Equipment Operator Training

Motor Grader

Washington State Department of Transportation
taff Development Branch

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This manual is solely concerned with grading methods and how to get the best work out of your grader.

It is designed to provide fundamental concepts and practices for operating graders consistent with the Washington State Transportation maintenance program.

The comprehensive range of graders covers four-wheel and six-wheel machines and in some cases these have all-wheel drive and all-wheel steer.

There are also six-wheel machines which feature leaning front wheels.

Grading methods for machines with leaning front wheels differ in some respects from methods used for other types, but grading instruction for all graders has been included in this manual.

The illustrations throughout show typical graders in action and are not intended to depict any particular model.

No attempt has been made to relate the operation of the graders to the controls, as these vary with each model and it is therefore essential for the operator to study the operating instructions for his machine in the Instruction Book or the Operator’s Manual before moving on to study grading techniques.

We begin with the most elementary instruction so that new operators may make a start and then move on to all forms and situations of grading where, it is hoped, even the experienced operator will find something to improve performance.
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Safety Rules

Since safety is a term all operators should be concerned with when operating equipment of any kind, let us begin this manual with some safety rules for operating graders at any time.

1. Prepare for safe operation by reading the manual for the machine and knowing where all controls are located and what they operate.

2. Be sure no one is under or around the machine before starting.

3. Mount the machine using hand holds and steps provided; face the machine and do not use the blade for a step.

4. Check all controls to be sure they are operating correctly before putting the machine to work.

5. Do not leave the machine unattended with the engine running.

6. When shutting down, always cool engine 3 to 5 minutes, lower all hydraulic equipment to the ground, and set parking brake before leaving the cab.

7. Dismount from the machine carefully using steps and handholds provided. Face the machine and do not use steering wheel or control levers for handholds.

8. Never coast the machine with transmission in neutral or with clutch disengaged. Maintain a ground speed consistent with conditions.

9. When you must tow or pull a unit, make sure the chain or cable is capable of withstanding the expected pull and securely fastened.

10. Avoid operating too close to banks or overhangs.

11. Be sure to shut off the engine when refueling.
12. When you must work on hydraulic attachments in the raised position, be sure to block them securely with blocks which will not crush.

13. Keep your machine clean of dirt, grease, and oil in order to see broken welds and parts.

14. Watch out for buried cables, conduit, and pipes. Contact the utility companies before operating in suspect areas.

15. Keep windshield and windows clean at all times.

16. Practice good housekeeping and clean out the cab at the end of each day.

17. Always look behind you before backing up.

18. Never ride the clutch.

19. Use caution when doing bank-sloping and ditch work. Keep the blade close to, or on the ground.

20. Always use proper traffic control when working on the right of way.

A Careful Operator is the Greatest Safety Device There Is

This section will be broken into four areas: Pre-starting procedures, starting procedures, end-trip inspection, and general operating procedures.

Equipment Inspections

Pre-Start Procedures

1. Grease the machine according to the operator’s manual. As you grease the machine, check for loose, worn, or broken parts, hydraulic system leaks, worn hoses, and leaks under the machine.

2. Check engine oil level.
3. Check coolant level in the radiator.
4. Check belts for adjustment and wear.
5. Check hydraulic oil level if equipped with hydraulic controls.
6. Check power steering reservoir.
7. Check precleaner and connections and dump the dust cup if the machine has one.
8. Check fuel level.
9. Check transmission oil level according to the manufacturer's operator's manual.
10. Lubricate the blade circle with grease.
11. Check tires, wheels, and lug nuts.

**Starting Procedures**

1. Make sure parking brake is set and place the transmission in neutral.
2. If appropriate, depress the clutch to lighten the load on the starter.
3. Never operate the starter more than 30 seconds. Then wait 2 minutes before using the starter again.
4. After the engine starts, check all gauges to see if they are operating. Also, check clutch, steering, lights, and controls. Other checks may be necessary on certain types of machines, but these points cover the general checks.
5. Use all controls to make sure they operate and to warm up hydraulic oil.

**General Shutdown Procedures and End Trip Checks**

1. Always park the machine as near to level as possible.
2. Always idle the engine for 3 to 5 minutes before shutting down.
3. Lower all hydraulic equipment to the ground and set the parking brake before leaving the cab.

4. Make a walk-around check for:
   a. Loose, worn, or broken parts.
   b. Hydraulic system hose and connection leaks.
   c. Any oil, grease, coolant, or fuel leaks.
   d. Tire and wheel defects.

5. After shutting down, check fuel, oil, coolant levels, and blade wear so that needed items can be brought out in the morning.

**Basic Facts and Terms**

Here are some general operating tips to help prolong machine life and give fewer breakdowns:

- Keep dirt out of engine openings by wiping off dirt and grease before opening filler necks and dipstick tubes.
- Be sure that containers used to carry oil and fuel are kept clean.
- Do not pour coolant into a hot engine unless conditions make it absolutely necessary.

Under such conditions, let the engine idle while pouring coolant in slowly. It is always a good idea to fuel at night in order to prevent condensation in the tank. Always come to a complete stop before changing directions.

Always use the decelerator, or throttle, to slow engine speed when shifting gears. Avoid unnecessary speed, particularly on rough ground. Do not spin the wheels, as this is hard on the machine and tires and also makes the surface rough. Always engage the clutch slowly and do not jerk the machine.
Something to always keep in mind is the basic design of any machine that you are operating. Remember that a motor grader is basically designed to level or smooth an area. It has a long wheelbase so that it can span short depressions or humps. The blade is carried in the center so that the hump can be cut off, or a depression filled, by the action of the machine. Do not "fight" the controls as this will keep the machine from performing its job. The tandem wheels also allow the wheels to rise and fall without a severe effect on the frame of the machine.

The moldboard is pulled by a draw bar which is fastened in the center of the front wheels. Remember that this is designed to take stress when it is pulled, and do not apply heavy pressure when the blade is lowered and you are operating in reverse.

The moldboard is attached to the circle near the center. This makes it necessary to watch both ends of the blade when operating. The reason for this is that when you lift one end of the blade the other end will go down about one-fourth the distance. Also, if the circle is not level, the blade setting will change if you change the angle of the blade. All these factors make it difficult to change blade settings while moving, so the fewer changes you make while moving, the better your work will be.

It is also important to learn to operate the machine while sitting down, so that you can feel movement in the machine. Learn to drive the machine in a straight line. This can best be done by watching ahead, lining up some object, and driving toward it. Do most of your turning around in the barrow-pits to avoid tearing the edge of the roadway with the tandems.

The following are terms normally used in describing grader operation:

A Sharp Blade — This refers to the angle of the blade and will be an angle greater than 30° from center, or straight across.
A Flat Blade — This also refers to the blade angle and will be from center (or straight) to 30°.

Pitch — This is the angle the cutting edge sits in relation to the road.

Heel — Trailing edge of blade.

Toe — Leading edge of blade.

Ice Blades — Serrated or saw-tooth cutting edges.

Loose Blade — This refers to setting the blade so that it touches the surface, but the weight of the blade is supported by the machine.

Tight Blade — This is setting the blade so that it has some down-pressure on the surface.

There are a lot of factors that influence blade settings. We will discuss these in the operating section of this manual, as they pertain to the different operations being performed. Try to make as few changes as possible while moving and your work will come out better. Always remember that when you adjust one end of the blade, the other end will also need adjustment. If you raise one end of the blade, the other will go down about one-fourth of the distance. Your blade setting will also change if you side-shift or turn the blade. All these factors are the reason why it is better to make as small, and as few changes as possible while moving. The machine will work to level the area if you set it right before starting a pass. Learn the “feel” of the controls on your machine so that you know how fast or slow they move the blade.

Adjustments

The blade is controlled in a number of ways. The ends can be raised or lowered independently of each other or together. It may be positioned across the line of travel, parallel to it, or at any angle. It can be shifted to the side and into a vertical position by power. There are also mechanical adjustments for extending its range.
The blade is ordinarily kept near the center of the tipping adjustment so that the top of the blade is directly over the cutting edge. Increasing the lean forward decreases cutting ability and causes the blade to ride over its load rather than to push it. It diminishes the likelihood of catching on solid obstructions and may be used for rapid, light planing of rather regular surfaces and for mixing operations. When leaned back, the blade cuts readily but tends to let the load ride over its top, and to dig into obstructions. In machines not carrying a scarifier this tilt may be used to cut hard surfaces.

**Blade Control**

The blade or moldboard (1) is the principle tool of the grader. It is carried by a rotating circle (2) and is readily maneuverable to a wide range of cutting positions by the hydraulic controls (3) (see Figure 1, Page 7).

The blade and circle are mounted on an “A” frame (4) which is supported at the front of the machine by a ball joint (5) also known as the “goose neck.”

Movement and positioning of the blade is shown in the following pages, but first refer to the appropriate instruction book or operator’s manual for details on the operating controls that are applicable to your particular grader.

**Side-Shift the Blade**

Side-shift the blade to the right and left with ram (6) (see Figure 2).

**Lift the Blade**

Lift and lower the blade with rams (7) and (8) using both rams to keep blade horizontal and then separately to raise left- or right-hand side (see Figure 2).
Rotate the Circle

Rotate the circle and blade with the hydraulic motors (9) (see Figure 1). (If circle lock is fitted, press control pedal to unlock: releasing pedal automatically locks circle again.)
Figure 2
Circle Side-Shift

Side-shift the circle to right and left, remembering that the movement to the left is limited by the mounting of the circle side-shift ram (10). Figure 1, Page 7, shows side-shift with ram (10) on right-hand side.

Some types of grader have side-mounted ram (10), and other types are fitted with centrally mounted ram and link (11). Both types can be adjusted for right- or left-hand high lift operation.

If left-hand high-lift operation is required, these rams must be changed over and the blade side-shift ram adjusted on the blade. Detailed instructions for changing over are given in the operator’s manual.

All blade movements described so far should be practiced, with the machine stationary, until they can be performed with ease.

Blade Pitch

The vertical angle of the blade can be adjusted, either manually, (Figure 3), or by power tilt rams, if these are fitted (see Figure 4 and Item 12, Figure 1 on Page 7).

The adjustment is made to suit the type of work the blade has to do.

When cutting hardpan or clay, the blade should be set back at the top. This is the most effective cutting angle.

For most normal grading work, the blade is set to a more vertical position.

General maintenance, where a spreading or dragging action is required, is best done with blade set forward at the top.
Blade High Lift

Having practiced and become familiar with the blade positions already described, the more complicated movement of blade high-lift can be considered. Remember that blade high lift cannot be performed on the left-hand side of the machine until the high lift-ram is changed over.

If a scarifier is fitted, it will be necessary to remove the center tooth to avoid it being fouled by the gooseneck at X. Three center teeth should be removed from some machines to avoid damage to hoses when going into high-lift (see Figure 5).

Detailed instructions for removing teeth are given in the operator’s manual.

Figure 5
Figure 6
To begin right-hand high-Lift, the blade should be parallel to, and not
more than, 3 inches above the ground (see Figure 6).

Rotate circle counterclockwise, slide the blade and side-shift the
cradle to the right.

Raise right-hand blade-lift ram to maximum.

Tilt circle up to the right by lowering left-hand lift ram and at the
same time raising circle high, lift ram.

Rotate circle clockwise to bring blade to position required.

Reverse the above movement to return blade to normal position.

Important Principles to Remember

Keep Rear Wheels on Level Ground

Keep rear wheels on level ground whenever possible — the grader is
easier to control and the blade setting is kept true.

Do Not Use High-Lift Unless Necessary

Do not use high-lift if the job can be done without it. The grader is
most efficient when the blade is under the frame, especially for rough
grading where more weight is required on the blade.

If possible, grate so that material is transferred downhill — it is easier
to work with gravity than against it.

Note: Equipment may vary, check your operator’s manual for
specific instructions for your grader.
Blade Carry Position

Rotate circle and tilt slightly up to bring the blade inside the grader wheels. In this position, the blade has less chance of causing damage. Always stow the blade like this for traveling between jobs and for parking or leaving the machine overnight.

Grading Techniques

In the following pages, it is assumed that the operator has studied the Operator’s Manual, is familiar with all controls, and has practiced the basic blade movements as described in the previous section.

Real proficiency means that all these operations can be carried out without having to stop and look at controls.

Basic Principles

Practically all grading is carried out with the grader traveling forward and with the blade lowered and set at an angle across the frame.

This action causes the cut material to “boil” along the blade to the outer edge where it is deposited as a windrow.

Forming and handling windrows is the basis of most grading operations.

Forming A Windrow

Set all wheels in the straight-ahead position and angle the blade until the heel is just outside the rear wheel.

The angle should be just sharp enough to let material roll freely off the heel of the blade.

Travel forward slowly in a low gear and lower blade into the ground — keeping it level. Try to match gear and speed to ground density.
Note action of material and try slight alterations of blade angle and forward speed until material rolls along blade and forms a windrow.

Most beginners do not angle the blade sufficiently to allow material to roll freely. They consequently use too much engine power. This is wasteful and causes unnecessary wear.

The expert operator learns to match engine power to work being done.

Most grader work places a side load on the machine, tending to push the front end sideways.

Lean the wheels in the same direction that the earth moves off the blade. This will help to counter the side thrust and keep the machine going straight ahead.

Articulated machines practice using the rear steer to offset the wheels. The front wheels are then steered to maintain correct direction.

In some operations, the windrow may pass between the rear wheels but never let the wheels run into a windrow.

Note: Figure 7 shows windrow being formed to the left. Similar, but opposite, positioning of blade and machine will, of course, form windrow to the right.
Figure 7
Handling a Windrow

Once formed, a windrow may have to be moved sideways across the road, or perhaps new material may have to be mixed with it. Whether moving or mixing, the routine is always to use the blade to pick up the windrow from one side of the machine and pass it to the other.

Loose windrowed dirt looks easy to move but this may not be the case. Depending on the type of material, you could have a full blade and get bogged down in just a few feet of travel.

For an articulated machine, offset it to place front wheels on one side of windrow and rear wheels clear of windrow that has been transferred.

In this position the front wheels pull the heel (rear end) of the blade and rear wheels push the toe (front end) of blade, and maximum balance and power are obtained. Also the blade may be more nearly square to the direction of travel and so handle more material and move it further.

To get more power behind the blade, lean the wheels to counter side thrust and angle the blade towards the windrow to reduce the load (see Figure 8).

Angle the blade to the left or right according to the job requirement. (Right-hand is illustrated and so moves windrow to the left). On approaching the windrow, lower your blade onto the ground, ensuring that it is level.

Travel slowly forward in a low gear and steer the machine until the toe of blade picks up the windrow. Note action of earth along blade and try alterations of blade angle, steering, and speed until the windrow passes smoothly from one side of the machine to the other.
Spreading a Windrow and Finishing

Windrows that have been deposited may have to be spread to a set thickness. Begin by having all the wheels straight and front wheels astride the windrow.

The blade must be level and square to the windrow.

Remember that for spreading, the blade pitch should be forward at the top. See Figures 3 and 4.

Set the cutting edge of your blade above the ground a distance equal to depth to which material is to be spread.
Figure 8
As your grader moves forward in low gear, the windrow is spread out by the blade under the full length of the cutting edge. If the windrow is very heavy, more than one pass may be needed to spread all material to the required depth.

**Finishing Without Leaving Tire Marks**

Occasionally, however, the surface may have to be finished to fine limits, for example, on air field runways and on highways.

In such cases, make the finishing pass with the blade only slightly angled and set to skim the surface. Set blade pitch forward at top.

With maximum circle and blade side-shift, it is possible to reach well beyond the rear tire and so leave a fine graded surface without tire marks.

Off-setting the wheels on articulated graders will, of course, increase this advantage.

Work in low gear and avoid sudden jerky movements on controls. With practice it will be possible to work to the finest limits.

**Grading Curves**

When grading curves always lean the top of the front wheels in the direction of the turn to help the grader to follow the sharper bends.

The ability to lean the front wheels can also be used to make minor adjustments to the point of the blade in order to follow an accurate line.

**Grading Around Obstacles**

**Do Not Force the Blade Through Obstructions**

Where the obstruction is not in the path of the wheels but only of the blade, side-shift the blade to avoid the obstruction, and return it to its former position when your are past the obstacle.
When an obstacle is large enough to be in the path of the wheels and blade, work as near as possible before steering away and side-shifting the blade, to make up for the away movement.

Take the blade as near to the obstruction as safety permits before side-shifting the blade and steer front wheels and side-shift the blade to return to the original path.

**Earth Road Maintenance**

Since light maintenance does not require moving large amounts of material, all types of grader operate in a similar manner. The blade is circled and side-shifted to make windrows outside or between rear wheels — dropped to cut high areas and lifted to fill low areas.

However, where conditions are rough, such as on haul roads where large dump trucks and other heavy equipment leave deep ruts and holes, it needs a powerful machine to level these out and keep the road in good condition.

Set the blade to cut just below ruts and potholes and move forward to form a windrow, using first or second gear depending on nature of ground and depth of cut.

If road is wide enough, work along one side and back along the other so that windrows form down the middle of the road. Set blade pitch back at the top for cutting.

The all-wheel-steer grader should be offset. This widens its stance and gives greater stability and more power at the blade.

On leaning-wheel machines, if load is heavy, lean front wheels over against the side thrust and angle the blade towards the delivery side to reduce the load.

When an even surface is obtained, set blade at right angles to respread windrows, angling blade vertically to give required camber or crown.
For spreading, blade pitch should be forward at the top. Use second gear if possible.

*Earth Road Construction*

**Remove Turf**

If sod has to be stripped off, set blade square to machine with cutting edge level. Lower the blade just sufficient to roll up sod as grader moves forward in first gear.

Usually only a few feet of sod can be cut before it has to be moved out of the way for the grader to continue. Once a long enough strip has been cleared, it can be widened much easier by taking about one-third of a blade length of sod at a time.

Work along road line as indicated by marker stakes if possible, but actual direction of operation may depend upon arrangements for disposal of sod.

*Level Surface*

After stripping sod, level the surface, filling hollows and holes left by trees, etc., with a light cut. Keep blade square and work along one side of road line and back down the other side. Use second gear.

*Mark Out Ditch*

The primary objective now is to establish a straight ditch line.

Line up front and rear wheels just inside ditch line stakes. Turn blade 45° forward and side-shift it to bring toe just to outside edge of right front tire (see Figure 9).

Raise the heel of blade until material will fall off its center to form windrow between rear wheels. Take a light cut of 9 to 12 inches at first. Work both sides of road line — up one side and down the other — using first gear. Keep front wheels upright on leaning-wheel graders unless there is much resistance, then wheels should be leaned away from the ditch to help keep to a straight line.
**First Ditch Cut**

When an accurate ditch line is established along both sides of the road, more material may be moved on successive passes. Line up the blade, as when marking out the ditch, and lower the toe to cut about 6 inches deeper or to a depth that will allow the grader to move forward smoothly.

Raise heel of blade to let windrow form between rear wheels as before. Use second gear if possible, and keep right-hand front and rear wheels in the ditch.

**Move Windrow Over**

After one or two ditch cuts, it will be necessary to move windrow over to the center out of the way. Trying to operate with tires running into soft, loose soil will only result in difficult and uneven work.

Use rear-steer to offset, leaving right-rear wheel in the ditch to help grader keep on course, and front wheels out of the ditch.

Set blade to pick up windrow and move it to center of road, passing it to left of rear wheels. Use second gear.

**Repeat Ditch Cuts**

Repeat ditch cuts as already described until required depth of ditch is reached, moving windrow over or spreading onto road as necessary.

**Grade Ditch Backslope**

When the ditch is deep enough, the backslope should be graded to leave a clean finish and prevent the edge from breaking down into the new ditch.

On leaning wheel machines, lean the top toward the bank slightly — this is an exception to the usual rule, but it helps in keeping the blade accurately positioned in the ditch.
Make the initial adjustment for backsloping operation out of the ditch. (Refer to your particular grader’s operation manual for adjustment procedures.)

Walk into the ditch and make the final adjustments by setting the heel of the blade at ditch bottom and the toe forward upon the backslope.

Pass windrow between rear wheels. Use first gear.

Clean Ditch

Material that might have fallen into the ditch during the backsloping operation may be removed by making a finishing pass to clean it up.

For Articulated Graders:

With right rear wheels in ditch and front wheels on the road, set blade to pick up windrow, move it up ditch inslope, and deposit it on the shoulder between rear wheels. Use first gear.

When ditch is cleared down both sides of road, move windrows into the center and spread, or haul away.

Finish Crown

If a crown to the earth road is required, set the blade square to the machine and angled vertically to give the required crown. The end of the blade should just reach the ditch shoulder. Take a very light cut and do not let dirt fall into ditch. Use second gear.

Flat Bottom Ditches

It is sometimes necessary to widen the ditch bottom for greater drainage capacity. The first step in making the flat bottom ditch is to cut another “V” ditch on the inside slope of the first, or as far from the center as the desired width of the flat bottom (see Figure 10).

More than one cut may have to be made to make the second ditch a similar depth to the first. Resulting windrows are to be moved up out of the way as before.
When the second "V" trench is cut, set the grader straight with right wheels in the ditch close to the backslope.

The full length of the blade should be placed level along the bottom of the ditch with toe behind the front wheel and heel at the base of the inner "V" trench. This will give a narrow, flat cut for the bottom of the ditch, and leaves the material on the inner slope to be moved up later onto the shoulder and spread (see Figure 11).

The rear wheel will compact the flat bottom.

Note that rotating the blade in the ditch will adjust the width of the flat bottom. Work in first gear, keeping the machine steady so as not to bite into the backslope with toe of the blade.

On leaning-wheel graders, lean top of front wheels away from ditch.
Ditch Cleaning

If ditch is dry, set right-hand front and rear wheels in ditch and toe of blade in bottom of ditch.

Angle the blade vertically so that material spills off the center of blade to deposit windrow between rear wheels. Use first gear.
Getting Out When Bogged Down

Should this happen, do not try to drive out — wheels will only spin and sink deeper. Use the down pressure of the blade to lift the machine out.

Set the blade level and square with timbers under the cutting edge. Lower the blade to the timbers and keep lift ram valves open until front wheels lift off the ground (see Figure 12).

Then using circle side-shift, move the whole front end of the grader over as far as possible towards firmer ground (see Figure 13).

Lower the wheels to the ground and repeat the operation until the grader can get sufficient grip to drive out.
**Grader Attachments**

**Using the Scarifier**

When the surface is too hard to be cut with the blade, the scarifier is used to loosen and tear it up and make it suitable for the blade to handle.

Set the scarifier teeth level and deep enough to get the required lifting action. On very hard surfaces, it may be necessary to remove some teeth to get better penetration. Remove alternate teeth from the block so that those remaining are evenly spaced (see Figure 14).

Obstructions, such as large stones, can be lifted out of the way with the scarifier.

Lower the scarifier into the ground and move the grader forward, very slowly, until scarifier teeth meet the underside of the stone.

Lift the scarifier while continuing to move slowly forward. STOP immediately if resistance becomes too strong — Do Not Force Grader Forward.

Repeat operation until stone is loose enough to be rolled aside.

**Snow Clearing**

The grader, fitted with an ice blade, is most effective at removing or smoothing compact snow and ice from the roadway. In ice blading operations, the blade should be rolled forward periodically during operation until you have reached a full roll — then start the procedure over again by rolling the moldboard back to the vertical position.

**“V” Snow Plow**

Make the first run with the “V” Plow down the middle of the road at a good speed.
Push back the snowbanks afterward with one side of the plow (see Figure 15).

With leaning-wheel graders, lean front wheels in the direction of the windrow to counter side thrust.

When using a grader fitted with a wing, during plowing operations, lean the wheels opposite the windrow to counter side thrust.
Figure 14
Figure 15
Operating Techniques

Work Patterns

The following discussion will concern work done by single graders. However, it is often efficient to have two or more of the machines working together, each performing one step in the work sequence. This speeds the job, produces better results than working small sections with individual machines, and reduces or eliminates blocking of roads with windrows.

Grading may be done in two general patterns. One is to work the two sides alternately, turning at the end of the strip. The second is doing one side at a time, with the reverse trips nonworking.

The pattern used is determined by the length of the strip being worked, the turning, spacing, and footing. The machine does its best work going forward, and this increased efficiency must be balanced against the time, labor, and risks involved in turning. In a long run, even difficult turning conditions may take an insignificant part of the working time, where easy turns may not be justified on a short run. A general rule is that a grader should not be turned if the strip is less than 1,000 feet long.

Side Casting

When the blade is set at an angle, the load pushed ahead of it tends to drift off to one side. The rolling action caused by the curve of the moldboard assists this side movement. As the blade is angled more sharply, the speed of the side-draft increases, so that the dirt is not carried forward as far, and a deeper cut can be made.

The sideward movement of the load exerts a thrust against the blade in the opposite direction, which tends to swing the front of the grader toward the leading edge. This thrust is handled by leaning the front wheels to pull against the side-draft, and steering enough to compensate for any side slipping, which occurs in spite of setting the front wheels to lean.
The most usual way in which to describe blade setting is to say that a blade set straight across is at zero and all other settings are described by their angular distance from that position. Most road shaping and maintenance is done at a 25° to 30° angle, with flatter settings for distributing windrows and sharper ones for hard cuts and ditching.

The angle of the blade is regulated by the circle-reverse control. The mechanism is self-locking and can be turned any desired amount. In some makes, it can be adjusted only while the blade is empty or doing light work, in others while pushing a heavy load.

Side shifting the circle from center will raise the blade and change its angle so that compensating adjustments may be necessary.

**Turns**

In turning, the front wheels are leaned all the way over in the direction the front of the frame is to turn, and left in this position for both forward and reverse movements until the turn is completed. If ditches or rough ground must be crossed, the machine should be backed into or across them. The oscillating tandem drive will readily climb ditches or obstructions, which would be difficult to cross with front wheels.

Turning may be a serious problem. Because of lack of a differential, the rear wheels drive straight forward and the tandem arrangement gives them considerable resistance to sideward movement. Weight on the front wheels is light and even when leaning properly, the tires may not have enough traction to turn the machine on loose material, but will skid and slide sideways.

If the front tires do grip enough for a sharp turn (minimum radius is about 36 feet), the rear wheels, on the inner side of the curve, must spin, or those on the outside drag enough to compensate for the different distances they travel. Turning a grader sharply, therefore, results in scuffing and gouging, which may be sufficient to damage soft surfaces.
It is therefore often necessary to make a gradual turn, either by swinging in a wide circle or by jockeying backward and forward, in order to avoid damaging or loosening the turn spot. It is sometimes possible to do most of the turning on ungraded areas where no damage will be done.

To make a left turn in cramped conditions, the wheels are leaned all the way to the left and turned by the steering wheel to the full left position. The grader is then moved forward until it runs out of room. The wheels are then turned to the right, but are kept leaning to the left, and the grader is backed up until there is enough room in front of it to complete the turn. The wheels are steered to the left again and the turn is completed. The process is the same for a right turn.

*Widening Shoulders*

This can be done in two ways. One way is to have trucks dumping material on the road surface. Repairing a washout on a steep shoulder is an example. Dump material in such a position that, as you work, the material will be carried into the location where it is needed. Work the material out over the shoulder leaving it high. By working the material out slowly you will pack it into the hole as you work. Always pull some material in towards the road and save it for finishing work. After you have the hole packed full, you can separate rocks and large chunks out of the windrow you saved by “high blading” it. Roll these over the shoulder and use the small material to put a “finish” on the work.

The other method is to bring the material up onto the road by cutting the back slope and ditch down. The material can be carried up onto the road and finished, as outlined above.

Any time you want to separate large rock out of material in a windrow, set the blade 3 or 4 inches above the ground. This will leave the finer material and carry the barge into a separate windrow.
Blade Mixing

The first area to discuss here is mixing salt and sand. Spread the material out at least the width of the blade, leaving a small windrow on one side. This will leave a smooth area several inches deep to spread the salt on. Roll the small windrows back over the top of the salt making a "sandwich" of salt and material. Then move to the outside and "pull" the material out of the "sandwich," in small windrows. This will use the full width of the blade to "roll" the material. The small windrow can then be pulled back to a central windrow. The salt and sand should then be mixed. If not, just repeat the process again.

For blade mixing oil, dry the material. It should then be put in a large windrow. When it is ready to mix, pull a small windrow out of the big windrow leaving about 2 or 3 inches of material with a slope toward the large windrow. Also leave a small windrow on the outside of the material pulled out. The tanker or distributor can then drive on this material to spread the asphalt.

The motor grader can then follow the tanker or distributor, covering the asphalt with a 2- or 3-inch lift, and continue in this manner until all the asphalt is in the material. Again, start pulling small windrows out.

Set your blade pitch so that the material will roll and mix thoroughly. If the material starts to "ball," put it in a large windrow and cut shallow lifts off the top. In this way, you can cut through the "oil balls."

In general, when mixing, always use caution not to cut too deep and get foreign material into the material being mixed. Always be sure to clean the area you are going to use, that is, cut weeds off and clean rocks, etc., off. Allow plenty of room to mix. Be careful not to lengthen your windrows out, and keep the ends tucked in. It will be much easier to mix if you keep the windrows even in depth.
Note: This procedure may not be applicable today, but is listed for reference.

**Blading Approaches**

Many times there will be a high area in the center of the approach. Set the machine on the oil surface and drive into the approach cutting this high area down and carrying the material toward the right of way boundary. Stop and leave the material in a pile near the end of the area to be worked. This may require more than one pass if the material is hard. When you have this completed, then turn the machine around and pick up the pile, carrying it toward the oil surface. If additional material is needed, dump it on top of the pile you already have. Leave a windrow set up on the outside edge of the approach and drop extra material, that may be in the blade, in a pile on the oil surface. When setting up this windrow, outline the approach with the windrow. Again, turn the machine around and set it up in the lane of traffic to turn into the approach. Pick up the pile and drive with front wheel on the outside edge of the windrow to carry the machine into the approach without falling in the depression. This will cause the blade to lay the material in with the correct curve and angle. Repeat this pass without running on the windrow, but straddling it to complete the first half of the approach. Any excess material can then be used on the other side of the approach by using the same steps. When completing the job, allow excess material to be strung out on the back of the approach.

The key to this operation is driving off the oil surface on an angle, as this puts the material down in the correct location.

**Spreading Bituminous Materials**

Road surfacing with asphalt, coated macadam or similar material is now usually done hot by a paving machine.

Should it be necessary, however, to use a grader on patching or repair work, or where a paving machine is not available, the blade should first be painted with oil to prevent material sticking.
If mixing has to be done, move material from one side of the road to the other and back again. Do this at a fair speed in third gear to give the material a good rolling action, with blade angled forward to about 30°.

When thoroughly mixed, spread material to the required depth with blade square across the machine and pitched forward at top, and front wheels astride the windrow using second gear.

**Patching**

This will be discussed in several subsections. Different types of patches will require slightly different methods. The first area to discuss is general steps. Always keep in mind the major objectives are to level the area, have a good ride, and to leave a good appearance. To accomplish this you must have straight shoulder lines and neat tapered ends. The ends must also have a taper in order to ride well.

**Preparations**

The first step in any patch is to cut off high spots and clean any old cracked or broken oil mat out of the hole. The surface must be clean in order for the asphalt tack coat to stick to the mat. It may be necessary to sweep some dust or dirt off to achieve a good bond. If the shoulder is higher than the mat, it is a good idea to cut this down level with the mat so water can drain away. Take all material to be wasted off in the barrow-pit and spread it out so that it is not a hazard to mowers. This also leaves a good appearance.

Be sure to extend the patch a short distance on each end of the patch so you can taper the ends. Try to stop and start the patch on level road, if possible. Spread the tack coat on the area to be repaired. Dump the premix on the tack coat only as this will help you to have neat ends. Try to avoid getting premix off of the tack coat at any time. Dump the premix, starting at the end you intend to work from, and stop before reaching the other end.
Single Lane

On half-road patches, take the premix to the center of the road on first pass. Operate with a moderately flat blade and a loose blade for the first pass. The flat blade will tend to even out premix which is not dumped evenly. The loose setting will keep you from cutting into the old mat and getting chunks in the material. When you reach the end of the tack, stop and lift the blade. At this time, you can use the back blade process. Drive forward and line the machine up so that you straddle the windrow. Go to a sharp and tight blade. When backing up, be sure to back in a straight line. The back of the blade will carry material back to the starting end of the patch and will also help to break up any chunks in the premix. Windrow position is very important. Be sure you do not put the material out too far towards the shoulder. It should be placed in the approximate center of the area on a two-lane road. Again, position the machine to straddle the windrow. This pass is the second most important pass you will make. Have the outside edge of the windrow falling where you want the edge of the patch to be. It should be setting on the edge of the existing mat. Be sure to drive straight during this pass. Before making this pass, be sure to have the windrow even in size, so premix will fall in a straight line coming off the blade. The exception to this might be, if there is a deep hole in the center, you would need more material there, but allow extra room during this area to hold a straight line on the outside of the windrow. When you reach the end of the patch stop. Raise the blade, leaving material in one pile on the end of the tack coat.

Second Pass

Turn the machine around and approach the patch from the opposite direction. Always stop close to the end of the patch and on level road. Set the toe of the blade directly behind the outside front wheel with a sharp angle. Be careful that the premix coming out of the blade will not fall under the rear wheels. Set the blade down using a loose blade. When you drive forward, put the outside front wheel slightly up on
the side of the windrow. The blade will pick up the pile and, as you
drive up on the windrow, this will raise the blade slightly making the
taper for that end. Be sure to drive the same height up on the wind-
row all the way across the patch. This will leave a level area, even
though it was not level to start with. When you reach the other end,
gradually edge back down onto the shoulder edge and this will lower
the blade putting the taper on this end. When the end of the tack coat
is reached, cut the wheels sharply into the road, and again stop and
leave material in a pile. The reasons for this is so the front wheels can
go over the pile, dropping the blade back down on the road to pick up
all material, to avoid adjustments. By running the tire on the edge of
the windrow, it will carry the machine level across holes and high
spots, and also pack the edge of the windrow so material does not
leak out of the blade ruining the straightness of the shoulder line. It
also gives you a level pass to guide from for the rest of the patch.
This is the most important pass of the patch.

When you back up, you can follow the tire tracks back packing the
edge line again. This is the only time you will ever run on a windrow,
as out on the mat it will make ridges.

Center Pass

The next pass is to carry material on out to the center of the road. Do
not use as sharp a blade setting on this pass, so that the windrow will
again even out. Position the machine to straddle the windrow and
carry premix to the center of the road. Stop on level road and tilt the
front wheels toward the toe of the blade. Use a flat blade and set it
down using a loose blade. As you drive forward, watch the blade and
when it has material in it, begin to straighten the front wheels. This
will raise the blade on both ends following the taper started by the
first lay-down pass. When you reach the other end, tilt the wheels
back down to run in that taper and cut the front wheels to the
shoulder and straddle the pile. On machines that do not have leaning
front wheels, the toe of the blade must be raised as you drive, and then the heel raised, to run the taper in. All other steps will be the same. Again, stop and raise the blade.

Finish Pass

Now turn the machine around and approach the patch stopping on level road. Again, use the wheel tilt method and set the blade at a sharp angle. You should have laid approximately two-thirds of the amount of premix that was dumped on the patch. Use the rest of the material to put a finish on the surface of the patch. Do not tilt the wheels as far down now, so that the blade will be close to surface of the patch. By using a sharp and tighter blade, any chunks will be carried in the blade and drag marks will be eliminated. Lay about half of the remaining material in this pass. The material should run out just before reaching the end of the patch and there will be no pile left. Back up and repeat the same pass, straddling the windrow with the heel just even with the edge of your patch. Let a very small amount of material roll off the edge along with the chunks. This will assure you that all drag marks will be filled and the surface will be even clear across the patch. If material does not come out all the way, you will have lines running in and out which are called “scallops.” By leaving the chunks along the edge, you can roll them down and leave a good appearance to the patch.

You may not have the material run out just perfect and you will have to take the windrow back to the center and then complete the patch. If this is necessary, do not carry the windrow clear to the edge. Leave room to put a wheel between the windrow and the edge and carry it back. Never come clear out to the edge until you are ready to finish the patch. If you have just a small pile at the end of the patch, you can blend this back over the patch but do not string it out down the road. If there is a lot of material left, shoot some more tack coat and put the premix on this. Do not blade it off into the ditch and waste it. One
way to tell if the blade is the right height above the area already laid, is to watch just behind the toe of the blade. It should just touch and roll a rock or two now and then as you move along.

Always make as few passes as possible so the material will not separate. Too much working will separate the rocks and fines and the rocks will whip off of the surface. Remember that blade pitch is important. You want to force the material under the blade so that the surface will be tighter, but not enough pressure to cause the patch to tear. Be sure that the toe of the blade is set correctly. If it is too loose, a ridge will be formed where the blade picks up the windrow. These are the basic steps in laying any patch and, if they are followed, you will get good patches.

**Full Road Patch**

Full road patches may be accomplished by shooting tack coat on one side and windrowing the dumped material to the center. The other side can then be tacked and material carried on across. By the time you reach the other shoulder, the material should be in position to set up your shoulder line. Begin laying material as outlined. When you reach the center, tight blade material across and set up that shoulder line. Again lay material to the center of the road. The remaining premix can then be used to finish work. These steps will give you a “tight blade” and then a lift laid on top.

**Half Sole**

A half sole is just a long patch and the same steps are followed. One thing different is that you will probably have to lay it in sections. When choosing a point to turn around, be sure to pick a spot where you can turn easily and off of the road surface. Do not turn the machine around on fresh laid oil mix as the tandems will tear it. Blend the ends back over the first section to eliminate all traces of an ending. Remember that a flat blade will tend to level more than a sharp blade. The additional reach will give this effect but it will also tend to tear the patch. The amount of angle you can use will depend
on the amount of heat and moisture in the premix, and the type of material used to produce the premix. For example, on a hot afternoon you could use a much flatter blade than on a cloudy morning. Most of your lay-down work should be done in low gear with the throttle open. This will give you “live” controls without excessive ground speed. Too much ground speed will cause a bounce in the machine causing “washboards” in the patch. If you have to dry the material, roll the entire windrow back and forth a few times, or spread it out and then pick it up.

Be sure to pick it all up to avoid separation.

Speed with a motor grader is made by making fewer passes and not with a high ground speed. In motor grader work, quality is a prime consideration because this is a permanent repair.

Road Center Patches

On patches where you do not have to form a shoulder line, such as a hole in the center of the road, just spread the material to one edge of the tack with a tight blade, then straddle the windrow and leave the toe tight to the road. As you drive forward, raise the heel slightly to begin laying material. Set both edges in this manner.

If patches are long and you have to wait on trucks, lay the loads back toward the work you have finished and blend the ends back over the finished work, being careful not to leave any bumps.

Long Depressions

Long depressions being filled will follow normal steps with the exception of putting markers out and laying more material in the marked area by driving higher on the windrow.

Bridge Ends

When patching a bridge end, set your shoulder windrow up so that it is very small as you come to the bridge. When you drive this windrow and approach the bridge, you will be able to run up on top
of the small part and avoid the bridge rail. Always lay towards the bridge on the shoulder cuts, then follow the normal steps for the rest of the patch. Be sure to allow enough lead distance so you do not raise the cars too suddenly. Run the taper from the end of the patch up to the bridge and make the raise gradual over the entire length of the patch.

**Cattle Guards**

If you have to patch a cattle guard, this patch will require caution so as not to lose the material down in the cattle guard. To avoid this, come up to the cattle guard watching the toe of the blade. When the material in front of the blade is close to the rails, use the circle reverse to flatten the blade so material will be pushed up close all along the length of the blade. Raise the blade and drive far enough forward to position the blade on the other side of the pile. Lower the blade and back up. This will carry the material back away from the cattle guard and it can be blended back over the patch. Handle both sides of the road in the same fashion.

**Sharp Curves**

When patching on sharp curves, ride higher on the windrow to allow for the tandems dropping down on the edge of the material as you turn.

**Rolling**

The last step in laying a patch is to roll it. This is very important as it will prevent loss of surface material due to “kick off” from high speed traffic. It is best to use a roller, but if you do not have one, roll it down using trucks.

Always roll the shoulder first and work the material toward the center of the road. If it has a steel drum, allow 4 to 6 inches to hang over the shoulder, but avoid letting the roller drum “tilt” back and forth as this will spoil your shoulder line. The rolling operation is very important
to your work. Avoid turning the roller on the “fresh” patch. Normally, roll the patch after it is completed. An exception would be a very deep hole. A small hole can be rolled with the grader wheel but on a large one, use the roller. Lay the asphalt mix to the center and then let the roller roll the material on this lift. Then another lift can be laid over this. If you can avoid having to roll in the middle of the patch, it is best, because the layers that are laid will bond together better. However, it is better to roll deep lifts individually to avoid having the material settle too much as traffic packs it. Two or 3 inches deeper in one area of your patch than another would be rolled with motor grader wheels. The reason why it is best to roll small areas with the motor grader wheels, is so that when the patch has stopped settling, it will be level. Do not over roll a patch as you can force the material out of the hole. About two trips across the patch will usually set it in place.

**Materials**

The type of aggregate used will affect procedures to a great degree. The type normally used is mixed with a liquid asphalt. Liquid asphalt has a solvent added to make it workable at a low temperature. An asphalt mix with a large amount of fines will also be hard to lay. This material is a “fluffy” or “sticky” type of premix that tends to drag along the road without going under the blade. This must be laid in deep lifts and rolled after every pass.

Mostly an SC asphalt is used. This stands for slow cure, and this type can be left in the stockpile for quite awhile.

MC or medium cure will be more difficult to work with when cool weather is encountered. It also should not be stockpiled for as long a time.

A type of material being used more often now is hot mix obtained from a mixing plant. This material must be worked at a very high temperature. It is used mostly with lay-down machines, but sometimes you may be called on to lay it with the motor grader. It
becomes unworkable very rapidly so speed is very important. It can be spread from the truck very evenly so your first pass should set up the shoulder line. Lay it back one pass and then dress to the outside. This will complete laying that load in three passes. Just dump one or two loads at a time and lay each load in layers. If it is a wide road, lay it in strips and then dump a small amount more on the center lift and dress it right to the edge to complete your finished surface. Be sure to roll each lift as you put them down, as you will be unable to get any compaction if it cools too much. If the lifts are too deep, you will have to wait to put the roller on it, or the hot material will push out of the hole. This is why it is important to lay it in lifts. You will only have about three passes or it will become unworkable. You might get four trips on a hot afternoon, but better results will be obtained with only three.

1:3:MG