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GRADERS & SCRAPERS BASICS & SAFETY

Main Category:	Civil Engineering
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Course #:	CIV-118
Course Content:	36 pgs
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OFFICIAL COURSE/EXAM

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CIV-118 EXAM PREVIEW

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Exam Preview:

1. When you are grading on a project where the passes are less than 1,000 feet, it is more efficient to grade in reverse or back the grader the entire distance to the starting point than it is to turn around and continue work from the far end.
    a. True
    b. False
2. According to the reference material, the prime mover has __-rear mounted single tires driven in tandem drive through gears and chains and a single-steering axle.
    a. 2
    b. 4
    c. 6
    d. 8
3. The moldboard with the cutting edge and end bits attached is called the blade. The blade is the working tool of the grader that can be lifted, lowered. rotated. tilted forward and backward, shifted to one side or the other, and angled horizontal. According to the reference material, the length of the blade is normally _______ feet.
    a. 8 or 10
    b. 10 or 12
    c. 12 or 14
    d. 14 or 16
4. Finish grading is a fine cut or fill of a surface to get the final desired elevation. This phase of a grading operation is called black topping. Black topping takes time and patience even for experienced operators.
    a. True
    b. False

5. When jobs are confined to short stretches or narrow widths, rotating the blade from forward to reverse grading position requires a circle reverse movement of only about __ degree.
    a. 100
    b. 90
    c. 80
    d. 70
6. According to the reference material, a scraper has three basic operating parts: the bowl, the apron, and the ejector.
    a. True
    b. False
7. The first step performed on a road project is to establish drainage normally through the use of a ditch. After the marking cut, position the blade at about a __-degree angle to perform an efficient ditch cut.
    a. 15
    b. 30
    c. 45
    d. 60
8. Using Table 10-1.-Approximate Speed Ranges Used in Various Grader Operations, which of the following operations can be done at a speed of 3 to 5 MPH?
    a. Maintenance
    b. Finishing
    c. Spreading
    d. Ditching
9. According to the reference material, downhill loading uses the force of gravity on the scraper to get larger loads in less time. The added force of gravity is 40 pounds per gross ton of weight per 1 percent of downhill grade.
    a. True
    b. False
10. The tractor is connected to the scraper by a vertical kingpin swivel connection usually in two parts with upper and lower pins. When you are steering, this connection permits turns of _____ degrees to each side of the center line of the scraper.
    a. 35 to 40
    b. 55 to 60
    c. 75 to 80
    d. 85 to 90

GRADERS AND SCRAPERS

BASICS & SAFETY

In the Naval Construction Force (NCF), graders and scrapers are essential tools used in the construction of airfields, ammo supply points (ASPs), roads, and site work. The primary purpose of the grader is to cut and move material with the blade for final shaping and finishing. The scraper is a large earthmover with the capability of digging, loading, hauling, dumping, and spreading material. This chapter covers the characteristics and basic principles of graders and scrapers operations.

GRADERS

Graders are multipurpose machines used primarily for general construction and maintenance of roads and runways, moving large amounts of materials laterally by side casting. Additionally, the grader can be used for crowning and leveling roads, mixing and spreading materials, ditching and bank sloping, blade mixing asphalt materials, snow removal, and scarifying.

The grader is a rubber-tired hydraulically operated, single-engine unit. The single engine provides power for all grader functions. The steering system, moldboard, and scarifier are hydraulically controlled.

Although the grader, at times, must be hauled to and from jobsites, the grader has an advantage over other heavy equipment because of its capability to travel over the road under its own power.

NOTE: When hauling a grader with a tractor-trailer, ensure the height of the grader cab clears all overhead obstacles.

A variety of makes and models of graders are used in the NCF. Each operator is responsible for reading the operator's manual to obtain detailed information about each make and model.

GRADER COMPONENTS

The basic grader consists of a prime mover and a grader mechanism. The principal parts of a grader are shown in figure 10-1.

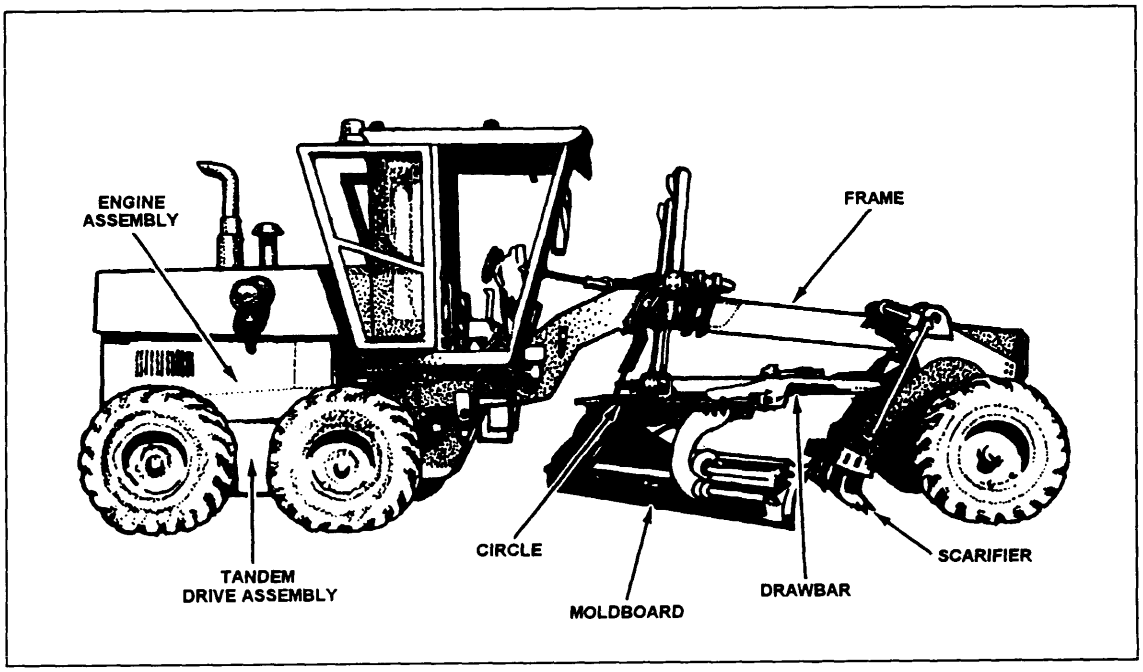


Figure 10-1.—Principal parts of a motor grader.

Prime Mover

The prime mover is a rubber-tired tractor, power-driven by a four- or six-cylinder diesel engine mounted at the rear. The prime mover has four-rear mounted single tires driven in tandem drive through gears and chains and a single-steering axle.

TANDEM DRIVE.— The tandem drive of the grader allows climbing over rocks, logs, or humps, and permits passing through depressions or ditches one wheel at a time. Having the capability to operate in this manner, one rear wheel can raise or lower, while the other remains on the same level with the front wheels thereby holding the grader on a level terrain (fig. 10-2). This is a very important feature. If the rest of the grader does not rise and fall when working uneven terrain, the grader blade does not vary its elevation, as the grader passes over its work.

ARTICULATED FRAME STEERING.— Some graders have frames that are hinged just forward of the

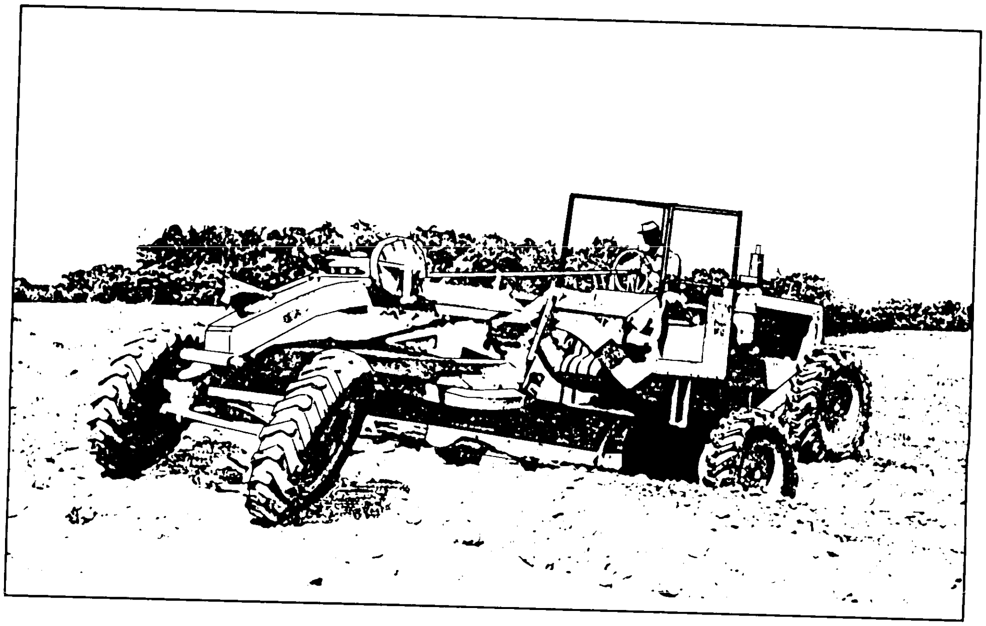


Figure 10-2.—Tandem drive.

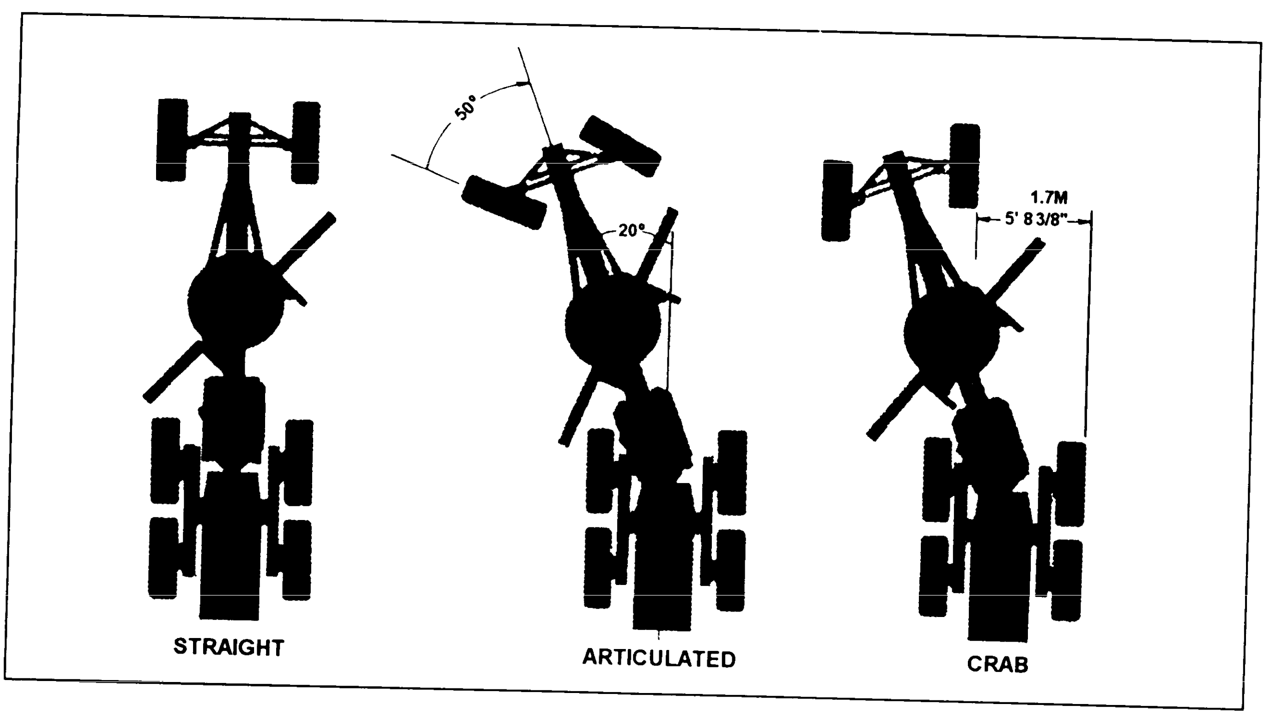


Figure 10-3.—Articulated grader.

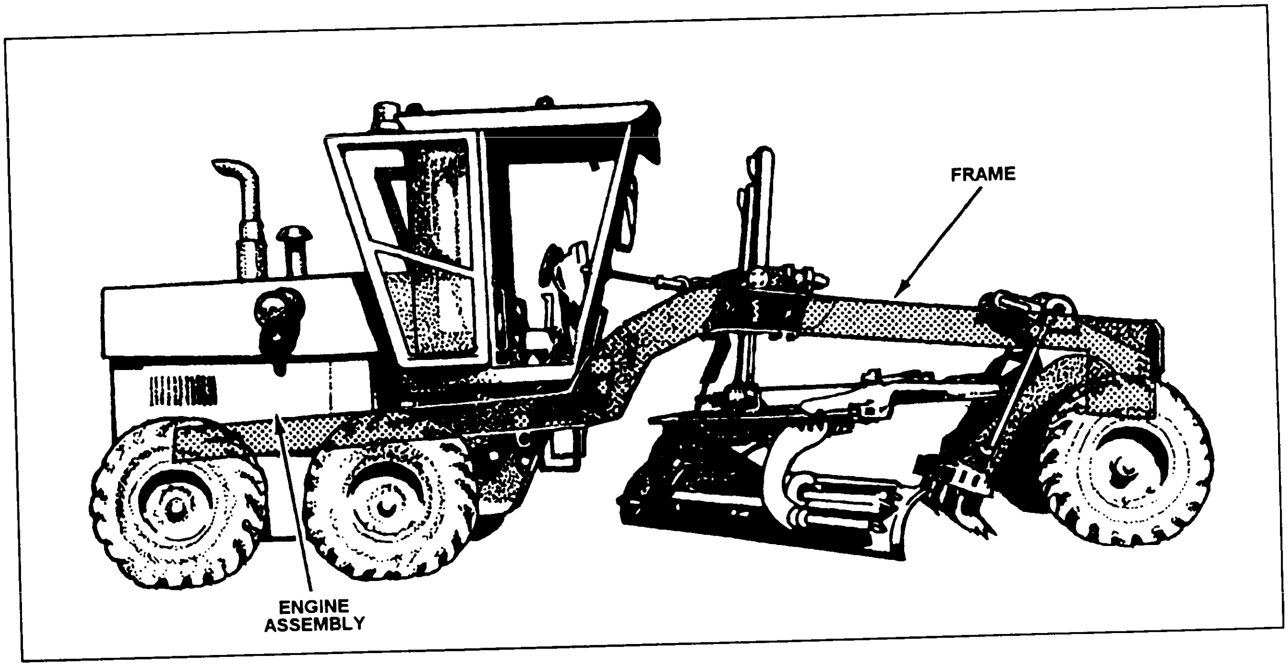


Figure 10-4.-Grader frame.

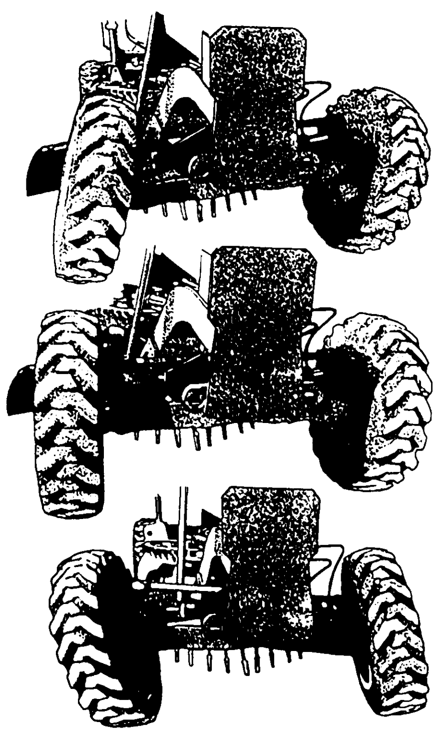


Figure 10-5.—Front axle.

engine with articulating controlled by a pair of hydraulic cylinders. The articulated frame steering allows for an increase in productivity and stability. The articulated frame has a shorter turning radius than the conventional grader (fig. 10-3). This allows for easier maneuvering in close quarters and quick turnaround at the end of a pass and enables the grader to carry a full blade of material around a curve. Crab steering helps compensate for side drift when turning a windrow, keeps tandems on a firm footing when clearing ditches, and increases stability on side slope work.

NOTE: Before articulating the grader, be aware of the position of the grader blade. With the blade angled in an acute position, articulating the grader sharply can position the rear tires to run into the blade.

Frame

The frame connected to the front axle extends the full length of the grader (fig. 10-4) and is high enough to allow space for carrying and manipulating the grading mechanism.

The front axle is compound. The lower section carries the weight of the grader, oscillates on a center pin, and is hinged to the bottom of the wheel spindle. The upper section of the axle is hinged to the top of the spindle, allowing the front wheels to lean as well as turn (fig. 10-5).

Moldboard

The moldboard with the cutting edge and end bits attached is called the **blade.** The blade is the working

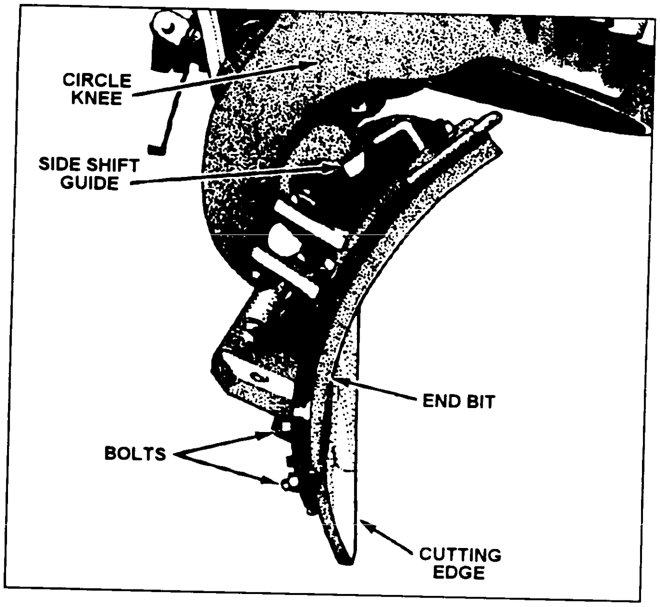


Figure 10-6.-Moldboard.

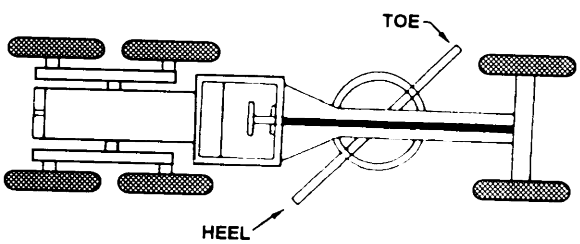


Figure 10-7.-Blade heel and toe.

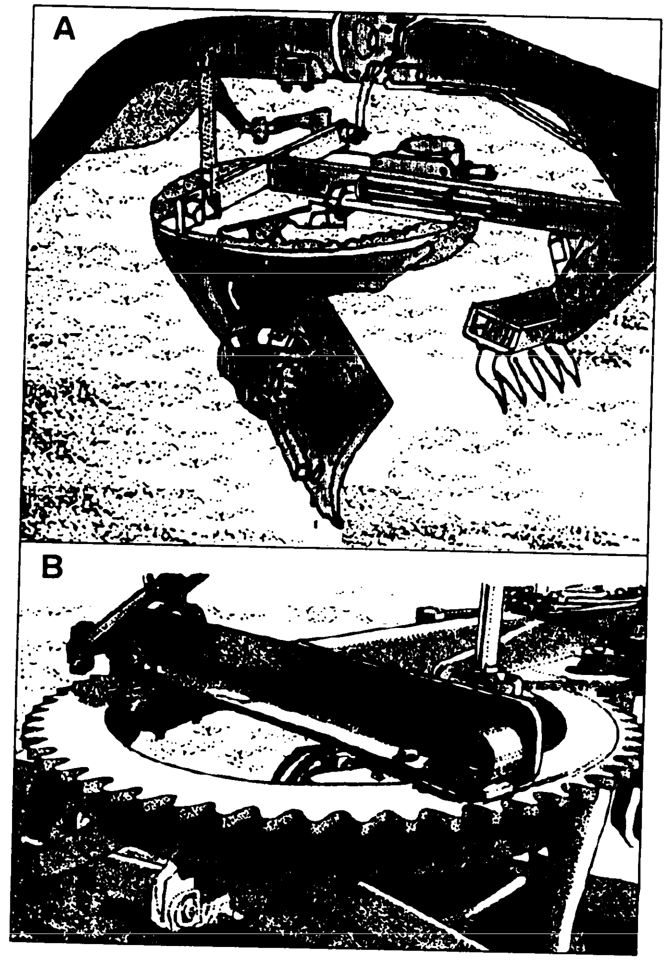


Figure 10-8.—Circle.

tool of the grader that can be lifted, lowered. rotated. tilted forward and backward, shifted to one side or the other, and angled horizontal (fig. 10-6).

The cutting edge and end bits are bolted to the moldboard. They act as wear plates and must be replaced or reversed when worn or broken. In most cases, the bolts will have to be replaced too.

NOTE: Always keep enough cutting edges and end bits on hand to protect the moldboard from wear or damage.

The length of the blade is normally 12 or 14 feet. The curve shape of the blade causes dirt to roll and mix, as it is cut and moved. The rotary movement of the dirt combined with the angle of the blade causes a side-cast drift of the material.

When the blade is angled to position one end ahead of the other, two terms are used to designate the blade ends. They are the *heel* and the *toe* of the blade. Figure 10-7 shows that the toe is the leading edge of the blade; the heel is the trailing edge. When the blade is turned so the toe is to your left, as you sit in the operator's seat, the material will side cast to your right and spill

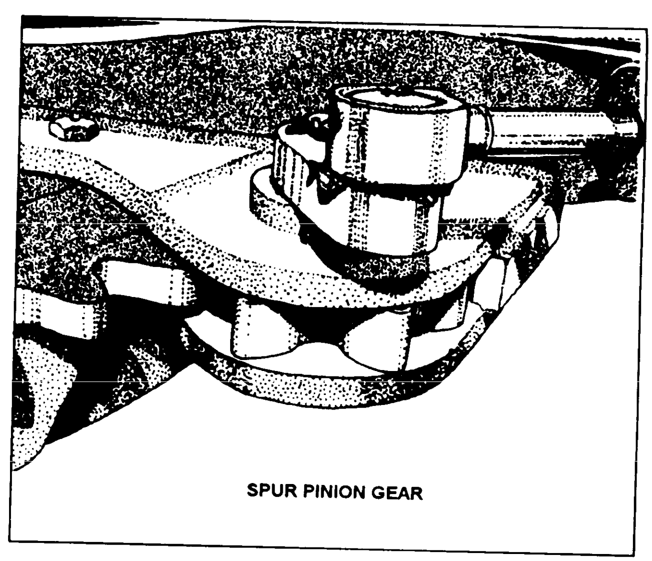


Figure 10-9.-Spur-pinion gear.

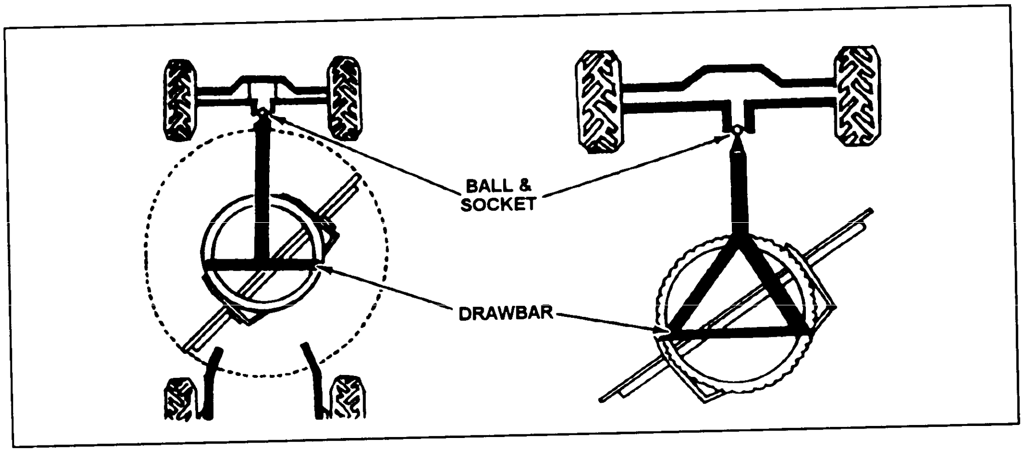


Figure 10-10.-Drawbar.

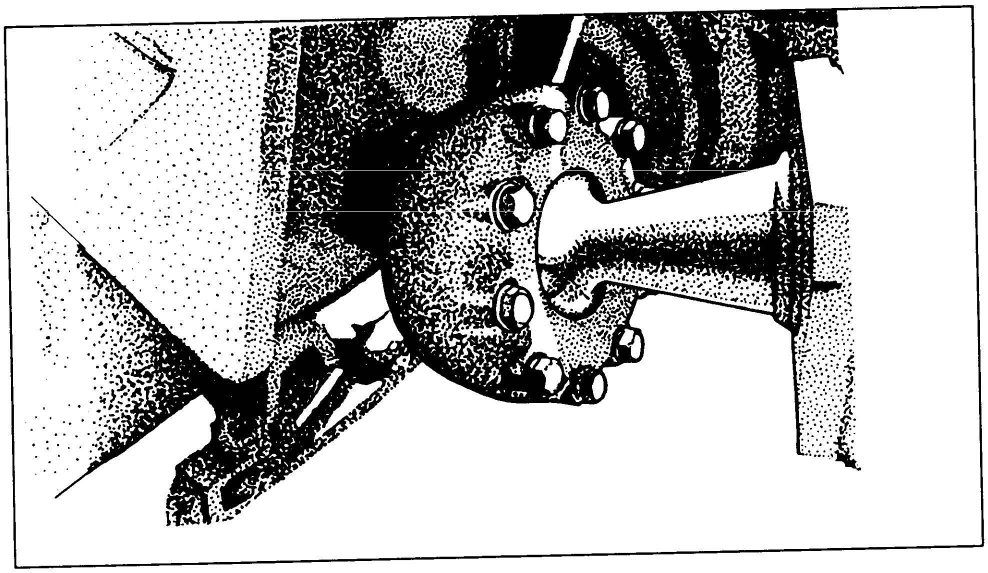


Figure 10-11.-Ball-and-socket connection.

off the heel. When the toe of the blade is to your right, the material will side cast to the left and spill off the heel.

The moldboard is supported and held in position by curved brackets, called **circle knees** and **side shift guides,** as shown in figure 10-6. They are attached to the underside of a rotatable ring, called the **circle.**

Cycle

The circle is a tooth-ring gear that is rotated in a supporting frame by the circle reverse mechanism. The circle teeth may be internal (fig. 10-8, view A) or external (fig. 10-8, view B), depending on the make and model of the grader.

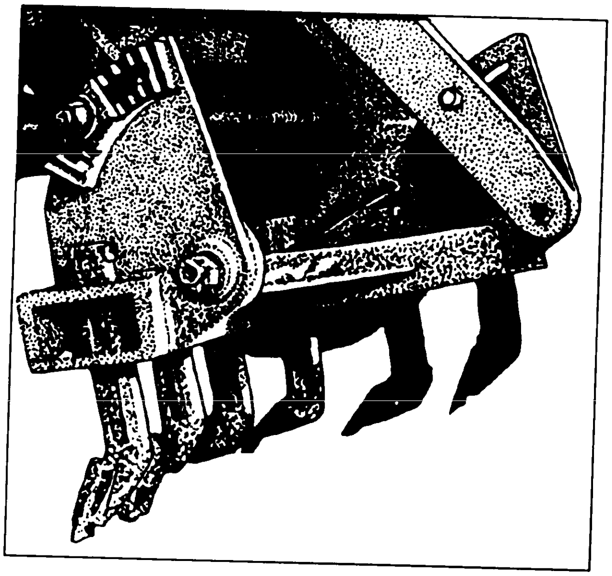
The circle is turned by a spur-pinion gear (fig. 10-9) that meshes with the circle teeth. The spur-pinion gear is held by the **drawbar** and is controlled by a lever in the operator's cab. Engaging the spur-pinion gear allows rotating the circle to the desired blade angle position.

Drawbar

The **drawbar** is a V- or T-shaped connection between the front of the grader frame and the circle (fig. 10-10). The drawbar holds the circle rigid and is fastened by a ball and socket that allows angular movement from side to side and up and down (fig. 10-11). The drawbar carries the full-horizontal load on the blade. Other components provide vertical and side support.

Scarifier

The **scarifier** is a hydraulically controlled unit with a set of teeth used to break up material too compacted



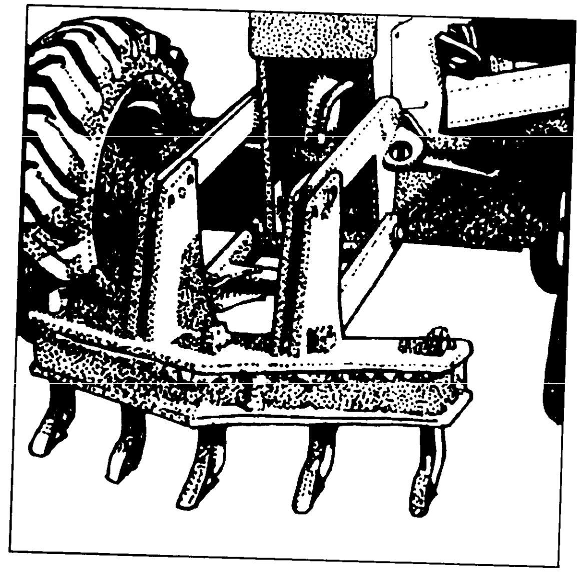


Figure 10-12.-Scarifiers.

to be penetrated by the blade. The scarifier is either pulled or pushed through the material, depending on the make and model of the grader and the position of the scarifier unit on the equipment. Figure 10-12 shows two types and locations of scarifies on graders.

The teeth, consisting of slender shanks with replaceable caps, are set in a V-shaped bar (fig. 10-13). The shanks are wedged or clipped in place and maybe adjusted for height or removed completely.

A scarifier with all the teeth is used for shallow penetration and light work. For hard or deeper penetration, remove every other tooth.

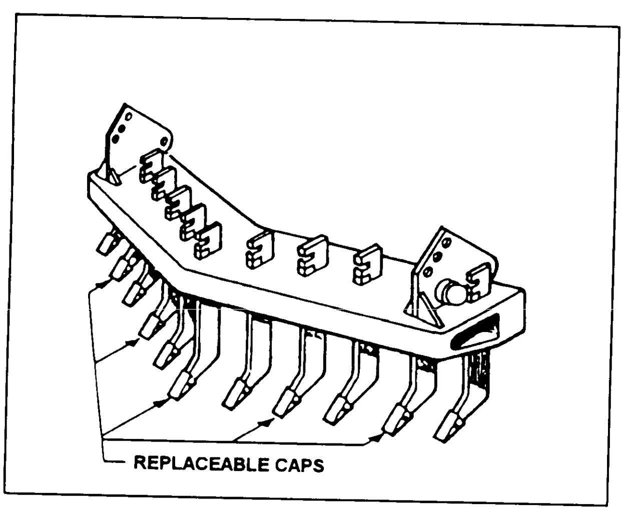


Figure 10-13.-Scarifier teeth.

GRADER OPERATIONS

Although the grader is a multipurpose machine that is capable of doing a variety of jobs, the performance of the grader depends largely upon the skill of the operator. The extensive skill required to perform as an effective grader operator is only gained through practice and on-the-job experience.

Wheel Lean

The proper use of the front wheels is a great aid in both steering and grading. In grading, lean the top of

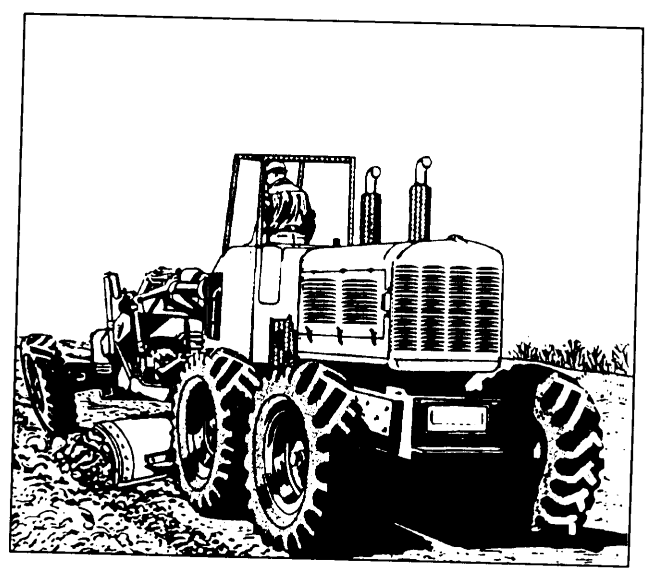


Figure 10-14.-Proper wheel lean.

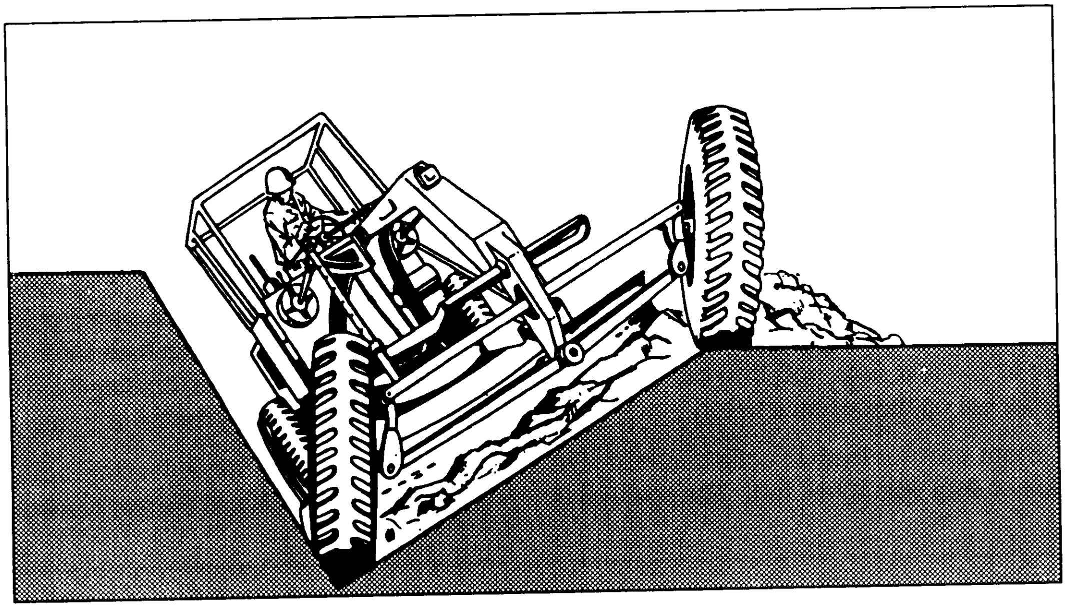


Figure 10-15.-Wheel lean on a ditch slope.

the wheels in the direction of the flow of material (the heel of the blade). For example, as shown in figure 10-14, viewed from the operator's seat, the toe of the blade is extended to the right of the grader side casting the material to the left. The material cut at the toe of the blade causes a pulling force exerted on the front end of the grader, wanting to pull the grader to the right. By leaning the top of the wheels to the left (heel) counteracts this pulling force.

When grading a ditch foreslope, as shown in figure 10-15, lean the top of the wheels enough to keep them in a vertical working position. This will lean technique will do the following: (1) keep the grader from drifting down the bottom of the foreslope and (2) keep the grader wheels from climbing the walls of the backslope.

On high bank-cutting operations, lean the top of the wheels toward the bank, as shown in figure 10-16. The blade engaged in the bank cut causes a pushing force, wanting to push the grader away from the bank. The wheel lean counteracts the force and helps keep the blade properly positioned for bank cutting.

Turning Around

When jobs are confined to short stretches or narrow widths, rotating the blade from forward to reverse grading position requires a circle reverse movement of only about 70 degrees (fig. 10-17). When reverse blading, the cut pass is normally made in reverse, while the side casting of the windrow pass is made on the forward trip, saving valuable time and speed in

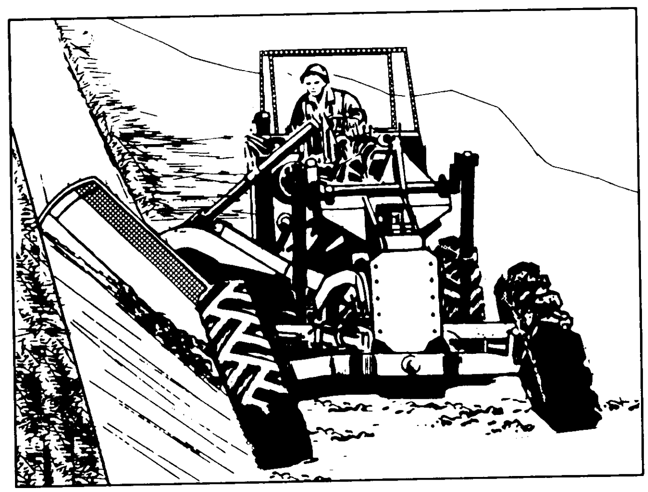


Figure 10-16.—Wheel lean on high bank-cutting operations.

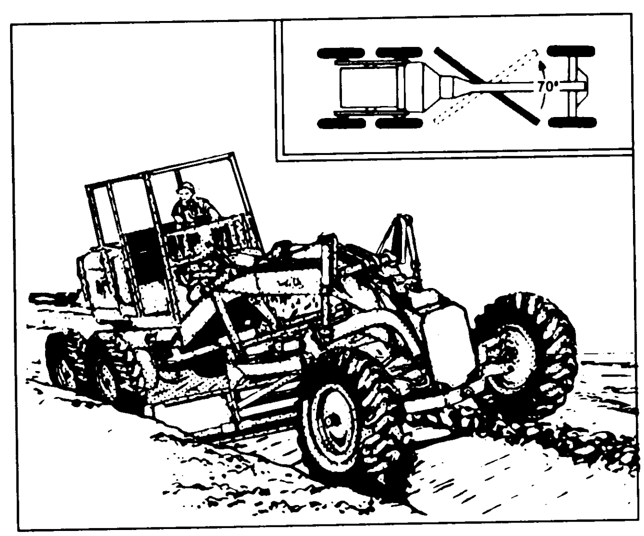


Figure 10-17.-Changing the blade from forward to reverse.

operations by eliminating frequent turning around of the grader.

NOTE: Reverse grading is only for operators who have developed superb skills in grader operations.

For reverse blading, if the scarifier unit is located just in front of the blade (behind the front axle), remove all of the scarifier teeth and fully retract the scarifier unit. This allows a clear area when changing the direction of the blade. When reverse blading, set the blade so the toe is just outside of the rear tires, and the heel side casts outside the front tire on the opposite side.

NOTE: Store scarifier teeth in collateral equipage or in a location so they will not be lost. The operator is responsible for all of the scarifier teeth assigned to the grader.

When you are grading on a project where the passes are less than 1,000 feet, it is more efficient to grade in recerse or vack the grader the entire distance to the starting point than it is to turn around and continue work from the far end, as shown in figure 10-18.

When you are grading on a projuct where the passes are 1,000 feet or more, it is then more efficient to turn the grader around and start blading from the far end back to the starting point, as shown in figure 10-19.

The combined maneuvering advantages of the leaning front wheels and the rear tandem drive are a big

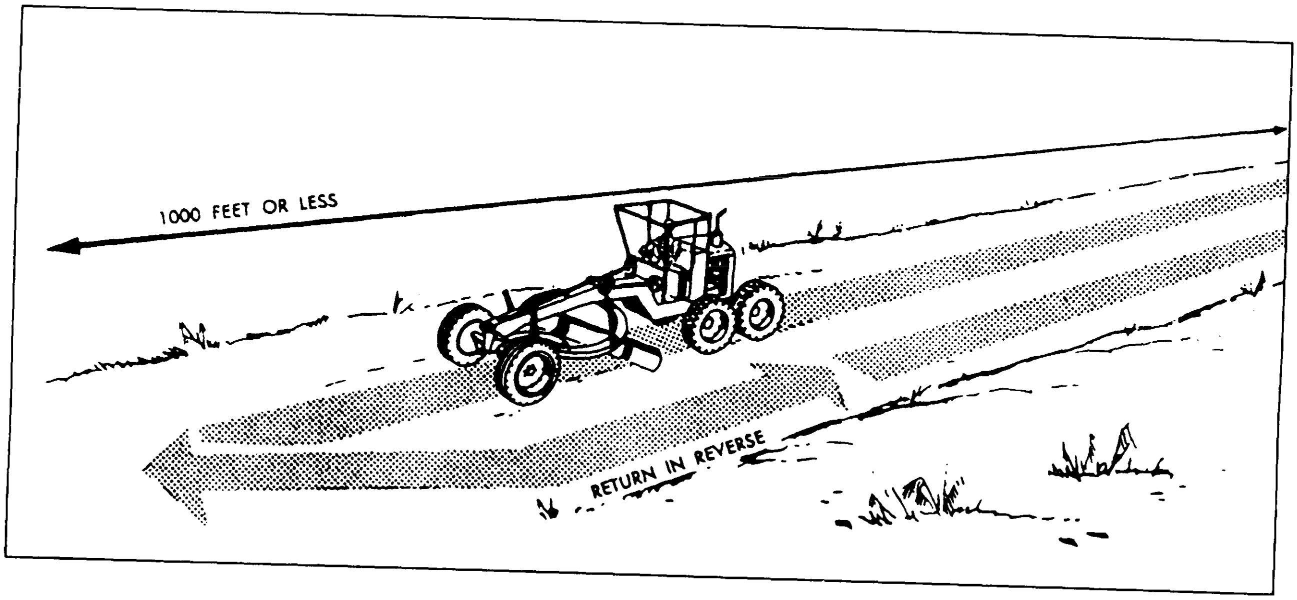


Figure 10-18.-Elinimate unproductive turning around.

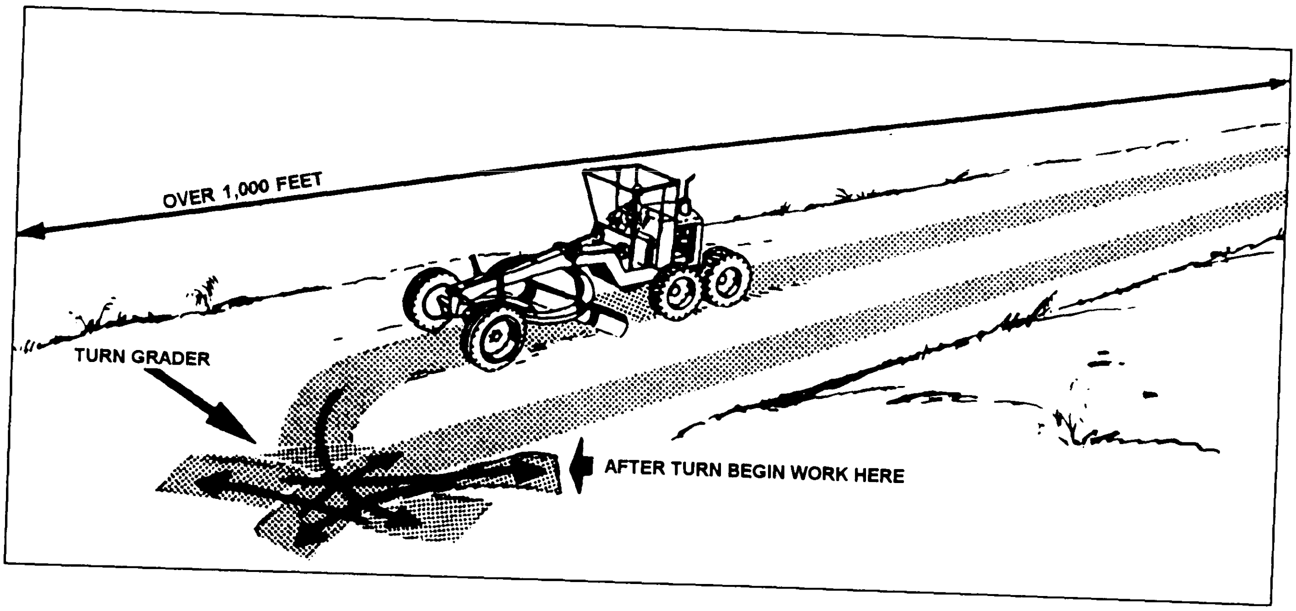


Figure 10-19.-Turning around.

help in turning the grader around on a construction project. Figure 10-20 shows a simple technique to turn the grader around. With the wheels leaned in the direction of the turn (A), back across the ditch (B), and then complete the turn (C). By keeping the front wheels on the roadway and leaning the wheels in the direction of the turn, you can make the grader turn with ease.

NOTE: Always back across the ditch and leave the front wheels on the roadway.

Blade Pitch

The blade pitch adjustment is a working tool that supports the cutting action of the blade and is hydraulically controlled by a lever in the operator's cab. Figure 10-21 shows the different blade pitch adjustments.

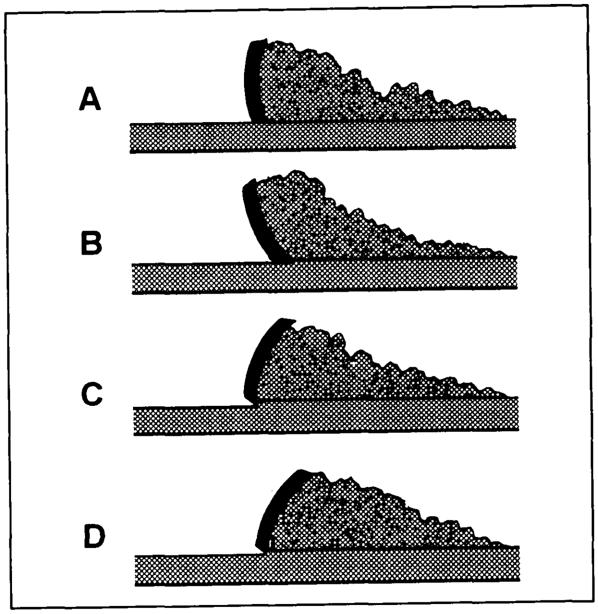


Figure 10-21.—Blade pitch.

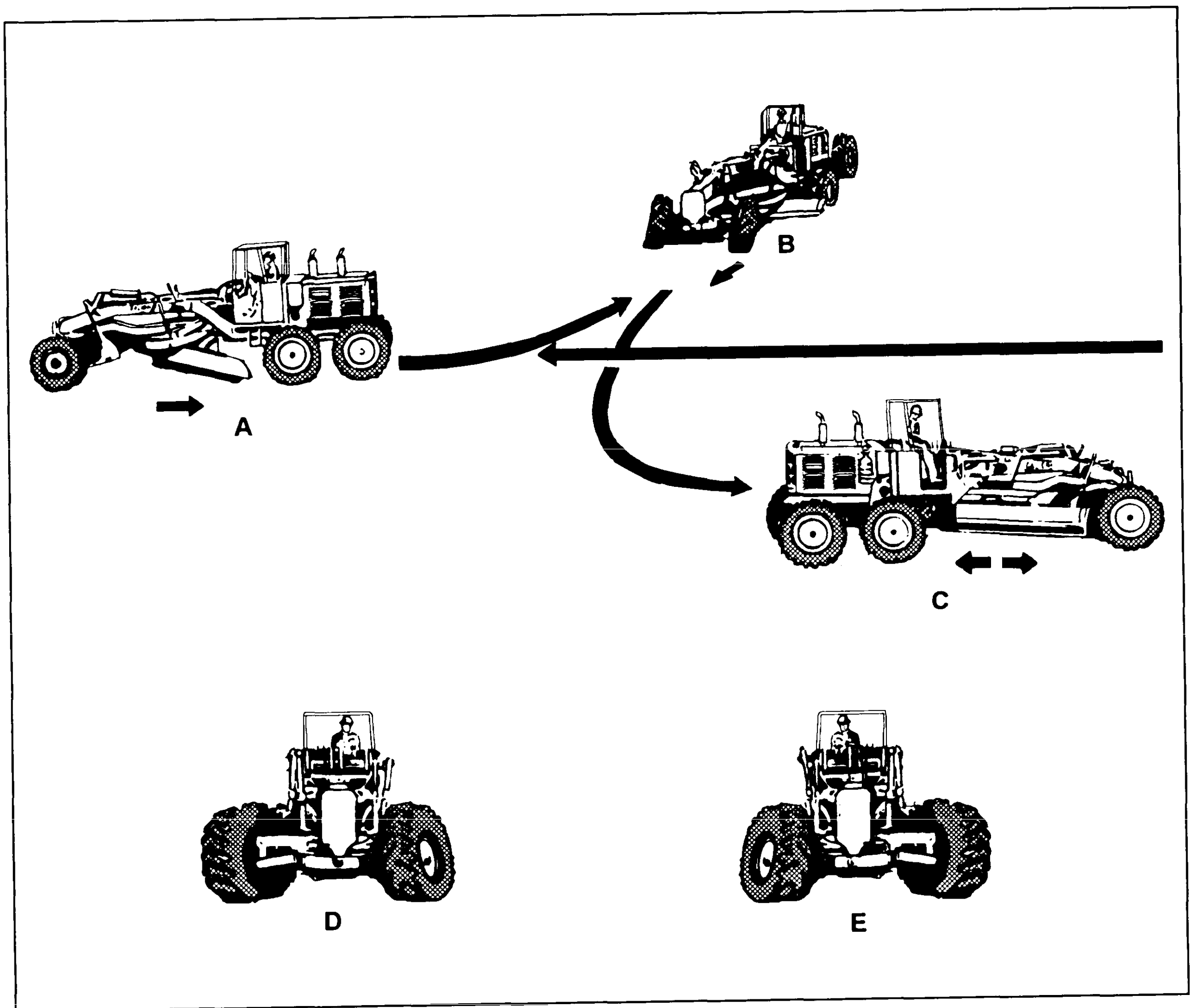


Figure 10-20.—Turning the grader around technique.

For normal grading operations, the upright position on the blade is used. For a greater cutting action, the backward pitch is used. For a greater mixing and rolling action on the material being side tasted, use a slight forward pitch. When spreading, finishing, or maintaining surface material, use a full forward pitch. This pitch accomplishes a partial compaction of the surface materials and assures filling any low spots.

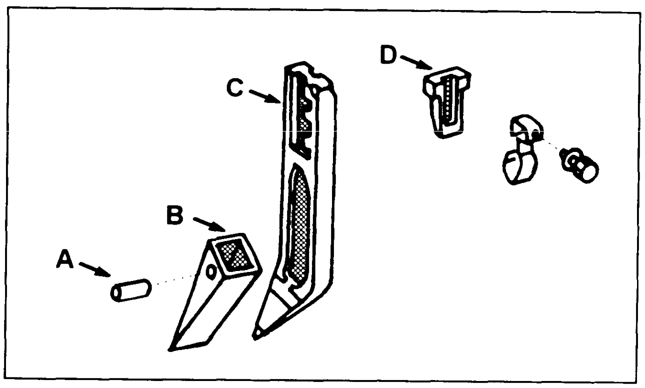
When selecting the correct blade pitch, you have to think about the type of operation, type of material, depth of cut, and speed of operation. Experience and practice enhance your skills to know which pitch positions achieves the best blading results for the type material.

Scarifying

Scarifying is breaking up hard or compacted materials, using the scarifier on the grader. A decision to scarify a road or not depends on the availability of water to obtain the proper moisture content of the material and the amount of traffic that travels the road. The proper moisture content supports the binding of the material required for compaction and is also used as dust control.

Just placing fill material on a dirt road to fill the ruts and potholes is a temporary fix. The fill material does not bind in the ruts and potholes and, therefore, will NOT remain in place.

The proper way to reshape a dirt road full of ruts and potholes is to scarify the surface to the depth of the depressions. This breaks up all the compacted surrounding surface materials. After scarifying the material, blade mix the surface materials, reshape the road, and compact.



A. Pin
B. Cap
C. Shank
D. Lock Wedge

Figure 10-22.—Scarifier tooth.

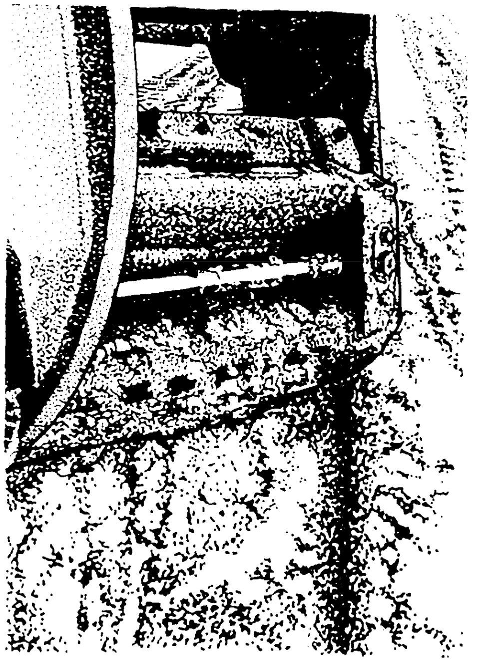


Figure 10-23.—Marking cut.

To scarify extremely hard or consolidated material, remove alternate scarifier teeth. This will ease passage of the scarifier through the material.

CAUTION

Never make sharp turns with the scarifier teeth in the ground. Making sharp turns damages the scarifier and possibly bends or breaks the teeth.

During prestart operations, check the scarifier teeth for wear. When the caps are worn enough to cause damage to the shank, replace the cap (fig. 10-22).

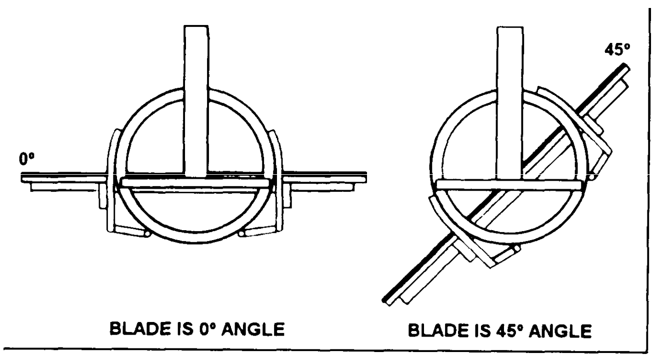


Figure 10-24.—45-degree position of the blade.

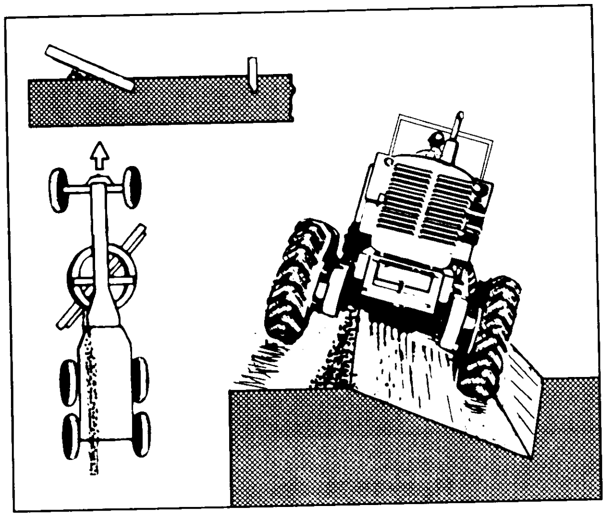


Figure 10-25.-Ditch cut.

Ditch Cut

The first step performed on a road project is to establish drainage normally through the use of a ditch. To construct a ditch, you must know how to cut a straight ditch line and make sure the ditch line stakes fit the plans.

The first cut to make is the **marking cut.** The marking cut is a 3- to 4-inch-deep cut made with the toe of the blade (fig. 10-23). The toe of the blade is positioned in line with the outside edge of the front tire. For cutting, the blade pitch is adjusted until the top and bottom edges of the moldboard are aligned Perpendicular to the ground. The marking cut is a technique used for easier grader control and straighter ditches.

After the marking cut, position the blade at about a 45-degree angle to perform an efficient **ditch cut** (fig. 10-24). The toe of the blade is positioned in line with the center of the lead tire, while the heel of the blade is raised to allow the windrow to form either inside or outside the rear wheels (fig. 10-25). It maybe necessary to remove the scarifier teeth to keep them from interfering with the blade.

NOTE: Do not forget to lean the top of the front wheels in the direction of the flow of the cut material.

After each ditch cut, the material should be windrowed or spread towards the middle of the road, away from the ditching operations. This technique is called **shoulder pickup.** To spread the windrow away from the ditch, position the front grader tire on the inside of the windrow. Side shift the blade and the circle so the toe is positioned to the outside of the windrow, as shown in figure 10-26. The heel is positioned to allow the windrow to side cast inside the rear tandem tires. The purpose of the shoulder pickup is to move the windrow away from the foreslope of the ditch.

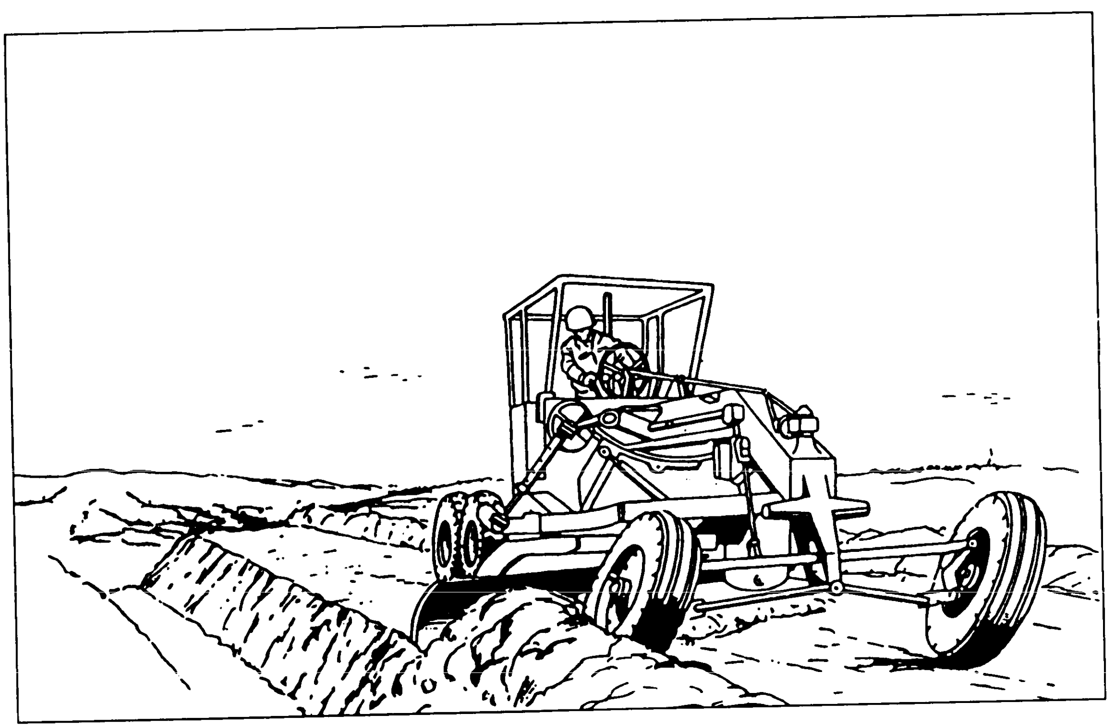


Figure 10-26.-Shoulder pickup.

The next pass to make is the **spreading pass** (fig. 10-27). The blade and circle are shifted back under the grader frame. While the grader straddles the windrow, the toe of the blade is positioned inside the front tire, and the heel is positioned to side cast the material outside the rear tandem tires. Depending on the amount of material, the spreading operation may require several passes. After spreading the material, the ditch cut, shoulder pickup, and spreading pass are performed until the desired depth of ditch is completed.

When the backslope of the ditch needs to be cut (fig. 10-28), position the circle and the blade with the heel resting at the bottom of the foreslope, so the material flows inside the right rear tandem tires. The toe of the blade should be forward toward the right front tire. The top of the wheels is leaned toward the backslope.

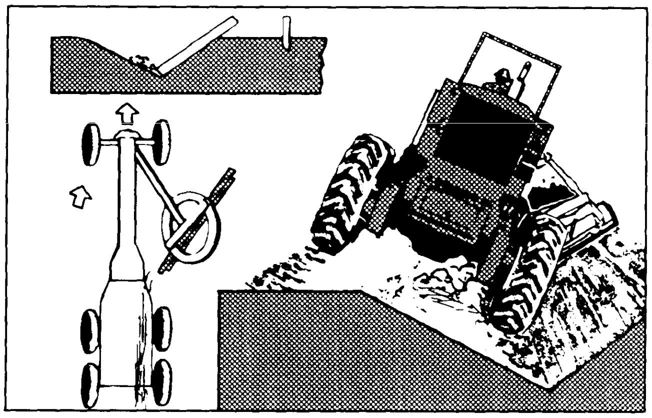


Figure 10-28.-Backslope cut.

When the ditch is to have a plain V-bottom, you now have to perform a clean-up pass on the foreslope to remove the material from the backslope cut. After the foreslope is clean, perform a shoulder pickup and a spreading pass to finish the ditching operations.

Flat-Bottom Ditch Cut

When a flat-bottomed ditch is required, proceed as follows:

Starting at the foreslope of the original V-ditch (A), as shown in figure 10-29, use the ditch-cutting procedures to cut another V-ditch. After the V-ditch is completed, the next step is to make a flat cut in the bottom of the ditch. This is performed by placing the complete length of the blade in the ditch. The toe is positioned at the base of the backslope (B), and the heel is positioned to side cast the windrow inside the rear tandem tires (C). This operation moves the material to the foreslope of the second V-ditch. To remove the material from the foreslope, perform the procedures used when removing material from a V-ditch.

Crown

The **crown,** or slope, of the road from the centerline of the road toward the shoulders provides drainage to the ditch. For crowning, angle and adjust the blade to conform to the specified angle of the crown. The material is side tasted in windrows from the shoulders of the road up toward the center line.

When the road has a ditch on each side, make the first pass down the length of one shoulder. When the length of the pass warrants, turn around and proceed down the length of the opposite shoulder with the blade

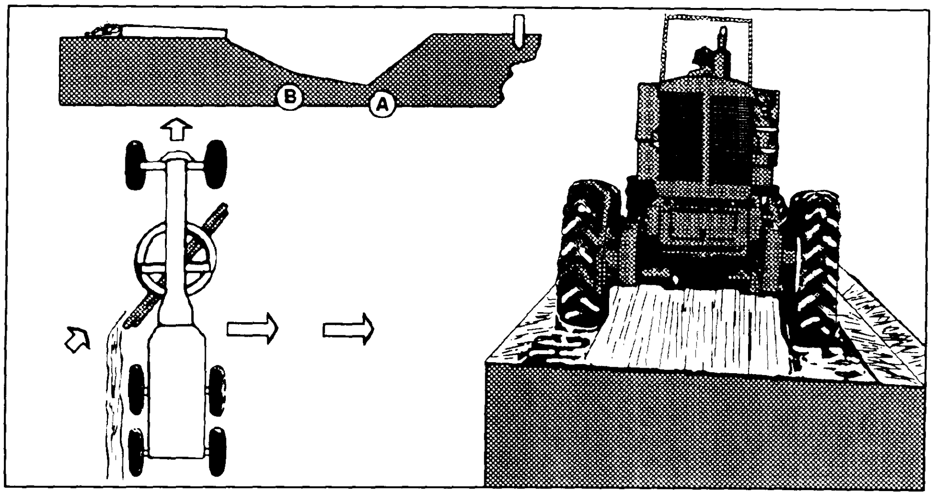


Figure 10-27.-Spreading pass.

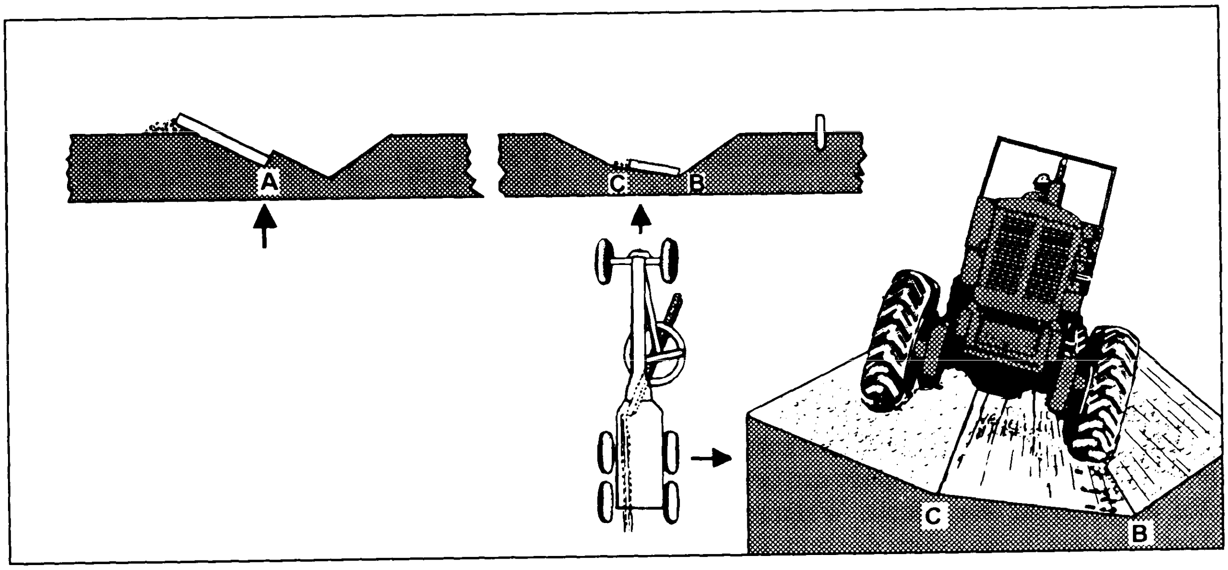


Figure 10-29.—Flat-bottom ditch cut.

Adjustment relative to the same position. When the distance is too short, backup and start on the opposite shoulder with the opposite blade angle adjustment. By repeating overlapping passes made in this manner, you can side cast two windrows from the shoulders to the center line where they are combined into one. The center windrow is then spread with the blade set at 0 degrees. Material spill around the blade ends is spread evenly among the slope of the crown.

NOTE: When grading, the operator cannot obtain a full-visual view of a project site from the operator's seat. For this reason, the operator should stop and climb off the grader periodically to take a visual look at the work area to determine work progress and areas that need attention.

High Bank Cuts

High bank cuts are used to cut or trim slopes on ditches, deep cuts, and high fills. The circle and blade are positioned vertically on the side of the grader. The toe of the blade is angled forward of the heel.

NOTE: Read the operator's manual for the type of grader you are operating to receive instructions on setting up the circle and blade for high bank-cutting operations.

When performing high bank cuts, lean the top of the front wheels towards the bank or slope. Move the grader into position and set the blade on the slope (fig. 10-30). When cutting, make light cuts with the toe of the blade. The heel of the blade does not require many adjustments. When too much down pressure is placed on the blade, you will lift the side off the grader or cut a gouge in the slope. After the high bank cut is performed, clean the cut material from the base of the slope, using the ditching technique.

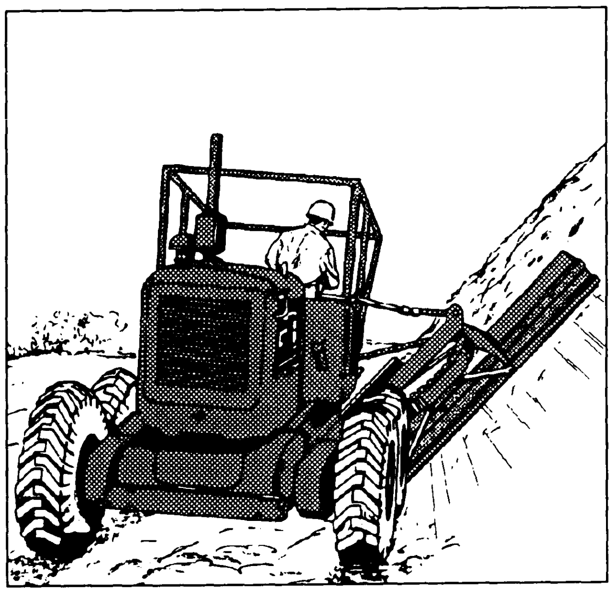


Figure 10-30.-High bank cut.

Wide Side Reach (Spreading)

A grader may be used in spreading piles of loose material. When there is space to work around the pile, the blade should be extended well to the side and angled to side cast the windrow to the inside of the rear tires. The pile is reduced by using a series of side cuts, as shown in figure 10-31. Piles to be spread by a grader should be spread dumped as much as possible. The load to be spread is limited by the power and traction of the grader.

When there is not enough room to use the wide side reach and the piles of material are not too high, the front wheels may be driven over the piles. The front axles push the top off the pile, and the blade cuts as much as power permits. The blade should be positioned well below its highest point, so when the grader gets hung up on the piles and loses traction, the blade can be raised to restore the weight to the rear wheels. When traction is lost and the tires spin, unnecessary tire wear increases.

Road Maintenance

The ability of the grader to blade mix materials used as road surfaces is an important function in road maintenance. When blade mixing, pitch the blade slightly forward and angled at about 30 degrees. This position gives the widest possible spread with maximum mixing action. In mixing, move the windrow from side to side by successive cuts with the blade.

To increase production, use several graders to operate, one behind another, on the same windrow (fig. 10-32). When the mixture is wet, mixing should continue until the mixture is dry. After mixing, the material is again side tasted into a windrow before spreading. During mixing, more bitumen or cement can be applied to any lean sections. All particles of the completed mix should be coated and uniform in color.

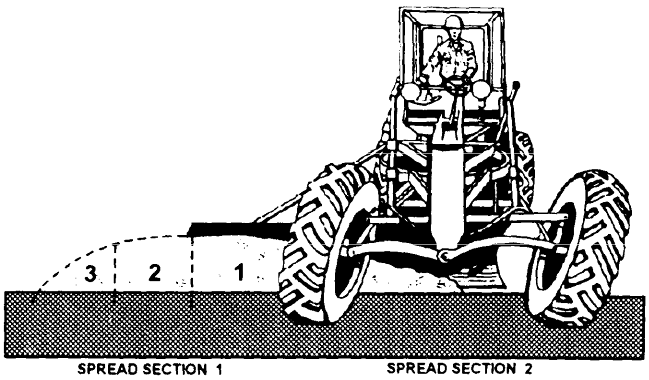


Figure 10-31.—Wide side reach.

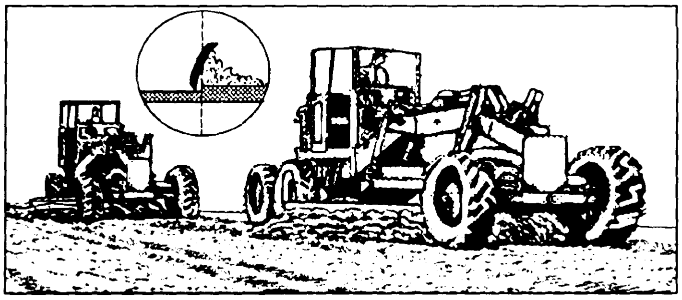


Figure 10-32.—Blade-mixing operation.

Blade-mixing operations are performed as rapidly as possible, consistent with the skill of the operator and the condition of the surface being maintained. However, when the grader is operated too fast, it will tend to bounce and give the surface a washboard appearance that will take additional time and passes to connect. When washboarding is not corrected, it will create unnecessary wear and tear on traffic using the road or work area.

Snow Removal

Graders can be used for snow removal in the same way as a snowplow. The blade and circle are adjusted to side cast snow and slush the same as if side casting road materials. When the cutting edges are not removed and replaced with a strip of hard rubber bolted to the moldboard, raise the blade at least 1/2 to 1 inch when removing snow from uneven pavement or a runway surface.

NOTE: Failure to make proper blade adjustments can result in not only damaging the cutting edges, moldboard, or grader, but also in gouging and tearing up the road or runway surface.

Finish Grading

Finish grading is a fine cut or fill of a surface to get the final desired elevation. This phase of a grading operation is called **blue topping.** Blue topping takes time and patience even for experienced operators.

When performing blue topping operations, make sure the grader cutting edges are not worn, the tires are the same size with the correct air pressure, and the tires are pointed in the right direction. Front tire treads should be pointed toward the rear, and rear tire treads should be pointed toward the front. Adjust the blade pitch all the way forward to scrape instead of cut.

Before making any cuts on a project, review the project grade hub stakes (blue tops) to note their location and how much you will have to cut or fill.

NOTE: Compaction of the surface must be done before finish grading can start. When you finish grading, it is better to cut 1/2 to 1 inch than to fill.

A technique used when performing blue topping operations is to divide the project into sections, working one section to final grade at a time. After the first section is to grade, you now have a reference point to start from to grade the other sections. As with any earthmoving equipment, it is best to have a level starting point.

When working each section, do not let the material build up into piles that the grader will have to run over. Windrow the material to the end or off the section and have a loader pickup the excess material and move it. If there is room, the excess material can be windrowed off the project for later removal.

When cutting, drag the blade over the top of the hub stake. Final grade is reached when the blade skims the top of the hub stake. Do not cut too deep and knock the hub stake out of the ground. When several passes are required to achieve final grade, the "cut boss" should clean off the top of the stakes so you can see them for your next pass.

Grader Estimates

A part of planning a construction project is estimating how long it will take to complete a construction activity. A work-output formula for preparing preliminary estimates for grader operations is as follows:

$$Total\ time = \frac{P \times D}{S \times E}$$

Where

Total time = Hours required to complete a grader operation

P = Number of passes (P) the grader must take to complete the operation

D = Distance (D) traveled in each pass expressed in miles

S = Speed (S) expressed in miles per hour

E = Grader efficiency (E) factor

The most difficult factor to estimate is the speed of the grader. As work progresses on a construction activity, conditions may require that the speed estimates of the grader be increased or decreased. A work output is computed for each operation that is performed at a different rate of speed. The total time of each operation for each different speed is added together to compute the total time of the grader operation. Table 10-1 lists the speeds normally used in various grader operations.

The grader efficiency (E) factor takes into account the fact that a 60-minute work hour rarely is attained. Efficiency varies, depending upon supervision, operator skill, maintenance requirements, and site conditions. A value of 60 percent is average, computed in decimal form as 0.6. The efficiency factor can be adjusted on each job.

Example problem:

Five miles of gravel road is to be leveled and reshaped by using a grader with a 12-foot blade. Six passes are estimated to complete the leveling and reshaping operation. The type of material permits passes 1 and 2 to be performed in second gear at 2.8 mph, passes 3 and 4 in third gear at 3.4 mph, and passes 5 and 6 in fourth gear at 5.4 mph. The efficiency factor for the job is 60 percent.

Calculate how long it will take to complete the job.

$$Total\ time\ for\ passes\ 1\ and\ 2 = \frac{2 \times 5}{2.8 \times 0.6} = \frac{10}{1.68} = 5.90\ hours$$

$$Total\ time\ for\ passes\ 3\ and\ 4 = \frac{2 \times 5}{3.4 \times 0.6} = \frac{10}{2.04} = 4.90\ hours$$

$$Total\ time\ for\ passes\ 5\ and\ 6 = \frac{2 \times 5}{5.4 \times 0.6} = \frac{10}{3.24} = 3.08\ hours$$

$$Total\ time\ of\ the\ project = 5.9 + 4.9 + 3.08 = 13.88\ hours$$

Always round your answer to the next higher number. In this case, 13.88 is rounded to 14 hours.

Table 10-1.-Approximate Speed Ranges Used in Various Grader Operations

OPERATION	SPEED (MPH)	OPERATION	SPEED (MPH)
MAINTENANCE	3 TO 10	BANK SLOPING	2
SPREADING	3 TO 6	SNOW REMOVAL	10 TO 15*
MIXING	5 TO 15	FINISHING	3 TO 5
DITCHING	2 TO 3		

*EXCEPTION TO MAXIMUM SPEED PERMISSABLE ON HIGH TYPE RUNWAYS AND HIGHWAYS.

GRADER SAFETY

Safety precautions that apply to graders are as follows:

- Keep hands, feet, and clothing away from power-driven parts.

- Clothing worn by the operator should be relatively tight and belted. Do not wear loose jackets, shirts, sleeves, or other items of clothing because of the danger of catching them in moving parts.

- Before starting the engine, always check the service brakes and the parking brake to ensure they are in proper working condition.

- Do not use the steering wheel as a handhold when getting on and off the grader.

- Keep hands, floors, and controls free from water, grease, and mud to ensure nonslip control.

- Never attempt to start or operate the grader except from the operator's station.

- Always keep the grader in gear when going down steep hills or grades.

- When transporting or driving on a road or highway at night or during the day, use accessory lights and devices for adequate warning to the operators of other vehicles. In this regard, check local government regulations.

- Never drive too close to the edge of a ditch or excavation.

- Do not leave the engine running while making adjustments or repairs unless specifically recommended.

- Never refuel when the engine is running. Do not smoke while filling the fuel tank or servicing the fuel system.

- Never leave the grader unattended with the engine running.

- Do not oil, grease, or adjust any part of the grader while it is in motion.

- Check for faulty wiring or loose connections.

- Keep a firm grip on the steering wheel at all times when speed is increased.

- Do not allow anyone near the grader while the driver is in the seat with the engine running.

- Reduce speed before turning or applying brakes. Drive at speeds slow enough to ensure your safety, especially over rough ground.

- Do not operate the grader so fast on hillsides or curves that you may tip over.

- When you are operating your grader, be sure your path ahead is clear to avoid collision with other equipment.

- Watch for overhead wires. Never touch wires with any part of the grader.

- Do not use the grader as a battering ram.

- Keep the working area as level as possible.

- Never allow anyone to work under a raised blade or other attachment.

- Do not leave the blade or other attachment in the raised position when it is not in use. Always lower it to the ground.

- Be sure bystanders are clear of the grader before lowering or moving the blade.

- Park the grader on level ground or across the slope.

- Remove all trash accumulation from the engine and the operator's station daily.

- Wear any required personal protective equipment.

SCRAPERS

Scrapers are designed for self-loading, hauling, and spreading material on long-haul earthmoving operations. Scrapers are most efficient when operated in light and medium materials that are nearly free of roots, stumps, and boulders. Heavy or consolidated materials require ripper-equipped dozers to rip open the surface and assist loading operations by pushing the scraper through the cut to achieve maximum loading. The dozer pushing the scraper is referred to as a push cat.

Scrapers are built with open tops to make them suitable for loading by crane clam shell, conveyor, or front-end loader. The types of scrapers used in the NCF are equipped with either a single engine or twin engine (fig. 10-33). On twin-engine scrapers, the one engine in the front is used to pull, and the one in the rear is used to push.

Another type of scraper used in the NCF is the paddle wheel scraper (fig. 10-34), also called the

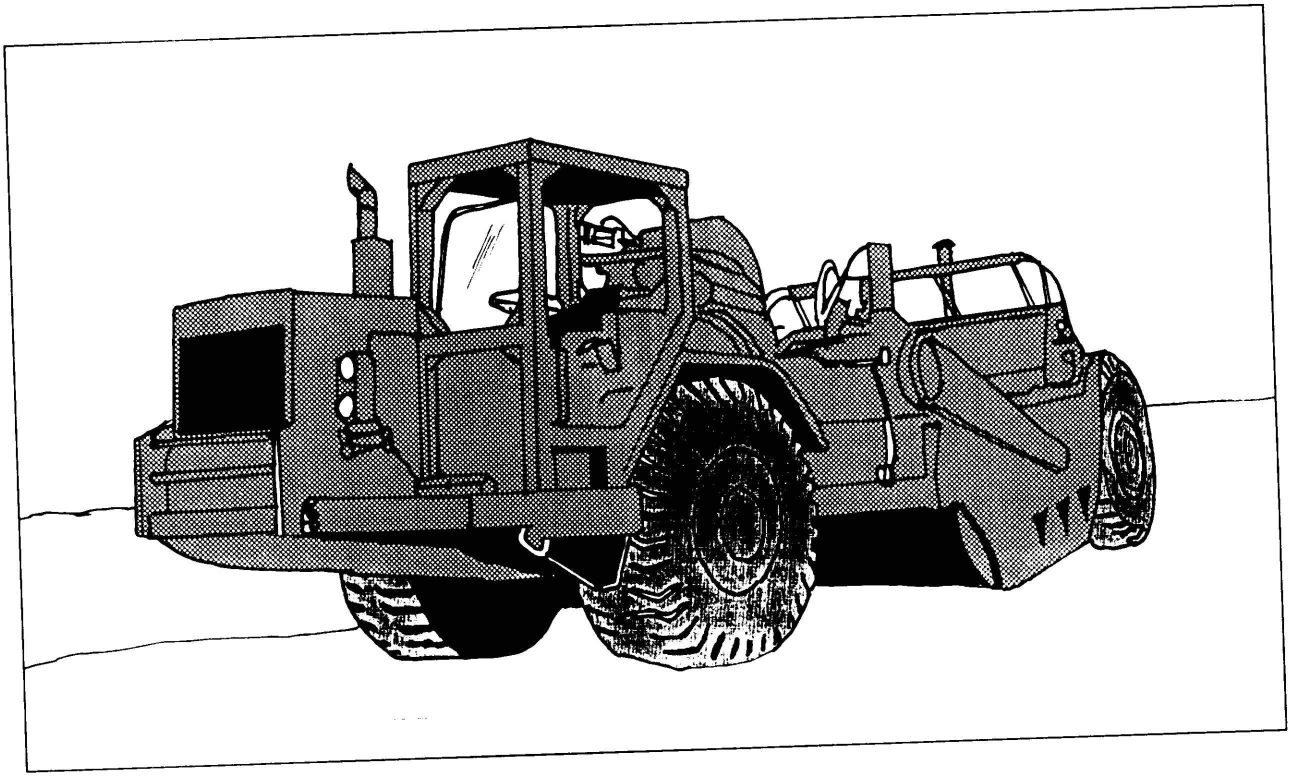


Figure 10-33.–Scraper.

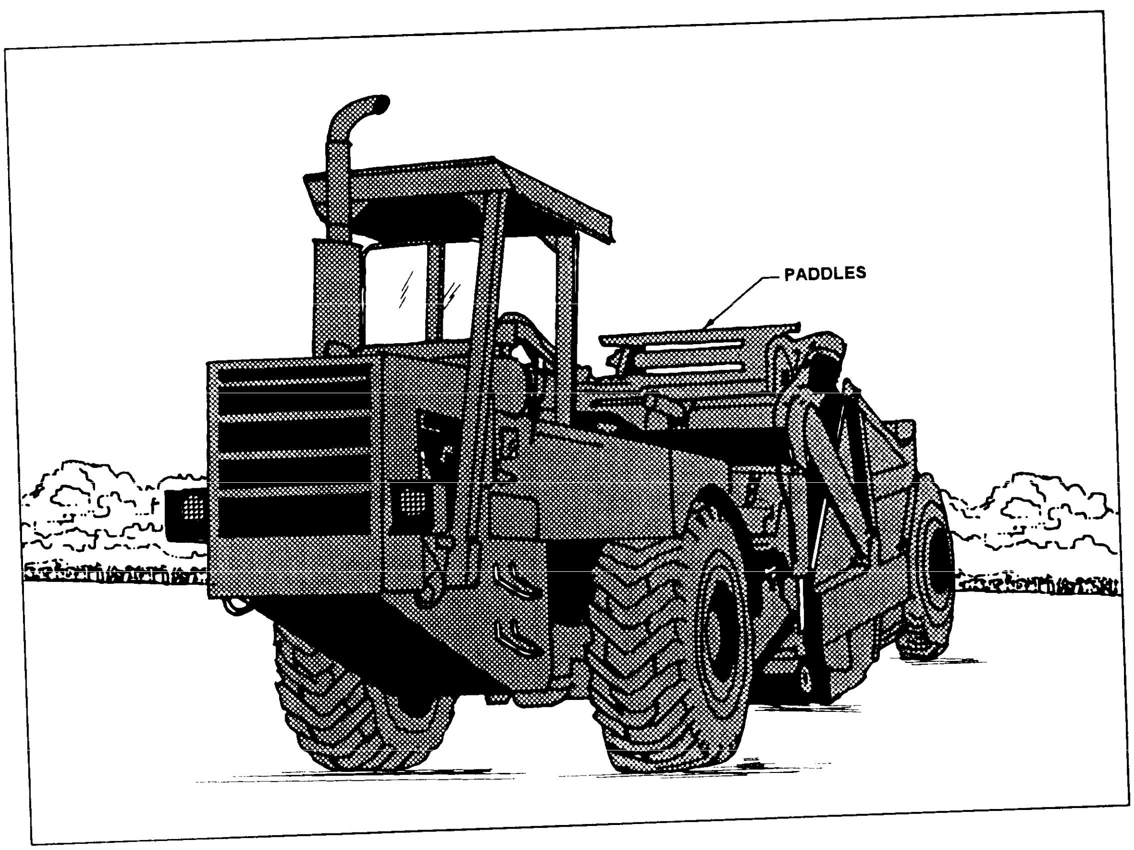


Figure 10-34.—Paddle wheel scraper.

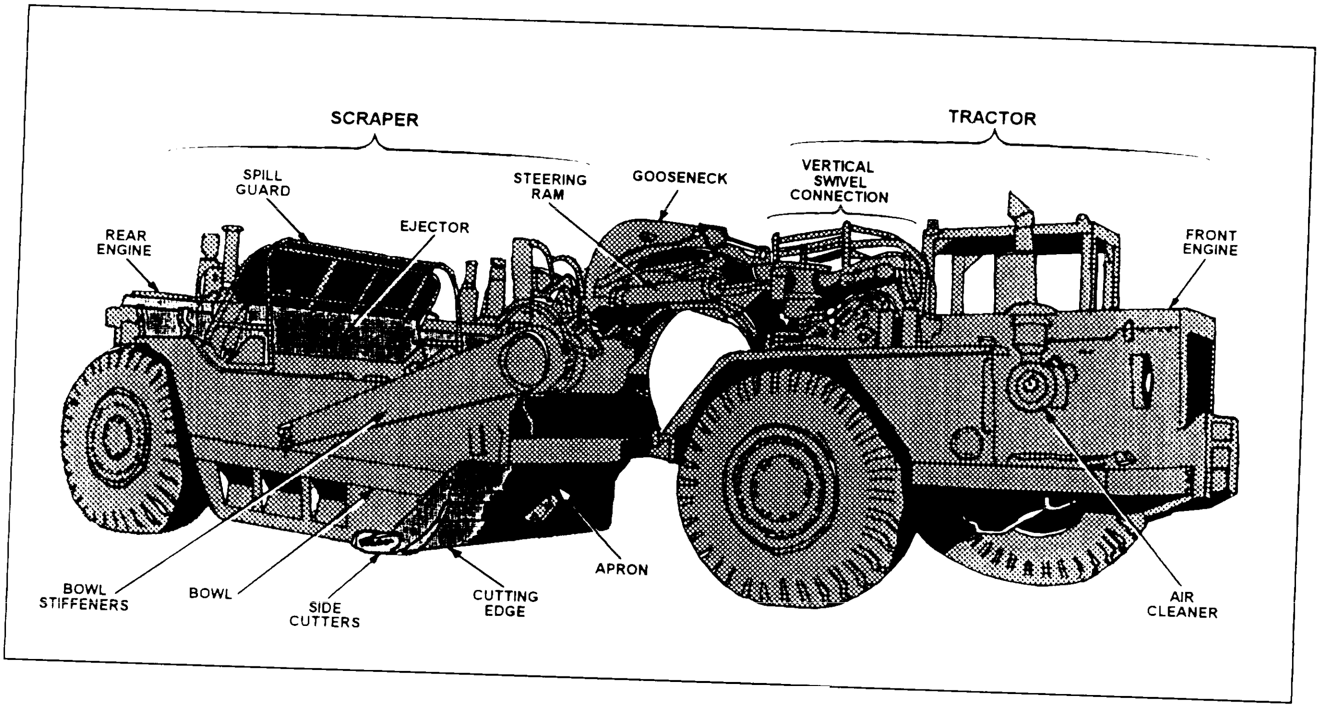


Figure 10-35.—Scraper nomenclature.

elevating scraper or self- loading scraper. This scraper, on most projects, requires no push cat for loading and is ideal for small- to medium-size earthmoving jobs. The scraper loads its pan from the top by means of a paddle wheel elevator after the material has been cut by the cutting edge. Material is not forced to the top as on other scrapers. The loaded material can also be unloaded by the paddle wheels, giving the operator more control of the desired depth of fill.

A variety of scrapers are used in the NCF. Each operator is responsible for reading the operator's manual to obtain detailed information about each make and model.

SCRAPER COMPONENTS

The scraper is made in two sections: the tractor and the scraper. The tractor contains the engine, the drive train and wheels, the hydraulic pumps, and the operator's cab. The tractor is connected to the scraper by a vertical kingpin swivel connection usually in two parts with upper and lower pins. When you are steering, this connection permits turns of 85 to 90 degrees to each side of the center line of the scraper. There is also a longitudinal horizontal hinge that permits the two sections to tip independently from side to side.

The gooseneck of the scraper arches up to allow space for the tractor wheels to roll under it on turns. The

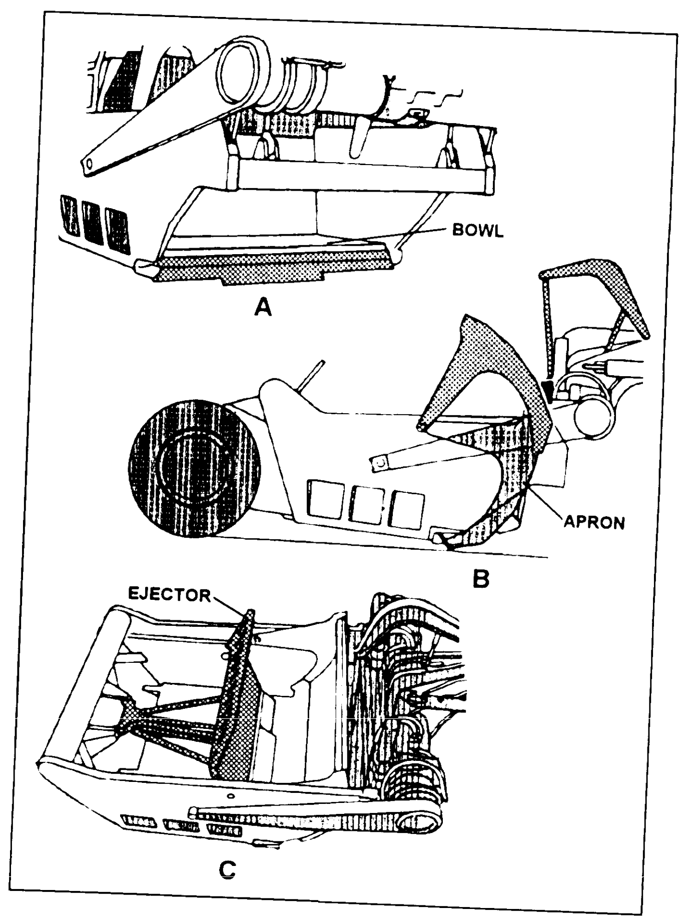


Figure 10-36.—Scraper bowl, apron, and ejector.

gooseneck then widens into a very massive crossbeam becoming a pair of side arms extending backward to the trunnion fastenings on the sides of the scraper bowl.

The gooseneck carries the steering cylinders, the lift cylinder and lever arm for the apron, and a pair of hoist cylinders for the bowl. Scraper nomenclature is shown in figure 10-35.

A scraper has three basic operating parts: the bowl, the apron, and the ejector.

Bowl

The bowl (fig. 10-36, view A) is a box with rigid sides, with the apron as a movable front, and the ejector as a movable back. The forward edge of the bowl is fitted with cutting edges. The cutting edges are made of wear-resistant steel and are bolted to the bottom of the bowl. The three main cutting edges areas follows:

1. The straight cutting edge is the most efficient for smooth finish grading.

2. The curved cutting edge penetrates more than the straight edge.

3. The three-piece cutting edge has the center piece positioned ahead of the two side pieces for deeper penetration. The center piece is referred to as the stinger (fig. 10-37).

The bottom front sides of the bowl usually have bolted-on wear plates called side cutters. The side cutters normally receive less wear than the cutting edges.

NOTE: Cutting edges that are worn or damaged should be replaced to prevent wear of the scraper bowl.

Apron

The apron (fig. 10-36, view B) forms the forward section and a variable amount of the bottom of the bowl assembly. When closed it rests at the cutting edges. The apron is hydraulically controlled by a lever in the operator's cab. When the apron is lifted, it moves upward and forward far enough to leave the whole front of the bowl open.

Ejector

The ejector is the rear wall of the bowl (fig. 10-36, view C). The most common ejector is hydraulically controlled and moves forward horizontally, forcing the load out of the bowl. It is supported by rollers riding on the floor and on tracks welded to the sides of the bowl.

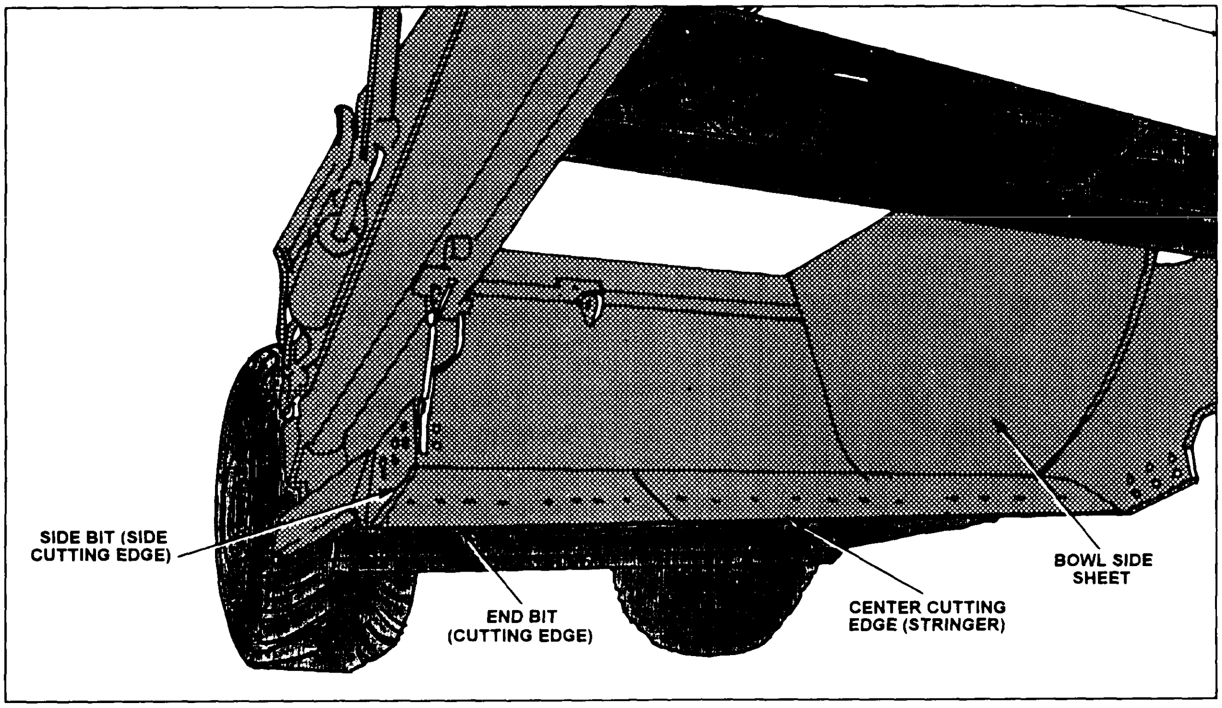


Figure 10-37.-Scraper cutting edges.

CONTROL LEVERS

Most scrapers have three basic control levers located on the right side of the operator's seat. The first lever is the **bowl lever** (fig. 10-38, view A). The bowl lever raises and lowers the bowl. The middle lever is the apron **control lever** (fig. 10-38, view B). The apron control lever opens and closes the apron, allowing the required amount of material to enter or be ejected from the bowl. The third lever is the **ejector lever** (fig. 10-39, view C). The ejector lever forces the dirt out of the bowl. For maximum hydraulic cylinder operating efficiency, the engine should be operated at maximum rated speed and the control levers moved to their extreme operating position.

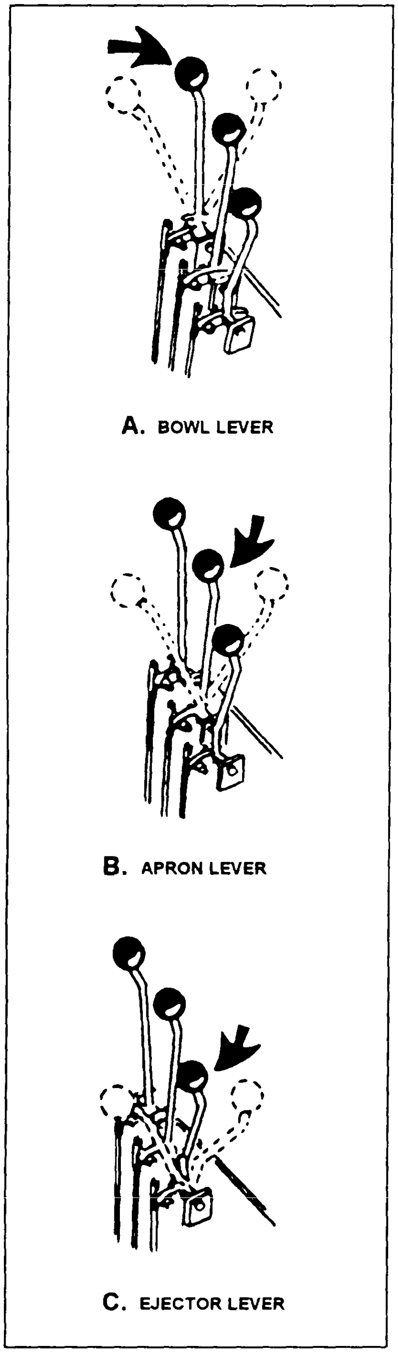


Figure 10-38.-Scraper control levers.

SCRAPER OPERATIONS

The greatest engine power is available when the engine is running at top governed speed. The proper transmission gear ratios must also be engaged to obtain maximum engine power output. When the transmission is placed in a too high a gear ratio for full engine power, the result is a **stall** condition in the transmission converter. Stalling the converter prevents the engine from operating at maximum efficiency and results in rapid overheating and premature wear of the converter or transmission.

The transmission must be downshifted correctly while the scraper is in motion to prevent damage to the power train. Improper downshifting overspeeds the transmission and engine and usually results in premature wear and unnecessary transmission breakdowns.

When moving the scraper from a full stop, always start with the transmission in low gear, depressing the throttle for the degree of acceleration required. A wide, open throttle provides the fastest acceleration under full-load conditions.

When running downgrade, avoid overspeeding the engine by keeping the scraper speed at, or below, the maximum speed for the transmission range engaged. As a general rule, downhill scraper speed should not exceed 5 mph more than that attained on level ground in the transmission ratio engaged.

When the selected transmission ratio is too high, slow the scraper with the service brakes until the transmission can be properly downshifted to the required range for the grade.

Downhill speed can be slowed, if necessary, by lowering the scraper bowl until the cutting edge drags enough to slow the scraper to the required speed to permit proper downshifting or stopping.

Do not **fan** the brakes by repeated depressing and releasing. This practice can reduce air pressure below the point required for proper breaking. The air pressure system should indicate 105 to 125 psi on the air pressure gauge for effective braking. When the gauge indicates a pressure drop below 105 psi for a long time, shutdown the scraper until the trouble is corrected.

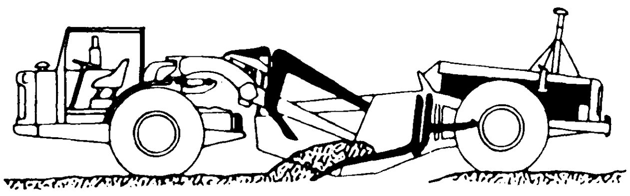


Figure 10-39.-Entering the cut.

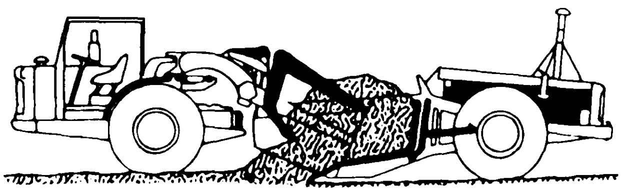


Figure 10-40.—Loading the bowl.

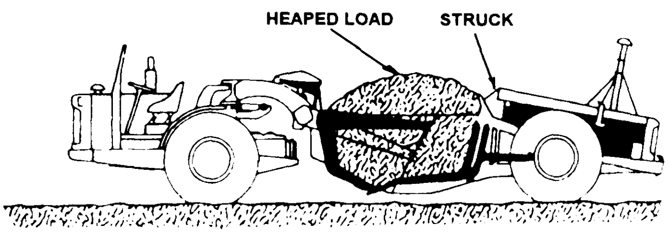


Figure 10-41.-Loaded bowl.

The scraper work cycle has four phases of operation: loading, hauling, spreading or unloading, and returning to the cut.

Loading

When loading, enter the cut with the ejector positioned at the rear of the bowl, open the apron enough to allow material to enter the bowl (normally 4 to 8 inches above the leading edge of the bowl), and then lower the bowl to cut a depth of 1 to 1 1/2 inches. The gear that the transmission is engaged in depends on the nature of the material being cut. For light, loose material, a relatively high gear can be used. For heavy compacted material, a low gear is used; however, to obtain a full load, you should use a lower gear, even in loose material. As the scraper proceeds through the cut, the material is loosened by the scraper cutting edges and forced into the bowl by the forward motion of the scraper (fig. 10-39).

NOTE: Avoid spinning the scraper tires during cut operations. Spinning the tires is nonproductive and causes expensive premature wear of the tires, differential, and transmission.

The material entering the bowl boils back against the ejector and forward against the apron (fig. 10-40). When the bowl is filled to capacity (commonly know as heaped), close the apron, and at the same time, raise the bowl 1 or 2 inches above the ground (fig. 10-41). On scrapers equipped with diverter valves in the apron hoist system, the bowl automatically starts raising, while the apron control lever is held in the lower position. After the scraper is fully loaded and the bowl is raised, continue to travel out of the cut with the scraper bowl at a height that spreads out the material that piles in front of the cutting edges.

The push cat supplies extra power to the scraper during loading operations. When a push cat is used, it should be positioned about 45 degrees off the lane to be cut. The scraper should start loading before the push cat makes a smooth contact with the rear push block (fig. 10-42).

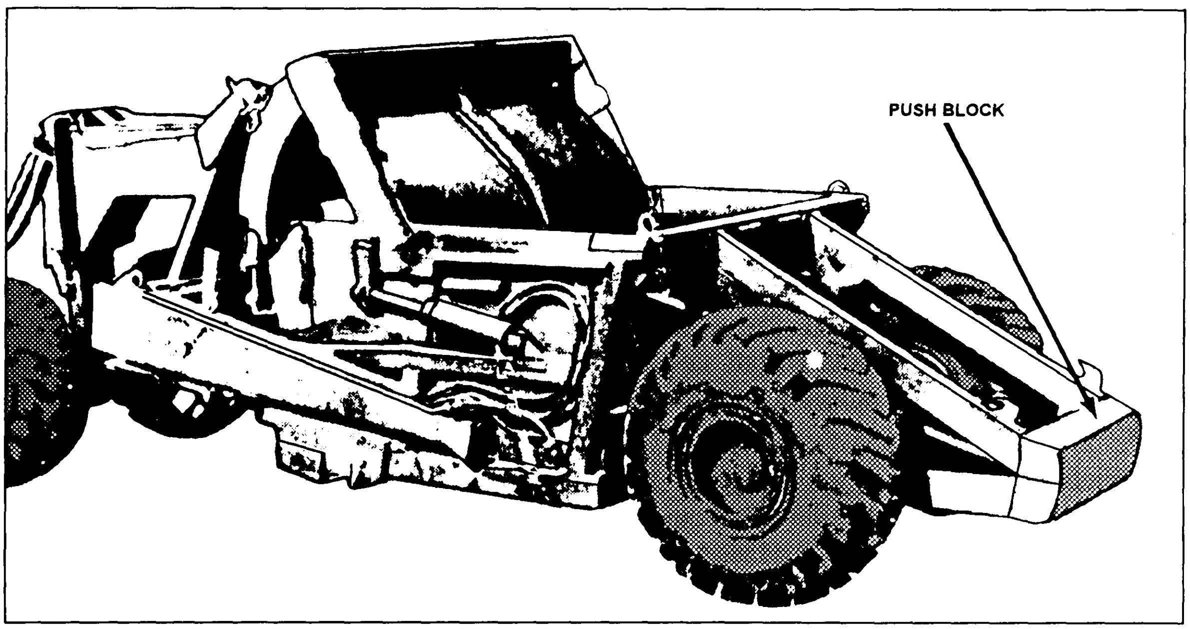


Figure 10-42.-Push block.

NOTE: The push cat operator should be extremely cautious in NOT hitting the rear scraper tires with the dozer blade.

The push cat operator must ensure that the reinforced section of the dozer blade is centered on the scraper rear push block. Additionally, the push cat operator must be alert to turns made by the scraper that might cause the push cat to apply unequal pushing force. This could result in the dozer blade contacting the scraper rear tires or causing the scraper to jackknife. The push cat should continue pushing after the scraper has a full load to give the scraper a boost in leaving the cut.

Hauling

After the scraper is fully loaded and has reached the haul road, the operator should raise the bowl to travel height and proceed to the fill or dump area in the highest gear range practicable. The bowl travel height should be no higher than needed to clear any obstacles on the haul road. A low bowl height allows better control of the scraper by keeping the center of gravity low and preventing the loss of time needed to lower the bowl, as the scraper approaches the fill area. The best bowl height is the height at which the bowl must be in when the load is spread.

When hauling down steep grades, lower the bowl until the blade drags to slow the scraper down. When traveling over a slippery haul road, keep the cutting edges as close to the road as possible to allow for a fast emergency stop by dropping the bowl.

When traveling over haul roads, avoid holes and large obstacles that may damage the scraper tires. When making sharp turns, allow enough clearance for the length and width of the scraper to keep the scraper wheels on the road.

Spreading or Unloading

When approaching the fill area, lower or raise the scraper bowl to the depth of fill desired. The speed of the scraper must also be adjusted for this depth, such as a high speed for a thin spread or a slower speed for a deep spread.

To start spreading, raise the apron by engaging the apron control lever to allow the material to fall out of the bowl. The size of the apron opening depends mainly upon the depth of the spread and type of material being spread; for example, a thin layer of free-flowing sand needs a fairly small apron opening and a high travel speed, while a thin spread of wet clay will need a larger opening and a slower travel speed.

After the apron opening has been adjusted and the dirt flowing through the opening lessens, engage the ejector lever to finish unloading the scraper bowl. When the scraper is empty, engage the ejector lever to return the ejector to the rear of the bowl and lower the apron.

Unloading techniques are as follows:

- Keep the scraper moving while unloading. Stopping when unloading on soft fill costs production time by needless shifting and the possible miring down of the scraper.
- Always make an even spread, so the next trip will not be rough.
- If possible, when traveling out of a fill, pass back over the area you have just filled to compact it with the large scraper tires.

Returning to the Cut

After the scraper is unloaded and has reached the haul road, return to the cut as soon as possible. When returning to the cut, carry the scraper bowl high enough to avoid any haul road obstacles, yet low enough for safe handling of the scraper. Carrying the bowl low allows for quick lowering of the bowl to stop the scraper in the event of an emergency. Allow plenty of room for the rear wheel of the scraper to avoid obstacles when making tight turns, and maintain a safe speed for the condition of the haul road.

WORKING DIFFICULT MATERIALS

Special operating techniques are required when performing scraper operations in difficult materials, such as wet or sticky material, loose sand or gravel, and large objects.

Wet and Sticky Materials

When unloading wet and sticky material, do not try to spread the material too thin. Always keep the bowl high enough to allow the material to flow back under the scraper. Open the apron wide enough to allow an easy flow out of the bowl, Bring the ejector forward with short, snappy movements of the ejector control lever to shake the material loose from it. Allow a little time between each ejector movement to avoid compacting the material between the apron and ejector. In some cases, shifting the ejector between forward and reverse gives the material that has been brought forward a chance to fall out the apron opening.

NOTE: When the material is spread too thin or the bowl is too low, the material will pack against the scraper cutting edge inside the bowl and will not eject.

Loose Sand and Gravel

Sand is a free-flowing material that tends to float ahead of the scraper cutting edges when being loaded. To obtain a heap scraper load when loading and to avoid being bogged down by the sand, use the technique called ***pump loading.*** To pump load, enter the cut with the apron open about 3 feet and the scraper cutting edges lowered into the sand. Continue through the cut until the engine(s) starts to lug down. Then lower the apron into the sand that has piled up in front of the scraper cutting edges, and raise the bowl 2 or 3 inches at a time. Do not completely close the apron or drop the bowl so deep that the engine stalls. This **pump loading** technique will ordinarily allow the scraper to get a full load.

When spreading sand, always spread it as thin as possible, and keep the scraper moving in the fill. A thin spread allows better compaction and makes it easier to travel over the fall.

To obtain a full load when loading gravel, you may have to **pump load** as performed with sand. The apron may be hard to close due to stones getting caught between the apron and cutting edges. A technique used to avoid the stones is to backup a few inches with the blade still in the ground while closing the apron. This should force the stones out and allow the apron to close all the way.

Large Objects

Scrapers are not designed to dig or transport large objects; however, they may be used for this purpose when more suitable equipment is not available.

Approach the object with the apron and scraper bowl fully raised. When the object is too large to clear underneath the tractor, bring the tractor past the object until the drive wheels are a few inches beyond it. Pivot the tractor sharply towards the object to allow the tractor to bypass the object, and bring the cutting edge into position for loading (fig. 10-43).

When the tractor reaches its sharpest angle of the turn, bring the scraper cutting edges within a few inches of the object. Lower the bowl, apply down pressure, and move forward. When the cutting edge hooks underneath the object, lift the bowl while inching forward. When the object slips off the cutting edge, back up and try again. You may have to approach the object from a different direction to get a grip to load the object.

To shove the object around, keep the ejector in the full forward position. When the object is to be picked up and carried, place the ejector in the normal fullback position. To close the apron completely after the object

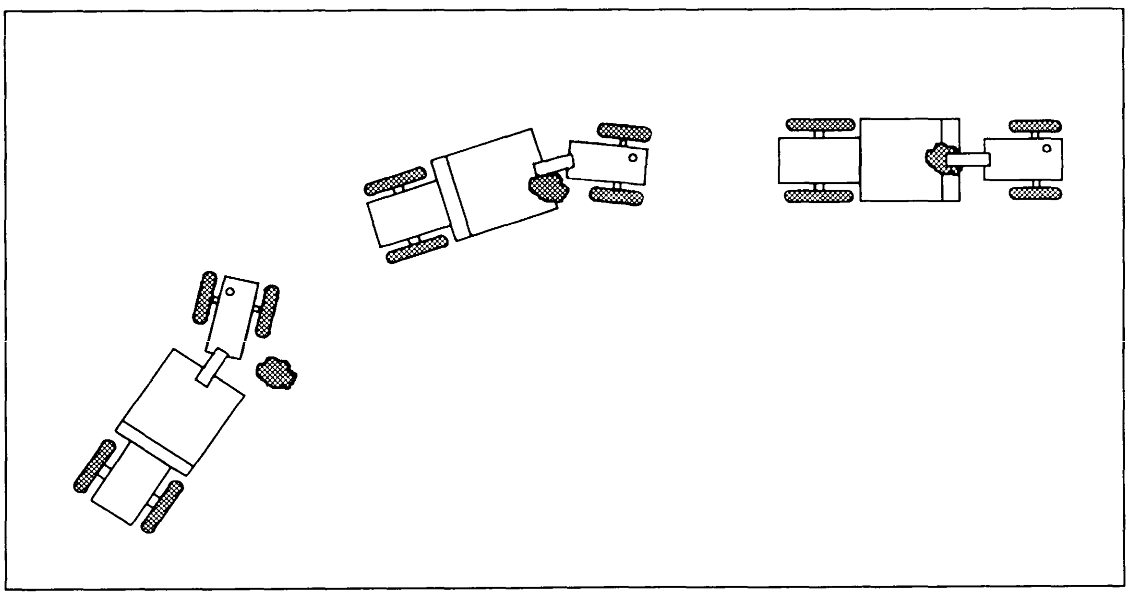


Figure 10-43.-Scraper maneuver to load large object.

has been loaded, scrape up a little dirt that will push the object back further into the bowl.

To unload the object, shift the ejector from forward to reverse several times to move the object around so it will fall out. After the object has been unloaded, turn the tractor sharply so the scraper clears the unloaded object.

NOTE: Use extreme care when handling large objects. Oversize objects, such as large rocks, can cause damage by denting, bending, or straining parts. Damage may also be done by accidental collision with large rocks during ordinary digging.

PRODUCTION TECHNIQUES

Scraper production techniques are used to achieve the most amount of work with the scrapers assigned. These techniques are as follows.

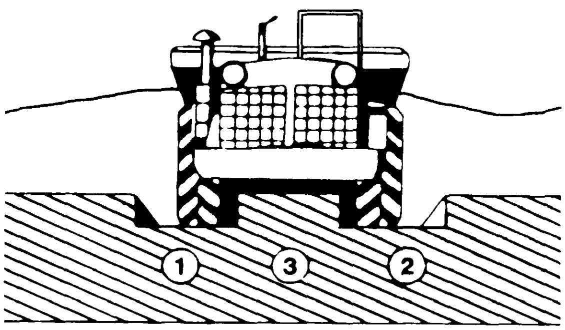


Figure 10-44.-Straddle loading.

Downhill Loading

Downhill loading uses the force of gravity on the scraper to get larger loads in less time. The added force of gravity is 20 pounds per gross ton of weight per 1 percent of downhill grade. The downhill pull adds more material per load, and the added material weight increases the total gravitational pull.

Straddle Loading

Straddle loading gains time on every third trip because the center strip loads with less resistance than a full cut. After the first scraper has made a cut, the second scraper should make a parallel cut and leave a 4- to 5-foot-wide island between the two cuts, as shown in figure 10-44. The third scraper can straddle this island of material to achieve a fast, less resistance load.

Back-track Loading

Back-track loading is the method where the cut is fairly short and loading in both directions is impractical. As shown in figure 10-45, too much time is spent back tracking and maneuvering the push cat for the next load. When the cut is wide enough, other methods should be tried.

Shuttle Loading

Shuttle loading is used for short cuts where it is possible to load in both directions, as shown in figure 10-46. The push cat pushes one scraper in one direction, then turns and push loads a second scraper in the opposite direction.

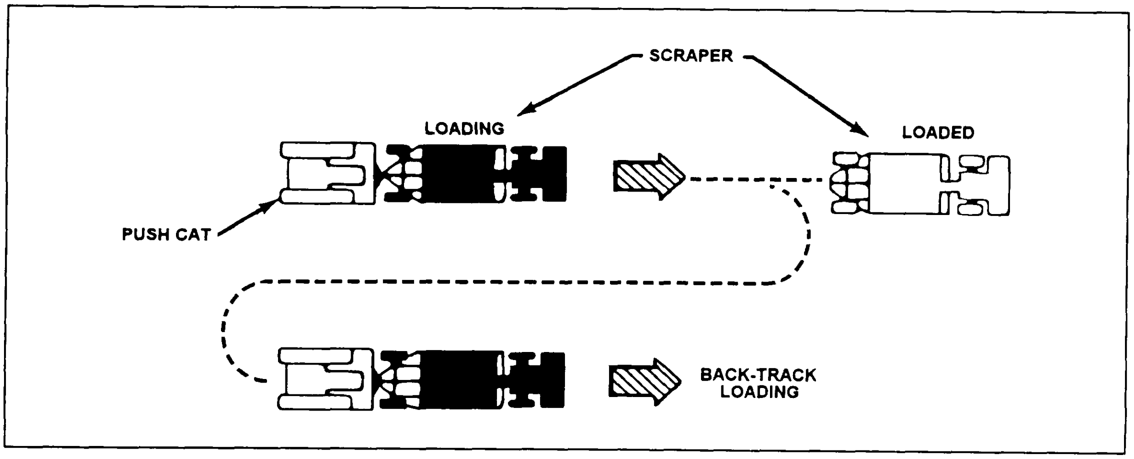


Figure 10-45.-Back-track loading.

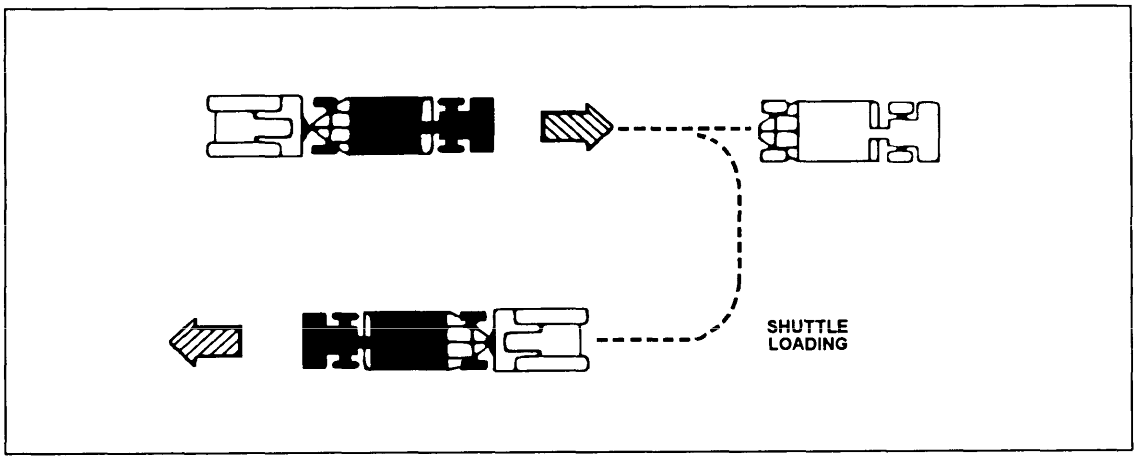


Figure 10-46.-Shuttle loading.

Chain Loading

Chain loading is used where the cut is fairly long, making it possible for the push cat to pickup two or more scraper loads without back tracking, as shown in figure 10-47. The push cat push loads one scraper, then moves in behind another scraper, moving parallel to the first in an adjacent lane.

Optimum Loading

Optimum loading is an operation when loading time and maximum output are critical. Push-loaded scrapers should be loaded within 1 minute and within a distance of 100 feet. More time and distance may be used to obtain more material when the haul is long enough, and the added material is great enough to offset hauling fewer loads because of longer loading time.

When scrapers are backed up at the cut waiting for push cat assistance, let the scrapers cut without attaining a heaped load. When push cats are waiting for scrapers, increase loading time to achieve maximum loading. Make sure push cats use wait time to dress the cut. In some cases, it will increase production to use a dozer full time to dress the cut. At the end of a workday, take the time to shape the cut for good drainage.

NOTE: Maintaining adequate drainage throughout a cut and fill operation reduces compulsory downtime caused by bad weather.

The rule of thumb used for computing the number of push cats required for a scraper operation is to divide the scraper cycle time by the push cat cycle time. When computing cycle time for a scraper, take the total time of loading, hauling, unloading, and return; for instance,

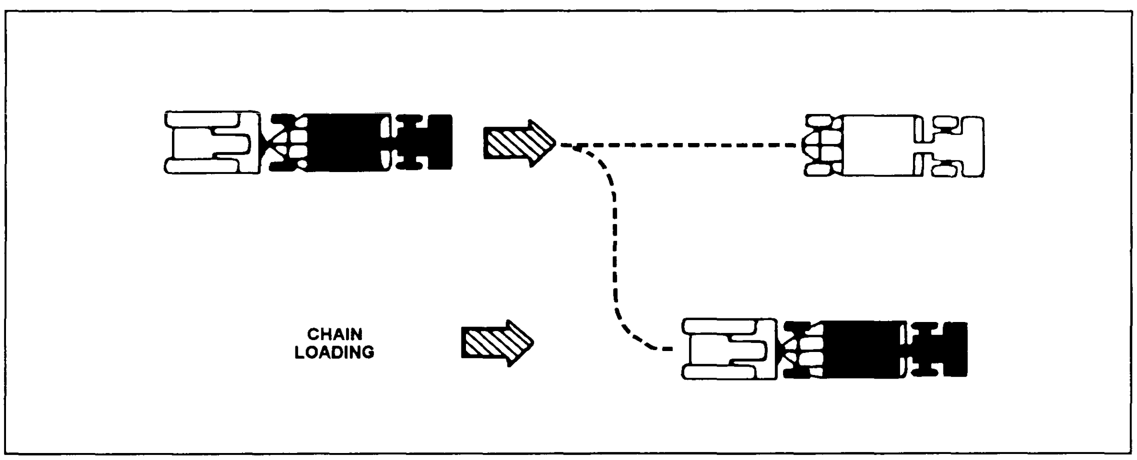


Figure 10-47.-Chain loading.

a 5-minute scraper cycle time divided by a l-minute push cat cycle time calls for five scrapers per push cat.

Turns

When making turns, turn within the shortest radius possible and at the highest safe speed When making turns to perform cut and spread operations, use the sequence shown in figure 10-48.

Haul Roads

Haul roads should be level and laid out so time is not wasted in maneuvering the scraper. A haul road that has drastic changes in elevation reduces production. Haul roads should be kept in good condition and moist. Roads kept moist, not wet, packs into a hard smooth surface that permits higher travel speeds. The moisture also controls dust that gets into all parts of the scraper, resulting in increased lubrication problems and premature wear. Additionally, controlling the dust allows better visibility.

If the haul road is a dirt road and needs grading, while returning to the cut, maintain the road occasionally with the scraper blade. This is performed by opening the apron approximately 12 inches above the cutting edges and the ejector positioned forward to within 6 inches of the cutting edge. The bowl is lowered until the cutting edges scrape about 1 to 2 inches of the road surface. By watching the road, the operator can vary the cutting action to trim small rises and carry the material to fill depressions, as the scraper travels the haul road These grading operations can be performed in second or third gear, depending upon road conditions. Grading should only be done when the road surface has ruts and rough or soft spots.

NOTE: Scrapers on the haul road should only travel in the highest gear that is safe for the road

Scraper Spacing Efficiently

Scrapers should be teamed by their speed whenever possible. The fastest scrapers should be assigned to one section of a job, while the slower ones are on another. They should use different haul roads if possible.

NOTE: No scraper can travel faster than the scraper ahead of it. Passing only increases the chances of accidents.

Scraper operators can help in traffic control by speeding up to close along gap and slowing down when too close. Efficient spacing supports the optimum use of the push cat. When unloading and lagging far behind the next scraper, spread the load at the beginning of a

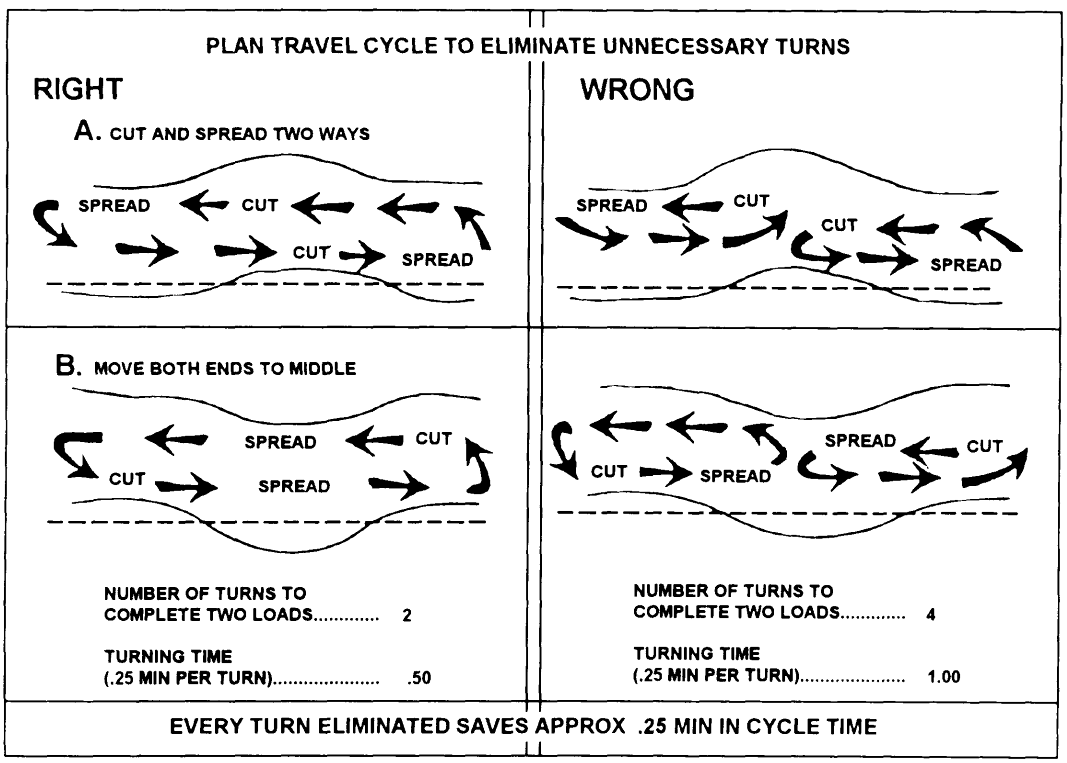


Figure 10-48.-Cut and spread sequence.

fill. When traveling too close to the next scraper, spread the load at the far end of the fall.

NOTE: Keep the scraper bowl as close to the ground as possible to lower its center of gravity and to keep it upright.

Spreading

Techniques for scraper spreading operations are as follows:

- Spread the first load at the start of the fill.
- Travel with subsequent loads over the previous fill, provided lifts are small.
- Make each following spread start at the end of the previous layer.
- Finish spreading in one full length before starting a new lane, so rollers can begin compaction.
- Route the scrapers to compact the fill. Overlapping the scraper tire tracks aids in the compaction of the entire area and reduces the compaction time necessary with a roller.
- Spread in the highest gear permitted by the condition of the fill area terrain.

NOTE: Slowly discharging loads at low speed slows down production and cycle time.

- Do not waste time on the fill. As soon as the load is spread, get the scraper back on the haul road and return to the cut. Plan your exit from the fill to avoid soft ground and detours around trees and other obstacles.
- As shown in figure 10-49, make the fill high on the outside edge. This prevents the scraper from sliding over the outside edge and helps in maintaining accurate slopes to desired heights. When the fill is not made in this manner, the scraper tends to work away from the edge of the fill, making it hard to maintain the correct slope. In inclement weather, build the low center up for drainage.

SCRAPER SAFETY

Safety precautions that apply to scrapers are as follows:

- Never operate a scraper at speeds that are unsafe.
- Always wear seat belts. Uneven terrain can cause a violent tilt of the scraper, causing possible personal injury by throwing you off or against the steering wheel if NOT secured in the operator's seat.

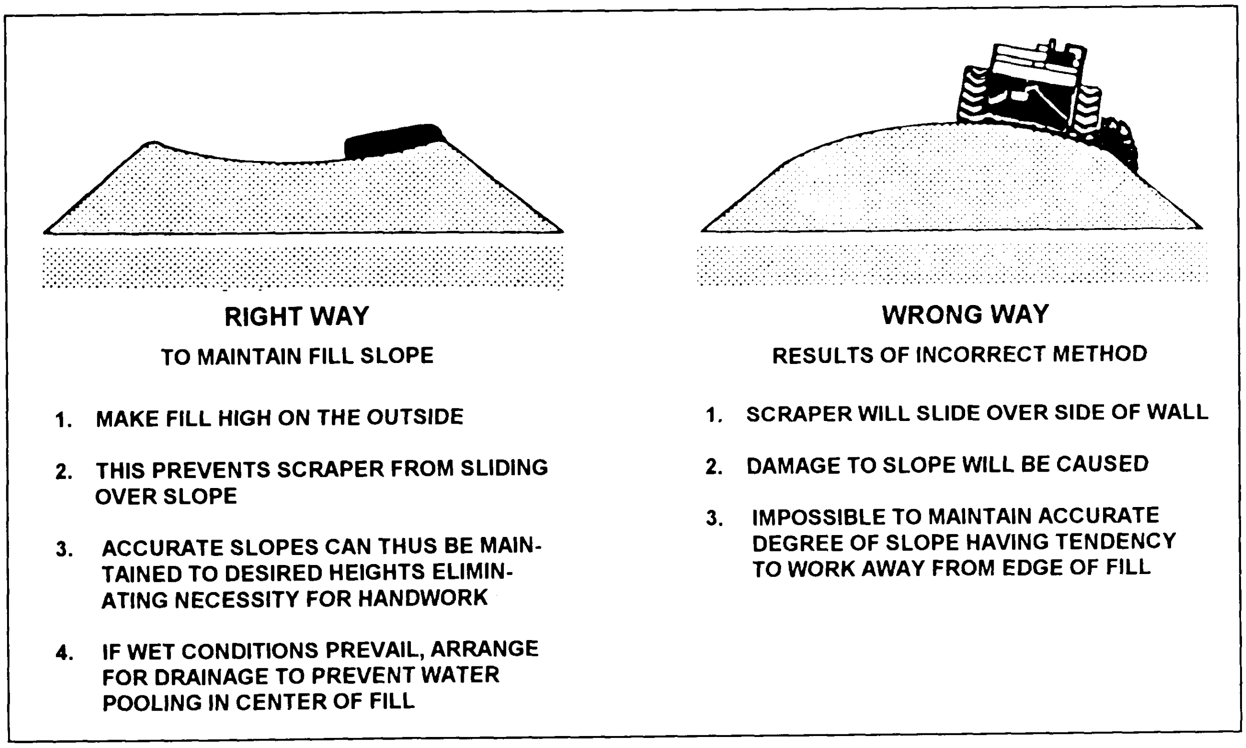


Figure 10-49.-Proper placement of fill material.

- Block up the scraper bowl and apron before performing any work on the cutting edges of the scraper.

- Keep the operator's cab clear of debris, grease, oil, and mud which can cause the operator to slip or fall.

- Never kick the scraper out of gear when going downhill. The increased speed will make control of the scraper very difficult. Keep the scraper in gear at all times and use the cutting edge to control the speed When the brakes fail to hold the load, lower and drag the scraper bowl.

- When securing the scraper, ensure the apron is closed and the bowl on the ground.

- Do NOT spread when turning.

- When working on slopes, always turn uphill.

- Do NOT drop the bowl suddenly; ease the cutting edge onto the ground.

- Load and spread when going downgrade, whenever possible.

- When constructing a fill, keep the outside edge high and the center low to prevent the scraper from sliding over the edge.

- When the scraper begins to fall off the fill, steer downhill, drop the bowl, and rapidly accelerate to maximum rpm. Do NOT attempt to turn the scraper back up the slope. Do NOT stop the forward motion of the scraper when there is any danger of the unit tipping over.

- Wear any required personal protective equipment, such as hard hats and steel toe safety shoes.

APPENDIX I

GLOSSARY

AGGREGATE— Crushed rock or gravel, screened to sizes for use in road surfaces, concrete, or bituminous mixes.

ANGLING DOZER (Angledozer)—A bulldozer with a blade that can be pivoted on a vertical center pin so as to cast its load to either side.

APRON— The front gate of a scraper body.

ASPHALT— A dark brown to black cementitious material in which the predominating constituents are bitumens that occur in nature or are obtained in petroleum processing. Asphalt is a constituent in varying proportions of most crude petroleums.

ASPHALT CEMENT— A fluxed or unfluxed asphalt specially prepared as to quality and consistency for direct use in the manufacture of asphalt pavements.

ASPHALT CONCRETE— High-quality thoroughly controlled hot mixture of asphalt cement and well-graded, high-quality aggregate, thoroughly compacted into a uniform, dense mass.

ASPHALT LEVELING COURSE— A course (asphalt aggregate mixture) of variable thickness used to eliminate irregularities in the contour of an existing surface before a superimposed treatment or construction.

ASPHALT, MEDIUM-CURING (MC)— Cutback asphalt, composed of asphalt cement and a kerosene type of diluent of medium volatility.

ASPHALT, RAPID-CURING (RC)— Cutback asphalt, composed of asphalt cement and naphtha or gasoline type of diluent of high volatility.

ASPHALT, SLOW-CURING (SC)— Cutback asphalt, composed of asphalt cement and oils of low volatility.

AUGER— A rotating drill having a screw thread that carries cuttings away from the face.

AUXILIARY— A helper or standby engine or unit.

AXIS OF ROTATION— The vertical line around which the upper structure rotates.

AXLE, LIVE— A revolving horizontal shaft.

BACKFILL— (1) The material used in refilling a ditch or other excavation. (2) The process of such refilling.

BAIL BLOCK— Block attached to a dragline bucket, through which rope line is reeved. Also referred to as "PADLOCK."

BAIL (BUCKET)— A yoke or spreader, hinged to the sides of a dragline bucket, to which is attached a connecting sheave or chain for hoisting and dragging operations.

BALL JOINT— A connection, consisting of a ball and socket, that will allow a limited hinge movement in any direction.

BANK— Specifically, a mass of soil rising above a digging or trucking level. Generally, any soil that is to be dug from its natural position.

BANK GRAVEL— Gravel found in natural deposits, usually more or less intermixed with fine material, such as sand or clay, and combinations thereof; gravelly clay, gravelly sand, clayey gravel, and sandy gravel indicate the varying proportions of the materials in the mixture.

BASE COURSE— The layer of material immediately beneath the surface or intermediate course. It may be composed of crushed stone, crushed slag, crushed or uncrushed gravel and sand, or combinations of these materials. It also may be bound with asphalt.

BANK YARDS— Yards of soil or rock measured in its original position (before digging).

BEDROCK— Solid rock, as distinguished from boulders.

BENCH— A working level or step in a cut that is made in several layers.

BINDER— (1) Fines which hold gravel together when it is dry. (2) A deposit check that makes a contract valid.

BITUMEN— A class of black or dark-colored (solid, semisolid, or viscous) cementitious substance, natural or manufactured, composed principally of high molecular weight hydrocarbons, or which asphalts, tars, pitches, and asphaltites are typical.

BLASTING MAT– A heavy, flexible fabric of woven wire rope or chain, used to confine blasts.

BLEEDING OR FLUSHING– Is the upward movement of asphalt in an asphalt pavement, resulting in the formation of a film of asphalt on the surface. The most common cause is too much asphalt in one or more of the pavement courses, resulting from too rich a plant mix, an improperly constructed seal coat, too heavy a prime or tack coat, or solvent-carrying asphalt to the surface. Bleeding or flushing usually occurs in hot weather.

BLUE TOPS— Grade stakes with blue tops to indicate finish grade level, usually a 2-inch by 2-inch by 6-inch hub stake.

BM— Bench mark.

BODY— The load carrying part of a truck or scraper.

BOGIE AXLE— Two or more axles, mounted to a frame so as to distribute the load between the axles and permit vertical oscillation of the axles.

BOOM CHORD— A main corner member of a lattice type of boom.

BOOM, CRANE— A long, light boom, usually of lattice construction.

BOOM HOIST— Mechanism to control the elevation of the boom and to support it.

BOOM LACING– Structural truss members at angles to and supporting the boom chords of a lattice type of boom.

BOOM, LATTICE— A long, light boom fabricated of crisscrossed steel or aluminum angles or tubing.

BOOM LENGTH— Boom length is a straight line through the center line of the boom pivot pinto the center line of the boom point load hoist sheave pin, measured along the longitudinal axis of the boom.

BOWL— (1) The bucket or body of a carrying scraper. (2) Sometimes the moldboard or blade of a dozer.

BUCKET— A part of an excavator that digs, lifts, and carries dirt.

BULLDOZER— (1) A tractor equipped with a front pusher blade. (2) In a machine shop, a horizontal press.

CAPILLARY ATTRACTION— The tendency of water to move into fine spaces, as between soil particles, regardless of gravity.

CASING— A pipe lining for a drilled hole.

CAT— (1) A trademark designation for any machine made by the Caterpillar Tractor Company. (2) Widely used to indicate a crawler tractor of any make.

CAT HEAD— A capstan winch.

CATWALK— A pathway, usually of wood or metal, that gives access to parts of large machines.

CENTRIFUGAL FORCE— Outward force exerted by a body moving in a curved line. It is the force that tends to tip a car over in going around a curve.

C-FRAME— An angling dozer lift and push frame.

CHECK VALVE— Any device that will allow fluid or air to pass through it in only one direction.

CHOKER— A chain or cable so fastened that it tightens on its load as it is pulled.

CIRCLE REVERSE— The mechanism that changes the angle of a grader blade.

CLAM— A clamshell bucket.

CLAMSHELL— (1) A shovel bucket with two jaws that clamp together by their own weight when it is lifted by the closing line. (2) A crane equipped with a clamshell bucket.

CLAMSHELL BUCKET— Usually consists of two or more similar scoops hinged together and a head assembly connected to the outer corners by struts. When the head and hinge are pulled toward each other, the scoops are forced together to dig and hold material. Control is by a holding line reeved over a boom point sheave and attached to the head assembly to support the bucket in open position and usually by a closing line also reeved over a boom point sheave, ending in a force amplifying tackle or other means between the head assembly and scoop hinge to close the bucket.

CLAMSHELL BUCKET, HYDRAULIC— Usually consists of two or more scoops hinged to a head assembly housing the hydraulic cylinder or cylinders and the force amplifying linkage to open and close the scoops and to supply the digging force for the scoops. The bucket assembly is suspended from the boom by a rope. Because digging ability is largely dependent upon bucket weight, buckets are supplied in various weight classes which range from light, for easily dug stockpiled materials, to heavy, for excavating hardpan material and the like.

CLAMSHELL EQUIPMENT— Machines with clamshell attachments are used to load material from stockpiles, gondola cars, barges, and the like, or from virgin soil generally out of small-area holes, deep trenches, or from below water. Orange peel buckets, grapples, and similar rope suspended attachments are included in this classification.

CLOSING LINE— The rope reeved from the hoist drum to control closing of a rope-operated clamshell bucket.

COFFERDAM— A set of temporary walls, designed to keep soil and/or water from entering an excavation.

COLLAR— A sliding ring, mounted on a shaft so that it does not revolve with it, used in clutches and transmissions.

COMPACTION— The act of compressing a given volume. Insufficient compaction of the asphalt pavement courses may result in channeling on the pavement surface. Compaction is usually accomplished by rolling.

CONVEYOR BELT— An endless belt of rubber-covered fabric that transports material on its upper surface.

CORRUGATIONS (WASHBOARDING) AND SHOVING— Are types of pavement distortion. Corrugation is a form of plastic movement typified by ripples across the asphalt pavement surface. Shoving is a form of plastic movement, resulting in localized bulging of the pavement surface. These distortions usually occur at points where traffic starts and stops, on hills where vehicles brake on the downgrade, on sharp curves, or where vehicles hit a bump and bounce up and down. They occur in asphalt layers that lack stability. Lack of stability may be caused by a mixture that is too rich in asphalt, has too high a proportion of fine aggregate, has coarse or fine aggregate that is too round or too smooth, or has asphalt cement that is too soft. It may also be due to excessive moisture, contamination due to oil spillage, or lack of aeration when placing mixes using liquid asphalt.

CRACKS— Breaks in the surface of an asphalt pavement.

CRACKS, ALLIGATOR— Interconnected cracks forming a series of small blocks resembling an alligator's skin or chicken wire, caused by excessive deflection of the surface over unstable subgrade or lower courses of the pavement.

CRACKS, EDGE JOINT— Are the separation of the joints between the pavement and the shoulder, commonly caused by the alternate wetting and drying beneath the shoulder surface. Other causes are shoulder settlement, mix shrinkage, and trucks straddling the joint.

CRACKS, LANE JOINT— Longitudinal separation along the seam between two paving lanes caused by a weak scam between adjoining spreads in the courses of the pavement.

CRACKS, REFLECTION— Cracks in asphalt overlays that reflect the crack pattern in the pavement structure underneath. They are caused by vertical or horizontal movements in the pavement beneath the overlay, brought on by expansion and contraction with temperature or moisture changes.

CRACKS, SHRINKAGE— Are interconnected cracks forming a series of large blocks, usually with sharp corners or angles. Frequently they are caused by volume change in either the asphalt mix or in the base or subgrade.

CRACKS, SLIPPAGE— Are crescent-shaped cracks that are open in the direction of the thrust of wheels on the pavement surface. They result when there is a lack of good bond between the surface layer and the course beneath.

CRANE— A mobile machine, used for lifting and moving loads without the use of a bucket.

CRANE MATS— A device, used for supporting machines on soft ground, usually of timber construction.

CREEP— (1) Very slow travel of a machine or a part. (2) Unwanted turning of a shaft due to drag in a fluid coupling or other disconnect device.

CRUMBER— A blade that follows the wheel or ladder of a ditching machine to clean and shape the bottom.

CULVERT— A pipe or small bridge for drainage under a road or structure.

CURVE, VERTICAL— A change in gradient of the center line of a road or pipe.

CUTBACK ASPHALTS— Mixture of asphalt cement and a cutting agent. There are three main types.

DATUM— Any level surface taken as a plane of reference from which to measure elevations.

DEADHEADING— Traveling without a load, except when traveling from the dumping area to the loading point.

DENSITY— The ratio of the weight of a substance to its volume.

DIESELING— In a compressor, explosions of mixtures of air and lubricating oil in the compression chambers and/or other parts of the air system.

DOLLY— A unit consisting of a draw tongue, an axle with wheels, and a turntable platform to support a gooseneck trailer.

DOUBLE-CLUTCHING— Disengaging and engaging the clutch twice during a single-gear shift (change of gears) to synchronize gear speeds.

DOWNSTREAM FACE— The dry side of a dam.

DOZER— Abbreviation of bulldozer.

DRAFT— Resistance to movement of a towed load.

DRAGLINE— A crane with a dragline attachment, used to excavate material from below the grade on which the crane is sitting.

DRAWBAR— A fixed or hinged bar, extending to the rear of a tractor and used as a fastening for lines and towed machines or loads.

DRAWBAR HORSEPOWER— A tractor's flywheel horsepower minus friction and slippage losses in the drive mechanism and the tracks or tires.

DRAWBAR PULL— The pull that a tractor can exert on a load attached to the drawbar. Depends on power, weight, and traction.

DRILL COLLAR— Thick-walled drill pipe, used immediately above a rotary bit to provide extra weight.

DRILL, PERCUSSION— A drill that hammers and rotates a steel and bit. Sometimes limited to large blast hole drills of the percussion type.

DRILL PIPE— The sections of a rotary drilling string, connecting the kelly with the bit or collars.

DRIVE SPROCKET— A drive roller with teeth that engage matching recesses or pins (bushings) in the track assembly.

DROP HAMMER— A pile-driving hammer that is lifted by a cable and that obtains striking power by falling freely.

DRUM, SPUDDING— In a churn drill, the winch that controls the drilling line.

EJECTOR— A clean-out device, usually a sliding plate.

EMBANKMENT— A fill whose top is higher than the adjoining surface.

EROSION— Wear caused by moving water or wind.

FACE— (1) The more or less vertical surface of rock exposed by blasting or excavating or the cutting end of a drill hole. (2) An edge of rock used as a starting point in figuring drilling and blasting. (3) The width of a roll crusher.

FACTOR OF SAFETY— The ratio of the ultimate strength of the material to the allowable or working stress.

FAIRLEAD— A device which lines up cable so that it will wind smoothly onto a drum.

FEATHER— To blend the edge of new material into the old surface smoothly.

FIFTH WHEEL— The weight-bearing swivel connection between highway type of tractors and semitrailers.

FILL— An earth or broken rock structure or embankment. Soil or loose rock used to raise a grade. Soil that has no value except bulk.

FLOAT— In reference to a dozer blade, to rest by its own weight or to be held from digging by upward pressure of a load of dirt against its moldboard.

FOOT— In tamping rollers, one of a number of projections from a cylindrical drum.

FOOT-POUND— Unit of work equal to the force in pounds multiplied by the distance in feet through which it acts. When a 1-pound force is exerted through a 1-foot distance, 1 foot-pound of work is done.

FOUR BY FOUR (4 x 4)— A vehicle with four wheels or sets of wheels, all engine-driven.

FREE FALL— Lowering of the hook (with or without a load) without it being coupled to the power train with the lowering speed being controlled by a retarding device, such as a brake.

FRONT-END LOADER— A tractor loader with a bucket that operates entirely at the front end of the tractor.

FROST— Frozen soil.

FROST LINE— The greatest depth to which ground may be expected to freeze.

GANTRY— (1) An overhead structure that supports machines or operating parts. (2) An upward extension of the revolving frame of a crane that holds the boom line sheaves.

GEAR— A toothed wheel, cone, or bar.

GOOSENECK— An arched connection, usually between a tractor and a trailer.

GRADE— (1) Usually the elevation of a real or planned surface. (2) Also means surface slope.

GRADER— A machine with a centrally located blade that can be angled to cast to either side with an independent hoist control on each side.

GRADE STAKE— A stake indicating the amount of cut or fill required to bring the ground to a specified level.

GRAVEL— (1) Rock fragments from 2mm to 64 mm (.08 to 2.5 inches) in diameter. (2) A mixture of such gravel with sand, cobbles, boulders, and not over 15 percent fines.

GRIEF STEM— See "KELLY."

GRIZZLY— (1) A coarse screen used to remove oversize pieces from earth or blasted rock. (Maybe spelled "grizzlie.") (2) A gate or closure on a chute.

GROUND PRESSURE— The weight of a machine, divided by the area in square inches of the ground directly supporting it.

GROUSER— Projecting lug(s) attached to or integral with the ma chine track shoes to provide additional tract ion.

GRUBBING— Digging out roots.

HAND LEVEL— A sighting level that does not have a tripod, base, or telescope.

HARDPAN— (1) Hard, tight soil. (2) A hard layer that may form just below plow depth on cultivated land.

HAUL DISTANCE— (1) Is the distance measured along the center line or most direct practical route between the center of the mass of excavation and the center of mass of the fill as finally placed. (2) It is the distance the material is moved.

HOLDING LINE— The cable reeved from a hoist drum for holding a clamshell bucket or grapple suspended during dumping and lowering operations.

HOOK, PINTLE— A towing bracket, having a fixed lower part and a hinged upper one, which, when locked together, makes a round opening.

HOPPER— A storage bin or a funnel that is loaded from the top and discharges through a door or chute in the bottom.

HORSEPOWER— (1) A measurement of power that includes the factors of force and speed. (2) The force required to lift 33,000 pounds 1 foot in 1 minute.

HORSEPOWER, DRAWBAR— Horsepower available to move a tractor and its load after deducting losses in the power train.

HOLDING LINE— The hoist cable for a clamshell bucket.

IDLER— Large end roller of a track assembly at the opposite end from the drive sprocket; the roller is not power-driven.

INJECTOR— In a diesel engine, the unit that sprays fuel into the combustion chamber.

JACK— (1) A mechanical or hydraulic lifting device. (2) A hydraulic ram or cylinder.

JACKKNIFE— A tractor and trailer in such an angle that the tractor cannot move forward.

JAW— (1) In a clutch, one of a pair of toothed rings, the teeth of which face each other. (2) In a crusher, one of a pair of nearly flat faces separated by a wedge-shaped opening.

JIB BOOM— An extension piece, hinged to the upper end of a crane boom.

KELLY— A square or fluted pipe which is turned by a drill rotary table, while it is free to move up and down in the table. Also called a "GRIEF STEM."

LAGGINGS— Removable and interchangeable drum spool shells for changing the hoist drum diameter to provide variation in rope speeds and line pulls.

LAY— The direction of twist in wires and strands in wire rope.

LAY, REGULAR— A wire rope construction in which the direction of twist of the wires in the strands is opposite to that of the strands in the rope.

LEVEL— To make level or to cause to conform to a specified grade.

LIFT— A layer or course of paving material, applied to a base or a previous layer.

LIP— The cutting edge of a bucket. Applied chiefly to edges including tooth sockets.

LOAD BINDER— A lever that pulls two grab hooks together and holds them by locking over the center.

LOADER, FRONT-END— A tractor loader that both digs and dumps in front.

LOAM— A soft easily worked soil, containing sand, silt, and clay.

LOOSE YARDS— Measurement of soil or rock after it has been loosened by digging or blasting.

LOW BED— A machinery trailer with a low deck.

LUFFING— Operation of changing the boom angle in the vertical plane. See "BOOM HOIST."

LUG DOWN— To slow down an engine by increasing its load beyond its capacity.

MASS DIAGRAM— A plotting of cumulative cuts and fills, used for engineering computation of construction jobs.

MINERAL DUST— The portion of the fine aggregate passing the 0.075-mm (No. 200) sieve.

MINERAL FILLER— A finely divided mineral product, at least 70 percent or which will pass a 0.075-mm (No. 200) sieve. Pulverized limestone is the most commonly manufactured filler, although other stone dust, hydrated lime, portland cement, and certain natural deposits of finely divided mineral matter are also used.

MISFIRE— Failure of all or part of an explosive charge to go off.

MOLDBOARD— A curved surface of a plow, dozer blade, grader blade, or other dirt-moving implement that gives dirt moving over it a rotary, spiral, or twisting movement.

MUCK— Mud rich in humus.

OIL— Any fluid lubricant, but not water.

OPEN-GRADED ASPHALT FRICTION COURSE— A pavement surface course that consists of high-void, asphalt plant mix that permits rapid drainage of rainwater through the course and out the shoulder. The mixture is characterized by a large percentage of one-sized coarse aggregate. This course prevents tire hydroplaning and provides a skid-resistant pavement surface.

OPTIMUM— Best.

OSCILLATION— Independent movement through a limited range, usually on a hinge.

OUTRIGGER— An outward extension of a frame that is supported by a jack or block, used to increase stability.

OVERBURDEN— Soil or rock lying on top of a pay formation.

PAN— A carrying scraper.

PAWL— A tooth or set of teeth, designed to lock against a ratchet.

PENETRATION— The consistency of a bituminous material expressed as a distance in tenths of a millimeter (0.1mm) that a standard needle penetrates vertically a sample of the material under specified conditions of loading, time, and temperature.

PERCENT OF GRADE— Measurement of slope, expressed as the ratio of the change in vertical distance (rise) to the change in horizontal distance (run) multiplied by 100.

PETCOCK— A small drain valve.

PILE CAP— An adapter between the pile-driving unit and the upper end of the pile, used to center the pile under the pile-driving unit and to reduce damage to the upper end of the pile.

PIONEERING— The first working over of rough or overgrown areas.

PIONEER ROAD— A primitive, temporary road built along the route of a job to provide means for moving equipment and men.

POND— A small lake.

PORT— Left side of a ship or boat.

POTHOLE— A small steel-sided hole caused by traffic wear.

POWER EXTRACTOR— A unit hanging from the hoist line or block and attached to the upper end of the pile and containing within itself a member (ram) which is caused to reciprocate either by means of externally supplied air, steam, or hydraulic fluid under pressure, or by internal combustion within the unit. Upward pull from the hoisting machinery supplements the extraction forces.

POWER PLANT— The power plant (or plants) includes the prime power source (which may be an internal combustion engine or electric motor) and the power takeoff.

POWER TAKEOFF— A place in a transmission or engine to which a shaft can be so attached as to drive an outside mechanism. A power takeoff may be direct drive, friction clutch, fluid coupling, hydrodynamic torque converter, hydrostatic, or an electric generator type.

POWER TRAIN— All moving parts connecting an engine with the point or points where work is accomplished.

PRIME MOVER— A tractor or other vehicle used to pull other machines.

PROPELLER SHAFT— Usually a main drive shaft fitted with universal joints.

PSI or psi— Pressure in pounds per square inch.

PUMP, DIAPHRAGM— A pump that moves water by the reciprocating motion of a diaphragm in a chamber having inlet and outlet check valves.

PUSHER— A tractor that pushes a scraper to help it pick up a load.

RAKE BLADE— A dozer blade or attachment made of spaced tines.

RAKE, ROCK— A heavy-duty rake blade.

RANGE POLE— A pole marked in alternate red and white bonds, 1 foot high.

RED TOPS— Grade stakes with red tops to indicate finish subgrade level, usually a 2-inch by 2-inch by 6-inch hub stake.

REFUSAL— The depth beyond which a pile cannot be driven.

RIPRAP— Heavy stones placed at the edge of the water to protect the soil from waves or current.

RIPPER— A towed machine, equipped with teeth, used primarily for loosening hard soil and soft rock.

ROAD OIL— A heavy petroleum oil, usually one of the slow-curing (sc) grades.

ROCK— The hard, firm, and stable parts of earth's crust.

ROTARY TILLER— A machine that loosens and mixes soil and vegetation by means of a high-speed rotor equipped with tines.

RPM or rpm— Revolutions per minute.

RUBBLE DRAINS— French drains.

RULE OF THUMB— A statement or formula that is not exactly correct but is accurate enough for use in rough figuring.

SAND— A loose soil, composed of particles between 1/16 mm and 2 mm in diameter.

SCRAPER (Carrying scraper) (Pan)— A digging, hauling, and grading machine, having a cutting edge, a carrying bowl, a movable front wall (apron), and a dumping or ejecting mechanism.

SCREEN— (1) A mesh or bar surface, used for separating pieces or particles of different sizes. (2) A filter.

SEIZE— To bind wire rope with soft wire to prevent it from raveling when it is cut.

SEMITRAILER— A towed vehicle whose front rests on the towing unit.

SHEEPSFOOT— A tamping roller with feet expanded at their outer tips.

SHOE— (1) A ground plate, forming a link of a track or bolted to a track link. (2) A support for a bulldozer blade or other digging edge to prevent cutting down. (3) A clean-up device following the buckets of a ditching machine.

SIDECASTING— Piling spoil alongside the excavation from which it is taken.

SNATCH BLOCK— A pulley in a case that can be easily fastened to lines or objects by means of a hook, ring, or shackle.

SPILLWAY— An overflow channel for a pond or a terrace channel.

SPROCKET— A gear that meshes with a chain or a crawler track.

STOCKPILE— Material dug and piled for future use.

STONE— Rock.

SUPERCHARGER— A blower that increases the intake pressure of an engine.

SURGE BIN— A compartment for temporary storage.

SWELL (Growth)— Increase of bulk in soil or rock when it is dug or blasted.

SWING LOCK— A swing lock is a mechanical engagement device, not dependent on friction, to hold the upper structure in one or more fixed positions with respect to the undercarriage. When provided, it must be constructed to prevent unintentional engagement or disengagement.

SWING BRAKE (Dynamic)— A dynamic swing brake is a device to stop, hold, or retard the rotating motion of the upper structure with respect to the undercarriage.

SWITCHBACK— A hair-pin curve.

TAG LINE— A line from a crane boom to a clamshell bucket that holds the bucket from spinning out of position.

TAMP— Pound or press soil to compact it.

TERRACE— A ridge, a ridge and hollow, or a flat bench built along a ground contour.

TERRAIN— Ground surface.

TOE— The projection of the bottom of a face beyond the top.

TOOTH ADAPTER— Main part of bucket or dipper to which a removable tooth is fastened.

TOPOGRAPHIC MAP— A map, indicating surface elevation and slope.

TOPSOIL— The topmost layer of soil, usually refers to soil containing humus that is capable of supporting good plant growth.

TORQUE— The twisting force exerted by or on a shaft (without reference to the speed of the shaft).

TRACK— A crawler track.

TRACK CARRIER ROLLERS— Rolling elements in/on a track frame that support and guide the upper track shoes or chain.

TRACK SHOES— The members of the track assembly that distribute the load to the supporting surface.

TRACTION— The total amount of driving push of a vehicle on a given surface.

TRENCH— A ditch.

TRUNNION (Walking beam or bar)— (1) An oscillating bar that allows changes in angle between a unit fastened to its center and another attached to both ends. (2) A heavy horizontal hinge.

UNDERCARRIAGE— The undercarriage is an assembly that supports the upper structure of the crane. It consists of an undercarriage frame, a swing bearing, or hook and load rollers, travel mechanism, and steering mechanism. The undercarriage may be either a crawler or wheeled type.

VISCOSITY— The resistance of a fluid to flow. A liquid with a high viscosity rating will resist flow more readily than will a liquid with a low viscosity. The Society of Automotive Engineers (S.A.E.) has developed a series of viscosity numbers for indicating viscosities of lubricating oils.

VOIDS— Empty spaces in a compacted mix, surrounded by asphalt-coated particles.

VOLTS— The electromotive force that will cause a current of 1 ampere to flow through a resistance of 1 ohm.

WATERLOGGED— Saturated with water. If conditions are too wet, you will be unable to work construction equipment.

WATERSHED— Area that drains into or pasta point.

WATER TABLE— The surface of underground, gravity-controlled water.

WHEEL AND AXLE ARRANGEMENT— The wheeled undercarriages.

WINCH— A drum that can be rotated so as to exert a strong pull while winding in a line.

WINDROW— A ridge of loose dirt.

WING WALL— A wall that guides a stream into a bridge opening or culvert barrel.

WORKING CYCLE— A complete set of operations. In an excavator, it usually includes loading, moving, dumping, and returning to the loading point.