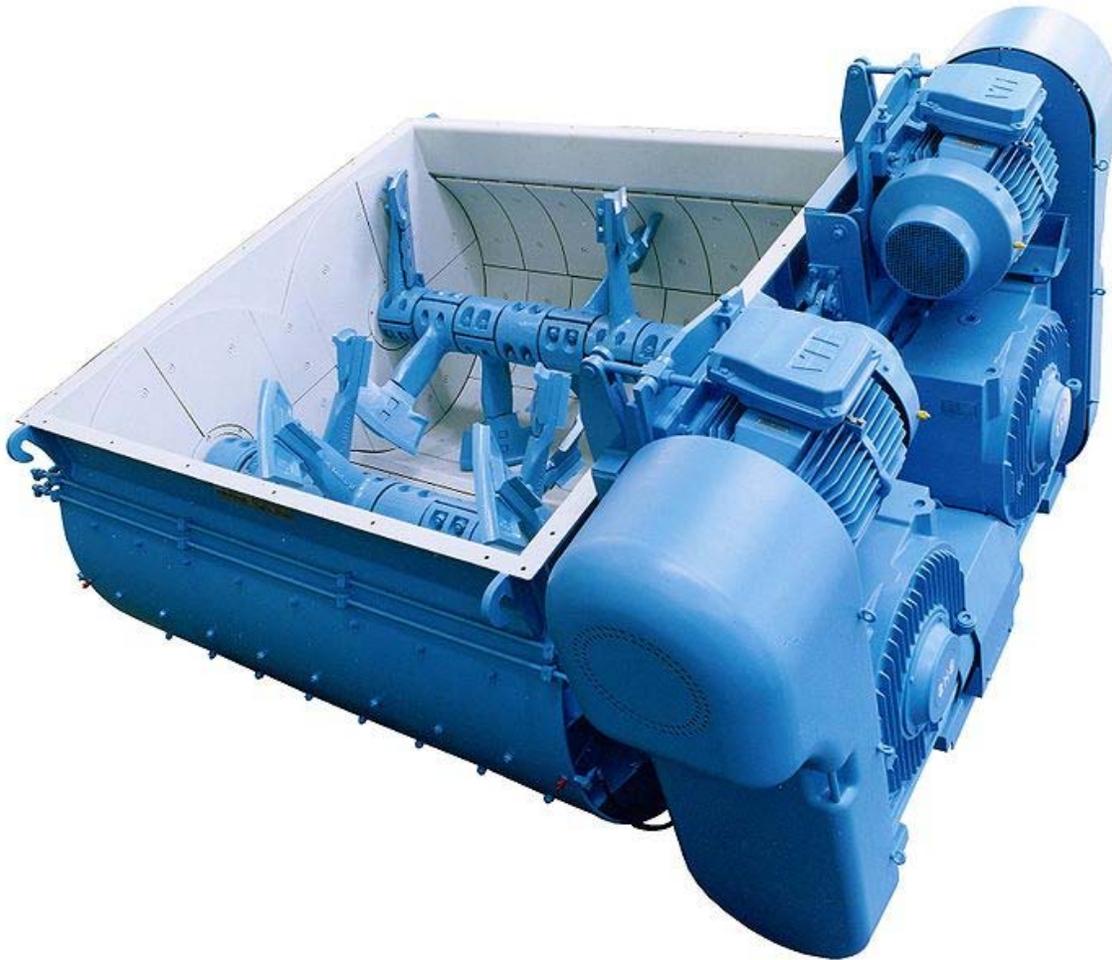


An outdated model of a small-scale concrete mixer. These older mixers are heavy and can not be moved as easily. They are still however equipped with a electrical motor, so they do not pollute the surroundings

A **concrete mixer** (also commonly called a **cement mixer**) is a device that homogeneously combines cement, aggregate such as sand or gravel, and water to form concrete. A typical concrete mixer uses a revolving drum to mix the components. For smaller volume works portable concrete mixers are often used so that the concrete can be made at the construction site, giving the workers ample time to use the concrete before it hardens. An alternative to a machine is mixing concrete or cement by hand. This is usually done in a wheelbarrow; however, several companies have recently begun to sell modified tarps for this purpose.

The concrete mixer was invented by Columbus industrialist Gebhardt Jaeger.

## ***Industrial mixers***



Twin-shaft concrete mixer.

Today's market increasingly requires consistent homogeneity and short mixing times for the industrial production of ready-mix concrete, and more so for precast/prestressed concrete. This has resulted in refinement of mixing technologies for concrete production. Different styles of stationary mixers have been developed, each with its own inherent strengths targeting different parts of the concrete production market. The most common mixers used today fall into 3 categories: Twin-shaft mixers, Vertical axis mixers (Pan and Planetary mixers) and Drum mixers (Reversing Drum and Tilting Drum).

Twin-shaft mixers are known for their high intensity mixing, and short mixing times. These mixers are typically used for high strength concrete, RCC and SCC, typically in batches of 2–6 m<sup>3</sup>. Vertical axis mixers are most commonly used for precast and prestressed concrete. This style of mixer cleans well between batches, and is favoured for coloured concrete, smaller batches (typically 0.75–3 m<sup>3</sup>), and multiple discharge points. Within this category, the Pan mixers are losing popularity to the more efficient Planetary (or counter-current) mixers as the additional mixing action helps in production of more

critical concrete mixes (colour consistency, SCC, etc.). Drum mixers (reversing drum mixer and tilting drum mixers) are used where large volumes of concrete are being produced (batch sizes of 3–9 m<sup>3</sup>). This type of mixer dominates the ready-mixed market as it is known to be capable of high production speeds, ideal for slump concrete, and where overall cost of production is important. Drum mixers are known to have the lowest maintenance and operating cost of the three styles of mixers. All the mixer styles have their own inherent strengths and weaknesses, and all three styles of mixers are used throughout the world to varying degrees of popularity.

### ***Concrete mixing transport truck***



Terex Advance front discharge truck with three lift axles including one tag axle



Front discharge truck cab detail



Volumetric Concrete Mixer



A rear-discharge concrete transport truck



### Low-Profile Mining and Tunneling Concrete Mixer Truck

Special concrete transport trucks (**in-transit mixers**) are made to transport and mix concrete up to the construction site. They can be charged with dry materials and water, with the mixing occurring during transport. With this process, the material has already been mixing. The concrete mixing transport truck maintains the material's liquid state through agitation, or turning of the drum, until delivery. The interior of the drum on a concrete mixing truck is fitted with a spiral blade. In one rotational direction, the concrete is pushed deeper into the drum. This is the direction the drum is rotated while the concrete is being transported to the building site. This is known as "charging" the mixer. When the drum rotates in the other direction, the Archimedes' screw-type arrangement "discharges", or forces the concrete out of the drum. From there it may go onto chutes to guide the viscous concrete directly to the job site. If the truck cannot get close enough to the site to use the chutes, the concrete may be discharged into a concrete pump, connected to a flexible hose, or onto a conveyor belt which can be extended some distance (typically ten or more meters). A pump provides the means to move the material to precise locations, multi-floor buildings, and other distance prohibitive locations. The drum is traditionally made of steel but on some newer trucks as a weight reduction measure, fiberglass has been used.

"Rear discharge" trucks require both a driver and a "chuteman" to guide the truck and chute back and forth to place concrete in the manner suitable to the contractor. Newer "front discharge" trucks have controls inside the cab of the truck to allow the driver to move the chute in all directions. The first front discharge mixer was designed and built by Royal W. Sims of Holladay, Utah.

Concrete mixers are equipped with anywhere from two axles and up. Four, 5 and 6 axle trucks are the most common with the number being determined by the load and local legislation governing allowable loads on the road. These are necessary to distribute the load evenly and allow operation on weight restricted roads and to reduce wear and tear on normal roads. A two or three axle truck during the winter when road weight limits are reduced has no usable payload in many jurisdictions. Other areas may require expensive permits to operate. Additional axles other than those used for steering ("steers") or drivetrain ("drives") may be installed between the steers and drives or behind the drives.

Mixers commonly will have multiple steering axles as well, which generally result in very large turning radii. To facilitate maneuvering the additional axles may be "lift axles" which allows them to be raised off the ground so that they do not scrub (get dragged sideways across the ground) on tight turns, or increase the vehicle's turning radius. Axles installed behind the drives are known as "tag axles" or "booster axles", and are often equipped to turn opposite to the steering axle to reduce scrubbing and automatically lift when the truck is put into a reverse gear.

Tractor trailer combination mixers where the mixer is installed on a trailer instead of a truck chassis are used in some jurisdictions, such as the province of Quebec where even 6 axle trucks would have trouble carrying a useful load.

Concrete mixers generally do not travel far from their plant, as the concrete begins to setup as soon as it is in the truck. Many contractors require that the concrete be in place within 90 minutes after loading. If the truck breaks down or for some other reason the concrete hardens in the truck, workers may need to enter the barrel with jackhammers; dynamite is still occasionally used to break up hardened concrete in the barrel under certain circumstances.

Stephen Stepanian filed a patent application for the first truck mixer in 1916. Trucks weigh 20,000 pounds (9,100 kg) to 30,000 pounds (14,000 kg), and can carry roughly 40,000 pounds (18,000 kg) of concrete although many varying sizes of Mixer Truck are currently in use. The most common truck capacity is 8 cubic yards (6 m<sup>3</sup>).

Most concrete mixers in the UK are limited to a speed of 56 miles per hour (90 km/h).

## **Concrete mixer trailer**



1 Yard Cart-Away Mixing Trailer

A variant of standard concrete transportation is the concrete or cement mixing trailer. These small versions of a transit-mix truck are used to supply short loads of concrete. These cart-away style trailers have a concrete mixing drum with a capacity of between 1-yard and 1.75 yards. Cart-aways are usually pulled behind a pick-up truck and batched from smaller batching systems. The mixing trailer system is popular with rental yards and building material locations, who use them to supply ready-mix to their regular customer base.

## **Television**

On an episode of *MythBusters*, experiments are done to see if dynamite can be used to clean out hardened concrete from inside of a mixer truck, with limited practical results. For the finale, an excessive amount of explosive (800 lbs of commercial blasting agent) is used, and is detonated from a long distance away. Only the engine block is recovered. The explosion left a very clear crater.

On an episode of *Wrecked - Life In The Crash Lane*, O'Hare Towing responds to a call on a construction site to recover a mixer truck that had become stuck in mud, continuing to sink and threatening to roll over. After several unsuccessful attempts to hoist the mixer using a heavy rotator wrecker, the foreman informs the wrecker driver that the mixing drum contains approximately 5 cubic yards of concrete, and asks whether emptying the drum would lighten the truck enough to enable the wrecker to recover it. After emptying the drum, the wrecker operator is able to winch the mixer truck out of the mud & onto solid ground.

In season 5, episode 1 of TV series *MacGyver*, the series' main character uses an engine from a small portable gasoline powered concrete mixer, in order to build an aeroplane

## Chapter- 4

# Excavator



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

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

### ***Terminology***

Excavators are also called **diggers**, a **JCB** (which is a proprietary name) or **360-degree excavators** sometimes abbreviated simply to **360**. Tracked excavators are sometimes

called "trackhoes" by analogy to the backhoe. In the UK, wheeled excavators are sometimes known as "rubber ducks." In Japan, the alias **Yumbo** (ユンボ *Yunbo*?) is sometimes used for excavators, after the 1961 Mitsubishi Yumbo Y35.

## **Usage**

Excavators are used in many ways:

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



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



Excavator demolishing a house. Note the hydraulic thumb



Link-Belt excavator trenching.

## ***Configurations***

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

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

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

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

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

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

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

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

### ***Excavator attachments***

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

## Chapter- 5

# Grader & Harvester (Forestry)

## Grader



Caterpillar 12G grader.



Modern grader in use by the U.S. military.



1918 grader.



Caterpillar 143H grader plowing snow in Ouray, Colorado.

A **grader**, also commonly referred to as a **road grader**, a **blade**, a **maintainer**, or a **motor grader**, is a construction machine with a long blade used to create a flat surface. Typical models have three axles, with the engine and cab situated above the rear axles at one end of the vehicle and a third axle at the front end of the vehicle, with the blade in between. In certain countries, for example in Finland, almost every grader is equipped with a second blade that is placed in front of the front axle. Some construction personnel refer to the entire machine as "the blade."

In civil engineering, the grader's purpose is to "finish grade" (refine, set precisely) the "rough grading" performed by heavy equipment or engineering vehicles such as scrapers and bulldozers.

Graders can produce inclined surfaces, to give cant (camber) to roads. In some countries they are used to produce drainage ditches with shallow V-shaped cross-sections on either side of highways.

Graders are commonly used in the construction and maintenance of dirt roads and gravel roads. In the construction of paved roads they are used to prepare the base course to create a wide flat surface for the asphalt to be placed on. Graders are also used to set native soil foundation pads to finish grade prior to the construction of large buildings.

In some locales such as Northern Europe, Canada, and places in the United States, graders are often used in municipal and residential snow removal. In scrubland and grassland areas of Australia and Africa, graders are often an essential piece of equipment on ranches, large farms, and plantations to make dirt tracks where the absence of rocks and trees means bulldozers are not required. A more recent innovation is the outfitting of graders with GPS technology, such as manufactured by Topcon Positioning Systems, Inc., Trimble Navigation, Leica Geosystems or Mikrofyn for precise grade control and (potentially) "stakeless" construction.

Graders are also used for underground mining.

Capacities range from a blade width of 2.50 to 7.30 m and engines from 93–373 kW (125–500 hp).

# Harvester (Forestry)



6-wheeled Valmet harvester



Small 4-wheeled Rottne harvester



Timberjack harvester



John Deere harvester in Sweden

A **harvester** is a type of heavy forestry vehicle employed in cut-to-length logging operations for felling, delimiting and bucking trees. A forest harvester is typically employed together with a forwarder that hauls the logs to a roadside landing.

### ***History***

Forest harvesters were mainly developed in Sweden and Finland and today do practically all of the commercial felling in these countries. The first fully mobile timber "harvester", the PIKA model 75, was introduced in 1973 by Finnish systems engineer Sakari Pinomäki and his company PIKA Forest Machines. The first single grip harvester head was introduced in the early 1980s by Swedish company SP Maskiner. Their use has become widespread throughout the rest of Northern Europe, particularly in the harvesting of plantation forests.

### ***Uses***

Harvesters are employed effectively in level to moderately steep terrain for clearcutting areas of forest. For very steep hills or for removing individual trees, humans working with chain saws are still preferred in some countries. In northern Europe small and manoeuvrable harvesters are used for thinning operations, manual felling is typically only

used in extreme conditions, where tree size exceeds the capacity of the harvester head or by small woodlot owners.

The principle aimed for in mechanised logging is "no feet on the forest floor", and the harvester and forwarder allow this to be achieved. Keeping humans inside the driving cab of the machine provides a safer and more comfortable working environment for industrial scale logging.

The leading manufacturers of harvesters are Timberjack (owned by John Deere), Valmet (owned by Komatsu) and Ponsse.

Harvesters are built on a robust all terrain vehicle, either wheeled or tracked. The vehicle may be articulated to provide tight turning capability around obstacles. A diesel engine provides power for both the vehicle and the harvesting mechanism through hydraulic drive. An extensible, articulated boom, similar to that on an excavator, reaches out from the vehicle to carry the **harvester head**. Some harvesters are adaptations of excavators with a new harvester head, while others are purpose-built vehicles.

"Combi" machines are available which combine the felling capability of a harvester with the load-carrying capability of a forwarder, allowing a single operator and machine to fell, process and transport trees. These novel type of vehicles are only competitive in operations with short distances to the landing.

***Felling head***



Harvester head



Harvester head, chainsaw visible

A typical harvester head consists of (from bottom to top, with head in vertical position)

- a chain saw to cut the tree at its base, and also cut it to length. The saw is hydraulically powered, rather than using the 2-stroke engine of a portable version. It has a more robust chain, and a higher power output than any saw that can be carried by a human.
- two or more curved delimiting knives which reach around the trunk to remove branches.
- two feed rollers to grasp the tree. The wheels pivot apart to allow the tree to be embraced by the harvester head, and pivot together to hug the tree tightly. The wheels are driven in rotation to force the cut tree stem through the delimiting knives.
- diameter sensors to calculate the volume of timber harvested in conjunction with
- a measuring wheel which measures the length of the stem as it is fed through the head.

All of this can be controlled by one operator sitting in the cab of the vehicle. A control computer can simplify mechanical movements and can keep records of the length and diameter of trees cut. Length is computed by either counting the rotations of the gripping wheels or, more commonly, using the measuring wheel. Diameter is computed from the

pivot angle of the gripping wheels or delimiting knives when hugging the tree. Length measurement also can be used for automated cutting of the tree into predefined lengths. Computer software can predict the volume of each stem based on analysing stems harvested previously. This information when used in conjunction with price lists for each specific log specification enables the optimisation of log recovery from the stem.

Harvesters are routinely available for cutting trees up to 900 mm in diameter, built on vehicles weighing up to 20 t, with a boom reaching up to 10 m radius. Larger, heavier vehicles do more damage to the forest floor, but a longer reach helps by allowing more trees to be harvested with fewer vehicle movements.

The approximate equivalent type of vehicle in full-tree logging systems are feller-bunchers.

## Chapter- 6

# Forklift Truck



A US airman operating a Hyster forklift

A **forklift** (also called a lift truck, a high/low, a stacker-truck, trailer loader, sideloader, fork truck, tow-motor or a fork hoist) is a powered industrial truck used to lift and transport materials. The modern forklift was developed in the 1920s by various companies including the transmission manufacturing company Clark and the hoist company Yale & Towne Manufacturing. The forklift has since become an indispensable piece of equipment in manufacturing and warehousing operations.

## History



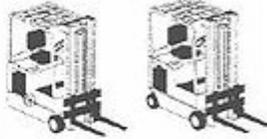
Toyota's first lift truck

The middle nineteenth century through the early twentieth century saw the developments that led to today's modern forklifts. The Pennsylvania Railroad in 1906 introduced battery powered platform trucks for moving luggage at their Altoona, Pennsylvania train station. World War I saw the development of different types of material handling equipment in the United Kingdom by Ransomes, Sims and Jeffries of Ipswich. This was in part due to the labor shortages caused by the war. In 1917 Clark in the United States began developing and using powered tractor and powered lift tractors in their factories. In 1919 the Towmotor Company and Yale & Towne Manufacturing in 1920 entered the lift truck market in the United States.

Continuing development and expanded use of the forklift continued through the 1920s and 1930s. World War II, like World War I before, spurred the use of forklift trucks in the war effort. Following the war, more efficient methods for storing products in warehouses were being implemented. Warehouses needed more maneuverable forklift trucks that could reach greater heights. New forklift models were made that filled this need. In 1956 Toyota introduced its first lift truck model, the Model LA, in Japan and sold its first forklift in the United States in 1967.

## Design types

### Forklift Classes and Lift Codes

Class #	Type of Propulsion and Operation	Lift Code	Description	Picture
I	Electric Motor Rider	4	Counterbalanced, sit-down, 3-wheel	
		5	Counterbalanced, sit-down, cushion (solid) tire	
		6	Counterbalanced, sit-down, pneumatic tire	
III	Electric Motor Walkie	2	Low-lift pallet	
		5	High lift reach type	
		7	High lift counterbalanced	
IV	Internal Combustion Engine Rider	3	Counterbalanced, sit-down, cushion (solid) tire	
V	Internal Combustion Engine Rider	4	Counterbalanced, sit-down, pneumatic tire	
VII	Rough Terrain	1	All types	



A truck mounted forklift called "Moffet".



A Raymond reach truck. Note the pantograph allowing the extension of the forks in tight aisles. This electric machine weighs over 7000lbs and can lift 4000lbs to 24 feet in the air.

The following is a list of the more common lift truck types. It is arranged from the smallest type of lift to largest:

- Hand pallet truck
- Walkie low lift truck (powered pallet truck, usually electrically powered)
- Rider low lift truck
- Towing tractor
- Walkie stacker
- Rider stacker

- Reach truck (small forklift, designed for small aisles, usually electrically powered, so-named because the forks can extend to reach the load)
- Electric counterbalanced truck
- IC counterbalanced truck
- Sideloader
- Telescopic handler
- Walkie Order Picking truck
- Rider Order Picking truck (commonly called an "Order Picker"; like a small forklift, except the operator rides up to the load and transfers it article by article)
- Articulated Very Narrow Aisle Counterbalanced trucks (commonly called "Flexi or Bendi Truck")
- Guided Very Narrow Aisle truck - 'Man Down' (a type of reach truck designed for aisles less than five feet wide) and 'Man Riser' Combination picker/Stacker truck
- Truck Mounted Forklift / Sod Loader

## **Specialty trucks**

At the other end of the spectrum from the counterbalanced forklift trucks are more 'high end' specialty trucks:

- **Articulated Counterbalance Trucks**

These are, unlike most lift trucks, front wheel steer, and are a hybrid VNA (Very Narrow Aisle) truck designed to be both able to offload trailers and place the load in narrow aisle racking. Increasingly these trucks are able to compete in terms of pallet storage density, lift heights and pallet throughput with Guided Very Narrow Aisle trucks.

- **Guided Very Narrow Aisle Trucks**

These are rail or wire guided and available with lift heights up to 40' non top-tied and 98' top-tied. Two forms are available; 'man-down' and 'man-riser' where the operator elevates with the load for increased visibility or for multilevel 'break bulk' order picking. This type of truck, unlike Articulated Narrow Aisle Trucks, requires a high standard of floor flatness.

- **Explosion proof trucks**

These are for operation in potentially explosive atmospheres found in chemical, petrochemical, pharmaceutical, food and drink, logistics or other industries handling flammable material. Commonly referred to as Pyroban trucks, in Europe they must meet the requirements of the ATEX 94/9/EC Directive if used in Zone 1, 2, 21 or 22 areas and be maintained accordingly.

In North America, internal combustion powered industrial vehicles carry Underwriters Laboratories ratings that are part of UL 558. Industrial trucks that are considered

"explosion proof" carry the designations GS for gasoline powered, DS for diesel powered, LPS for liquified propane or GS/LPS for a dual fuel gasoline/liquified propane powered truck.

- **U.S. Military 10K-AT "Adverse Terrain"**

## **Automated forklift trucks**

In order to decrease work wages, reduce operational cost and improve productivity, automated forklifts have also been developed. Automated forklifts are also called forked automated guided vehicles and are already available from a growing number of suppliers.

## **Counterbalanced forklift components**

A typical counterbalanced forklift contains the following components:



Image of an electric forklift with component descriptions

- **Truck Frame** - is the base of the machine to which the mast, axles, wheels, counterweight, overhead guard and power source are attached. The frame may have fuel and hydraulic fluid tanks constructed as part of the frame assembly.

- **Counterweight** - is a mass attached to the rear of the forklift truck frame. The purpose of the counterweight is to counterbalance the load being lifted. In an electric forklift the large lead-acid battery itself may serve as part of the counterweight.
- **Cab** - is the area that contains a seat for the operator along with the control pedals, steering wheel, levers, switches and a dashboard containing operator readouts. The cab area may be open air or enclosed, but it is covered by the cage-like overhead guard assembly. The 'Cab' can also be equipped with a Cab Heater for cold climate countries.
- **Overhead Guard** - is a metal roof supported by posts at each corner of the cab that helps protect the operator from any falling objects. On some forklifts, the overhead guard is an integrated part of the frame assembly.
- **Power Source** - may consist of an internal combustion engine that can be powered by LP gas, CNG gas, gasoline or diesel fuel. Electric forklifts are powered by either a battery or fuel cells that provides power to the electric motors. The electric motors used on a forklift may be either DC or AC types.
- **Tilt Cylinders** - are hydraulic cylinders that are mounted to the truck frame and the mast. The tilt cylinders pivot the mast to assist in engaging a load.
- **Mast** - is the vertical assembly that does the work of raising and lowering the load. It is made up of interlocking rails that also provide lateral stability. The interlocking rails may either have rollers or bushings as guides. The mast is driven hydraulically, and operated by one or more hydraulic cylinders directly or using chains from the cylinder/s. It may be mounted to the front axle or the frame of the forklift.
- **Carriage** - is the component to which the forks or other attachments mount. It is mounted into and moves up and down the mast rails by means of chains or by being directly attached to the hydraulic cylinder. Like the mast, the carriage may have either rollers or bushings to guide it in the interlocking mast rails.
- **Load Back Rest** - is a rack-like extension that is either bolted or welded to the carriage in order to prevent the load from shifting backward when the carriage is lifted to full height.
- **Attachments** - may consist of forks or tines that are the L-shaped members that engage the load. A variety of other types of material handling attachments are available. Some attachments include sidershifters, slipsheet attachments, carton clamps, multipurpose clamps, rotators, fork positioners, carpet poles, pole handlers, container handlers and roll clamps.

## Attachments

Below is a list of common forklift attachments:

- **Dimensioning Devices**-fork truck mounted dimensioning systems provide dimensions for the cargo to facilitate truck trailer space utilization and to support warehouse automation systems. The systems normally communicate the dimensions via 802.11 radios. NTEP certified dimensioning devices are available to support commercial activities that bill based on volume.
- **Sideshifter** - is a hydraulic attachment that allows the operator to move the tines (forks) and backrest laterally. This allows easier placement of a load without having to reposition the truck.
- **Rotator** - To aid the handling of skids that may have become excessively tilted and other specialty material handling needs some forklifts are fitted with an attachment that allows the tines to be rotated. This type of attachment may also be used for dumping containers for quick unloading.
- **Fork Positioner** - is a hydraulic attachment that moves the tines (forks) together or apart. This removes the need for the operator to manually adjust the tines for different sized loads.
- **Roll and Barrel Clamp Attachment** - A mechanical or hydraulic attachment used to squeeze the item to be moved. It is used for handling barrels, kegs, or paper rolls. This type of attachment may also have a rotate function. The rotate function would help an operator to insert a vertically stored paper into the horizontal intake of a printing press for example.
- **Pole Attachments** - In some locations, such as carpet warehouses, a long metal pole is used instead of forks to lift carpet rolls. Similar devices, though much larger, are used to pick up metal coils.
- **Carton and Multipurpose Clamp Attachments** - are hydraulic attachments that allow the operator to open and close around a load, squeezing it to pick it up. Products like cartons, boxes and bales can be moved with this type attachment. With these attachments in use, the forklift truck is sometimes referred to as a clamp truck.
- **Slip Sheet Attachment (Push - Pull)** - is a hydraulic attachment that reaches forward, clamps onto a slip sheet and draws the slip sheet onto wide and thin metal forks for transport. The attachment will push the slip sheet and load off the forks for placement.
- **Drum Handler Attachment** - is a mechanical attachment that slides onto the tines (forks). It usually has a spring loaded jaw that grips the top lip edge of a

drum for transport. Another type grabs around the drum in a manner similar to the roll or barrel attachments.

- **Man Basket** - a lift platform that slides onto the tines (forks) and is meant for hoisting workers. The man basket has railings to keep the person from falling and brackets for attaching a safety harness. Also, a stap or chain is used to attach the man basket to the carriage of the forklift.
- **Telescopic Forks** - are hydraulic attachments that allow the operator to operate in warehouse design for "double-deep stacking", which means that two pallet shelves are placed behind each other without any aisle between them.
- **Scales** -Fork truck mounted scales enable operators to efficiently weigh the pallets they handle without interrupting their workflow by travelling to a platform scale. Scales are available that provide legal-for-trade weights for operations that involve billing by weight. They are easily retrofitted to the truck by hanging on the carriage in the same manner as forks hang on the truck.

Any attachment on a forklift will reduce its nominal load rating, which is computed with a stock fork carriage and forks. The actual load rating may be significantly lower.

## **Replacing or adding attachments**

It's possible to replace an existing attachment or add one to a lift that doesn't already have one. Considerations include forklift type, capacity, carriage type, and number of hydraulic functions (that power the attachment features). As mentioned in the preceding section, replacing or adding an attachment may reduce (down-rate) the safe lifting capacity of the forklift truck.

Forklift attachment manufacturers offer on-line calculators to estimate the safe lifting capacity when using a particular attachment, but only the forklift truck manufacturer can give accurate lifting capacities. Before installing any attachment, you should contact your local authorized dealer of your forklift brand, and ask them to begin re-rating your lift according to the attachment you want to install. Once re-rated you should receive a new factory authorized specification plate to replace the original currently found on your lift.

## **Adding hydraulic functions**

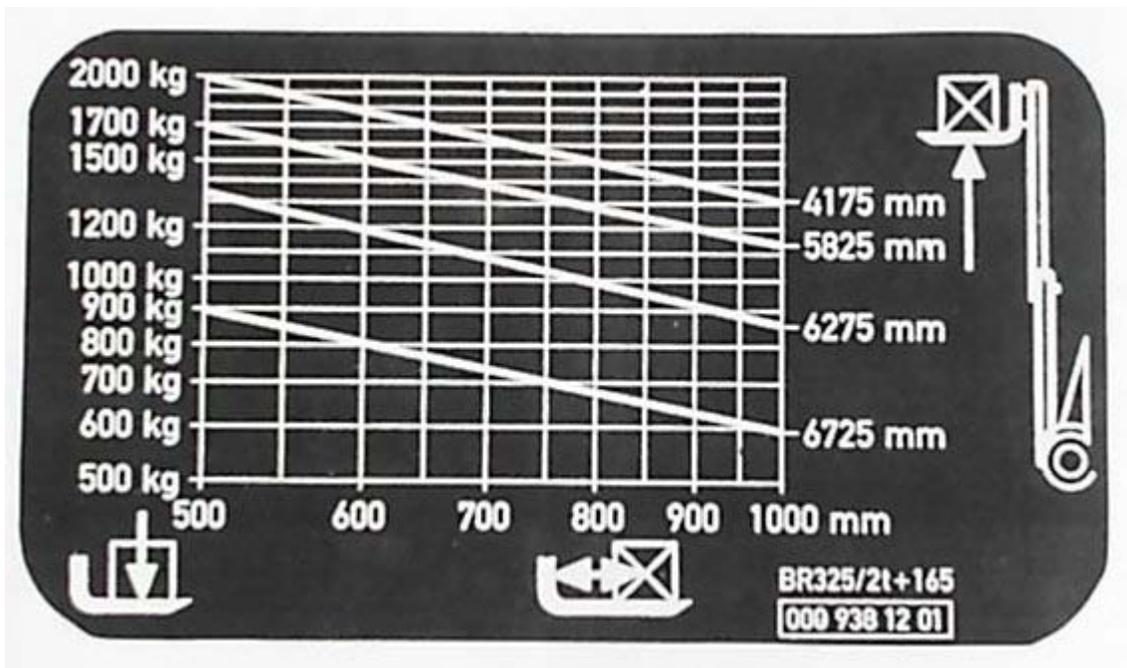
In the context of attachments, a hydraulic function consists of a valve on the forklift with a lever near the operator that provides two passages of pressurized hydraulic oil to power the attachment features. Sometimes an attachment has more features than your forklift has hydraulic functions, and one or more need to be added.

There are many ways of adding hydraulic functions (also known as adding a valve). The forklift manufacturer makes valves and hose routing accessories, but the parts and labor to install can be prohibitively expensive. Other ways include adding a solenoid valve in

conjunction with a hose or cable reel that diverts oil flow from an existing function. However, hose and cable reels can block the operator's view and are problematic, easily damaged. The Ditto Valve kit uses a solenoid valve and special HydWire hoses, in which the wire reinforcing braid doubles as an electrical conduit. These hoses replace those already on the forklift, nesting in the original reeving, keeping it safe from damage and out of the operators field of vision.

### ***Forklift control and capabilities***

Forklift trucks are available in many variations and load capacities. In a typical warehouse setting most forklifts used have load capacities between one to five tons. Larger machines, up to 50 tons lift capacity are used for lifting heavier loads, including loaded shipping containers.



a typical load capacity chart

In addition to a control to raise and lower the forks (also known as blades or tines), the operator can tilt the mast to compensate for a load's tendency to angle the blades toward the ground and risk slipping off the forks. Tilt also provides a limited ability to operate on non-level ground. Skilled forklift operators annually compete in obstacle and timed challenges at regional forklift rodeos.

## General operations



A forklift transporting a pallet of potted plants.

Forklifts are rated for loads at a specified maximum weight and a specified forward centre of gravity. This information is located on a nameplate provided by the manufacturer, and loads must not exceed these specifications. In many jurisdictions it is illegal to remove or tamper with the nameplate without the permission of the forklift manufacturer.

An important aspect of forklift operation is that most have rear-wheel steering. While this increases maneuverability in tight cornering situations, it differs from a driver's traditional experience with other wheeled vehicles. While steering, as there is no caster action, it is unnecessary to apply steering force to maintain a constant rate of turn.

Another critical characteristic of the forklift is its instability. The forklift and load must be considered a unit with a continually varying centre of gravity with every movement of the load. A forklift must never negotiate a turn at speed with a raised load, where centrifugal and gravitational forces may combine to cause a disastrous tip-over accident. The forklift are designed with a load limit for the forks which is decreased with fork elevation and undercutting of the load (i.e. load does not butt against the fork "L"). A loading plate for loading reference is usually located on the forklift. A forklift should not be used as a personnel lift without the fitting of specific safety equipment, such as a "cherry picker" or "cage".

## **Forklift use in warehouse and distribution centers**

Forklifts are a critical element of warehouses and distribution centers. It's imperative that these structures be designed to accommodate their efficient and safe movement.

In the case of Drive-In/Drive-Thru Racking, a forklift needs to travel inside a storage bay that is multiple pallet positions deep to place or retrieve a pallet. Oftentimes, forklift drivers are guided into the bay through guide rails on the floor and the pallet is placed on cantilevered arms or rails. These maneuvers require well-trained operators. Since every pallet requires the truck to enter the storage structure, damage is more common than with other types of storage. In designing a drive-in system, dimensions of the fork truck, including overall width and mast width, must be carefully considered.

## ***Lift truck associations and organizations***

There are many national as well as continental associations related to the industrial truck industry. Some of the major organizations are listed as:

- **Industrial Truck Association (ITA)** (North America)
- **Material Handling Equipment Distributors Association (MHEDA)** (North America)
- **Fédération Européenne de la Manutention - European Federation of Materials Handling (FEM)**
- **Fork Lift Truck Association (FLTA)** (UK)
- **British Industrial Truck Association (BITA)**
- **Japan Industrial Vehicles Association (JIVA)**
- **Korean Construction Equipment Manufacturers Association (KOCEMA)**

There are many significant contacts among these organizations and they have established joint statistical and engineering programs. One program is the *World Industrial Trucks Statistics (WITS)* which is published every month to the association memberships. The statistics are separated by area (continent), country and class of machine. While the statistics are generic, and do not count production from most of the smaller manufacturers, the information is significant for its depth. These contacts have brought to a common definition of a Class System which all the major manufacturers adhere to.

## ***Forklift safety organizations***

### **Standards**

Forklift safety is subject to a variety of standards world wide. The most important standard is the ANSI B56—of which stewardship has now been passed from the American National Standards Institute (ANSI) to the Industrial Truck Standards Development Foundation after multi-year negotiations. ITSDF is a non-profit organization whose only purpose is the promulgation and modernization of the B56 standard.

Other standards have been implemented in the United States by the Occupational Safety and Health Administration (OSHA) and in the United Kingdom by the Health and Safety Executive. In many countries forklift truck operators must be trained and certified to operate forklift trucks. Certification may be required for each individual class of lift that an operator would use.

### **Forklift Training in the United Kingdom**

In the UK, the Provision and Use of Work Equipment Regulations (PUWER) state that operators of fork lift trucks must be adequately trained in their operation, but the nature of this training is not specified. Third party organisations have developed de-facto 'best practice' standards for forklift training, commonly referred to in the UK as a 'forklift license', but such training is **not** a legal requirement as is commonly believed. Organised training however helps to demonstrate that an employer has taken steps to ensure its 'duty of care' in the unfortunate event of an accident. The details below represent the de-facto standards proscribed by training organisations.

In the UK, Forklift Training is carried out by a number of different organisations, which all Forklift Instructors must be registered with at least one of them. Although R.T.I.T.B. operators are registered on a database which has to be renewed a 3 yearly basis, the amount of time determined between refresher courses is subject to the H&S Executive, Insurance companies or company policies. The H&S Executive (HSG136 Workplace Transport Safety) does recommend re-training/testing every 3 to 5 years.

United Kingdom Forklift Instructors can be registered to one of the following, though registration is not compulsory to instruct;

RTITB

Independent Training Standards Scheme and Register (ITSSAR)

Association of Industrial Truck Trainers (AITT)

National Plant Operators Registration Scheme (NPORS)

CITB-ConstructionSkills

Lantra - Sector Skills Council for the environmental and land-based sector

There are various different training companies across the UK that can provide training on-site and off-site, these can be independent instructors or part of a training company.

There are also various training centres across the United Kingdom that can provide individuals not already trained to use a Forklift Truck to help gain a certificate of competence.

In the United Kingdom training falls into four different categories;

REFRESHER - People who have gained a Forklift Training Certificate and need to be brought up to date with new laws and/or regulations.

CONVERSION - People who have been trained on a type of truck recently, and need to start using a different type.

SEMI-EXPERIENCED - People who are competent on a forklift truck, but have never been certificated.

NOVICE - Never been on a Forklift Truck before and never been certificated.

The courses can last for 1 day for a Refresher or a Conversion course, to 5 days for a Novice course. It is recommended that United Kingdom Forklift Instructors train a maximum of Three People per day, this does not include classroom work.

## Chapter- 7

# Loader (Equipment)



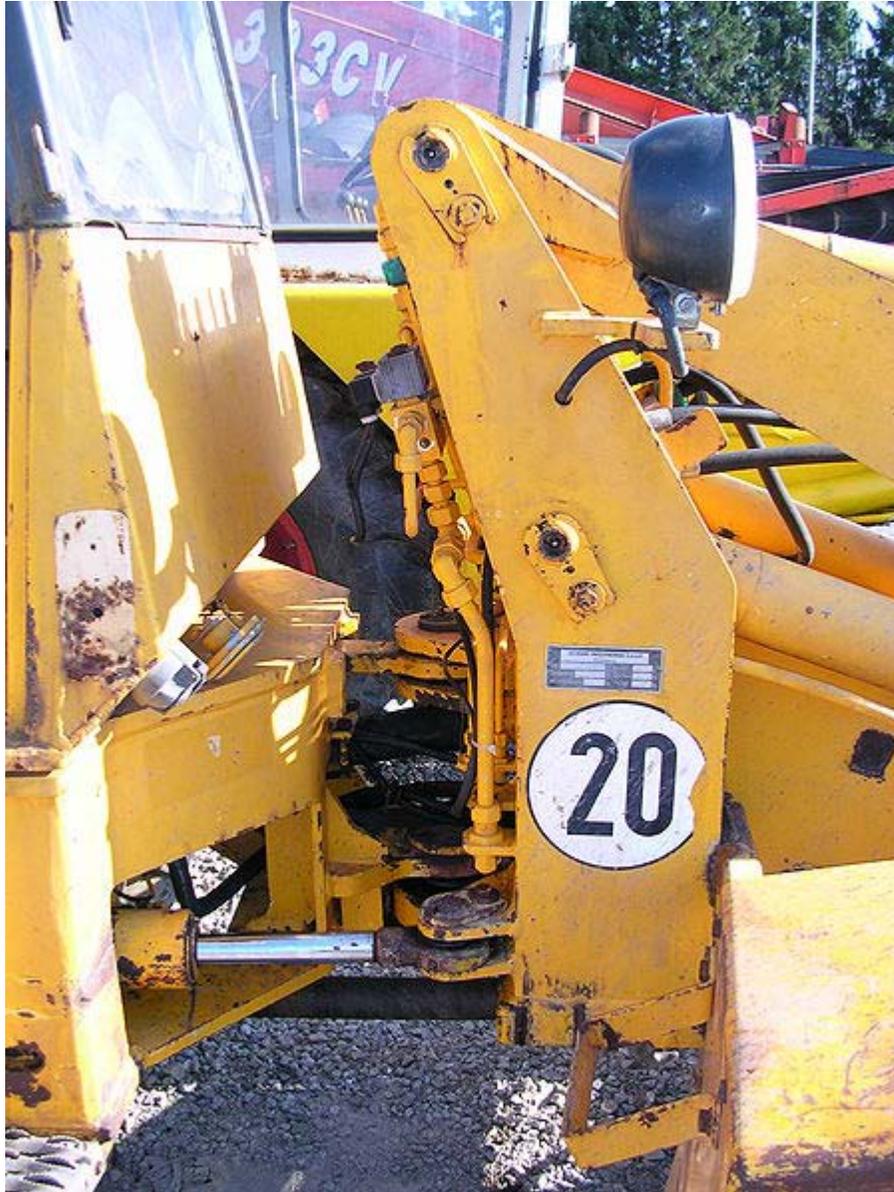
Volvo L120E front loader



Caterpillar 988 adapted for log handling



A track loader



Close-up of articulated steering apparatus



Loader removing snow in Jyväskylä, Finland.

A **loader** is a heavy equipment machine often used in construction, primarily used to load material (such as asphalt, demolition debris, dirt, snow, feed, gravel, logs, raw minerals, recycled material, rock, sand, and woodchips) into or onto another type of machinery (such as a dump truck, conveyor belt, feed-hopper, or railcar).

### ***Heavy equipment front loaders***

A loader (also known as: **bucket loader**, **front loader**, **front end loader**, **payloader**, **scoop loader**, **shovel**, **skip loader**, and/or **wheel loader**) is a type of tractor, usually wheeled, sometimes on tracks, that has a front mounted square wide bucket connected to the end of two booms (arms) to scoop up loose material from the ground, such as dirt, sand or gravel, and move it from one place to another without pushing the material across the ground. A loader is commonly used to move a stockpiled material from ground level and deposit it into an awaiting dump truck or into an open trench excavation.

The loader assembly may be a removable attachment or permanently mounted. Often the bucket can be replaced with other devices or tools—for example, many can mount forks to lift heavy pallets or shipping containers, and a hydraulically-opening "clamshell" bucket allows a loader to act as a light dozer or scraper. The bucket can also be augmented with devices like a bale grapppler for handling large bales of hay or straw.

Large **loaders**, such as the *Kawasaki 95ZV-2*, *John Deere 844K*, *Caterpillar 950H*, *Volvo L120E*, *Case 921E*, or *Hitachi ZW310* usually have only a front bucket and are called *Front Loaders*, whereas small loader tractors are often also equipped with a small backhoe and are called backhoe loaders or loader backhoes or JCBs, after the company that first invented them.

The largest loader in the world is LeTourneau L-2350. Currently these large loaders are in production in the Longview, Texas facility. The L-2350 uses a diesel electric propulsion system similar to that used in a locomotive. Each rubber tired wheel is driven by its own independent electric motor.

Loaders are used mainly for uploading materials into trucks, laying pipe, clearing rubble, and digging. A loader is not the most efficient machine for digging as it cannot dig very deep below the level of its wheels, like a backhoe can. The capacity of a loader bucket can be anywhere from 0.5 to 36 m<sup>3</sup> depending upon the size of the machine and its application. The front loader's bucket capacity is generally much bigger than a bucket capacity of a backhoe loader.

Unlike most bulldozers, most loaders are wheeled and not tracked, although track loaders are common. They are successful where sharp edged materials in construction debris would damage rubber wheels, or where the ground is soft and muddy. Wheels provide better mobility and speed and do not damage paved roads as much as tracks, but provide less traction.

In construction areas loaders are also used to transport building materials - such as bricks, pipe, metal bars, and digging tools - over short distances.

Front loaders are commonly used to remove snow especially from sidewalks, parking lots, and other areas too small for using snowplows and other heavy equipment. They are sometimes used as snowplows with a snowplow attachment but commonly have a bucket or snowbasket, which can also be used to load snow into the rear compartment of a snowplow or dump truck.

High-tip buckets are suitable for light materials such as chip, peat and light gravel and when the bucket is emptied from a height.

Unlike backhoes or standard tractors fitted with a front bucket, many large loaders do not use automotive steering mechanisms. Instead, they steer by a hydraulically actuated pivot point set exactly between the front and rear axles. This is referred to as "articulated steering" and allows the front axle to be solid, allowing it to carry greater weight. Articulated steering provides better maneuverability for a given wheelbase. Since the front wheels and attachment rotate on the same axis, the operator is able to "steer" his load in an arc after positioning the machine, which can be useful. The tradeoff is that when the machine is "twisted" to one side and a heavy load is lifted high, it has a greater risk of turning over to the "wide" side.

Front loaders gained popularity during the last two decades, especially in urban engineering projects and small earthmoving works. Heavy equipment manufacturers offer a wide range of loader sizes and duties.

The term "loader" is also used in the debris removal field to describe the boom on a grapple truck.

### ***Armored Wheel Loaders***



IDF armored wheel loader

The Israeli Combat Engineering Corps use armored Caterpillar 966 wheel loader for construction and combat engineering missions in hostile territories such as the West Bank. They are often seen building or removing road blocks, building bases and fortifications and starting in 2005, demolishing small houses. The IDF added armor plating for the loader, protecting it against rocks, stones, molotov cocktails, and light gunfire.

Rio de Janeiro's police elite squad BOPE have recently acquired one wheel loader of military purposes to open routes and make way for the police in Rio de Janeiro's slums, which are controlled, and blocked, by drugdealers. It is nicknamed "The Skulls' Transformer", being a reference to how they call themselves -- "The Skulls".

## ***Tractor front loaders***

These loaders are a popular addition to tractors from 50 to 200 hp. Its current 'drive-in' form was originally designed and developed in 1958 by a company called Quicke. They were developed to perform a multitude of farming tasks, and are popular due to their relatively low cost (compared to Telehandler) and high versatility. Tractor loaders can be fitted with many attachments such as hydraulic grabs and spikes to assist with bale and silage handling, forks for pallet work, and buckets for more general farm activities.

## ***Compact front end loaders***



Semi-curved compact loader on a John Deere compact utility tractor



Visibility comparison of different loader designs

Popular additions to compact utility tractors and farm tractors are **Front End Loaders**, also referred to as a **FEL**. Compact utility tractors, also called CUTs are small tractors, typically with 18 to 50 horsepower (37 kW) and used primarily for grounds maintenance and landscape chores. There are 2 primary designs of compact tractor **FELs**, the traditional dogleg designed style and the curved arm style.

John Deere Tractor manufactures a semi-curved loader design that does not feature the one piece curved arm, but also is not of the traditional two piece design. New Holland Ag introduced a compact loader with a one piece curved arm on its compact utility tractors, similar one piece curved arm loaders are now available on compact tractors on many brands including Case/Farmall, and some Montana and Kioti tractors. Kubota markets traditional loader designs on most of its compact tractors but now features a semi-curved loader design similar to the John Deere loader design on several of its small tractors.

While the **Front End Loaders** on CUT size tractors are capable of many tasks, given their relatively small size and low capacities when compared to commercial loaders, the compact loaders can be made more useful with some simple options. A **Toothbar** is commonly added to the front edge of a loader bucket to aid with digging. Some loaders are equipped with a quick coupler, otherwise known as a **Quick Attach (QA)** system, the *QA* system allows the bucket to be removed easily and other tools to be added in its

place. Common additions would include a set of **Pallet Forks** for lifting pallets of goods or a **Bale Spear** for lifting hay bales.



Compact utility tractor with a front loader showing two different measurement points for loader capacities

### ***Skid loaders & track loaders***

A skid loader is a small loader utilizing four wheels with hydraulic drive that directs power to either, or both, sides of the vehicle. Very similar in appearance and design is the track loader, which utilizes a continuous track on either side of the vehicle instead of the wheels. Since the expiration of Bobcat's patent on its quick-connect system, newer tractor models are standardizing on that popular format for front end attachments.

### ***Swingloaders***

A swing loader is a rigid frame loader with a swinging boom. The boom can swing 180 degrees or more. Swingloaders are primarily used by the railroad industry to lay rail. Like other loaders many attachments can be attached to the boom such as magnets, forks, and buckets. Smaller swingloaders are used in farming applications for loading out. A swinging boom is advantageous where space is limited. The loader is able to lift on all sides and dump off on all sides.

## Gallery



A Hanomag loader



DK45 with and without a toothbar on the bucket



A relatively small front loader



A loader with a specialized claw used to move logs at a sawmill



A Caterpillar 930G fitted with a loader rake on a residential construction site in South Florida.



The front of a Caterpillar 930G fitted with loader rake.

## Chapter- 8

# Road Roller



John Deere roller being used to compact the ground before placing concrete



An old diesel road roller

A **road roller** (sometimes called a *roller-compactor*, or just *roller*) is a compactor type engineering vehicle used to compact soil, gravel, concrete, or asphalt in the construction of roads and foundations, similar rollers are used also at landfills or in agriculture.

In some parts of the world, road rollers are still known colloquially as steam rollers, regardless of their method of propulsion. This typically only applies to the largest examples (used for road-making).

## History



Horse-drawn road roller from 1800



Steam-powered roller



Zettelmeyer diesel road roller

The first road rollers were horse-drawn, and were probably just borrowed farm implements.

Since the effectiveness of a roller depends to a large extent on its weight, self-powered vehicles replaced horse-drawn rollers from the mid-19th century. The first such vehicles were steam rollers. Double-cylinder designs were preferred. Single-cylinder steam rollers were uncommon and unpopular, as the power impulses from the steam engine would produce slight waves in the road. Some road companies in the United States used steamrollers through the 1950s, and in the UK, some remained in commercial service until the early 1970s.

As internal combustion engine technology improved during the 20th century, kerosene-, gasoline- (petrol), and diesel-powered rollers gradually replaced their steam-powered counterparts. The first internal-combustion powered road rollers were very similar to the steam rollers they replaced. They used similar mechanisms to transmit power from the engine to the wheels, typically large, exposed spur gears. Some companies did not like them in their infancy, as the engines of the era were typically difficult to start, particularly the kerosene-powered ones.

Virtually all road rollers in commercial use now use diesel power.

## **Uses**

Road rollers use the weight of the vehicle to compress the surface being rolled. Initial compaction of the substrate is done using a **pneumatic-tyred roller**, with two rows (front and back) of pneumatic tyres. The flexibility of the tyres, with a certain amount of vertical movement of the wheels, enables the roller to operate effectively on uneven ground. The finish is done using metal-drum rollers to ensure a smooth, even result.

Rollers are also used in landfill compaction. Such compactors typically have knobbed ("sheeps-foot") wheels, and do not achieve a smooth surface. The knobs aid in compression due to the smaller area contacting the ground.

## **Configurations**

The roller can be a simple drum with a handle that is operated by one person, and weighs 100 pounds, or as large as a ride-on road roller weighing 21 short tons (44,000 lb or 20 tonnes) and costing more than US\$150,000. A landfill unit can weigh 59 short tons (54 tonnes). On some machines the drums may be filled with water.

## **Roller Types**

- Manual walk-behind
- Powered walk-behind (electric or diesel/gas powered)
- Trench roller (manual units or radio-frequency remote control)
- Ride-on
- Ride-on with knock-down bar
- Ride-on articulating-swivel
- Vibratory
- Pneumatic-tyre
- Tandem roller
- Tractor-mounted and -powered



Powered, vibrating walk-behind



Ride-on with articulating-swivel (small machine)



Ride-on with articulating-swivel (large machine)



Vibrating Dynapac CC232



A Caterpillar CS-533E vibratory roller.



Pneumatic roller



A road-roller powered by a tractor mounted on it from rural India



Road roller, museum, Tenterfield, NSW

## Drum types

Drums come in various widths: 24-to-84 inches

- Single-drum sheeps/pad-foot (soil)
- Single-drum smooth (asphalt)
- Double-drum (duplex) sheeps/pad-foot (soil)
- Double-drum (duplex) smooth (asphalt)
- 3-wheel cleat with bulldozing blade (landfills)

## Variations and features

- On some machines, the drums may be filled with water on site to achieve the desired weight. When empty, the lighter machine is easier and cheaper to transport between work sites.
- Additional compaction may be achieved by vibrating the roller drums, making a small, light machine perform as well as a much heavier one. Vibration is typically caused by a free-spinning hydrostatic motor inside the drum to whose shaft eccentric weights have been attached.

- Water lubrication may be provided to the drum surface to prevent (for example) hot asphalt sticking to the drum
- Hydraulic transmissions permit greater design flexibility, while early examples used direct mechanical drives; hydraulics reduce the number of moving parts exposed to contamination.
- Human-propelled rollers may only have a single roller drum.
- Self-propelled rollers may have two drums, mounted one in front of the other (format known as "duplex"), or three rolls, or just one, with the back rollers replaced with treaded pneumatic tyres for increased traction

## Chapter- 9

# Tractor



Tractor pulling a chisel plow, Slovenia.

A **tractor** is a vehicle specifically designed to deliver a high tractive effort (or torque) at slow speeds, for the purposes of hauling a trailer or machinery used in agriculture or construction. Most commonly, the term is used to describe a farm vehicle that provides the power and traction to mechanize agricultural tasks, especially (and originally) tillage but nowadays a great variety of tasks. Agricultural implements may be towed behind or mounted on the tractor, and the tractor may also provide a source of power if the implement is mechanised. Another common use of the term, "tractor unit", describes the power unit of a semi-trailer truck (articulated lorry).

The word *tractor* was taken from Latin, being the agent noun of *trahere* "to pull". The first recorded use of the word meaning "an engine or vehicle for pulling wagons or ploughs" occurred in 1901, displacing the earlier term *traction engine* (1859).

### ***National variations***

In Britain, Ireland, Australia, India, Spain, Argentina, and Germany the word "tractor" usually means "farm tractor", and the use of the word "tractor" to mean other types of vehicles is familiar to the vehicle trade but unfamiliar to much of the general public. In Canada and the US the word may also refer to the road tractor portion of a tractor trailer truck.

### ***History***



1882 Harrison Machine Works steam-powered tractor

The first powered farm implements in the early 19th century were portable engines – steam engines on wheels that could be used to drive mechanical farm machinery by way of a flexible belt. Around 1850, the first traction engines were developed from these, and were widely adopted for agricultural use. The first tractors were steam-powered plowing engines. They were used in pairs, placed on either side of a field to haul a plow back and forth between them using a wire cable. Where soil conditions permitted (as in the United States) steam tractors were used to direct-haul plows, but in the UK and elsewhere plowing engines were used for cable-hauled plowing instead. Steam-powered agricultural

engines remained in use well into the 20th century until reliable internal combustion engines had been developed.

In 1892, John Froelich invented and built the first gasoline/petrol-powered tractor in Clayton County, Iowa, USA. After receiving a patent Froelich started up the Waterloo Gasoline Engine Company, investing all of his assets which by 1895, all would be lost and his business resigned to become a failure.

After graduating from the University of Wisconsin, Charles W. Hart and Charles H. Parr developed a two-cylinder gasoline engine and set up their business in Charles City, Iowa. In 1903 the firm built fifteen "tractors". A term with Latin roots coined by Hart and Parr and a combination of the words traction and power. The 14,000 pound #3 is the oldest surviving internal combustion engine tractor in the United States and is on display at the Smithsonian National Museum of American History in Washington D.C. The two-cylinder engine has a unique hit-and-miss firing cycle that produced 30 horsepower at the belt and 18 at the drawbar.

In Britain, the first recorded tractor sale was the oil-burning Hornsby-Ackroyd Patent Safety Oil Traction engine, in 1897. However, the first commercially successful design was Dan Albone's three-wheel Ivel tractor of 1902. In 1908, the Saunderson Tractor and Implement Co. of Bedford introduced a four-wheel design, and went on to become the largest tractor manufacturer outside the U.S. at that time.

While unpopular at first, these gasoline-powered machines began to catch on in the 1910s when they became smaller and more affordable. Henry Ford introduced the Fordson, the first mass-produced tractor in 1917. They were built in the U.S., Ireland, England and Russia and by 1923, Fordson had 77% of the U.S. market. The Fordson dispensed with a frame, using the strength of the engine block to hold the machine together. By the 1920s, tractors with a gasoline-powered internal combustion engine had become the norm.

## ***Farm tractor design, power and transmission***

### **Tractor configurations**

Tractors can be generally classified as two-wheel drive, two-wheel drive with front wheel assist, four-wheel drive (often with articulated steering), or track tractors (with either two or four powered rubber tracks).

The classic farm tractor is a simple open vehicle, with two very large driving wheels on an axle below and slightly behind a single seat (the seat and steering wheel consequently are in the center), and the engine in front of the driver, with two steerable wheels below the engine compartment. This basic design has remained unchanged for a number of years, but enclosed cabs are fitted on almost all modern models, for reasons of operator safety and comfort.



A 1958 Series II Field Marshall--the classic standard tread farm tractor configuration

In some localities with heavy or wet soils, notably in the Central Valley of California, the "Caterpillar" or "crawler" type of tracked tractor became popular in the 1930s, due to superior traction and floatation. These were usually maneuvered through the use of turning brake pedals and separate track clutches operated by levers rather than a steering wheel.



Volvo T25, 1956, Gasoline tractor



A modern 4-wheel drive farm tractor

Four-wheel drive tractors began to appear in the 1960s. Some four-wheel drive tractors have the standard "two large, two small" configuration typical of smaller tractors, while some have four large powered wheels. The larger tractors are typically an articulated center-hinged design steered by hydraulic cylinders that move the forward power unit while the trailing unit is not steered separately.

In the early 21st century, articulated or non-articulated, steerable multi-track "tractors" have largely supplanted the "Caterpillar" type for farm use. Larger types of modern farm tractors include articulated four wheel or eight wheel drive units with one or two power units which are hinged in the middle and steered by hydraulic clutches or pumps. A relatively recent development is the replacement of wheels or steel crawler-type tracks with flexible steel-reinforced rubber tracks, usually powered by hydrostatic or completely hydraulic driving mechanisms. The configuration of these tractors bears little resemblance to the classic farm tractor design.



A modern steerable all-tracked power unit planting wheat in North Dakota

## Engine and fuels

The predecessors of modern tractors, traction engines, used steam engines for power. Since the turn of the 20th century, internal combustion engines have been the power source of choice. Between 1900 and 1960, gasoline was the predominant fuel, with kerosene and ethanol being common alternatives. Generally one engine could burn any of those, although cold starting was easiest on gasoline. Often a small auxiliary fuel tank was available to hold gasoline for cold starting and warm-up, while the main fuel tank held whatever fuel was most convenient or least expensive for the particular farmer. Diesellisation gained momentum starting in the 1960s, and modern farm tractors usually employ diesel engines, which range in power output from 18 to 575 horsepower (15 to 480 kW). Size and output are dependent on application, with smaller tractors for lawn mowing, landscaping, orchard work, and truck farming, and larger tractors for vast fields of wheat, maize, soy, and other bulk crops. Liquefied petroleum gas (LPG) or propane also have been used as tractor fuels, but require special pressurized fuel tanks and filling equipment so are less prevalent in most markets.

## Transmission

Most older farm tractors use a manual transmission. They have several gear ratios, typically 3 to 6, sometimes multiplied into 2 or 3 ranges. This arrangement provides a set of discrete ratios that, combined with the varying of the throttle, allow final-drive speeds from less than one mile per hour up to about 25 miles per hour (40 km/h), with the lower speeds used for working the land and the highest speeds used on the road.

Slow, controllable speeds are necessary for most operations that are performed with a tractor. They help give the farmer a larger degree of control in certain situations, such as field work. However, when travelling on public roads, the slow operating speeds can cause problems, such as long queues or tailbacks, which can delay or annoy motorists in cars and trucks. These motorists are responsible for being duly careful around farm tractors and sharing the road with them, but many shirk this responsibility, so various ways to minimize the interaction or minimize the speed differential are employed where feasible. Some countries (for example the Netherlands) employ a road sign on some roads that means "no farm tractors". Some modern tractors, such as the JCB *Fastrac*, are now capable of much higher road speeds of around 50 mph (80 km/h).



An older model European farm tractor. These types of tractors are still common in Eastern Europe

Older tractors usually have unsynchronized transmission design, which often requires that the operator stop the tractor in order to shift between gears. This mode of use is inherently unsuited to some of the work that tractors do, and has been circumvented in various ways over the years. For existing unsynchronized tractors, the methods of circumvention are double clutching or power-shifting, both of which require the operator to rely on skill to speed-match the gears while shifting. Both of these solutions are undesirable from a risk-mitigation standpoint because of what can go wrong if the operator makes a mistake – transmission damage is possible, and loss of vehicle control can occur if the tractor is towing a heavy load either uphill or downhill – something that tractors often do. Therefore, operator's manuals for most of these tractors state that one must always stop the tractor before shifting, and they do not even mention the

alternatives. As already said, that mode of use is inherently unsuited to some of the work that tractors do, so better options were pursued for newer tractor designs.



Cutaway of modern tractor

In these, unsynchronized transmission designs were replaced with synchronization or with a continuously variable transmission (CVT). Either a synchronized manual transmission with enough available gear ratios (often achieved with dual ranges, high and low) or a CVT allow the engine speed to be matched to the desired final-drive speed while keeping engine speed within the appropriate rpm range for power generation (the working range) (whereas throttling back to achieve the desired final-drive speed is a trade-off that leaves the working range). The problems, solutions, and developments described here also describe the history of transmission evolution in semi-trailer trucks. The biggest difference is fleet turnover; whereas most of the old road tractors have long since been scrapped, many of the old farm tractors are still in use. Therefore, old transmission design and operation is primarily just of historical interest in trucking, whereas in farming it still often affects daily life.

### ***Hitches and power applications***

The power produced by the engine must be transmitted to the implement or equipment in order to do the actual work intended for the equipment. This may be accomplished via a

drawbar or hitch system if the implement is to be towed or otherwise pulled through the tractive power of the engine, or via a pulley or power takeoff system if the implement is stationary, or a combination of the two.

## **Drawbars**

Until the 1950s, plows and other tillage equipment usually were connected to the tractor via a drawbar, or a proprietary connecting system. The classic drawbar is simply a steel bar attached to the tractor (or in some cases, as in the early Fordsons, cast as part of the rear transmission housing) to which the hitch of the implement was attached with a pin or by a loop and clevis. The implement could be readily attached and removed, allowing the tractor to be used for other purposes on a daily basis. If the tractor was equipped with a swinging drawbar, the drawbar could be set at the center or offset from center to allow the tractor to run outside the path of the implement.

The drawbar system necessitated that the implement have its own running gear (usually wheels) and in the case of a plow, chisel cultivator or harrow, some sort of lift mechanism to raise it out of the ground at turns or for transport. Drawbars necessarily posed a rollover risk depending on how the tractive torque was applied. The Fordson tractors (of which more units were produced and placed in service than any other farm tractor) was extremely prone to roll over backwards due to an excessively short wheelbase. The linkage between the implement and the tractor usually had some slack which could lead to jerky starts and greater wear and tear on the tractor and the equipment.



A large modern John Deere model 9400 four wheel drive tractor with tripled wheels and a drawbar-towed tool chain including one-pass tillage equipment, planter and fertilizer applicator with tanks

Drawbars were appropriate to the dawn of mechanization, because they were very simple in concept and because as the tractor replaced the horse, existing horse-drawn implements usually already had running gear. As the history of mechanization progressed, however, the advantages of other hitching systems became apparent, leading to new developments. Depending on the function for which a tractor is used, however, the drawbar is still one of the usual means of attaching an implement to a tractor.

### **Fixed mounts**

Some tractor manufacturers produced matching equipment that could be directly mounted on the tractor. Examples included front-end loaders, belly mowers, row crop cultivators, corn pickers and corn planters. In most cases, these fixed mounts were proprietary and unique to each make of tractor, so that an implement produced by John Deere, for example, could not be attached to a Minneapolis Moline tractor. Another disadvantage was that mounting usually required some time and labor, resulting in the implement being semi-permanently attached with bolts or other mounting hardware. Usually it was impractical to remove the implement and reinstall it on a day-to-day basis. As a result, the tractor was unavailable for other uses and dedicated to a single use for an appreciable

period of time. An implement generally would be mounted at the beginning of its season of use (such as tillage, planting or harvesting) and removed only when the likely use season had ended.

### **Three-point hitches and quick hitches**

The drawbar system was virtually the exclusive method of attaching implements (other than direct attachment to the tractor) before Harry Ferguson developed the three-point hitch. Equipment attached to the three-point hitch can be raised or lowered hydraulically with a control lever. The equipment attached to the three-point hitch is usually completely supported by the tractor. Another way to attach an implement is via a Quick Hitch, which is attached to the three-point hitch. This enables a single person to attach an implement quicker and put the person in less danger when attaching the implement.



A modern three point hitch

The three-point hitch revolutionized farm tractors and their implements.

Almost every tractor today features Ferguson's 3 point linkage or a derivative of it. The three-point hitch allows for easy attachment and detachment of implements while allowing the implement to function as a part of the tractor almost as if it were attached by a fixed mount. Previously, when the implement hit an obstacle the towing link would break or the tractor could flip over. Ferguson's genius was to combine a connection via two lower and one upper lift arms that were connected to a hydraulic lifting ram. The ram was in turn connected to the upper of the 3 links so that increased drag (as when a plough hits a rock) caused the hydraulics to lift the implement until the obstacle was passed.

Other manufacturers copied Ferguson's invention, or developed variations of it. For example, International Harvester's Farmall tractors had a two-point "Fast Hitch" and John Deere had a power lift that was similar but not as flexible as the Ferguson invention. Recently, Bobcat's patent on its front loader connection (inspired by these earlier systems) has expired; and compact tractors are now being outfitted with quick-connect attachments for their front-end loaders.

## **Power take-off systems and hydraulics**

In addition to towing an implement or supplying tractive power through the wheels, most tractors have a means to transfer power to another machine such as a baler, swather, or mower. Unless it functions solely by pulling it through or over the ground, a towed implement needs its own power source (such as a baler or combine with a separate engine) or else a means of transmitting power from the tractor to the mechanical operations of the equipment.

Early tractors used belts or cables wrapped around the flywheel or a separate belt pulley to power stationary equipment, such as a threshing machine, buzz saw, silage blower, or stationary baler. In most cases, it was not practical for the tractor and equipment to move with a flexible belt or cable between them, so this system necessitated that the tractor remain in one location with the work brought to the equipment, or that the tractor be relocated at each turn and the power set-up reapplied (as in cable-drawn plowing systems used in early steam tractor operations).



A PTO shaft connected to a tractor.

Modern tractors use a power take-off (PTO) shaft to provide rotary power to machinery that may be stationary or pulled. The PTO shaft generally is at the rear of the tractor, and can be connected to an implement that is either towed by a drawbar or a three-point hitch.

This eliminates the need for a separate implement-mounted power source, which is almost never seen in modern farm equipment.

Virtually all modern tractors can also provide external hydraulic fluid and electrical power to the equipment they are towing, either by hoses or wires.

## **Operation**



A lawn tractor towing a cargo cart

Modern tractors have many electrical switches and levers in the cab for controlling the multitude of different functions available on the tractor.

## **Pedals**

Modern farm tractors usually have four or five foot-pedals for the operator on the floor of the tractor.

The pedal on the left is the clutch. The operator presses on this pedal to disengage the transmission for either shifting gears or stopping the tractor. Some modern tractors have (or as optional equipment) a button on the gear stick for controlling the clutch, in addition to the standard pedal.

Two of the pedals on the right are the brakes. The left brake pedal stops the left rear wheel and the right brake pedal does the same with the right side. This independent left and right wheel braking augments the steering of the tractor when only the two rear wheels are driven. This is usually done when it is necessary to make a sharp turn. The

split brake pedal is also used in mud or soft dirt to control a tire that spins due to loss of traction. The operator presses both pedals together to stop the tractor. For tractors with additional front-wheel drive, this operation often engages the 4-wheel locking differential (diff-lock) to help stop the tractor when traveling at road speeds.

The pedal furthest to the right is the foot throttle. Unlike in automobiles, it can also be controlled from a hand-operated lever ("hand throttle"). This helps provide a constant speed in field work. It also helps provide continuous power for stationary tractors that are operating an implement by shaft or belt. The foot throttle gives the operator more automobile-like control over the speed of the tractor for road work. This is a feature of more recent tractors; older tractors often did not have this feature. In the UK it is mandatory to use the foot pedal to control engine speed while travelling on the road. Some tractors, especially those designed for row-crop work, have a 'de-accelerator' pedal, which operates in the reverse fashion to an automobile throttle, in that the pedal is pushed down to slow the engine. This is to allow fine control over the speed of the tractor when maneuvering at the end of crop rows in fields- the operating speed of the engine is set using the hand throttle, and if the operator wishes to slow the tractor to turn, he simply has to press the pedal, turn and release it once the turn is completed, rather than having to alter the setting of the hand throttle twice during the maneuver.

A fifth pedal is traditionally included just in front of the driver's seat to operate the rear diff-lock, which prevents wheelslip. The differential normally allows the outside wheel to travel faster than the inside wheel during a turn. However, in low-traction conditions on a soft surface the same mechanism could allow one wheel to slip, further reducing traction. The diff-lock overrides this, forcing both wheels to turn at the same speed, reducing wheel slip and improving traction. Care must be taken to unlock the differential before turning, usually by hitting the pedal a second time, since the tractor cannot perform a turn with the diff-lock engaged. In modern tractors this pedal is replaced with an electrical switch.

## **Levers and switches**

Many functions that were once controlled with a lever have been replaced with some model of electrical switch with the rise of indirect computer controlling of functions in modern tractors.

Until the beginning of the 60's tractors had a single register of gears, hence one gear stick. Often 3-5 forwards and 1 reverse. Then group gears were introduced, hence another gear stick. Later on control of the reverse gear was moved to a special stick that controls direction and adding a gear stick or a lever attached at the side of the steering wheel. Nowadays with CVT or other clutch-free gear types there are fewer sticks for controlling the transmission, some replaced with electrical switches or totally computer controlled.

The three-point hitch was controlled with a lever for adjusting the position, or as with the earliest ones, just the function for raising or lowering the hitch. With modern electrical systems it's often replaced with a potentiometer for lower bound position and another one

for the upper bound and a switch allowing automatic adjustment of the hitch between these settings.

The external hydraulics also originally had levers but nowadays often replaced with some form of electrical switch, the same goes for the power take-off shaft.

## Safety

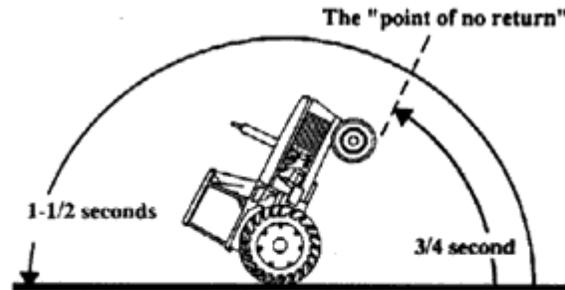


Figure 3. The "point of no return" during a rear turnover may be reached in 3/4 of a second.  
(Source: Agricultural Safety, Deere and Company, Inc.)

### Farm tractor rear turnover



The classic Row Crop tractor (an Allis-Chalmers WD). Note the absence of any rollover protection system.

Agriculture in the United States is one of the most hazardous industries, only surpassed by mining and construction. No other farm machine is so identified with the hazards of production agriculture as the tractor. Tractor-related injuries account for approximately

32% of the fatalities and 6% of the non-fatal injuries in agriculture. Over 50% is attributed to tractor overturns.

The roll over protection structure (ROPS) and seat belt, when worn, are the two most important safety devices to protect operators from death during tractor overturns.

Modern tractors have rollover protection systems (ROPS) to prevent an operator from being crushed if the tractor overturns. It is important to remember that the ROPS does not prevent tractor overturns. Rather, it prevents the operator from being crushed during an overturn. This is especially important in open-air tractors, where the ROPS is a steel beam that extends above the operator's seat. For tractors with operator cabs, the ROPS is part of the frame of the cab. A ROPS with enclosed cab further reduces the likelihood of serious injury because the operator is protected by the sides and windows of the cab.

ROPS were first required by legislation in Sweden in 1959. Before ROPS were required, some farmers died when their tractors rolled on top of them. Row-crop tractors, before ROPS, were particularly dangerous because of their 'tricycle' design with the two front wheels spaced close together and angled inward toward the ground. Some farmers were killed by rollovers while operating tractors along steep slopes. Others have been killed while attempting to tow or pull an excessive load from above axle height, or when cold weather caused the tires to freeze to the ground, in both cases causing the tractor to pivot around the rear axle.

For the ROPS to work as designed, the operator must stay within the protective frame of the ROPS. This means the operator must wear the seat belt. Not wearing the seat belt may defeat the primary purpose of the ROPS.

## ***Applications and variations***

### **Farm tractor applications**



A modern John Deere 8110 Farm Tractor plowing a field using a chisel plow.



A tractor pulling a rototiller

The most common use of the term "tractor" is for the vehicles used on farms. The farm tractor is used for pulling or pushing agricultural machinery or trailers, for plowing, tilling, disking, harrowing, planting, and similar tasks.



A farm tractor used to power a pump for irrigating a plot of land

A variety of specialty farm tractors have been developed for particular uses. These include "row crop" tractors with adjustable tread width to allow the tractor to pass down rows of corn, tomatoes or other crops without crushing the plants, "wheatland" or "standard" tractors with non-adjustable fixed wheels and a lower center of gravity for plowing and other heavy field work for broadcast crops, and "high crop" tractors with adjustable tread and increased ground clearance, often used in the cultivation of cotton and other high-growing row crop plant operations, and "utility tractors", typically smaller tractors with a low center of gravity and short turning radius, used for general purposes around the farmstead. Many utility tractors are used for non-farm grading, landscape maintenance and excavation purposes, particularly with loaders, backhoes, pallet forks and similar devices. Small garden or lawn tractors designed for suburban and semi-rural gardening and landscape maintenance also exist in a variety of configurations.



A tractor with a chaser bin.

Some farm-type tractors are found elsewhere than on farms: with large universities' gardening departments, in public parks, or for highway workman use with blowtorch cylinders strapped to its sides and a pneumatic drill air compressor permanently fastened over its power take-off. These are often fitted with grass (turf) tyres which are less damaging to soft surfaces than agricultural tires.

### **Precision agriculture**

Space technology has been incorporated into agriculture in the form of GPS devices, and robust on-board computers installed as *optional features* on farm tractors. These technologies are used in modern, precision farming techniques. The spin-offs from the space race have actually facilitated automation in plowing and the use of autosteer systems drone on tractors that are manned but only steered at the end of a row, the idea being to neither overlap and use more fuel nor leave streaks when performing jobs such as cultivating.

## Engineering tractors



Ebro farm tractor

The durability and engine power of tractors made them very suitable for engineering tasks. Tractors can be fitted with engineering tools such as dozer blade, bucket, hoe, ripper, and so on. The most common attachments for the front of a tractor are dozer blade or a bucket. When attached with engineering tools the tractor is called an engineering vehicle.

A bulldozer is a track-type tractor attached with blade in the front and a rope-winch behind. Bulldozers are very powerful tractors and have excellent ground-hold, as their main tasks are to push or drag things.

Bulldozers have been further modified over time to evolve into new machines which are capable of working in ways that the original bulldozer can not. 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, rock and similar loose material to load it into trucks.

A front-loader or loader is a tractor with an engineering tool which consists of two hydraulic powered arms on either side of the front engine compartment and a tilting implement. This is usually a wide open box called a bucket but other common attachments are a pallet fork and a bale grapppler.

Other modifications to the original bulldozer include making the machine smaller to let it operate in small work areas where movement is limited. There are also tiny wheeled loaders, officially called Skid-steer loaders but nicknamed "Bobcat" after the original manufacturer, which are particularly suited for small excavation projects in confined areas.

## Backhoe loader



A common backhoe-loader. The backhoe is on the left, the bucket/blade on the right.

The most common variation of the classic farm **tractor** is the **hoe**, also called a **hoe-loader**. As the name implies, it has a loader assembly on the front and a backhoe on the back. Backhoes attach to a 3 point hitch on farm or industrial tractors. Industrial tractors are often heavier in construction particularly with regards to the use of steel grill for protection from rocks and the use of construction tires. 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.

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, loading trucks, breaking asphalt and paving roads. Some buckets have a retractable bottom, enabling them to empty their load more quickly and efficiently. Buckets with retractable bottoms are also often used for grading and scratching off sand. The front assembly may be a removable attachment or permanently mounted. Often the bucket can be replaced with other devices or tools.

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.

In the UK, the word "JCB" is sometimes used colloquially as a genericized trademark for any such type of engineering vehicle. The term JCB now appears in the Oxford English Dictionary, although it is still legally a trademark of J. C. Bamford Ltd. The term "digger" is also commonly used.

## Compact Utility Tractor



In the middle is a 24 hp (18 kW) diesel CUT illustrating the size difference between a small 40 hp farm tractor and a garden tractor

A Compact Utility Tractor, also called a CUT is a smaller version of an agricultural tractor but designed primarily for landscaping and estate management type tasks rather than for planting and harvesting on a commercial scale. Typical CUTs range in from 20 to 50 horsepower (15-37 kW) with available power take off (PTO) horsepower ranging from 15 to 45 hp (11-34 kW). CUTs are often equipped with both a mid-mounted PTO and a standard rear PTO, especially those below 40 horsepower (30 kW). The mid-mount PTO shaft typically rotates at/near 2000 rpms and is typically used to power such implements as mid-mount finish mower, a front mounted snow blower or front mounted

rotary broom. The rear PTO is standardized at 540 rpms for the North American markets, but in some parts of the world a dual 540/1000 rpm PTO is standard and implements are available for either standard in those markets.



Howse brand modular Subsoiler mounted to a tractor



Broadcast seeder mounted to a Kubota Compact Utility Tractor

One of the most common attachment for a Compact Utility Tractor is the front end loader or FEL. Like the larger agricultural tractors, a CUT will have an adjustable three-point hitch that is hydraulically controlled. Typically a CUT will have four wheel drive, or more correctly 4 wheel assist. Modern Compact Utility Tractors often feature a Hydrostatic transmission, but many variants of gear drive transmissions are also offered from low priced simple gear transmissions to synchronized transmissions to advanced glide-shift transmissions. All modern CUTs feature a government mandated roll over protection structure (ROPS) just like agricultural tractors. The most well known brands in North America include Kubota, John Deere Tractor, New Holland Ag, Case-Farmall and Massey-Ferguson. Although less common, compact backhoes are often attached to compact utility tractors.



JD 71 Flexi Planter for tractors 20 to 35 horsepower

Compact Utility Tractors require special smaller implements than full size agricultural tractors. Very common implements include the box blade, the grader blade, the landscape rake, the post hole digger (*or post hole auger*), the rotary cutter (*also called a slasher or a brush hog*), a mid or rear mount finish mower, broadcast seeder, subsoiler and the rototiller (*also rotary tiller*). In northern climates, a rear mounted snow blower is very common, on smaller CUTs some models are available with front mounted snow blowers that are powered by a mid-PTO shaft. There are many more implement brands than there are tractor brands offering CUT owners a wide selection of choice.

For small scale farming or large scale gardening, there are some planting and harvesting implements sized for CUTs. One and two row planting units are commonly available as are cultivators, sprayers and different types of seeders (*slit, rotary and drop*).

## Row-crop tractor



An Oliver Row Crop 60 tractor

A **row-crop tractor** is a tractor tailored specifically to the growing of row crops (crops grown in rows, as in truck farming), and most especially to cultivating. Cultivating can take place anytime from soon after the crop plants have sprouted until soon before they are harvested. Several rounds of cultivating may be done over the season. A row-crop tractor essentially brings together a farm tractor and its cultivator into one machine, in the same way that motive power has been combined into other machinery (for example, horseless carriages combined the motive power into transport vehicles; self-propelled guns combined the artillery tractor and its gun into one machine).

The earliest win from introducing tractors to mechanize agriculture was in reducing the heavy efforts of plowing and harrowing before planting, which could often be (almost literally) backbreaking tasks for humans and draft animals. Early tractors were used mainly to alleviate this drudgery. But they tended to be very big and heavy, so they were not well suited to getting into a field of already-planted row crops to do weed control. Row-crop tractors—light, affordable, and reliable—corrected this flaw.

*Row crop* itself refers to any farm crop that is cultivated in rows. The United States Environmental Protection Agency (EPA) defines 'row crop' as "Agricultural crop planted, usually with mechanical planting devices, in individual rows that are spaced to permit machine traffic during the early parts of the growing season"

## Row-crop tractor history



A Farmall *Regular*

The first tractors designed for the ability to fit between rows of crops were made by International Harvester (IH), with development beginning in the 1920s. The first row-crop tractors made by IH were called "Farmalls". The cultivator mounted in the front so it was easily visible. Additionally, the tractor had a narrow front end; the front tires were spaced very closely and angled in towards the bottom. The back wheels straddled two rows and it could cultivate four rows at once.

From 1924 until 1963, Farmalls were the largest selling row-crop tractors.

To compete, John Deere designed the Model C which had a wide front and could cultivate three rows at once. Only 112 prototypes were made as Deere realized that sales would be lost to Farmall if their model did less. In 1928, John Deere released the Model C anyway, only as the Model GP (General Purpose) to avoid confusion with the Model D when order over the then unclear phone.

Oliver refined its "Row Crop" model early in 1930. Until 1935, the 18-27 was Oliver-Hart-Parr's only row-crop tractor. Many Oliver row crop models are referred to as "Oliver Row Crop 77" or "Oliver Row Crop 88" etc.

## Row-crop tractor safety



Allis-Chalmers WD. Note the absence of any rollover protection system.

Many early row-crop tractors had a tricycle design with two closely spaced front tires, and some even had a single front tire. This made it dangerous to operate on the side of a steep hill, and, as a result, many farmers died from tractor rollovers. Also, early row-crop tractors had no rollover protection system (ROPS), meaning that if the tractor flipped back the operator could be crushed. Sweden was the first country which passed legislation requiring ROPS, in 1959.

Over 50% of tractor related injuries and deaths are attributed to tractor rollover.

### Modern row-crop tractors

The Canadian agricultural equipment manufacturer Versatile makes row-crop tractors that are 250 and 280 horsepower (190 and 210 kW); powered by an 8.3 liter Cummins Diesel engine.

Modern row crop tractors have rollover protection systems in the form of a reinforced cab or a roll bar.

### Garden tractors

Garden Tractors (also called Mini Tractors) are small, light and simple tractors designed for use in domestic gardens. Garden Tractors are usually designed primarily for cutting grass, being fitted with horizontal rotary cutting decks. Visually, the distinction between a garden tractor and a ride-on lawnmower is often hard to make - generally Garden

Tractors are more sturdily built, with stronger frames, axles and transmissions rated for ground-engaging applications. Garden Tractors are generally capable of mounting other implements such as harrows, cultivators/rotavators, sweepers, rollers and dozer-blades. Like ride-on mowers, Garden Tractors generally have a vertical-crankshaft engine with a belt-drive to a transaxle-type transmission (usually of 4- or 5-speeds, although some may also have two-speed reduction gearboxes or a hydrostatic drive). However, Wheel Horse (now part of Toro) garden tractors have horizontal-crankshaft engines with belt-drive, whilst Allen/Gutbrod tractors had an automotive-type clutch and gearbox. The engines are generally a 1- or 2-cylinder petrol (gasoline) engine, although diesel engine models are also available, especially in Europe.

In the U.S., the term riding lawn mower today often is used to refer to mid or rear engined machines. Front-engined tractor layout machines designed primarily for cutting grass and light towing are called lawn tractors; and heavier duty tractors of the same overall size, often shaft driven, are called garden tractors. The primary differences between a lawn tractor and a garden tractor are the transmission torque handling capability, frame durability, the rear wheels (garden tractors almost always have multiple mounting bolts, while most lawn tractors have a single bolt or clip on the hub), and the ability to attach ground engaging equipment such as plows or disk-harrows. Craftsman, MTD, Snapper, and other major mowing equipment manufacturers use these terms.

As well as dedicated manufacturers, many makers of agricultural tractors have made (or continue to make) ranges of garden tractors, such as Case, Massey-Ferguson, International Harvester and John Deere.

## **Two-wheel tractors**

Although most people think first of four-wheel vehicles when they think of tractors, a tractor may have one or more axles. The key benefit is the power itself, which only takes one axle to provide. Single-axle tractors, more often called two-wheel tractors or walk-behind tractors, have had many users ever since the beginning of internal combustion engine tractors. They tend to be small and affordable. This was especially true before the 1960s, when a walk-behind tractor could often be more affordable than a two-axle tractor of comparable power. Today's compact utility tractors and advanced garden tractors may negate most of that market advantage, but two-wheel tractors still enjoy a loyal following, especially where an already-paid-for two-wheel tractor is financially superior to a compact or garden tractor that would have to be purchased. Regions where two-wheel tractors are especially prevalent today include India, China, and Southeast Asia.

## **Orchard tractors**

Tractors tailored to use in fruit orchards typically have features suited to passing under tree branches with impunity. These include a lower overall profile; reduced tree-branch-snagging risk (via underslung exhaust pipes rather than smoke-stack-style exhaust, and large sheetmetal cowlings and fairings that allow branches to deflect and slide off rather

than catch); spark arrestors on the exhaust tips; and often wire cages to protect the operator from snags.

### **Automobile-conversion tractors and other homemade versions**



A Ford rebuilt to an EPA tractor.



An "A tractor" based on Volvo 760. Notice the slow-vehicle triangle and the longer boot.



A Volvo Duett rebuilt to an EPA tractor. Obviously the intended use is no longer as a farm vehicle.

The ingenuity of farm mechanics, coupled in some cases with OEM or aftermarket assistance, has often resulted in the conversion of automobiles for use as farm tractors. In the United States, this trend was especially strong from the 1910s through 1950s. It began early in the development of vehicles powered by internal combustion engines, with blacksmiths and amateur mechanics tinkering in their shops. Especially during the interwar period, dozens of manufacturers (Montgomery Ward among them) marketed aftermarket kits for converting Ford Model Ts for use as tractors. (These were sometimes called "Hoover Wagons" during the Great Depression, although this term was usually reserved for automobiles converted to horse-drawn buggy use when gasoline was unavailable or unaffordable). Ford even considered producing an "official" optional kit. Many Model A Fords also were converted for this purpose. In later years, some farm mechanics have been known to convert more modern trucks or cars for use as tractors, more often as curiosities or for recreational purposes (rather than out of the earlier motives of pure necessity or frugality).

During World War II, a shortage of tractors in Sweden led to the development of the so-called *EPA tractor* (EPA was a chain of discount stores and it was often used to signify something lacking in quality). An EPA tractor was simply an automobile, truck or lorry, with the passenger space cut off behind the front seats, equipped with two gearboxes in a row. When done to an older car with a ladder frame, the result was not dissimilar to a tractor and could be used as one.

After the war it remained popular, now not as a farm vehicle, but as a way for young people without a driver's license to own something similar to a car. Since it was legally seen as a tractor it could be driven from 16 years of age and only required a tractor license. Eventually the legal loophole was closed and no new EPA tractors were allowed to be made, but the remaining were still legal, something that led to inflated prices and many protests from people that preferred EPA tractors to ordinary cars.

In March 1975 a similar type of vehicle was introduced in Sweden, the *A tractor* [from *arbetstraktor* (work tractor)]. The main difference is that an A tractor has a top speed of 30 km/h. This is usually done by fitting two gearboxes in a row and not using one of them. Volvo Duett was for a long time the primary choice for conversion to an EPA or A tractor, but, since supplies have dried up, other cars have been used, in most cases a Volvo.

Another type of homemade tractors are ones that are fabricated from scratch. The "from scratch" description is relative, as often individual components will be repurposed from earlier vehicles or machinery (e.g., engines, gearboxes, axle housings); but the tractor's overall chassis is essentially designed and built by the owner (e.g., a frame is welded from bar stock—channel stock, angle stock, flat stock, etc.). As with automobile conversions, the heyday of this type of tractor, at least in developed economies, lies in the past, when there were large populations of blue-collar workers for whom metalworking and farming were prevalent parts of their lives. (For example, many 19th- and 20th-century New England and Midwestern machinists and factory workers had grown up on farms.) Backyard fabrication was a natural activity to them (whereas it might seem daunting to most people today).

### Alternative machine types 'called' tractors



Road tractor pulling a flatbed trailer

The term *tractor* (US & Canada) or *tractor unit* (UK) is also applied to:

- **Road tractors, tractor units** or traction heads, familiar as the front end of an articulated lorry / semi-trailer truck. They are heavy-duty vehicles with large engines and several axles.
  - The majority of these tractors are designed to pull long semi-trailers, most often to transport freight of some kind over a significant distance, and is connected to the trailer with a fifth wheel coupling. In England this type of "tractor" is often called an "artic cab" (short for *articulated cab*).
  - A minority is the ballast tractor, whose load is hauled from a drawbar.
- *Pushback tractors* are used on airports to move aircraft on the ground, most commonly pushing aircraft away from their parking stands.
- Locomotive tractors (engines) or Rail car movers
  - The amalgamation of machines, electrical generators, controls and devices that comprise the traction component of railway vehicles
- Artillery tractors
  - Vehicles used to tow artillery pieces of varying weights.
- NASA and other space agencies use very large tractors to ferry launch vehicles such as booster rockets and space shuttles from their hangars to (and, in rare cases, from) the launchpad.
- A pipe-tractor is a device used for conveying advanced instruments into pipes for measurement and data logging, and the purging of well holes, sewer pipes and other inaccessible tubes.



Diesel-electric locomotive at work



Komsomolets Soviet artillery tractor



A Trackmobile 4150



Aircraft Pushback tractor

### ***Glossary of tractor-related terms not explained elsewhere***

<b>Term</b>	<b>Explanation</b>
Nebraska tractor tests	Tests, mandated by a Nebraska law and administered by the University of Nebraska, that objectively tested the performance of all brands sold in that state. In the 1920s and 1930s, an era of snake oil sales and advertising tactics, the Nebraska tests helped farmers throughout North America to see through marketing claims and make informed buying decisions. The tests continue today, making sure that the snake oil, which has mostly been vanquished, stays that way.
tractor war(s) great tractor war(s)	A period of ruinous competition and price warring between tractor manufacturers in the 1920s. Led to a consolidation in the industry.



An unusual application - road roller powered by a tractor-drive



A single tractor in Brazil.

## Chapter- 10

# 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 AWPs 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's 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.

AWP's 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's 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's 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's 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's 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's 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's sold per year in the US) the market crashed in the early 2000s, leading to a strong contraction amongst the manufacturers.

## Chapter- 11

# 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 weight 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- 12

# 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- 13

# 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- 14

# 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- 15

# 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

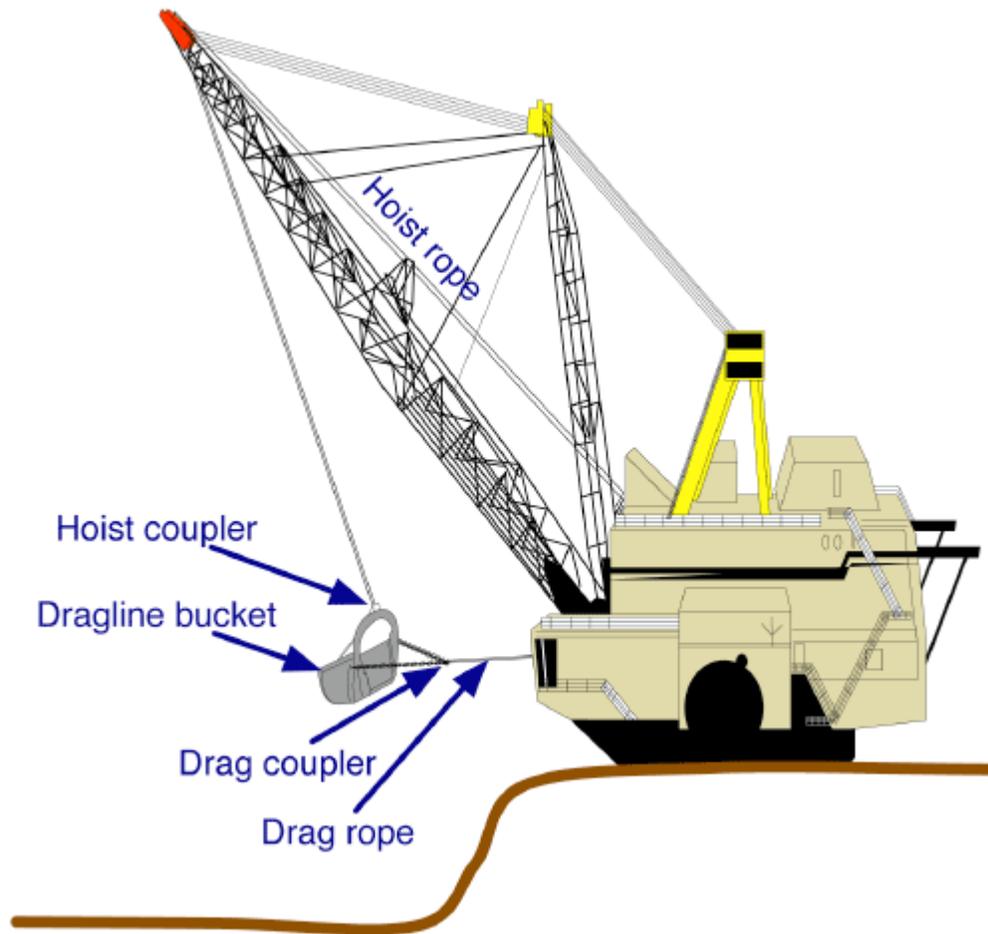
1926. So popular were these machines that the name Monighan became a generic term for dragline. In the early 1930s, Bucyrus-Erie began purchasing shares of Monighan stock with Monighan's approval. Bucyrus purchased a controlling interest and the joint company became known as Bucyrus-Monighan until the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

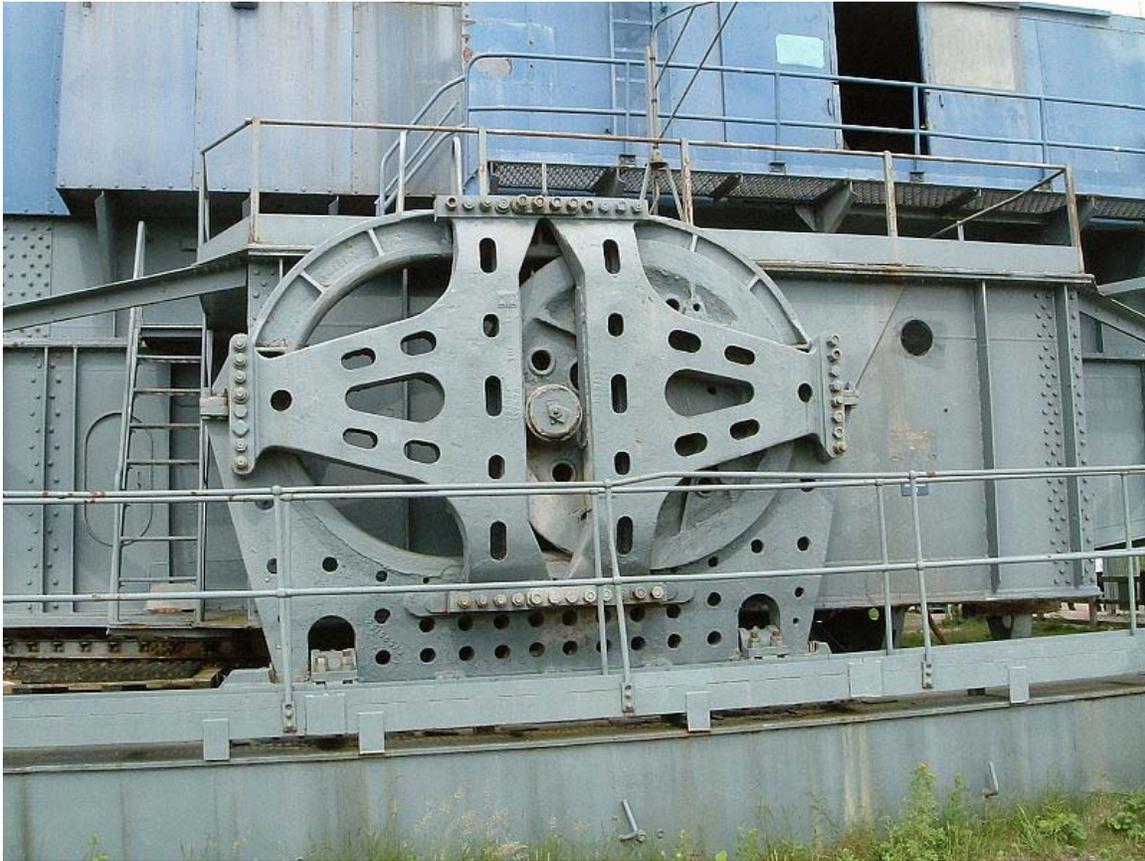
In all but the smallest of draglines, movement is accomplished by "walking" using feet or pontoons, as caterpillar tracks place too much pressure on the ground, and have great difficulty under the immense weight of the dragline. Maximum speed is only at most a few metres per minute since the feet must 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- 16

# 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***

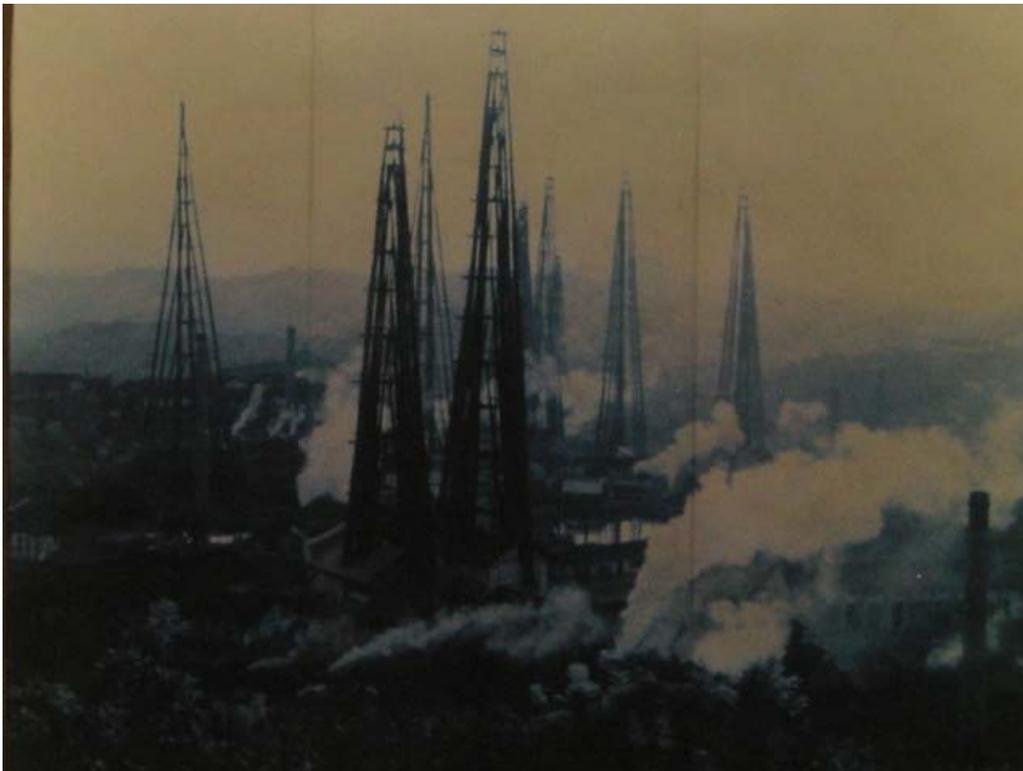
New technology uses smaller portable trailer mounted rigs with shorter 10 foot (3.0 m) drill pipe. DIY users and missionary groups use these to drill water wells as they can be operated by 1 or 2 people with a minimal skill level. The shorter drill pipe also allows a much smaller mast, which gives a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

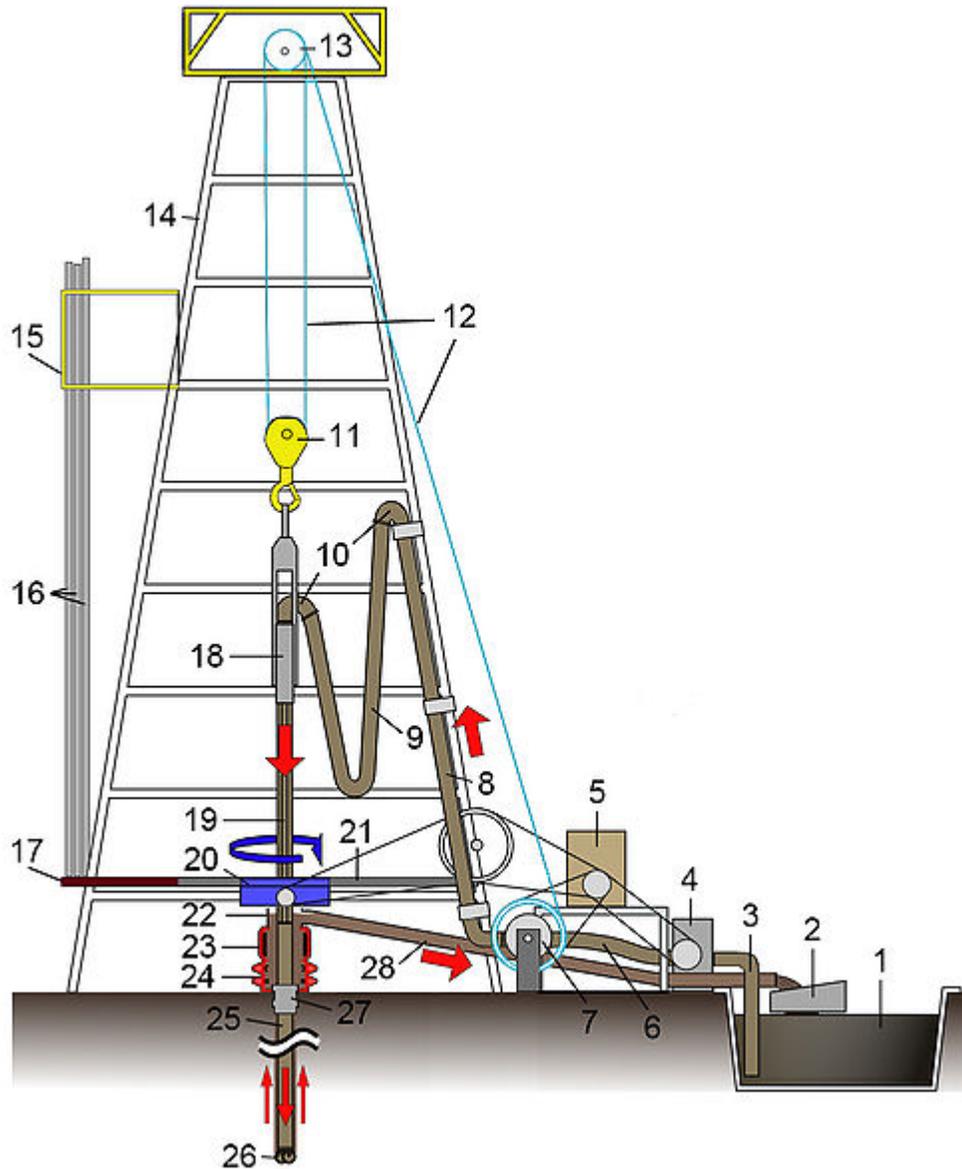
A unique drilling operation in deep ocean water was named Project Mohole.

### ***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.