

Chapter 3

Scrapers

The design of scrapers (tractor scrapers) allows for loading, hauling, dumping, and spreading of loose materials. Use a scraper for medium-haul earthmoving operations and for moving ripped materials and shot rock. The haul distance (zone of operation), the load volume, and the type and grade of surface traveled on are the primary factors in determining whether to use a scraper on a particular job. The optimum haul distance for small- and medium-size scrapers is 3,000 feet or less.

DESCRIPTION

3-46. *Figure 3-1, page 3-2, shows a CAT® 621B single-powered-axle wheel scraper. The CAT 621 is designed to operate using a push tractor for loading assistance. The air-droppable CAT 613B wheel scraper has a chain-elevator loading mechanism that allows it to load without the assistance of a push tractor. The basic operating parts of a scraper are these:*

- **Bowl.** The bowl is the loading and carrying component. It has a cutting edge, which extends across the front bottom edge. Lower the bowl until the cutting edge enters the ground for loading, raise it for carrying, and lower it to the desired lift thickness for dumping and spreading.
- **Apron.** The apron is the front wall of the bowl. It is independent of the bowl and, when raised, it provides an opening for loading and spreading. Lower the apron during hauling to prevent spillage.
- **Ejector.** The ejector is the rear wall of the bowl. Keep the ejector in the rear position when loading and hauling materials. Activate the ejector to move forward during spreading to provide positive discharge of materials.

CAPACITY

3-47. *Struck capacity means the bowl has a full load of material that is level with its sides. Heaped capacity means the material is heaped in the bowl and slopes down on a 1:1 repose slope to the sides of the bowl. In practice, these will be LCY of material because of how a scraper loads. Therefore, load volume in terms of BCY moved depends on both the bowl size and the material type being loaded. The rated volumetric capacity of the Army 621B scraper is 14-cubic-yards struck and 20-cubic-yards heaped. The capacity of the CAT 613B scraper is 11-cubic-yards heaped. Elevating scrapers, like the Army 613, are not given struck capacity ratings.*

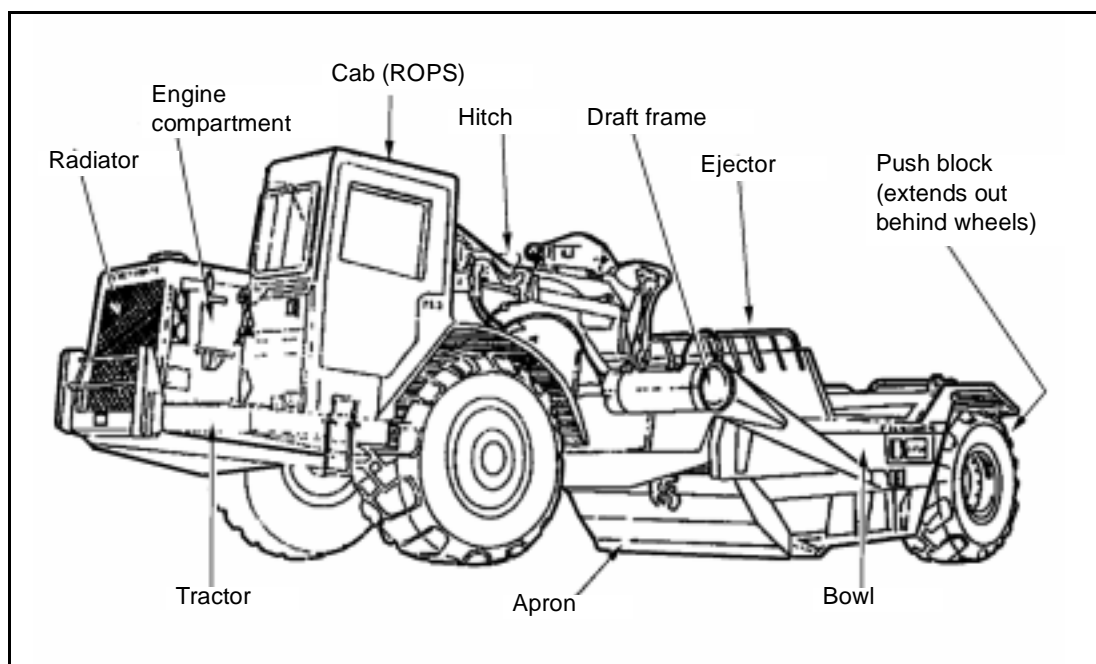


Figure 3-18. CAT 621B Wheel Scraper

OPERATING RANGE

3-48. The optimum haul distance for the small- and medium-size scrapers is 300 to 3,000 feet. There are larger scrapers that are effective up to 5,000 feet.

SELECTION

3-49. A scraper is a compromise between a machine designed exclusively for either loading or hauling. For medium-distance movement of material, a scraper is better than a dozer because of its travel-speed advantage and it is better than a truck because of its fast load time, typically less than a minute. Another advantage of the scraper is that it can spread its own load and quickly complete the dump cycle.

PRODUCTION CYCLE

3-50. The production cycle for a scraper consists of six operations—loading, haul travel, dumping and spreading, turning at the dump site, return travel, and turning and positioning to load. *Figure 3-2* shows the functions of the apron, bowl, and ejector during loading, hauling, and dumping.

LOADING

3-51. The CAT 621 loads with push-tractor assistance. This scraper can load to a limited extent without assistance, but requires push loading to achieve maximum production. Pusher assistance is necessary to reduce loading time and wheel spinning. Reducing scraper wheel spinning increases tire life. The scraper should not depend on the pusher to do all the work. Conversely, do not spin the scraper's wheels to pull away from the pusher. Use pusher assistance for either straight, downhill, or straddle loading. Always load the scraper in the direction of haul. Do not turn the scraper at the same time it is

accelerating from the loading operation. The CAT 613 is a self-loading machine, and pushing during loading will damage the scraper's loading elevator.

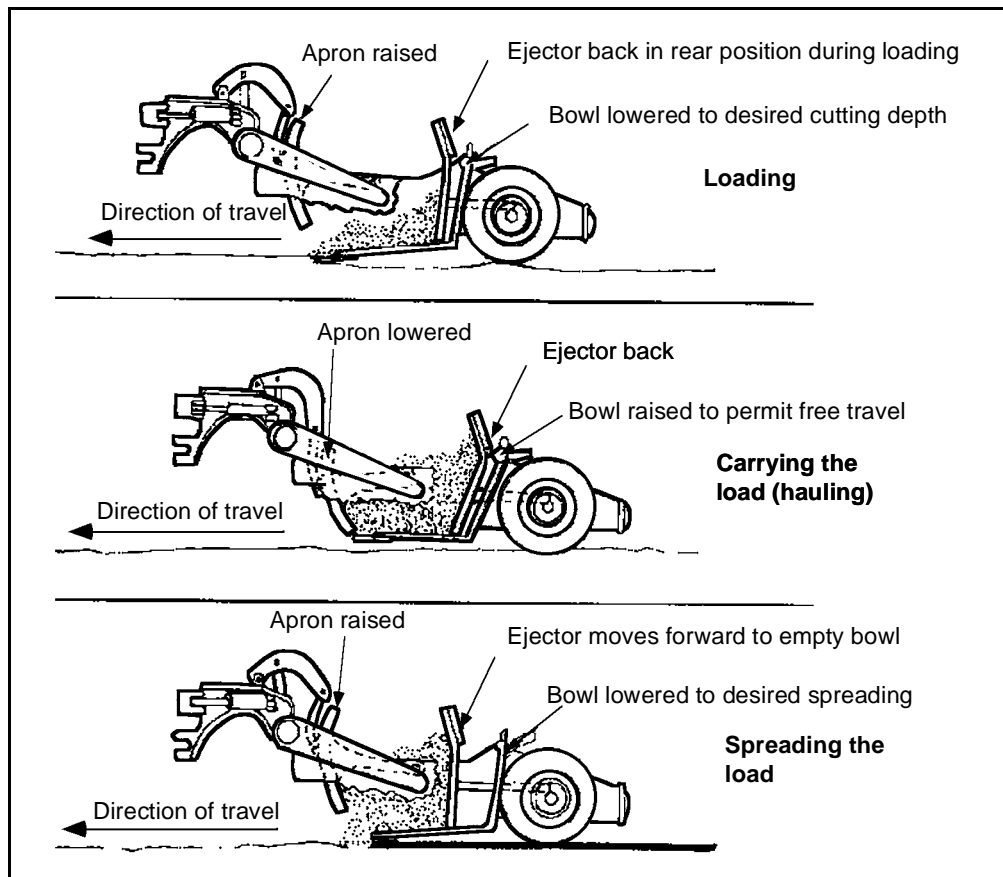


Figure 3-19. Functions of the Apron, Bowl, and Ejector

Downhill Loading

3-52. Downhill loading enables a scraper to obtain larger loads in less time. Each 1 percent of favorable grade is equivalent to increasing the loading force by 20 pounds per ton of gross scraper weight.

Straddle Loading

3-53. Straddle loading (*Figure 3-3, page 3-4*) requires three cuts with a scraper. The first two cuts should be parallel, leaving a ridge between the two cuts. The scraper straddles this ridge of earth to make the final cut. The ridge should be no wider than the distance between a scraper's wheels. With straddle loading, time is gained on every third trip because the center strip loads with less resistance than a full cut.

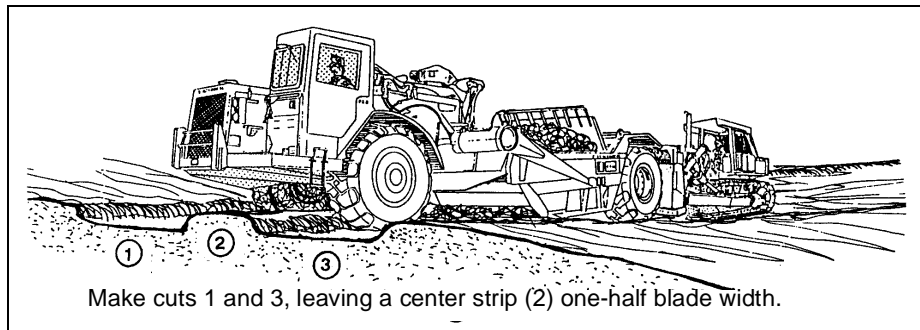


Figure 3-20. Straddle Loading With Pusher Assistance

Push-Loading

3-54. **Back-Track.** Use the back-track push-loading technique (*Figure 3-4*) where it is impractical to load in both directions. However, this method is inefficient due to the time spent in backing up and repositioning for the next load.

3-55. **Chain.** Use the chain push-loading technique (*Figure 3-4*) where the cut is fairly long, making it possible to pick up two or more scraper loads without backtracking. The pusher pushes one scraper, then moves behind another scraper that is moving in the same direction in an adjacent lane.

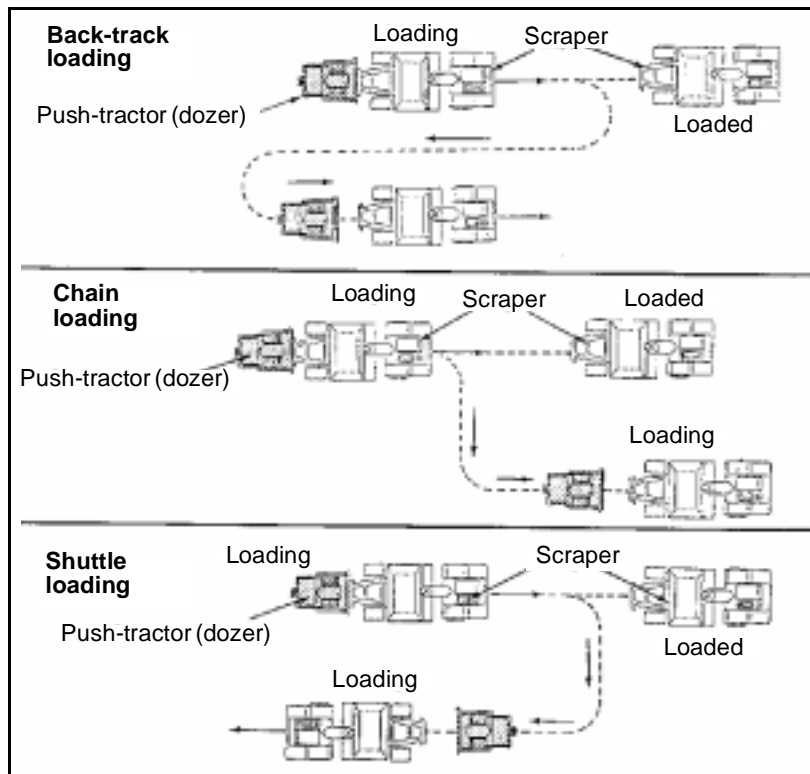


Figure 3-21. Push-Loading Techniques

3-56. **Shuttle.** Use the shuttle push-loading technique (*Figure 3-4*) for short cuts where it is possible to load in both directions. The pusher pushes one scraper, then turns and pushes a second scraper in the opposite direction.

Cut-and-Load Sequence

3-57. The scraper loading sequence is as follows:

Step 1. Use the service brake to reduce scraper travel speed when close to the cut (loading lane), and downshift to first gear for loading.

Step 2. Move the ejector to the rear.

Step 3. Open the apron partway.

Step 4. Lower the bowl to an efficient cut depth after the scraper enters the cut. Continue moving forward until the dozer contacts the scraper and begins pushing. If the scraper tires spin before the dozer makes contact, stop and allow the dozer to assist. When the dozer makes contact, push down both the differential lock and the transmission hold pedal and proceed in second gear. The cut should be as deep as possible, but it should allow the scraper to move forward at a constant speed without lugging the engine. Decrease the cut depth if the scraper or pusher lugs or if the drive wheels slip. Use the router bits on the vertical side of the bowl to gauge the depth of cut. Once an efficient depth of cut is determined, use that same depth on successive passes.

Step 5. Mark the cut. When cutting—

- Regulate the apron opening to prevent material from piling up in front of the lip or falling out of the bowl.
- Keep the machine moving in a straight line while maintaining pusher and scraper alignment.
- Do not overload the scraper. Overloading lowers efficiency and places unnecessary stresses on the machine.
- Raise and lower the bowl rapidly when loading loose material such as sand.

NOTE: When a push tractor is used, it should be waiting about 45° off of the lane to be cut. This allows the loading unit to come in with the least delay and difficulty.

Step 6. Raise the bowl slowly when full, while at the same time closing the apron to prevent spillage.

Step 7. Allow the pusher to help the machine out of the cut area, if necessary.

NOTE: When exiting the cut, release the transmission hold and/or the differential lock, if in use. Accelerate to travel speed as quickly as possible. Travel a few feet before lifting the bowl to the carrying position. This spreads any loose material piled up in front of the bowl and allows the following scraper to maintain speed.

Materials

3-58. **Loam and Clay.** . Loam and most clay soils cut easily and rapidly with minimum effort. However, loosen very hard clay with a dozer ripper before loading.

3-59. **Sand.** Since sand has little or no cohesion between its particles, it has a tendency to run ahead of the scraper blade and apron. The condition is worse for finer and drier particles. When loading sand, the best method is as follows:

Step 1. Enter the loading area fast, lowering the bowl slowly, and pick up as much material as possible using the momentum of the scraper unit. This will fill the hard-to-reach rear area of the bowl.

Step 2. Shift to a lower gear once the momentum is lost, and allow the pusher to assist.

Step 3. Pump the bowl up and down (*Figure 3-5*). For best pumping results, drop the bowl as the scraper's rear wheels roll into the depression of the previously pumped area and raise the bowl as the wheels are climbing out of the depression.

Step 4. Drop the bowl sharply two or three times at the end of the loading area to top out the load. Then close the apron, raise the bowl, and exit the cut area.

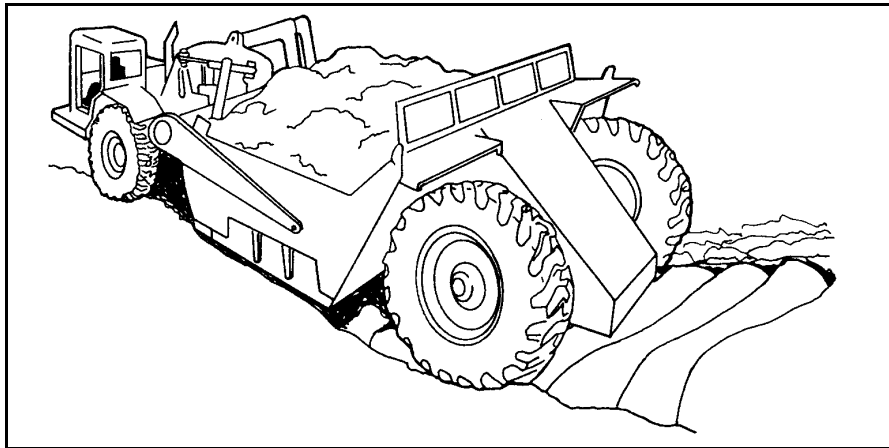


Figure 3-22. Pumping a Scraper Bowl to Load Sand

3-60. **Rock and Shale.** Loading rock and shale with a scraper is a difficult task that causes severe wear and tear on the equipment. Ripping will ease this problem. Ripping depth should exceed the depth of the scraper cut. When loading the scraper, leave a loose layer of ripped material under the tires to provide better traction and to reduce both track and tire wear. Some soft rock and shale can be loaded without ripping.

3-61. Start the scraper's cutting edge in dirt (if possible) when loading stratified rock. Move in to catch the blade in planes of lamination. This forces material into the bowl. Pick up loose rock or shale on the level or on a slight upgrade, with the blade following the lamination planes.

Load Time

3-62. Loading time is critical for obtaining maximum scraper production. Push loading should normally take less than one minute within a distance of 100 feet (time and distance change with the material being loaded). Studies of load volume versus loading time indicate that for a normal operation, about 85 percent of scraper load capacity is achieved in the first 0.5 minute of loading. Another 0.5 minute will only produce about another 12 percent increase in

load volume. Therefore, extra loading time (past about one minute) is not worth the effect because increased total cycle time will decrease production.

Borrow-Pit Operation

3-63. It is essential to have highly competent personnel in the borrow-pit area. Traffic control within the borrow-pit area reduces waiting time and excess travel of earthmoving support units. Maintaining adequate drainage throughout the borrow pit will reduce downtime caused by bad weather.

HAULING

3-64. Hauling, or travel time, includes the haul time and the return time. Here the power and traction characteristics of the scraper become very important. The following factors can greatly effect travel time.

Haul-Route Location

3-65. Lay out the haul routes to eliminate unnecessary maneuvering. Plan the job to avoid adverse grades that could drastically reduce production. Remember, where grades permit, the shortest distance between two points is always a straight line.

Road Maintenance

3-66. Keep haul roads in good condition. A well-maintained haul road permits traveling at higher speeds, increases safety, and reduces operator fatigue and equipment wear.

- **Ruts and rough surfaces.** Use a grader or dozer to eliminate ruts and rough (washboard) surfaces. (See *Chapter 4* for haul-road maintenance with a grader.)
- **Dust.** Use water distributors to reduce dust. Reducing the amount of dust helps alleviate additional mechanical wear, provides better visibility, and lessens the chance of accidents. Keeping roads moist (but not wet) allows them to pack into hard, smooth surfaces permitting higher travel speeds.

Travel Conditions

3-67. Once on the haul road, the scraper should travel in the highest safe gear appropriate for road conditions. When possible, carry the scraper bowl fairly close to the ground (about 18 inches). This lowers the center of gravity of the scraper and reduces the chance of overturning.

- **Lugging.** Avoid unnecessary lugging of the engine. Downshift when losing momentum. Lugging the engine usually results in a slower speed than the top range of the next lower gear. Although the machine can make it, it is best to downshift and accelerate faster. Lugging causes a decrease in engine revolutions per minute (rpm) thereby reducing hydraulic pressure. This will result in a loss of steering control.
- **Coasting.** Never coast on a downgrade. When approaching a downgrade, slow down and downshift the transmission. To prevent unwanted upshifting, use the transmission hold on a downgrade if it is available. Also, use it when approaching an upgrade or in rough

underfooting. To control speed on a downgrade, use the retarder and service brakes. Engine speed should not exceed the manufacturer's recommended rpm.

DUMPING AND SPREADING

3-68. When dumping, lower the bowl to the desired lift height and open the apron at the beginning of the dump area. Dump and spread in the highest gear permitted by haul-road conditions and fill-material characteristics. Constant speed, along with bowl height, will help to maintain a uniform depth of lift. Slowly dribbling the load at low speed slows down the cycle.

Dumping Procedure

Step 1. Move steadily across the spreading area.

Step 2. Open the apron fully as the scraper reaches the location to begin dumping. Move the ejector forward to push the material out of the bowl.

Step 3. Maintain a straight path through the spread area.

Step 4. Close the apron when all the material is out of the bowl, and return the ejector to the rear of the bowl.

Step 5. Raise the bowl slowly to clear obstacles (12 to 18 inches) during the return trip to the loading area.

Spreading Sequence (Figure 3-6)

Step 1. Dump and spread the first load at the front of the fill.

Step 2. Travel with subsequent loads over the previous fill, provided the lifts are shallow.

Step 3. Start each following dump at the end of the previous fill.

Step 4. Finish dumping and spreading one full lane before starting a new one so that rollers can start compaction.

Step 5. Repeat this method in the next lane. Do not waste time on the fill. The scraper should return to the cut area as fast as possible after dumping the load. Plan the egress from the fill area to avoid soft ground or detours around trees or other obstacles.

NOTE: Route the scrapers to compact the fill. Overlap wheel paths to aid in compaction of the entire area and to reduce compaction time for rollers.

CAUTION

Do not try to force wet or sticky material out of the bowl too fast. This will cause the material to roll up in front, which can damage the hydraulic system.

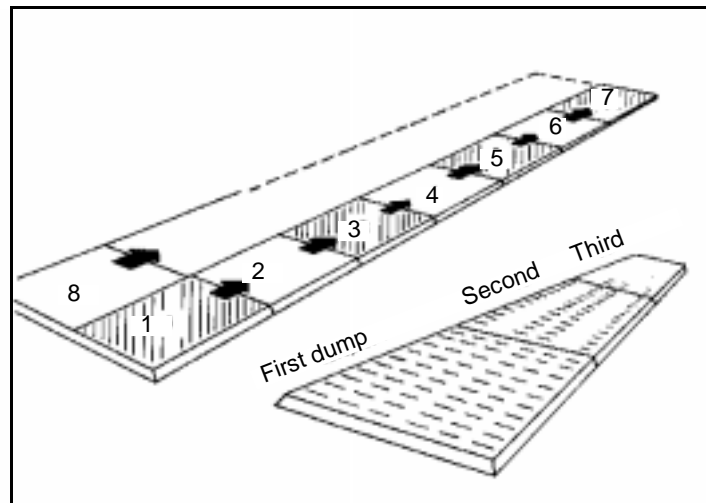


Figure 3-23. Spreading Sequence

Fill Slope

3-69. To maintain the desired fill slope, make the fill high on the outside edges. This will prevent the scraper from sliding over the slope and damaging the slope. If there is rain, build up the low center for drainage, or use a grader to cut the outside edge down, creating a crown in the middle of the area.

Materials

3-70. Different materials require different dumping and spreading procedures.

3-71. **Sand.** Spread sand as thin as possible to allow better compaction and to make traveling over the fill easier.

3-72. **Wet or Sticky Material.** Wet or sticky material may be difficult to unload or spread. When operating in these material types—

- Do not try to spread the material too thin.
- Keep the bowl high enough to allow the material to pass under the scraper. Material not having enough room to pass under the scraper will roll up inside the bowl into a solid mass that is difficult to eject.
- Bring the ejector forward about 12 inches at a time.
- Back the ejector about 6 inches after each forward movement. This breaks the suction between the material and the bowl.
- Repeat this procedure until the bowl is empty.

PRODUCTION ESTIMATES

3-73. Following is an explanation of production estimating based on a step-by-step method using the CAT 621B scraper. When developing data for production estimates, consider all factors that influence production. Consider the scraper's weight, the weight of the load, and the average grade and rolling resistance of both the haul and return routes in arriving at a cycle time. The

same steps are applicable to other makes and models of scrapers, using the appropriate tables and charts for those scrapers.

Step 1. Determine the vehicle weight, empty and loaded.

- **Empty vehicle weight (EVW), in tons.** Using *Table 3-1*, first determine the EVW from the EVW column based on the specific make and model of the scraper.
- **Weight of load, in tons.** Determine the weight of the load in pounds by determining the scraper load volume in cubic yards (this is in LCY of the material) and the material unit weight (in pounds per LCY). If no specific material-weight data is available, use the information in *Table 1-2, page 1-4*, as an estimate. Multiply the scraper load volume by the unit weight in pounds per LCY of the material to be excavated. Then, convert the resulting weight into tons by dividing the amount by 2,000.

$$\text{Weight of load (pounds)} = \text{scraper load volume (LCY)} \times \text{material unit weight (pounds per LCY)}$$

$$\text{Weight of load (tons)} = \frac{\text{weight of load (pounds)}}{2,000}$$

Table 3-6. Scraper Specifications

Make and Model	Heaped Capacity (Cubic Yards)	EVW (Tons)
CAT 613B	11	15.6
CAT 621B	20	33.3

- **Loaded or gross vehicle weight (GVW).** Determine the GVW by adding the EVW (tons) and the weight of load (tons).

$$\text{GVW (tons)} = \text{EVW (tons)} + \text{weight of load (tons)}$$

EXAMPLE

Determine the GVW of a CAT 621B single-powered scraper with a 20 LCY load of dry loam.

From *Table 1-2*, dry loam is 1,900 to 2,200 pounds per LCY. Use an average value of 2,050 pounds per LCY.

$$\text{Weight of load (tons)} = \frac{20 \text{ LCY} \times 2,050 \text{ pounds per LCY}}{2,000 \text{ pounds per ton}} = 20.5 \text{ tons}$$

$$\text{EVW} = 33.3 \text{ tons}$$

$$\text{GVW} = 33.3 \text{ tons} + 20.5 \text{ tons} = 53.8 \text{ tons}$$

Step 2. Determine the average grade (in percent) and the distance (in feet) for both the haul and return routes. Uphill grades are positive (+) and downhill grades are negative (-). Obtain this information from a mass diagram or a haul-route profile.

EXAMPLE

The project mass diagram indicates that there is a 5 percent downhill grade from cut to fill and that the one-way distance is 800 feet. The same route will be used for both the haul and the return.

Haul:

Average grade = -5 percent

Distance = 800 feet

Return:

Average grade = +5 percent

Distance = 800 feet

Step 3. Determine the rolling resistance (in pounds). Rolling resistance is the force resisting the movement of a vehicle on level ground. This is primarily caused by the tires penetrating the road's surface, the tires flexing, and internal gear friction (*Figure 3-7, page 3-12*). Express the rolling resistance for a given road surface in pounds per ton of vehicle weight. *Table 3-2, page 3-12*, gives some representative rolling-resistance values for various types of road surfaces. If the expected tire penetration is known, determine the rolling resistance for the haul and the return using the following formulas:

$$RR_{\text{Haul}} = (40 + [30 \times TP]) \times GVW$$

$$RR_{\text{Return}} = (40 + [30 \times TP]) \times EVW$$

where—

RR_{Haul} = haul rolling resistance, in pounds

RR_{Return} = return rolling resistance, in pounds

40 = constant that represents the flexing of the driving mechanism, in pounds per ton

30 = constant that represents the force required to climb out of the rut, in pounds per ton per inch

TP = tire penetration, in inches (may be different for the haul and the return)

EXAMPLE

Determine the rolling resistance (haul and return) for a CAT 621B scraper carrying a 20.5-ton load if the tire penetration during the haul is 3 inches and the tire penetration on the return is 1 inch.

$$RR_{\text{Haul}} = (40 + [30 \times 3 \text{ inches}]) \times 53.8 \text{ tons} = 6,994 \text{ pounds}$$

$$RR_{\text{Return}} = (40 + [30 \times 1 \text{ inch}]) \times 33.3 \text{ tons} = 2,331 \text{ pounds}$$

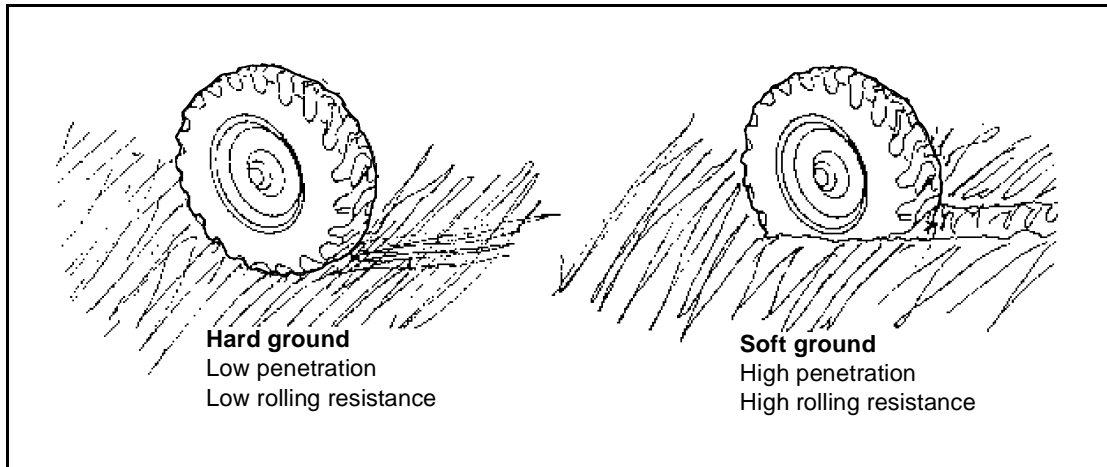


Figure 3-24. Rolling Resistance

Table 3-7. Representative Rolling-Resistance Values

Road Condition	Resistance Value (Pounds Per Ton)
Hard, smooth surface with no tire penetration (well maintained)	40
Firm, smooth surface, flexing slightly under load (well maintained)	65
Flexible dirt roadway (irregular surface): With about 1 inch of tire penetration	100
With up to 4 inches of tire penetration	150
Soft, muddy roadway (irregular surface or sand) with over 6 inches of tire penetration	220 to 400

Step 4. Determine the grade resistance or the grade assistance. Grade resistance is the opposing force of gravity that a vehicle must overcome to move uphill. Grade assistance is the helping force of gravity that pulls a vehicle downhill. For uphill (adverse) grades, the vehicle needs more power to move as it must overcome both rolling and grade resistance. For downhill (favorable) grades, the helping force of gravity produces additional pounds of pull to propel the vehicle. Indicate adverse grades by a plus (+) and favorable grades by a minus (-). In earthmoving, measure grades in percent of slope. This is the ratio between the vertical rise or fall, and the horizontal distance in which the rise or fall occurs. For instance, a rise of 1 foot in a 20-foot horizontal distance is a +5

percent grade ($1/20 \times 100$). Use the following formula to determine the grade resistance or grade assistance:

$$\text{GR}(+) \text{ or } \text{GA}(-) = 20 \times \text{percent grade} \times \text{vehicle weight (tons)}$$

Therefore—

$$\text{GR}(+)_{\text{Haul}} \text{ or } \text{GA}(-)_{\text{Haul}} = 20 \times \text{percent grade} \times \text{GVW (tons)}$$

$$\text{GR}(+)_{\text{Return}} \text{ or } \text{GA}(-)_{\text{Return}} = 20 \times \text{percent grade} \times \text{EVW (tons)}$$

where—

GR(+) = grade resistance, in pounds

GA(-) = grade assistance, in pounds

20 = constant that represents 20 pounds per ton of vehicle weight per degree of slope

NOTE: Enter the percent grade as a percent not as a decimal.

EXAMPLE

Determine the grade resistance and grade assistance for a CAT 621B scraper carrying a 20.5-ton load on a -5 percent grade from cut to fill.

$$\text{GA}(-)_{\text{Haul}} = 20 \times (-5 \text{ percent}) \times 53.8 \text{ tons (GVW)} = -5,380 \text{ pounds}$$

$$\text{GR}(+)_{\text{Return}} = 20 \times (+5 \text{ percent}) \times 33.3 \text{ tons (EVW)} = +3,330 \text{ pounds}$$

Step 5. Determine the rimpull required. Rimpull required is a measure of the force needed (in pounds) to overcome the vehicle's rolling resistance and grade assistance/grade resistance. Use the following formula to determine the rimpull required:

$$\text{RPR} = \text{RR} + \text{GA}(-) \text{ or } \text{GR}(+)$$

where—

RPR = rimpull required, in pounds

RR = rolling resistance, in pounds

GA(-) = grade assistance, in pounds

GR(+) = grade resistance, in pounds

EXAMPLE

Determine the rimpull required on the haul and return based on the following data:

$$\text{RR}_{\text{Haul}} = 6,994 \text{ pounds; } \text{GA}(-) = -5,380 \text{ pounds}$$

$$\text{RR}_{\text{Return}} = 2,331 \text{ pounds; } \text{GR}(+) = +3,330 \text{ pounds}$$

$$\text{RPR}_{\text{Haul}} = 6,994 \text{ pounds} + (-5,380) \text{ pounds} = 1,614 \text{ pounds}$$

$$\text{RPR}_{\text{Return}} = 2,331 \text{ pounds} + (+3,330) \text{ pounds} = 5,661 \text{ pounds}$$

Available rimpull is the amount of force that can actually be developed as limited by traction. The engine may be able to develop the rimpull, but the rimpull must be able to be transferred at the point where the tire touches the ground. Therefore, required rimpull must always be less than available rimpull, or there will be tire slippage and the work will not be accomplished.

Step 6. Determine the travel speed.

- The travel speed of a piece of equipment is the maximum speed at which the vehicle can develop the rimpull required to overcome the opposing forces of grade and rolling resistance. The manufacturer normally provides this information in tables or charts. *Figures 3-8 and 3-9* show rimpull charts for the CAT 621B and the CAT 613B.
- To determine the travel speed, locate the rimpull required for either the haul or return on the left side of the chart. Read to the right until intersecting the line representing the highest gear which can achieve that amount of rimpull. Read down from the gear intersect to determine the maximum travel speed.

NOTE: Determine the travel speed for both the haul and the return.

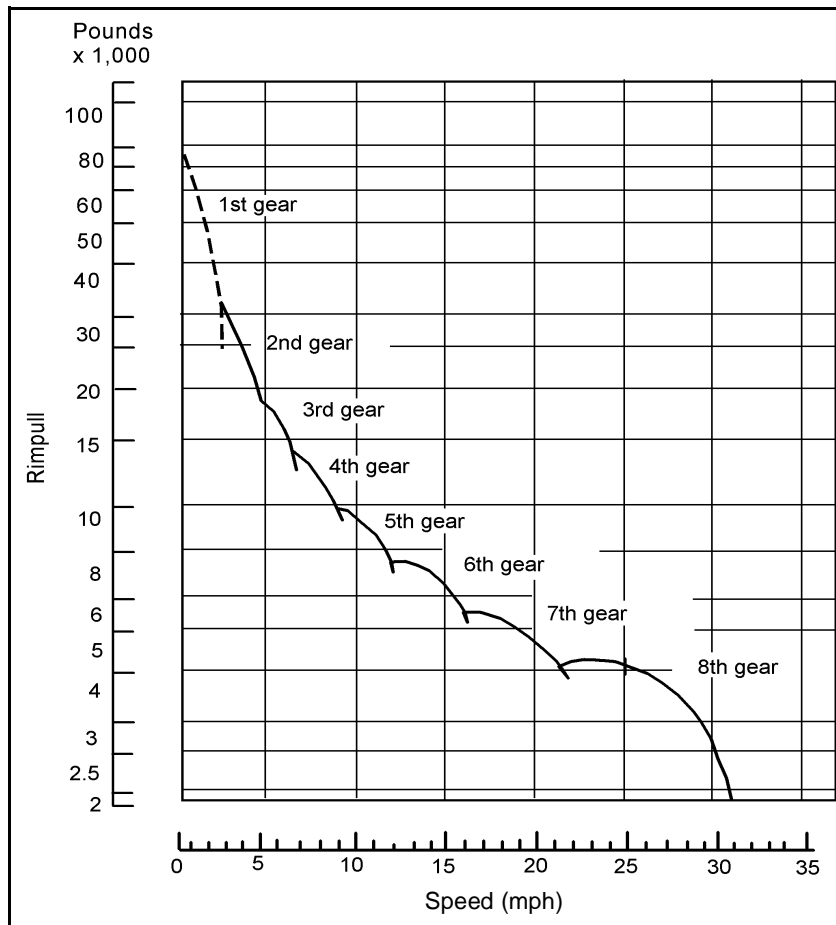


Figure 3-25. Speed Chart for the CAT 621B

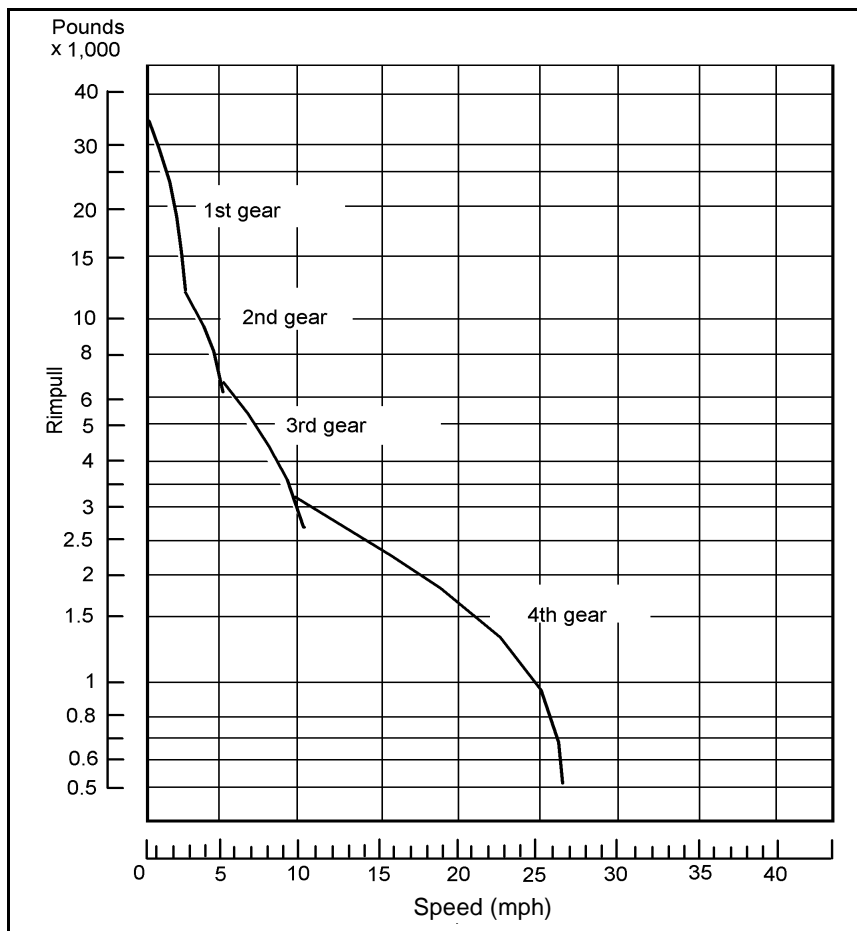


Figure 3-26. Speed Chart for the CAT 613B

EXAMPLE

Determine the maximum travel speed for a CAT 621B scraper, based on the following data.

$RPR_{Haul} = 1,614$ pounds

$RPR_{Return} = 5,661$ pounds

First, determine the travel speed for the haul. Refer to *Figure 3-8* and locate 1,614 pounds on the scale. This is below the lowest scale number of 2,000 pounds so use the bottom line on the rimpull scale. Read right to determine travel gear (eighth gear) and down to determine travel speed (31 miles per hour [mph]).

Second, determine the travel speed for the return. Refer to *Figure 3-8* and locate 5,661 pounds (interpolate between 5,000 and 6,000 on the rimpull scale). Read right to determine travel gear (seventh gear) and down to determine travel speed (17 mph).

NOTE: If computed travel speed (either haul or return) exceeds the unit's standing operating procedure (SOP) maximum allowable speed, determine the travel time based on the maximum allowable speed in the SOP.

Step 7. Determine the total travel time. Total travel time is the sum of the time it takes the vehicle to complete one haul and one return.

$$\text{Total TT} = \text{TT}_{\text{Haul}} + \text{TT}_{\text{Return}}$$

where—

TT = travel time

- First, determine the haul travel time.

$$\text{TT}_{\text{Haul}} = \frac{\text{average haul distance (feet)}}{88 \times \text{travel speed}_{\text{Haul}}}$$

where—

TT = travel time, in minutes

88 = conversion factor used to convert mph into feet per minute (fpm)

- Second, determine the return travel time (in minutes).

$$\text{TT}_{\text{Return}} = \frac{\text{average return distance (feet)}}{88 \times \text{travel speed}_{\text{Return}}}$$

where—

TT = travel time, in minutes

88 = conversion factor used to convert mph into fpm

NOTE: The haul and return routes are not always the same. Be sure to use the correct haul distance for each computation.

EXAMPLE

Determine the total travel time for a CAT 621B based on a haul speed of 31 mph, a return speed of 17 mph, and a haul distance of 800 feet. The unit's SOP limits scraper travel speed to 25 mph.

Determine the haul and the return travel time.

$$\text{TT}_{\text{Haul}} = \frac{800 \text{ feet}}{88 \times 25 \text{ mph}} = 0.36 \text{ minute}$$

$$\text{TT}_{\text{Return}} = \frac{800 \text{ feet}}{88 \times 17 \text{ mph}} = 0.54 \text{ minute}$$

Determine the total travel time.

$$\text{Total TT} = 0.36 \text{ minute} + 0.54 \text{ minute} = 0.9 \text{ minute}$$

Step 8. Determine the cycle time.

- The cycle time is the sum of the total travel time and the time required for loading, dumping, turning at the dump site, and turning and positioning to load, plus the time to accelerate/decelerate during the haul and return.
- The average dump time for scrapers having a heaped capacity of less than 25 cubic yards is 0.3 minute. The type or size of the scraper does not significantly affect the turning time. Average turning time in the cut is 0.3 minute and 0.21 minute on the fill. The cut turning time is slightly higher because of congestion in the area and the necessity of spotting for loading. Therefore, for both the CAT 613 and the CAT 621 scrapers, allow 0.81 minute for dumping, turning at the dump site,

and turning at the load site. The question of the time for loading is the consequential variable.

- A good average time for loading the CAT 621 with a D8 or equivalent-size push tractor is 0.85 minute. Modify the time for loading or the assumed load volume if using a smaller push tractor. With a D7, expect load times approaching 1 minute. The self-loading CAT 613 requires 0.9 minute to load in good material. Good means loam, loose clay, or sandy material. Encountering tight materials will increase the loading duration. To determine the turn-and-dump time and the load time for a special piece of equipment, time the equipment as it goes through a few cycles.

$$CT = \text{total TT} + TD + LT$$

where—

CT = total scraper cycle time, in minutes

TT = travel time

TD = total turn and dump time

LT = load time

EXAMPLE

Determine the cycle time for a CAT 621B scraper with a D7 push tractor based on a travel time of 0.9 minute and an average turn and dump and load time.

$$CT \text{ (minutes)} = 0.9 \text{ minute} + 0.81 \text{ minute} + 1 \text{ minute} = 2.71 \text{ minutes}$$

Step 9. Determine the trips per hour. To determine the number of trips per hour, divide the working minutes per hour by the cycle time. Normally there are about 50 minutes per hour of productive time on a well-managed scraper job. However, if the cut is in a tight area such as a ditch or if the embankment is a narrow bridge header, the estimator should consider lowering the productive time to a 45-minute working hour.

$$TPH = \frac{\text{working minutes per hour}}{CT}$$

where—

TPH = trips per hour

CT = total scraper cycle time, in minutes

EXAMPLE

Determine how many trips per hour a CAT 621B can make based on a 50-minute working hour and a cycle time of 2.71 minutes per trip.

$$TPH = \frac{50 \text{ minutes}}{2.71 \text{ minutes per trip}} = 18.5 \text{ trips}$$

Step 10. Determine the hourly production rate. To determine the hourly production rate, the average size of the load (in LCY) and the number of trips per hour must be known. The capacity of the scraper, the material type, and the method of loading will determine the average size of load.

$$P = \text{TPH} \times \text{average LCY per load}$$

where—

P = hourly production rate, in LCY per hour

TPH = trips per hour

NOTE: To convert from LCY to either BCY or CCY, multiply the production rate by a soil conversion factor from *Table 1-1, page 1-4*.

$$P (\text{BCY per hour or CCY per hour}) = P (\text{LCY per hour}) \times \text{conversion factor}$$

where—

P = hourly production rate

EXAMPLE

Determine the hourly production rate in BCY per hour for a CAT 621B working in loam, making 18.5 trips per hour, with an average load of 20 LCY.

$$P (\text{LCY per hour}) = 18.5 \text{ TPH} \times 20 \text{ LCY per load} = 370 \text{ LCY per hour}$$

$$P (\text{BCY per hour}) = 370 \text{ LCY per hour} \times 0.8 = 296 \text{ BCY per hour}$$

Step 11. Determine the total time in hours required to complete the mission. To determine the total time required to complete a mission, the total volume to move, the hourly production rate, and the number of scrapers to be used on the job must be known.

$$\text{Total time (hours)} = \frac{Q}{P \times N}$$

where—

Q = total volume to move, in BCY

P = hourly production rate, in BCY per hour

N = number of scrapers

EXAMPLE

Determine how many hours it would take to move 19,440 BCY, using three CAT 621B scrapers, each with an hourly production rate of 296 BCY per hour.

$$\text{Total time (hours)} = \frac{19,440}{296 \text{ BCY per hour} \times 3} = 22 \text{ hours}$$

If it is necessary to complete the job in a specified time, use the same basic formula to determine the required number of scrapers.

$$\text{Number of scrapers required} = \frac{Q}{P \times H}$$

where—

Q = total volume to move, in BCY

P = hourly production rate, in BCY per hour

H = required number of hours

Step 12. Determine the number of push tractors required. The number of push tractors required is a ratio of the scraper cycle time to the push-tractor cycle time. The self-loading CAT 613 does not use a push tractor, so this part of the analysis is not necessary when using self-loading scrapers.

$$N = \frac{CT}{PT}$$

where—

N = number of push tractors required

CT = total scraper cycle time, in minutes

PT = total pusher cycle time, in minutes

- Load time (discussed in *step 8*). A CAT 621B loading with a D7 push tractor requires about 1 minute to load. This is the time the push tractor is in contact with the scraper.
- Push-tractor cycle time. Once a scraper load time has been determined, use the following formula to determine the push-tractor cycle time.

$$PT = (1.4 \times LT) + 0.25$$

where—

PT = total push-tractor cycle time

1.4 = constant that represents scraper load time and push-tractor travel time between scrapers

LT = load time

0.25 = constant that represents push-tractor positioning time

At this point, the number of scrapers that a single push tractor will support can be determined.

EXAMPLE

Determine how many CAT 621B scrapers a single push tractor can support if the scraper cycle time is 2.71 minutes and the scraper load time is 1 minute.

$$PT = (1.4 \times 1) + 0.25 = 1.65 \text{ minutes}$$

$$\text{Number of scrapers} = \frac{2.71 \text{ minutes}}{1.65 \text{ minutes}} = 1.64 \text{ scrapers}$$

This example shows that the push-tractor cycle time will control the production when using only one push tractor and more than one scraper on the project. The push-tractor production formula is—

$$P = \frac{\text{working minutes per hour}}{PT} \times \text{scraper load (LCY)}$$

where—

P = hourly production rate, in LCY per hour

PT = total push-tractor cycle time, in minutes

As was done in step 10, convert the production into BCY or CCY by using the *Table 1-1, page 1-4*, soil conversion factors.

EXAMPLE

Determine what the production will be in BCY if a single push tractor, with a cycle time of 1.65 minutes supports two CAT 621B scrapers hauling 20 LCY of loam. Assume a 50-minute working hour. The scrapers have a cycle time of 2.71 minutes.

$$\text{Number of scrapers one pusher can support} = \frac{2.71 \text{ minutes}}{1.65 \text{ minutes}} = 1.64 \text{ scrapers}$$

Therefore, if using only one push tractor, the pusher cycle time will control production.

$$P \text{ (BCY per hour)} = \frac{50}{1.65} \times 20 \text{ LCY} \times 0.8 = 485 \text{ BCY per hour}$$

NOTE: If the incorrect assumption was made that one pusher could handle two scrapers, the production would have been calculated at 590 BCY per hour.

$$P \text{ (BCY per hour)} = \frac{50 \text{ minutes}}{2.71 \text{ minutes}} \times 2 \text{ scrapers} \times 20 \text{ LCY} \times 0.8 = 590 \text{ BCY per hour}$$

where—

P = hourly production rate

Once the number of scrapers that one push tractor can support has been determined, use the following formula to determine how many push tractors are needed to support the job if using additional scrapers.

$$\text{Number of push tractors required} = \frac{\text{number of scrapers on job}}{\text{number of scrapers a push tractor can support}}$$

EXAMPLE

Determine how many push tractors are required on a job that has nine 621B scrapers, if a single push tractor can support 1.64 scrapers.

$$\text{Number of push tractors required} = \frac{9 \text{ scrapers}}{1.64 \text{ scrapers per push tractor}} = 6 \text{ push tractors}$$