EARTHWORK MATHINES

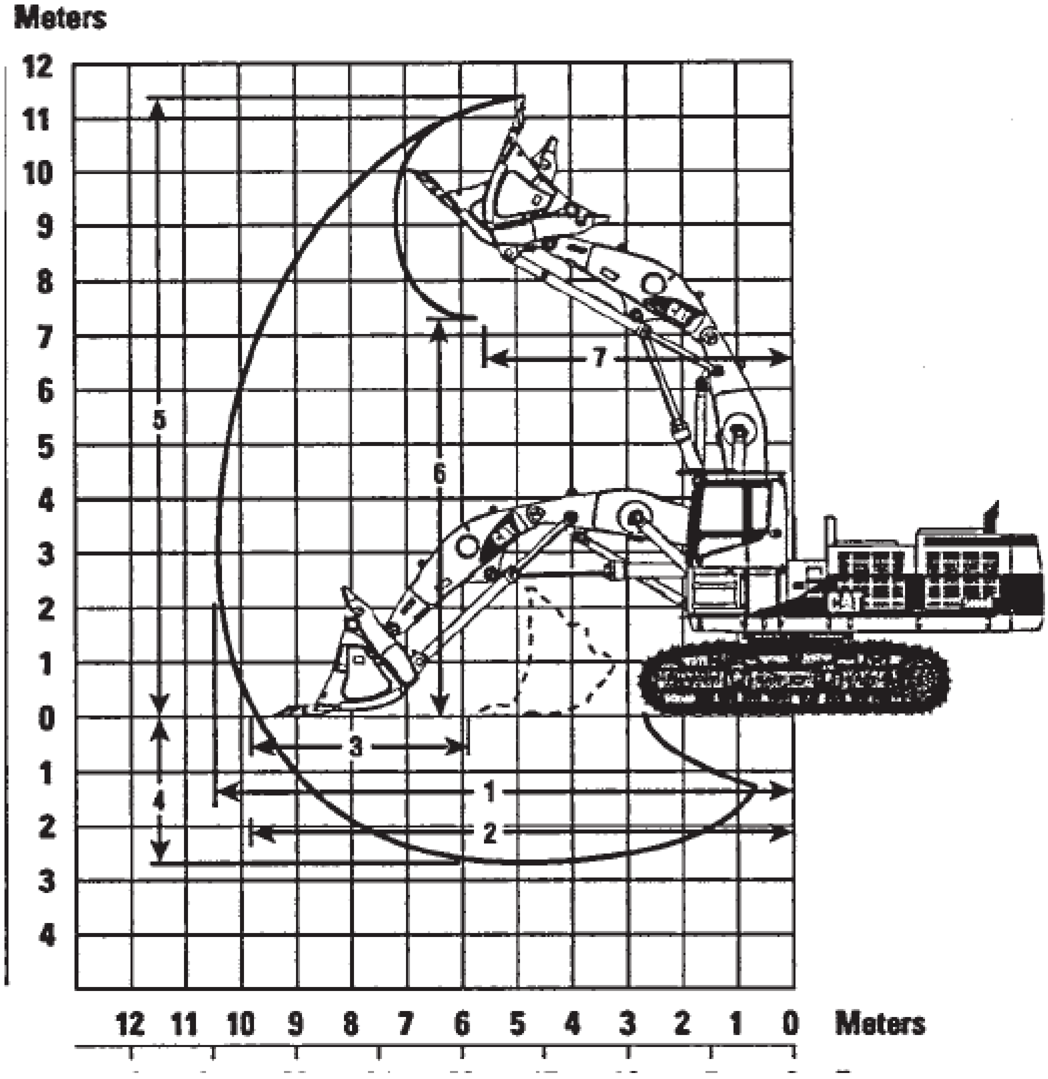
1. Excavators

Like its cable-operated counterpart, the full-revolving hydraulic excavator may be said to be made up of three structures: the revolving deck unit, the travel base, and the attachment. In hydraulic machines these distinctions remain clear only while considering the frames, arms, and other mechanical parts. The hydraulic system is operative in both deck and attachment, and often in the base as well. This discussion will first cover the mechanical arrangements, including the placement of the principal hydraulic units; and will then deal with the generation and distribution of the hydraulic power. The revolving unit consists essentially of a heavy rectangular steel deck, formed and reinforced to carry engine, pumps, attachment, controls, and cab; and to rest and revolve on a turntable. Some parts are heavy steel plate and specially shaped ribs and bases, others may be open girders. The center of rotation is usually forward of the center. The area of greatest strain, and therefore of heaviest construction, includes this spot, the mounting hinges for the boom just forward of it, and the hinges for the hoist cylinder(s) on the front edge of the deck. The forward location of the rotation center places the major part of the deck weight at the rear, where it serves to counterbalance the weight and pull of the shovel or backhoe. This effect is usually increased by placing the engine and pumps across the rear.

Counterweight. In addition to counterbalancing by arrangement of parts, there is usually a massive counterweight of shaped iron attached to the rear of the deck outside the cab. This may be very heavy, up to almost one-fifth of total excavator weight. The swing axis is centered in the travel unit, so that the front of the deck is set back from the front of the tracks, and the rear edge overhangs. This overhang is increased by the counterweight. There is even greater overhang at the side, when the top is swung 90°. This overhang or tail swing must be allowed for in placing the excavator for work. It is sometimes desirable to remove counterweight, to suit a lighter attachment, to reduce tail swing, or to lighten the machine to move it across a bridge of doubtful strength or to avoid overloading a trailer. Most of the larger machines provide standard or optional means to handle counterweight by engine power. There may be a pair of hydraulic cylinders mounted on the back, with connections to a valve and pump.

Engine. Standard power is diesel, from less than 100 horsepower to over 1,000. While bigger machines have bigger engines, there does not seem to be a standard ratio between power and either machine weight or bucket capacity.

Drives. One or more hydraulic pumps may be driven directly by a shaft behind the clutch, in line with the engine crankshaft. But it is perhaps more usual for the pumps to be offset from this shaft, in a group of two or more, with drive-through gears. Most of these machines have hydraulic drive to all functions. Cylinders operate parts directly, or through simple levers. Motors drive through reduction gears and sometimes through more or less extensive mechanical arrangements also.



Cab. The cab may be almost identical with that for a cable shovel. It is always of the circle vision type, with the roof higher than the machinery covering. Windows have shatterproof glass for weather protection and vandal resistance. Some windows may be fixed, others may be moved by cranks or on slides, or removed after loosening bolts. There may be a skylight or roof window, which is helpful in watching out for wires and tree branches. Standard cab location is on the right front corner of the deck, beside the boom. However, it may be on the left side. Controls for all phases of machine operation, plus gauges and warning lights, are grouped here. Most full-revolving hydraulic excavators have crawler mountings. However, they can be adapted to truck carriers and self-propelled wheel mountings.

Carbody. The carbody is a massive frame that includes the turntable and the dead axles or cross members that transmit its weight to the track frames. It carries the large ring gear that engages with the swing pinion extending downward from the deck frame.

Tracks. Track frames are single or double beams welded to the outer ends of the dead axles in the carbody. Either of two types of track may be used. One is the traditional linked-shoe construction. The other follows the crawler tractor design of a roller chain with bolted-on shoes. Shoes are usually of the semigrouser type with three low cleats. Drive wheels, idlers, and rollers conform to the type of track.

Propel. The propel, traction, or travel drive to the tracks may come from a pair of live axles set across the center of the carbody, or from a pair of reversible hydraulic motors fastened to the track frames. Axles are usually driven by a hydraulic motor on the deck, through reduction gears, a vertical shaft, and bevel gears. However, a hydraulic motor may be located in the axle housing, and turn them through a reduction-type transmission. In the axle mechanism, a pair of brakes and jaw clutches provide for steering while traveling, and for holding the machine while working. Control is usually hydraulic. Friction brakes may be used instead of jaws. Hydraulic motors, usually of the hydrostatic (axial piston) type, can be mounted in any convenient location on the inner surface of the track frames, and connected to the bull wheel axle by sets of reduction gears. Direct-mounted hydraulic motors permit independent track movement on two sides. This makes possible counterrotation on the tracks for the spin turns. This feature makes it easy to turn in the length of the machine with little ground disturbance, and to maneuver accurately in very restricted spaces. Most hydraulic excavators are designed for hoe use only. The hoe might therefore be considered as an integral part of the machine. However, it can be taken off and put back on, there are often options in stick length, and it may carry working tools other than hoe buckets. Present capacity of buckets ranges from less than 1⁄2 yard to over 20 yards.

Construction. All hydraulic hoe attachments are made of three strong structural members: the boom, the stick, and the bucket. These are hinged to each other, and the boom is hinged to the excavator deck. Movement at each of these hinges is controlled by two-way hydraulic cylinders.

Boom. The boom is almost always of the bent or gooseneck type, concave toward the ground. It usually has one bend or angle, but may have two. This shape serves three purposes. It allows space to pull the bucket closer to the machine, permits deeper digging without interference from the tracks, and enables the operator to see past it more easily when it is raised. The boom foot is hinged to massive trunions 2 or more feet back from the deck edge. They are usually in front of the swing center, but may be behind it. If there are two points of attachment to the boom, the upper one is used for maximum digging depth, the lower for maximum dump height. The outer end of the boom is usually prolonged into a two-piece bracket, in which the stick is held by a heavy hinge pin or pins. The stick cylinder is mounted on the boom top.

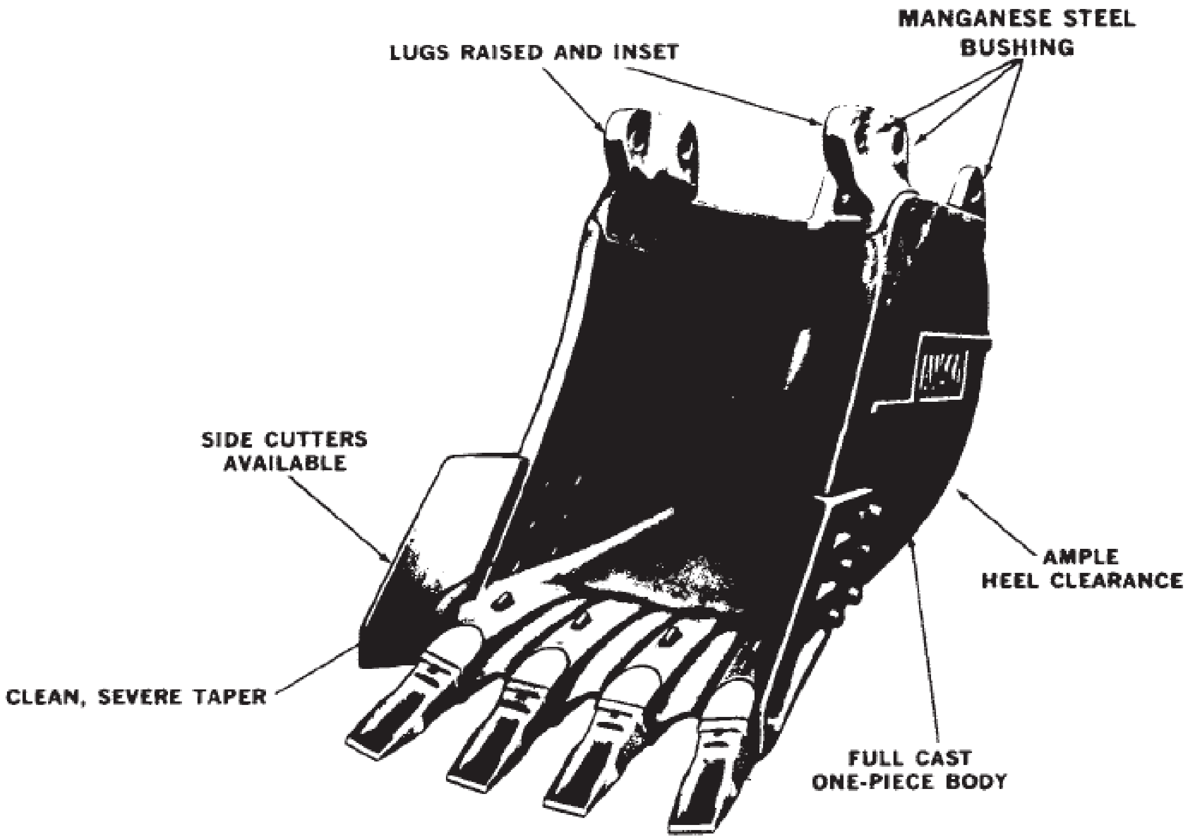
Stick. The stick, dipper stick, or arm is hinged to the end of the boom, and is connected to the stick cylinder rod at its upper (back) end, and to the bucket and bucket dump arms at the bottom or front. It is usually one-piece, but may extend and retract by telescoping. The stick's connection to the boom is much nearer the top than the bottom of the stick. The proportion between the two sections varies widely in different makes and models. The bucket teeth will be moved by the stick cylinder 4 to 8 times faster and farther than its piston moves, with one-fourth to one-eighth the force. Some machines provide two places for the boom-to-stick hinge. The one that is closer to the bucket will supply more power for hard digging; the other will provide more speed in easier work. The motions of the stick are variously described. Extending the cylinder forces the bucket in toward the machine, crowding it into the digging.

Bucket Mounting. The bucket, which will be described below, is connected to the lower end of the stick by a hinge pin, and to a triangular set of paired dump arms because the bucket has such an extended arc of rotary movement around the stick hinge. When the cylinder is extended, the bucket teeth move inward in a curling or digging motion. When it is retracted, the bucket opens or extends.

Several sets of holes may be provided, so that bucket action can be changed by moving hinge pins. The choice is between a combination of greater speed and range of movement in bucket control, or slower motion and greater digging and breakout force. Selection depends on the work being done and the operator's preference, and is likely to be changed only under unusual conditions.

Buckets. The bucket is sometimes called a dipper or a tool. The primary use of a backhoe is digging ditches, although it is also well adapted to digging basements, and general excavation. For efficiency in ditches, the bucket should cut the full required width on every pass. Therefore, buckets are usually supplied in a number of widths, ranging generally from 30 to 48 inches but available for some models down to 24 inches and up to 5 feet. Narrow buckets tend to be deep in proportion to width, and may fill poorly in chunky or rocky digging. If width is the same, reducing depth from the front edge reduces capacity, but may increase efficiency in loading enough to compensate. A standard-width bucket intended for very hard digging might be made smaller (shallower) so that it could be reinforced without too great weight. The bucket is usually slightly wider at the open or front end, to reduce friction at the sides and to allow for easier dumping. Additional clearance from trench walls may be obtained, and bucket cutting width increased by 2 to 8 or more inches, by installing sidecutters. They may be fixedwidth or adjustable, smooth-edged or toothed. Sidecutters are useful in accommodating a bucket to a wider trench, cramming more dirt into a narrow bucket, reducing drag in sticky soil, and reducing wear on the front edges. Wide buckets may have poor penetration. General-purpose buckets for basements and pits are usually intermediate in width and capacity. A bucket may be replaced by a single ripper tooth. This is intended for loosening and breaking, rather than excavating, but in certain soil types it may be able to cut a very narrow ditch for cable installation. The digging edge is almost always equipped with teeth, which are removable for reversing, sharpening, or replacement.

Other Attachments. Excavators are made to be very versatile machines with the variety of attachments that can be used on them. Many of the attachments are for excavation type operations. These include: the hoeclamp for handling stumps and boulders, and the hydraulic breaker for breaking up rocks or other hard objects. Some other commonly used attachments to show the versatility of the hydraulic excavator for excavation operations

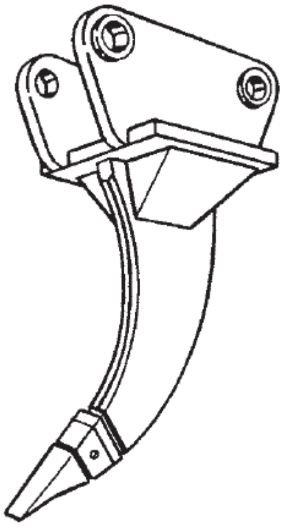


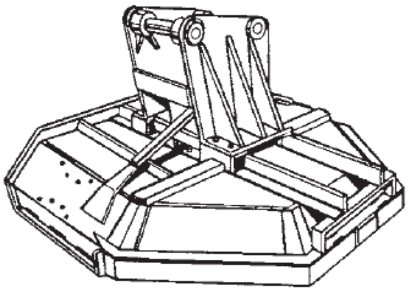
The bucket should be closed when full and lifted out of the ground. Swing must not be started until it has lifted clear. If spoil is being dumped right alongside the ditch, it may not be necessary to close the bucket fully, and swing will be very short. If dumping is into a truck, it should be as near the ditch as possible, and swing may not be started until the bucket is high enough to clear the truck. The ditch is deepened and cut toward the carrier by a series of similar passes. The far end can be trimmed to a vertical slope for a short distance down by opening the bucket wider; but if the ditch is deep, there will be a curve at the bottom that cannot be reached from this position. However, the carrier can be moved backward far enough to cut a square end (if it is needed), as there is ample clearance between the nearest part of the ditch and the carrier. The bottom of the ditch is finished by making the final pass with the bucket level, using the hydraulic down pressure of the boom. This cleans up soil spill, evens out irregularities and tooth marks, and leaves an excellent surface for pipe or granular material.

If a boulder or heavy root is encountered, it may not be practical to remove it by direct pull of the boom retract. Much greater force can be applied by putting the bucket in a level or downtilted position, getting the teeth under the obstacle, and closing the bucket. The floor will act as a fulcrum to aid the teeth in prying the object up, providing a powerful breakout force without dragging or tipping the machine. When a boulder is too large to be pried out in this manner, it is necessary to widen the ditch until it is freed. A ramp is dug from it to the ground surface, the carrier is moved ahead a short distance, and the retract used to drag or roll the stone to the surface, where it can be rolled to the side. Heavy lifts and any side pushing or pulling should be done with the boom retracted to obtain additional force and reduce strain.

Grading. These machines are particularly well adapted to finish grading. The retractable boom makes it possible to draw in a bucket or grading blade in a smooth line that is not disturbed by hinge action of a boom or the effect of bumps on wheels or tracks. Its reach ranges from 30 feet from center pin in the small machine with a standard boom to almost 45 feet in the large model with a boom extension for mine or tunnel scaling work. When doing light grading up or down a slope, the bucket or blade is kept in light contact with the ground as it is drawn in by the telescoping boom. When the ground is below the level of the boom pivot, retracting tends to pull the bucket up, so that for a level grade the boom-lowering valve must be kept partly open to compensate. If the ground slopes steeply upward, the boom may have to be lowered as the bucket moves in, to keep a straight-line contact. The bucket or blade may be tilted to follow an uneven contour, or to work an even contour from a side angle. Hydraulic control permits keeping the bucket at its most efficient digging angle at any point in its reach, and dumping just where desired. With the boom tilt it gives precise control, and allows exact cutting of floors and sloped or vertical walls in cellars and ditches. It is adept at shaping and fine-grading roadsides under even difficult conditions, and can stay safely on the road as it works. Pull-type buckets are available in widths from 15 to 72 inches, and the digging action of push buckets resembles that of a front-end loader bucket with remote control. There is an 8-foot scraper blade for grading where dirt does not have to be picked up, and a ripper for breaking pavement or loosening hard dirt. Boom extensions and offset booms can be obtained.

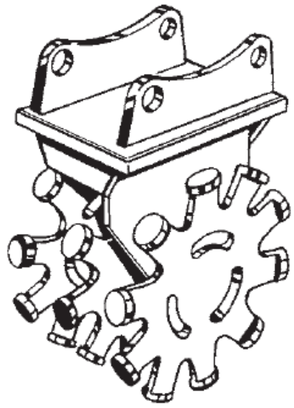
Rippers
Function: Attaches to or replaces bucket for lighter ripping applications. *Used with:* Backhoe-loader, hydraulic excavator, skid-steer loader.



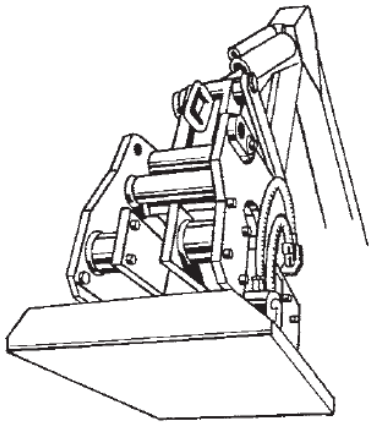


Brush cutter
Function: Cuts down heavy brush and small trees using rotary cutters with cutting teeth. Can be angled to cut in culverts or hillsides. *Used with:* Backhoe-loader, excavator.

Compactor, Wheel
Function: Compacts material in trench. Clamps to bucket or replaces bucket, depending on model. May be equipped with hydraulic power to lock and unlock. *Used with:* Backhoe, excavator.



Compactors, Vibratory Plate
Function: Compacts dirt, sand or gravel. Reaches into confined areas or below grade. Sometimes used to drive sheeting, piles or posts. *Used with:* Backhoe-loader, excavator.



Go to the outline

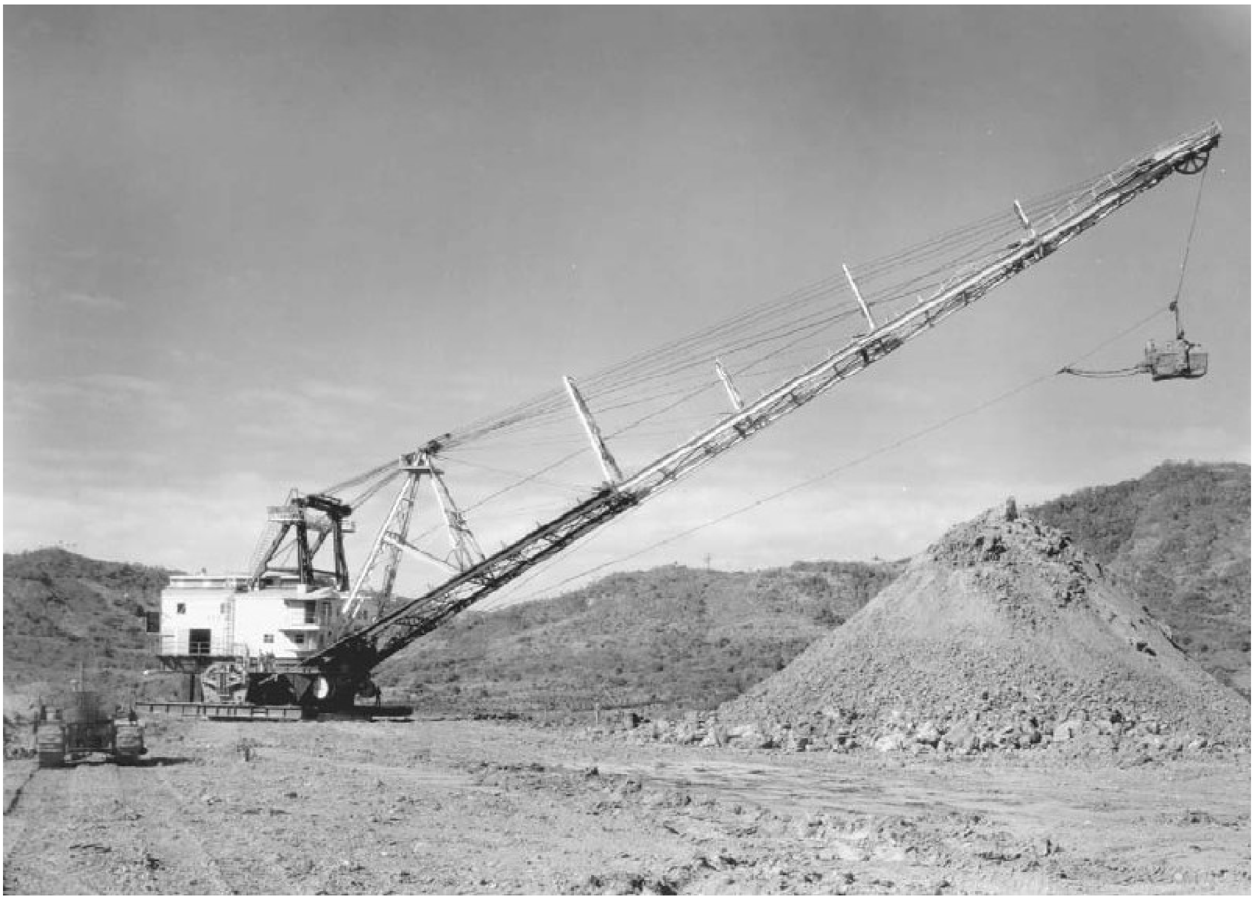
2. Dragline

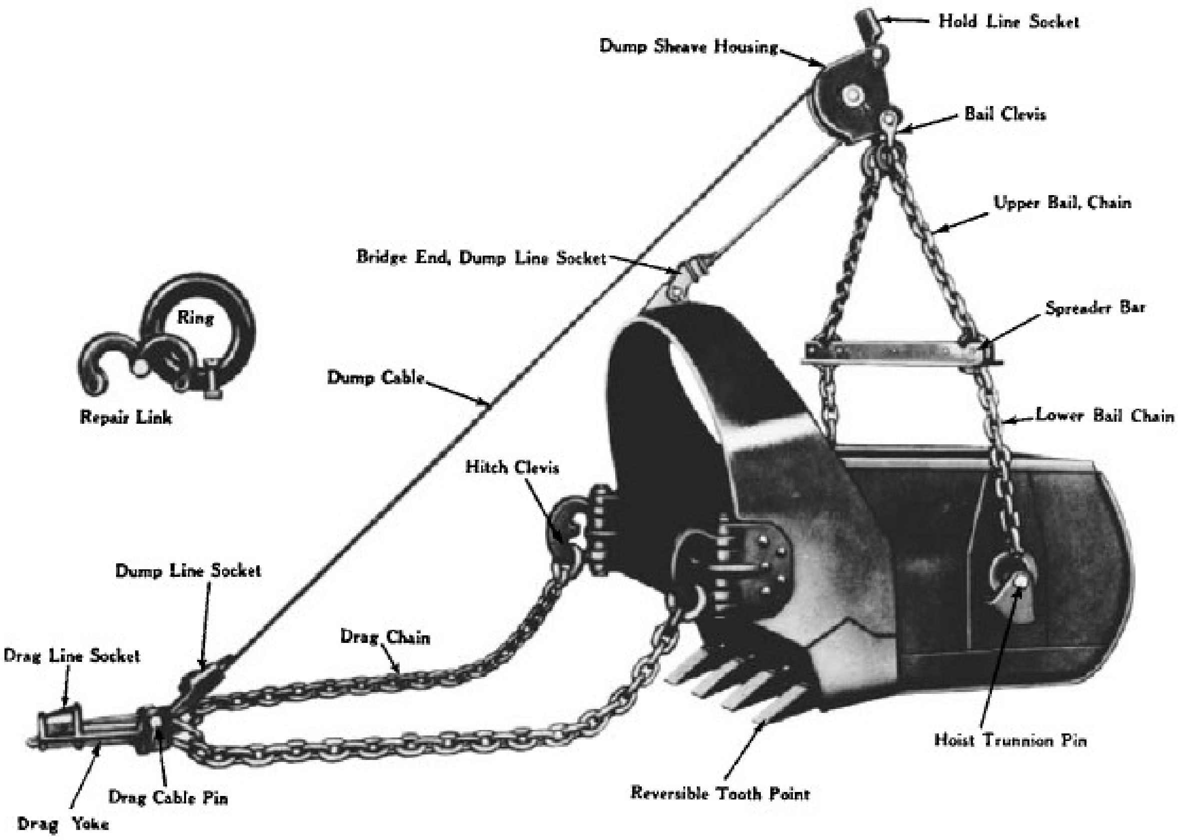
A dragline attachment. It has a long light crane boom, with a fairlead set at its foot, and a bucket attached to the machine only by cables.

Boom. The boom is of lattice construction. It may be of welded steel angles, angle corners and tubular braces, or all tubular. Very long booms sometimes use aluminum sections near the tip. Each boom is made up of at least two sections, tapering from their bolted center connection toward the end. The bottom is reinforced to hinge on the boom foot pins, and the top to hold the point sheaves. Additional sections, usually in lengths of 5 or 10 feet, can be placed between the upper and lower sections to obtain extra reach or dumping height. If the boom is intended for dragline work only, it carries one large sheave on the point; but if it is to be used for a clamshell also, it has two. A smaller sheave is carried on each side for the boom support line.

Fairlead. The fairlead is a device mounted on the boom or boom foot, which lines up the drag cable to spool smoothly onto the drum, even when the bucket is far off to the side. A common type has the front pulleys mounted in a frame on a vertical hinge, and a pair of vertical sheaves in a frame behind them.

Bucket. A pair of drag chains is attached to the front of the bucket, through brackets by which the pull point may be moved up or down. The upper position is used for deep or hard digging as it pulls the teeth into a steeper angle. The drag chains converge in a drag yoke to which the drag cable is fastened. The hoist (bail) chains are attached to pivot (trunion) pins toward the rear of the bucket sides, rise vertically to a spreader bar, then converge to fasten to the dump sheave housing, which in turn is fastened to the end of the hoist cable. Dragline buckets are made in various weights: light ones for digging soft earth, and rehandling stockpiles of material; medium-weight for general work, and heavy and extra heavy for deep and rocky digging. A light bucket means less weight to be lifted each cycle; a heavy one has better penetration and wear resistance. Light buckets may sometimes be obtained with a toothless cutting edge which is excellent for stripping soft topsoil, grading, and cleaning up.




Hold Line Socket
Dump Sheave Housing
Bail Clevis
Upper Bail, Chain
Bridge End, Dump Line Socket
Spreader Bar
Ring
Repair Link
Dump Cable
Lower Bail Chain
Hitch Clevis
Dump Line Socket
Drag Chain
Drag Line Socket
Hoist Trunnion Pin
Drag Cable Pin
Reversible Tooth Point
Drag Yoke

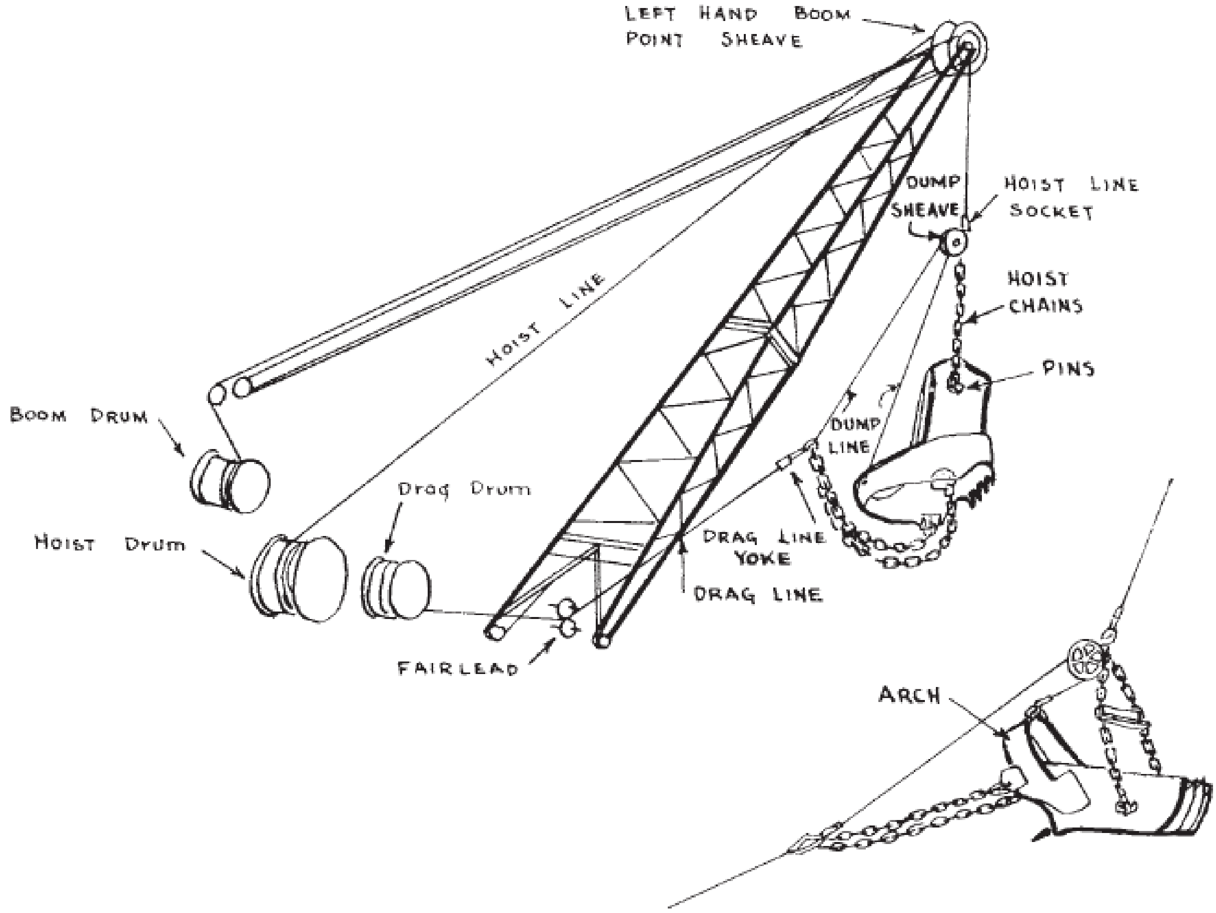
Perforated or sieve buckets are standard buckets with a number of holes cut in the back and sides. These are useful in wet digging as water is pushed through the holes by incoming dirt and any remainder drains out while the bucket is being lifted. Water can be almost entirely manipulated out of a standard bucket if it is possible to take a deep bite so that a massive chunk of earth will push it out, particularly if the bucket can be pulled up a steep bank to dump any remaining water. However, if it is not possible to get a good bite, the perforations are necessary to avoid profitless carrying of water and sloppy spoil piles or loads. Very thin mud or fine dry soil may be lost through the holes, but most digging, wet or dry, can be handled. Some operators weld 3⁄8- or 1⁄2-inch chain in the rear corners of solid or perforated buckets, as the slapping of the loose ends helps to dump sticky soil and to clean out thin layers remaining on the bucket sides and bottom and in corners after dumping. The effectiveness of penetration of a dragline bucket decreases with depth below the machine, as the drag cable then pulls in a more upward direction, raising the teeth out of the soil. This can be compensated for in part by reversing or sharpening the teeth; by using a longer boom which, by permitting digging farther from the shovel, decreases the upward angle of the drag cable; or by fastening the drag cable higher on the bucket. Larger and heavier buckets dig much better at the same depth and distance. Choice of bucket size is determined by the materials to be handled and the length of the boom. For example, a 3⁄4-yard machine usually has a 40-foot boom and uses a 3⁄4-yard general-purpose bucket. However, if the material to be dug is very heavy or tends to come up in amounts greater than the bucket capacity, if a longer boom is used without extra counterweight, or if digging is so hard or abrasive that a heavy-duty bucket is needed, then 5⁄8-yard capacity should be more satisfactory. The same machine might use a 7⁄8- or 1-yard light bucket on a standard boom in handling coal or dry humus.

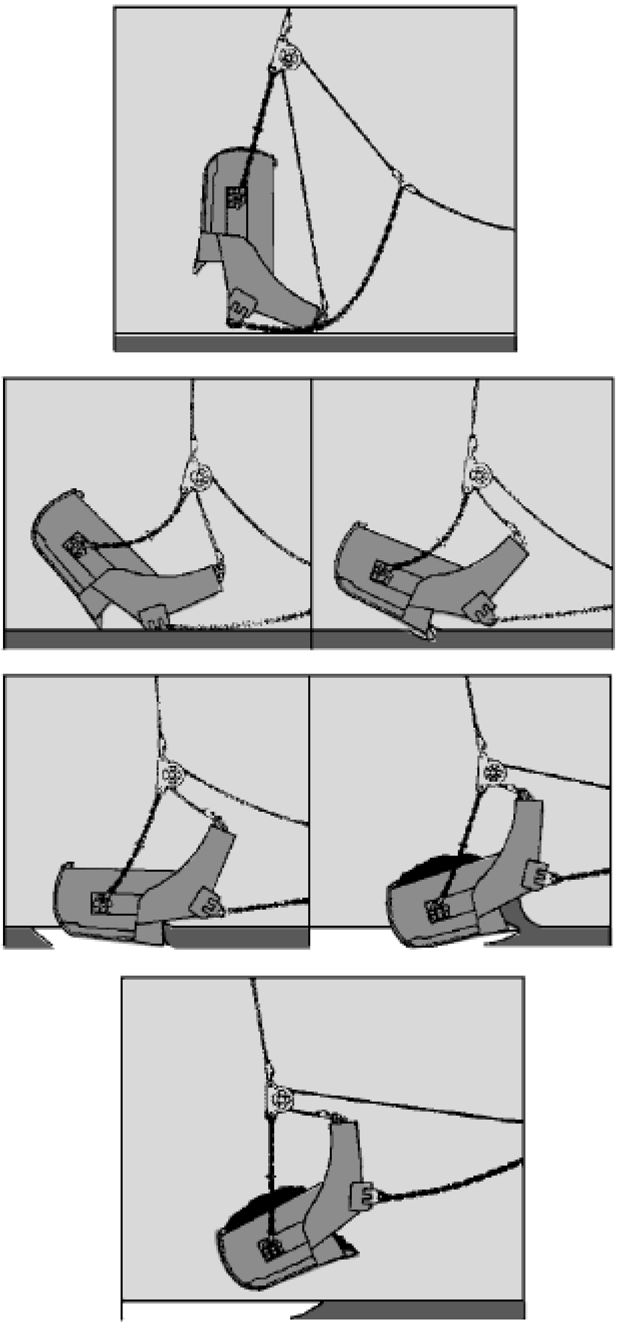
Reeving. The dump cable runs from the top of the bucket arch over the dump sheave and forward to the drag yoke. The boom line is a standard four-part rigging, similar to the dipper boom support, except that a longer cable is needed.

The hoist line runs from the hoist drum over a large boom point sheave and down to the dump sheave case. The drag cable runs from the drag (digging) drum through the fairlead to the drag yoke. Some machines have a light multiple line from the boom hoist drum to a hanging padlock sheave set, and a heavier two-part line from there to the boom point. This shortens the inner cable, which is most subject to wear. One inner line can be used with different boom lengths.

Bucket Action. If the bucket is lifted with the hoist while the drag cable is slack, it will hang in fully dumped position. If tension is then put on the drag cable, it will pull on the dump cable before the slack is out of the drag chains. The dump cable will pull the front of the bucket up, toward the dump sheave. Releasing the drag cable will allow the dump cable to run back over the sheave, and the bucket will return to dump position, pivoting on the hoist chain pins. If the bucket is then lowered to the ground, it will turn to a horizontal position, or will rest on its teeth and arch, depending on its balance. A pull on the drag cable will now tip the bucket forward or backward onto its teeth, and the teeth and lip will dig in as it is dragged toward the shovel. If the pull is continued with the hoist line slack, the bucket will cut to a depth determined by its weight, the angle and sharpness of its teeth, and the resistance of the soil. If so deep a cut is not wanted, some tension is put on the hoist line, raising the bucket slightly. If the dump cable is long, the bucket will be raised in the rear by the hoist chains. A short dump line will cause an upward pull on the arch, raising the front of the bucket as much as or more than the rear. In either case the depth of cut is reduced. A further pull on the hoist will raise the bucket clear of the ground. Whether the bucket will remain in the carrying position, or partially dump while being raised, depends on opposing forces acting through the dump cable. The weight of the bucket front pulls down on the arch end of the cable, and the tension between the hoist and drag cables tends to stretch its drag-yoke-to-dump-sheave section and pull the bucket up. In effect, the dump cable must pinch the other two cables together in order to obtain slack to drop the front of the bucket.

A wide angle between hoist and drag cables can be had when picking the bucket out of the soil, either by pulling the bucket close to the shovel, or by keeping the boom at a low angle. Bringing the bucket all the way in usually wastes time and causes wear on bucket and chains which might be avoided if it were picked up as soon as full. A low boom has a tendency to tip the shovel when heavily loaded, and often cannot be used because of obstructions or height of dump. A short dump cable makes it difficult to dump except directly under the boom point. If a live boom is used, it is possible to dig low and dump high, but this takes extra time and work. The technique used will depend on the job and on the operator's preference. There is generally at least one good method of handling any situation.





Digging. In an ordinary dragline digging cycle, the bucket is not thrown or cast. It is lowered into the pit with both lines taut, the hoist brake being almost wholly released, then reapplied smoothly as the bucket is about to strike the ground, and the drag brake is released enough to allow the bucket to drop straight instead of following an arc centering on the fairlead. When the bucket rests on the ground, the hoist cable is slackened slightly and the drag clutch engaged. The drag cable pulls the bucket, with the teeth digging in and cutting a slice of dirt which piles inside the bucket. If the hoist brake is locked, the bucket will move up in an arc centering on the boom point, and on level ground may pivot so the teeth dig more sharply but no longer have the full weight of the bucket to force them in. Ordinarily, the hoist brake is released enough to let the bucket cut level or follow the pit contour. If the pit slopes up toward the shovel, which is the most favorable digging condition, it may be necessary to partially engage the hoist clutch to avoid digging in, or to prevent the hoist line from becoming too slack and allowing the chains and dump sheave to slump into the bucket.

Hoisting. When the bucket is filled, the hoist clutch is fully engaged and the bucket is lifted clear of the ground. If the bucket has a tendency to dump, the drag may be left engaged until the angle between drag and hoist cables is sufficiently wide to hold it. The drag clutch is then released and the hoist is continued, with the drag brake applied just enough to allow the hoist to pull the bucket forward and upward under the boom, without slackening the lines enough to dump it. If the drag brake is applied too tightly, the bucket may hit the boom. The swing is started as soon as the bucket is clear of the ground. This is the period of heaviest load in the dragline cycle, as the machine is simultaneously lifting a load, pulling against the drag brake with the hoist clutch, and swinging. If overloads are picked up in the bucket, they may so slow the line and swing speeds that less dirt will be moved per hour than if smaller bites were taken.

Dumping. Hoisting is discontinued as soon as the bucket is high enough to be dumped. When the swing is completed, the drag brake is released, partially or wholly, and the bucket swings out and dumps. A long dump cable will permit normal dumping inside the boom point, a short one under it only. Raising the boom will bring the dump point closer, lowering it puts it at a greater distance. It is poor operation to raise the bucket higher than necessary before dumping. Clearance should be allowed so as not to strike trucks or other receptacles, but piles can be barely cleared. This saves time on a short swing and fuel and wear and tear under any circumstances.

Casting. If the bucket is to be thrown or cast, it is pulled close in by the drag cable during the swing to the pit, with the hoist line held at a length that will keep the bucket above any obstructions during the cast. When the swing is completed, the drag brake and clutch are released and the bucket swings outward like a pendulum. When it is just short of the farthest point of this swing, the hoist brake is released and the bucket falls downward and outward (B). It is checked by gradual application of both brakes just before hitting the ground, as otherwise it might be damaged, overturned, or tangled in its chains. It should then rest on the ground in the same position as if lowered and respond to drag pull similarly, except that if the pit floor is level, the hoist cable slackens as the bucket approaches the boom point and tightens again after it has passed under it. A swing throw may also be used. During the swing from dump to pit, the drag cable is left slack and the hoist held so that the bucket is high enough to clear obstructions. The centrifugal force of the swing will pull the bucket outward, and the hoist brake should be released at the proper point so that the bucket will land where it is wanted. The swing should be checked as soon as the hoist brake is released, and hoist and drag brakes applied gently as or just before the bucket strikes. This swing throw requires much more expert operation than the other type and may damage the shovel seriously if improperly done. Another technique is to make a pendulum throw while the shovel is swinging so that the centrifugal force adds to the outward sweep of the bucket. Throwing to dump is a similar process, but usually the height of the piles prevents the use of a long enough hoist line to obtain much distance. The weight of the load, however, causes the bucket to cast farther than it could on the same length line if empty. A combination pendulum and swing throw is most effective, particularly if the shovel is dumping at 180° from the pit and can revolve in a full circle so that it can dump without stopping. If the load sticks in a bucket which is thrown to dump, it may overturn the shovel. The distance the bucket can be thrown is affected by the skill of the operator, the length and angle of the boom, the weight of the bucket, the depth of the pit, and even the wind. Casting onto a surface level with the tracks, the teeth ought to reach farther than the boom point would if lowered to a horizontal position. Much greater distance is attained when casting into a pit. Manufacturers are wary about recommending or discussing throwing of buckets, because a careless operator may thus bang a good bucket into scrap iron in a short time, and the swing throw has possibilities for wrecking the boom as well. Beginners will do well to thoroughly master ordinary digging before practicing throws, particularly if they have trouble with tangled cables. Throwing the bucket usually slows the digging cycle by several seconds, and reduces accuracy of work, so that digging should be done inside the boom point when practicable.

Tangles. If a drag cable becomes tangled, it is a good procedure to throw the empty bucket, as often the whole tangle can be unwound in this way, and at worst very few wraps will be left on the drum to be straightened. If the drag cable becomes bent or kinked so that it does not spool on smoothly, the bucket should be dragged in all the way a few times with a load to straighten it. If the bucket is swinging in the air, the drag should be wound in while it is swinging out and holding the cable under tension, and held while it is swinging in and the cable is slack. If the cable is running smoothly, this precaution need not be taken. If the hoist cable becomes tangled, the bucket should be rested on the ground, the hoist brake released, and the machine swung. When the hoist cable is unwound past the tangles or to the anchor, the hoist clutch should be engaged and the swing clutch disengaged. The cable should then reel back properly, unless crushed or kinked, in which case tension should be put on it as it is wound in, by partially engaging the swing clutch to keep the boom from swinging back easily over the bucket. The cables should not be allowed to run all the way out in a throw, for if the momentum of the bucket is stopped abruptly by the cable anchor, the anchor may tear out of the drum. Manufacturers often supply and specify a drag cable which is so short that it is unsafe for casting.

Novice Operators. To the novice, the dragline is apt to seem a very loose, rough, and contrary machine. Special provisions have to be made in every movement to keep the bucket from jerking and swinging, but these soon become automatic and very precise control can be obtained eventually. The beginner will obtain the best results by keeping the bucket fairly close in, except when actually digging or dumping, by making slow starts and slow stops when swinging, and dragging the brakes slightly to avoid spinning out the cables.

Bucket Wander. As the bucket is pulled in, it is liable to be deflected by irregularities and find a path considerably to one side of a direct line. Also, the shovel may swing by gravity during the haulin if it is not standing level. In either case the drag cable will not be directly under the boom. The fairlead sheaves will put it in correct alignment for the drum, but if the angle is sharper than the fairlead pivot can meet, the cable will be dragged across the fairlead guard plate and will wear the cable, and wear or possibly tear off the guard. The shovel boom should be kept in line with the cable by the use of the swing lever.

Boom Twist. As a loaded bucket is lifted, the boom will tend to swing over it. However, if the boom is held to one side by the swing clutches during hoisting, or if a heavy, oversize load such as a stump is partially lifted, then dragged along the ground by the swing, a powerful twisting force is applied to the boom. In order to give a long reach without prohibitive weight, a dragline boom is of light skeleton construction that is not intended to withstand heavy side and twisting strains. Sometimes a boom so strained will collapse, but more often will twist slightly, bending some of the cross braces particularly on the lower side. Once twisted, normal loads may increase the damage and failure will follow if the boom is not straightened. A good ironworker is needed to properly repair such a boom; but if the bent members are angle irons, it may be kept in service quite a while by straightening them with a jack. A stout plank is placed inside the boom across the corner angles as a support for an automobile jack that can push the pieces straight. This type of repair should not be attempted on tubular members as they lose their strength if flattened.

Applications. The dragline does not have the positive digging force of the front shovel and the backhoe; as the bucket is not weighted or held in alignment by rigid structures and can therefore bounce, tip over forward, or drift sideward when it encounters hard material. This weakness increases with depth, and is particularly noticeable in small machines, as the weight and bulk of a large bucket are insufficient to give considerable stability and penetration. The dragline experiences its greatest difficulty in cutting down and is able to continue a deep cut opened by other machines or by blasting in much harder material than it could dig from the surface. The outstanding advantage of a dragline over most other rigs is long reach for both digging and dumping, plus the ability to dig below the tracks. It has the further good point of a high cycle speed, being second only to the dipper stick in this regard. It will be preferred to the front shovel for truck loading where the earth is not too tough, and where the original grade is better than the new, because of water, mud rock outcrops, steep ramps, or other problems within the excavation. Because of its greater reach, it will be preferred to the backhoe in any situation where it is capable of digging the soil effectively, where precisely cut vertical sides are not required, and where there is room for it to swing. The dragline is the only practical attachment for extensive digging in mud, as its reach enables it to handle a wide area from a single stand and the sliding motion of the bucket avoids trouble with suction. It is also the best machine for many stripping operations in which the spoil is highpiled away from the pit, but is rivaled by long-boomed dipper stripping shovels if the spoil is to be moved across a narrow pit as in some strip mining. Draglines with skillful operators do an excellent job of topsoil stripping, grading, and spreading piles of earth, but except under wet conditions they do not usually do as well as bulldozers of comparable ability.

Go to the outline

3. Tractor-mounted backhoe

hydraulic hoe attachment similar to that described for revolving excavators can be mounted on the back of a wheel tractor, a crawler tractor, a drag trencher, or a truck. A two-wheel-drive tractor equipped with a front loader is the standard type of carrier. It is usual to install permanent mounting brackets on the tractor, then use pins, hooks, and/or tie bars for more or less quick installation and removal of the hoe unit. The quick-detachable model is designed for four-wheel-drive units, and includes a seat. On two-wheeldrive units, the tractor seat may swivel to give access to the hoe. There are also integral units, in which the tractor has mountings for both hoe and loader built into its own frame. These units are almost always smaller and lighter than full-revolving rigs, but they are nevertheless powerful and capable machines. Boom, stick, and bucket are similar to those on the larger machines, but there are many differences in detail.

Swing. The boom and associated digging parts are mounted on a small turntable that swings through only about half a circle, 175° to 210° on different models. Full swing is not practical because the tractor is in the way. The pivot is usually a pair of pins, upper and lower. Power is from a pair of hydraulic cylinders based on the nonrevolving frame. The rods may be connected to brackets, or to opposite ends of a roller chain meshing with a sprocket on the rotating section. A partial-swing vane motor may replace the pistons. Swing is usually very fast, as there is no heavy deck full of machinery to move. Acceleration and deceleration are rapid, allowing 90° swings to be completed in as little as 3 seconds. Action is likely to be jerky. Partial swing causes little difficulty in straight, open work, like digging a ditch across a field. But it creates serious problems with complicated jobs. ***Stabilizers.*** A pair of heavy stabilizer arms or outriggers is hinged to the sides of the turntable base. They are raised and lowered by two-way cylinders. Cleated shoes on their outer ends are forced down against or into the ground while digging, to increase stability against tipping, and against being dragged by the bucket.

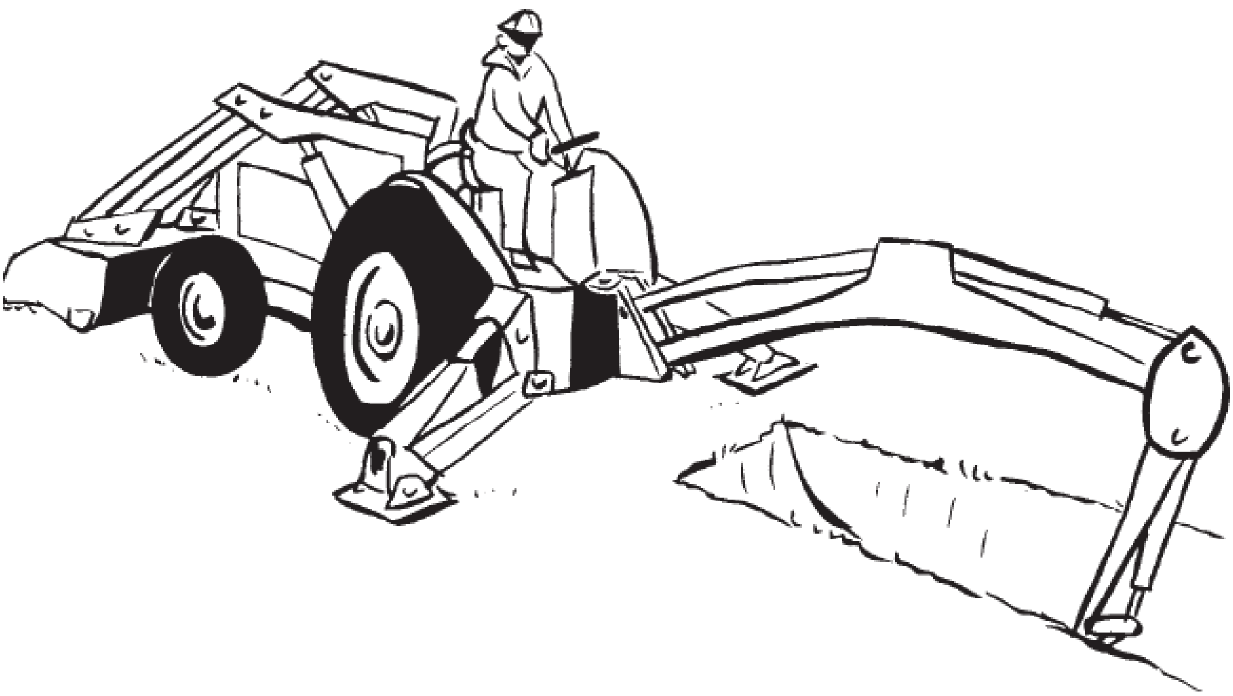
Hydraulics. The pump and reservoir are usually in the tractor. The most convenient arrangement is to have one pump for the backhoe and another for the loader. It is more usual to have one pump, and a diversion valve to route the flow to whichever unit is in use. A backhoe and loader are not used for digging at the same time, but it is frequently necessary to make position adjustments in one while working with the other. A pair of hoses with quick-detachable couplings brings the fluid to the valve bank in the hoe. There are six operating valves, and usually six levers. But four functions may be performed by two joystick levers, that move to the sides as well as back and forth. There are also universal controls, whose levers actuate cables that can be switched from one valve to another, so that the operator can make up her or his own pattern. Pressure in different machines is variable, and is not always stated in specifications. Many models range from 2,000 to 3,000 pounds per square inch, with flow 15 to 35 gallons per minute.

Buckets. Buckets are similar in construction and linkage to those of the big machines, but differ in size. The smallest standard models seem to be 12 inches wide, with a capacity of 3 cubic feet; the largest, 36 inches wide with more than 1⁄2-yard capacity. In addition, there are specialty buckets on miniature hoes as narrow as 6 inches. Even a standard-size tractor hoe may replace the bucket with a ripper tooth as narrow as 3 inches. This is primarily designed for penetrating very hard, frozen, or bouldery soil, but it may dig a slot for cable or conduit installation.

Applications. The tractor-mounted hoe is a small, powerful, and fairly economical package. It can be driven between jobs, or carried easily on a light trailer. As a ditch digger, it can work in places that are difficult or impossible for larger machines, cross lawns without damage (except under unusually soft conditions), make narrow ditches, and show a high production rate. It does not trench as fast as the continuous-type ditchers discussed in the next chapter, but it can handle special situations that are difficult for them, can work in rocky soil, and can handle oversize pieces. It is also a handy utility tool. It can dig out stumps and boulders so big that it cannot possibly lift them, can load trucks with either the hoe or the loader end in emergencies, and can serve as a light-duty (but very jerky) crane. The boom, stick, and bucket are similar in action to full-swing attachments. Differences in operation include managing the tractor as a travel unit and counterweight, use of stabilizers, arranging work so that it can be done with limited swing, and doing heavy digging with a light machine.

Positioning for Digging. The tractor is driven to the work spot, and maneuvered so that it is centered on the centerline of a ditch, the rear wheels toward the starting point, and about 3⁄4 of the hoe's maximum reach from it. The operator centers the steering wheel, puts the tractor in neutral, and locks its brakes. If one hydraulic pump supplies both loader and backhoe, the operator sets a diversion valve to deliver flow to the hoe. If there are separate circuits, he or she lowers the loader bucket to the ground. The bucket will hold the tractor most effectively if it is put in fully dumped position, and forced down against the ground. The operator then flips the seat over or swings it around, and sits rearward on the tractor, facing the hoe and its controls. In the terminology accepted by the trade, the operator is still facing forward, and hoe motions are described accordingly.

Stabilizers. The two outside controls are used to push the stabilizers outward and downward, pressing them firmly against the ground so as to take just a little weight off the tractor's tires.



If the ground is uneven, one is extended farther than the other, to make similar pressure on each side. If the ground slopes to the side, the low one is pushed down harder, to reduce or eliminate tractor tip. Occasionally, you may wish to put a block under the stabilizer on the low side, or level the ground by some superficial digging. The standard stabilizer shoe has a ridge or cleat on its undersurface, to penetrate and grip the ground. This is likely to tear up a lawn, not so much from original penetration as from dragging and twisting during digging.

Very rarely, you may prefer to try digging without setting stabilizers, for this reason. On soft ground, a plank may be placed to support the stabilizers.

Digging. Digging motions are the same as those described earlier for the full-revolving excavator. However, this machine is probably very much lighter in proportion to digging power, and is more likely to be dragged into the work. This dragging occurs as you pull or crowd the bucket inward against digging resistance. It is strongest at ground level, and reduces somewhat with depth. Cutting a thin slice generates less pull than a thick one, but it takes longer and wears the bucket more. Rapid, small changes in bucket angle as it is brought in reduces resistance. Curling or closing the bucket provides powerful digging and breakout force at the bucket teeth, with little or no pull on the tractor. Starting a deep cut, then curling the bucket as soon as resistance builds up, will usually provide good digging with little dragging. In general, you try to dig for production, but lighten the cut every time you feel a drag-the-tractor force developing. The reaction is a split-second one, which is difficult at first but soon becomes practically automatic.

Moving. To move when a section of digging is finished, the stabilizers (and the loader bucket if it is down) are raised. The bucket is placed on the ditch bottom with its floor at a slight angle, with the stick almost vertical, but leaning slightly toward the tractor. Pushing the hoist and crowd levers slowly forward will now lift the back of the tractor off the ground, and roll it forward on its front wheels. If it does not go far enough, the maneuver is repeated. Then the stabilizers are put down, and digging is resumed. The tractor may be moved to the side in somewhat the same manner. The bucket is curled halfway, placed in the ditch a little forward (away from the tractor) of the boom point, and forced down by the boom cylinder until the rear (big) wheels are clear of the ground. The hoe is then swung until the tractor is in the desired position. Then it is lowered, and the stabilizers are set for digging

Stability. The total weight of a tractor-hoe, including its loader, is much smaller in proportion to digging power than that of a full-revolving machine. Stability is therefore more of a problem. Down pressure on the bucket tends to lift the rear wheels off the ground. Upward pull lifts the front wheels. Rearward (toward the tractor) pull may either dig the dirt or drag the tractor. Tractor weight must be increased to its maximum by putting water and calcium chloride, or perhaps mineral dust, in all four tires. The loader bucket may be filled with dirt, or piled with rocks or other heavy objects. It may be held in the air for counterbalance (and for convenience in moving), or may rest on the ground for resistance to dragging. Stabilizers should be put down far enough to take a little of the weight off the rear tires, as will be indicated by a slight change in shape at the bottom. Tires must never be lifted clear of the ground, or even so that most of the weight is off them, except one side in leveling on a slope. On ordinary ground, a ridge on each stabilizer pad sinks all the way in. Rear wheels are locked by the tractor brakes. Even with these precautions, weight and grip on the ground are small in proportion to the digging forces—crowd and curl—which may be more than 6 tons. The operator must limit the force he exerts to the ability of the machine to keep its position. Digging without pulling the tractor may be the hardest thing for the beginner to learn, as was discussed earlier, but it ordinarily offers few problems to the experienced operator. It is largely a matter of learning manipulation of the bucket to obtain penetration without excessive pull. When the tractor is dragged toward the digging, it is usually necessary to reposition it with the bucket. If the movement has not been straight, it may be necessary to drive the tractor to get it in proper alignment. Stability against tipping is ordinarily not a major problem in digging. But if the tractor is not level, or is being used to lift heavy objects with a chain, this must be considered. It usually has least stability when the load is at a 60° angle from center, on either side if level, on the low side if not level. Tipping tendency is reduced by bringing the load in toward the tractor, or stopped by setting it down.

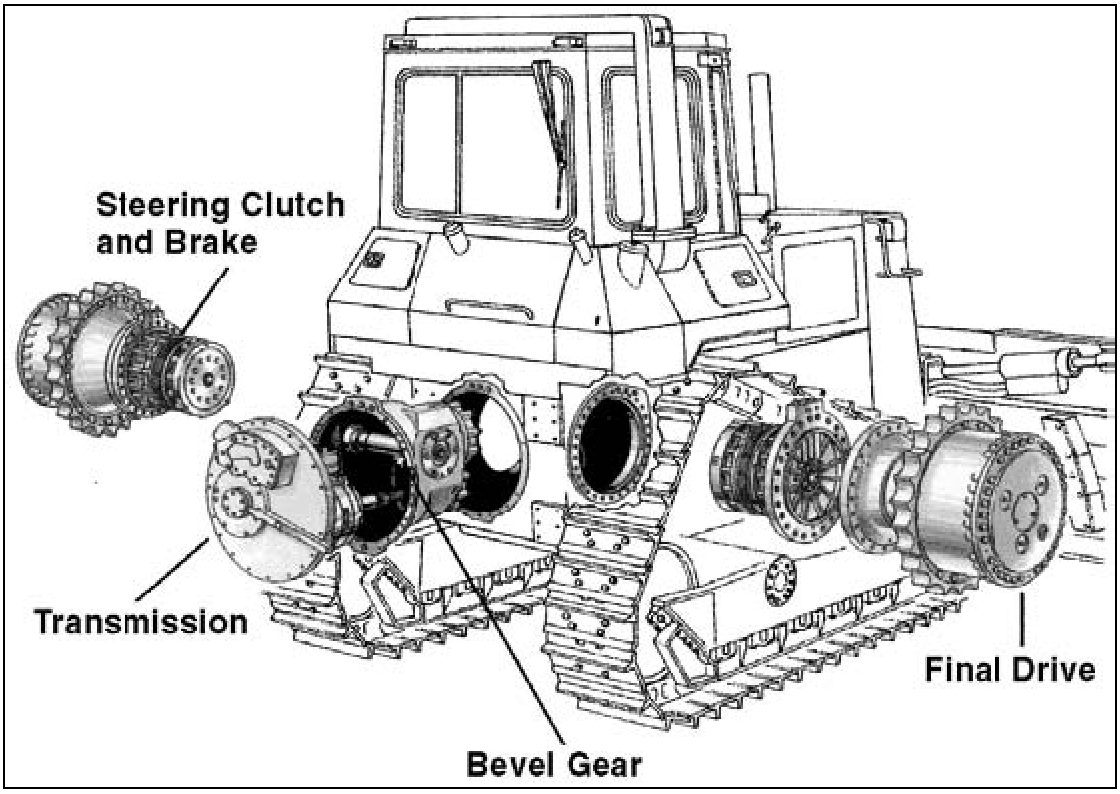
Slopes. A side slope affects stability of a hoe, making digging motions difficult to control, and produces a ditch that is out of plumb (side not vertical). A slight slope may be ignored, or corrected with the stabilizers by putting pressure on the downhill one until it levels the tractor, or adding a block. For a steeper slope it is advisable to make a cut or shallow trench for the uphill stabilizer and wheel, using the spoil as fill for the downhill side if necessary. This cut may be made by the loader bucket, preferably pushing downhill, or by the hoe. A shallow leveling cut may be made by the hoe on fairly steep side grades, as little material is dug and accuracy is not important. This may extend the full length of the hillside, or just be scooped out for digging position. When the tractor is tipped, it is much more stable dumping uphill from the ditch than downhill, and this side is generally (but not always) favorable for backfilling. If there is a choice between trenching up a hill or down it, work with the tractor heading downhill. This reduces the principal problem of dragging the tractor toward the digging, and is much more stable against tipping when dumping the bucket. An exception to this advice is that in wet ground it may be desirable to dig uphill to avoid ponding of water in the digging area.

Close Work. Tractor mounting is better than full revolving for working close to buildings or trees, as it is not necessary to allow space for a tail swing. One wheel can be rubbed against the obstruction, if necessary. It is sometimes possible to get closer to a wall by backing the machine up to it at an angle for short cuts. The front wheels may be turned parallel to the wall, so that the tractor can be boosted by the bucket from one digging position to another. If the tractor has a frame-tilt capability 13.34C, that mechanism can be used to advantage in close work.

Go to the outline

4. Bulldozers

Crawler (track-laying) tractors have a weight range from 4 or 5 tons to almost 150 tons. Maximum horsepower is over 1,000. The Caterpillar tractors started the bull wheel sprocket above and slightly ahead of the rear track idler wheel, to keep out of the dirt and environment, for better servicing and durability, and to improve balance and stability.



Engine. The engine is usually diesel, although in the smaller sizes, it may be gasoline-fueled. Power is rated first as net engine horsepower, meaning the net horsepower at the flywheel with the engine driving all accessories normal to tractor operation. The second standard of measurement is drawbar pull or horsepower. This is the usual rating for tractors with direct mechanical drive. Power may also be measured in terms of pounds of drawbar pull, a factor that is limited by traction and that may be increased by mounting a bulldozer or any extra weight. Crawlers with power shift and/or torque converters are generally rated in pounds of drawbar pull at a given speed.

Clutch. Crawlers with mechanical drive have an engine or flywheel clutch with one or two discs, that are used to cut off the drivetrain when stopping the machine or shifting gears. When the machine is to be used to carry a loader or for any other very heavy service, the discs may be set with long-wearing, heat-resistant ceramic discs; or be kept in a circulating bath of oil that reduces wear and takes away heat. The clutch is usually controlled by a hand lever at the operator's left. Large machines have a hydraulic booster to reduce operator effort and ensure sufficient engagement pressure.

Torque Converter. Most large crawlers have a torque converter instead of, or in addition to, an engine clutch. This device, described in Chap. 12, provides shock-absorbing slippage between engine and tracks, multiplies torque so that fewer transmission gear ratios are needed, and allows on-themove power shifting among those ratios that are used.

Center Frame. Rigidity of the center section is obtained by making the steering clutch and transmission housings in one heavy casting or weldment with internal braces, together with heavy construction of all cases forward to the radiator. In addition, a pair of heavy side beams may run forward from the transmission case, supporting the engine, the crankcase guard, and the radiator base. A front pull hook may be bolted to the crankcase guard, which is a plate protecting the bottom of the engine. Use of this hook for heavy pulls is a greater strain on the tractor than use of the drawbar.

Transmission—Manual Shift. This type of transmission, used in machines with friction clutches, is compact, with very heavy construction. Shifting may be done by sliding spur gears, but newer machines may have constant-mesh helical gears with synchronized shifting. The number of gear speeds varies in different models and may be from two to eight forward speeds, and one to six reverse speeds. The engine clutch must be disengaged for any conventional gearshift. There may be a lock that will prevent any gear from disengaging unless the clutch is fully released. There is a universal joint in the shaft from the clutch to the transmission to prevent damage if these two units should get slightly out of alignment. The driveshaft from the rear of the transmission ends immediately in a bevel gear that drives the live axle ring gear. The transmission and bevel gears operate in a sealed box that contains sufficient oil or fluid grease to lubricate all the gears and bearings by dip, splash, or pressure spray.

Transmission—Power Shift. Tractors equipped with torque converters usually have power shift (shift-on-the-go) transmissions with two or more speeds in each direction. The shifting is done by pairs of friction clutches connecting and disconnecting gears in the drive line, or by brakes controlling planetary gear sets. The shifting lever may control these by mechanical linkage, or hydraulic means.

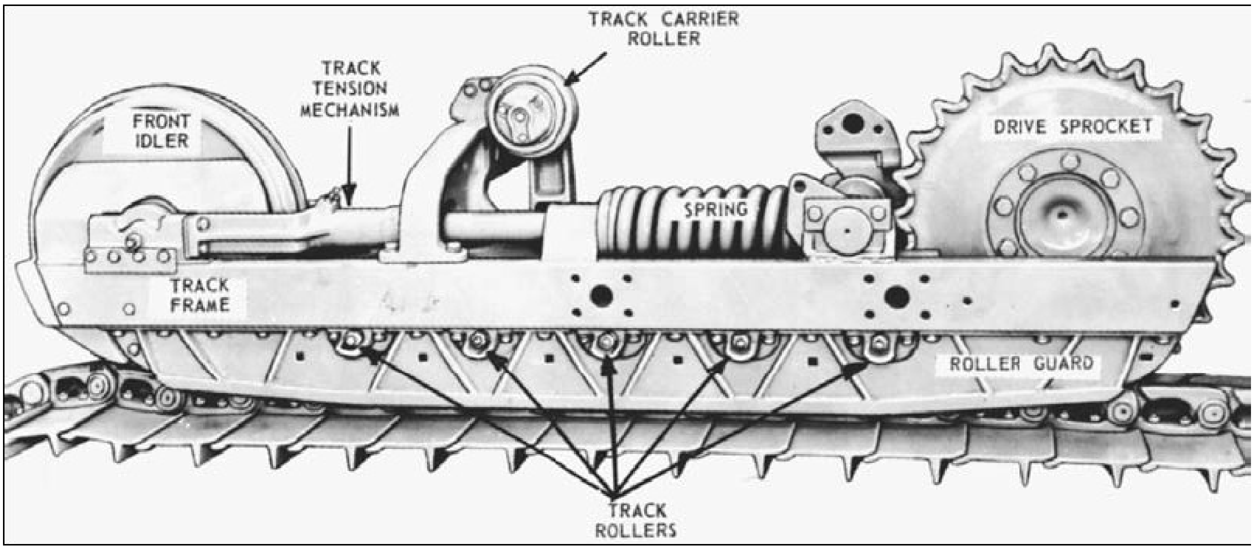
Power Takeoff. The standard power takeoff is a connection that will turn a shaft inserted through the rear wall of the gear case. It is used to power accessories such as cable control units, a winch, or a hydraulic pump. If the transmission is compound, the takeoff may have two gear ratios; otherwise its speed is controlled only by the engine. It is engaged by releasing the engine clutch, meshing a sliding jaw, and reengaging the clutch. The takeoff usually turns more slowly than the engine. It operates in neutral or any gear, but not when the engine clutch is disengaged. It is not affected by the steering clutches. Lack of power in the takeoff when the engine clutch is released, or when the output shaft of a torque converter is slowed by heavy load, results in inefficiency in many operations. There are therefore an increasing number of constant-running “live” power takeoffs, that can be operated whenever the engine is running, regardless of clutch position or converter action.

Rear-Drive Assembly. The rear-drive or live axle assembly for clutch and brake steering. At each side of the ring gear, the axle extends through a section of the case which is kept free of grease by means of seals on the axle and by a drain hole in the bottom. The holes must be plugged while working in mud or water. In each of these compartments is a multiple-disc clutch and a band brake. This pair of clutches and brakes is used for steering in the same manner as those on the shovel live axles; but, being always of the friction type, they are smooth in operation. Next to the steering clutch compartment on each side is the final drive. This is a dip-lubricated gear set of either single or double reduction construction. The large outer gear is attached to a short axle which turns the bull wheel (sprocket) that drives the track. Grease seals are used where the axle enters the final drive case, and where the bull wheel drive leaves it.

Dead Axle. The dead axle, or pivot shaft, is a hinge pin which runs across the back of the tractor, through or forward of the final drive cases. It ties the track frames and center section together but allows them to oscillate vertically. In addition, it usually serves as an axle for the bull wheel.

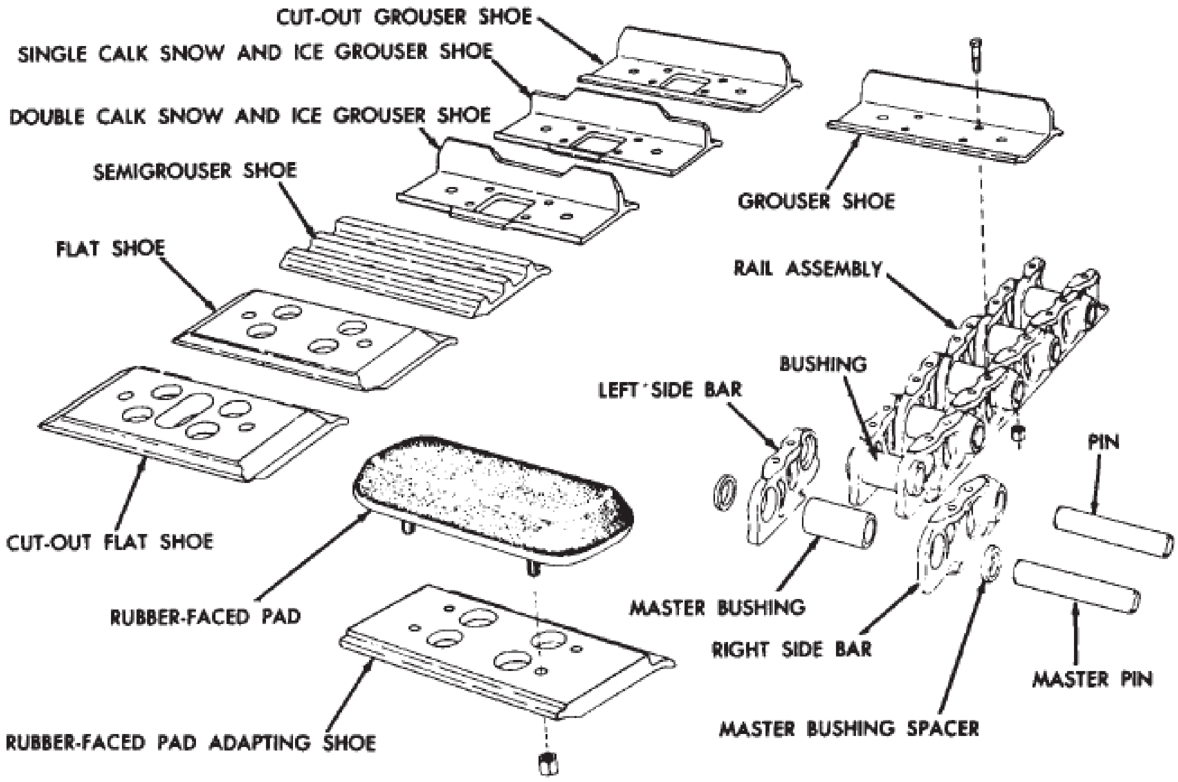
Bull Wheel. The bull wheel is a big sprocket of very heavy construction. The wheel itself is usually a flat disc, widening to shallow teeth at the rim. Hollows between them mesh with the track pin bushings, providing positive drive to the track.

Tracks. The track frame and mechanism is similar in general appearance. The live axles turn large toothed wheels, called drive sprockets or bull wheels, that are at the rear of the track frames or elevated. The frames rest on the small truck or track rollers. The idlers, which are smoothed flanged wheels similar in size to the drive sprockets, are mounted on spring-cushioned yokes at the front of the frames, or both front and back with an elevated bull wheel sprocket. One or two small support rollers are mounted above each frame, except in very small machines, to prevent excessive sagging in the upper track section.



The track itself consists of a true roller chain and bolted-on shoes. The parts of a track chain. Certain types of stiff mud, and wet snow, may build up in the track and in the sprocket hollows so that the sprocket will spin, usually with abrupt and damaging stops and starts, and will probably make the track overtight at the same time. This condition may make work difficult or impossible, as repeated hand cleaning may be required. Ice and mud shoes usually have openings in the center that permit the sprocket teeth to force the snow out through them, leaving the inner parts comparatively free. There are also cutaway sprockets that allow mud to squeeze through openings in the tooth bottoms. This is one of the reasons that Caterpillar Inc. introduced the elevated sprockets for their crawler tractors. There are a great many types of track shoes. The standard construction is a flat plate with a single high cleat or grouser across it. This affords good traction and protection against sideslipping under most conditions, but will not grip on ice or frozen ground, and tears up surfaces on which the machine works. If the tracks spin, each grouser acts as a bucket on a ditching machine, taking dirt from beneath and piling it at the rear. As a result, the machine may dig itself down into trouble very rapidly on soft ground when heavily loaded. In addition, such piles make backing up in the same path a very rough trip. Flat shoes are used on machines that usually carry rather than push, and those that work in unpaved yards that would be cut up by the cleats. They have been used on bulldozers and shovel dozers, but usually do not give enough traction and permit a dangerous amount of sideslipping. Rubber-face pads are used by some crawler tractors, sometimes called utility tractors, that work inside buildings and on paved roads. Traction is better than with flat shoes on hard surfaces, and scuffing and scarring are reduced to a minimum. They are usually not rugged enough for heavy pushing. Semigrousers are flat shoes that carry two to three low cleats. They are the most satisfactory equipment for front loaders, as they do not dig up the ground in spinning and turning as much as full grousers, without reducing traction and stability as severely as flat shoes. Snow and ice plates usually feature cutout or skeleton shoes, and high cleats. A wide-track machine has much better stability on side slopes; in carrying high loads, it fouls less with mud; and it is possible to mount wide shoes on it for swamp work. It is heavier, is generally more clumsy to maneuver in restricted spaces, but can turn with a load with less difficulty than a standard model, and does not get stuck as readily.

Track Wheels. The rollers and idlers are flanged in order to keep the track in line. The idler customarily has a wide center flange that fits between the track links. The track and support rollers have outer flanges that are on each side of the track rail. They may also have an inner flange. On the bottom, it is usual to alternate single- and double-flanged rollers. Rollers and idlers revolve on fixed axles. They may have tapered roller bearings, or solid-sleeve types made of bronze or special metals. Good seals, to keep lubricant in and dirt out, are very important.



The most successful type, the "positive" seal, consists of two finely machined rings, one attached to the axle and one to the hub, which are pressed against each other by springs. These rings fit so perfectly that neither dirt nor grease can get past them, and they are hard enough to outlast other wearing parts.

Adjustment. The big idler is held in position by a sliding yoke backed by a spring, or by a cylinder of compressed nitrogen, which pushes it forward in order to keep tension in the track. If the track collides with something, or an object is caught between the track and the idler, or sand or snow builds up on the sprocket or rails, the idler can move back by compressing the spring, thus absorbing the shock, or relieving the tension on the track. Hydraulic track adjusters usually consist of a piston in a tight cylinder that has a grease fitting. The piston rod is an extension of the idler yoke. Pumping grease into the cylinder pushes the idler forward and tightens the track; bleeding grease through the fitting or a relief valve allows the idler to move back and release the track. Hydraulic adjusters are very easy to use, but any leakage in them is likely to put the tractor out of action. The tractor should be moved backward and forward a few times during adjustment to equalize upper and lower tension. A properly adjusted track should sag a little at the top when the machine moves forward.

Drawbar. The drawbar is a heavy steel tow bar, fastened under the center of the tractor, extending backward across a support bracket, and projecting to the rear. It can swing horizontally and is held in the desired position by a pin or bolt through the bracket or by a pair of bolts in a clamp. It is desirable that the anchor of the drawbar be as low and as far forward as the construction of the tractor will permit for best distribution of stress.

Go to the outline

5. Scrapers

The bottom-dump scrapers discussed in this chapter are also known as carrying scrapers or pans, and by various trade names. They are highly mobile excavators with a centrally located bowl that digs, carries, and spreads loads. There are a wide range of types and sizes. Struck capacity is usually between 6 and 56 yards, but there are larger and smaller units also. The typical modern scraper is a self-powered, rubber-tire unit. Controls are usually hydraulic or a combination cable-hydraulic. Standard or conventional self-powered models have power and traction sufficient for most hauling needs, but require the help of pusher tractors or other machines in order to dig efficiently. Self-loading scrapers, which ordinarily do not need pusher help, may have two engines with separate drive axles for extra power, or an elevator that reduces loading resistance. There are also full trailer scrapers, which are towed by a drawbar attached to a separate tractor. These were once the dominant type, and are still useful for farming and in special situations. They are self-loading if the tractor is large in proportion to scraper capacity.

Scrapers are of primary importance in earthmoving. They are the standard tool for alternating cuts and fills, under the wide range of conditions where the cut is firm enough to support them, and the soil (including rock that is soft, ripped, or blasted) is digable. The scraper digs, hauls, and spreads in a single cycle. It works in thin layers in the cut and on the fill, without limit as to the number of layers, so that its efficiency is not particularly affected by depth of cut or height of fill. Its use causes considerable compaction of fills, and favors proper use of rollers. In various models, its economical haul distance ranges from less than 1,000 feet to nearly a mile. Where conditions are favorable, it can move earth for those distances at lower cost per cubic yard than any other type of earthmover. It is not only an excellent machine for bulk earthmoving, but a precision finishing tool as well. The cutting edge is carried between front and rear wheels, so that it is unaffected by pitching, and the operator can control its position very accurately. If job conditions give enough time, the operator can cut or fill accurately to grade, and when space is wide enough for maneuvering, can build crowns and slopes as well. The standard or conventional scraper is a single-engine self-powered machine. It is made in two distinct sections, tractor and scraper, which are connected by a swivel hitch and hydraulic lines. In steering, the two parts pivot on this swivel. The scraper has three basic operating parts: the bowl, the apron, and the ejector or tailgate. In addition, it includes the gooseneck and the scraper (trailer) wheels.

Gooseneck. In front, the gooseneck or yoke has a vertical swivel connection with the tractor, which is usually in two parts with two pivots, upper and lower. It permits turns of 85 to 90° to each side of center. In addition, there are horizontal links that permit the two sections to tip independently through a limited angle. Behind the swivel, it arches up to allow space for the tractor wheels to roll under it on turns, then widens into a very massive crossbeam, and is finally a pair of side arms extending backward and somewhat downward to trunnion fastenings on the sides of the scraper bowl. The gooseneck carries the steering cylinders, the lift cylinder and lever arm for the apron, and a pair of hoist cylinders for the bowl. All of these may have two-way action, or be one-way with return by gravity, springs, or counteracting cylinder.

Bowl. The bowl, is the principal member and carries the cutting edge. It is substantially a box with rigid sides, with the apron forming a movable front and the ejector a movable back. Extensions of the sides converge behind the rear axle, forming a case for the ejector cylinder, and support for a bumper by which the machine may be pushed. The bowl is supported at the rear by the rear or scraper axle, at the center by trunnions on the ends of the draft arms, and at the front by a pair of hydraulic cylinders suspended from the gooseneck. The pull of the tractor is applied through the gooseneck. Most of it is transmitted by the trunnions at the bowl center, but a variable amount comes through the lift cylinders, depending on their position. The floor is cut forward of the centerline and fitted with a cutting edge, often called a knife. This edge is usually very hard steel plate in three pieces—a wide center one and narrower ends, fastened with plow bolts with smooth sides up. The sections can be removed, inverted, and reinstalled when worn on one side. For most work, the center piece is set farther forward than the sides. It is mounted back flush with the ends only when the job is grading, working light cuts, or in sand. Teeth may be bolted to the center section, to improve penetration in difficult ground. They interfere with dumping and spreading and are laborious to install and remove, particularly on a worn edge. They are used more often on elevating scrapers than on standard models. The fronts of the bowl sides, at the bottom, usually have bolted-on wear plates, called side cutters. These receive less wear than the bottom edge, but eventually need replacement.

Apron. The apron forms the forward side and a variable amount of the bottom of the scraper assembly. When in a down or closed position, it rests against the scraper bowl at the cutting edge. When lifted, it moves upward far enough to leave the whole front of the bowl open. It is lifted, lowered, and in some models clamped down forcibly, by a hydraulic cylinder which usually is linked near the base of a lever hinged to the gooseneck. Since apron movement calls for travel through a considerable distance without (usually) the need for much brute force, this third-class lever arrangement is efficient. When the scraper is digging (loading), the apron is held at the moderate distance forward of and/or above the cutting edge. Dug material moves both backward into the bowl and forward onto the apron. In sand, the apron may be kept in a digging position for compaction; in chunky or boulder-filled soil it must be kept up and forward to be out of the way. Occasionally, down pressure is used on the apron to clamp bulky objects against the bowl, in order to carry them in a half-loaded position. There may be a mechanical adjustment in the apron lift, to obtain a larger opening at the expense of tight closing. The higher position may be useful in loading big pieces.

Ejector (Tailgate). The ejector is the rear wall of the bowl. It is usually a sliding or bulldozer type, that moves forward horizontally, forcing the load out of the bowl, over the cutting edge. It is supported by rollers riding on the floor, and on tracks welded to the sides of the bowl. Power is a two-way hydraulic cylinder inside the rear pusher block (bumper) frame. Machines of the larger sizes may have two cylinders, and they may be telescoping in design, to increase the length of push in proportion to casing length.

Controls. A typical arrangement of controls for scraper movements. The levers operate independently unless some optional combination control is used. The bowl lever has three standard positions, RAISE, HOLD, and LOWER (DOWN). LOWER is with pressure, so that on hard soil continued movement will raise the scraper, with weight resting on the cutting edge. The DOWN position is useful for emergency slowing or stopping on a downgrade. The apron lever also has the three positions, to raise, hold, or lower with pressure. It may also have a FLOAT position, to cause the apron to rest by its own weight. The ejector control has three standard positions: FORWARD (EJECT), HOLD, and RETURN. There may be a FAST RETURN also. There is often an automatic control, so that it can be held in RETURN by a detent until the return is complete. It then kicks itself into HOLD. This cycle is canceled by the operator's moving any control.

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6. Graders

Most heavy graders are tandem drive units of the type. The diesel engine, with 125 to 275 horsepower, is mounted at the rear, and drives four single wheels in tandem pairs through gears and chains. The frame connection to the front axle is long and high, to allow space for carrying and manipulating the moldboards or blade under it. The central location of the blade, and the long wheelbase of the machine, provide natural stability for the cutting edge. Smooth-acting, multidirectional control provides precision finishing ability. Weight range is from 13 to 20 tons. Lighter grading machines will be discussed in other sections.

Clutch. In many types of grader operation, the engine clutch may be used frequently under heavy load. It is required to be always smooth in operation. A clutch may be retained even when the machine is equipped with torque converter.

Transmission. Graders need slow, powerful gearing for heavy or precise work, moderate speeds for lighter or less fussy jobs, and also travel speeds up to 20 to 30 miles per hour. There must also be a choice of reverse speeds, as some heavy work may be done backing up, but most reversing is for return travel only, and should be brisk. There may be six to nine forward speeds, and two to nine reverse, in either direct drive or power shift. An eight-speed, direct-drive, power-shift transmission pattern. If there is a converter, it is usually single-stage. It may be equipped with an output shaft governor, to keep ground speed uniform in spite of changes in load. There may be an input clutch in the converter, or a modulating pedal to momentarily disengage the transmission (and power to the wheels) while moving the blade. The clutch is also used for small, exact machine movements.

Hydrostatic Drive. The CMI tandem graders use an all-hydraulic drive system that replaces clutch, torque converter, transmission, and a parallel shafting. There is a fixed-displacement piston pump driven by the engine, which supplies power to a pair of motors geared to a two-speed rear axle.

Power Train. A bevel gear on the transmission output shaft is meshed with a bevel on an intermediate shaft, which turns the inner, live, or drive axles through spur gears. An option available for some graders is variable horsepower. With that variable, when the grader is shifted to higher gears, an electrical system on the transmission moves an automatic stop to a higher setting on the fuel governor. More fuel is injected, giving more power for high-speed, light-load work. For example, Caterpillar's 140H grader moves from a net 150 to 185 horsepower in gears 4 to 8 forward and 3 to 6 reverse. The tandem drive case carries the outer axles, supports the weight of the machine, and provides protection and lubrication. It is pivoted on the inner axle housing, to permit both wheels to follow ground contour.

Tires. Tires are of a special heavy-duty design for grader work. They are preferably the same size all around, but front ones may be smaller and/or lighter, unless it is an all-wheel-drive grader. Traction tread is usual, but the fronts may be ribbed.

Brakes. There are usually brakes on each of the four drive wheels, but none on the fronts. They may be either shoe or multiple-disc design, and are applied by booster-assisted hydraulic pressure. Or there may be a single disc brake in the transmission, acting through the four wheels. The parking brake is usually on the lower transmission shaft, on the end opposite the drive pinion, and is operated by a hand lever.

Throttle. Basic governed engine speed is set by a hand throttle, which may be a lever on the console. There is usually an accelerator for speeding the engine beyond throttle setting, and a decelerator for slowing it. These may be combined in one rocker pedal, providing acceleration for toe pressure and deceleration for heel pressure.

Frame and Front Axle. The rear of the frame is a pair of beams that support the engine and the power train. Forward of the operator's station these slope upward and converge into a single beam of reinforced box cross section. This may slope down to the front axle hinge, or end in a column above it. The front of the frame may be a mounting plate for front-end accessories, and/or project forward far enough to serve as a narrow bumper. The front axle is compound. The lower section usually carries weight of the machine, may be arched high in the center for clearance over windrows, and ends below the wheel spindles. It oscillates on a central pin, and is hinged to wheel spindle brackets just below the kingpins. The upper section, of lighter construction, is substantially a straight bar (lean bar) hinged to the tops of the hub brackets. It can be moved from side to side by a hydraulic cylinder, or by mechanical means. When moved off-center, it causes the front wheels to lean sideward. The angle may be as much as 18°. Wheels are leaned to increase their resistance to sliding sideward on the ground because of load on the blade, or steering stresses. Steering may be mechanical with a booster, or by a hydraulic cylinder located behind or above the axle, and operating through a more or less conventional linkage. The cylinder control is equipped with a follower valve that keeps a direct relationship with the position of the steering wheel. Special arrangements may be made to avoid interference between leaning and steering.

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