

Introduction to Brake Systems – Study Guide

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Introduction

Everybody knows that when you press your foot on the brake pedal the vehicle is supposed to stop. But how does the pressure from your foot get to the wheels with enough force to stop a heavy vehicle? In the following sections, we will study the systems and components required to allow brakes to work effectively.

Course Objectives

Upon completion of this course, technicians should understand and be able to apply their knowledge of:

- Brake functions and components
- Split hydraulic systems
- Master cylinder operations
- Balance control systems
- Power brake booster systems
- Disc brake operation
- Micrometer reading
- Drum brake operation
- Brake fluids
- Brake bleeding operations
- Brake lines and hoses
- Basic diagnosis

Using the Job Sheets

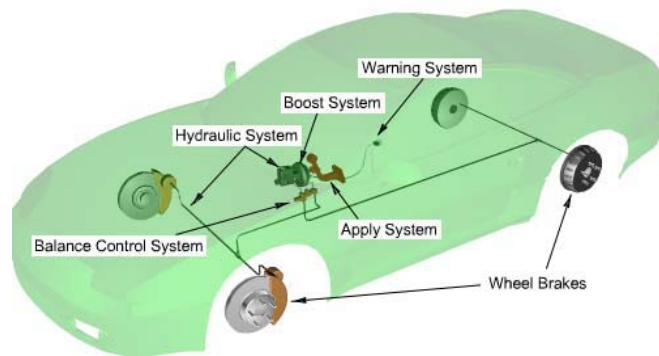
As you proceed through the online module, on some pages you will find links that will open a window with a printable procedure or job sheet containing hands-on lab activities based on the NATEF standards related to the content you are studying. When you come upon a procedure or job sheet link, click on it and print the job sheet for completion in the shop. See your instructor for guidance in completing the job sheets. Some jobs sheets will require supplemental materials such as a vehicle service manual, equipment manual, or other references.

Brake System Functions

Automotive brakes are designed to slow and stop a vehicle by transforming kinetic (motion) energy into heat energy. As the brake linings contact the drums/rotors they create friction which produces the heat energy. The intensity of the heat is proportional to the vehicle speed, the weight of the vehicle, and the quickness of the stop. Faster speeds, heavier vehicles, and quicker stops equal more heat.

Automotive brake systems can be broken down into several different sub-systems (fig. 1):

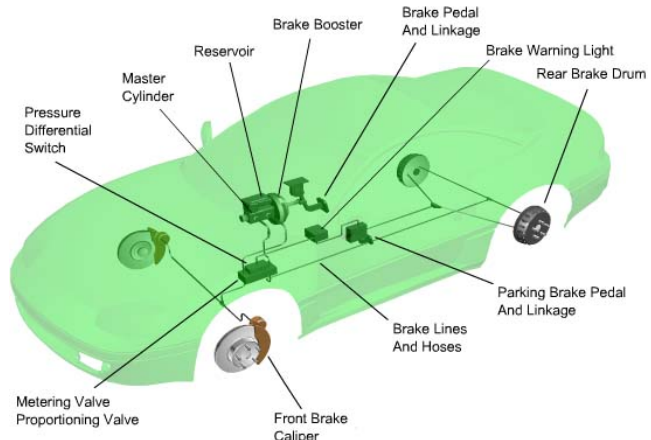
- Apply system
- Boost system
- Hydraulic system
- Wheel brakes
- Balance control system
- Warning system



(fig. 1) Base Brake Systems

Base brake components are the parts of the brake system commonly found on all vehicles. The term "base brakes" does not include either Antilock or Traction Control systems. Base brake components include:

- Brake pedal and linkage
- Power assist system
- Master cylinder, hoses and lines
- Brake rotors and pads
- Brake drums and shoes
- Balance controls (proportioning valve and metering valve), if equipped
- Brake pressure and other warning systems
- Parking brake pedal and linkage



(fig. 2) Base Brake Components

Split Hydraulic Systems

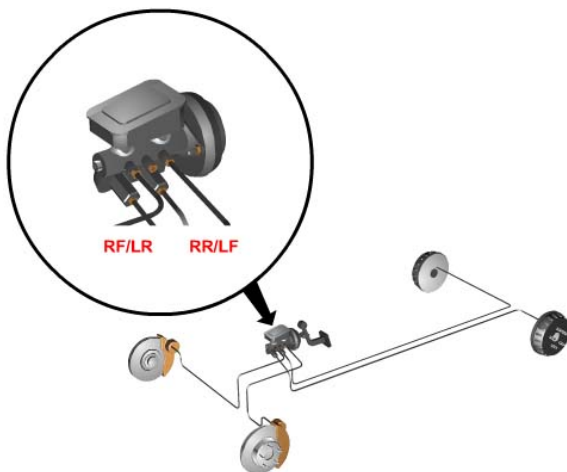
A partial loss of brake pressure makes it difficult or even impossible to apply the brakes. Therefore, federal law requires that all vehicles have two separate and independent hydraulic systems. In this way, the failure of one system will not result in a complete brake loss even though braking will still be severely reduced.

The two split systems used almost exclusively are:

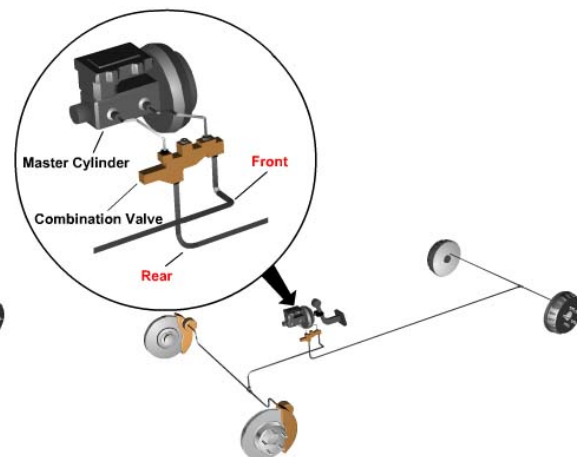
- **Diagonally split** – used on most front wheel drive vehicles
- **Front/rear split** – used on most rear wheel drive vehicles

On a diagonally-split system (fig. 3), the left-front and right-rear brakes (LF/RR) are connected to one channel of the master cylinder while the right-front and left-rear brakes (RF/LR) are connected to the other channel of the master cylinder. This system is typically installed on front wheel drive vehicles because they have a front-heavy weight distribution and approximately 70% of the braking occurs at the front brakes. As such, if one part of a diagonal system failed, the overall braking would only be reduced to 50% rather than to 30% if both front brakes were lost. Diagonally-split systems also use proportioning valves either in the master cylinder circuits or in the rear brake lines to maintain the proper front to rear pressure balance. Proportioning valves will be covered in a later section.

On a front/rear split system (fig. 4), both front wheel brakes work together on one system (channel) while both rear wheel brakes work together on a separate system.



(fig. 3) Diagonally-split Hydraulic System



(fig. 4) Front/Rear Split Hydraulic System

Hydraulic System

An important hydraulic principle states that fluids do not compress or produce any measurable friction. Also, fluid pressure does not diminish when transferred within a closed system. That means that if there is no leak in a system, the pressure at the wheels will be the same as the pressure from the master cylinder.

A second hydraulic principle states that a relationship exists between:

- Force and piston area
- Piston travel and piston area

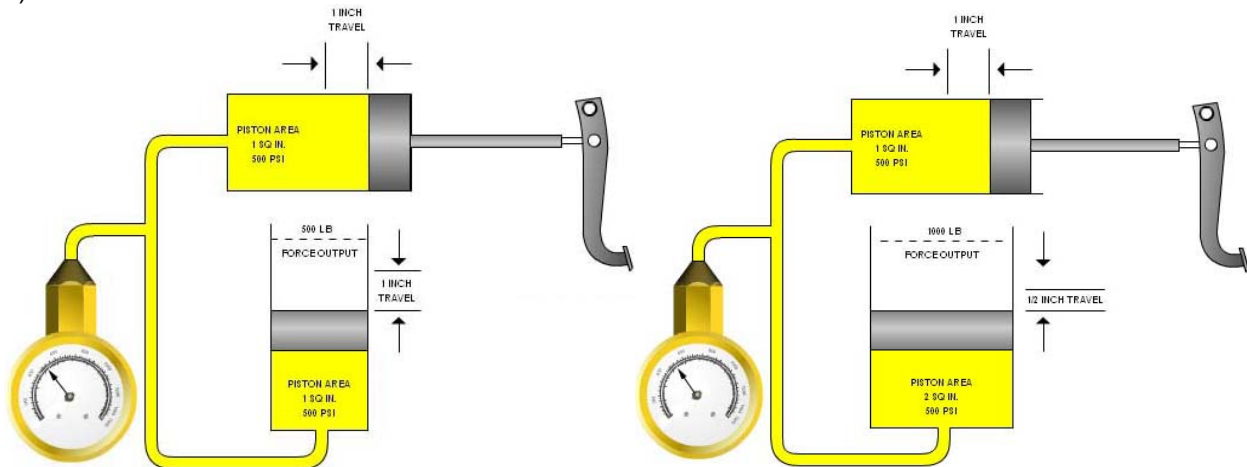
From the first principle, if a master cylinder generates 500 **psi**, it also transfers 500 **psi** to the pistons in each wheel cylinder (remember that fluid pressure remains constant).

In the second principle (fig. 5), when pressure from a one-square-inch master cylinder piston exerts 500 psi on a wheel cylinder piston, which also has one-square-inch surface area, the wheel cylinder piston transfers 500 **pounds of force** to the brake shoe (500 psi x 1 in. sq. = 500 lbs.)

However, if the same one-square-inch master cylinder piston exerts 500 psi on a wheel cylinder piston that has a two-square-inch area, the wheel cylinder piston will transfer 1,000 **pounds of force** to the brake lining (500 psi x 2 in. sq. = 1,000 lbs.)

Additionally, different piston sizes not only affect the amount of brake force applied, they also determine the travel distance of the different pistons. For instance, if the one-square-inch master cylinder piston moves **one inch**, a one-square-inch wheel cylinder piston will also move **one inch** (with the same force) (fig. 5).

If that same one-square-inch master cylinder piston moves **one inch**, then a two-square-inch wheel cylinder piston (twice the size) will move just **one-half inch** (half the distance) but with twice the force (fig. 6)



(fig. 5) Piston Area and Travel (1 inch)

(fig. 6) Piston Area and Travel (1/2inch)

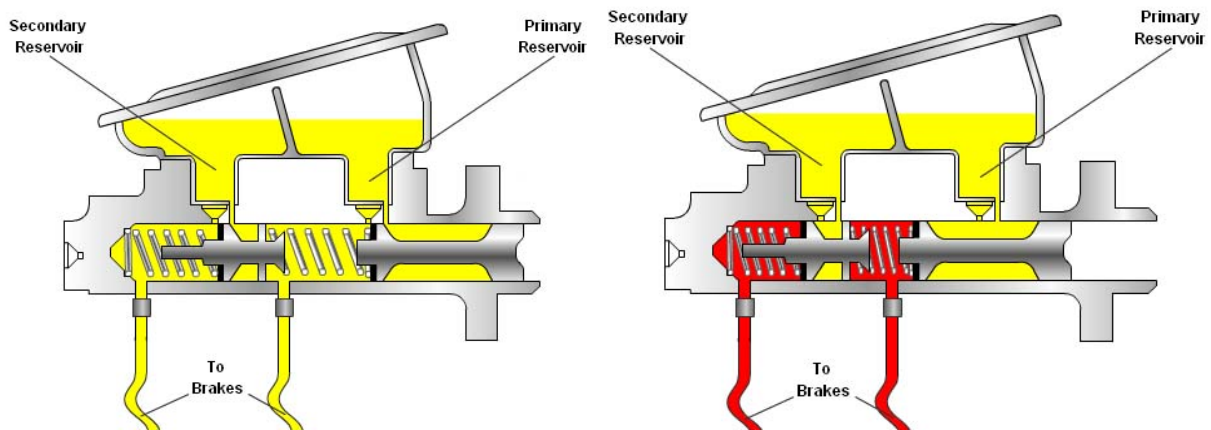
Master Cylinder

- Converts mechanical force from the brake pedal, power booster and push rod into hydraulic pressure
- Contain pistons, piston seals, return springs and internal brake fluid ports.
- Also has a fluid reservoir that may either be an integral part of the unit or remotely mounted. The reservoir itself will have a removable cap with a rubber diaphragm seal that must be in good condition to seal properly.
- Most reservoirs also have a low brake fluid level switch to alert the driver of a low fluid condition.

The Master Cylinder in Action

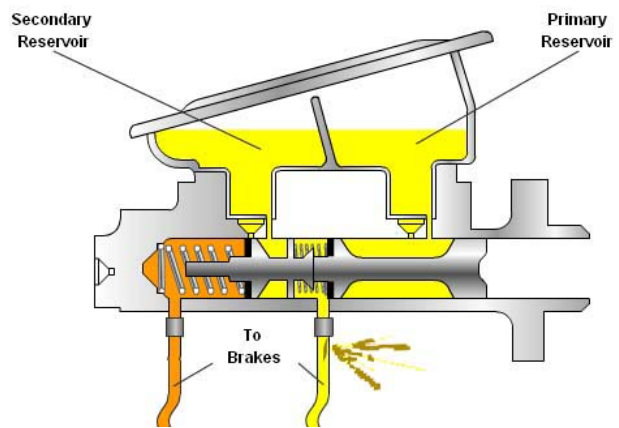
As you can see in figure 7 there are two pistons (primary and secondary) and two springs inside the master cylinder.

- When the brake pedal is pressed, a push rod moves the primary piston forward which begins to build pressure in the primary chamber and lines. As the brake pedal is depressed further, the pressure continues to increase.
- Fluid pressure between the primary and secondary piston then forces the secondary piston forward and pressurizes the fluid in the secondary circuit.
- If the brakes are operating properly, the pressure will be the same in both circuits.



(fig. 7) Brakes released (left); Brakes applied (right)

If there is a leak in one of the brake circuits, that circuit will not be able to maintain pressure. Figure 8 shows what happens when one of the circuits develops a leak. In this example, the leak is in the primary circuit and the pressure between the primary and secondary pistons is lost. This pressure loss causes the primary piston to mechanically contact the secondary piston and the master cylinder now behaves as if it has only one piston. The secondary circuit will continue to function correctly, however the driver will have to press the pedal further to activate it. In addition, since only two wheels now have pressure, the braking power will be reduced.



(fig. 8) Master Cylinder with a Primary Circuit Leak

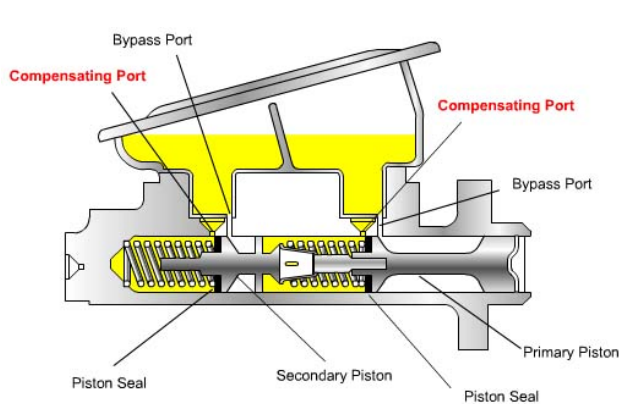
Compensating Ports

- Small holes that are located between the master cylinder reservoir and the front side, or pressure side, of the master cylinder pistons
- When the master cylinder pistons are in the at-rest position (no braking-figure 9), the piston seals uncover the compensating ports and open the passages between the reservoir and the wheel brake channel.
- Allow for the normal expansion and contraction of brake fluid due to changes in temperature
- Assist in fluid return after brake release (See Bypass Port section below)

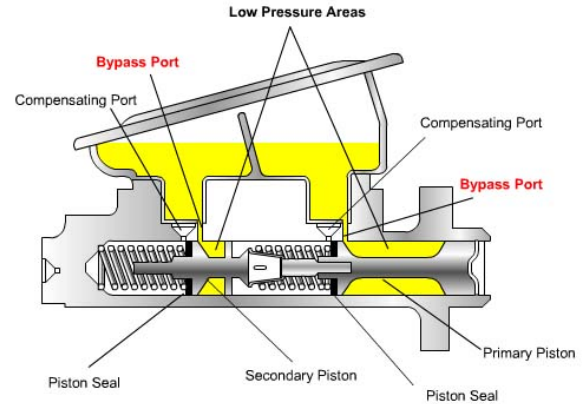
Note: When the brakes are released, the piston seals on both the primary and secondary pistons are located between the compensating port and the bypass port. During braking, the piston seals close the compensating port passages to the reservoir which prevents high pressure fluid from entering the reservoir

Bypass Ports

- The bypass ports, like the compensating ports, are passages that are open between the reservoir and the master cylinder chambers (fig. 10). However, the bypass ports are open to the low-pressure or back side of the pistons.
- Allow the master cylinder pistons to return to the at-rest position rapidly.



(fig. 9) Compensating Ports



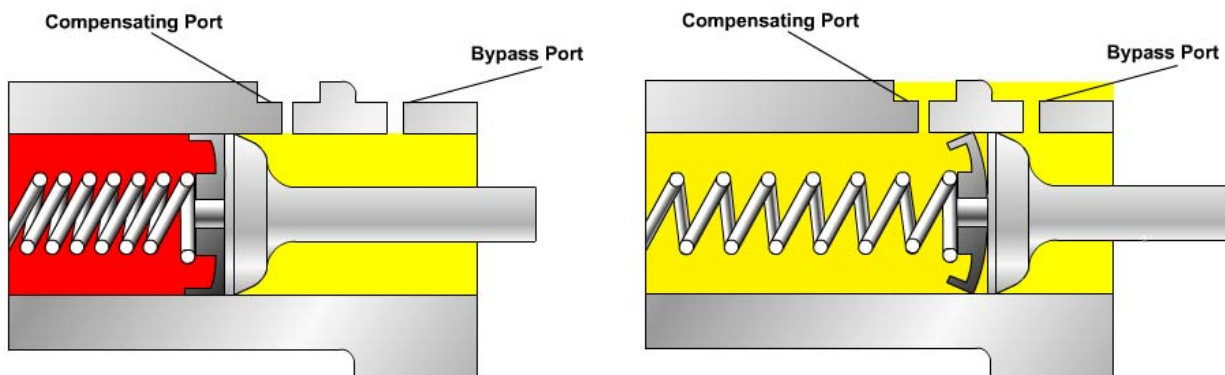
(fig. 10) Bypass Ports

During brake release, the following occurs:

- Strong springs in the master cylinder force the pistons back to the at-rest position faster than the brake fluid can return through the hydraulic channels. The pistons must return rapidly so they can be ready for another forward stroke, if necessary. This rapid piston return movement could create a vacuum in the master cylinder high pressure chambers, which would delay brake release.
- The bypass ports allow brake fluid from the reservoir to fill the low-pressure piston chambers.
- Brake fluid from the low pressure chambers then passes through holes in the pistons and bypasses the piston lip seals. The pistons can then return without any “dragging” (fig. 11).

Since this “return action” causes additional fluid to be moved to the front of the piston, it results in an excess amount of fluid being present there, as even more fluid returns from the calipers and wheel cylinders. This excess fluid is easily returned to the reservoir through the now-open compensating ports.

Note: “Piston dragging” can also occur if the seals are installed backward.



(fig. 11) Master Cylinder Return Operation: applied (left); releasing (right)

Residual Check Valve (drum brakes only)

- Included in the master cylinder
- Located in the ports where the brake lines connect to the master cylinder

- Maintain a small amount of residual pressure in the brake lines and wheel cylinders
- That pressure is then used to hold the wheel cylinder cups tightly against the cylinder and prevent air from being pulled past the cylinder cups as the brakes are released.
- Not used on disc brakes, as they would cause the disc brake pads to drag upon release

Master Cylinder Leaks

Master cylinders are subject to two types of leaks – External and Internal:

- External leaks - brake fluid can usually be seen running down the face of the power booster.
- Internal leaks - the brake pedal will usually fall away when foot pressure is applied.

Refer to specific vehicle information for leak diagnostics and servicing procedures.

Balance Control Systems

Many late model vehicles are equipped with front disc brakes and rear drum brakes and are generally heavier in the front than in the rear. As a result, different pressures are sometimes required between the front and rear to ensure even braking. These are some of the items to be aware of concerning this “braking differential”:

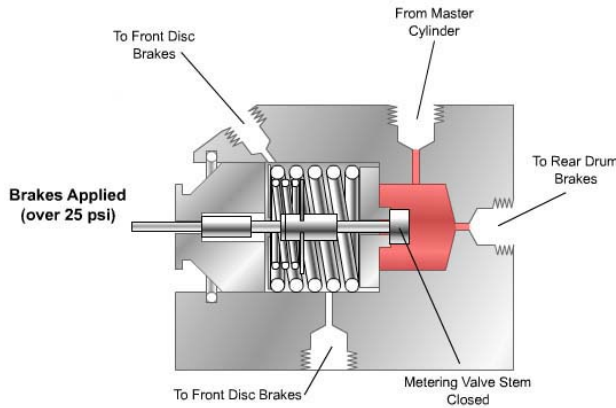
- Disc brakes can apply at lower pressures than drum brakes.
- Metering valves are used to prevent the front disc brakes from applying before the rear drum brakes.
- If the same hydraulic pressure is simultaneously applied to both the front disc and rear drum brakes during heavy brake application, the rear brakes can lock up, resulting in a skid and loss of vehicle control.
- Proportioning valve(s) are used to prevent rear brake lockup by limiting hydraulic pressure to the rear brakes during heavy braking.
- The metering valve and the proportioning valve are often housed in a single unit, called a combination valve, in many rear-wheel-drive vehicles equipped with front disc and rear drum brakes.
- Most vehicles are equipped with some form of pressure differential valve and switch which will activate a dashboard warning light if pressure is lost in either of the hydraulic channels. This switch is typically located in a combination valve or on the master cylinder.

Metering Valve

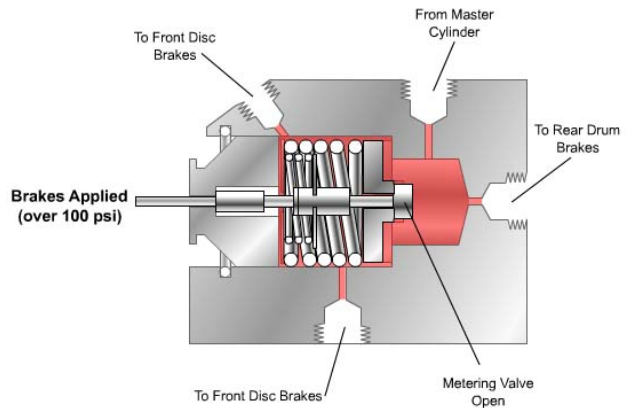
As a result of their design, rear drum brake shoes must move a greater distance to apply as compared to disc brake pads. If the same pressure were applied to both the front disc and rear drum brakes, at the same time, the front discs would “catch” much sooner than the rears and cause the vehicle to be thrown forward. Metering valves are therefore used to compensate for this condition by blocking fluid pressure to the front disc brakes until the rear shoes have had time to make contact with the drums.

- As the brakes are first applied, fluid pressure rises above a calibrated value (approximately 25 psi - figure 12) which closes the metering valve stem and blocks the fluid pressure from reaching the front disc brakes. However, fluid pressure is still applied to the rear brakes, which move the shoes out to contact the drums.
- Once the shoes begin to contact the drums, the pressure in the rear brake system starts to rise dramatically. After the pressure reaches a second calibrated value (about 100 psi - figure 13) the metering valve opens and begins to apply the front disc brakes.
- As the brakes are released and the system pressure again drops below 25 psi, the valve stem reopens to allow fluid to return to the master cylinder (fig. 14). Notice also in figures 12 through 14 that there is a difference between the valve stem and the valve itself. Each is operated by a separate spring and has a separate function.

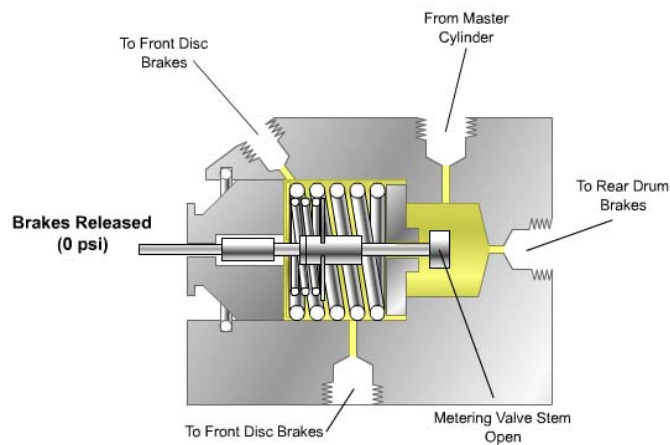
Note: The two pressure points (25 psi & 100 psi in this example) are calibrated based on the size and weight of a particular vehicle. Metering valves are **not** universally interchangeable even though they may appear to be identical.



(fig. 12) Brakes Applied (over 25 psi), metering valve stem closed



(fig. 13) Brakes Applied (over 100 psi), metering valve open

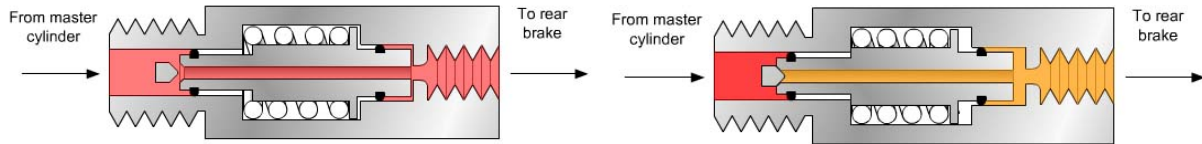


(fig. 14) Brakes Released (below 25 psi), metering valve stem is open

Proportioning Valve

Under heavy braking conditions, rear drum brakes are more susceptible to premature lock-up than the front disc brakes. Part of the reason is that rapid braking forces tend to pitch the vehicle forward which, in turn, reduces the weight on the rear wheels. Reducing the weight on the rear wheels increases the likelihood of lock-up. Proportioning valves are therefore used in the rear hydraulic circuit(s) to help prevent this sort of premature lock-up.

- During normal braking, or when the brakes are first applied, the proportioning valve is open and has no effect. Fluid enters the valve through the end with the smaller piston area (fig. 15), passes through the small bore, and exits to the rear brakes.
- Notice that the outlet end of the valve piston has a larger surface area than the inlet end of the valve. When fluid pressure rises rapidly in the valve (under hard braking), it exerts a greater force on the larger outlet piston than it does on the smaller inlet piston. This action moves the valve, against spring pressure, toward the inlet and closes the center valve. With the valve closed, pressure to the rear brakes is blocked (fig. 16).
- As the inlet pressure from the master cylinder continues to rise, it eventually becomes high enough to overcome the larger outlet piston and the valve opens again, allowing additional pressure to the rear brakes. The reopening of the valve then increases pressure on the outlet side, which again closes the valve. This cycle is repeated several times a second and keeps the pressure to the rear brakes proportionately less than the pressure to the front disc brakes. The proportional cycling action therefore makes for more positive braking under adverse conditions.



Normal Braking

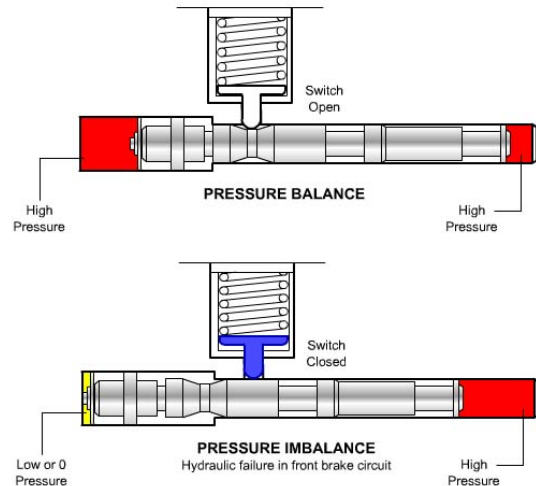
(fig. 15) Proportioning Valve Open During Normal Braking

Hard Braking

(fig. 15) Proportioning Valve Modulating During Heavy Braking

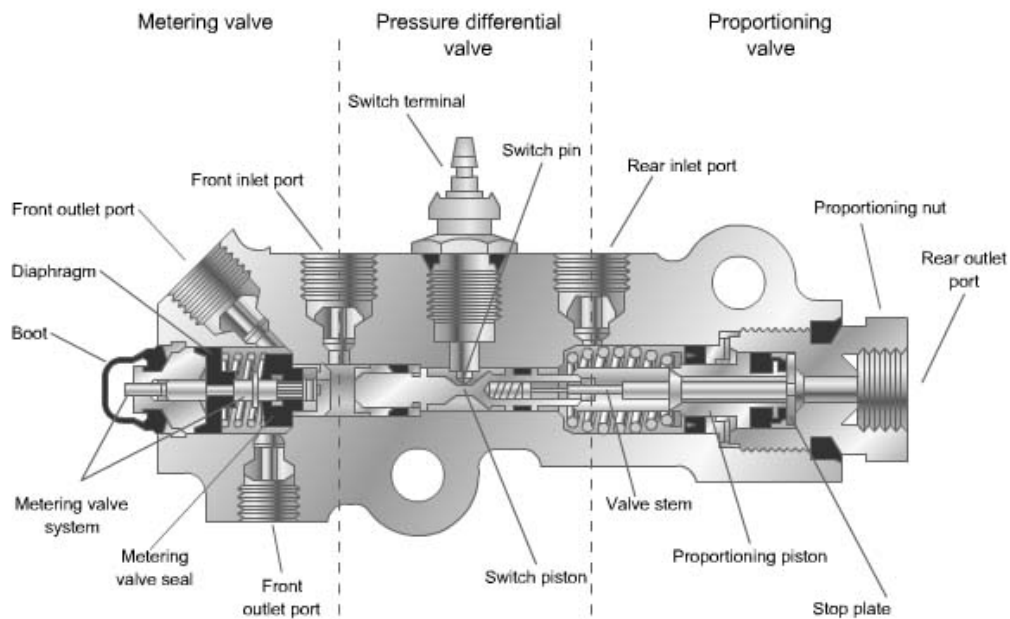
Pressure Differential Valve (Switch)

- (fig. 17) Spring-loaded plunger valves that are used to turn on dashboard warning lights if hydraulic pressure is lost in either channel of a hydraulic brake system
- Once the pressure loss problem is repaired, some valves will automatically reset themselves while others must be bled to reset. Refer to the appropriate service material for the applicable procedure.



(fig. 17) Pressure Differential Valve

The metering valve, proportioning valve, and the pressure differential switch are sometimes housed together in a single unit called a **combination valve** (fig. 18). Combination valves are used only on Front/Rear split brake systems.



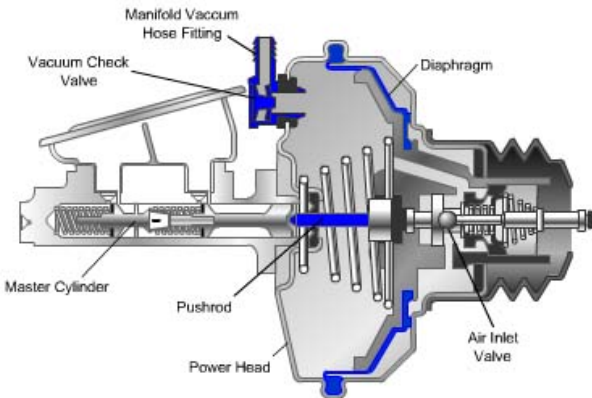
(fig. 18) Combination Valve with Metering Valve, Proportioning Valve and Pressure Differential Valve

Power Assist System

Most modern vehicles are equipped with a power assist (boost) system to aid the driver when applying the brakes. The two most common types of assist systems are **vacuum assist** and **hydraulic assist**.

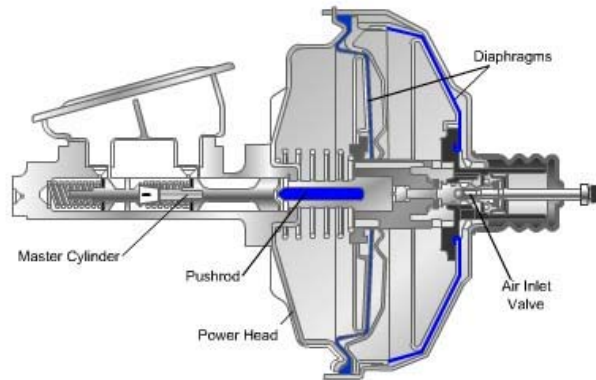
Vacuum Booster

The two (2) types of vacuum boosters used on modern vehicles are the single-diaphragm (fig. 19) and the tandem-diaphragm (or dual-diaphragm) booster (fig. 20). Both booster types operate similarly but the tandem-diaphragm booster is smaller in diameter and is used on vehicles where space is critical.



Single Diaphragm Booster

(fig. 19)

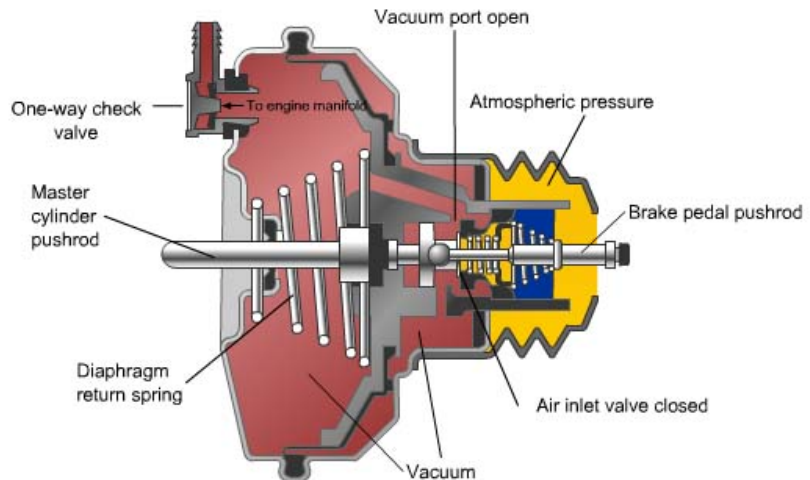


Tandem Diaphragm Booster

(fig. 20)

For simplicity, we will refer to a single-diaphragm vacuum brake booster in this example.

Vacuum boosters are mounted between the brake pedal pushrod and the master cylinder and receive engine vacuum through a hose and **check valve** (one way valve). The check valve holds vacuum pressure and assures power assist capability during times of low engine vacuum (i.e. the engine quits). With the check valve in place, a booster will have enough reserve vacuum for 2-3 brake applications after engine vacuum is lost (fig. 21).



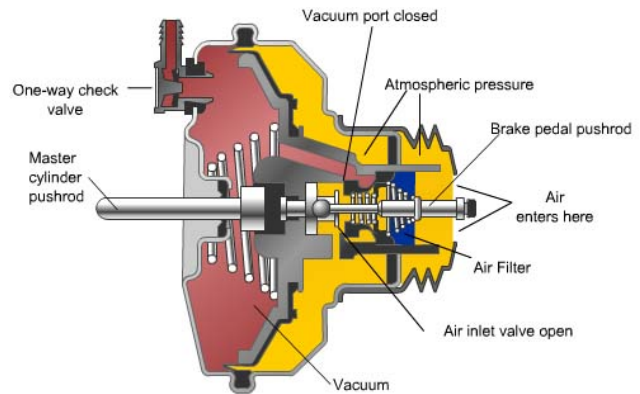
Vacuum Brake Booster

(fig. 21) Booster at Rest with Vacuum on Both Sides of Diaphragm

Vacuum boosters operate as follows:

- When the brake pedal is released, an internal vacuum port is open which allows engine vacuum to flow from the check valve to both sides of the diaphragm. With equal pressure (vacuum) on both sides, the diaphragm is held to the rear by spring pressure (fig. 21).

- As the brakes are applied, the brake pedal pushrod moves forward, which closes the vacuum port and opens the air inlet valve. This action seals off the backside of the diaphragm from the vacuum source and at the same time allows filtered atmospheric air pressure to pass through the air inlet valve to the diaphragm backside. The combination of atmospheric pressure on the backside and vacuum on the front side then moves the diaphragm and master cylinder pushrod forward to apply the brakes (fig. 22).

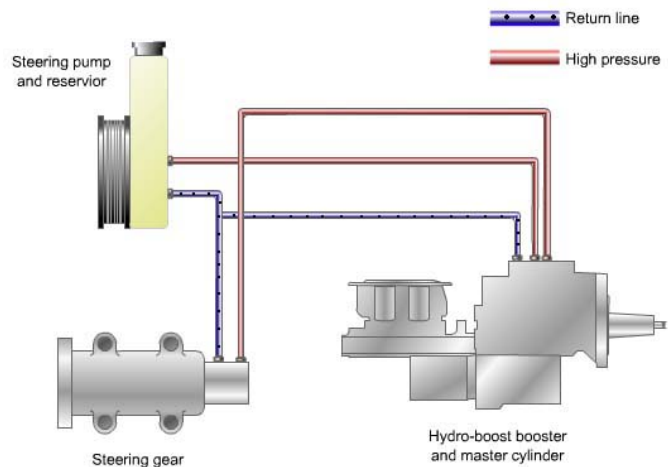


Vacuum Brake Booster (Applied)
(fig. 22) Vacuum Port Closed

Hydraulic Assist Boost System

Hydraulic brake assist systems are used on many vehicles with limited underhood space or vehicles with engines that cannot consistently produce sufficient vacuum to operate a vacuum power boost system. These include:

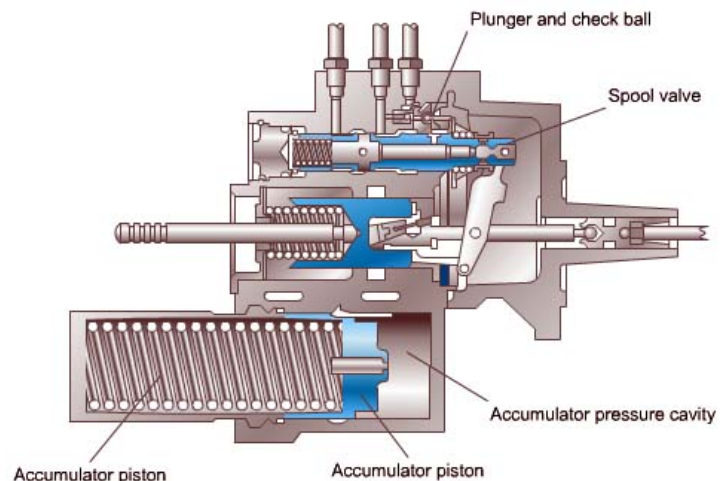
- Diesel engines
- Turbocharged engines
- Engines that operate at high load (low vacuum) such as truck applications.



(fig. 23) Hydraulic Assist System

The most common type of hydraulic-assist system uses pressure from the power steering pump to provide power brake assist. Power steering pump pressure is used to both help apply the brakes and also to charge an accumulator for engine-off assist (fig. 23).

- When hydraulic pressure fills an accumulator, it pushes a rubber seal against a piston and collapses the internal spring. If the power steering pump stops (the engine quits), the spring will expand and push the fluid into the booster for braking assist.
- Accumulators can typically provide sufficient (emergency) hydraulic pressure for two or three (2 or 3) brake applications if power steering pressure is lost (fig. 24).



(fig. 24) Hydraulic Booster with Accumulator

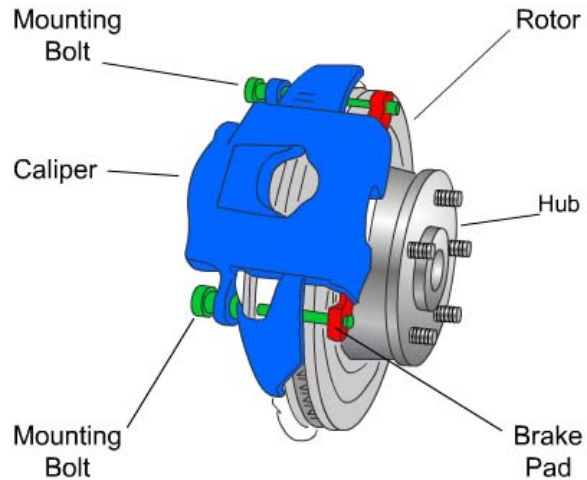
Disc Brakes

Disc brakes are used on the front of all modern vehicles, while some have both front and rear disc brakes. The advantages of disc brakes over drum brakes include:

- Better fade resistance
- Reduced pulling and grabbing
- Self-adjustment capability

Disc brakes consist of the following components (fig. 25):

- Rotor
- Hub
- Caliper assembly
- Brake pads
- Mounting bolts



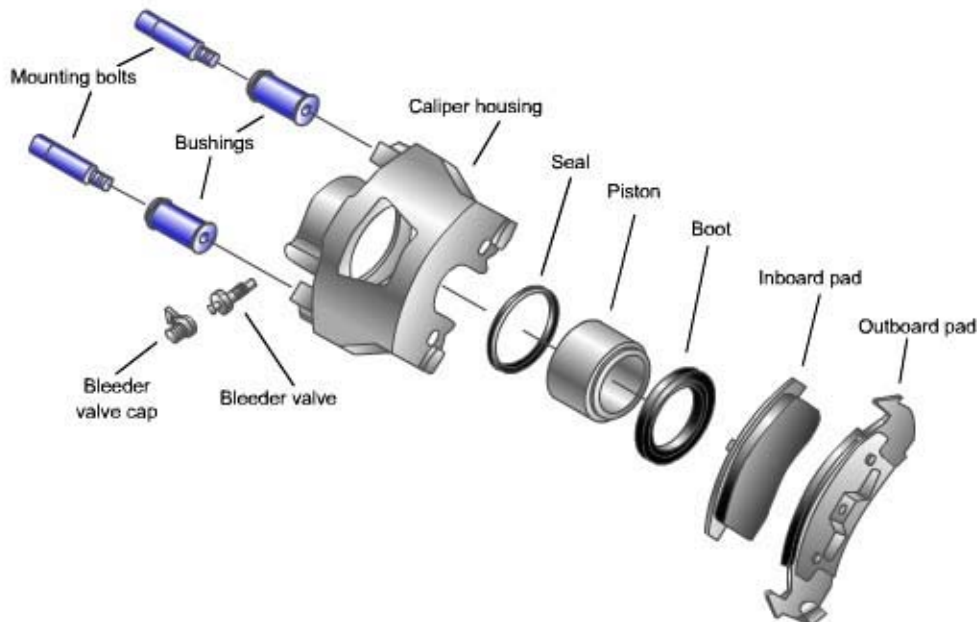
(fig. 25) Principle Parts of a Disc Brake

Disc Brake Caliper

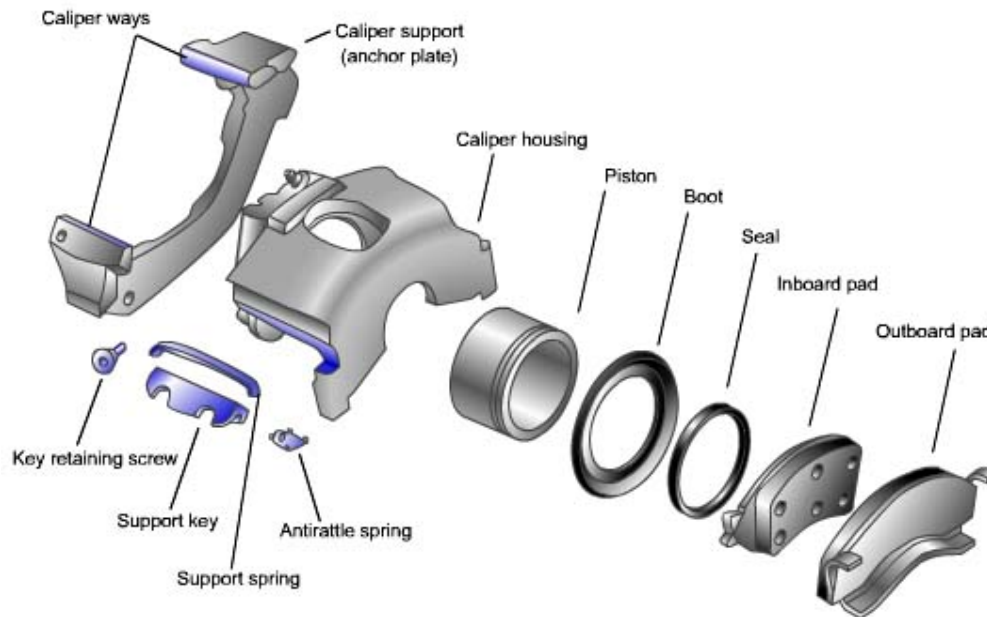
The disc brake caliper converts hydraulic pressure from the master cylinder to a mechanical force that pushes the brake pads against the rotor. The caliper body is a U-shaped casting mounted over the rotor and is typically made of iron or aluminum. All calipers, regardless of design, contain these major parts (fig. 26):

- Caliper body or housing
- Internal hydraulic passages
- One or more pistons
- Piston seals
- Dust boots
- Bleeder screw
- Inboard and outboard disc pads
- Mounting bolts

The most common types of disc brakes are the **floating caliper** and the **sliding caliper**. Both the floating and sliding calipers operate identically and the only difference is in the mounting. Specifically, floating calipers slide on mounting bolts and bushings (fig. 26) while sliding calipers operate on machined guides and bushings (fig. 27).



(fig. 26) Floating Caliper on Mounting Bolts and Bushings



(fig. 27) Machined Guide Sliding Caliper

Disc Brake Rotors

The rotor (or rotor/hub assembly) is attached to the wheel and provides the friction surface that the disc brake pads clamp against to slow and stop a vehicle.

Rotors must be machined and maintained to very close tolerances. Those that are warped (excessive lateral runout) or have excessive thickness variation (different thicknesses around the rotor) can cause vibrations and shutter during braking.

Typical Rotor Tolerances: *

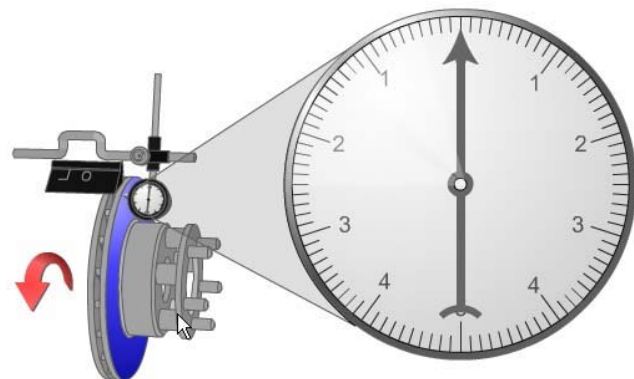
Lateral runout	0 – 0.003 in. (0.08 mm)
Thickness variation	0 - 0.0001 in. (0.00254 mm)

* Refer to vehicle service manual for specifications.

Measuring Rotor Lateral Runout

Excessive heat can cause rotors to warp. This warpage, or lateral runout, can cause braking problems and must be measured to determine if turning, or cutting, the rotors is required. With the rotor mounted on the vehicle, a dial indicator is used to determine the runout. The amount the dial indicator needle deflects while the rotor is rotated is the lateral runout.

Suppose that in figure 28 the dial indicator needle moved left -0.002 inch (0.051 mm) and then right + 0.003 inch (0.076 mm). The total runout is therefore 0.005 inch (0.127 mm) and could indicate that the rotor needs to be refinished or replaced (refer to vehicle service manual for specifications).

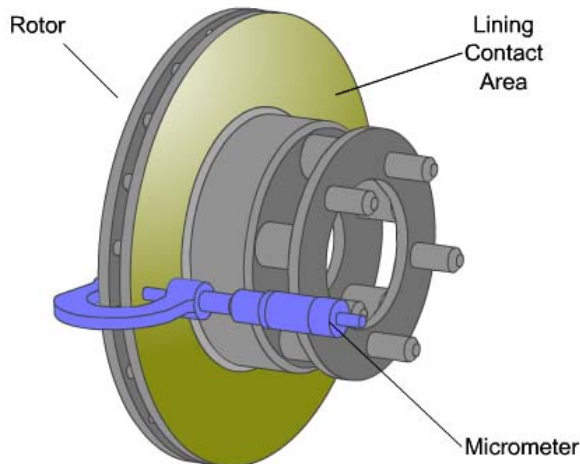


(fig. 28) Lateral Runout Measurement

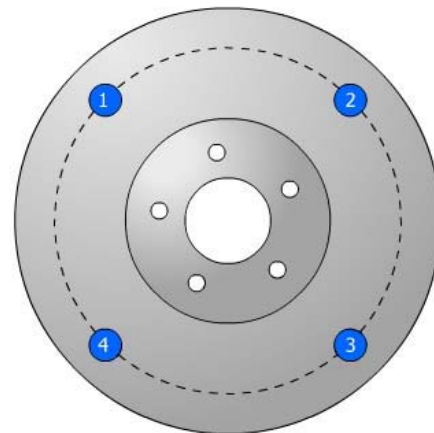
Measuring Rotor Thickness Variation

Rotors must be measured for thickness variation if the customer is experiencing a problem with a vibrating or pulsating brake pedal. Thickness variations can be caused by excessive heating and cooling of the rotor, and even a small variation can cause an adverse braking condition.

Precision brake micrometers must be used when measuring the thickness variation of brake rotors. A difference of more than 0.0003 inch (0.0076 mm) between four measurements (fig. 30) may require that the rotor be refinished or replaced during brake service (refer to vehicle service manual for specifications).



Measuring for Rotor Thickness Variation
(fig. 29)

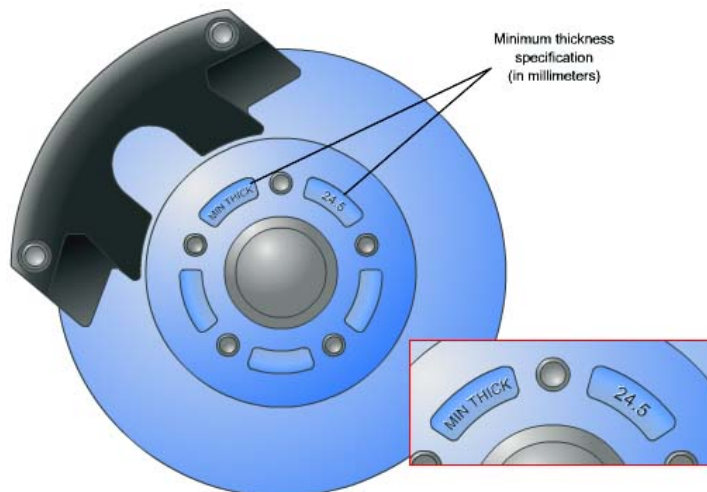


Measure rotor in four or more locations.
(fig. 30)

Rotor Refinishing

Rotors should be refinished only in cases of:

- Excessive lateral runout
- Excessive thickness variation
- Excessive surface scoring



(fig. 31) Discard Dimension on a Rotor

Additionally, there are two specifications that must be observed when refinishing rotors:

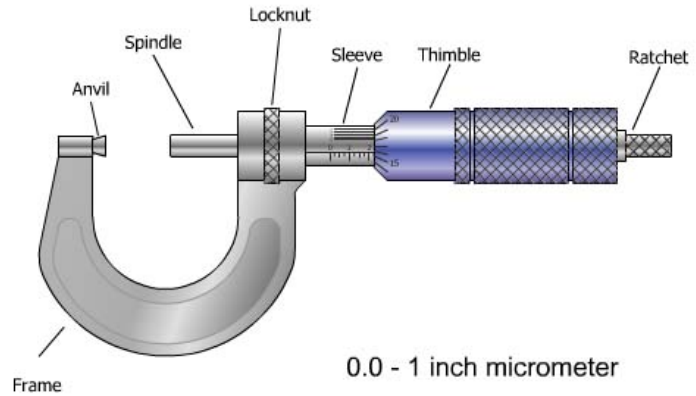
- **Discard specification** – This specification is usually stamped or cast into the rotor. Rotors can be reused to this ‘minimum thickness’ specification **if the rotor is not refinished** (fig. 31).
- **Minimum refinish specification** – This specification is found in the vehicle service manual and is the minimum thickness to which a rotor can be refinished. The difference between the discard and refinish specifications is to allow for the wear that takes place as the new pads burnish, or wear into, the **refinished** rotor.

Reading a 0 to 1 Inch English Micrometer

The major components of a micrometer are (fig. 32):

- Frame
- Spindle and Thimble
- Sleeve
- Anvil
- Ratchet
- Locknut

The spindle and thimble are made together and are threaded into the sleeve. When the thimble is rotated the thimble and spindle move in or out on precision threads (fig. 32).

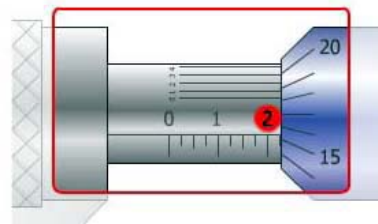


(fig. 32) Major Parts of an English Micrometer

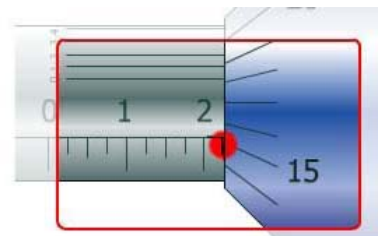
Reading an English Micrometer

A "One Inch" micrometer always measures a fraction of one (1) inch and measurements are made in four easy steps.

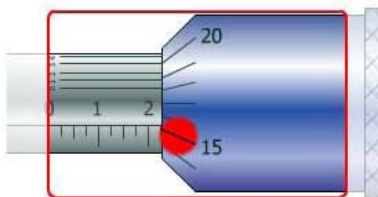
- **Step 1-** Read the largest number that is exposed on the sleeve as shown at right. In this case the largest number exposed is 2. Record this value in step 1 as 0.2 inch (200/1000 inch).
- **Step 2-** Count the number of marks that are exposed to the right of the number 2 as shown. Each mark equals 0.025 inch. In this example, one mark is exposed for a total of .025 inch (1 X 0.025 = 0.025). Record this in step 2 as 0.025 inch (25/1000 inch).
- **Step 3-** Next we find the line number on the thimble that aligns with, or is just below, the horizontal line on the sleeve. The sleeve line in this example is between 15 and 16. Record this in step 3 as 0.015 inch (15/1000 inch).
- **Step 4-** The Vernier Scale, for the most precise measurement, is located on top of the sleeve. Look for the one Vernier line that most perfectly aligns with any line on the thimble. In this case, Vernier line number 3 aligns with the thimble most closely. Record this in step 4 as 0.0003 inch (3/10,000 inch).



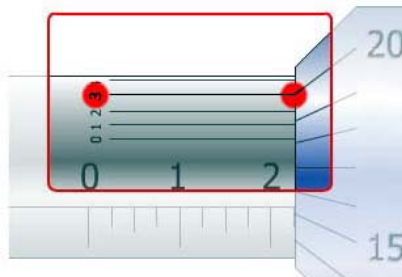
Step 1



Step 2



Step 3



Step 4

Now we simply total the numbers recorded in step 1 through step 4.

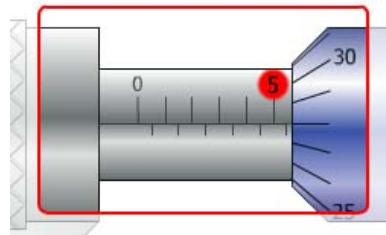
Step 1 0.2
 Step 2 0.025
 Step 3 0.015
 Step 4 0.0003
 Total = 0.2403 inch (2403/10,000 inch)

Note: This example was performed with a one inch micrometer for demonstration purposes. If the micrometer being used on a crankshaft journal, for instance, were a 4 inch tool, then the measurements would be performed exactly as shown above except that three inches would be added to the measurement total. Likewise, a 2 inch micrometer would add one inch, a 3 inch micrometer would add 2 inches, etc.

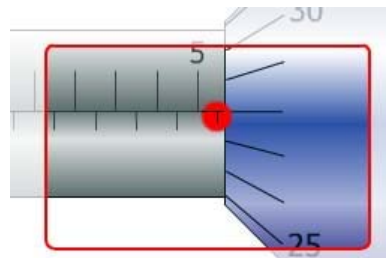
Reading Metric Micrometers

Reading a metric micrometer is similar to reading an English micrometer except that there are typically only three readings instead of four.

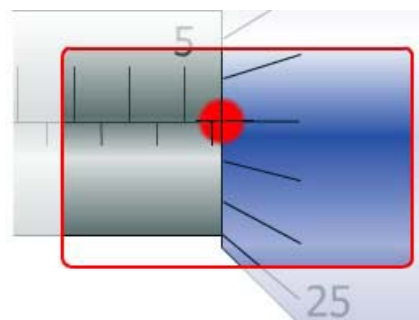
- On a metric micrometer the upper scale of the sleeve measures in 1.0 mm increments while the lower scale measures 0.5 mm increments.
- The thimble is divided into fifty (50) equal parts of 0.1 mm each, which means that one (1) complete revolution of the thimble equals 0.5 mm.
- Note that metric micrometers do not have a Vernier scale.
- In the example shown here, the upper scale reads 5.0 mm, the lower scale reads 0.5 mm and the thimble reads 0.28 mm for a total of 5.78 mm ($5.0 + 0.5 + 0.28 = 5.78$ mm).



Step 1



Step 2



Step 3

Recorded Totals

Step 1:	5.00 mm
Step 2:	0.50 mm
Step 3:	0.28 mm
	Total = 5.78 mm

Drum Brakes

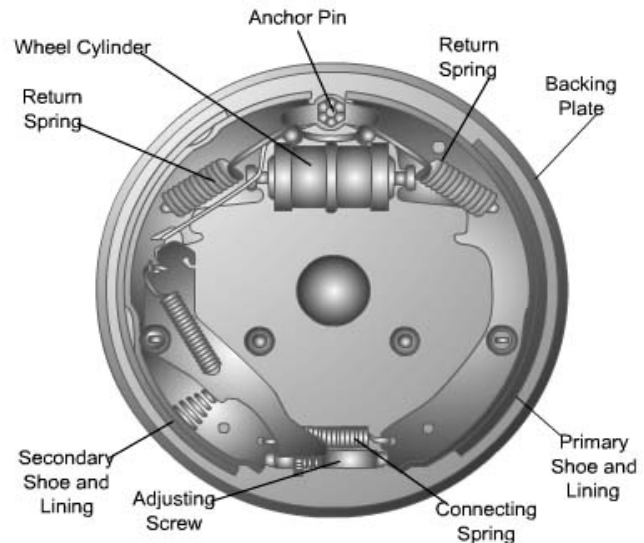
A drum brake unit consists of two brake shoes mounted on a stationary backing plate. When the brake pedal is pressed, a hydraulically activated wheel cylinder pushes the shoes out to contact a rotating drum which creates friction and slows the vehicle. As the pedal is released, return springs retract the shoes to their original position.

- Late model vehicles that use drum brakes will have them only on the rear wheels.
- The two most common types of drum brakes that we will deal with are **duo-servo** and **leading-trailing**.

Duo-servo Brakes

Consist of the following components (fig. 38):

- Brake drum
- One primary shoe and one secondary shoe with friction linings
- Hydraulic wheel cylinder
- Anchor pin
- Backing plate
- Adjusting screw
- Return springs, hold down springs, connecting springs
- Adjusting linkages and springs

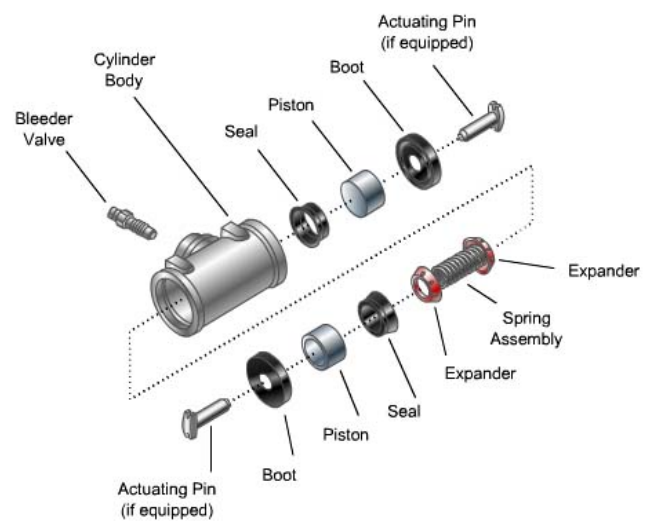


(fig. 38) Duo-servo Drum Brake

Wheel Cylinders

Consist of the following parts (fig. 39):

- Cylinder
- Two pistons
- Two lip seal piston cups
- Expander spring assembly
- Two protective dust covers
- Two actuating pins (some models)
- Bleeder valve



(fig. 39) Wheel Cylinder

Duo-servo Brake Operation

When duo-servo brakes are in the released position, return springs hold the bottoms of the shoes against the adjusting screw while the tops of the shoes are held against the anchor pin. As the brake pedal is pressed, the following occurs (fig. 38):

- Hydraulic pressure from the master cylinder to the wheel cylinder forces both wheel cylinder pistons outward to press the shoes against the drum.
- As the brake shoes contact the rotating drum, frictional force causes both shoes to rotate slightly. This action causes the secondary shoe (the one toward the rear of the vehicle) to jam against the anchor pin and forces the wheel cylinder piston back into the wheel cylinder.
- The rotating action of the primary brake shoe (the front one) causes the secondary shoe to wedge into the drum with a force that is greater than the just the hydraulic pressure would cause.
- Because of the wedging action, both shoes must be pulled away from the drum (by the return springs) when the brakes are released. Additionally, there are other springs that hold the brake shoes in place and return the adjuster arm after it actuates (fig. 38).
- As a result of this design, the secondary shoes must perform more of the braking than the

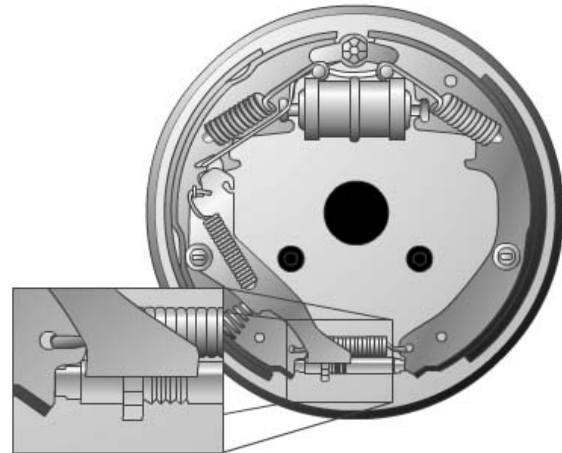
primary shoes. Therefore, the secondary shoes usually wear more and are typically larger than the primary shoes.

As a general rule-of-thumb, the heavier a drum-brake-equipped vehicle is, the more likely it is to have a duo-servo brake system.

Self-adjusters

Drum brake systems have a self-adjust capability to compensate for wear on the brake shoes.

- Self-adjuster mechanism consists of a series of links, springs, retainers and a star wheel (screw) adjuster.
- Rotational action of the brake shoes activates the self-adjuster linkage when the brakes are applied and the vehicle is moving in reverse (fig. 41).

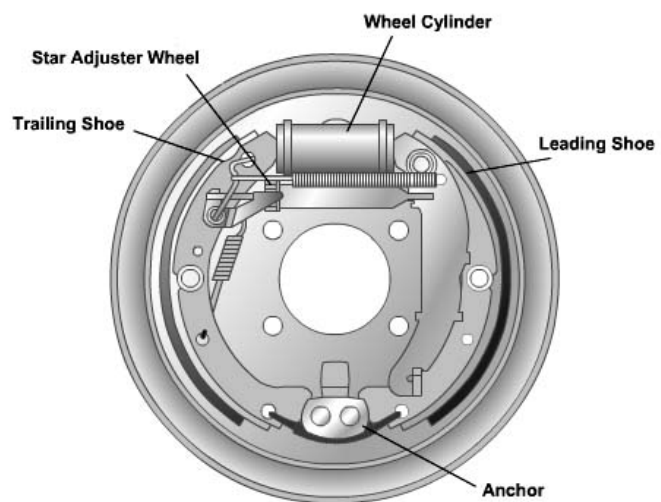


(fig. 41) Brake Adjuster Operation (duo-servo)

Leading-trailing Brake Operation

Three major differences between duo-servo and leading-trailing drum brakes:

- 1) Leading-trailing systems have the anchor pin mounted at the bottom of the backing plate rather than at the top (fig. 42).
- 2) Neither shoe pushes against the other in leading-trailing.
- 3) Leading-trailing drum brakes are automatically adjusted when the **parking brake** is applied and released.



(fig. 42) Typical Leading-trailing Brake

The operation of leading-trailing brakes is much simpler than duo-servo systems:

- When the brake pedal is pressed, a wheel cylinder pushes equally on each brake shoe.
- In turn, this forces the top of each shoe outward toward the drum, and each shoe pivots on the anchor located at the bottom of the backing plate.
- Drum friction pulls the leading (forward) shoe into tighter contact with the drum and aids the hydraulic force of the wheel cylinder. This action provides most of the braking force.
- The secondary shoe is not self-energizing as in Duo-servo but does provide some braking force due to the action of the wheel cylinder. When backing up, the opposite action takes place.

In leading-trailing systems both the primary and secondary brake linings are typically identical in size. As a general rule-of-thumb, the lighter a drum-brake-equipped vehicle is, the more likely it is to have a leading-trailing brake system.

Brake Drums

Any time brake service is performed, all brake drums should be inspected for the following:

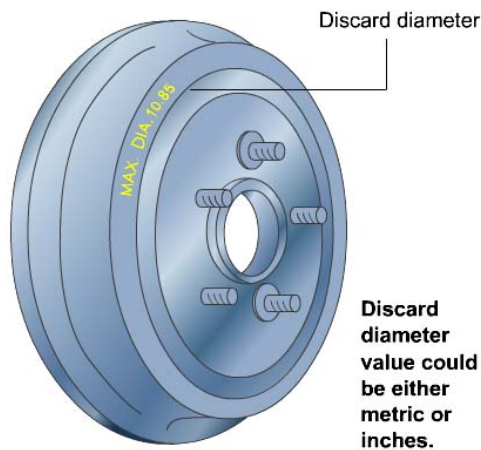
- Excessive wear or scoring
- Hot spots or heat checks
- Out-of-round
- Distortion
- Cracks

Any brake drum that is cracked must be replaced. Those that have hot spots, distortion, or are out-of-round can cause braking problem such as pulling, vibration, chatter, noise and pulsation. Many times these drums can be refinished and reused, other times they must be replaced. Drums that exhibit minor scoring but have no other problems can sometimes be reused without refinishing; however, it is critical that the diameter of a drum be measured to determine if it can be safely refinished and reused.

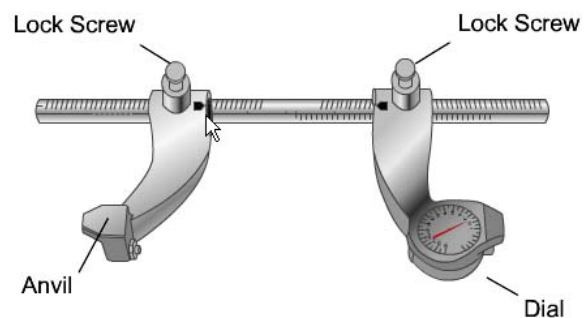
Measuring Brake Drums

When measuring brake drums to determine if they can be reused, there are two specifications that must be understood.

- **Maximum refinish diameter** – the maximum diameter to which a drum can be turned and still be reinstalled on a vehicle. The maximum refinish diameter specification lets the technician know that there is enough material remaining on the drum to be used safely and without an increase in the potential for failure. Maximum refinish diameters vary between drums. The actual specifications are available in the applicable service manual for the vehicle being repaired.
- **Discard diameter** – ‘Maximum discard’ is the diameter to which a drum can be reused **if not refinished**. If a drum exceeds the maximum discard diameter, either from refinishing or through normal wear, it must be discarded. The maximum discard specification is usually stamped or cast into the drum surface (fig. 43). The difference between the maximum refinish specification and the maximum discard specification is the amount that must be allowed for the drum to wear after refinishing.
- A drum micrometer, as shown in figure 44, is required to accurately measure a brake drum’s diameter.



(fig. 43) Maximum Discard Specification



(fig. 44) English Drum Micrometer

Procedure for reading an English drum micrometer

Refer to figures 44 and 45, and use the measurement specifications below for the example:

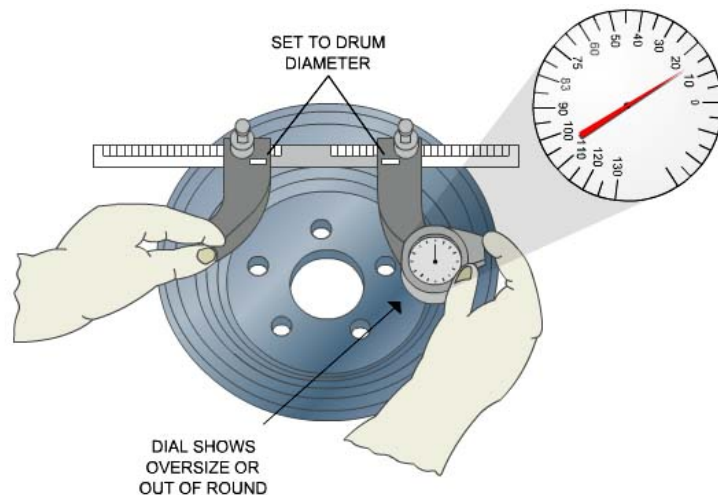
Original (new) drum diameter	11.375 inches
Maximum refinish diameter	11.435 inches
Discard diameter	11.465 inches

- Move the anvil leg of the drum micrometer along the graduated shaft until the “whole” number of the drum diameter (in this example, 11) is aligned on the shaft. Tighten the lock screw.
- Next, move the dial indicator leg along the graduated shaft until the “whole” number of the drum diameter (11) is aligned on that side.
- Now, move the dial indicator three (3) additional notches outward (you will feel a click at each notch) and tighten its lock screw.

Note: Each notch is equal to precisely 1/8 (0.125) inch and also aligns with a mark on the shaft. Therefore 3 notches are equal to 3×0.125 inch = 0.375 inch.

The drum micrometer is now set to the new drum diameter of 11.375 inches. In actual use, it may be necessary to move the dial indicator leg one notch in either direction from this point since all new drums don't come in increments of .125 inch.

- To use the micrometer, place it inside the drum and hold it flat against the rim of the drum (fig. 45).
- Hold the anvil end steady against the inside of the drum and move the dial, or right end, back and forth slowly to obtain the highest reading.
- The highest reading achieved is the amount that the drum is oversized, given in thousandths of an inch.



(fig. 45) Measuring a Brake Drum Diameter

In this case we add the dial indicator reading, 0.015 inch, to the original drum diameter setting of our micrometer, 11.375, to get our total diameter of 11.390 inches ($11.375 + 0.015 = 11.390$ inches). To determine how much metal we can remove from this drum and still use it, we simply subtract the measured diameter from the maximum refinish diameter ($11.435 - 11.390 = 0.045$). For this example, a maximum of 0.045 inch (or 45/1000 inch) can be machined from the drum.

Some Brake Service Thoughts

Always inspect and measure the brake drums when replacing brake linings or if any of the following symptoms occur:

- | | |
|-----------------------|---------------|
| -Pulsation | -Brake fade |
| -Chatter | -Wheel drag |
| -Brakes too sensitive | -Spongy pedal |

Resurface drums if:

- Taper or out-of-roundness exceeds 0.006 inch (0.15 mm)
- Scoring exceeds 0.060 inch (1.52 mm)

Replace drums if:

- The maximum diameter reading equals or exceeds the discard dimension.
- The drum is under the discard dimension but refinishing would not leave at least 0.030 inch (0.76 mm) allowance for wear.

Brake Fluid

The specifications for all automotive brake fluids are defined by the Federal Motor Vehicle Safety Standards and are assigned Department of Transportation (DOT) numbers.

Qualities that brake fluid must have:

- Free flowing at low and high temperatures
- A boiling point over 400 degrees F. (204 degrees C.)
- Low freezing point
- Non-corrosive to metal or rubber brake parts
- Ability to lubricate metal and rubber parts
- Hygroscopic - Ability to absorb moisture that enters the hydraulic system

The three (3) brake fluids currently assigned DOT numbers are DOT 3, DOT 4 and DOT 5. DOT 3 and DOT 4 are polyalkylene-glyco-ether mixtures while DOT 5 is silicone based. All domestic and most import car manufacturers specify and require DOT 3 brake fluid (some imports require DOT 4 as it has a higher boiling point). DOT 5 brake fluid is not currently used in any domestic or import vehicles (fig. 46).



(fig. 46) DOT 3 and DOT 4 Brake Fluids

Precautions must always be observed when working with brake fluids:

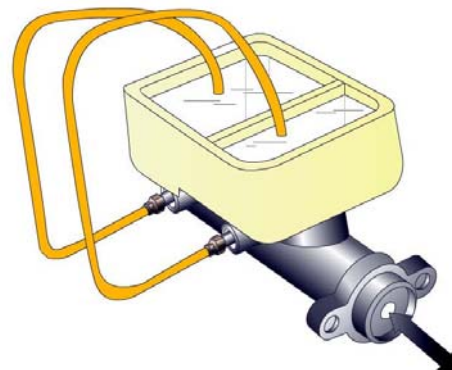
- Brake fluid is toxic to the human body.
- Brake fluid can damage painted surfaces.
- Brake fluid contaminated with moisture, dirt, petroleum or other foreign material will damage the hydraulic system internally.
- Only denatured alcohol or other approved cleaners should be used when cleaning brake hydraulic parts.
- Use only fresh, clean brake fluid (never reuse old brake fluid).
- Never mix brake fluids with any other fluids, including other types of brake fluid (e.g. DOT 3 and DOT 4).

Bleeding Brakes

Any time a brake hydraulic system is opened to the atmosphere for repairs or due to a leak, the system must be bled to remove the air. Unlike brake fluid, air is compressible and can cause a spongy brake pedal, brake pull and ineffective brake application.

Master Cylinder Bleeding

It is always a good idea to bench bleed a master cylinder after servicing and before installing/reinstalling it on the vehicle. One method for bench bleeding a master cylinder requires attaching two (2) brake lines to the master cylinder (fig. 47) and directing them back into the reservoir. Fill the reservoir(s) with clean DOT brake fluid and slowly push the master cylinder pistons in several times until air bubbles are no longer seen. This procedure will save time and fluid when bleeding the hydraulic system after the master cylinder has been reinstalled.



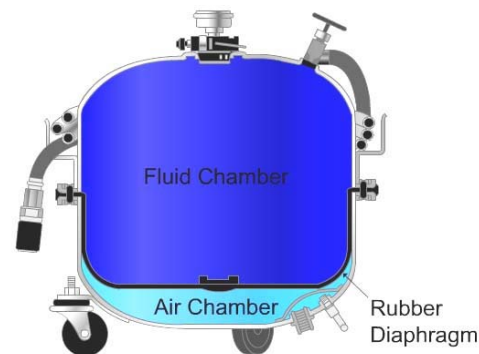
(fig. 47) Bench Bleeding Master Cylinder

The two (2) most commonly used methods for bleeding brakes are:

- Pressure bleeding
- Manual bleeding

Pressure Bleeding

A pressure bleeder is a special tank that is divided into two (2) chambers by a rubber diaphragm. The upper chamber is filled with clean fresh DOT 3 brake fluid while the lower chamber is pressurized with air. The rubber diaphragm keeps the brake fluid separated from the air (fig. 48). Pressure bleeding is often the preferred method for bleeding brakes since one person can do the job alone and the master cylinder does not have to be repeatedly refilled during the process.

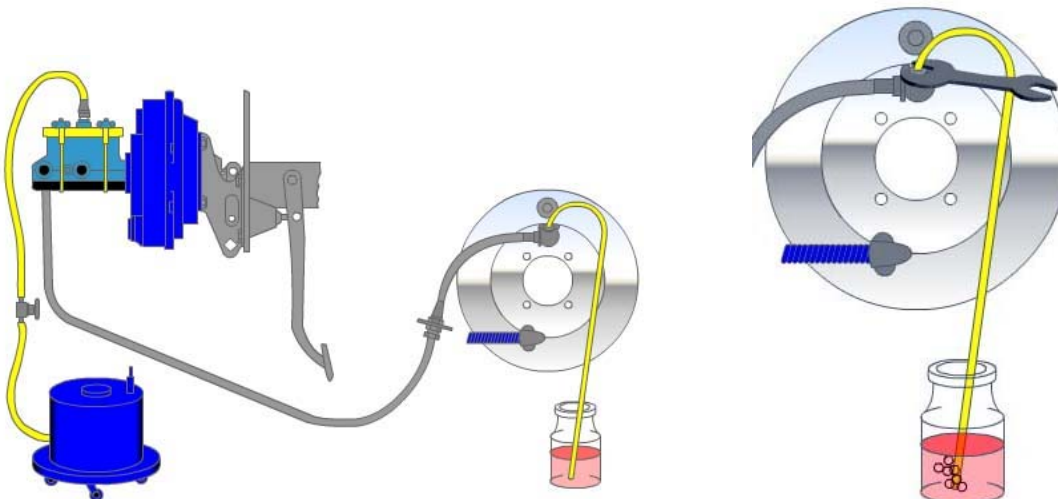


(fig. 48) Typical Brake Pressure Bleeder

Pressure bleeders are attached to the master cylinder with a hose and a special adapter (fig. 49). The special adapter seals the pressure bleeder to the master cylinder to prevent fluid and air leaking into or out of the system. To pressure bleed a brake system:

- Fill the pressure bleeder with clean DOT 3 brake fluid and charge the air reservoir with fifteen (15) to twenty (20) psi (105 – 140 kPa) of air.
- Fill the master cylinder reservoir to the proper level, usually about one quarter (1/4) inch from the top. Install the bleeder adapter to the master cylinder reservoir, attach the supply hose from the pressure bleeder to the adapter, and open the supply valve.
- Attach a bleeder hose to the wheel cylinder bleeder valve and extend the end of the hose into a clear glass container partially filled with DOT 3 brake fluid (fig. 50).
- Open the bleeder valve. Any air trapped in the system can be seen as bubbles escaping from the bleeder hose. Close the bleeder valve after all air bubbles have been expelled.
- Repeat the bleeding process for all four (4) wheels.
- Remove the pressure bleeding equipment and fill the master cylinder to the proper level. Test the brakes to make sure the pedal is firm before driving the vehicle.

Note: A valve depressor tool may be required to bleed the front disc brake calipers on vehicles equipped with a metering valve.



(fig. 49) Pressure Bleeder w/Master Cylinder Adapter (fig. 50) Air Bubbles Bleeding from a Brake System

Manual Bleeding

The manual brake bleeding process requires two (2) technicians and the fluid level in the master cylinder must be checked often.

- Technician # 1 begins the procedure by pressing the brake pedal to build up fluid pressure.
- Technician # 1 then continues to hold a steady pressure on the brake pedal while Technician # 2 opens the bleeder valve and observes as fluid and air bubbles are expelled. The brake pedal will go to the floor and Technician # 1 will continue to hold steady pressure on the brake pedal until Technician # 2 closes the bleeder valve.
- This process is repeated until all the air has been expelled. Repeat the process for all four (4) wheels.
- Check and refill the master cylinder between wheels and when the procedure is completed. Test the brakes to make sure the pedal is firm before driving the vehicle.

Note: Do not allow the master cylinder to run out of fluid or air will be introduced into the system.

Note: A valve depressor tool may be required to bleed the front disc brake calipers on vehicles equipped with a metering valve.

Bleeding Order

One of the oldest adages in the automotive service industry involves brake bleeding. The old saying is that you should bleed the brakes starting farthest from the master cylinder and move progressively closer with each wheel. However, few understand where this belief originated. As with most firmly held beliefs, there is some truth in this one, but it is no longer universally applicable as it once was. The history is this; before front-wheel-drive vehicles became commonplace, most vehicles had rear-wheel-drive and front/rear split brake systems (at least after the advent of dual-piston master cylinders). In order to bleed the front brakes, it was necessary to build up enough pressure in the rear brakes to open the metering valve and allow fluid to reach the fronts. So, technicians would bleed the right-rear first, since it is the longest brake line, and then move to the left rear. After the rears were clear of trapped air, the fronts could be bled starting with the longest line (right-front). This system is still applicable today for vehicles with front/rear split systems. However, it does not apply with diagonally-split systems (mostly front-wheel-drive) for two reasons; 1) diagonally-split systems do not have a metering valve and 2) the right-rear and left-rear brakes are on separate systems.

If the procedure above is used on a diagonally-split system and the right-rear brake is bled followed by the left-rear, then the left-front brake portion, which is only half bled (right-rear is done) will tend to aerate or make bubbles in the fluid as the pedal is pressed to bleed the left-rear. Once you have bubbles in the fluid, it can be extremely difficult to get the lines clear and you may have to wait for the air and the fluid to separate again before continuing.

So what is the proper bleeding order to use? It depends on the vehicle. If it is a front-rear split system, start with one of the rear brakes (it really doesn't matter which but most people start with the right-rear), then move to the other rear brake. That will completely bleed that system (the rears). Then bleed the front brakes. Again the order is really unimportant. If the vehicle has a diagonally split system, you can begin wherever you like but, **and this is important**, whichever you do first, the opposite brake must be next to prevent the possibility of aeration. If the right-rear is first, the left-front must be next. Start with the right-front? Then the left-rear is second. Most seasoned technicians will typically go from right-rear to left-front then from left-rear to right-front. That is usually a good idea since a consistent procedure helps to avoid errors.

Note: because of the nature of some Antilock Brake systems, certain vehicles will use a specific bleeding order to help ensure that all of the air is removed from that unit. If that is the case, follow the manufacturer's instructions.

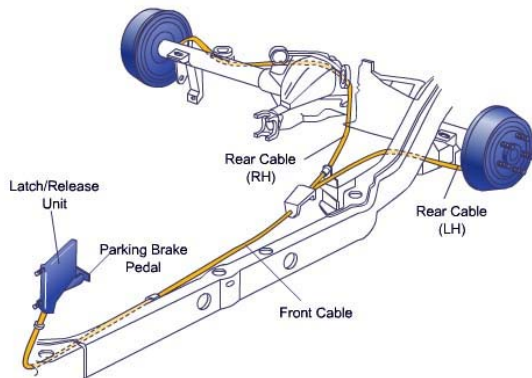
Parking Brake

Federal Motor Vehicle Safety Standards require that automotive parking brakes be capable of holding a vehicle stationary on a 30 degree grade.

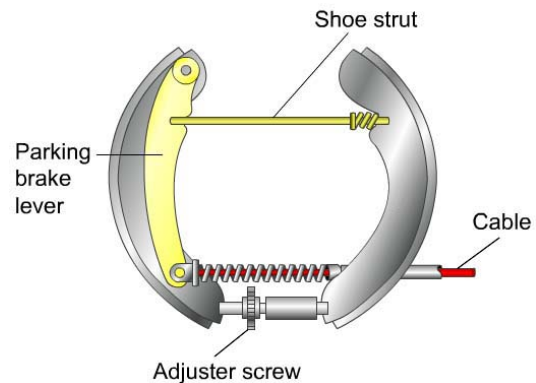
The parking brake systems on most vehicles use either a hand or foot operated lever and cables to mechanically apply the rear wheel brakes (fig. 51).

Parking Brake - Drum (Duo-Servo)

When a driver applies the parking brake on a vehicle equipped with rear drum brakes, it pulls cables that are attached to actuator levers and struts inside the brake drum. These actuator levers and struts mechanically apply the brakes by pushing both brake shoes outward into the drum (fig. 52).



(fig. 51) Typical Parking Brake System



(fig. 52) Parking Brake Strut and Actuator Lever (Duo-Servo)

Disc Brakes with Integral Parking Brake

Many vehicles that are equipped with rear disc brakes require a regular application of the parking brake to keep the rear disc brakes in proper adjustment. Unlike front disc brakes, rear disc brakes on these vehicles are not self-adjusting. The two (2) most common types of caliper-actuated parking brakes are the:

- Screw-and-nut
- Ball-and-ramp

Screw and Nut Parking Brake

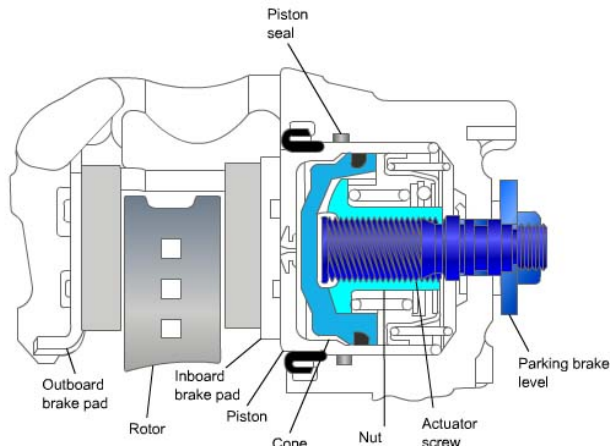
When the parking brake is applied on a rear-disc-equipped vehicle (fig. 53) the following occurs:

1. The cable actuated parking brake lever rotates an actuator screw
2. The actuator screw unthreads on a nut inside the piston.
3. As the screw turns, it moves the nut outward by pressing against a cone inside the piston.
4. The piston applies the inboard pad against the rotor. The movement of the piston also causes the caliper assembly to slide and apply the outboard pad.
5. An adjuster spring inside the nut and cone rotates the nut outward when the parking brakes are released to provide self-adjustment. Rotation of the nut also takes up clearance as the brake pads wear.

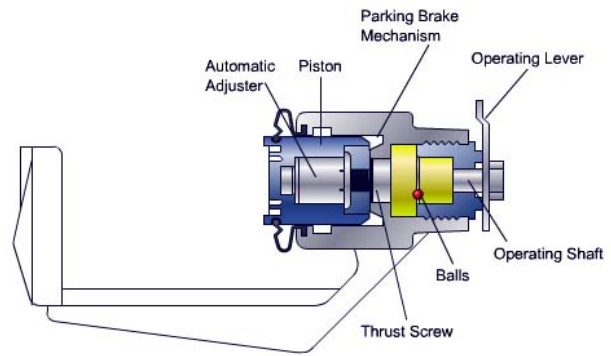
Ball-and-Ramp Parking Brake

In the ball-and-ramp park brake system (fig. 54) the caliper lever is attached to a shaft inside the caliper that has a small plate on the other end. A second plate is attached to a thrust screw inside the caliper piston. Three (3) steel balls separate the two (2) plates.

- When the parking brake is applied, the caliper lever rotates the shaft and plate.
- Ramps on the surface of the plate force the balls outward against similar ramps in the other plate.
- This action forces the thrust screw and piston outward applying the brake.
- When the park brake is released, an adjuster nut inside the piston rotates on the thrust screw to take up excessive clearance and provide self-adjustment.



(fig. 53) Screw-and-Nut Parking Brake Mechanism

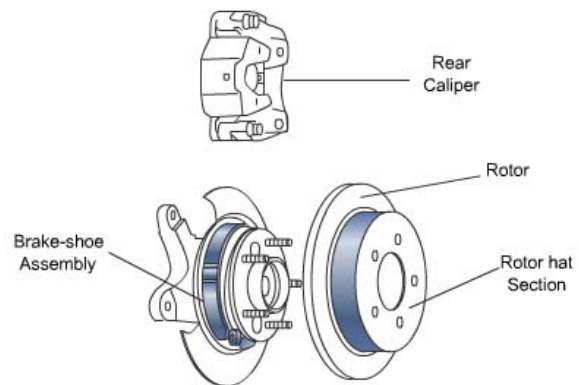


(fig. 54) Ball-and-Ramp Parking Brake Mechanism

Drum-in-Hat Parking Brake

Some later model vehicles with four (4) wheel disc brakes use a small drum brake incorporated into the rear rotor (fig. 55) called a drum-in-hat system.

- Consists of a simple, cable activated shoe assembly that applies against a drum machined inside the rotor hat section
- The rear caliper does not have to perform both service and parking brake functions.
- The parking brake shoes for this system are manually adjusted when installed, and, theoretically, should never need readjustment.



(fig. 55) Drum-In-Hat Parking Brake

Note: Kinked or binding parking brake cables or linkages could prevent a parking brake from applying or releasing properly. This could also cause the brake warning light to remain on even after the parking brake is released.

Brake Lines and Hoses

- Transfer fluid pressure from the master cylinder to the brake calipers and wheel cylinders
- On some vehicles, pressure can exceed 1000 psi.
- Brake hoses (the shorter rubber-covered sections that connect at the wheels) must also maintain a high degree of flexibility.
- Because of the pressures involved, only double-walled steel brake tubing is approved for use in brake lines.

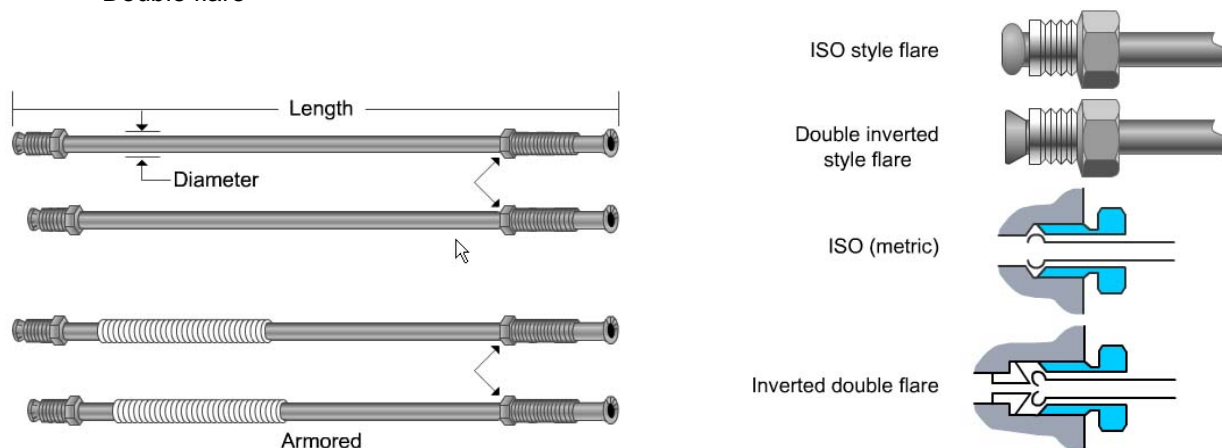
Warning: Never use copper tubing as a replacement. It cannot withstand the high pressure or the vibration to which brake lines are exposed. Fluid leakage and system failure can result.

When replacing a brake line, it is advisable to purchase a preformed OEM replacement, as they are of the correct length, bend, and strength to handle the system demands. It can also be more cost-effective, since bending and flaring brake lines can be quite time consuming. In addition to OEM replacements, aftermarket lines are also available in various lengths and diameters. Many are also pre-flared and have flare nuts installed (fig. 56). Aftermarket bulk brake line is also available which can be cut to length and flared as needed. Keep in mind that this is a job to be performed only by those with the requisite tools

and skills. Additionally, care must always be exercised when bending any brake line so as to not kink and weaken the line.

All vehicles utilize one of two methods of brake line connection flaring (fig. 57) and each requires its own special tools and flare nuts. They are:

- ISO (International Standards Organization) flare
- Double flare



(fig. 56) Brake Tubing with Flared Ends and Flare Nuts Installed; (fig. 57) ISO and Inverted Double Flares

Brake Hoses

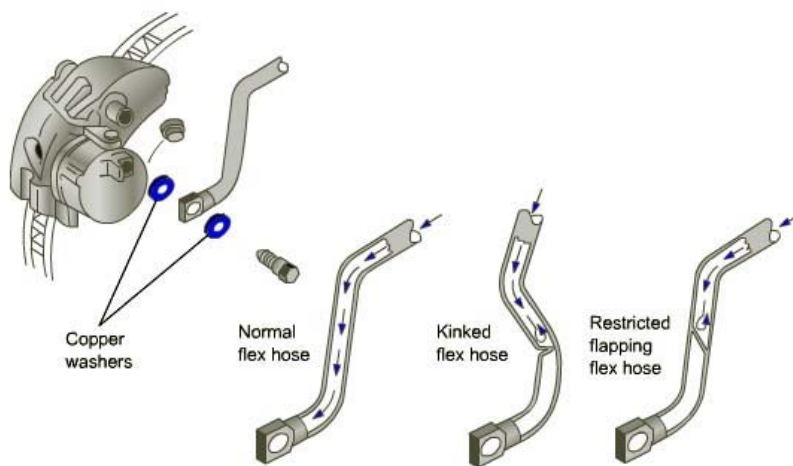
- Designed to distribute high pressure brake fluid to the wheel brakes (fig. 58)
- Must also allow for the vertical movement of the suspension and the side-to-side motion of the front wheels as the driver steers the vehicle
- These forces are substantial and can weaken the hoses over time.

When performing brake service, always remember to:

- Inspect the hoses for damage, kinks or ballooning
- Inspect hoses for proper routing
- Never hang a caliper from a rubber brake hose
- Replace the copper sealing washers when replacing brake hoses

Defective or damaged hoses can balloon or swell, which will store brake fluid pressure and cause the vehicle to pull during braking or give a low pedal concern.

A blocked, restricted, or kinked brake hose can also cause the vehicle to pull during braking. In this case the pull will be to the opposite direction of the problem component. That means that a left-front hose that is blocked, restricted, or kinked would cause a pull to the right and a right-front hose failure would cause a pull to the left during braking.



(fig. 58) Brake Hoses and Failure Modes

BASE BRAKE DIAGNOSIS

Diagnosing brake problems can be simplified by following a few basic steps:

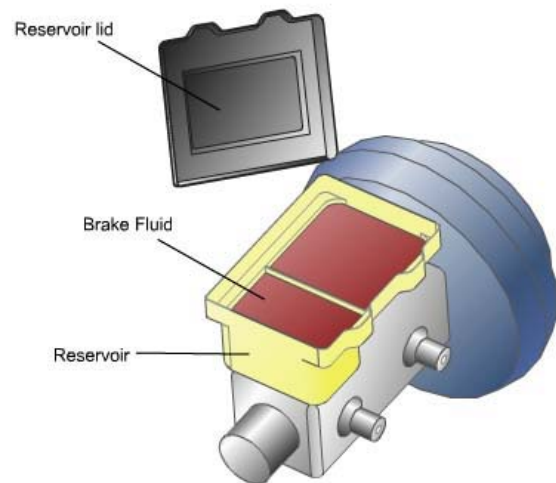
- Listen to the customer
- Verify the complaint
- Perform a visual inspection
- Conduct a brake pedal check
- Test Drive (before and after repairs)

Listen to the customer...ask the necessary questions

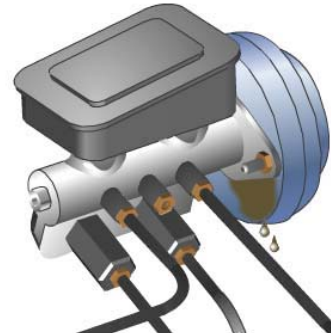
- What kind of problem did the customer experience?
- Under what conditions did the problem occur?
- Does the problem occur with every brake apply?

Visual inspection

- **Fluid levels** – remove the master cylinder reservoir cover and inspect the fluid level in both chambers (fig. 59). Some reservoirs have both Hot and Cold fill level indications, make sure you use the correct level. Low fluid level in either chamber could be either the result of normal brake lining wear or it could indicate an external leak.
- **External leaks** – visually check the master cylinder (fig. 60), calipers (fig. 61), and/or wheel cylinders (fig. 62) for leaks. Fluid will be visible on the face of the power brake booster if the master cylinder is leaking from its rear seal.



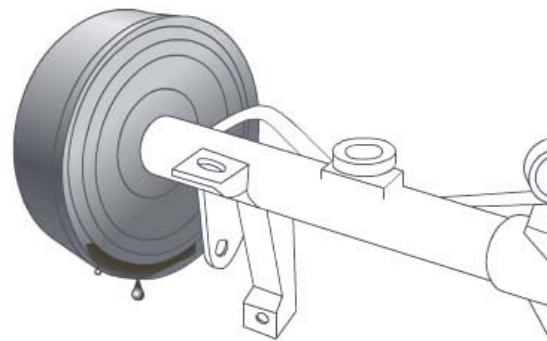
(fig. 59) Check Fluid Level



(fig. 60) Fluid Leaking from Master Cylinder



(fig. 61) The bottom of the caliper will be damp with fluid if a disc brake is leaking.



(fig. 62) The bottom of the backing plate will be damp with fluid if a wheel cylinder is leaking.

Note: Leaking calipers or wheel cylinders can coat the brake pads or shoes with brake fluid and cause complaints such as wheel lock up, brake squeal, pulling and ineffective braking.

WARNING: Leaks should be repaired before driving any vehicle.

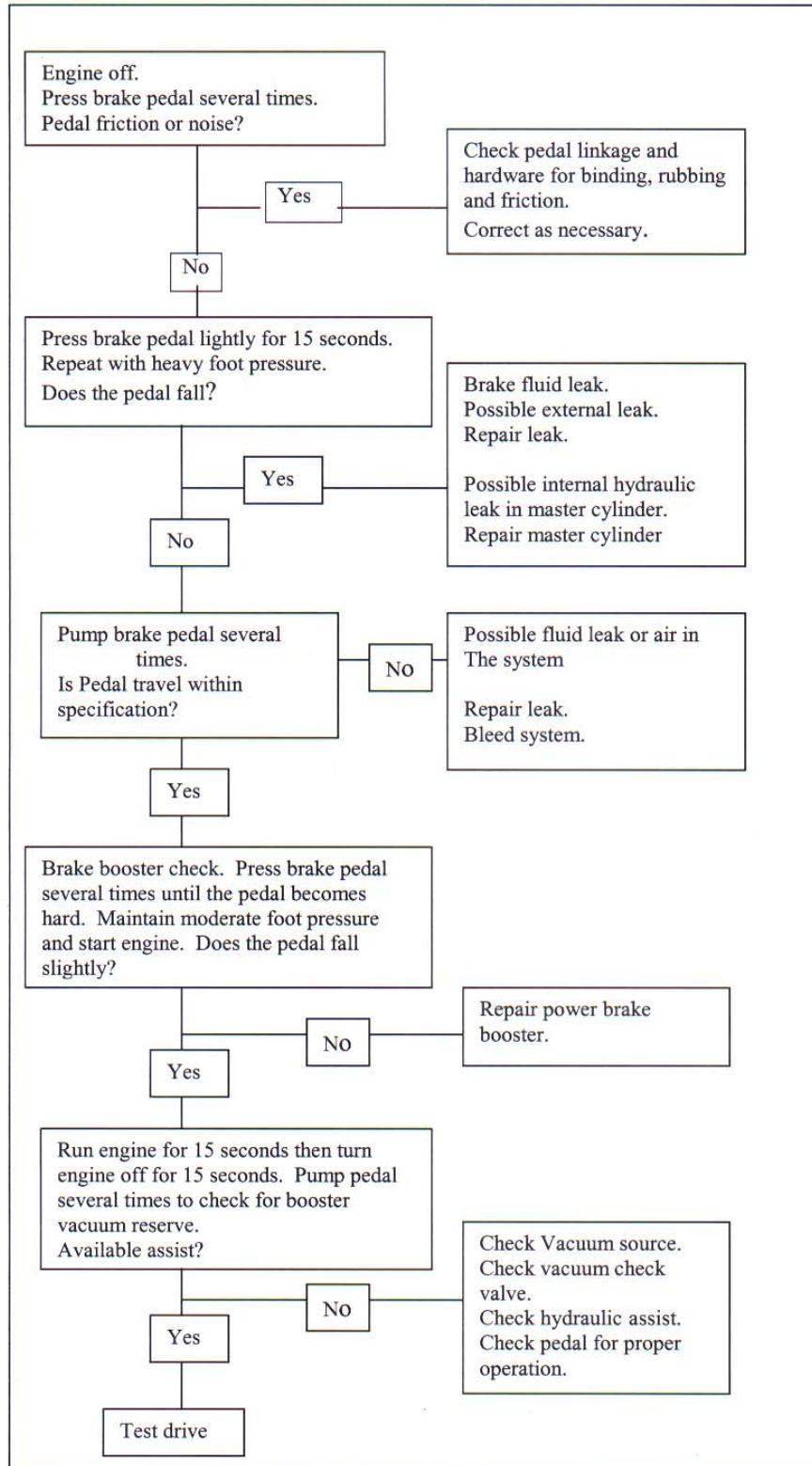
- **Parking brake operation** – With the key on and the engine off, engage the parking brake. The brake should apply with approximately half travel of the lever or pedal and the brake warning light should turn on. Deactivate the parking brake and it should release immediately. The lever or pedal should return to the release position and the warning light should turn off. Any problems with the engagement or release of the parking brake could indicate a binding linkage.
- **Brake warning light** – With the key on and engine off (parking brake disengaged), if a brake warning light comes on, with or without applying the service brakes, it could indicate a hydraulic failure in the system.

WARNING: Repair the hydraulic system before driving the vehicle.

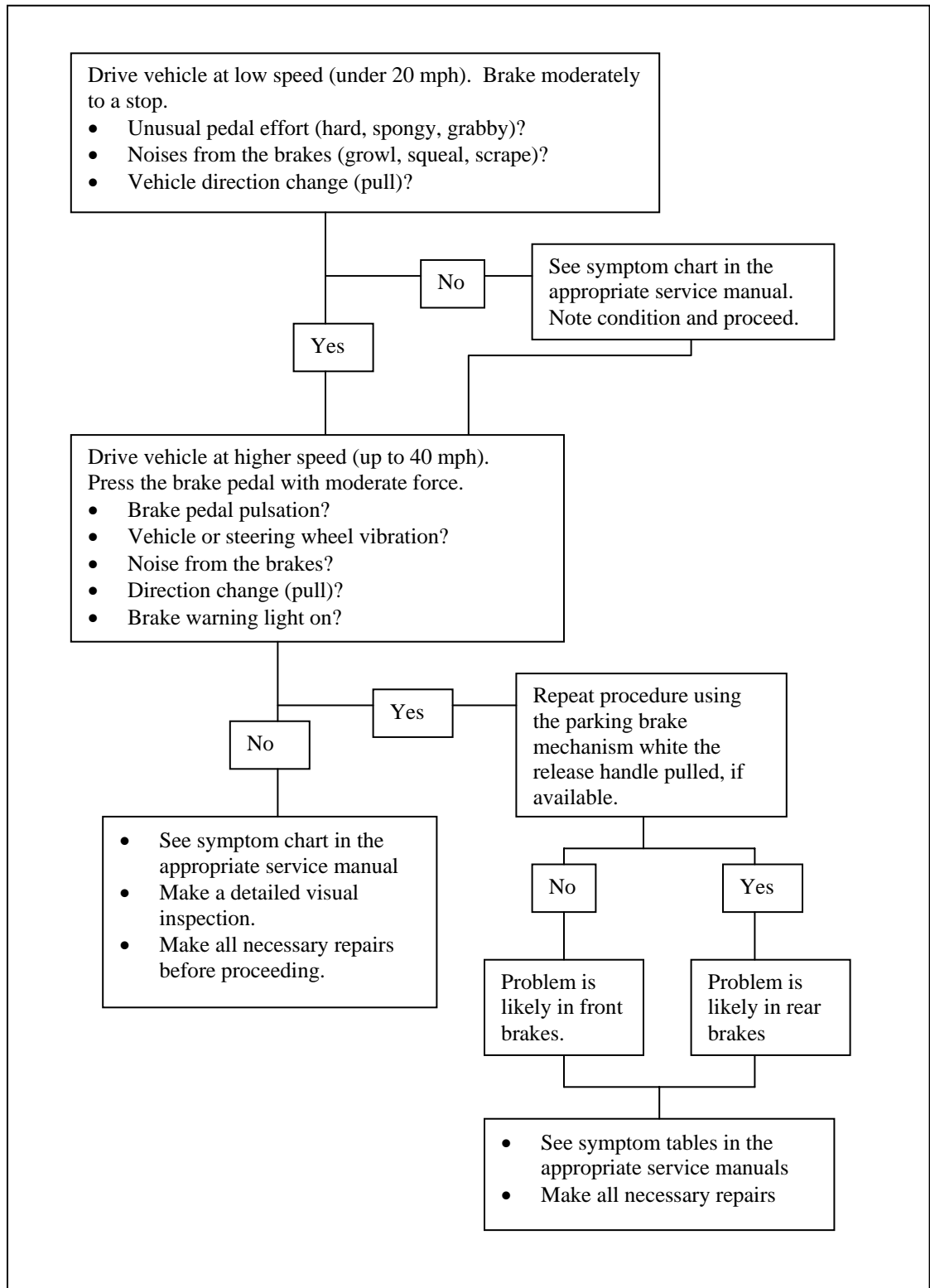
Detailed Visual Inspection

Component	Inspect for:	Corrective Action
Brake pipes and hoses	Leaks Crimps or restrictions	Repair or replace as necessary
Parking brake cables	Excessive Slack Corrosion that could prevent brake application or release	Clean, lubricate, adjust or replace as necessary
Parking brake operation	Proper operation Wheels rotate (parking brake engaged) Wheels cannot be rotated without excessive drag (parking brake disengaged)	Clean, lubricate, adjust or replace as necessary
Brake linings	Excessive wear	Replace
Brake hardware and hold-downs	Damage, wear or corrosion Missing Components	Replace
Brake Rotors	Wear (reduced thickness) Deep scoring or scratches Thickness variation Lateral runout Excessive heat checking	Replace Compare to specifications Machine or replace as indicated
Brake Drums	Wear (excessive diameter) Deep scoring or scratches Taper (bell mouth) Out of round Excessive heat checking	Compare to service limit specifications

Brake Pedal Checks



Test Drive



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