Engineering Vehicles

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First Edition, 2012

ISBN 978-81-323-4364-6

Published by:
White Word Publications
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
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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 ft²) is dropped, while thick snow can require up to 40 g/m² (8 lb/1000 ft²) 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 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.

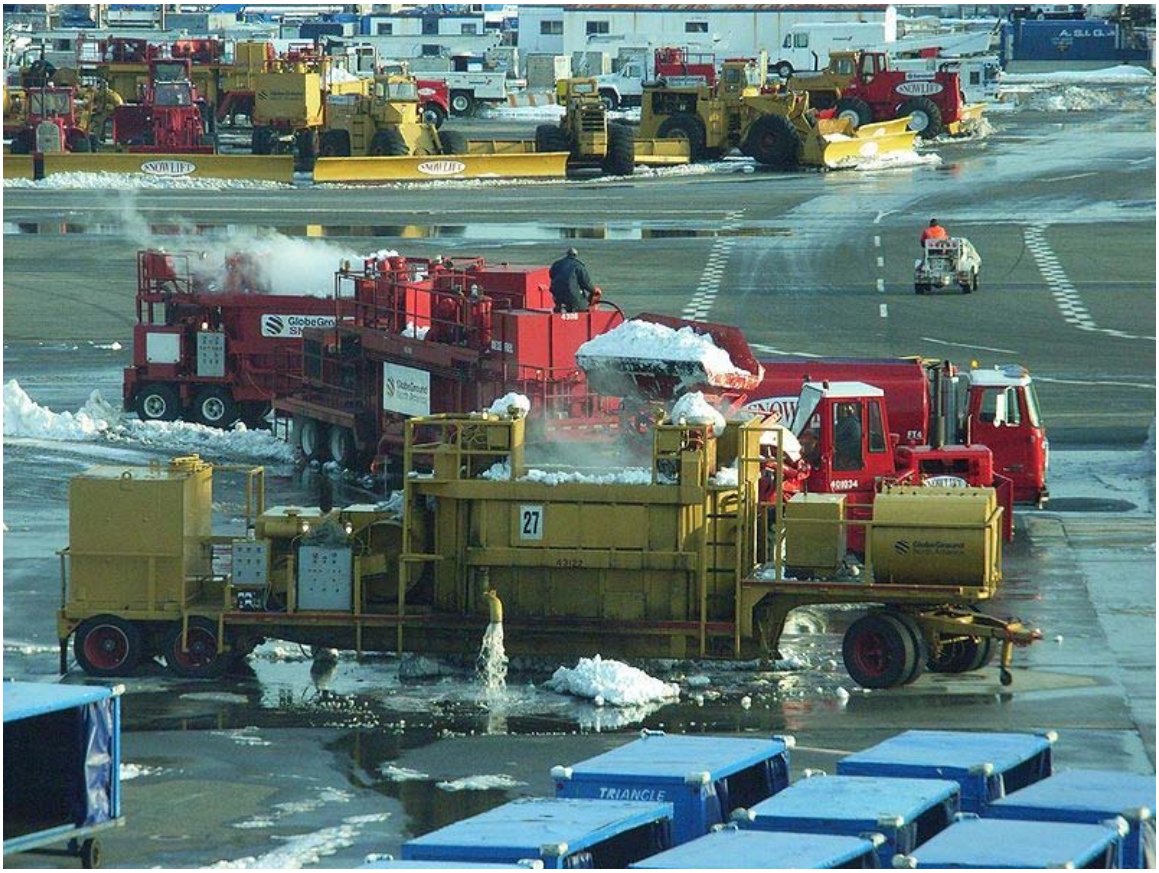
Snow groomer

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

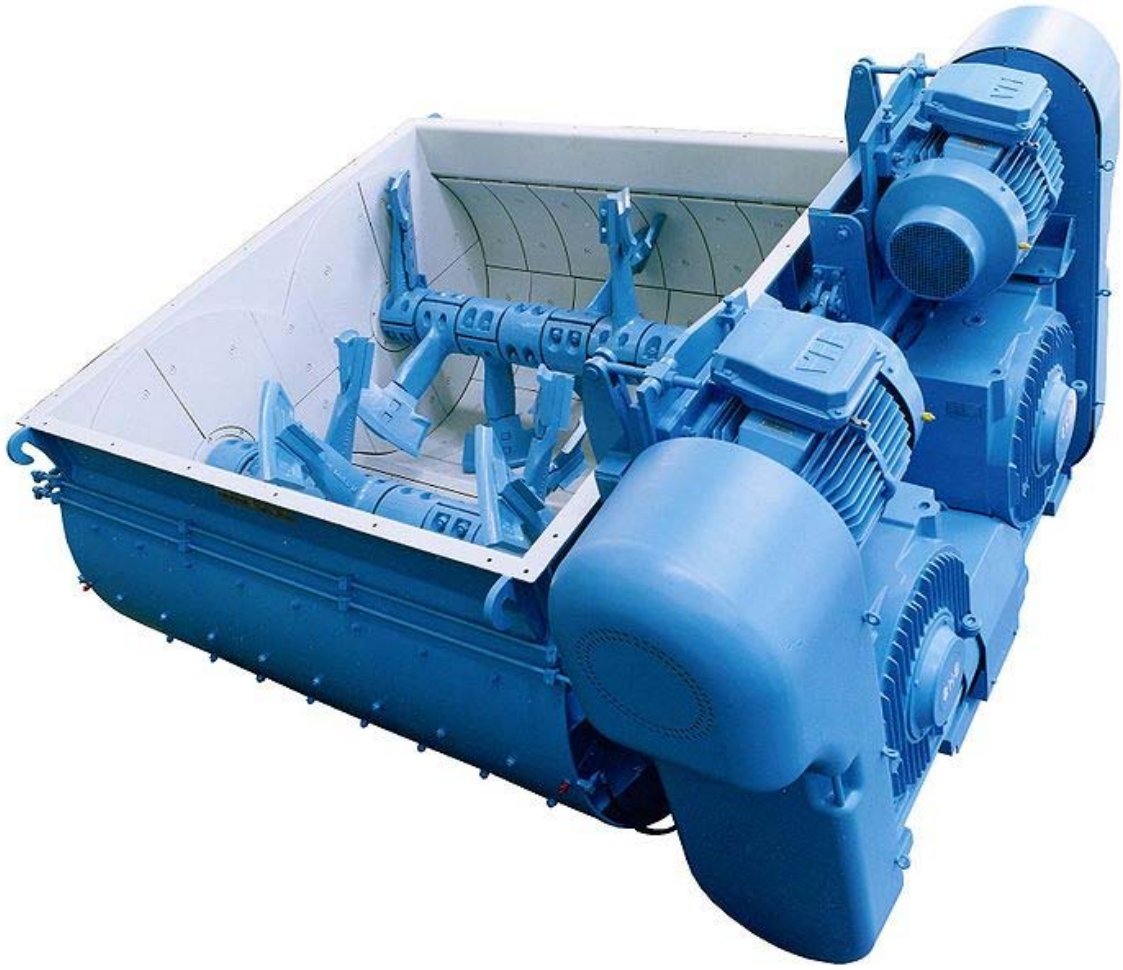
This portable concrete/motar mixer has wheels and a towing tongue so that it can be towed by a motor vehicle and moved around the worksite by hand, and its rotation is powered by mains electricity. The lever allows the concrete/mortar to be tipped into a wheelbarrow.

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^3. 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^3), 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^3). 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^3).

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^3.

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

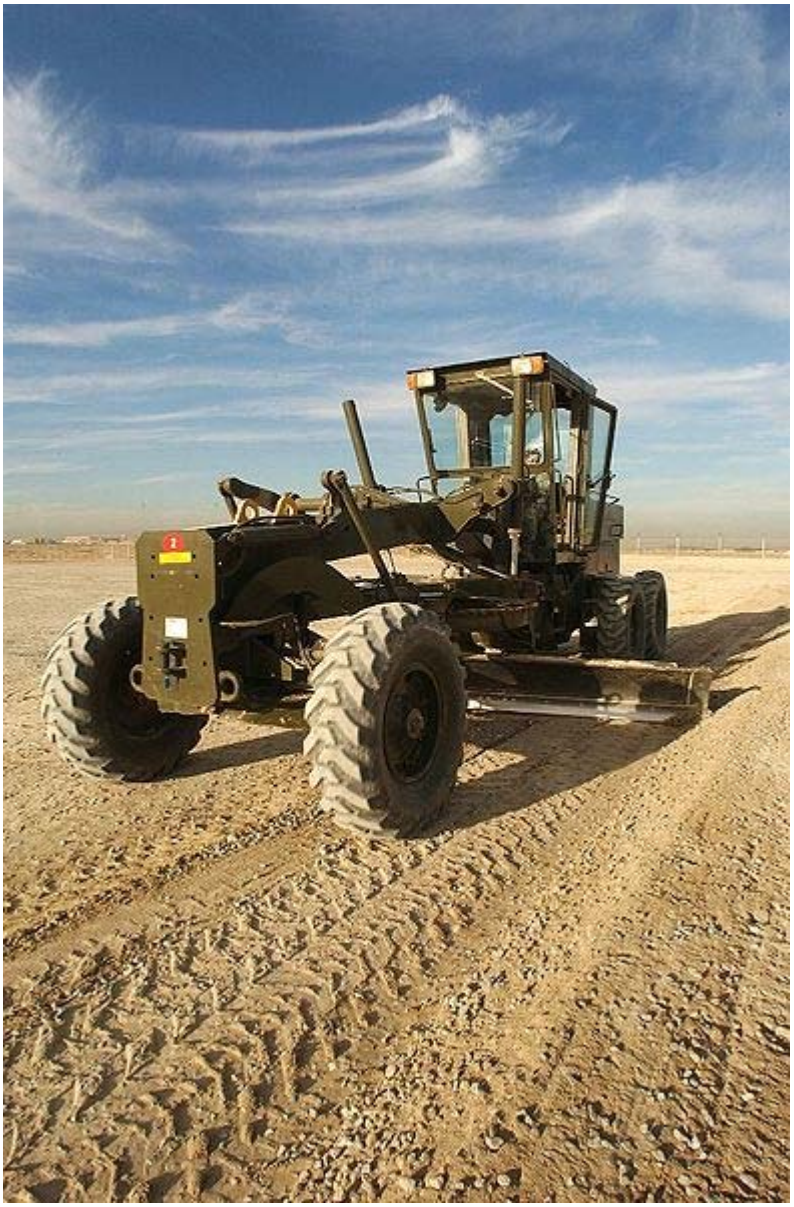
In recent years, hydraulic excavator capabilities have expanded far beyond excavation tasks with buckets. With the advent of hydraulic powered attachments such as a breaker, a grapple or an auger, the excavator is frequently used in many applications other than excavation. Many excavators feature a quick 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, delimbing 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 delimbing 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 delimbing 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 delimbing 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 pickcle 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 sideshifters, 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

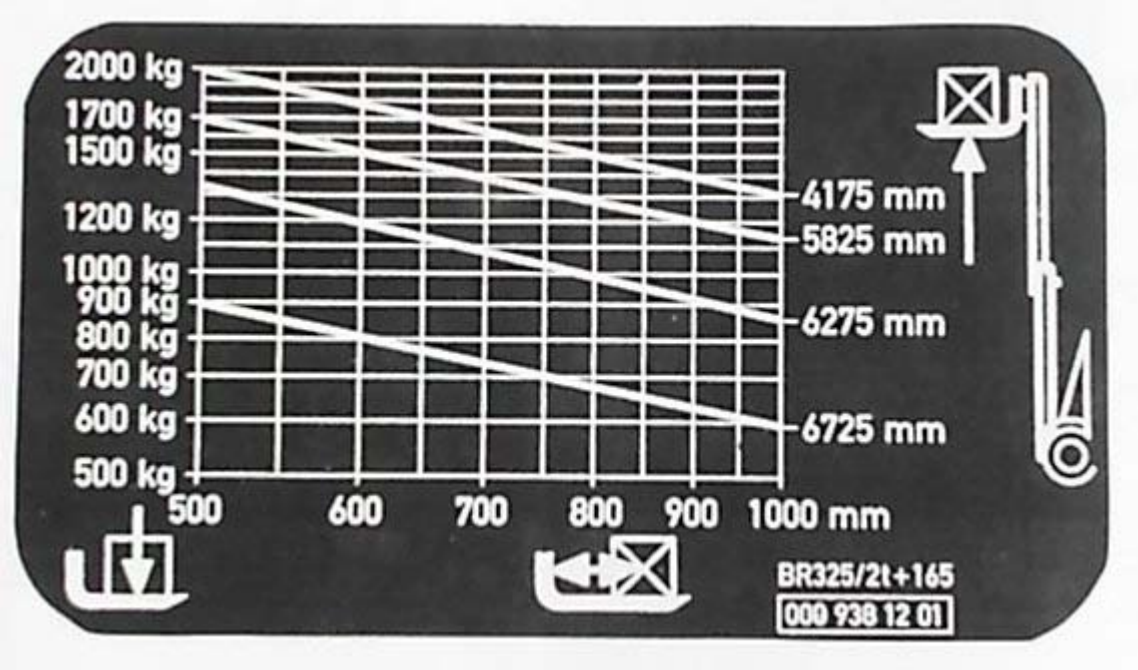
In the context of attachments, a hydraulic function consists of a valve on the forklift with a lever near the operator that provides two passages of pressurized hydraulic oil to power the attachment features. Sometimes an attachment has more features than your forklift has hydraulic functions, and one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

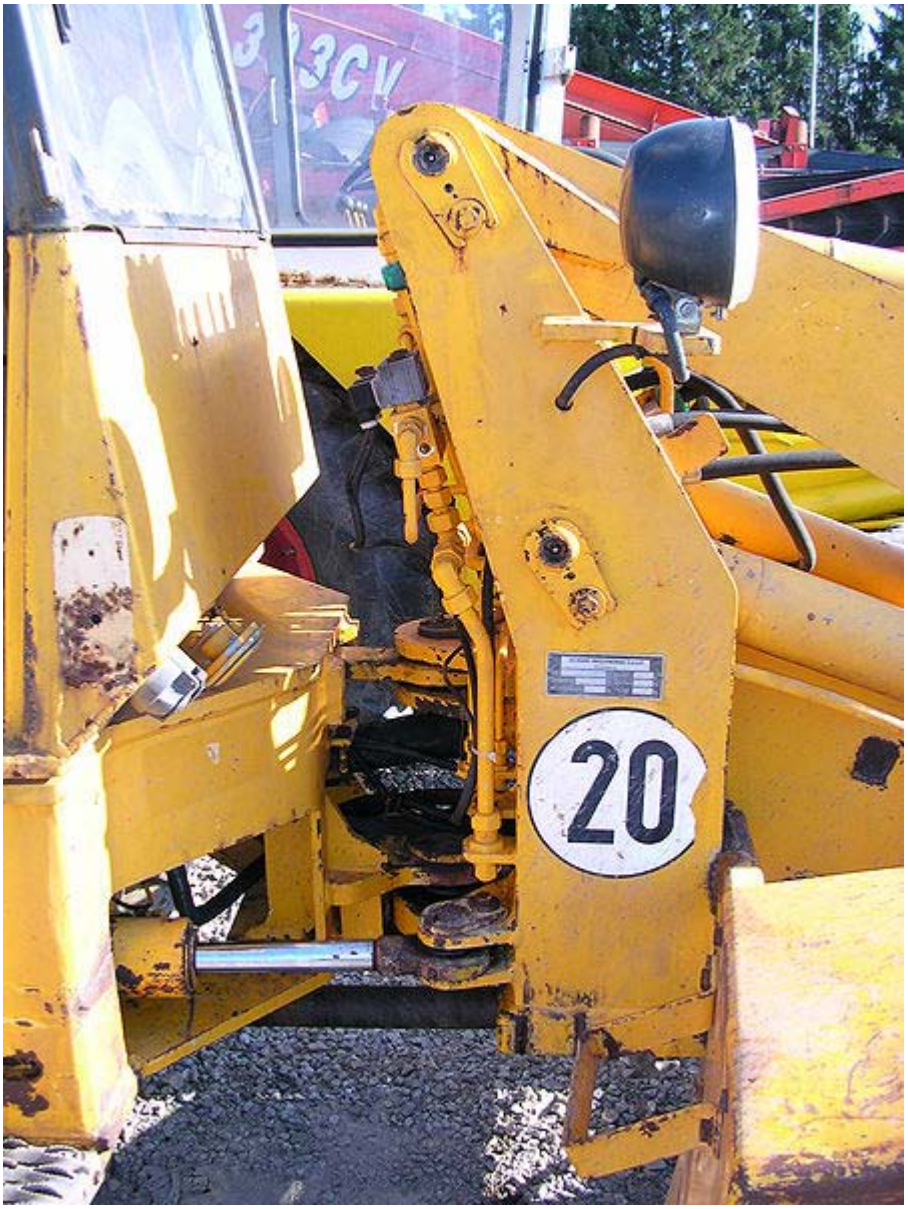
Chapter 7

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 grappler 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^3 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 **FEL**s, 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. Dieselisation 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. Liquified 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 Harvestor'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

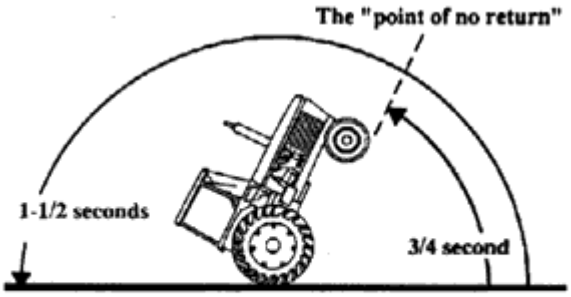


Figure 3. The "point of no return" during a rear turnover may be reached in 3/4 of a second.
(Source: Agricultural Safety, Deere and Company, Inc.)

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 grappler.

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 an "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

Term	Explanation
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

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. The versatility of tractors in soft ground for logging and road building contributed to the development of 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 **calfdozer**.

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 11

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.

Chapter 12

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.High Michelle How r u?

Standard dump truck

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

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

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

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

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

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

Articulated dump truck

Articulated dump truck or dumper

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

Transfer dump truck

Example of a transfer truck and trailer

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

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

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

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

Truck and pup

Tandem dump truck

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

Superdump truck

Example of a Superdump body and trailing axle

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

Semi trailer end dump truck

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

Semi trailer bottom dump truck

Bottom dump trailer.

A semi bottom dump (or "belly dump") is a 3-axle tractor pulling a 2-axle trailer with a clam shell type dump gate in the belly of the trailer. The key advantage of a semi bottom dump is its ability to lay material in a wind row (a linear heap). In addition, a semi bottom dump is maneuverable in reverse, unlike the double and triple trailer configurations described below. These trailers may be found either of the windrow type shown in the photo, or may be of the 'cross spread' type with the gates opening front to rear instead of left and right. The cross spread gates will actually spread gravel fairly evenly the width of the trailer. by comparison, the windrow gates leave a pile in the middle. The cross spreads jam and do not work well with larger materials. Likewise they are not suitable for use where spreading is not desired such as when hot asphalt paving material is being dumped into a paving machine.

Double and triple trailer bottom dump truck

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

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

long, to spread the weight over more distance. It is in this context that double and triple bottoms are found within the US.

Side dump truck

Side Dump Industries Train Set.

A *side dump truck*(S.D.T)consists of a 3-axle tractor pulling a 2-axle semi-trailer. It has hydraulic rams which tilt the dump body onto its side, spilling the material to either the left or right side of the trailer. The key advantages of the side dump are that it allows rapid unloading and can carry more weight in western United States. In addition, it is almost immune to upset (tipping over) while dumping unlike the semi end dumps which are very prone to tipping over. It is, however, highly likely that a side dump trailer will tip over if dumping is stopped prematurely. Also, when dumping lose 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.