THE THEORY AND APPLICATION OF SURFACE EARTH MOVING EQUIPMENT

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The Theory and Application of Surface

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INTRODUCTION

Man has always been surrounded by great resources, but it is only to the extent that he could use these resources that they have been of value to him. The first great step in the utilization of these resources was the application of simple hand tools to his every-day necessities. Today, complex and powerful machines roar across the face of the earth building roads, moving mountains, digging great holes and turning the centuries old courses of rivers.

Machinery has not yet reached its maximum development but it has reached a point where the degree of intelligent application of tools, detailed efficiency in their use and continued striving for higher production are the fundamental considerations deciding the extent to which a user is successful.

Although fundamental in scope, it is hoped that the material in this thesis will create interest and under-standing in the theory and application of surface earth moving machines.

POWER SHOVELS AND CRANES

To properly discuss the theory of the design of a piece of equipment one should have at least some knowledge of the basic operations of the machine. In the case of power shovels and cranes, the four basic operations may be summed up as follows: (1) crowding, the forcing of the dipper into the earth, (2) hoisting, the pulling of the dipper through the earth and lifting of it above the digging level, (3) swinging, the horizontal transfer of the dipper from one point to another, (4) traveling, the moving of the machine from one place to another. These four basic operations apply to all power shovels and cranes, but there are many ways of accomplishing them.

To start on a discussion of the machines themselves it would probably be best to divide them into their major components. The first major component to be taken into consideration is the revolving superstructure. The revolving superstructure is a platform on which are mounted the engine and the mechanism which permits hoisting and swinging as well as the transmission of travel power. The superstructure as a whole is made up of the following elements.

(1) The bed plate is the foundation on which is mounted all of the operating mechanism. This plate may be of cast

steel or welded construction. Boom hinge brackets are provided at the front end of the bed plate for attaching the front end operating equipment.

(2) On the bed plate is erected the A Frame and machinery frame.

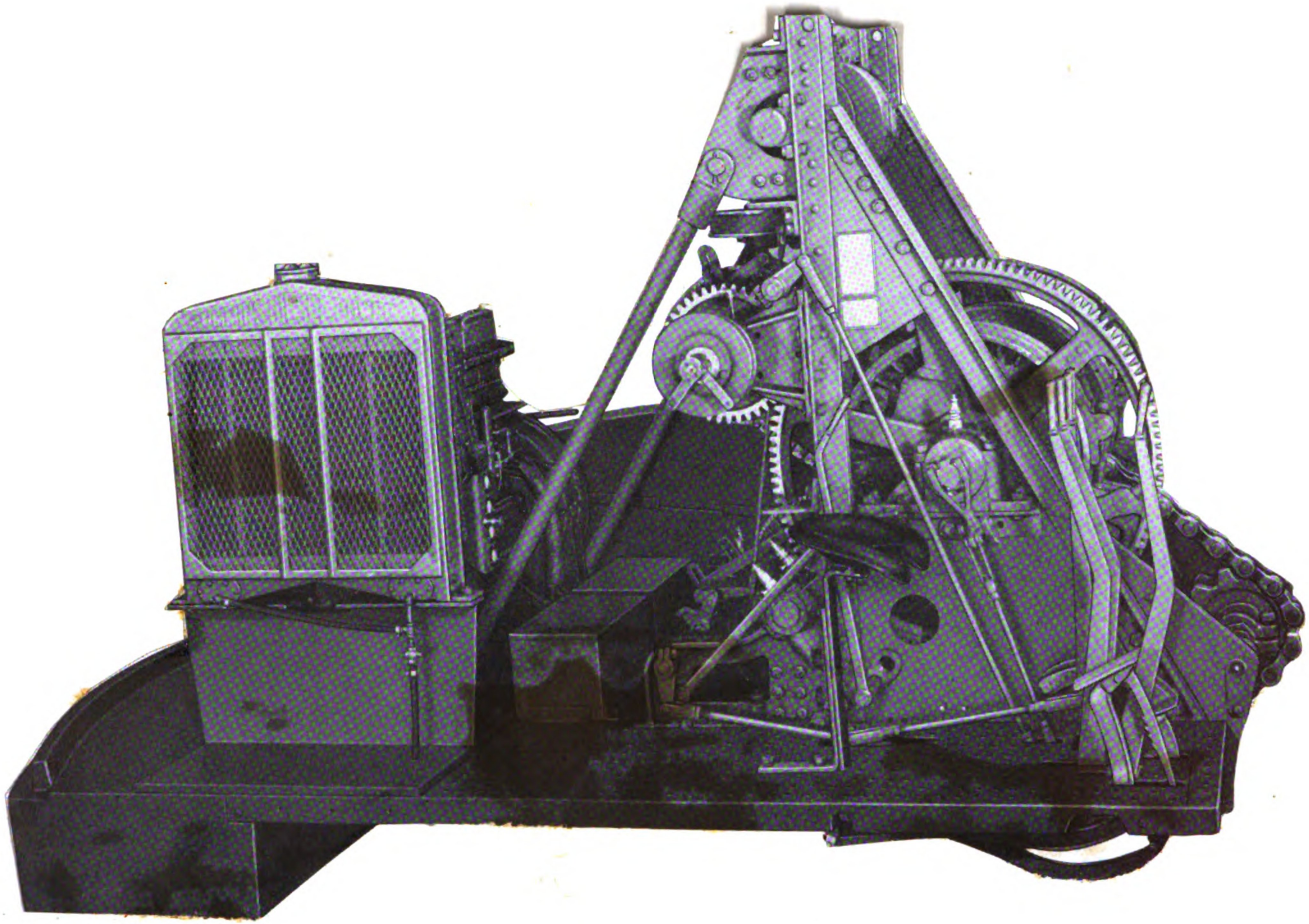
The A Frame consists of a triangular structure made up of the bed plate, a vertical member, and slanting front struts. The A Frame provides an elevated position for the boom derricking lead sheaves and cables which support the boom equipment. It also helps absorb the stresses of the boom pull.

The Machinery Frame furnishes the means of attaching the power shafting, the operating equipment, etc.

(3) The power equipment may be gasoline, Diesel or electric. These internal combustion engines are of the high torque, industrial type with speeds of 800 to 1800 R.P.M. Any standard commercial type of electric motor may be used.

(4) The power take off and transmission furnishes the means whereby the power from the power equipment may be transmitted to the operating equipment. The first step is a power take off which may be through a plate disc clutch or a hydraulic coupling. The power then goes through a speed reduction assembly consisting of a train of gears, a chain drive or a combination of the two.

To further explain the operations of the revolving superstructure the operation of the equipment mounted on the bed plate should be explained. The boom on any machine may be



Typical arrangement of power plant,

A frame, and power take-off on a shovel bed plate raised or lowered through an arc, pivoting about its point of attachment at the front of the bed plate. This is known as boom derricking or lowering, and a boom hoist or derricking device must be installed on the revolving superstructure.

The hoisting mechanism provides a method of lifting or lowering loads in a vertical plane. The hoisting mechanism usually consists of two drums which may be mounted side by side on one shaft or on two shafts in tandem.

Each hoist drum is controlled independently by a clutch and a brake. The controls actuating the clutches may be straight mechanical, mechanical with booster clutches, hydraulic air or vacuum. Usual lifting operations may require only one drum which is called the Main Hoist. However two drums are provided to accommodate clamshell and dragline service and the second drum is called the Secondary Hoist drum.

The entire superstructure or turntable may be revolved through 360 degrees in either direction. This is accomplished through the swing mechanism. The swing mechanism consists of a vertical swing shaft and the proper mechanism and swing clutches on the superstructure so that the vertical shaft and consequently the superstructure may be rotated in either direction.

The power mechanism and control clutches for propelling the traveling crawler or wheel mountings are provided by the travel mechanism on the superstructure.

The transference of the propelling power from the superstructure into the mounting requires a vertical travel shaft much like the swing shaft. This shaft is located at the axis or center of rotation of the superstructure. Through suitable clutches the operator may select the proper direction of rotation for forward or reverse travel.

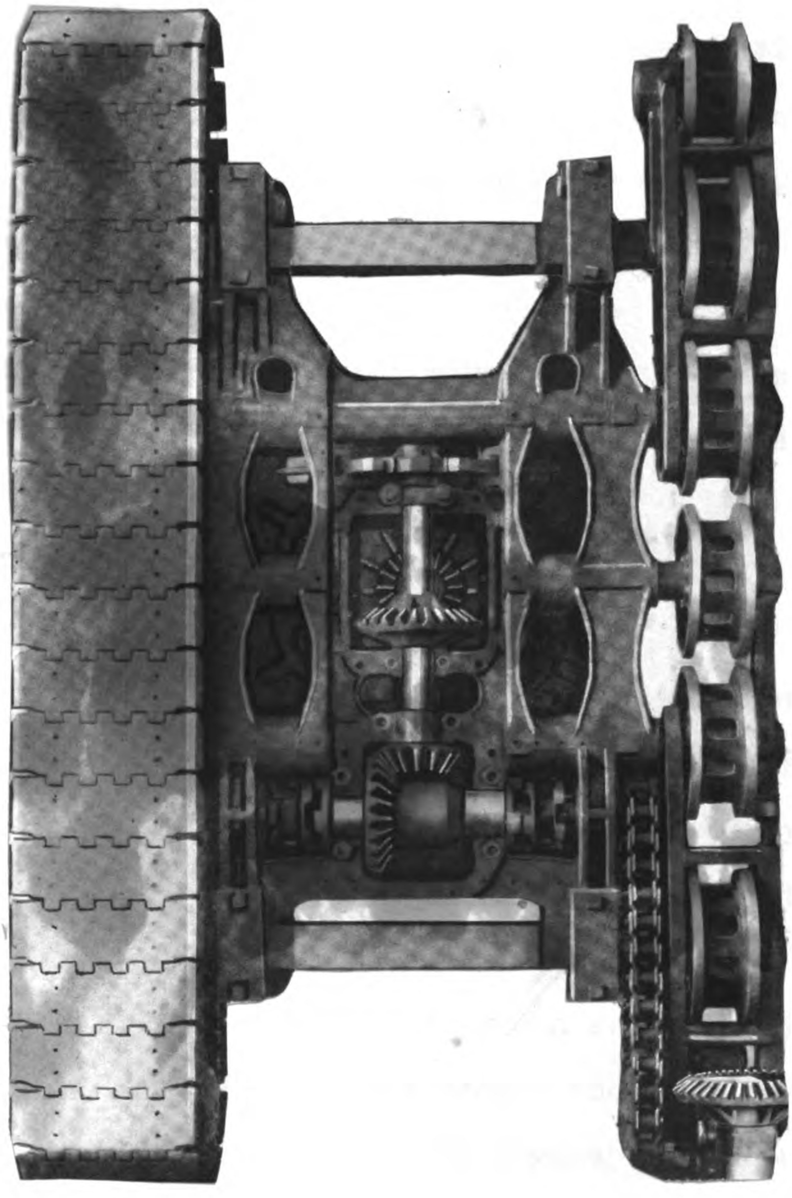
The second major component of the shovel is the mounting. There are three types of mountings: crawler mountings, truck mountings, and wheel mountings.

In general, crawler mountings are those of the track laying type with two parallel continuous crawler or tread belts. The crawler mounting consists of four primary parts as follows.

(1) The crawler car body which transfers the revolving superstructure and weight into the crawler frame. It also houses the vertical and horizontal propelling shafts, and the clutches or brakes which control crawler steering.

(2) The crawler frame, on which the crawler car body rests and is secured, includes the side frames, rollers, and final end drive mechanism. The crawler frame serves the further purpose of distributing the weight loads over a much greater area.

(3) The crawler tread consists of tread shoes or links which are pin hinged together in a continuous belt and which fit around the side frames. The length and width of the tread belt provides considerable ground bearing area which gives further weight distribution resulting in the low ground pressure that enables the crawler mounting to overcome many



Shovel crawler mounting with one track removed soft-ground conditions.

(4) The power flow or final drive to the crawler tread belts may be chains or gears. Either method transmits the propelling unit along the ground, Crawler mounting speeds usually range from 1/2 to 2 miles per hour and one or more travel speeds may be available.

In addition to the crawler mountings just discussed, the revolving superstructures or turntables of power shovels and cranes may be mounted on rubber tired mountings of which there are two main classifications: truck mountings and wheel mountings.

Truck mountings may be heavy duty commercial motor-trucks, reinforced and modified as necessary for the mounting of shovels and cranes, or they may be chassis specially designed by crane manufactures for this purpose. Generally the chassis is called a carrier.

Such units of either type are known as two-engine truck mountings because a separate and second engine is provided to propel the mounting on which the turntable is mounted. There is also a design in which the carrier engine is used to drive the mechanism on the superstructure.

Truck mountings may be supported by two or three axles and the method of driving the carrier wheels may be chain or gear drive. Drives are designated by standard automotive nomenclature as follows: (1) two axles with rear axle driven is 4x2, (2) two axles with front and rear axles driven is 4x4,

(3) three axles with the two rear axles driven is 6x4, (4) three axles with three axles driven is 6x6. In other words the first number in the designation is the total number of wheels, and the second number in the designation is the number of driven wheels.

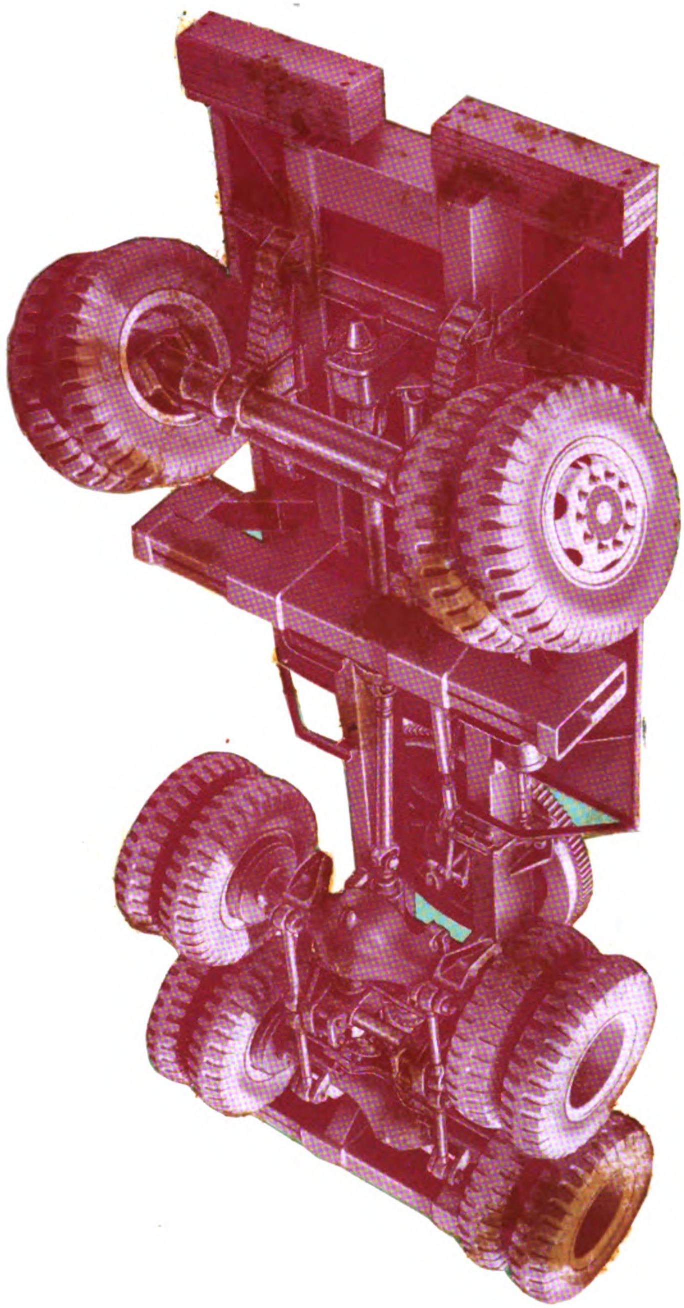
Two engine truck mountings usually have a range of four to ten speeds forward and two speeds reverse. The top speed of the above truck mountings is usually about 30 miles per hour.

Wheel mounting, that is, single engine mountings are also rubber tired mountings. They differ from the truck mountings just discussed in that they have only one engine for powering both the superstructure equipment and to propel the carrier. This engine is mounted on the superstructure. Different mountings are described as 6x6, 6x4, 4x4, 4x2, following the same manner of designation as described for truck mountings.

Wheel mountings require a specially designed chassis. Also all controls for steering, braking, gear shifting, etc. are located in the operator's cab.

Wheel mountings also differ from truck mountings in that they usually afford a range of one to four speeds with a top speed of approximately ten to twenty miles per hour.

In addition to the types of mountings already discussed there are several types of special mountings which are designed to do a specific type of job. Three of these special mountings are (1) the pier or stationary mountings, (2) the



Truck mounting featuring a 4 x 6 type drive portal or gantry mounting which is a high structual steel mounting that travels on rails, (3) barge mountings.

The next major component of the power shovel to be discussed is the front end operating equipment. There are five basic types of front ends which are interchangeable. They are the shovel, crane, clamshell, dragline, and back hoe.

Since the shovel boom is probably the most fundamental and most widely used type of front end it will be described first.

Shovel boom equipment includes the shovel, the boom proper, the dipper stick and the dipper stick trip mechanism. In addition it includes some mechanism on the superstructure for crowding and retracting the dipper stick.

The dipper stick is mounted about halfway up the boom on the shipper shaft, and slides back and forth relative to the boom. The front end of the stick, carrying the dipper, may be raised or lowered as the stick may be pivoted about the shipper shaft at any point along the length of the stick.

The operations involved in shovel work are:

(1) The hoisting operation by which the dipper is pulled through the material being dug.

(2) The crowding operation by which the dipper is thrust or forced through the material being dug.

(3) The retracting operation by which the dipper is withdrawn or pulled out of the material

being dug.

(4) Hoisting and crowding are usually employed simultaneously in the digging cycle to force the dipper into the material at the same time it is being pulled through the material.

Except when an individual electric motor is used, power for crowding and retracting is transmitted from the superstructure to the boom by a system of chains or cables or a combination of the two. In order to give a clearer picture of the three main types of crowding mechanisms a more detailed explanation is necessary. The first type, the independent or positive chain crowd requires the use of only one drum on the superstructure. This is the hoist drum which controls the hoist cable used to raise and lower the dipper. This method does require that the superstructure be equipped with a separate crowd shaft or some type of reversable shaft which may be rotated in either direction so it can actuate the chain drive in either direction. The chain crowd drive extends from the crowd shaft or reversing mechanism on the superstructure to the boom foot and then up the boom to the shipper shaft. Thus by controlling the direction of the crowd shaft on the superstructure, the shipper shaft pinion may be rotated in either direction so that the dipper stick may be crowded or retracted. In this design hoisting may be independent of crowding or retracting, or may be used in combination with either crowding or retracting.

In this type of crowd, power is transmitted from the shipper shaft to the dipper stick, and thus to the dipper, by a rack and pinion drive which consists of a geared pinion on the shipper shaft which meshes with a rack or flat gear on the dipper stick.

The second type of crowd mechanism is the independent or positive cable crowd. The characteristics of this mechanism are very similar to those of the chain crowd. In this design, however, cables replace the chains, and two cable drums are required on the superstructure. One of the drums is used to hoist the dipper by means of the hoist cable. The other drum is reversible and is used to operate the crowd and retract cables. The drum to which the separate crowd and retract cables are attached must be reversible so as to provide for the pull of the cables in either direction to effect crowding or retracting the dipper. In this case when the crowd cable is wound on the drum, it crowds or forces out the dipper stick. When the drum is reversed the retract cable is wound on the drum thereby causing the dipper stick to retract.

Since, in this type of crowd, the power is usually applied by cables to the ends of the dipper stick, it is only necessary to provide a guide or sleeve at the shipper shaft through which the stick slides freely in either direction. This sleeve is mounted on and pivots about the shipper shaft.

A third type of crowd mechanism is the combination cable crowd which differs from the previous two types in that (1) it uses both hoist drums on the superstructure but does not require any reversing drum or mechanism and (2) the crowding motion may only be effected automatically and simultaneously with hoisting operations. As the combination hoist and crowd cable is wound on the drum, the dipper is hoisted, and because the front end of this cable is brought down and dead ended on the rear of the dipper stick, the stick is simultaneously forced out or crowded. This design permits straight hoisting, without crowding, but crowding can never be effected without hoisting.

The retract cable is attached to the second drum, with the front end of the cable dead ended at the dipper end of the dipper stick. Thus as this cable is wound about the drum it will pull back or retract the dipper stick.

This type of crowd may be used with either the rack and pinion drive at the shipper shaft, or if the cables are attached to the ends of the dipper stick, the guiding sleeve may be used.

Other types of crowds include (1) a combination of the independent cable and the independent chain crowd; (2) a dual crowd which combines both the independent cable crowd and the combination cable crowd and (3) the use of individual electric motors to drive each operation.

Another type of front end equipment is the lifting crane. Lifting cranes are primarily units for lifting an object, transferring the object to a new location by swinging of the superstructure or traveling the entire unit, then lowering or placing the object in its new location.

Though the lifting crane boom is not used for excavation by itself, it will be described here since it is a part of dragline and clamshell equipment.

Basic lifting crane equipment consists of a common crane boom, hoist drum lagging for the desired line speeds and pulls, and a hook block to provide the required parts of line for the lifting service specified.

The common crane boom is usually made in two sections separable at the center into upper and lower sections, with a boom head and a system of sheaves located at the upper end of the upper section.

The crane boom upper and lower sections may be fastened together by three methods: (1) by pin and clevis connections; (2) by splice plates; (3) by bolted flange plates.

The standard lengths of the common crane boom will often not be sufficient for the job to be done. There are, therefore, two methods by which the length of the boom may be increased to increase the working ranges and reaches.

One of these is the use of a boom extension or jib. This consists of an extension which can be added to the head of the boom and is usually added for steel erecting or single line work. Boom tip extensions may be used as straight extensions, that is as straight extensions of the boom, or may be used as gooseneck extensions in which case they are offset from the center-line of the boom.

The second method of lengthening the boom is by the insertion of intermediate center sections between the top and lower sections of the boom proper. Usually intermediate center sections may be used in multiples up to any maximum boom length specified by the manufacturer. The method of connecting center sections is by the same method of connection as used on the common crane boom.

When booms are lengthened to a certain point, some manufacturers require the installation of a gantry or high A-Frame. This is simply an extension added to the standard A-Frame to elevate the derricking lead sheaves.

One type of front end equipment of a specialized nature is the clamshell. The name "clamshell" is derived from the general shape and operation of the bucket used on this machine. In general, the clamshell buckets consists of two halves or shells, hinged together at the top so that the bucket can be opened, or so that the two can be drawn together to form a sort of bowl-like arrangement. At the start of the digging cycle the bucket rests on the material with the shell open. As the hoist or closing line is wound up on the drum, the two halves of the bucket come together, digging their way through the material and filling the bucket as they come together. While the bucket is closing the weight of the bucket helps bite into and penetrate the material being dug. This is the only "crowding" action available with a clamshell.

Clamshells consists of a common crane boom, a tagline, hoist drum laggings for the proper line pulls and speeds, and a clamshell bucket and proper cables.

The tagline is a small cable under tension which keeps the bucket from spinning, swaying, twisting, or drifting.

Both hoist drums are used for clamshell work, one for the cable which (1) closes the bucket when it is digging into the material and (2) then hoists it to dumping height. This is known as the closing line which is reeved in the bucket. The cable from the other drum is fastened to the top of the bucket, and serves to hold the bucket suspended when dumping. This is known as the holding line. Dumping is effected by releasing the closing line.

The fourth common type of front equipment is the dragline. The dragline derives its name from the dragline bucket. The dragline bucket may be described as a bucket which is tossed away from the machine onto the material and is then dragged toward the machine, filling the bucket with material as it is dragged in and pulled through the material.

Dragline equipment consists of a standard common crane boom, the fairhead, hoist drum laggings for proper line pulls and speeds, dragline bucket, and proper cables.

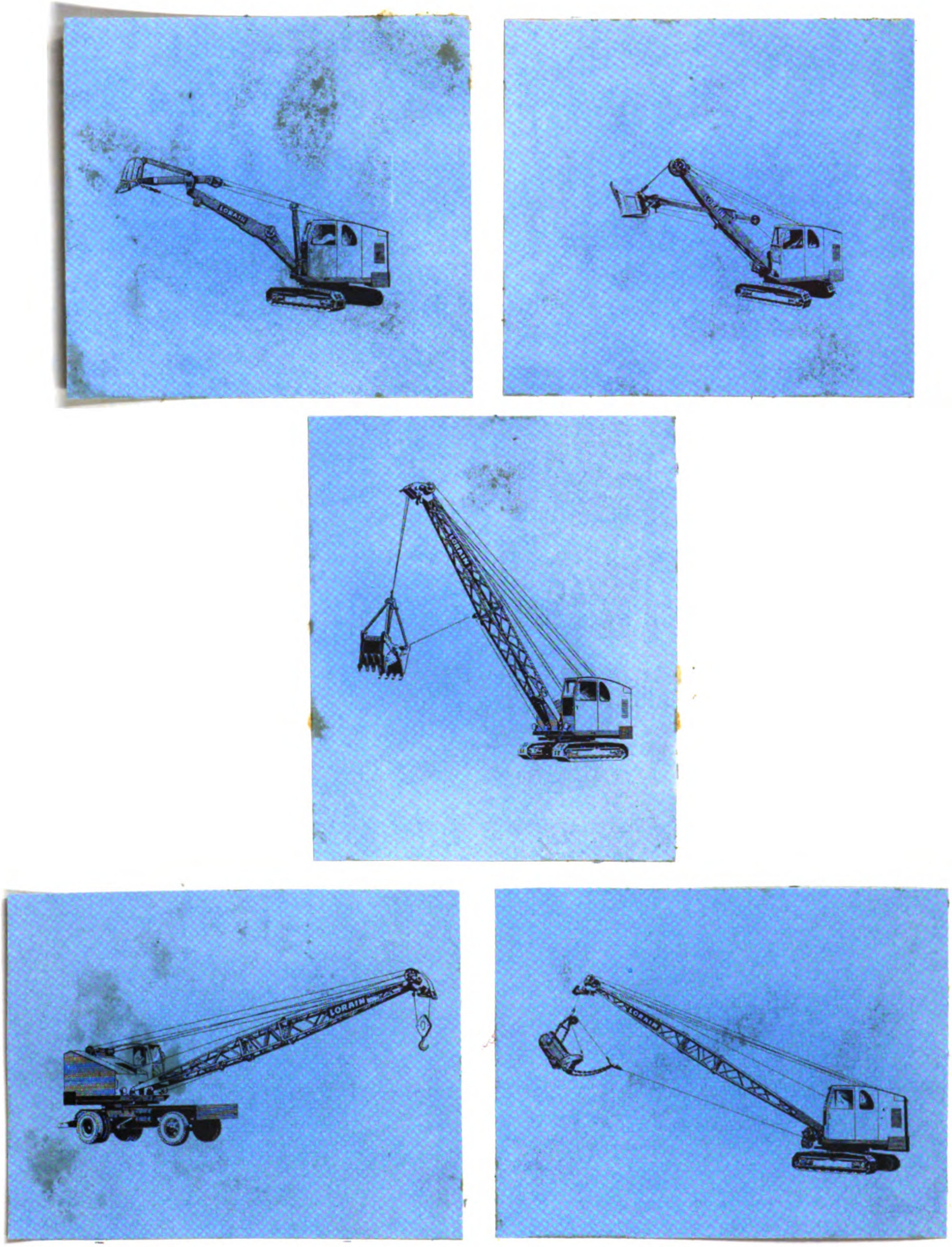
The fairhead is a device of sheaves or rollers, the purpose of which is to guide the drag cable from the bucket to the drag drum. The fairhead is located usually near the foot of the crane boom.

The dragline unit requires the use of both hoist drums. One cable goes over the head of the boom and is used to raise and lower the bucket. The other cable is the dragline cable and runs from the secondary hoist drum through the fairhead and to the bucket. It is used to pull the bucket in through the material during the digging operation and releases it for dumping after it has been raised to the proper position.

The fifth type of front end equipment is the back-hoe. This equipment is so named because its digging action resembles that of the garden hoe in that the dipper is on an arm which is pulled toward the machine.

The hoe consists of a boom with a dipper stick pivoted at the end of the boom, a dipper attached to the lower end of the dipper stick, proper drum laggings and a mast or A-Frame that is located at or near the boom hinges to provide proper hoist cable leads.

In operation, (1) the boom, with dipper arm extended, is lowered into the excavation: (2) then the dipper is pulled or dragged toward the machine with the drag cable; (3) when the dipper is filled, the entire boom assembly is raised by the hoist cable; and (4) the load is dumped by extending the dipper stick. If you will think of your hand as the dipper, your forearm as the dipper stick, and your upper arm as the boom, and remember how you used to dig holes on the beach, you'll have a good idea of how the hoe works.



Examples of the basic types of

front-end equipment

TRACTORS

The type of tractor most widely used in earthmoving is the crawler tractor. The crawler tractor is primarily the result of a need for a machine to tow, push, pull, power or mount construction equipment. It is designed to withstand the abuse and rough handling encountered on jobs where it is used. It is a basic "pioneer" tool of construction work and it serves as a prime mover for pulling and pushing loads, power for winches and hoists, and a moving mount for side booms, bulldozer blades, and front end buckets. Its main distinguishing feature, the crawler tracks, are used because they give the maximum tractive effort for the soil and ground conditions in which they operate, and because the length and width of the tracks bridge many ruts and ground irregularities.

The crawler tracks are made up of connected rigid steel plates. The plates, or track shoes as they are called, are of varying design, depending on the use to which they are put. The characteristic ridge on the shoe which digs into the ground for gripping action is called the grouser. The grouser varies in height from 2 1/4" to 2 3/4" depending on the tractor size. Semi-grousers are so called because their height is approximately 1/3 the height of the standard grouser. They are used where good dig-in traction is needed and the tractor work requires much pivoting with little forward motion of the tractor. The reduced height of the grouser reduces the power needed and stresses set up in turning. They also permit track slippage before excessive stress can be placed on the tractor or attached equipment. Semi-grousers are also used where a full grouser would injure the surface on which the track is riding.

Track treads vary in width from 7" to 28", depending on the size of tractor, and the use to which it is to be put. If a track is wide it gives reduced ground loading per square inch and improves flotation. If the track is narrow, the ground pressure per square inch is greater and in soft ground there is a tendency to sink in. Track slippage is a shearing action. On some soils such as a firm clay loam, increasing the ground pressure per square inch increases the density of the soil and decreases the tendency of the soil to shear. However, many soils such as a dry powdery earth, do not compact well and to reduce track slippage it is necessary to use a wide track which will present more area to be sheared even though it reduces the ground pressure. There is for each weight of tractor and use of tractor on given soil conditions one track width which best fits the operation. In general the ground pressure in pounds per square inch of crawler tracks varies approximately between 6.50 to 8.25. This is about equal to the pressure per square inch exerted by a man standing on the ground. Tracks should not be wider than necessary to effectively perform the job to be done. Because the track is supported near its centerline, extreme widths increase wear due to greater twisting action when the load is carried on the side of the track. Extreme widths or lengths also increase the difficulty of steering.

Track shoes are furnished with rubber surfaces, flat metal surfaces and for use in ice and snow. They may also be heat treated for extremely rough operation on hard surfaces such as rocks, or to reduce abrasion wear as in fine hard sand.

Crawler tractors are usually steered by means of multiple disc clutches connecting the power to each track. Disengaging the clutch stops the power to a track, and when the tractor is pulling a load, causes the tractor to turn in the direction of the track which has stopped.

When the tractor is being pushed by the load, as when the tractor is going down grade with the engine braking the load, disengaging a clutch causes the tractor to turn away from that track. Sharpness of turning can be increased by braking the track on the side in which it is desired to turn.

In addition to the two steering clutches, there is also a master clutch similar to the clutch in a car which connects the engine power to the transmission.

Speed control is done by means of a throttle lever.

Clutches are also actuated by hand levers instead of foot pedals.

Tractors are rated by size and power. Size is important because, as an important rule of thumb, a tractor with adequate power can exert on its drawbar a pull equal to approximately 90% of its weight. Pulls in excess of this cause the tracks to slip.

The pull developed on the drawbar is usually expressed in pounds or as drawbar horsepower. Engine horsepower is also used as an index, however, because of various frictional losses between the engine back to the tracks, the engine horsepower will not indicate the pulls and speeds available. Drawbar horsepower will also not indicate the speed and pulls available.

Tractor balance is an important characteristic of tractor design. If the tractor is heavy on one end, it tends to dig in at that end. Adding more length of track to offset this condition makes it more difficult to steer and increases track wear. Furthermore some tractors have front equipment, such as bulldozers, while others carry the load on the rear, such as in scraper pulling.

There is no perfect "all purpose" design, but rather all designs are the result of compromises with what is needed and that which is practical.

One of the most important recent developments in crawler tractors is the application of the hydraulic torque converter. This device installed between the master clutch and the transmission serves two main purposes:

(1) As a device permitting the elimination of most of the transmission gears, and to increase or decrease the torque.

(2) As a fluid coupling between the engine and the transmission.

The torque converter principle is not new, having been used for years in hundreds of power installations such as boats, trucks, and busses where a strong, smooth power flow of rapid flexibility was needed.

As a prime mover the crawler tractor is superior to rubber tired hauling units in its ability to travel rougher terrain and exert stronger drawbar pull. The versatility and the characteristics of the hydraulic torque converter have increased the variety of the operations that a crawler can perform and have improved the effectiveness with which it can perform many of these operations.

Characterized by the fluid absorption of shock loads and the impossibility of stalling the engine, this converter enables the tractor to develop its maximum drawbar pull when most needed. Automatically adjusting itself to the load, the torque converter develops a greater and greater output as the load on the tractor is increased, making it no longer necessary to slip the clutch to maintain engine speed as with the all gear transmission.

The following is a list of some of the advantages of the torque converter over the all gear transmission.

(1) The converter automatically develops increased turning force on the tracks as the tractor is loaded.

(2) Drawbar pull is limited only by the traction of the crawler tracks.

(3) Eliminates the overloading of the engine resulting when its speed is "lugged" down, by permitting the engine to operate at a speed range where it develops high torque and horsepower.

(4) The fluid in the converter absorbs shock loads. This reduces tractor wear.

(5) On soft footing, smooth speed and power flow improves flotation by reducing jerking of the tracks when the master clutch is engaged.

(6) When the tractor is used to power a winch or hoist it enables the development of high line pull at low line speed. The engine can be throttled so that the line speeds are low, yet the engine speed is kept sufficiently high so that it doesn't "lug" down or stall.

(7) When the tractor is used as a pusher tractor, it tends to synchronize its speed and power with the unit being pushed and results in a

steady, continuous pushing action.

(8) Greatly reduces the amount of gear shifting done. This saves on clutch wear, reduces operator fatigue, and simplifies tractor operation.

The most important trend in types of earthmoving equipment in recent years has been the application of rubber tired equipment for both the tractor or power unit and the units used with tractors. Like any equipment, it has its advantages and disadvantages. In general it may be said that on long hauls, over 1000 feet, the rubber tired unit will haul more dirt at a lower cost than will a crawler tractor. The hauling speeds of crawler tractors are considerably less than the rubber tired tractors. With this increase of speed in the rubber tired tractors there is also a marked decrease in the pounds of pulling power.

The standard type of wheel tractor is made by several manufacturers, some of the leading ones being International Harvester Company and Minneapolis-Moline.

There are several manufacturers that make specialized pulling tractors. These tractors have two large rubber tired drive wheels and are used to pull scrapers and dump wagons. They can not be used without the unit they are designed to pull since the balance of the tractor depends on the two drive wheels and the balancing weight of the load. The steering of these machines is much the same as that of the crawler type tractor. In order to turn, less power is applied to the wheel on the side of the turn, thereby causing the other wheel to turn faster and push the tractor toward the other side. The main difference in the steering mechanism of the crawler type and the two wheeled type of tractor is that the tracks on the crawlers are controlled either by clutches or a power steering mechanism while the two wheeled types are almost always steered by an electrical or mechanical power steering mechanism. The two main selling points of these two wheeled tractors are the short turning radius and the increased speed. The maximum loaded speed of these units is about 16 miles per hour.

The latest development in heavy duty tractors is a tractor manufactured by the Le Tourneau Co. It has four large rubber tired driving wheels. The tractor is steered in the same manner as a crawler type. One unique feature of this tractor is that the operator sits in front of the engine directly behind the blade. These tractors are made in two sizes with diesel power plants of 180 to 300 horsepower. The pulling power of these tractors comes much closer to that of an equivalent sized crawler than any other type of rubber tired pulling unit and still speeds up to 16.3 miles per hour are obtainable. Maximum speed can be obtained in both forward and reverse travel.

Four wheel rubber tired tractor

Rubber tired "Tournadozer"tractor

TRACTOR MOUNTED EQUIPMENT

The bulldozer is the traditional "work horse" of earth moving equipment. No other one piece of equipment offers such a variety of loading, pushing, or lifting operations and can apply these in so many different ways.

The "dozer family" consists of angledozers, tiltdozers, pushdozers, dozecasters, and trailbuilders, which are various trade names for bulldozers which may be tilted, angled out on one corner, or will permit one corner to drop lower than the other for better penetration, or for side hill cutting.

The bulldozer is basically a slightly curved pushing blade mounted on the front of a tractor. It is attached to the tractor by two long push beams, and may be raised or lowered either hydraulically or by cable controls. Since the bulldozer depends on more or less "brute strength" to move the dirt or objects in front of it, it is made of heavy gauge steel plate. The steel is usually heat-treated to give it extra toughness.

For clearing land a special blade is used. It has adjustable teeth protruding from the bottom of the blade. These teeth help dig up roots and large boulders.

One type of tractor equipment that is becoming very popular is the "tractor shovel." The tractor shovel consists of either a crawler type or a wheel type tractor with a hydraulically operated bucket mounted on the front end. The bucket may be dumped at any height, quickly or slowly, in part or all at once. The unit is ideally suited for basement excavation, loading trucks, maintaining stock piles, snow removal, and a multitude of miscellaneous jobs. Buckets are most generally of 3/4, 1, and 2 cubic yard capacity. The 2 yard buckets are used for snow removal. For bulldozer work a quickly interchangeable bulldozer is available.

TRACTOR-DRAWN EQUIPMENT

The tractor drawn scraper is designed to dig, load, haul, dump, and spread. The main parts of the scraper are as follows:

(1) The bowl which holds the dirt. In some scrapers the bowl is hinged and tips forward to roll the dirt out.

(2) The apron, a curved wall in front of the bowl which opens and closes to operate the flow of dirt in and out of the bowl.

(3) In some scrapers, a tailgate, which is a wall in the rear of the bowl used to push the dirt out of the bowl.

(4) The cutting edge which is lowered into the dirt to make a shallow cut.

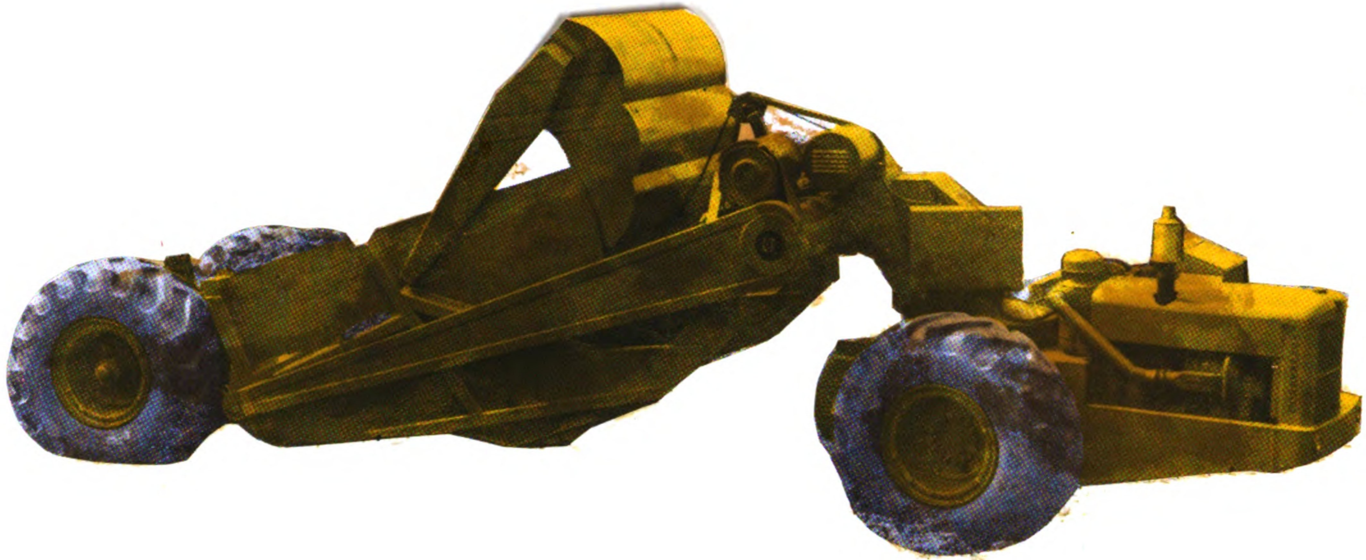
These machines dig their own load during the forward motion of the accompanying tractor. A cutting blade which may be raised or lowered to maintain any digging depth down to about 8 inches is pulled through the earth and the dug material travels up its face into a carrying bowl, and falls forward into a carrying apron. When the two are loaded the apron is allowed to drop and enclose all of the loaded dirt.

The apron having closed, the entire bowl is then raised away from the ground through a sheave and cable arrangement to allow carrying the load to its resting place. Great pneumatic tires cushion the shock to reduce hauling work. At the fill, dropping the cutting edge to a desired height above the ground, the blade forms a strike-off control under which all of the load is spread.

The front apron opens first, dumping its load on the ground in front of the blade. Forward motion of the tractor allows all dumped dirt to roll under the blade into the area between the bottom of the blade and the ground level. A rear gate, forming the back of the carrying bowl, is then pulled forward to push out all the remaining dirt and allow its spread under the blade.

For jobs requiring a smaller scraper there are several kinds of two wheel scrapers made. Most of the two wheeled scrapers are similar in operation to the already described four wheeled models. The Heil Company manufactures a two wheeled scraper that dumps its load from the rear of the bowl. In all models of two wheeled scrapers the load is more or less balanced over the wheels when it is in the carrying position. The capacity range of these scrapers is from two to four cubic yards.

The tractor drawn dump wagon is similar in many respects to the tractor drawn scraper except that it can merely haul and dump its load. The most widely used type of dump wagons



"Tournapull" tractor pulling two wheel scraper is the bottom dump type. The construction of these wagons is such that the bottom of the carrying bowl consists of two doors which open from the center outward. These doors are operated by a single cable from the cable power control on the tractor. Since these wagons do not have to load themselves, it is possible for them to have enough clearance so that the bottom doors may be dropped completely open and still not interfer with the operation of the unit by dragging in the dirt.

Another type of dump wagon is the side dump. Dumping to the side is accomplished by tilting the whole carrying box. The capacities of these dump wagons range from six cubic yards to the huge coal haulers of 40 ton capacities.

With the advent of high speed rubber tired hauling equipment, it became apparent that the conventional methods of loading sometimes impaired the efficiency of the hauling unit. Large capacity and speed on the haul road were in many cases offset by limitations of loading equipment. In order to reduce hauling costs to the lowest possible figure, the Euclid Road Machinery Company has designed a loading machine that has proved to be one of the most important developments for the earth moving industry in recent years. Built to match the efficiency of other large earth moving equipment, the largest unit made weighs approximately 50,000 pounds. It has its own 150 horsepower engine to operate an endless belt. The belt is angled up and out so as to dump the dirt into a truck underneath.

For efficient use the quantities of dirt to be moved should be large, the ground fairly level, and the distance of travel area sufficiently great so that not much time is lost in turning the unit around and maneuvering the trucks or wagons under the belt.

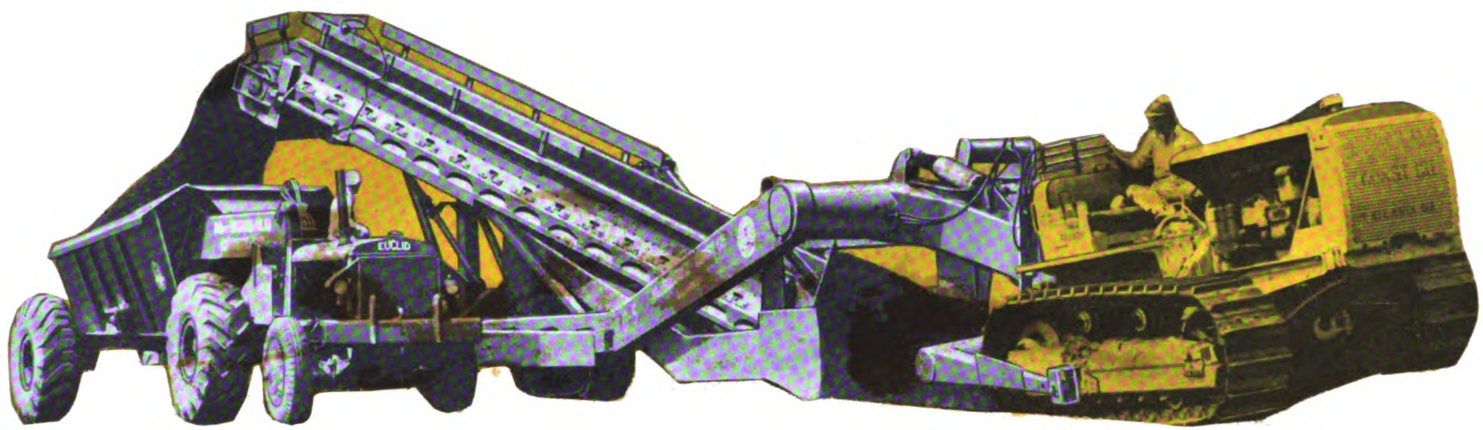
The soil must be of a type that the cutting edge and belt can handle. Scarifying or breaking up the soil may ease the load on the cutting edge and help give an even flow of dirt on the belt. Ground conditions should be such that the trucks or wagons being loaded have good traction and do not get stuck easily.

It is extremely important for maximum production that the output of the belt be balanced with the number of trucks or wagons so that the trucks will not "bunch up" while waiting to get a load or time be lost because a truck is not available.

Because of the great weight of this unit and the power required to take an even, deep cut, only the largest size tractors made are suitable for pulling the unit. In this work the torque converter tractor is valuable not only because of its size, but because it is the only tractor that uses a hydraulic torque converter. The use of this converter eliminates the necessity of hundreds of disengagements of the tractor master clutch as one truck pulls away and another moves up.

Positive controls permit instant adjustment of width, depth and angle of cut and make it possible to grade slopes and ditches. All loader operations are controlled by the tractor operator. The control lever assembly, consisting of three levers mounted on the rear of the tractor are within easy reach of the operator. The speed of the engine is controlled by a clutch to reduce the engine speed when the belt is stopped and to open the throttle when the belt is started.

A rooter is in reality an extra heavy duty plow. Since it is used to break up ground that is too heavy or hard for other types of equipment, it must be able to withstand the roughest kind of treatment. Most rooters are made of heavy steel plate welded into a box type frame. The wheels are of the nonclogging, steel tread type to take the severe shocks subjected to them and still give good flotation. The number of teeth varies from one to three, and the maximum depth is about 30". The frame may be filled with water or sand to give extra weight. The depth of the furrow is controlled by the tractor operator by either a hydraulic or cable control system.



Crawler tractor pulling a Euclid endless belt loader

MOTOR GRADERS AND PATROL GRADERS

The motor grader was originally developed for grading and maintenance of gravel or rock surfaced roads. Modern improvements, however, have given this machine a wide diversification of uses and made it a year-round machine.

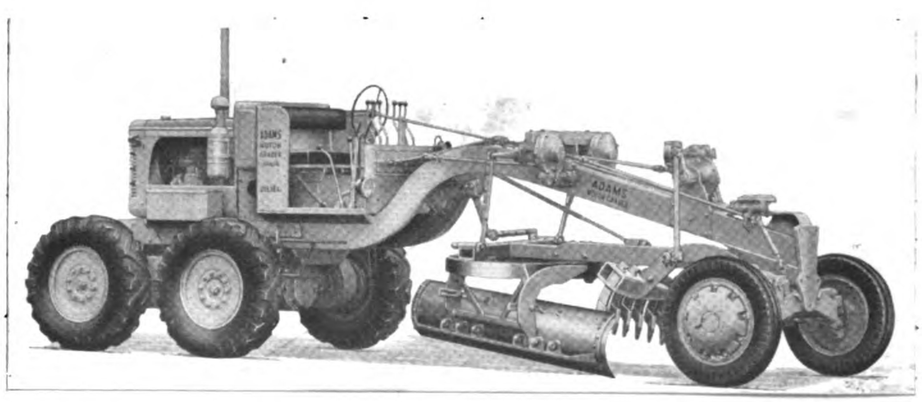
Tandem rear wheels and leaning front wheels have improved traction and steering. Equipped with a V type snow plow, together with its standard blade, it is an excellent machine for snow removal. It is used for terracing, bank sloping, grading, leveling and shaping roads, shoulders and ditches.

The rolling action of the well designed blades make it an effective machine for mixing and spreading bituminous materials. A scarifer attachment on the fron enables it to break and loosen soil.

The blades can be turned through 360° so that the machine can be used in either direction. The blade can be moved to the side so that grading can be done on sloping or vertical banks. Speeds up to 17 miles per hour enable this machine to move rapidly from one job to another.

The patrol grader is primarily used for maintenance of gravel or rock surfaced roads. It is smaller than the motor-grader and costs less. Although it cannot perform as wide a variety of jobs as the motor grader, it fills a need for a lower cost unit where only limited work is required.

Conveyor type bucket loader with cutting blade



Heavy duty motor grader

BUCKET LOADERS

The bucket loader is a highly specialized machine that has been developed to load trucks and wagons. These machines can be mounted on either rubber tires or crawler tracks. The machine itself consists of a spiral digger which digs the dirt and forces it toward the bottom of the conveyor belt. On the conveyor belt is mounted a number of steel buckets. These buckets have toothed cutting blades as do the digging spirals. The dug material is carried in the buckets up to the top of the conveyor where it is dumped into the waiting trucks or wagons.

The digging speed of the machine is about 27 feet per minute and the traveling speed is about three and one half miles per hour.

The conveyor boom can be lowered when the machine is going from one job to another so that the necessary headroom clearance is about ten feet. These loaders are completely self-powered for both loading operations and traveling.

LONG RANGE EARTH MOVING EQUIPMENT

The slackline cableway excavator is a machine that digs its load, lifts it free of the excavation, conveys, and dumps it at any pre-determined point along the span. The combining of digging, conveying, elevating, and dumping in one continuous rapid cycle of operation, makes it possible with this machine to move material from a deep excavation directly to an elevated dumping point at a minimum cost per yard.

The operating principle of these machines is very simple. The digging bucket is suspended from a trolley carrier which travels on an inclined track cable. This track cable is slackened off to lower the bucket into the excavation, and tightened to lift the bucket into the air for hauling up to the dumping point.

The power unit is a two drum hoist. A load cable, attached to the front of the bucket, leads over a guide block at the top of the mast or tower down to the front drum of the hoist. With the bucket resting on the ground, a short forward pull on the load cable causes the bucket to dig in and fill to capacity. After the bucket is loaded, the track cable is raised by winding up the tension cable on the rear drum of the hoist, thus causing the bucket to clear the unexcavated material. The load is then conveyed along the track cable to the dumping point by winding up the load cable.

The chain mountings by which the bucket is suspended from the carrier are so arranged that the bucket automatically tips forward and downward when the load cable has pulled it to a point where a dump block, which is attached to the mountings comes in contact with a stop button on the track cable. This stop button of course is so located that the material is dumped at the appointed place. After dumping, the empty bucket returns by gravity down the track cable to the desired digging point.

Most generally this type of machine is used where the material to be excavated has a good depth, and also where the material is of a nature that will cause it to cave or flow to the bottom of the cut. Operating under these conditions the line of operation does not have to be changed very often. To take care of such shifting as is necessary, the machines are equipped with a simple shifting device. In principle this consists of a bridle cable running at right angles to the track cable. The ends of this cable are anchored by means of deadmen anchors. A movable frame on the bridle cable provides a means of attaching the outer end of the track cable. This frame is held in place on the bridle by means of large clamps. When it is necessary to change the line of operation the bolts of these clamps are loosened and they, together with the bridle frame, are moved along the bridle cable to the desired location. The clamps are then tightened and the operation proceeds.

Where machines are to be operated in non-caving material, or where the material to be excavated is shallow as to require frequent shifting the, to bring out the greatest efficiency of the machines, some method of rapid shifting devices take different forms, depending upon the requirements of each individual job. At times they may be in principle to the ordinary bridle anchor, but with power provision for moving the bridle frame. Then again it may be preferable that a moving tail tower be provided for the outer end of the machine.

Each size of machine is provided with a cableway hoist of the proper size and power. The front drum of the hoist, which handles the load line, is equipped with two speeds of operation. In digging, when a slow powerful line pull is necessary, the low speed of this drum is used. Then when the bucket is conveyed to the dumping point, and a high line speed and a comparatively low power is required, the high speed gearing of the front drum is put into operation. This allows the greatest degree of efficiency in the operation of these machines. These hoists are powered with electric motors, or gasoline or Diesel engines, or can be operated by belt drive. Steam operated hoists can be furnished when necessary.

The labor requirement for operating these machines is very small. Most installations require the full time of only one man, and that is the operator of the hoist unit. Occasionally for oiling, changing of the line operation, etc., the part time services of another man will be required.

The machines are economical in their consumption of fuel and power. As it will be noted that for a considerable portion of the cycle of operation, when the empty bucket is returning to the digging point, no power is required.

There is a minimum number of wearing parts and consequently the maintenance expense is very low.

Slackline cableways are divided into three distinct classifications according to size. These are:

(1) Small slackline cableway excavators with bucket capacities of 1/3 to 3/4 cubic yards.

(2) Medium slackline cableway excavators with bucket capacities of 1 to 2 cubic yards.

(3) Large slackline cableway excavators with bucket capacities of 2 cubic yards and over.

The power drag scraper is a powerful excavator and a rapid conveyor. It reduces to simplest terms the long range handling of materials; earth, clay, broken rock, coal, and bulk materials.

The equipment consists mainly of a bottomless scraper bucket attached by front and rear bridle chains to two long wire cables, one known as the load cable and the other the backhaul cable, which winds and unwinds on two-drum hoists. At the head end of the installation, both operating cables pass through guide blocks attached to a head frame or mast. At the rear end of the installation, the backhaul cable passes around a movable tail block.

The power drag scraper is very easy to operate. Material can be dug, conveyed considerable distances, and automatically dumped without introducing any other labor or any intermediate handling equipment. More important still, this long line of operation can be shifted over a large area without delay or difficulty, simply by changing the location of the guide blocks. The delivery point may be a hopper, crusher, car, truck, or storage place. Digging and dumping points can both be controlled with the required accuracy. A power drag scraper will dig any material that a plow can penetrate. It will operate on a hillside or on mushy ground as well as on dry level ground.

Drag scraper machines are built in numerous sizes and variations. The capacities of the buckets vary from 1/3 to 15 cubic yards.

The main items that make up a complete drag scraper are: (1) A scraper bucket; (2) A set of guide blocks; (3) A set of operating cables; (4) A complete bridle anchor; (5) A gasoline, Deisel, electric, or belt drive hoist.

The following items may be required: (6) Guy cables; (7) A hand operated rapid shifting device (8) A power-operated rapid shifting device.

The tautline cableway is a very specialized type of long range excavator. It is used for various material handling problems where the material has to be picked up, conveyed, and lowered. They are equipped with either skips or with orange peel buckets. These machines are designed in three types: (1) Both towers stationary; (2) One tower stationary and the other traveling radially; (3) Both towers traveling on parallel tracks. Load capacities range from one ton to twenty tons; spans range up to 500 feet, for the one ton to five ton cableways, and up to 2000 feet or more for the larger cableways.

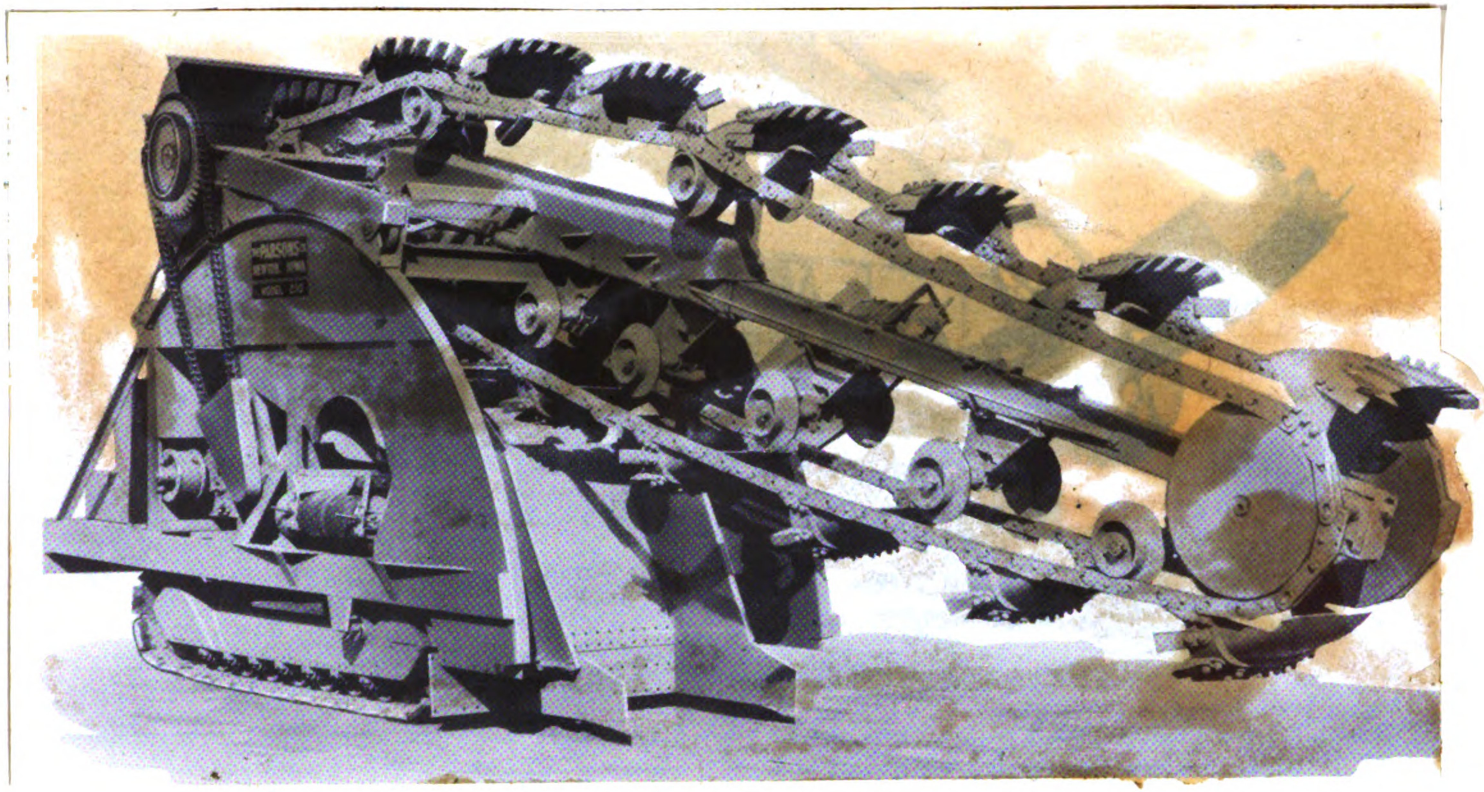
TRENCHERS

Almost all large scale trenching that is done today is done by mechanical trenchers or ditchers. These machines are of two main types. The first type, used mostly for the smaller trenching jobs, is the wheel trencher. The principle of operation is a wheel on which is mounted a number of digging buckets. These buckets are lowered to the desired depth with the wheel turning. The buckets dig into the earth and throw the dirt up onto a short conveyor which dumps the dirt to the side. These machines are the most rigid type of trencher made.

The larger machines are usually of the endless belt or conveyor type. In these machines the dirt is dug by a number of buckets which travel on a chain belt about an adjustable boom. This boom may be set at the desired depth. The buckets empty into a conveyor which empties to the side. Some of the largest machines have two booms that work side by side. The larger machines are used where a deeper trench is needed.

The digging speeds of both types are from 2.5" to 118" per minute. The maximum digging depth of the wheel type is about 5'6". The maximum depth of the ladder type is about 20'. The maximum width of trench dug by the wheel type using sidecutters is 36". The maximum width of trench dug by the ladder type with sidecutters is 72".

The wheel types usually have about twenty-five digging speeds while the average number of digging speeds for the ladder type is about forty-five.



Conveyor type trencher with crawler mounting

TRUCKS

Almost every manufacturer of motor trucks makes at least one model that can be used as a dump truck. These trucks range from the light weight Ford and Chevorlet trucks to the special built Mack and Euclid models.

The smallest truck made that is suitable for a dump box is a two ton size, while the largest dump truck made today is a 32 ton size. All of the recently manufactured trucks have hydraulically raised dump boxes.

The engines that power these trucks range in power from 94 horsepower to 275 horsepower. The smaller of these engines are gasoline while the medium size are either gasoline or Diesel, and the largest are all Diesel.

The light-weight models usually have four forward speeds and a two speed axle. The heaviest trucks have six or eight forward speeds and a two speed axle.

A typical small dump truck will have a gross vehical weight of approximately 12,000 pounds. The minimum turning radius is about 35 feet. The maximum empty speed is about 60 miles per hour and the loaded speed about 35 miles per hour.

Two manufacturers of trucks, Mack and Euclid, make extra large heavy-duty trucks. The Euclid 22 ton rear dump model

Heavy duty Euclid truck

Specifications

14.8 cu.yds. struck measure.

44,000 lb. payload capacity.

225 to 275 h.p. Diesel engine.

Top loaded speed 31.2 m.p.h.

has a gross vehical weight of 84,000 pounds. The maximum loaded speed is about 28 miles per hour, and the maximum empty speed is 31 miles per hour. The minimum turning radius is 63½ feet.

There are a number of specially designed dump trucks in use at the present time. A typical one, the Koehring Dumptor, has its dump box in front of the driver. The box is dumped by gravity, and the capacity of the box is six yards.

EQUIPMENT TRANSPORTATION

One of the major problems of excavating engineers is the transportation of heavy equipment.

For long hauls the equipment that cannot travel under its own power is shipped by railway. Often such equipment as heavy trucks travel under their own power, at the same time transporting other equipment.

Highway transportation of heavy equipment requires a large pulling truck and a large flat-bed trailer. These trailers are capable of carrying very heavy loads and still keep within the highway load limits. This is done by increasing the number of wheels, thereby decreasing the bearing pressure. These trailers are of the low-bed type so that the equipment they are carrying will require as little head clearance as possible.

The capacities of these trailers range from eight tons up to 67 tons. The maximum hauling speed of these trailers is seldom over 20 miles per hour. Flat-bed trailers are all purpose trailers and may carry almost any kind of heavy load.

Some trailers are made to carry only one piece of equipment. They are called single purpose skeleton trailers because they consist of a frame mounted on wheels. Such trailers are usually made for small or medium size shovels.

The trailer is loaded by running the shovel up on blocks and then running the trailer with the front wheels removed in under the shovel. The front wheels are then attached to the frame and the blocks removed. This type of trailer is not suitable for the larger type of shovels.

For small earthmoving equipment light weight two-wheel trailers are often used. These can be pulled by smaller trucks and cost considerably less than the large multi-wheeled trailers.

BLASTING EQUIPMENT

Blasting is a means of aiding excavation that is efficient and relatively inexpensive, but often overlooked. Many engineers do not realize how much blasting can speed up excavation operations.

For blasting rock the equipment necessary consists of drills that are capable of sinking holes for the charges, the blasting machine, caps and wires, and the explosives themselves.

The types of drills that are available for rock drilling are varied and numerous. They range is size from small hand operated "jackhammers", to large quarry type drills that are mounted on crawlers.

For small jobs the blasting holes may be sunk with hand operated drills. These drills are easily moved, easily operated, have small initial cost, and require little upkeep. The main disadvantage of these drills is that they are limit- in the size and depth of hole they are capable of drilling.

The next larger type of drill is the wagon drill. This drilling outfit consists of an air drill mounted on a three wheeled wagon. These drills are capable of sinking holes up to twelve feet deep. They are reported to drill more than twice as fast as a hand held drill because of the more even pressure on the bit. A wagon drill is generally operated by one man.

When sinking holes in tunnels or in mines drills called drifters are often used. These drills are mounted on a mounting which consists of a vertical post to which the drill is clamped so as to allow drilling in any direction. The forward motion of the drill is actuated either by hand or by an air powered motor.

In quarries and on very large construction jobs such as dam construction, a type of drill that is becoming increasingly popular is the large rig type drill that is mounted on crawlers. These drills have made amazing reductions in rock drilling by combining mobility, speed in drilling deep holes, and low up-keep. The newer models are equipped to rotate the drill point in addition to the vertical blows which occur over 200 times per minute. The latest models also have a method of cleaning the cuttings out of the hole which increases the drilling speed and can be operated in any weather. This method is to force air into the hole through the center of the drill shaft. A suction hose covers the top of the hole. The cuttings are thereby forced out of the hole without the use of water. This method is not hampered by cold weather which would freeze water if it had been used.

The drills discussed above have been described in relation to blasting. Many of them are equally well adapted to rock drilling operations other than those connected with blasting.

The actual blasting equipment consists of blasting machines and their allied equipment. Blasting machines are usually made in three sizes. On large jobs a 50 cap or a 30 cap machine is used. For small jobs blasting men usually prefer a twist type 10 cap machine. The size of machine is designated by the number of electric blasting caps for which it can supply sufficient current for detonation.

The large machines are preferable where there is a large amount of blasting to be done because it provides a means of detonating the charges simultaneously. Simultaneous detonation of a number of charges increases the efficiency of the explosive considerably. These machines are actually a generator which is operated by forcing a plunger down. The handle of the plunger protrudes above the top of the case while on the bottom of the plunger is a gear rack which meshes with a gear on the shaft of the generator.

The 10 cap machine is much lighter than the larger machines, weighing only 5 pounds. It is operated on the same principle except that the generator shaft is turned by twisting a handle instead of a plunger. Though these machines have a 10 cap capacity they are often used in preference to fuse caps on single charges because of the increased safety.

Any electrical circuit used in blasting should be checked before use with a galvonometer. This insures a good circuit without the danger of any charges being set off.

The explosives themselves vary greatly in their characteristics with each different type going under a manufacturer's tradename. The power of various explosives is generally classified using the power of straight nitroglycerin dynamite as a standard.

In recent years the trend has been towards safer explosives, that is, explosives that are more difficult to detonate. Many of these new types of explosives have ammonium nitrate for a base instead of nitroglycerin. They have almost as much power as the nitro-dynamites and, grade for grade, cost less.

POWER SHOVELS AND CRANES

The various types of equipment that have been described in part one have been developed because of the inadequacy of former equipment to do a job efficiently.

With the many types of equipment that are in use today it is obvious that the work zones of one piece of equipment will overlap the work zones of other equipment. This condition requires that each job be analyzed to determine what equipment will do the work most efficiently.

To facilitate the discussion of job analysis it can be broken down into two component parts as follows: (1) the selection of the right type of equipment; (2) the selection of the right size of equipment.

A discussion of the first part, the selection of the right type of equipment, brings up the reasons for building the five types of front end operating equipment used on power shovels and cranes. To understand the applications of the various types of front end equipment it is necessary to know the advantages and limitations of each.

In starting with the shovel it will be noticed that its design permits power to be applied so as to force the dipper into the material being dug. It is because of this characteristic that the shovel is a postive digging tool that is capable of digging the hardest materials. The shovel will dig anything from sand to rock. The following paragraphs tell how a shovel can be used.

A shovel will dig a bank of rock or dirt. Practical applications of this would be digging in a gravel bank or a clay pit, stripping overburden, making cuts in highway construction, or any job where there is a good bank to work against.

The shovel will also work below grade or ground level for construction of shallow ditches or roadside berms. It will dig a trench, the depth of which is limited by the length or reach of the dipper stick. Although this is not a typical or usual application of a shovel, it does indicate a possible use of this type of unit for short or emergency jobs such as road culverts or cross drains.

Another possible use of a shovel is to control the dipper so that it makes a horizontal cutting stroke. This is useful in finish grading. This type of operation is also used in stripping topsoil. A slight variation of this type of control is to have the dipper cut on an angle so that it may be used to slope, dress or trim slopes or banks.

After the dipper has been filled it must be dumped. One method of doing this is to load into hauling units at the same level as the shovel. Another method of dumping materials is to load into hauling units which are above the ground or digging level. This is often necessary because of space limitations, poor drainage, and other conditions. In this

Stripping coal with a 35 cubic
yard shovel

case the height of the bank on which units may be loaded is controlled by the ranges of the shovel boom and stick.

Often when stripping overburden the shovel will dump its load into spoil banks. When working on hillside or mountain highway construction a shovel may dispose of its load by casting it over the lower bank. When shovels are used in gravel pits or other pits the load is often dumped into a belt conveyor or a grizzly.

To summarize, a shovel should be used under the following conditions:

(1) Where the material to be dug is firm or hard.

(2) Where the excavation is large enough, or covers enough space to provide sufficient working area for the shovel to work and for hauling equipment to have access to the shovel.

(3) Where the disposal of materials requires dumping above or at ground level.

(4) Where the nature of the excavation provides a sufficient depth to utilize the full productive ability of the shovel.

In the following discussion, the working applications of the common crane boom will be confined to clamshell and dragline work.

A clamshell can dig or spot dump below or at, or above the level of the machine. Because of this it is an ideal machine for handling or placing material at a higher or lower level than would be possible with the shovel or dragline.

The clamshell is often used for digging foundations, fottings, pier holes, trenches, or cellars. This digging application indicates how the clamshell may be used to dig downwardly in a vertical direction for digging pier holes, footings, etc. Another digging application of the clamshell is to dig trenches or work in trenches which are sheathed and have criss-cross bracing. In the latter case the clamshell bucket, operating in a vertical direction, can be easily dropped and worked through t he bracing of the sheathing. Another useful application of the clamshell is to trim banks. This is done by resting the bucket on the top of the bank and letting the weight of the bucket cause it to slide down the bank, trimming the surface as it descends.

Clamshells are also used on many material handling jobs, on construction jobs and around industrial plants. Typical uses for these jobs would be loading or unloading railroad cars where accurate digging and dumping are needed. The height of the boom is put to good advantage when building stockpiles. The height of the clamshell is also utilized when charging high bins.

To summarize, the broad general conditions which control the use of clamshells are as follows:

(1) Where the materials to be dug are relatively soft or loose up to medium hard.

(2) Where the digging and material handling is in a vertical plane and below, at, or above the ground level.

(3) Where the digging is practically straight down, as in digging shafts.

(4) Where accurate dumping or disposal is required.

(5) Where high dumping is required such as building a stockpile or charging bins.

(6) Digging sheathed trenches.

A dragline is used to dig dirt, shale and well shot rock, to strip overburden, dig basements and borrow pits.

When using the dragline to dig trenches the trenches may be of three types: (1) with straight vertical side walls where the material will stand, or (2) with V-sloping side walls. The depth of the trench is limited only by the length of the cable. Like the clamshell, the dragline can load into hauling units or onto spoil piles.

As already stated, the dragline can dig well below the ground level. It is best adapted to jobs where the materials are soft to medium hard. The dragline is ideal on jobs where wet bottom conditions exist. In this case the unit may remain on the top on dry, firm footing. Cleaning ditches and dredging river sand and gravel are typical conditions.

Where it is desired to cast or dump the material as far from the unit as possible, the dragline is the ideal unit. The long, low booms used on draglines usually permit dumping material farther away from the unit than with any other method. However, hauling units may be loaded with the dragline where materials must be removed to a greater distance, or materials may be re-cast by the dragline.

The hoe may be said to be a cross between a dragline and a shovel as it incorporates some of the characteristics of each and overcomes some of the limitations of each. The hoe, of course, is primarily a unit to dig below ground level. It will, however, dig harder materials than the clamshell or the dragline because the weight of the boom itself may be used to force or crowd the dipper into the material. It is limited in digging depth by the length of the boom and dipper stick. The hoe dipper may be more accurately controlled than the dragline bucket and is therefore better suited for close limit work.

The hoe is used to dig trenches, footings, and basements. On small residence basements the hoe offers many advantages. It digs straight, vertical walls, it cuts a level floor, it trims corners neatly and squarely, it can dig sewer and water connections, it always works from the top on dry safe ground, and it reduces hand trim to a minimum.

Digging trenches is naturally one of the primary and universal uses of the hoe. Its ability to dig hard materials, to be controlled precisely, to cut straight walls and to grade the bottom of the trench, are all advantages of the hoe on this class of work.

The hoe may dispose of materials in two ways, either load into hauling units or dump onto spoil banks.

In general, a hoe should be used under the following

Trench hoe on sewer construction

Rock excavation with a 1/2 cubic yard shovel conditions:

(1) When the excavation is below ground level.

(2) When the material to be dug is firm to hard.

(3) When the excavation must be trimmed closely.

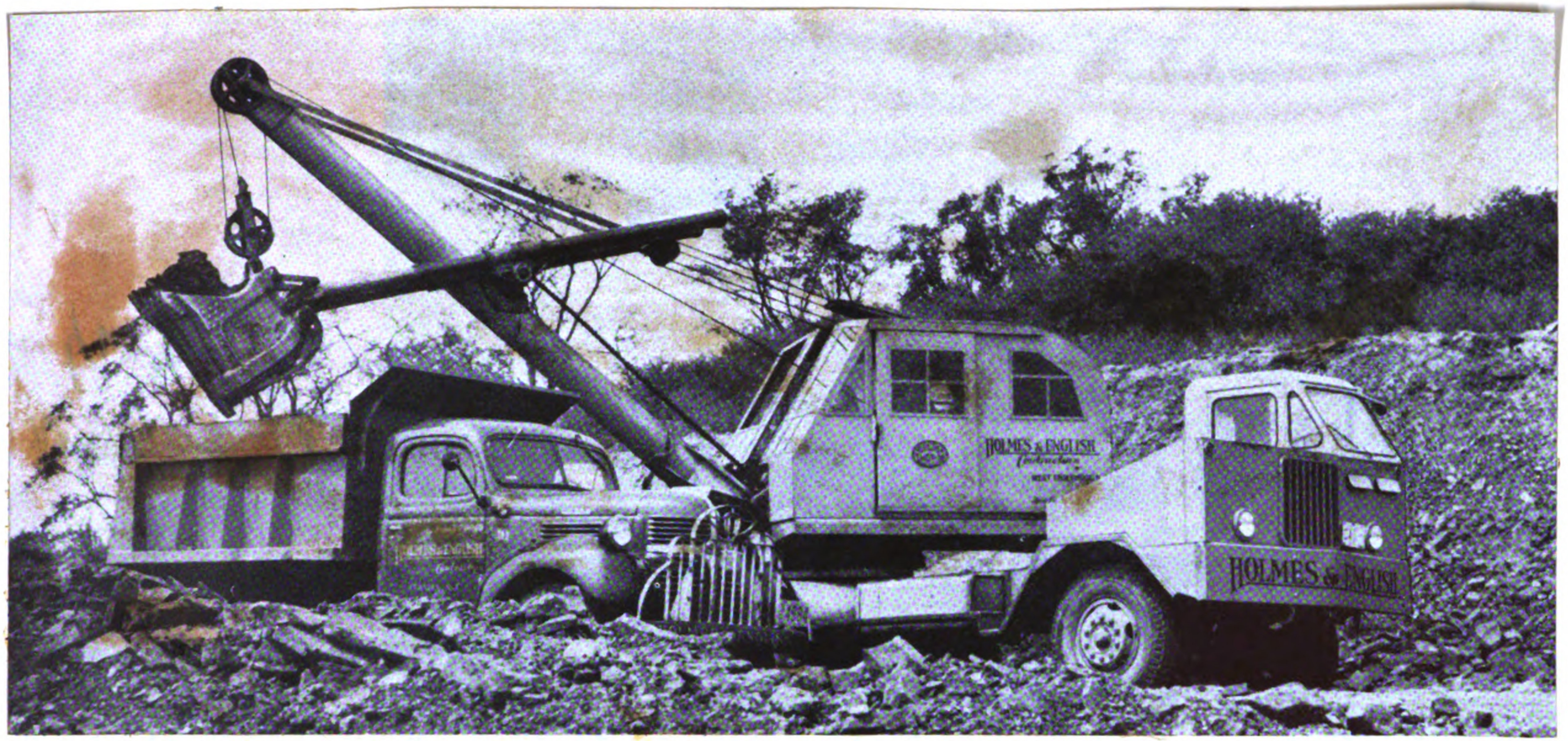
(4) When the disposal or dumping of the materials is at rather short range.

After the determination is made of the proper type of boom to handle the job or material, the question of the proper mounting should be considered. Here again the discussion must be very general as the correct solution can only be made when the actual job conditions and requirements are known. Generally it will be necessary to consider the ground or surface conditions of the job and the required mobility on the job to determine the proper mounting.

Generally the crawler is a universal type of mounting that can be used under almost any and every job condition. The crawler, of course, is the best mounting for soft ground or wet bottom conditions.

The crawler, however, has a top speed of only approximately $1\frac{1}{2}$ to 2 miles per hour. It therefore should not be moved long distances under its own power. This would be very severe on the crawler mechanism, and incidentally, long distance crawler travel is restricted in some sections of the country. The alternative is to use a trailer and a towing unit.

On the other hand, there are many operations that call for constant and relatively rapid movement of the machine



Excavating loose earth with 3/4 cu. yd. shovel around the job. Further, there are many smaller jobs that require shovel or crane efficiency but will not stand the expense and time of moving equipment that lacks rapid mobility. Rubber tired mountings best meet these requirements. The single engine or wheel mounting usually provides one to four speeds ranging from one half to ten or twenty miles per hour.

All controls for such units are located in the operator's cab and steering, backing, and gear shifting are effected from this position.

The truck type mounting is automotive in character. It provides the maximum in mobility both as to speed and distance. Usually the units provide four to ten speeds with a range of one to thirty miles per hour.

Further such vehicles are generally built with multiple axles and with dual tires to provide tire capacity for soft ground flotation which enables the unit to operate as an off the highway vehicle. As such it is not limited to hard surface roads but can be used, within reasonable limits, for cross country, off the road travel, at lower speeds.

The next consideration is the determination of the size of machine for the job based on the output of the machine or the output required by the job.

To estimate the yardage production on a job is a real problem. If all conditions were the same on all jobs, it would not be difficult, but jobs are as different as night and day. There are many factors which must be considered, some of can be learned through experience only.

For instance, the chart titled "Power Shovel Yardages" has been developed to indicate how the type of material dug affects the hourly yardage output. The top line covers "Moist Loam or Sandy Clay", the middle line covers "Clay, Hard, Tough", the lower line covers "Rock, Poorly Blasted." Hourly yardages for these materials are given for machines of 3/8 to 2½ yard capacity as listed across the bottom of the chart.

If a 1½ yard shovel is taken for example, note that the output may vary from 115 yards per hour for poorly blasted rock to 285 yards per hour for moist loam. Similar variations in yardages exist for machines of all other capacities.

It should be kept in mind that the figures in the yardage chart are based on the following conditions.

The first is that the cubic yards per hour are bank measure which means that they are cubic yards in the ground rather than cubic yards in the hauling unit. There is a big difference between a cubic yard in the bank and a cubic yard in a truck. This is because of the swell of the earth or its increase in volume due to voids when it is dug and loosened.

The second condition is that the machine is working at a cut of a depth that is suitable for maximum digging efficiency. This depth may be called the optimum depth, and may be defined as follows: the optimum depth of cut for various sizes of shovels may be defined as "that depth of cut which produces the greatest output and at which the dipper comes up with a full load without undue crowding." The optimum depth does not represent and has nothing to do with the maximum digging range.

Thirdly, the output figures are based on continuous operation, 60 minutes per working hour, without any delays.

Fourth, these figures are based on each dipper full being swung through 90° of arc before dumping. This is important since a larger swing or a smaller swing will either consume more time or save time.

Fifth, these tables are based on all materials being loaded into hauling units. With the further understanding that the hauling units are properly "sized" to shovel capacity and that there are enough of them to take away all of the material which the shovel can dig.

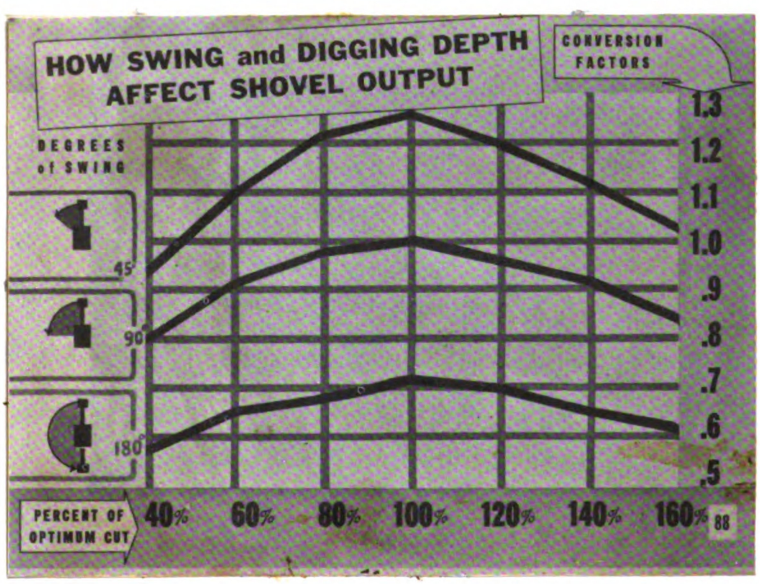
SHOVEL DIPPER CAPACITY IN CU. YDS.

Class of Material	3/8	1/2	3/4	1	1¼	1½	1¾	2	2½
Moist Loam or Light Sandy Clay	3.8′ 85	4.6′ 115	5.3′ 165	6.0′ 205	6.5′ 250	7.0′ 285	7.4′ 320	7.8′ 355	8.4′ 405
Sand and Gravel	3.8′ 80	4.6′ 110	5.3′ 155	6.0′ 200	6.5′ 230	7.0′ 270	7.4′ 300	7.8′ 330	8.4′ 390
Good Common Earth	4.5′ 70	5.7′ 95	6.8′ 135	7.8′ 175	8.5′ 210	9.2′ 240	9.7′ 270	10.2′ 300	11.2′ 350
Clay, Hard, Tough	6.0′ 50	7.0′ 75	8.0′ 110	9.0′ 145	9.8′ 180	10.7′ 210	11.5′ 235	12.2′ 265	13.3′ 310
Rock, Well Blasted	40	60	95	125	155	180	205	230	275
Common, with Rocks and Roots	30	50	80	105	130	155	180	200	245
Clay, Wet and Sticky	6.0′ 25	7.0′ 40	8.0′ 70	9.0′ 95	9.8′ 120	10.7′ 145	11.5′ 165	12.2′ 185	13.3′ 230
Rock, Poorly Blasted	15	25	50	75	95	115	140	160	195

It is important to note how the degrees of swing and the optimum depth of cut affect shovel yardage output. Since variations in either of these conditions will have a considerable effect on the yardage output, a chart has been prepared to show what happens when swing and depth of cut vary from the conditions on which the previous basic hourly yardages are established.

At the top of this chart is shown a line covering the reduction in swing from 90° to 45°, the middle line shows the 90° used in the previous chart, the bottom line shows the variations when the swing is increased from 90° to 180°.

Across the bottom are plotted percentages covering variations in the depth of optimum cut.



There are two sets of factors on every job which have a great deal to do with the output of the equipment on the job. They are the Job Factor and the Management Factor.

Job factors are the physical conditions which pertain to a specific job. They affect the production rate but do not include the class of material to be handled. Job factors may be divided into three main headings:

(1) Topography and the dimensions of the work.

(2) The surface and weather conditions.

(3) The specification requirements.

The management factors are the factors which affect the output through the efficiency of the operation. These factors include the following:

(1) The selection, training, and direction of men.

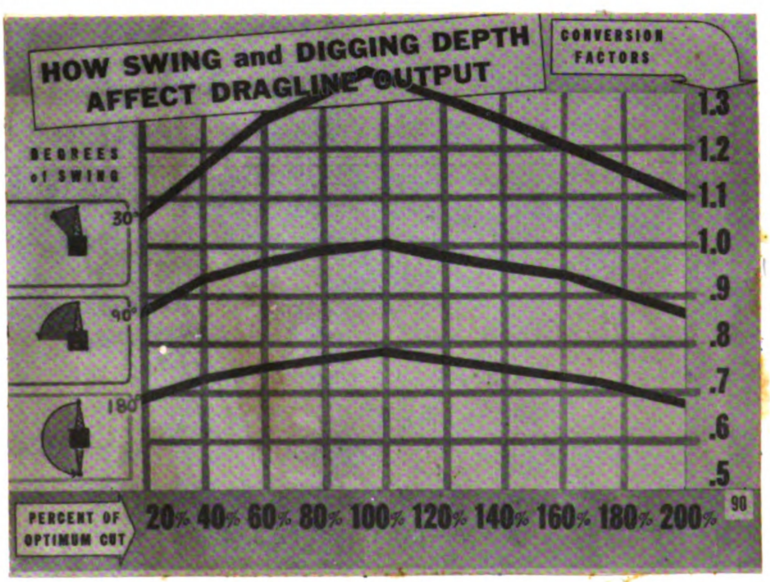
(2) The selection, care, and handling of equipment.

(3) The planning and laying out of the job, and the coordination of the operations.

To further emphasize the importance of selecting the right type of machine for a job the following two tables have been inserted to give an accurate comparison of the yardage outputs of two machines that are often regarded as interchangeable in their applications. These tables are the same in every way as the tables on shovels with the exception that these tables pertain to draglines.

It might be added that in using these tables the conditions under which they apply are just as important as the figures on the yardage output and they should be thoroughly studied to ascertain the results that any change might cause.

SHORT BOOM DRAGLINE PERFORMANCE-CU. YDS.									
Class of Material	3/8	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/2
Light Moist Clay or Loam	5.0′ 70	5.5′ 95	6.0′ 130	6.6′ 160	7.0′ 195	7.4′ 220	7.7′ 245	8.0′ 265	8.5′ 305
Sand or Gravel	5.0′ 65	5.5′ 90	6.0′ 125	6.6′ 155	7.0′ 185	7.4′ 210	7.7′ 235	8.0′ 255	8.5′ 295
Good Common	6.0′ 55	6.7′ 75	7.4′ 105	8.0′ 135	8.5′ 165	9.0′ 190	9.5′ 210	9.9′ 230	10.5′ 265
Clay, Hard, Tough	7.3′ 35	8.0′ 55	8.7′ 90	9.3′ 110	10.0′ 135	10.7′ 160	11.3′ 180	11.8′ 195	12.3′ 230
Clay, Wet, Sticky	7.3′ 20	8.0′ 30	8.7′ 55	9.3′ 75	10.0′ 95	10.7′ 110	11.3′ 130	11.8′ 145	12.3′ 175



TRACTORS

A tractor without any mounted equipment is primarly a piece of equipment for pulling other units. This is true of both crawler and wheel tractors. Because of the great number of differences in the design of tractors they are used for pulling everything from small wagons to 25 ton loaders and 30 yard scrapers.

In the design of the crawler tractor speed has been sacrificed in order to increase traction, flotation, and ability to withstand rough use. This type of design makes the crawler tractor suitable for pioneer work, that is, work where there are no roads.

The three most important "pulling" jobs of a crawler are pulling scrapers, rooters, and loaders. The crawler is well suited to pull these units because it is capable of exerting an extremely large, slow pull. The pulling of dump wagons is usually done by large wheel tractors since wagons are generally used where the ground conditions are fair to good.

The duties of the two wheeled rubber tired tractor need little explanation since these units are usually designed for one purpose and are not suitable for other uses. They will be covered later in the section on scrapers.

One additional advantage of the crawler tractor is that the vibration of the running tractor along with the great weight of the tractor produces an excellent combination for compacting earth. Crawler tractors are seldom used solely for compacting earth, but it is a useful feature when bulldozing and spreading with scrapers.

Both crawler type and wheel type tractors are used to mount various equipment such as winches, small bucket loaders, bullclams, and skid loaders.

Crawler type tractors and the new Le Tourneau four wheeled tractors are widely used as pusher units for tractor-scraper units.

TRACTOR MOUNTED EQUIPMENT

The list of tractor mounted equipment is generally started with the bulldozer. The "dozer" family includes a number of variations of the basic bulldozer. These different types were listed and described in Part I.

The function for which the bulldozer was originally designed is the clearing of land. There is no other piece of equipment that is able to clear land so easily and efficiently. For this job of clearing land a straight bulldozer blade may be used, or a specially designed blade such as an angle dozer, a blade with an extension for giving more leverage when felling trees, or a blade fitted with a number of teeth to give added digging ability. The latter type of blade not only clears the trees and brush on the surface, but it also rakes out all underground root structure and large rocks. This is an advantage since it leaves the land ready to plow.

The most common use of bulldozers other than clearing is in short haul excavation. This might be said to cover all excavation up to 300 feet. Many contractors use dozers over longer distances. For ordinary digging there is little choice between the straight blade and the angled blade. In light material the angledozer with the straight blade setting carries slightly greater loads because of the wider blade.

The digging pass is generally made in low gear and some times in second gear. The return is made in high gear. In some modern tractors it is not necessary to turn around even to return on long hauls, as the tractor can be backed at high speed simply by shifting the reverse lever. Reverse speeds in these models are as fast as the forward speeds. This has materially increased bulldozer production and increased the length of profitable haul. Forward speed with a load averages about 132 feet per minute, and return speeds are now available in a range up to 475 feet per minute.

Bulldozer dirt production is greatly increased by pushing down hill or cutting in a slot. The curvature and tilt of the blade should be such as to cause the dirt to be rolled away rather than to be just pushed along. The consistency of the dirt will have a direct bearing on this.

Besides short haul excavation, in which the bulldozer cuts longitudinally down a hump and places material in a low spot, side borrow is often resorted to, working at right angles to the location line, pushing materials toward the center from both sides. Typical of this work is ditch excavation to crown up old roadways, or nearby excavation to throw up a small levee or embankment. These last are obviously only feasible on flat alignment.

Bulldozers may also be used for charging traps and grizzlies by using a ramp.

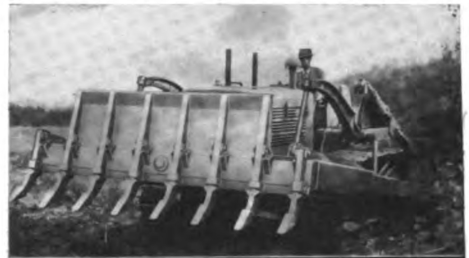
Bulldozers are not generally considered as finishing equipment. They may however be used to do rough finishing such as spreading piles of dirt left by dump trucks. The main reason that the bulldozer is not suitable for close finishing is that the wheel base of the tractor is so short as to cause a bobbing of the blade on anything but the slowest of travel.

An increasing number of tractor shovels are being used where the two operations of bulldozing and loading occur at the same time. When the bucket is in the down position it is essentially the same as a straight bulldozer, in fact there are many more times when such units are used in the down position than as a loader.

Loading trucks is an operation for which the tractor shovel is ideally suited. For efficient operation, the tractor, after it is loaded should not have to travel more than 10 or 15 feet to get to the truck. Distances greater than this result in too much lost time in traveling. If possible the tractor should dig in a ninety degree or less arc from the truck. Observance of these two principles will enable the unit to service more trucks per hour.

There are a number of other units such as winches, hoists, etc. that can be mounted on tractors. These are not used for earthmoving and so will not be discussed here.


HYDRAULIC BULLDOZERS


GRUBBERS


POWER CONTROL UNITS


SCRAPER-BULLGRADER DUAL UNITS


HYDRAULIC BULLGRADERS


CABLE BULLDOZERS

Examples of tractor drawn and tractor mounted equipment

TRACTOR DRAWN EQUIPMENT

The tractor drawn scraper should always be considered where the three operations of loading, hauling, and spreading occur together.

When working in borrow areas the power for the scraper may be furnished by one pulling tractor, or by an additional tractor that helps by either pushing or pulling. In order to be economical, a helper tractor should be able to service several scrapers. Usually this is not possible if the length of haul is very short since the scrapers would tend to bunch up behind the helper. When using some of the smaller models of scrapers one tractor may be used to pull two scrapers. In this case it is necessary for the tractor to have a dual set of controls to operate both scrapers. The scope of the job will determine the most economical size of machinery to be used.

A scraper is especially suited to working on fills. The material is carried over the previously spread dirt so that the weight of the unit helps in compacting the fill at the same time it is spreading its load. When using scrapers on fills, the fill should be maintained high against the outside slopes. This keeps the scraper from sliding down the slope, and destroying it as it would if the outsides were left low. Routing scrapers over different paths adds to the compaction of the fill.

A scraper will spread its load in the same time a truck will dump its load, so the cost of the spreader accompanying the truck is saved by using a scraper.

In many instances the tractor drawn scraper is used as a finishing tool. The following features make them units that are capable of precise finishing work:

(1) A long wheel base that stabilizes the action of the blade

(2) The ability to skim very thin layers from high spots and to carry them to low spots for disposal, along with several additional yards for that purpose if desired.

(3) 7 to 10 ft. blade widths under precise, rapid control

(4) Works on slopes up to 2 on 1 transversely, to finish slopes.

The deciding factor on choosing between a crawler type tractor and a two wheeled rubber tired type for pulling scrapers is the length of haul. While the crawler has greater traction and therefore may get bigger loads without a helper, it is not generally efficient on long hauls. The two wheeled type needs a helper tractor to get a full load, but it hauls at truck speeds so that it is suitable for long hauls.

The tractor drawn loader for use on large excavations was described in Part I. The factors determining the application of the unit were included in the description of the design, therefore it will not be necessary to repeat them here.

The tractor drawn ripper is used for breaking ground surfaces that are too tough for other equipment. When a contractor can avoid using a ripper he will do so since it is always an extra operation. The surfaces that usually require a ripper range from hardpan and shale to old pavements. These tools are always pulled by a crawler because of the great force necessary to force the teeth through the hard surface.

MOTOR GRADERS AND PATROL GRADERS

The uses of the various types of graders were discussed in some detail in Part I. They are made in two general sizes. The large size is called a motor grader, and the smaller size is called a patrol grader.

The motor grader is used for finishing work, surface material mixing, and snow removal where considerable power is needed. For sloping ditches, shaping road shoulders, and other deep cut precise grading jobs there is no other piece of equipment as nearly suitable as the heavy duty motor grader.

There are many grading jobs which do not require as heavy and powerful a machine as the motor grader. On these jobs it is often wise to use a patrol grader, thereby saving on both the initial cost and the operating costs. The patrol grader is well suited to most grading operations where a deep cut in heavy material is not common. Maintenance of gravel surfaced roads is a common job for the patrol grader.

BUCKET LOADERS

The jobs that require a bucket loader, other than snow removal, are usually around material pits and stock piles. Since these machines will not dig into hard surfaces they are not suited to most jobs that occur in the field. In use with loose materials such as gravel and sand, these machines will load small to medium sized trucks as fast as a shovel, are more easily moved from one location to another, and are more economical in both initial cost and operating costs.

Various models of these machines have special attachments which are designed for snow removal. This added feature makes the bucket loader an excellent machine for municiple use, since it can be used as an all season machine.

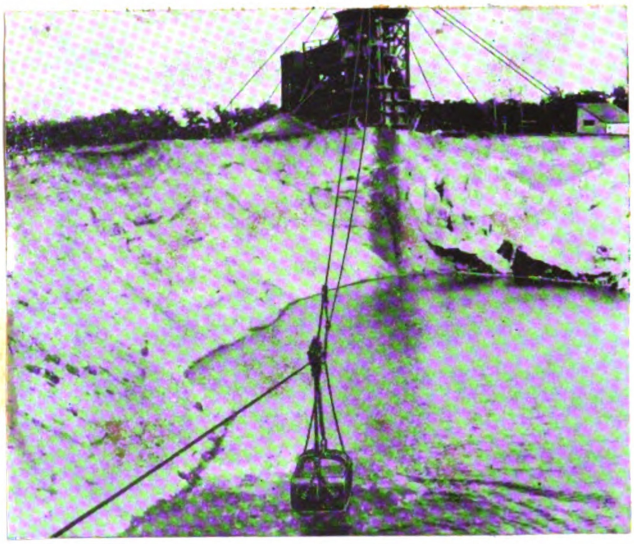
These machines are made even more versatile by the choice of mountings available. For work on good ground surfaces the machine may have a rubber tired mounting which allows the machine to move from one job to another at truck speeds. For use on wet bottom surfaces the machine is usually mounted on crawlers.

LONG RANGE EARTHMOVING EQUIPMENT

Wherever it is necessary to dig materials from ponds, rivers, deep pits, and move the materials to an elevated delivery point such as a bin, hopper, or high pile, the problem can often be solved by a slackline cableway excavator. These machines, as can be seen from the description in Part I, are suited to jobs that are more or less uncommon. Both the slackline cableway and power drag scraper types of excavators are usually designed for specific jobs. The manufacturer usually makes a survey of the type and size of machine needed for a certain job and then builds a machine that meets those requirements. Because of this feature of these machines, their application can best be illustrated by the accompanying pictures.

Examples of slackline cableways as used

in open pit mining



Examples of slackline cableways excavating gravel under dry and wet bottom conditions

Slackline cableway with extra long span

TRENCHERS

A trencher is a very specialized type of excavator. It was designed for one type of job, and while it does that job well, it is not suitable for any other kind of work.

These machines are manufactured in a variety of sizes, and are suitable for digging almost any type of trench. They are best suited to large jobs such as pipe lines and cable laying.

The size of machine required is governed by the size of the trench to be dug and the kind of material encountered. For cable laying projects where the trench has to be fairly deep and not very wide, the trencher should be equipped with as narrow buckets as possible. This reduces the amount of dirt dug and it allows the machine to dig faster.

All standard models of trenchers are mounted on crawler mountings. These mountings enable the machine to traverse difficult terrain and still maintain a stable base which is a necessary condition for digging a straight trench.

When digging large trenches the ladder type of trencher is generally used. This type of machine will dig to a greater depth, and if an exceptionally wide trench is desired, two side by side booms can be operated at the same time. Although these large machines move many times the amount of earth moved by the smaller models, their digging speeds are almost as great as the speeds of the smaller machines.

Wheel type trencher cutting through
semi-solid rock

TRUCKS

The design and size range of motor trucks is so wide and varied that some model of dump truck can be found on just about every construction project.

To start with the smaller sizes of trucks it may be said that these trucks are the common means of hauling relatively small yardages of earth long distances. The three main advantages of lightweight dump trucks are: (1) ease of operation, (2) rapid traveling speed, (3) relatively low cost.

The sizes of the trucks used on earthmoving projects are determined by the yardages to be hauled and the condition of the hauling road. The largest of trucks, such as are built by Mack and Euclid, are capable of carrying huge loads over the roughest of roads without any injury to the truck.

The number of trucks that should be used on a job is governed by the loading facilities. Generally speaking, if a shovel with a large dipper is being used then trucks with large carrying capacities should be used. This helps prevent lost time caused by the trucks bunching up at either end of the hauling cycle.

BLASTING

Blasting is the most efficient and the most inexpensive method of dislodging solid and semi-solid rock so that it can be handled by earthmoving equipment. Extensive research has been carried on by the country's explosive manufacturers to improve agricultural and construction explosives.

In quarries and mines where rock is encountered in large quantities the economical use of explosives requires a considerable amount of rock drilling equipment. This equipment may consist of anything from small hand drills to large drilling machines which are mounted on crawler mountings. Usually on large jobs it is more economical to use large drilling equipment since more holes are needed and faster drilling saves labor costs and increases production. Past experiences have shown that it doesn't pay to go easy on the number and sizes of charges used in heavy rock blasting. Undersized charges often leave the rock in such large chunks that secondary blasting is necessary which increases the cost per yard and decreases production.

Pipeliners and dredge-boat operators often have the occasion to use explosives. In trenching explosives are especially useful in crossing rivers. In blasting trenches for pipelines and cables across rivers where the water is is comparatively shallow, it is common practice to tie bundles of dynamite cartridges along a cable which is then submerged and covered with sand bags. Since this is a rather slow method, dynamite cartridges which can be fastened into a single rigid charge are taped onto a cable and then drawn across the river. When ditching with explosives in swamps and other wet bottom land where it is impossible to use a trencher there are two general methods which may be used. The first method is the propagation method. The principle of this method is the detonation of all of the charges by one detonating cap. This can be done only in wet soils where the concussion of the first charge to go off is transmitted to the adjacent charge and so on down the line.

The second general method is the electric method. This is done by priming each hole with an electric cap and then setting off the caps with a blasting machine. This method is the hardest of the two since each hole has to be primed, but it is the only method that is satisfactory in dry soils and rock.

Clearing land is often a job for blasting explosives. It constitutes an inexpensive method of ridding land of stumps and large boulders when heavy equipment is not available or is considered too costly to use.

In recent years it has become increasingly popular to speed up the settling of fills by the use of dynamite. Dynamite is also used to help the filling of "sink holes." This is done by drilling holes through the topsoil where the hole is to be filled and placing charges in these holes. When the charges are set off they tend to force the unstable soil to the side where it will not bother the fill.

When using explosives for almost any job it is possible to obtain detailed instructions on their use from the manufacturer of the explosive. If the job is of considerable size many of the explosive companies will send a technical representative to aid in carrying out the operation.