Hydraulic Brakes and Air-Over-Hydraulic Brake Systems

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Objectives

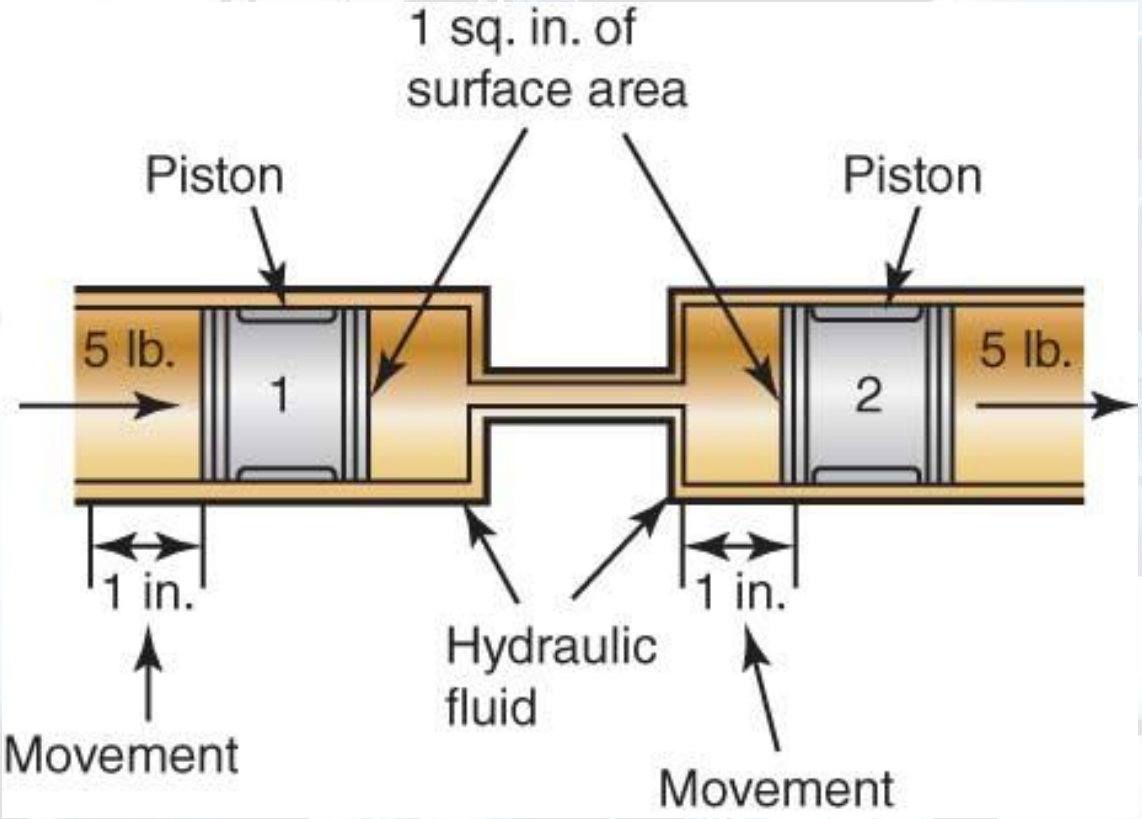
- Describe the principles of operation of a hydraulic brake system.
- Identify the major components in a truck hydraulic brake system.
- Describe the operation of drum brakes in a hydraulic braking system.
- Describe the operation of wheel cylinders and calipers.
- List the major components of a master cylinder.
- Identify the hydraulic valves and controls used in hydraulic brake systems.

Objectives (cont.)

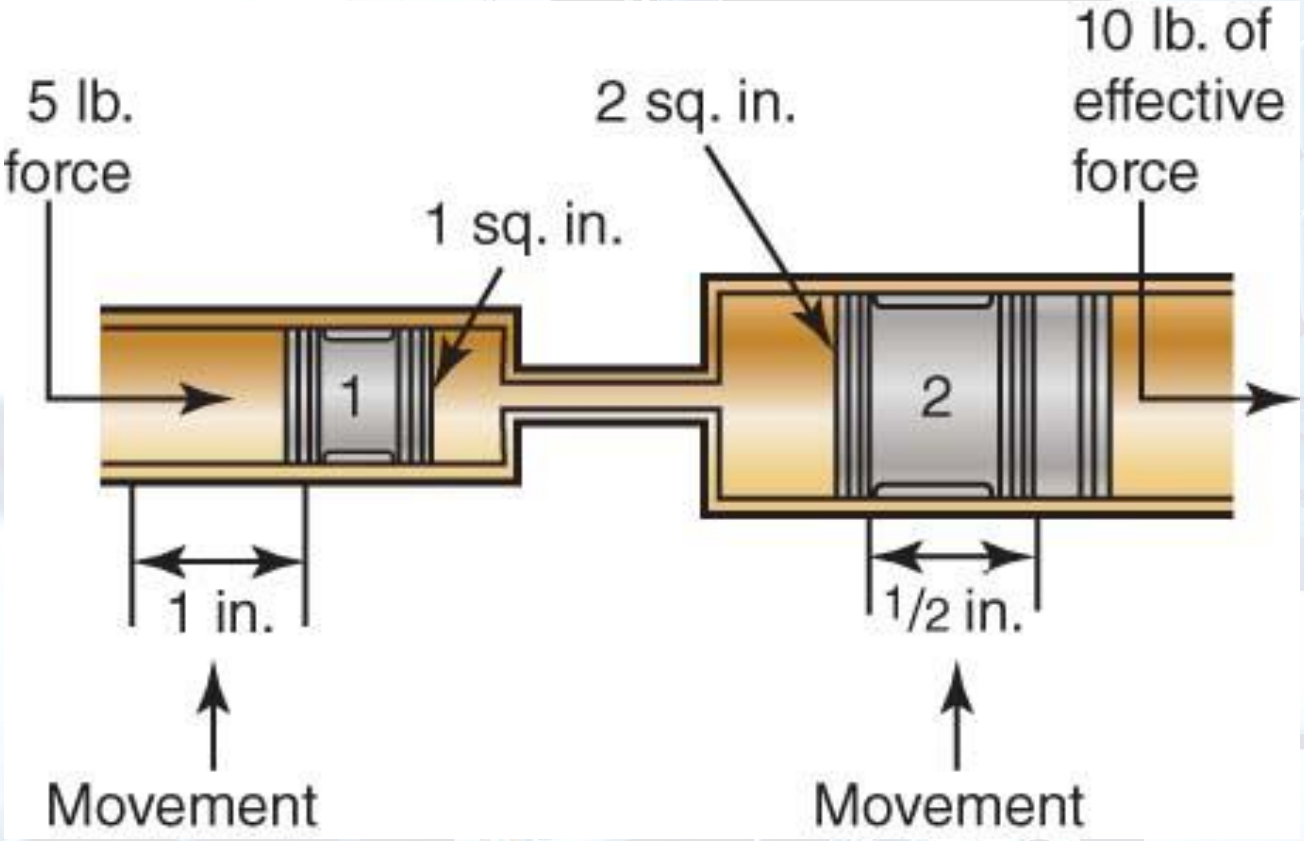
- Explain the operation of a hydraulic power booster.
- List the major components of an air-over-hydraulic braking system.
- Outline some typical maintenance and service procedures performed on hydraulic and air-over-hydraulic brake systems.
- Bench bleed a master cylinder.
- Identify the methods used to bleed brakes.
- Describe the operation of a typical hydraulic ABS.

INTRODUCTION

Hydraulic brakes are used on light- and medium duty trucks up to Class 7 weight category. Hydraulic brakes work on the premise that if mechanical force is applied to a liquid in a closed circuit, it can be used to transmit motion or multiply and apply force.



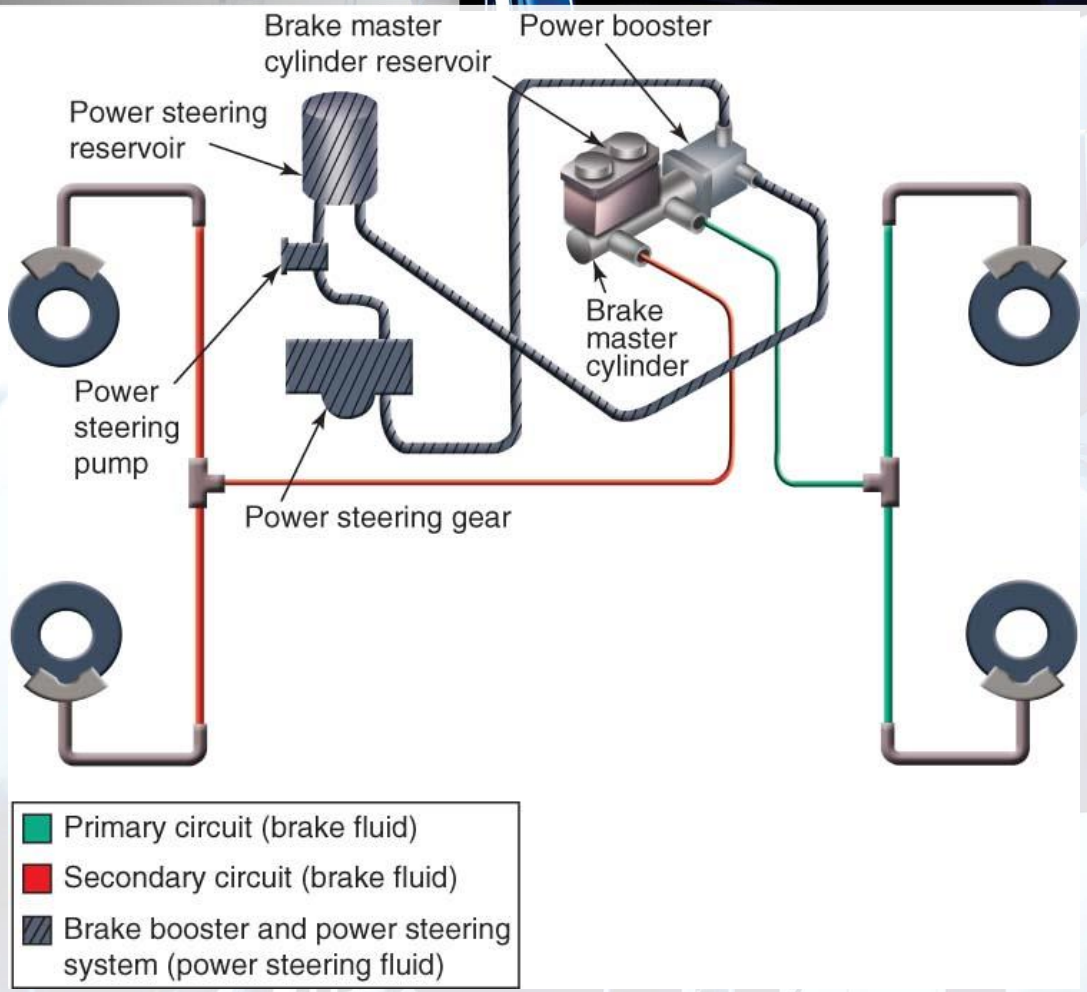
Force and movement are transmitted equally.



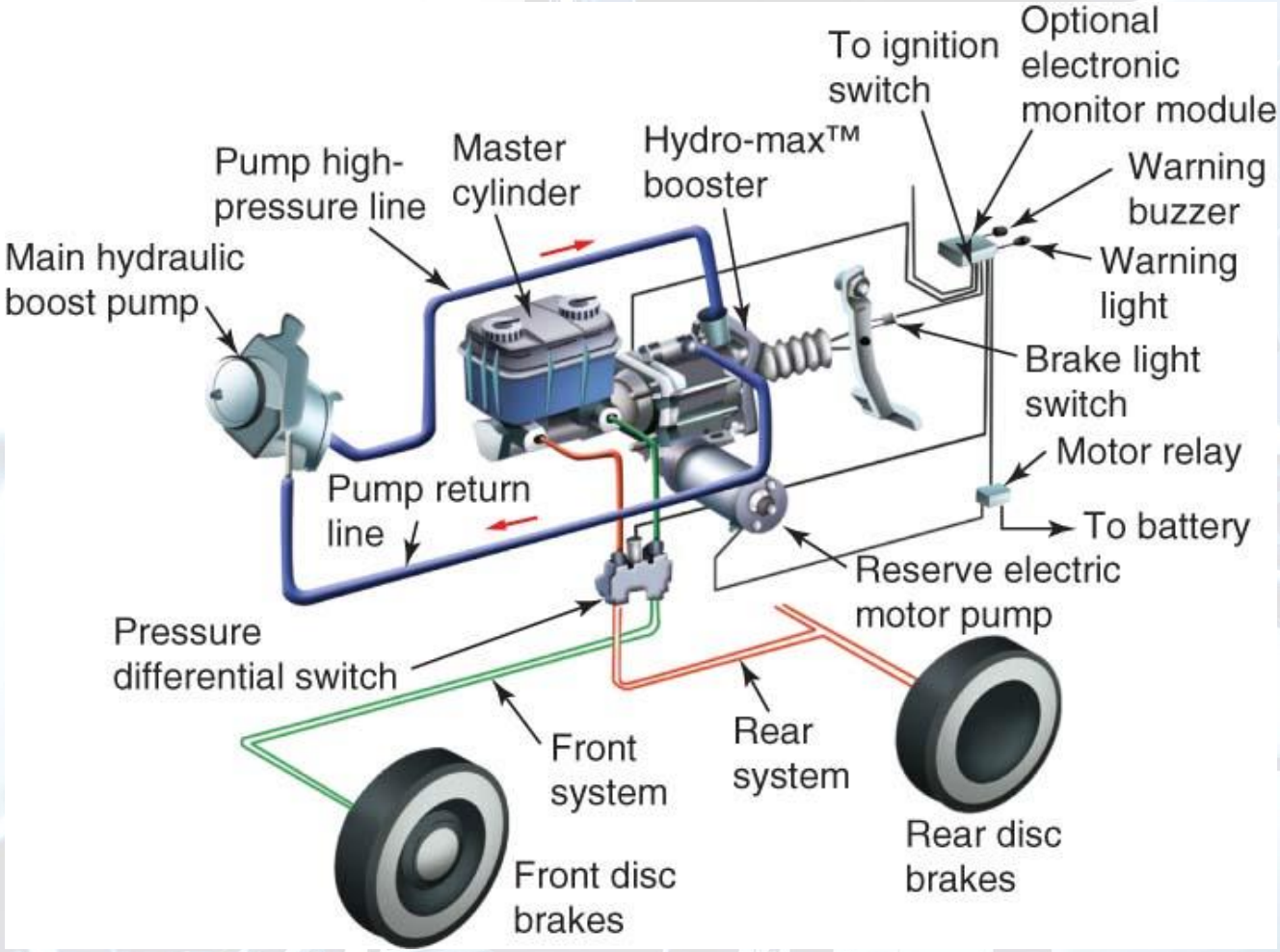
Force increases—movement decreases.

FMVSS 105

This federal legislation performs the same role in hydraulic brake standards as FMVSS 121 does with air brakes. FMVSS 105 requires that all highway-use hydraulic brake systems be dual circuit and have the ability to park and perform mechanical emergency stop and park operation.



Four-wheel hydraulic disc brake system with power assist: typical of many school bus systems



Schematic of a dual-circuit, split disc hydraulic brake system

HYDRAULIC BRAKE FLUID

Brake fluid standards are set by the Society of Automotive Engineers (SAE) and Department of Transportation (DOT). There are three categories of brake fluid, known as DOT 3, DOT 4, and DOT 5. DOT 3 and 4 use a polyglycol base. These are **hygroscopic,** meaning that they are designed to absorb moisture that enters the system.

Shop Talk

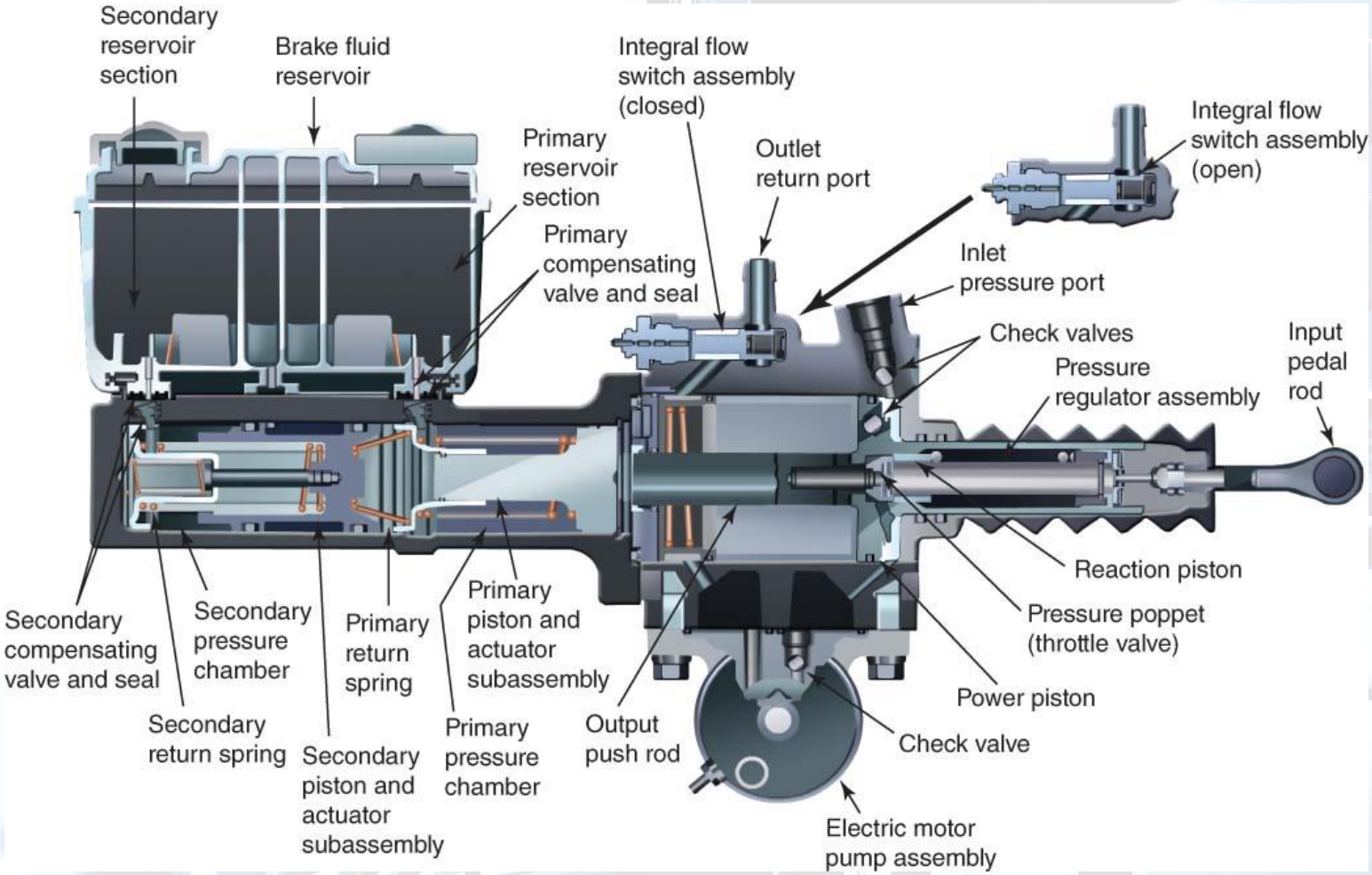
Hygroscopic brake fluid can absorb airborne moisture rapidly. If DOT 3 and 4 brake fluids are left uncovered in a container, they can be ruined in as little as 1 hour.

WARNING

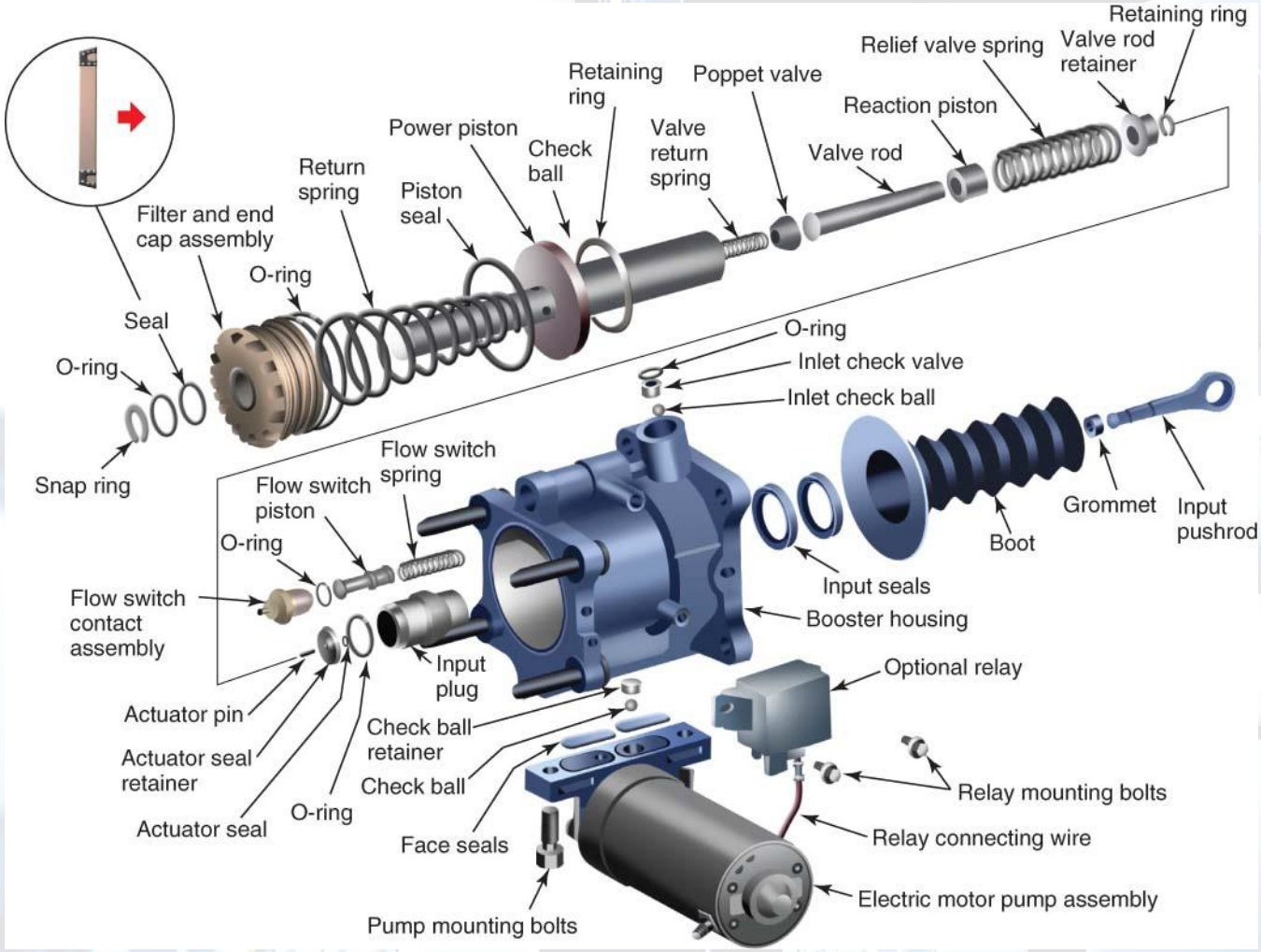
Brake fluid splashed into eyes can cause extreme irritation and potentially damage eyesight. Always wear safety glasses when working on brake systems.

CAUTION

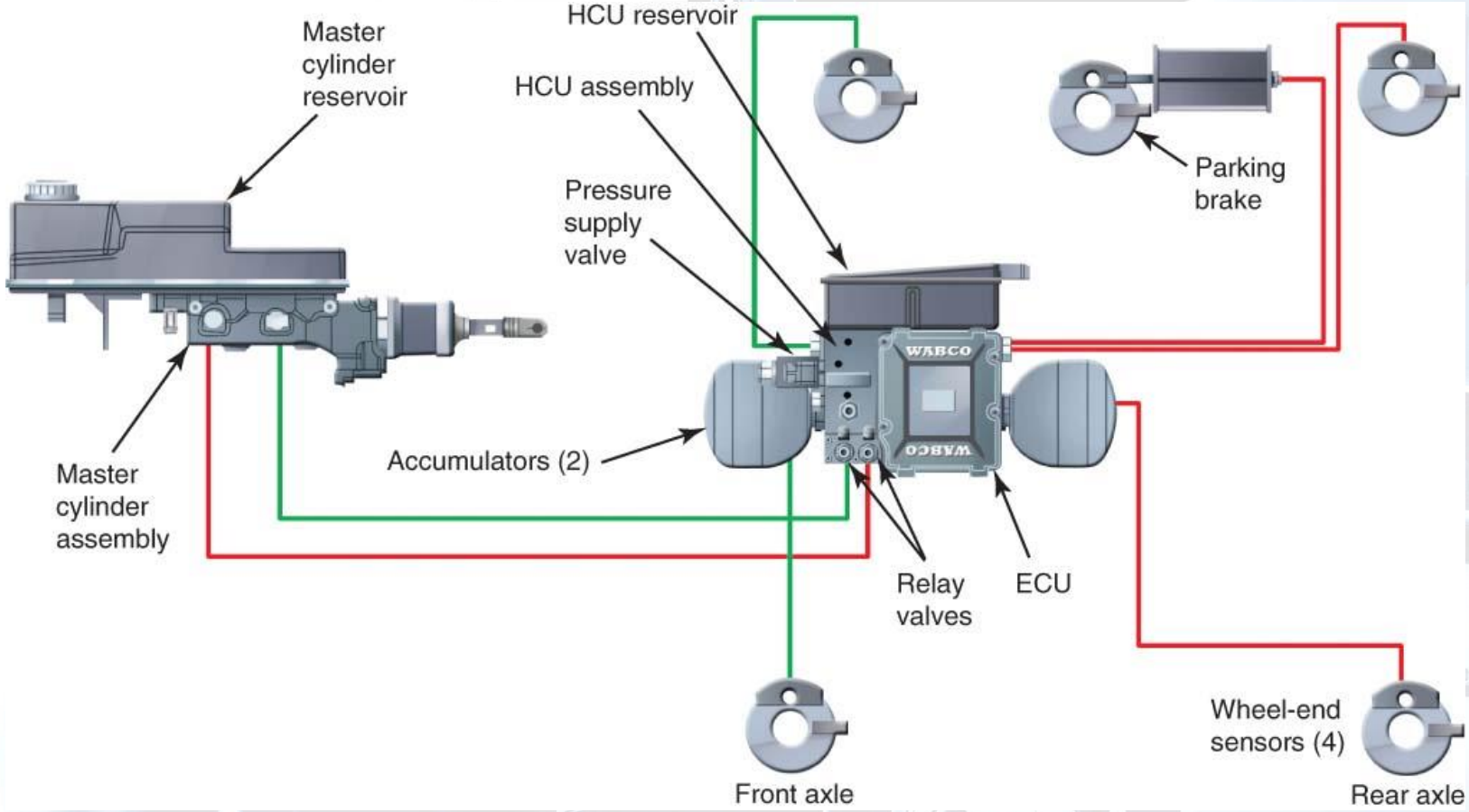
Brake fluids contain compounds that can break down paint. Handle brake fluid carefully and if it comes into contact with paint, immediately remove it using alcohol followed by water.



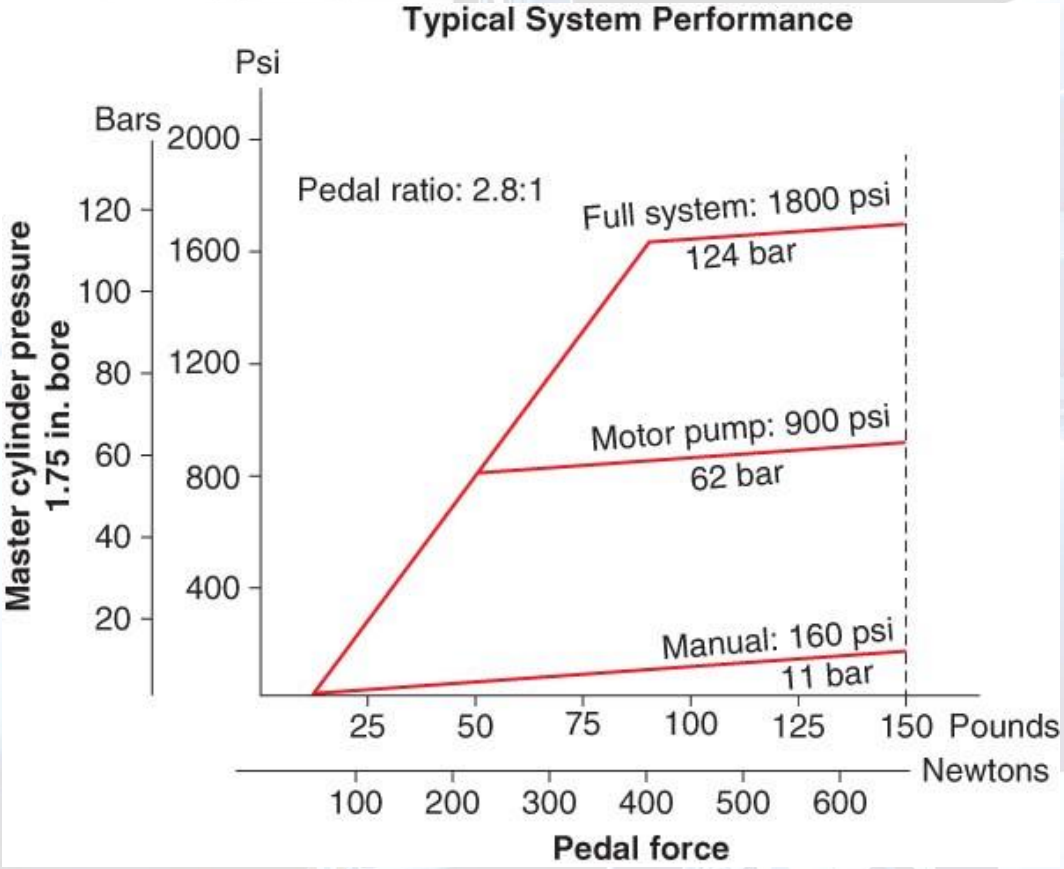
Operating principle of a dual-circuit master cylinder



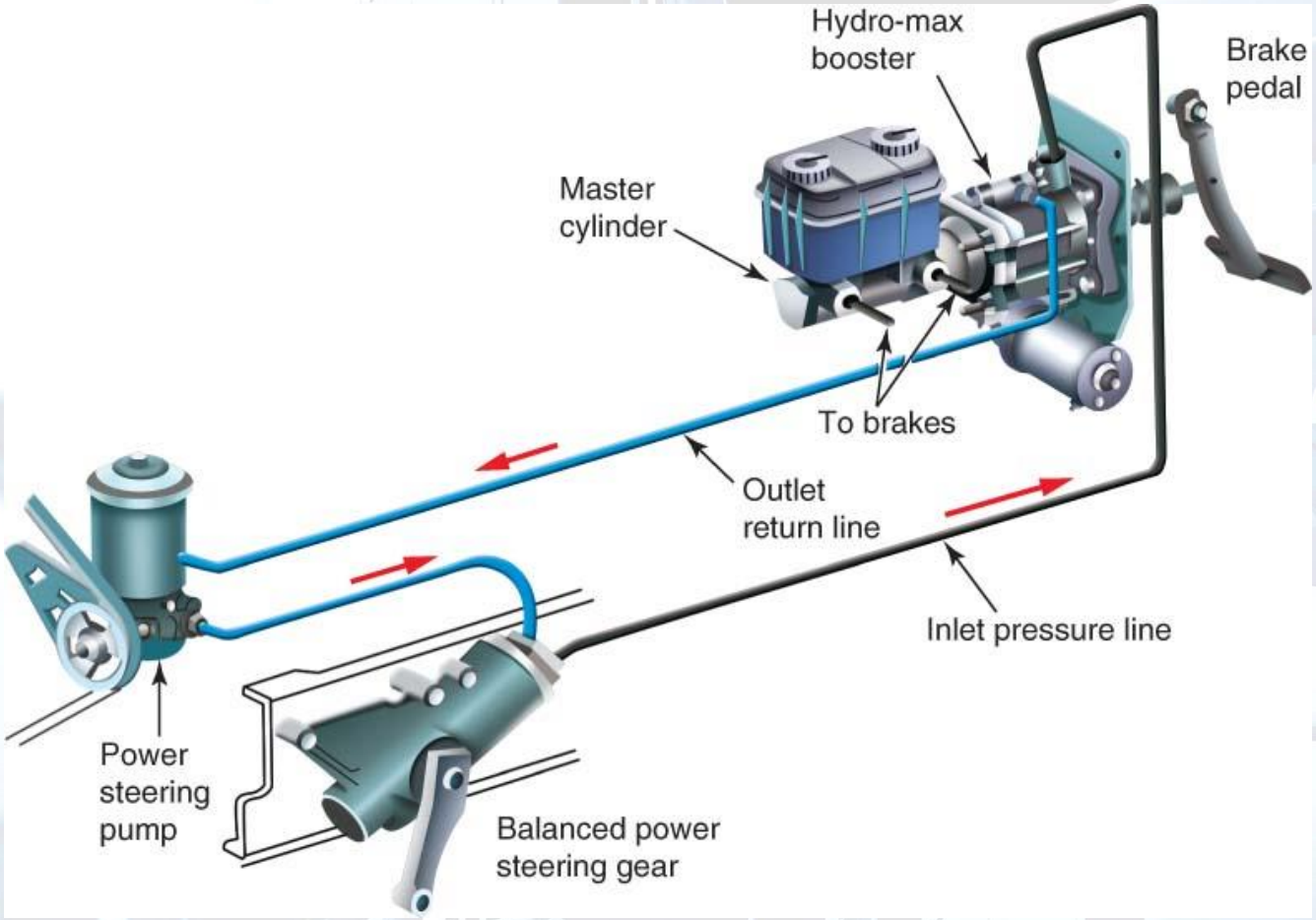
Exploded view of a hydro-max booster assembly



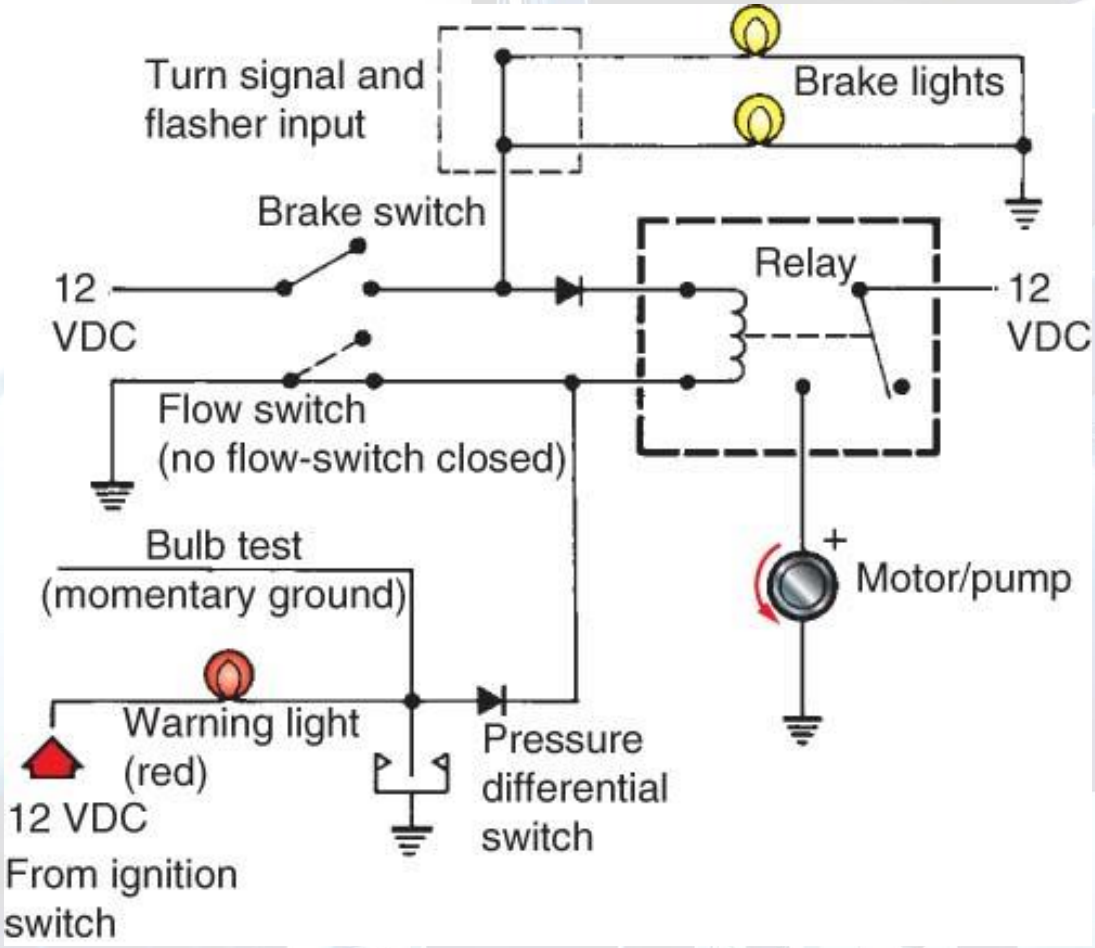
Circuit layout of a hydraulic power booster brake system highlighting the role of the HCU



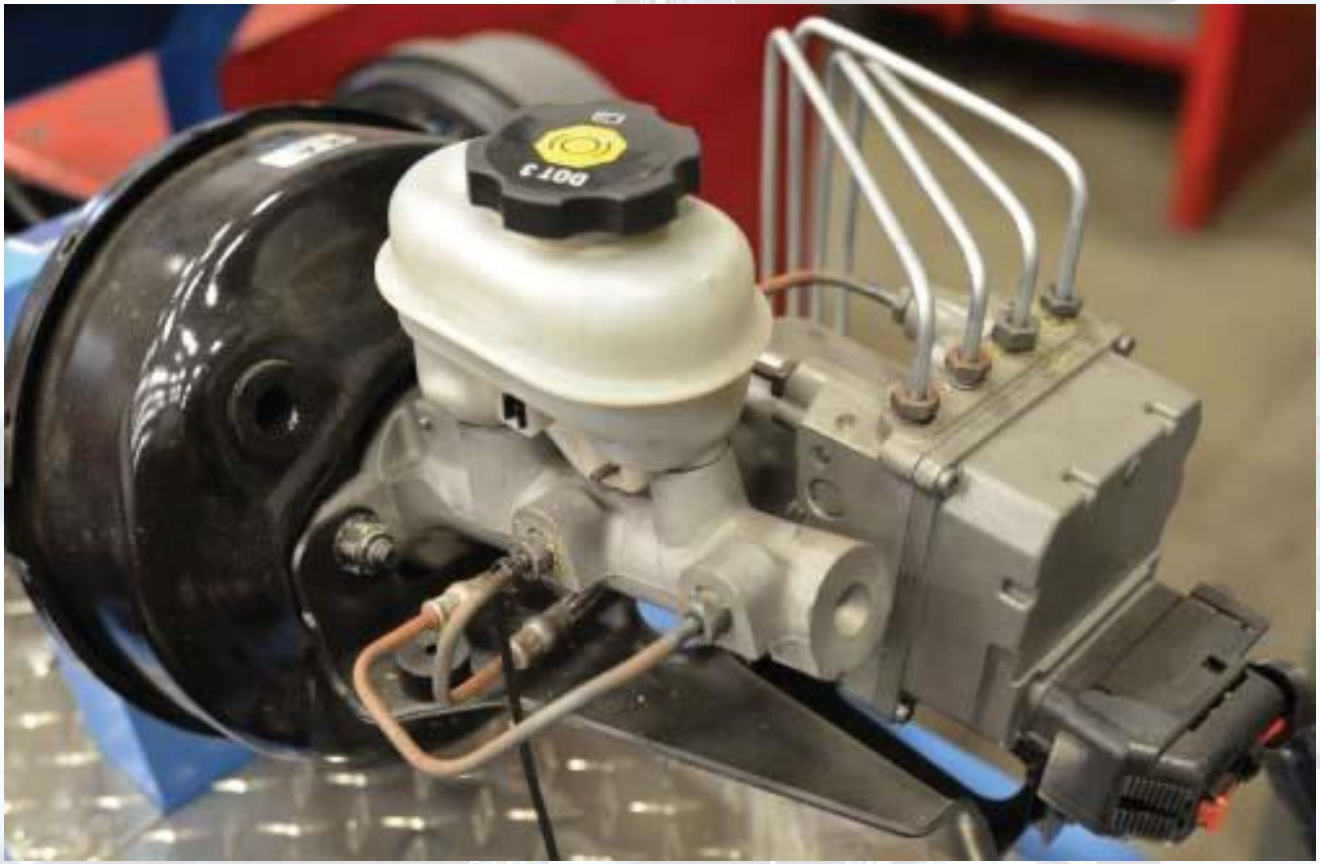
Pedal pressure correlated to performance in a hydro-max brake system. Circuit layout of a hydraulic power booster brake system.



Hydraulic booster charged by the power steering pump.



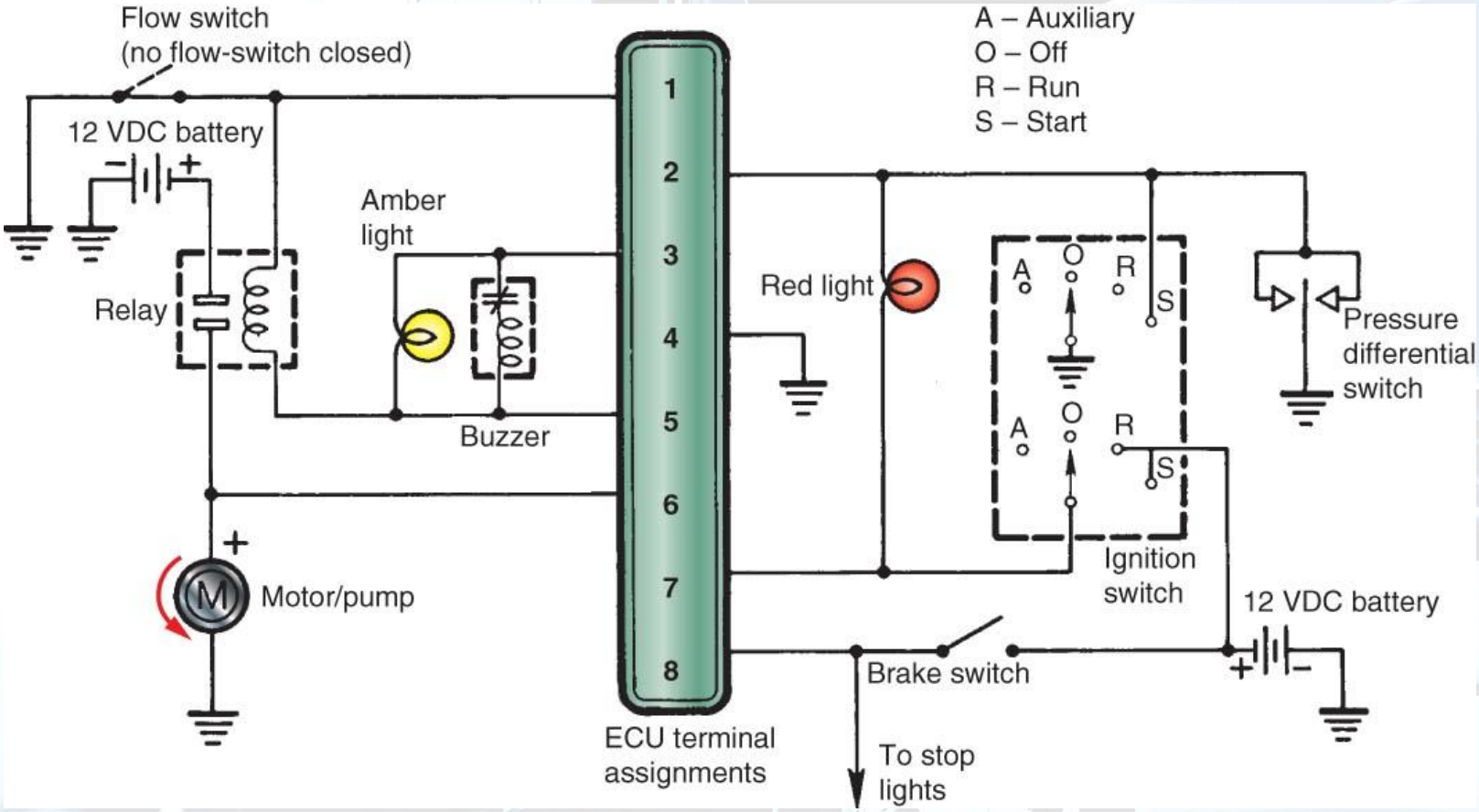
Operation and warning system used on a hydro-max brakes system



Medium-duty hydro-boost system

Pressure Differential Valve

All dual-circuit hydraulic systems have a **pressure differential valve** and brake warning light system, operated by a mechanically or hydraulically actuated electric switch. Its function is to indicate to the driver when one-half of the system is not functioning. It typically consists of a cylinder inside of which is a spool valve. Each end of the spool valve is subject to hydraulic pressure from either side of the circuits within the brake system (primary and secondary circuits).



Widely used optional Bendix controller module brake circuit

Metering Valves

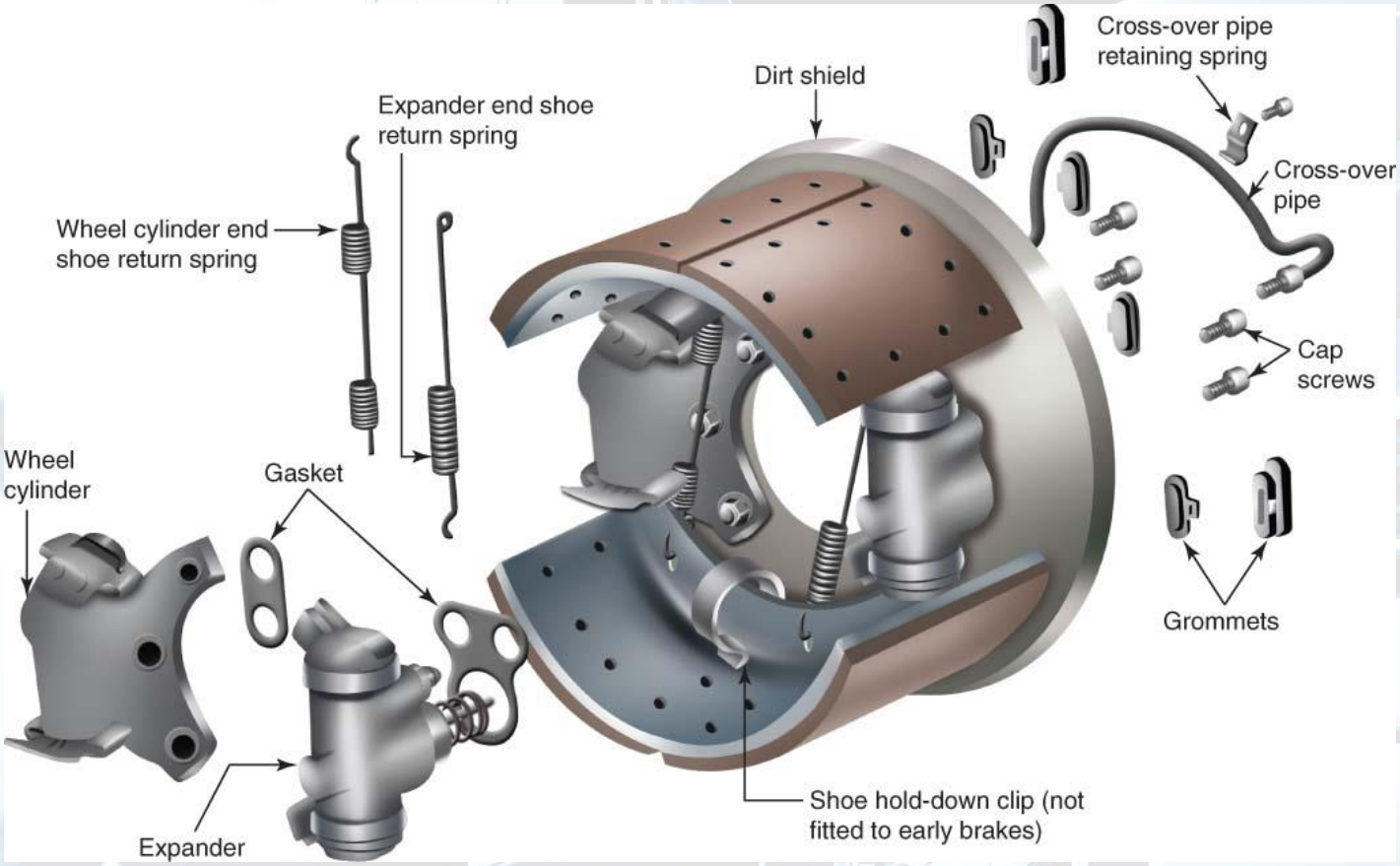
Metering valves are incorporated into a hydraulic brake system that uses disc brakes on the front axle and drum brakes on the rear axle. Disc brakes have much lower lag times than drum brakes. Lag time means the time between the first movement of the brake pedal and the moment that braking effort is applied. Metering valves delay the application of the front brakes until pressure has been established in the rear brake circuit.

Proportioning Valves

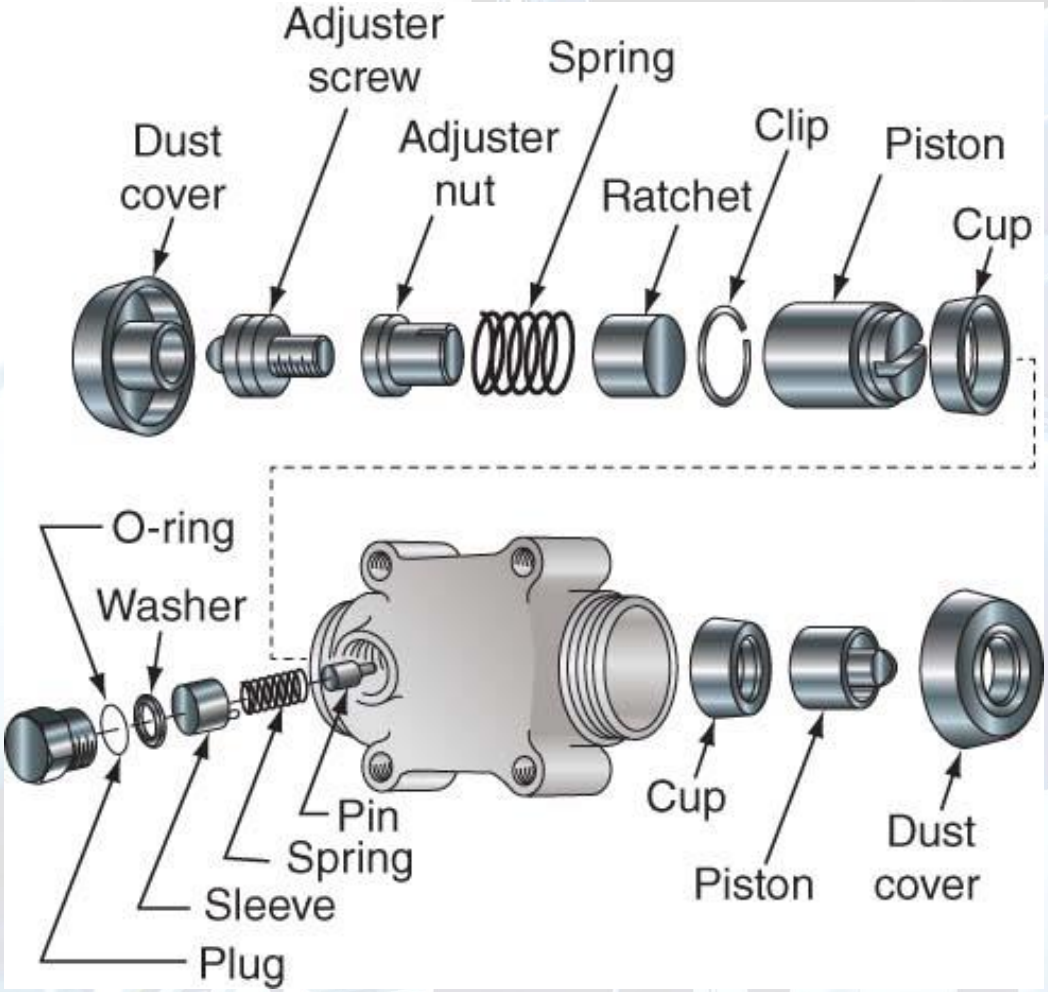
Proportioning valves also are used in systems using front disc and rear drum brakes. During braking, the vehicle is thrust forward onto the front axle. This is known as load transfer, and the more severe the braking, the greater the load transfer onto the front axle. Load transfer can result in rear wheel drum brake lock-up. Proportioning valves prevent pressure delivered to the rear wheel brakes from exceeding a predetermined pressure value under hard braking conditions..

Load Proportioning Valves

Some trucks use load-sensitive, rear-wheel proportioning valves called load proportioning valves (LPVs). Pressure is applied to the rear wheels according to how much weight is on the rear of the vehicle. The vehicle weight is sensed by mounting the valve on a frame cross-member and using a linkage and lever system attached to the rear axle housing. In this way, as the load increases over the rear axle, the rear brakes can assume a greater proportion of the required vehicle braking.

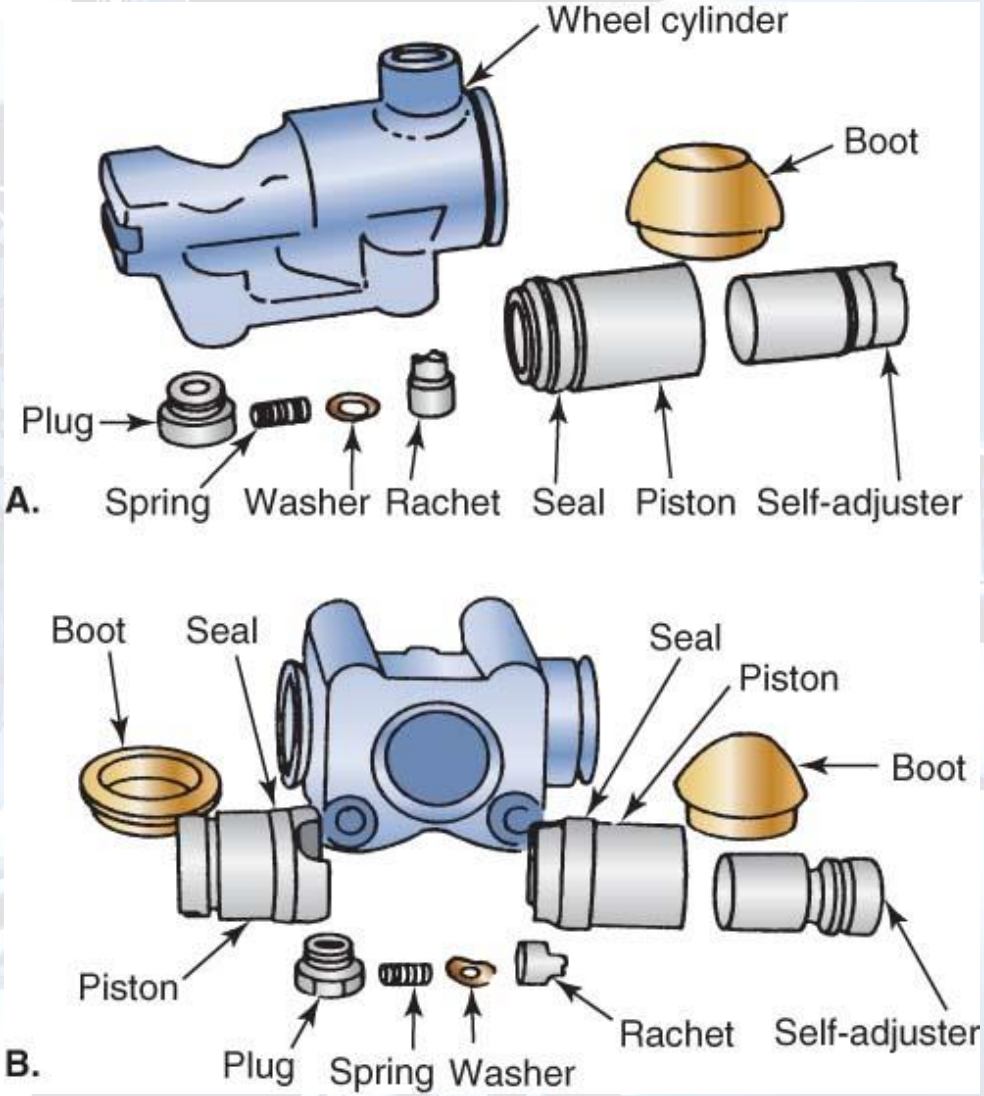


Components of an automatic adjusting, two leading shoe drum brake



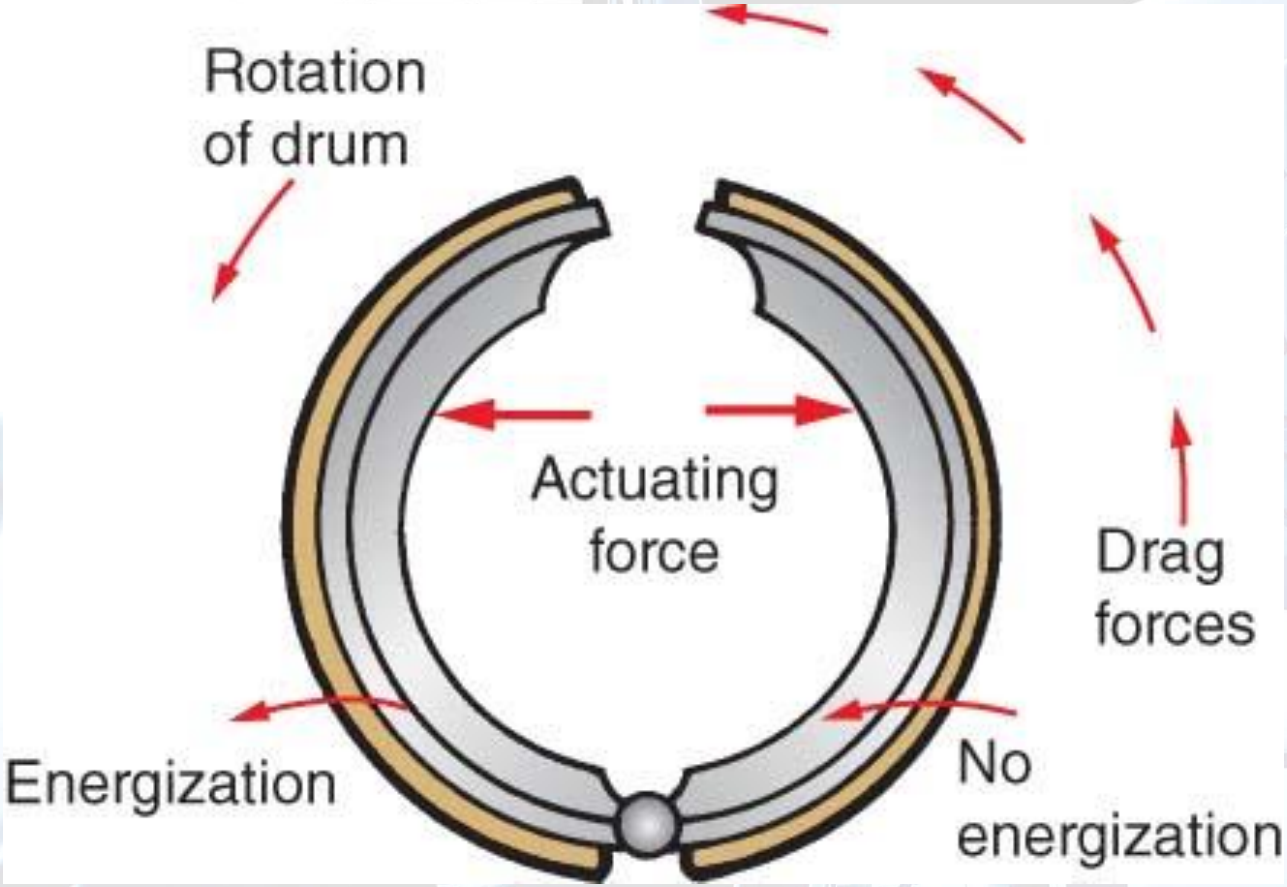
Exploded view of a double-acting wheel cylinder

(A) Exploded view of a single-acting, front-wheel cylinder; (B) exploded view of a double-acting, rear-wheel cylinder

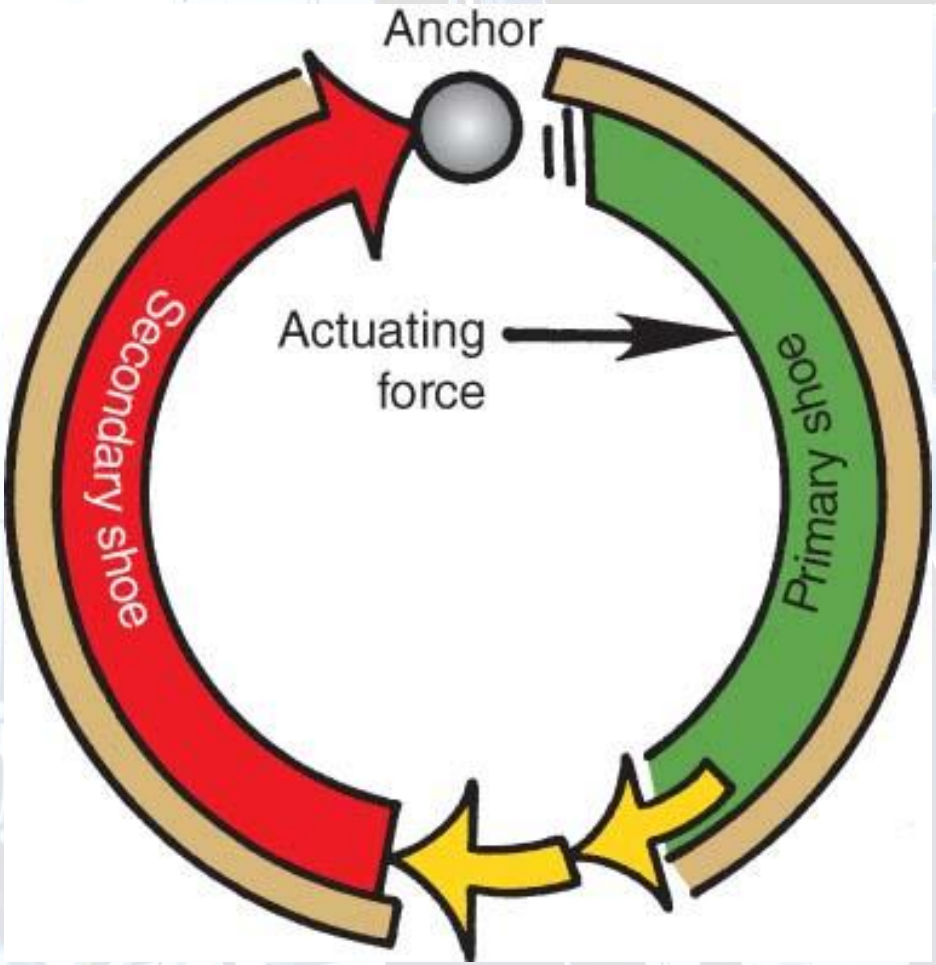


Drum Brakes

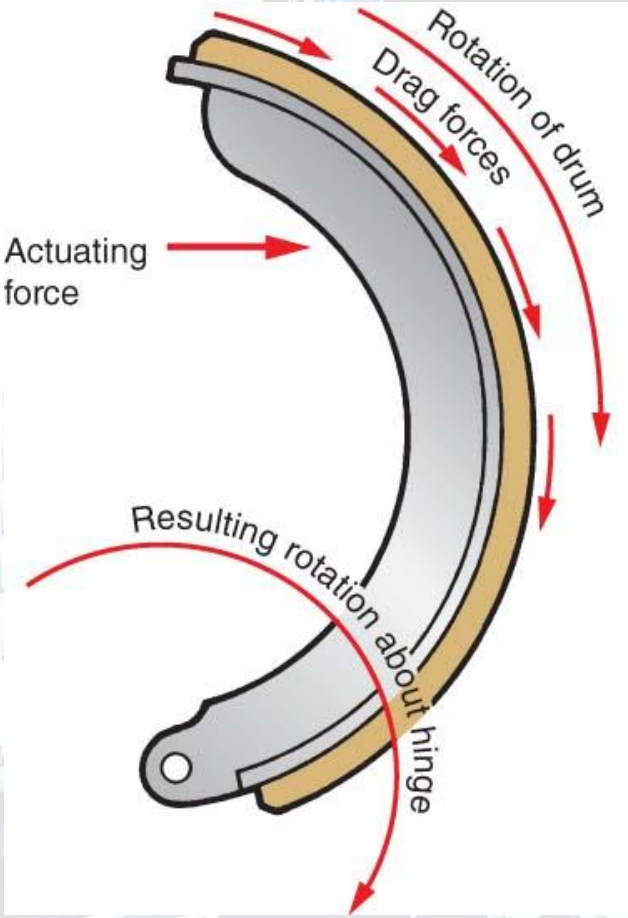
As with the air brake, a hydraulic drum brake assembly consists of a cast-iron drum that is bolted to, and rotates with, the vehicle wheel, and a backing plate that is attached to the axle. The shoes, wheel cylinders, automatic adjusters, and linkages are mounted to the fixed backing plate.



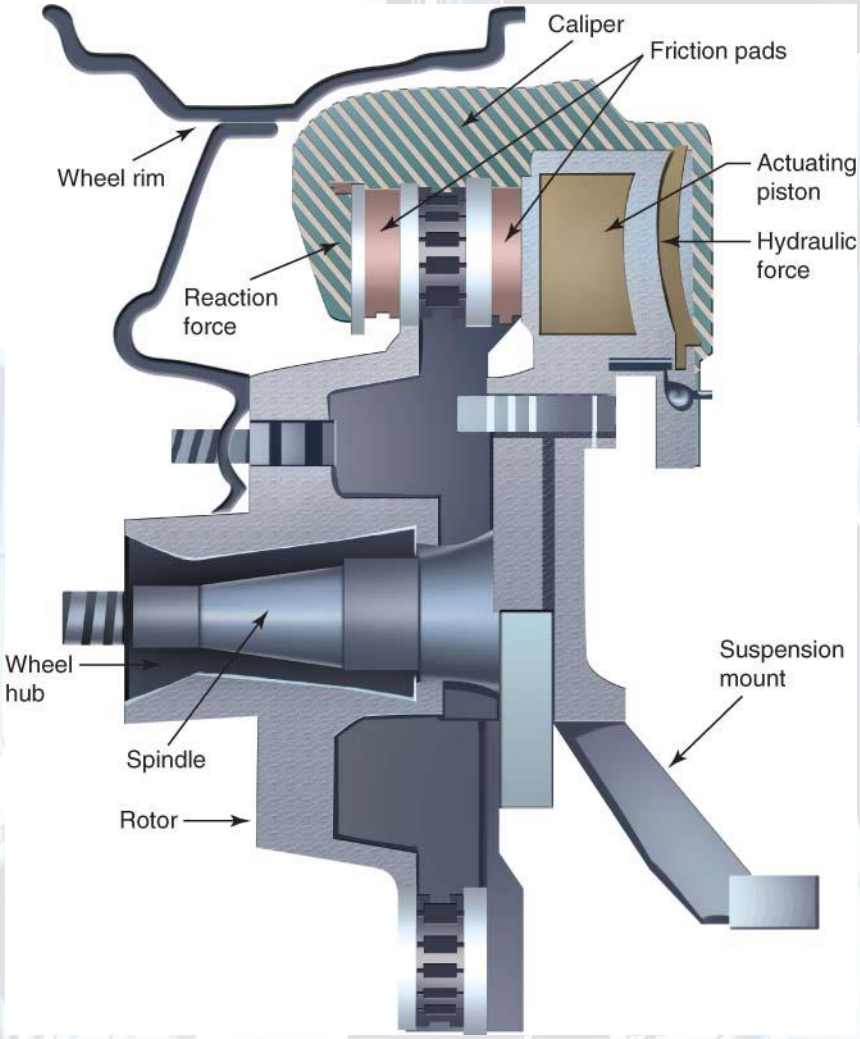
Non-servo brake action



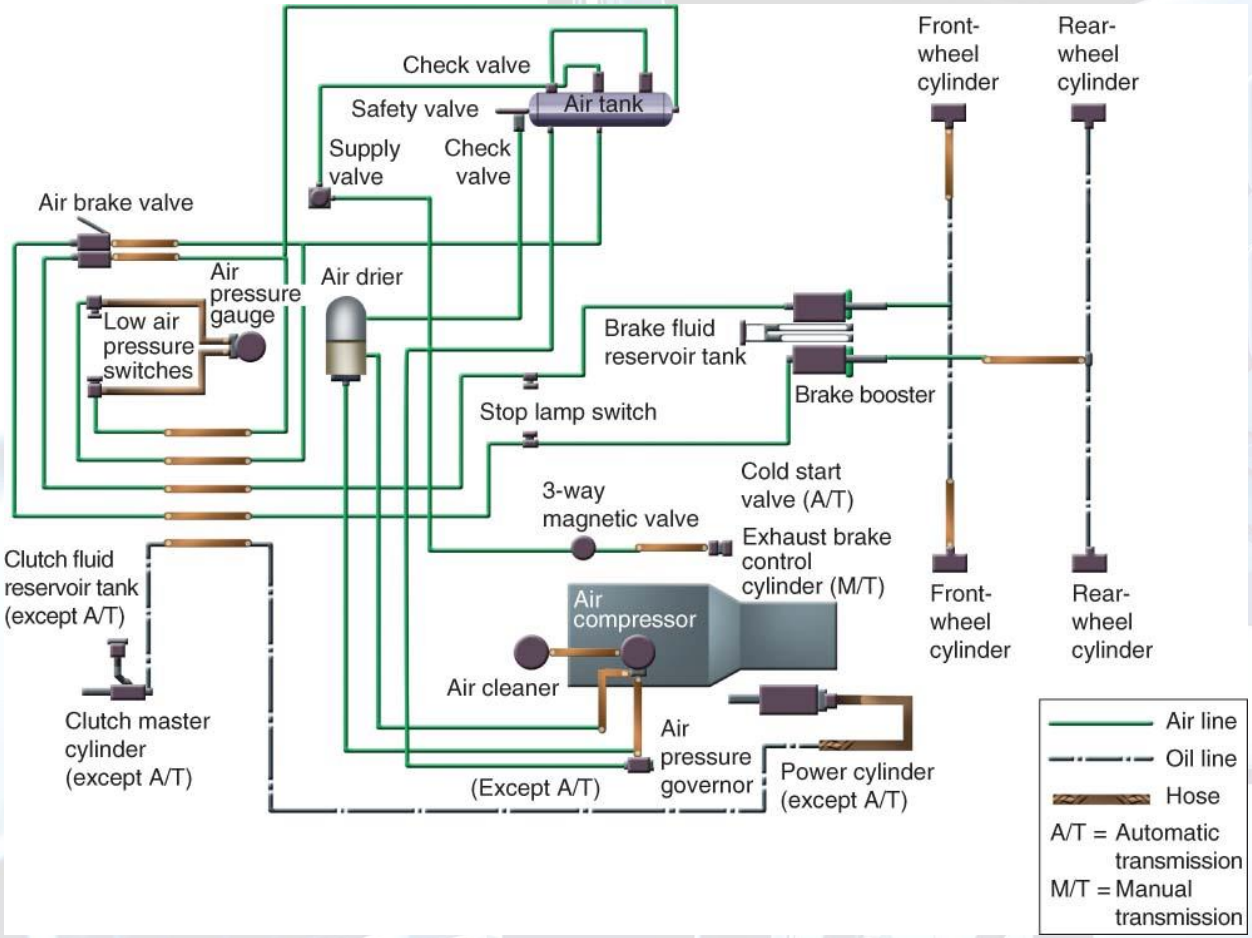
Servo brake action



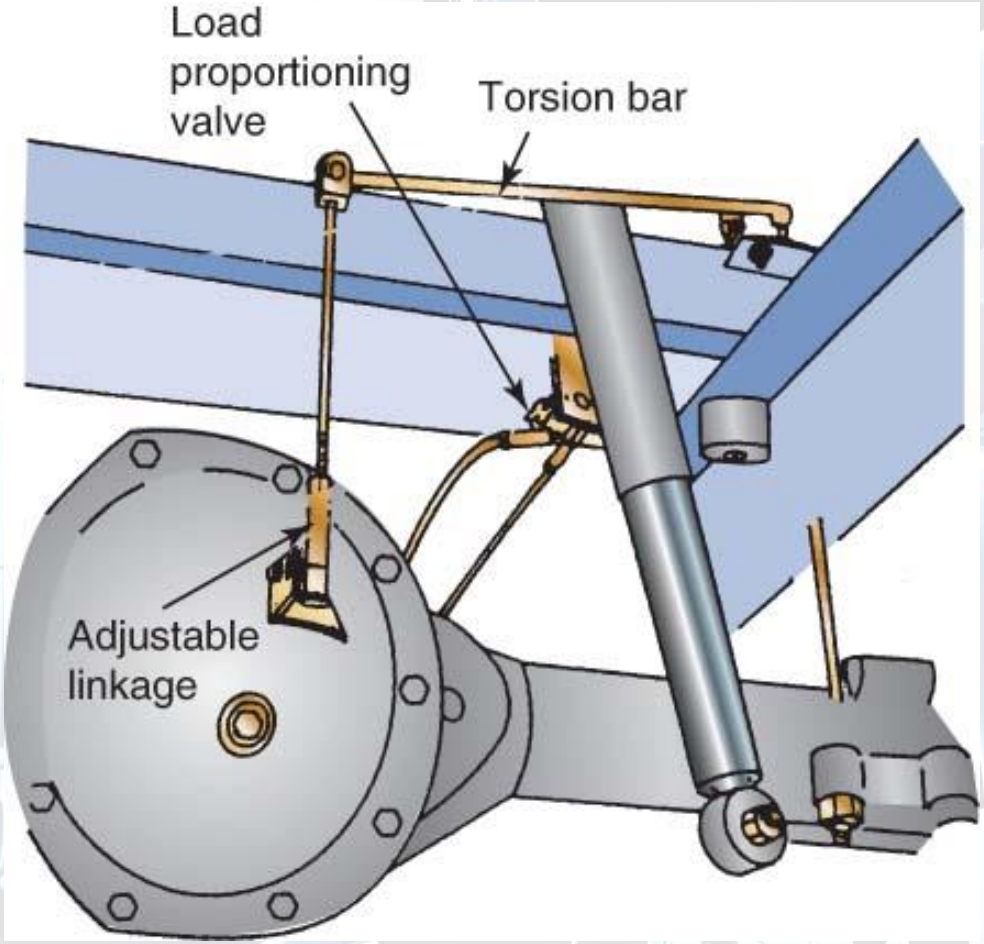
How a shoe becomes self-energizing



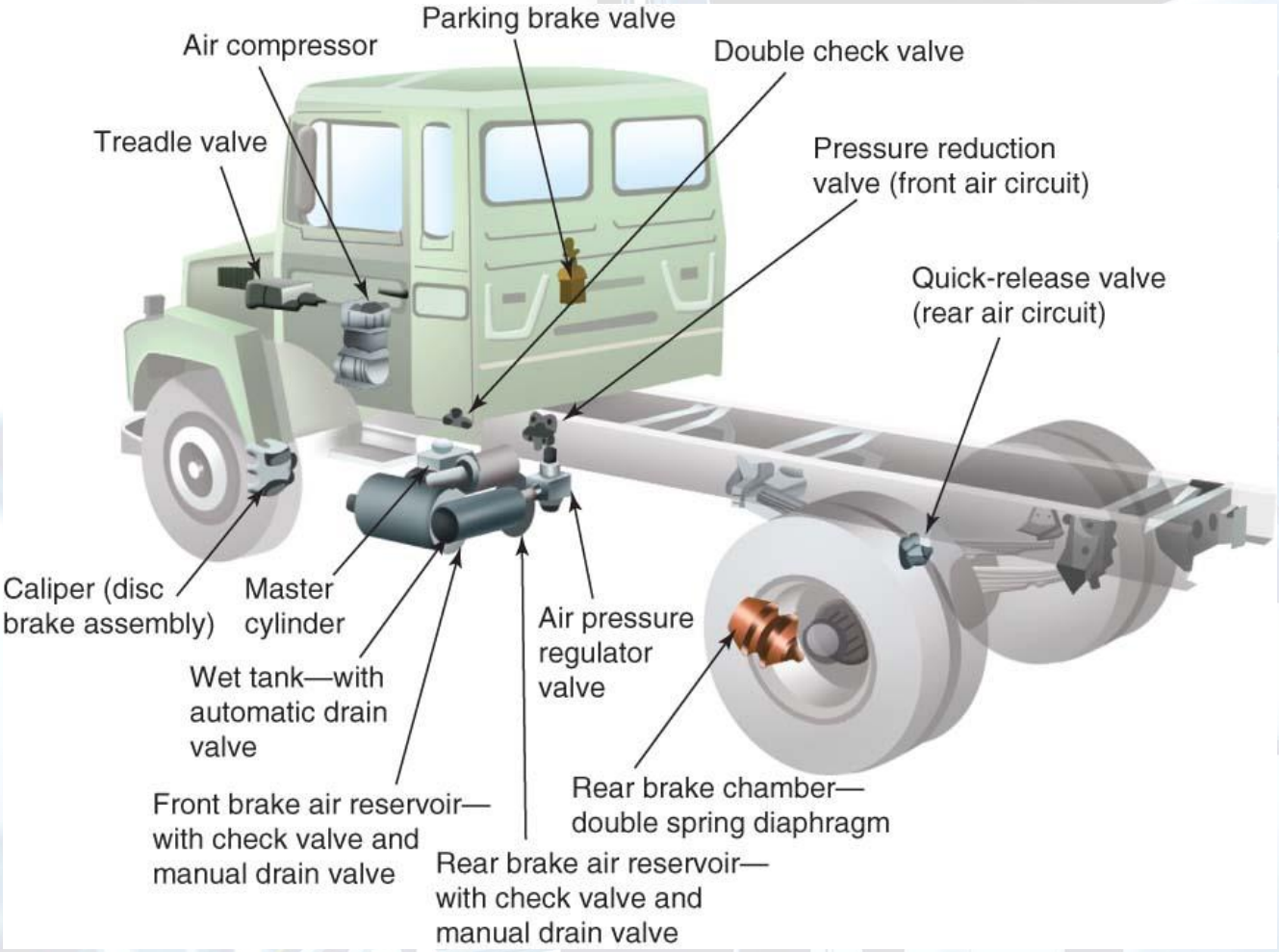
Key components of a disc brake assembly



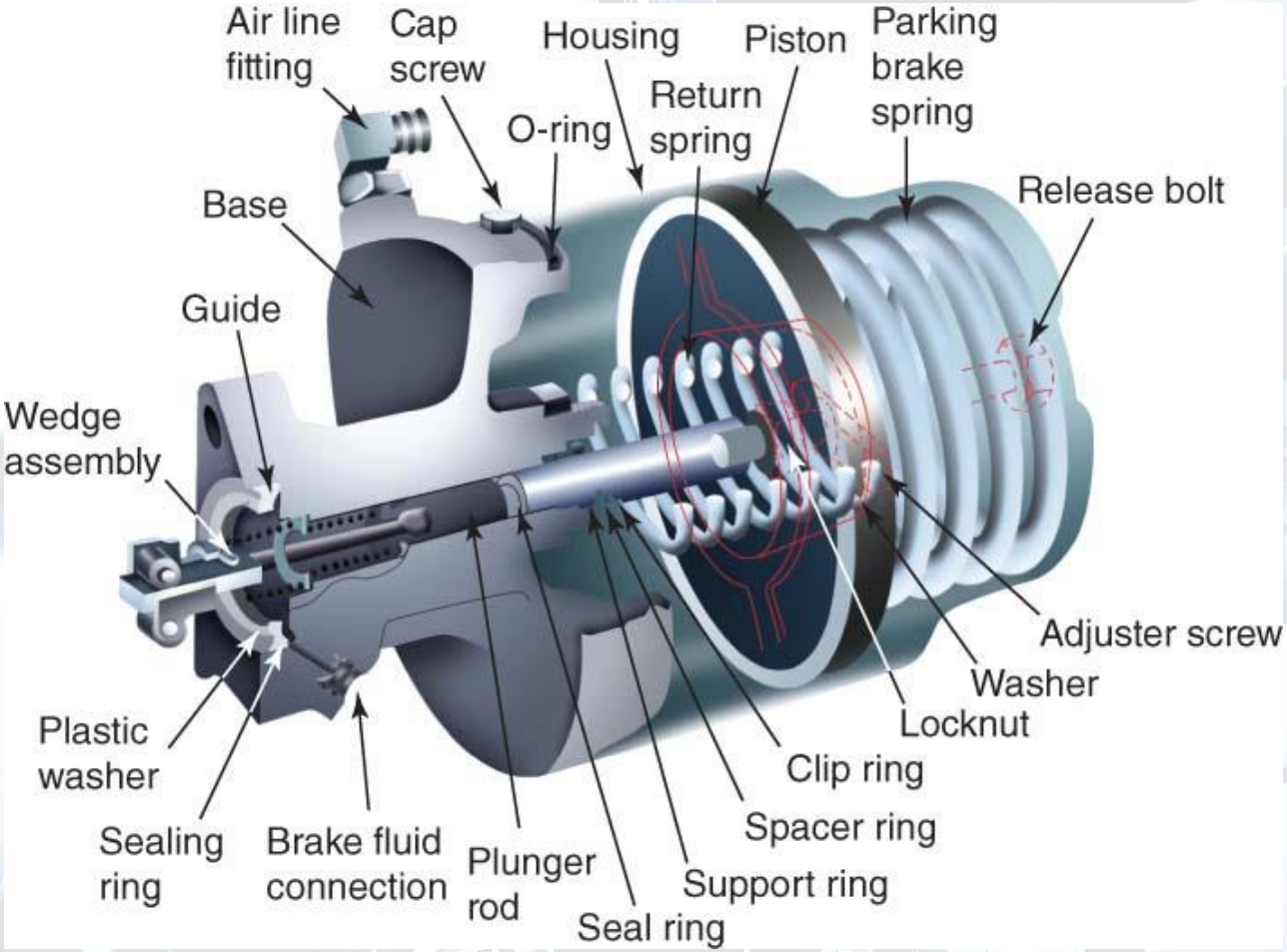
A typical air-over-hydraulic brake system (A/T—automatic transmission and M/T—manual transmission)



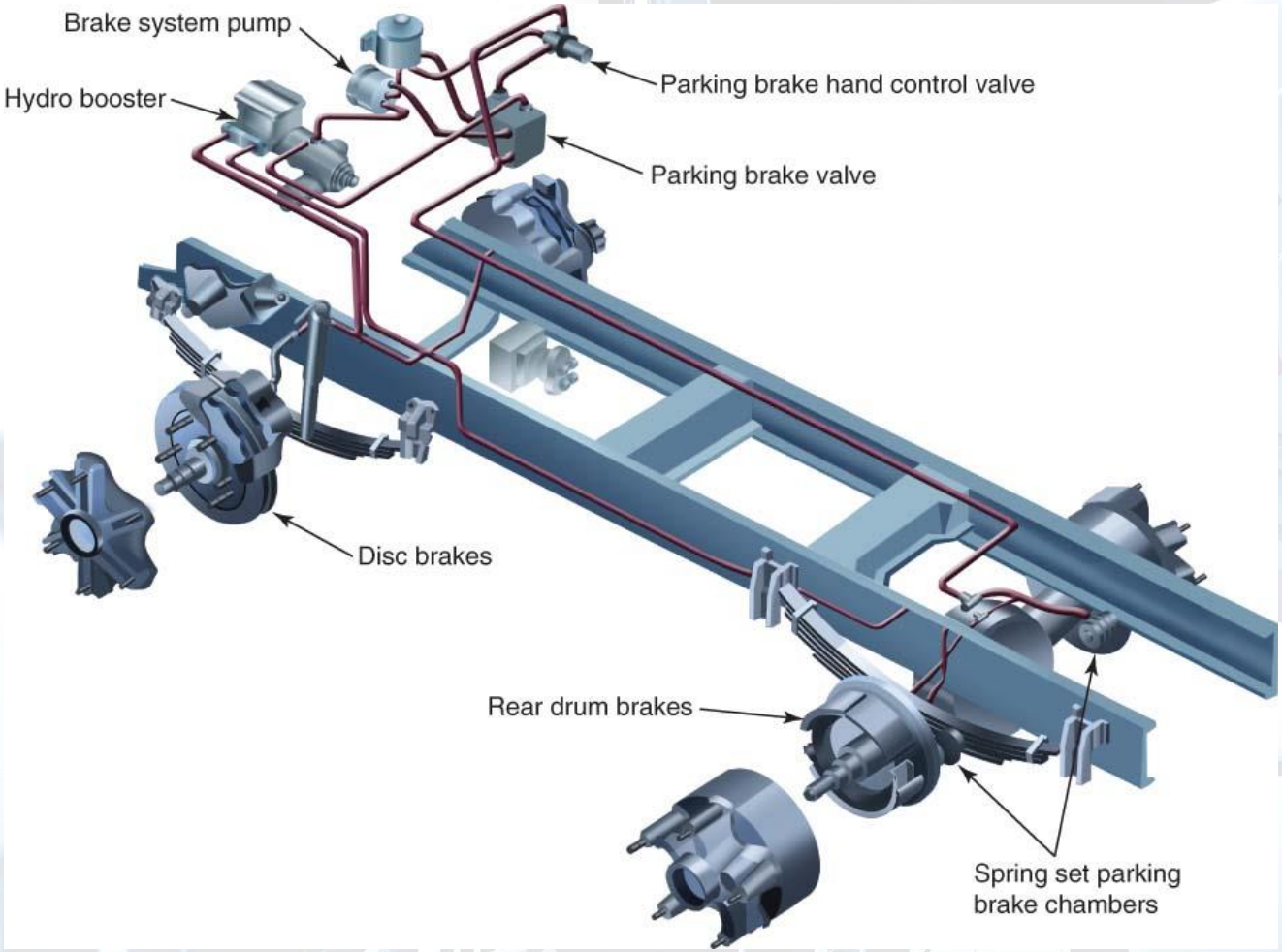
Location of one type of load proportioning valve. The torsion bar deflects as load increases.



Location of air-over-hydraulic brake components



Spring brake canister components



System with hydraulic discs in front and air-actuated, S-cam brakes in the rear

HEAVY-DUTY BRAKE FLUID

Some hydraulic brake systems use a non-petroleum-based hydraulic brake fluid such as SAE J1703 or SAE J17021. Other hydraulic systems use petroleum-based brake fluids (mineral oil). It is important to ensure that the correct brake fluid is used in the vehicle brake system and incompatible fluids are not mixed. Use of the wrong brake fluid can damage the cup seals of the wheel cylinders and pistons and can result in brake failure.

CAUTION

Never use brake fluid from a container that has been used to store any other liquid. Mineral oil, alcohol, antifreeze, cleaning solvents, and water, in trace quantities, can contaminate brake fluid. Contaminated brake fluid will cause piston cups and valve seals in the master cylinder to swell and deteriorate. One way of checking brake fluid is to place a small quantity of brake fluid drained from the system into a clear glass jar. Separation of the fluid into visible layers is an indication of contamination or mixed types of brake fluid. It generally is regarded as good practice to discard used brake fluid that has been bled from the system. Contaminated fluid usually appears darker. Brake fluid drained from the bleeding operation may contain dirt particles or other contamination and should not be reused.

CHANGING BRAKE FLUID

It is a recommended practice to change brake fluid whenever a major brake repair is performed. The system can be flushed with clean brake fluid, isopropyl alcohol, or rubbing alcohol. A simple flushing technique is to pour the flushing agent into the master cylinder reservoir and open all bleed screws in the system. The brake pedal is then pumped to force the flushing agent through the system.

Servicing a Master Cylinder

A master cylinder should be removed from a truck using the following procedure:

1. Disconnect the negative battery cable.
2. Disconnect the pressure differential (brake light warning) switch if equipped.
3. Disconnect and cap the hydraulic lines at the master cylinder to prevent dirt from entering. (On some trucks using remote reservoirs, it may be necessary to disconnect the lines connecting the reservoirs with the master cylinder.)
4. Remove the master cylinder from the brake booster assembly.

Shop Talk

Use a rebuild kit and assembly fluid or brake fluid to reassemble the master cylinder. Take special care to ensure that new rubber components are not damaged, crimped, or pinched during reassembly. Note how the components fit together when replacing the seals, especially the direction the rubber seals face on the pistons. Some rebuild kits provide a primary piston assembly. The assembly procedure simply reverses the disassembly sequence.

METERING VALVE SERVICE

On systems with front disc and rear drum brakes, inspect the metering valve whenever the brakes are serviced. A trace amount of fluid inside the protection boot does not indicate a defective metering valve, but evidence of a larger amount of fluid indicates wear and the need to replace it.

Shop Talk

A pressure bleeder ball and OEM software is usually required to bleed ABS brakes (shown later in Figure 29–34). Use regulated shop air pressure, at a MAXIMUM of 15 psi (103 kPa), to the bleeder ball. When a pressure bleeder is used to bleed a system that includes a metering valve, the valve stem must either be pushed in or pulled out to open the valve. Manual bleeding using the brake pedal develops sufficient pressure to overcome the metering valve, and the stem does not have to be held open. Always follow the OEM recommended procedure for bleeding ABS brakes.

PRESSURE DIFFERENTIAL VALVES

The pressure differential valve should re-center automatically on the first application of the brakes after repair work. However, some pressure differential valves may require manual resetting. After repairs have been completed, open a bleeder screw in a portion of the hydraulic circuit that was not worked on.

PROPORTIONING VALVE

The proportioning valve also should be inspected whenever the brakes are serviced. To check valve operation, install a pair of hydraulic gauges upstream and downstream of the proportioning valve and ensure that the rear brake pressure is proportioned to specification. If this is not the case or the valve is leaking, it must be replaced. Make sure that the valve port marked R (*rear)* is connected to the rear brake lines.

WHEEL CYLINDERS

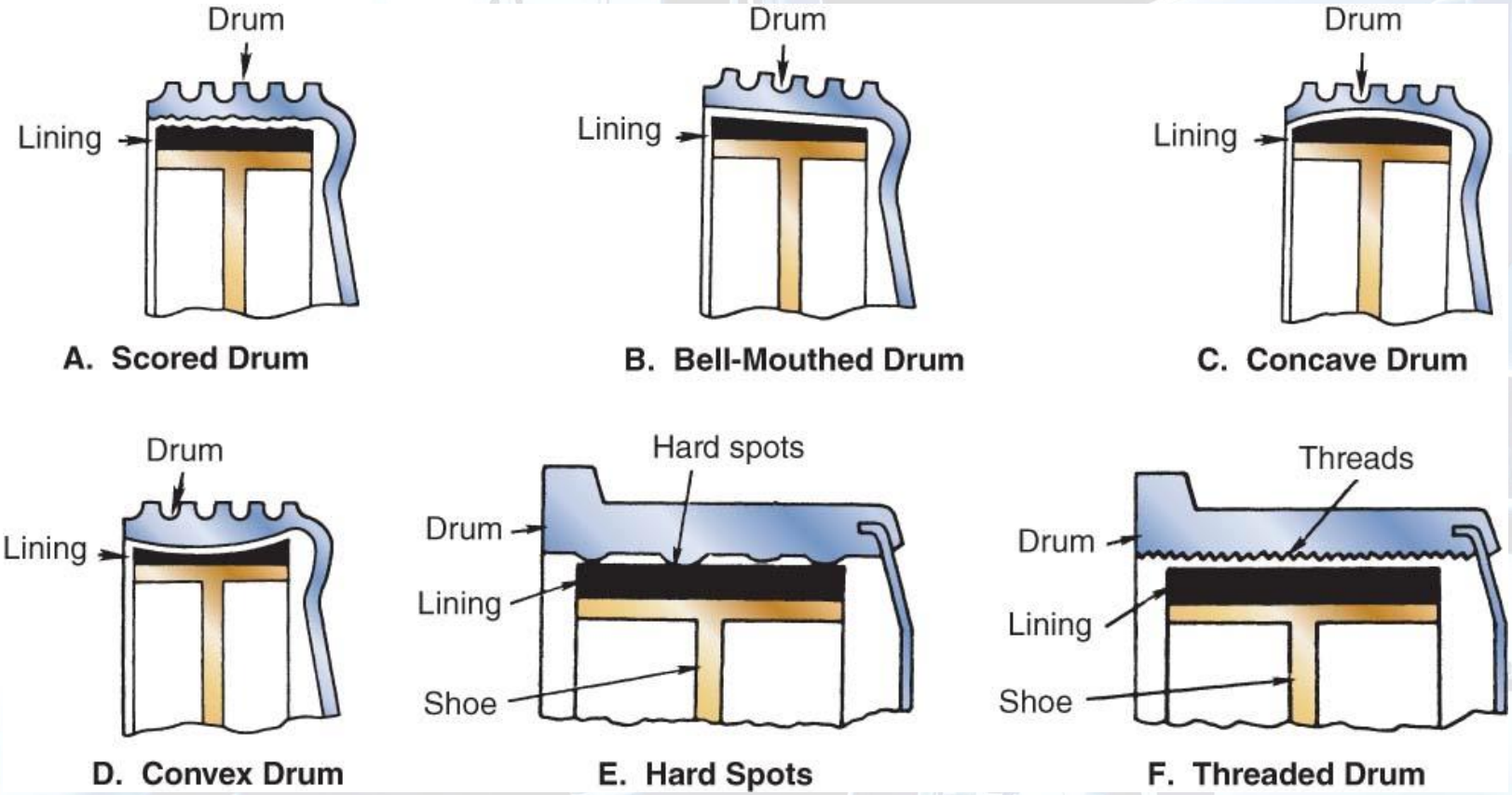
Wheel cylinders should be at least externally inspected during any routine brake job. Any evidence of leakage should be a reason to recondition the unit.

CAUTION

Leaking at the wheel seals after a brake job may occur resulting from the repositioning of cups onto dirt or sludge.

CAUTION

Severe overheating is caused by drums that are machined too thin, improper lining-to-drum contact, incorrect lining friction ratings, or vehicle overloading. A probable driver complaint would be brake fade.



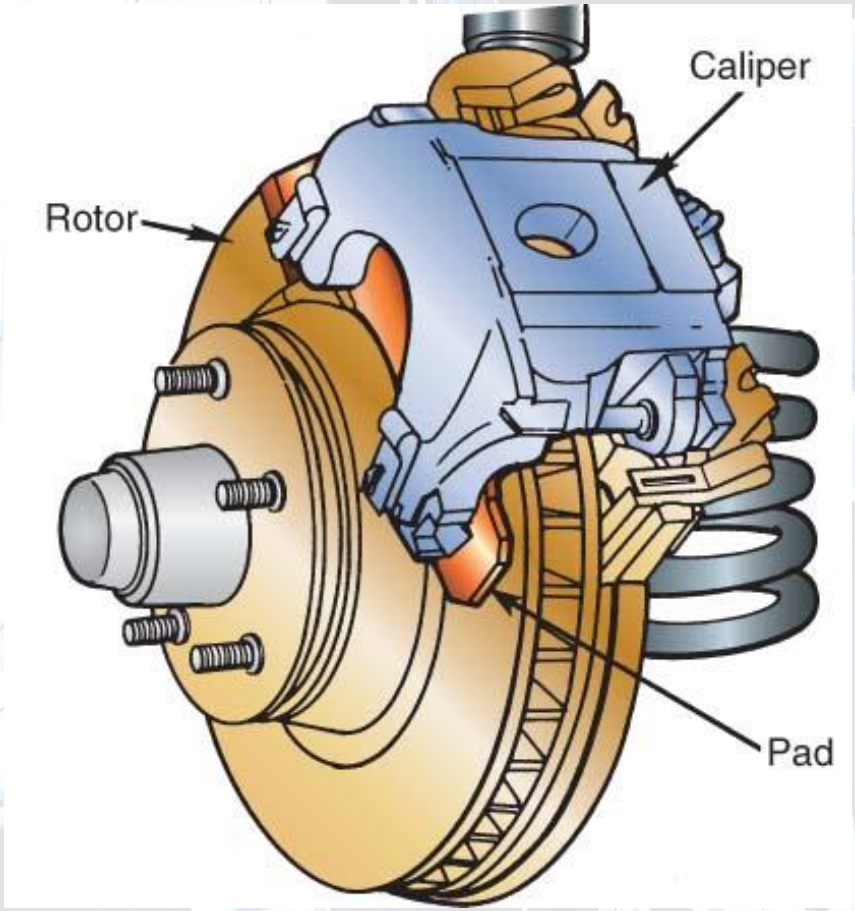
Drum wear conditions

Tech Tip

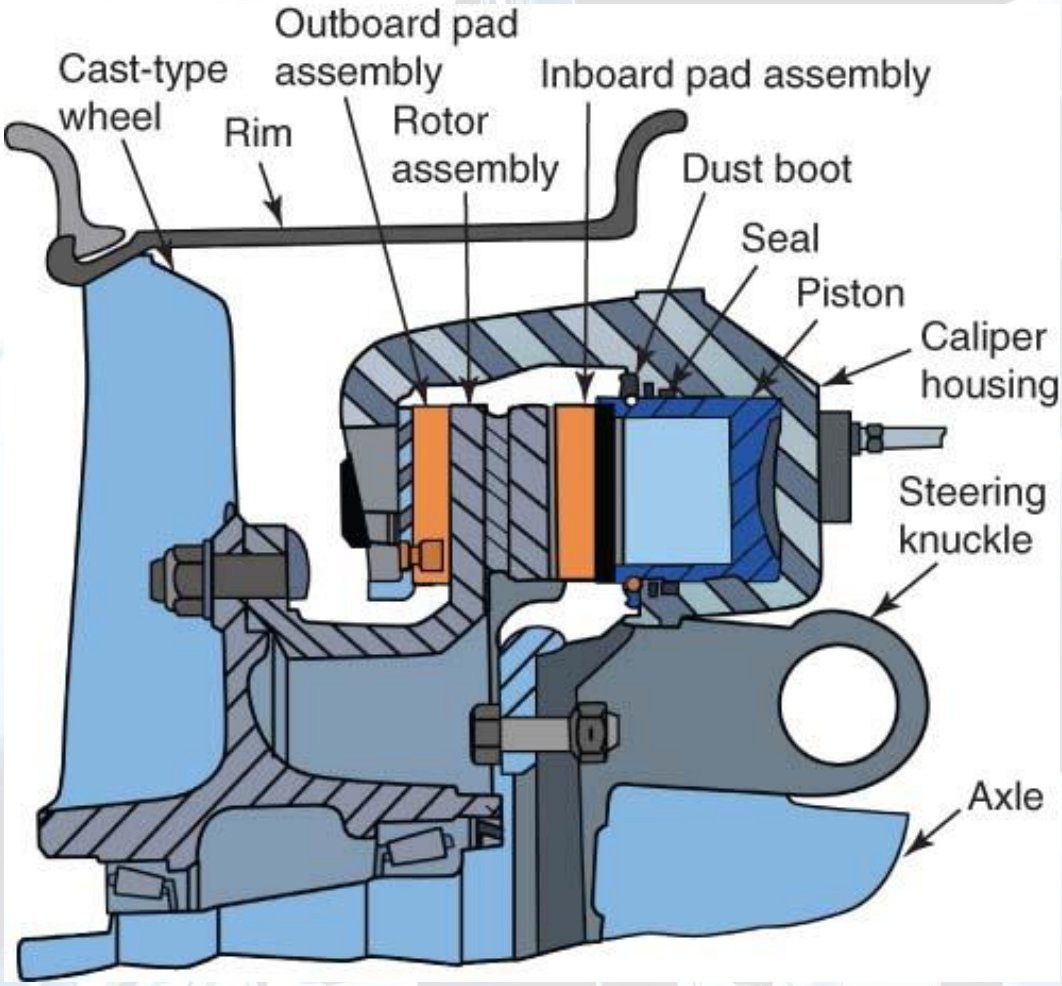
Servo brake replacement shoes usually have different lining thicknesses. In most cases, the shoe with the thicker lining should be installed in the secondary shoe position facing the rear of the vehicle.

Shop Talk

Never paint the outside of the drum. Paint will act as an insulator and slow heat dissipation. The heat absorbed by the drum during braking must be dissipated to the atmosphere around the drum. Overheated brakes result in brake fade!



Hydraulic disc brake assembly



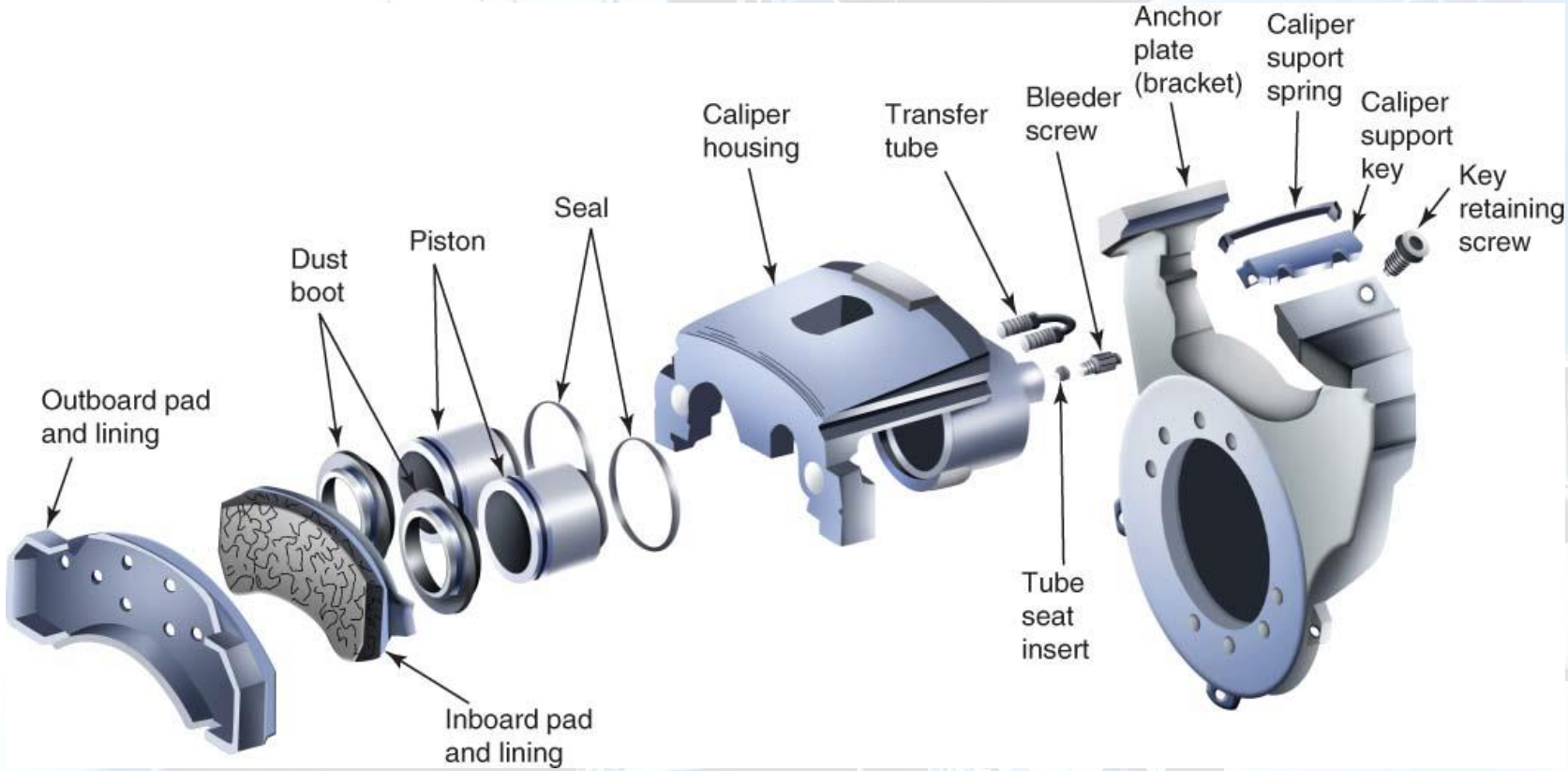
Cutaway view of a hydraulic disc brake assembly

CAUTION

Many OEMs recommend removing the brake hose or supporting the caliper when disassembling a disc brake assembly, especially on ABS. Never force the piston inboard without at least opening the bleed screw because contaminants tend to collect in the caliper bore. When the piston is forced inward, this dirt can be forced back to the master cylinder. Also, any sludge in the master cylinder is disturbed. Foreign material half the width of a human hair has been known to render ABS inoperative. It helps to rotate the caliper, so that the bleed screw position is facing downward helping to evacuate dirt.

CAUTION

In cases where only the brake pads are to be replaced the caliper does not need to be hydraulically disconnected. Make sure that when the caliper assembly is separated, it is not allowed to hang by the brake hoses that can internally damage the hose.



Components of a hydraulically actuated, two-piston caliper assembly

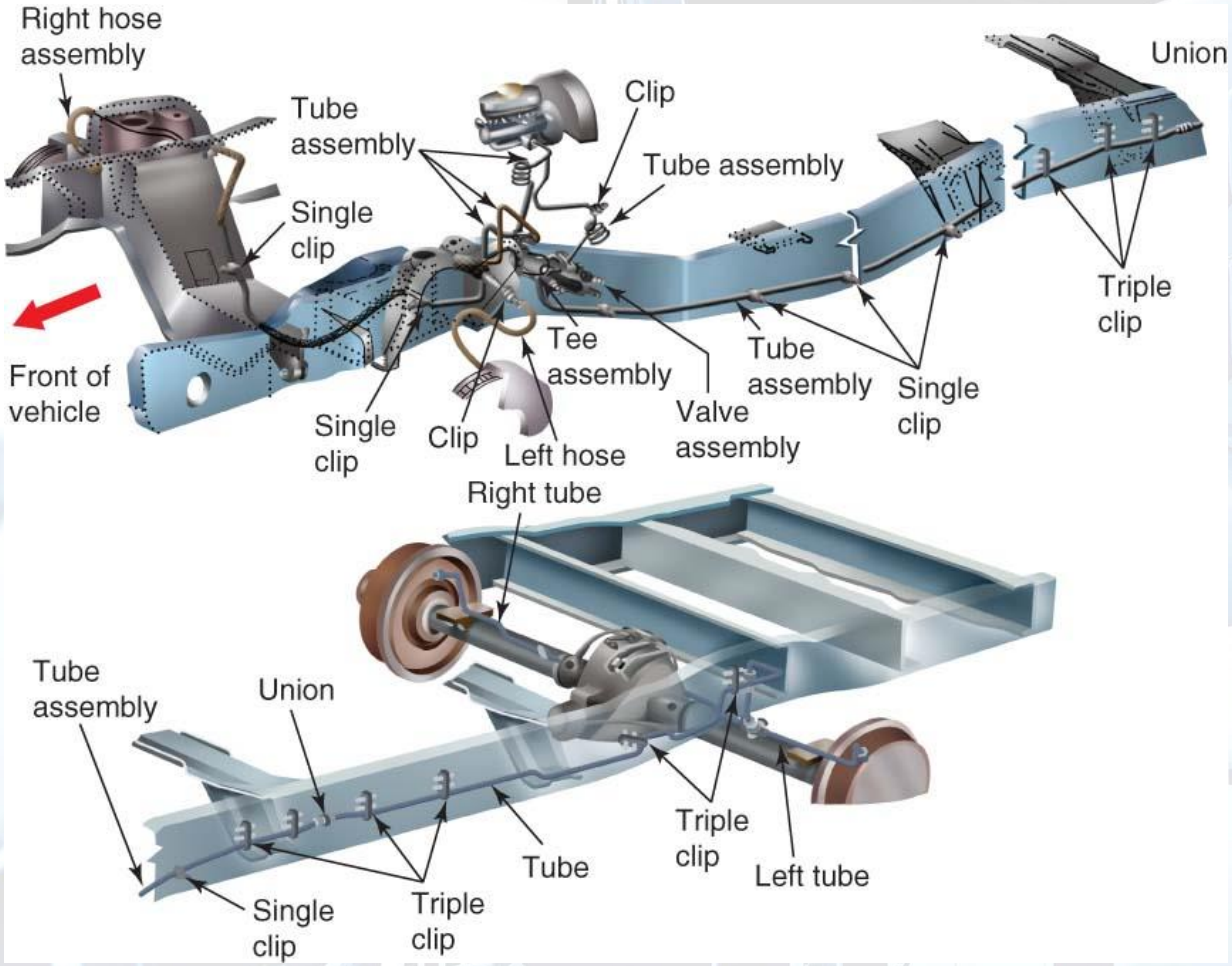
Shop Talk

When axial or radial runout specifications are provided by OEMs, they are expressed in total indicated runout (TIR). TIR is calculated by adding the most positive to the most negative reading through one complete revolution when using a dial indicator. For instance, if, after zeroing the dial indicator, a maximum positive reading of 0.001 inch (0.0254 mm) and maximum negative reading of 0.002 inch (0.0508 mm) occurs through one rotation, perform the following calculation to obtain the TIR:

− 0.001 inch + 0.002 inch = 0.003 inch (0.0762 mm) TIR

Shop Talk

Excessive rotor runout or wobble increases pedal travel because the condition opens up the caliper piston and can cause pedal pulsation and chatter when the brakes are applied.

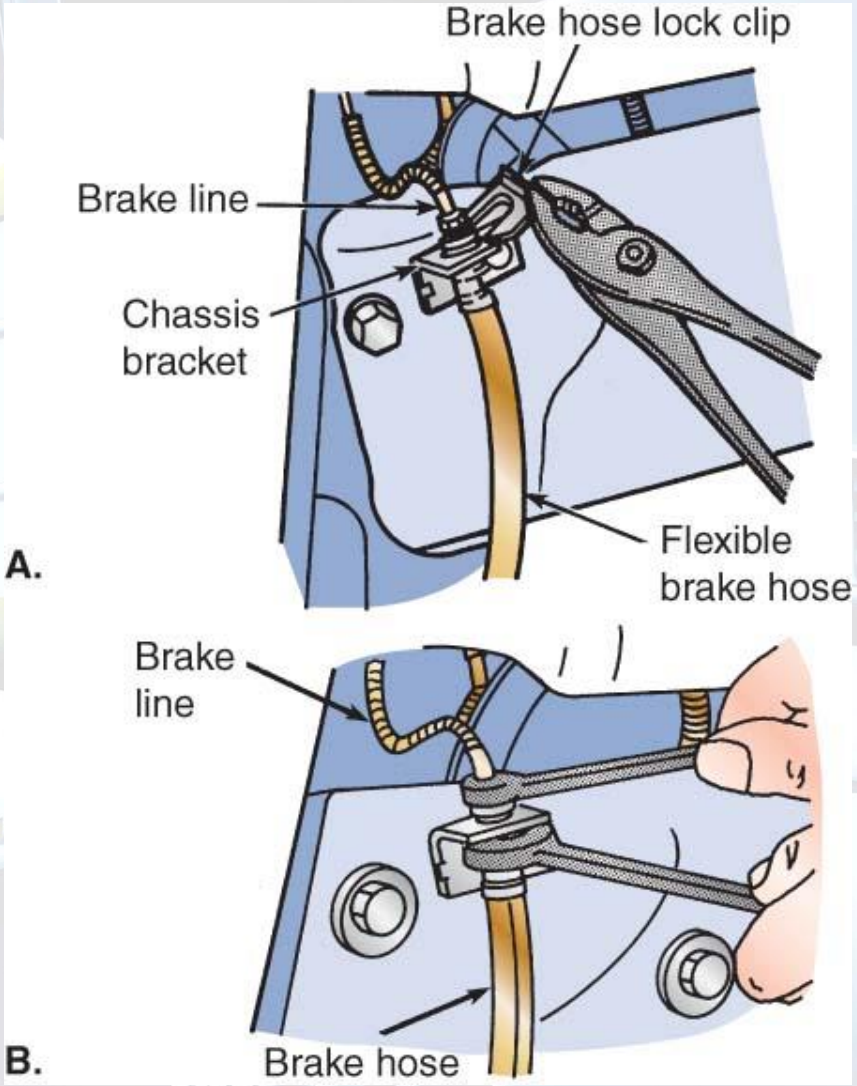


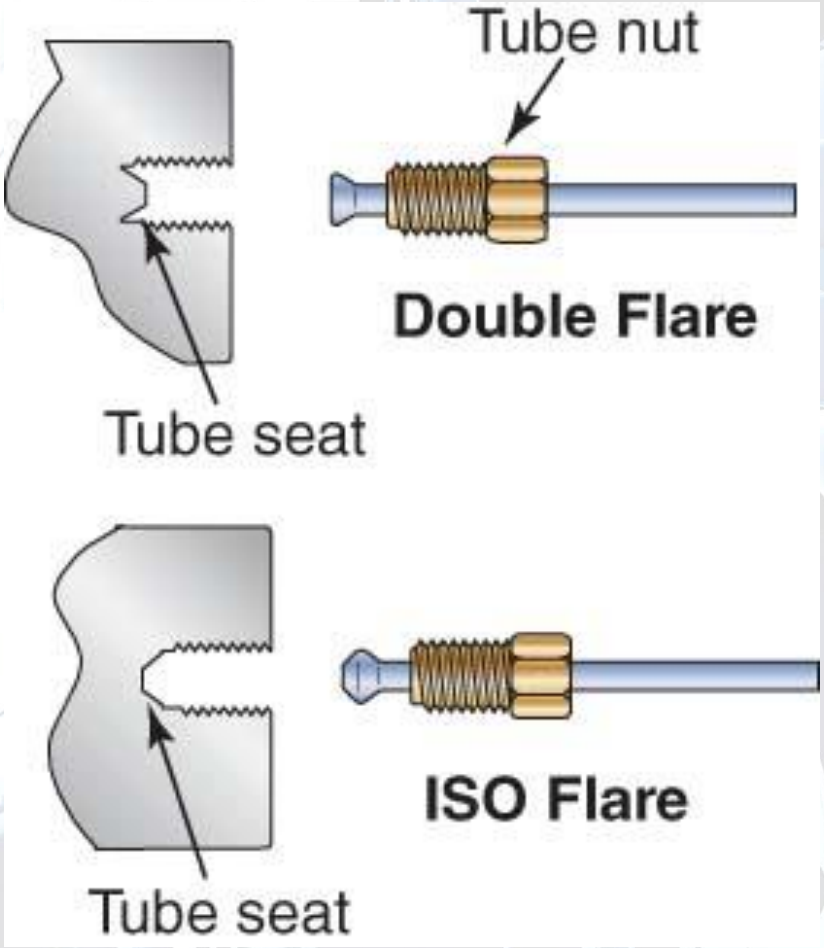
Typical truck hydraulic brake line circuit routing

CAUTION

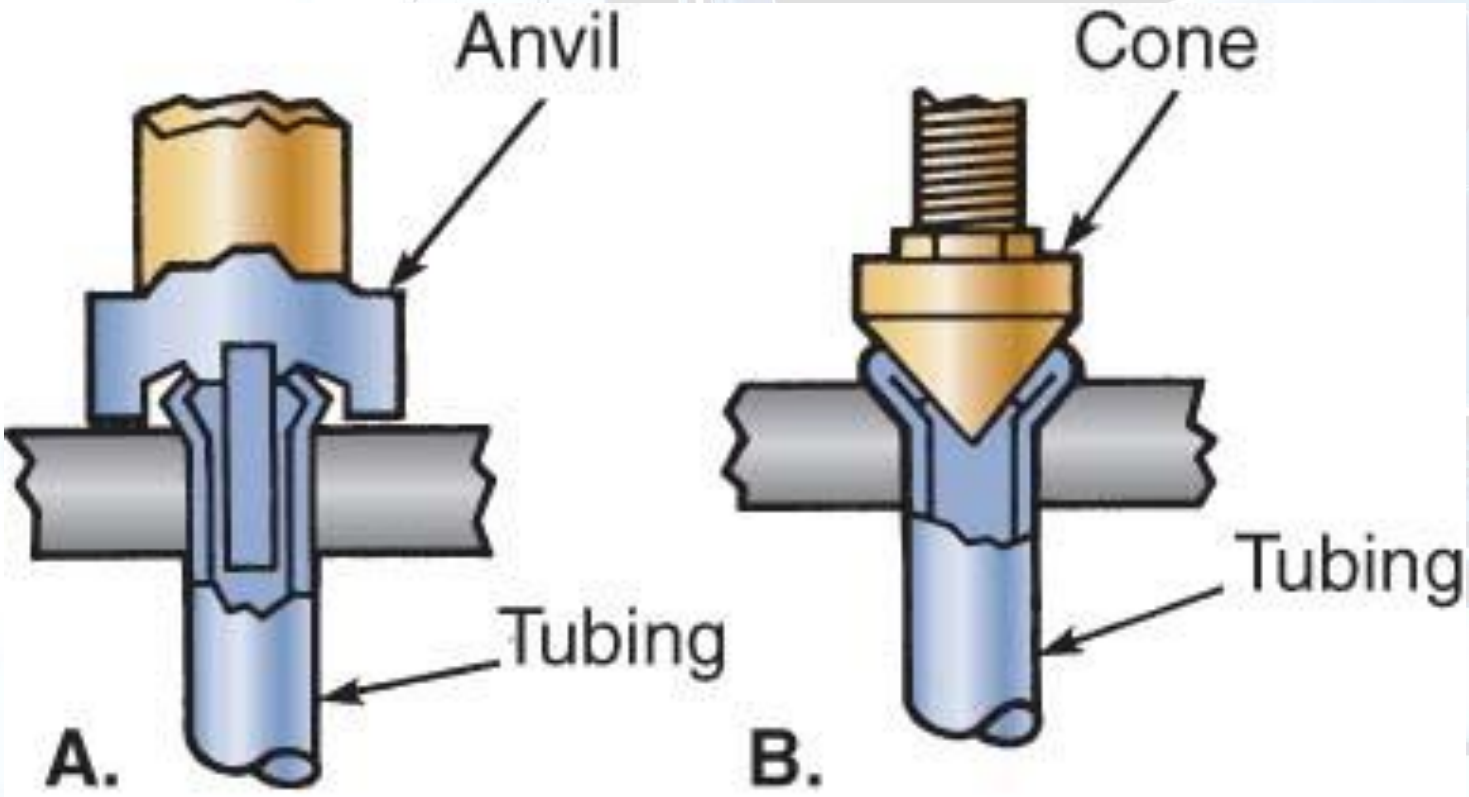
Never clamp brake hoses off with Vise-Grip™ or “locking pliers.” The result will be internal damage of the hose and premature failure.

Brake hose replacement. (A) Remove the lock clip from the chassis bracket; and (B) disconnect the female end first.

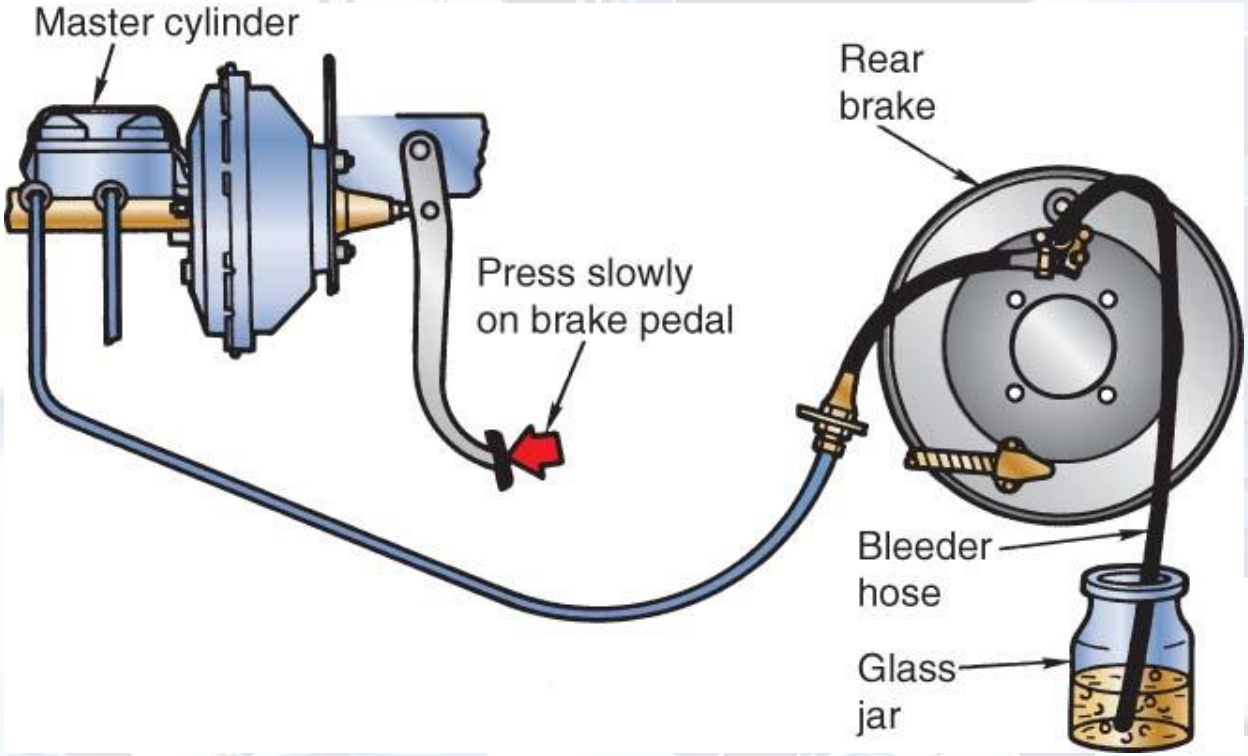




Two common types of line flares and their seats

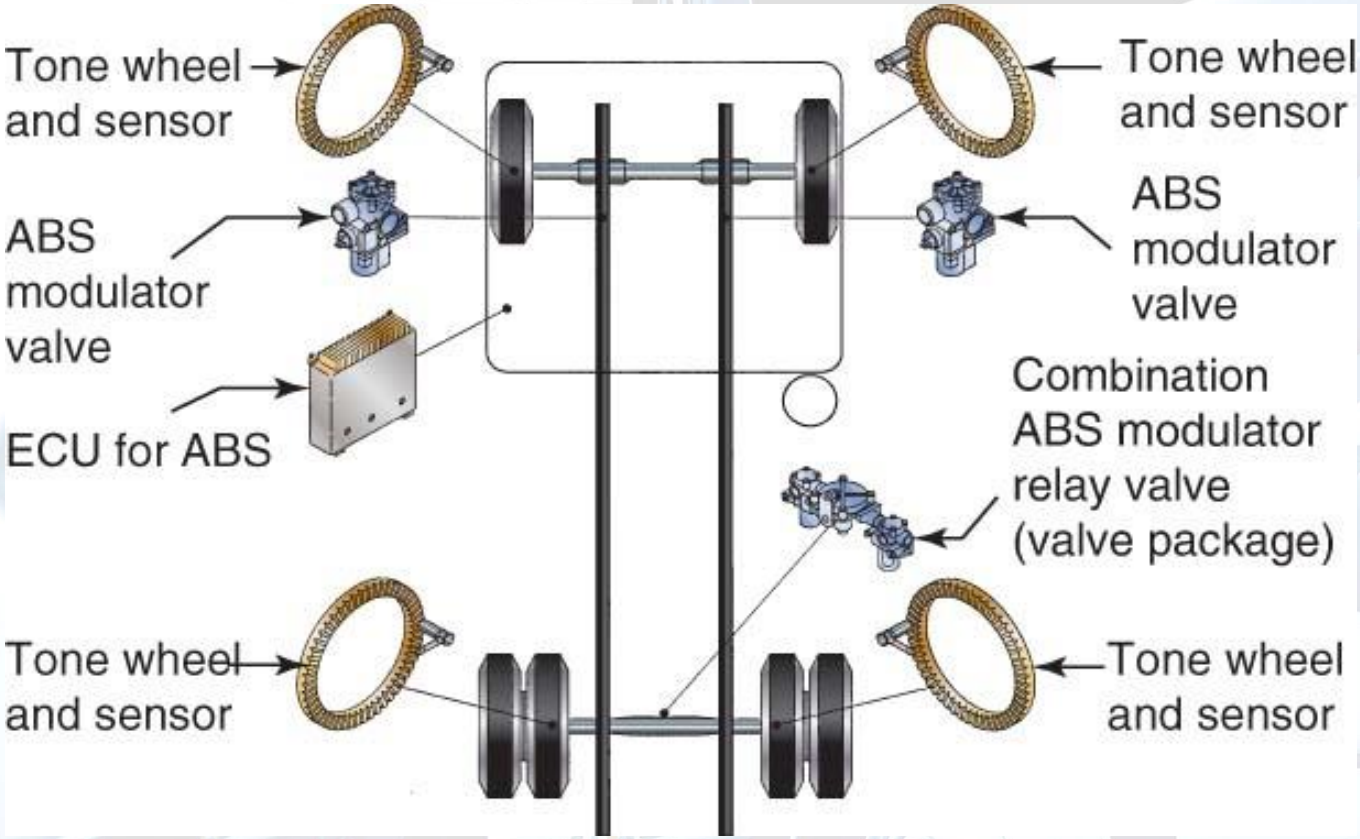


(A) Anvil folds tubing; and (B) cone performs second fold and doubles seat thickness.



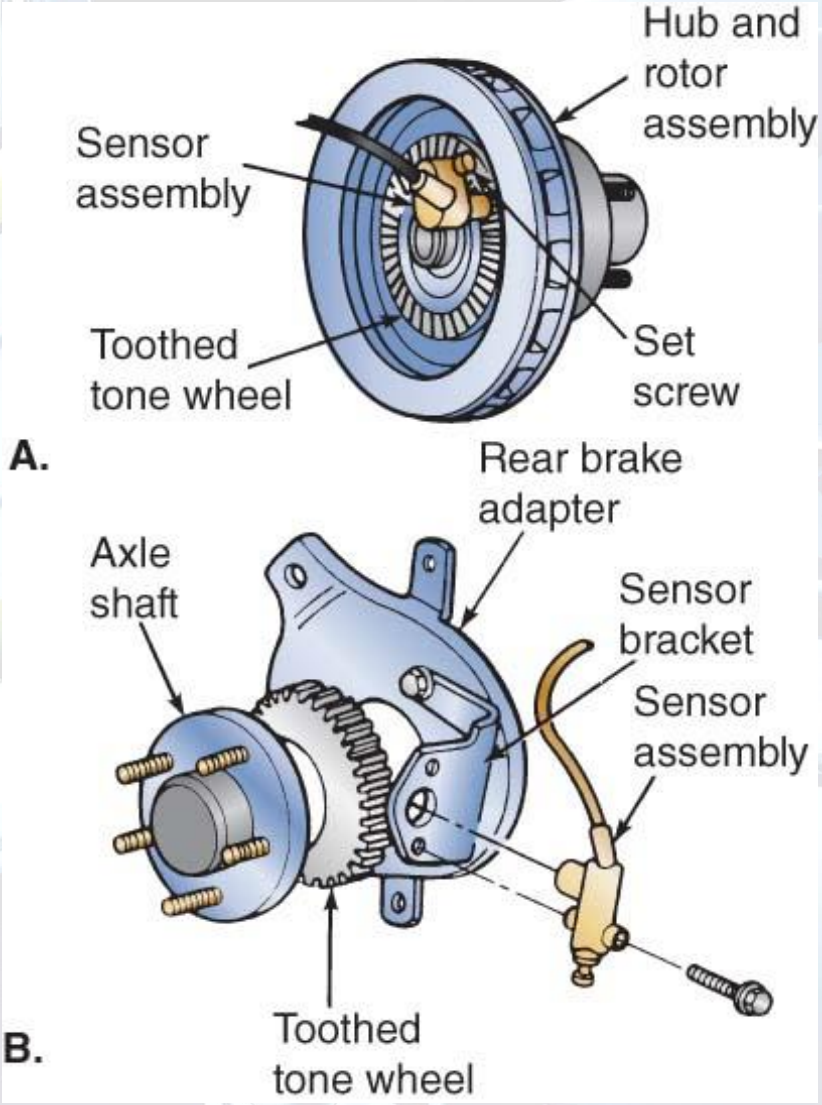
Manual brake bleeding technique

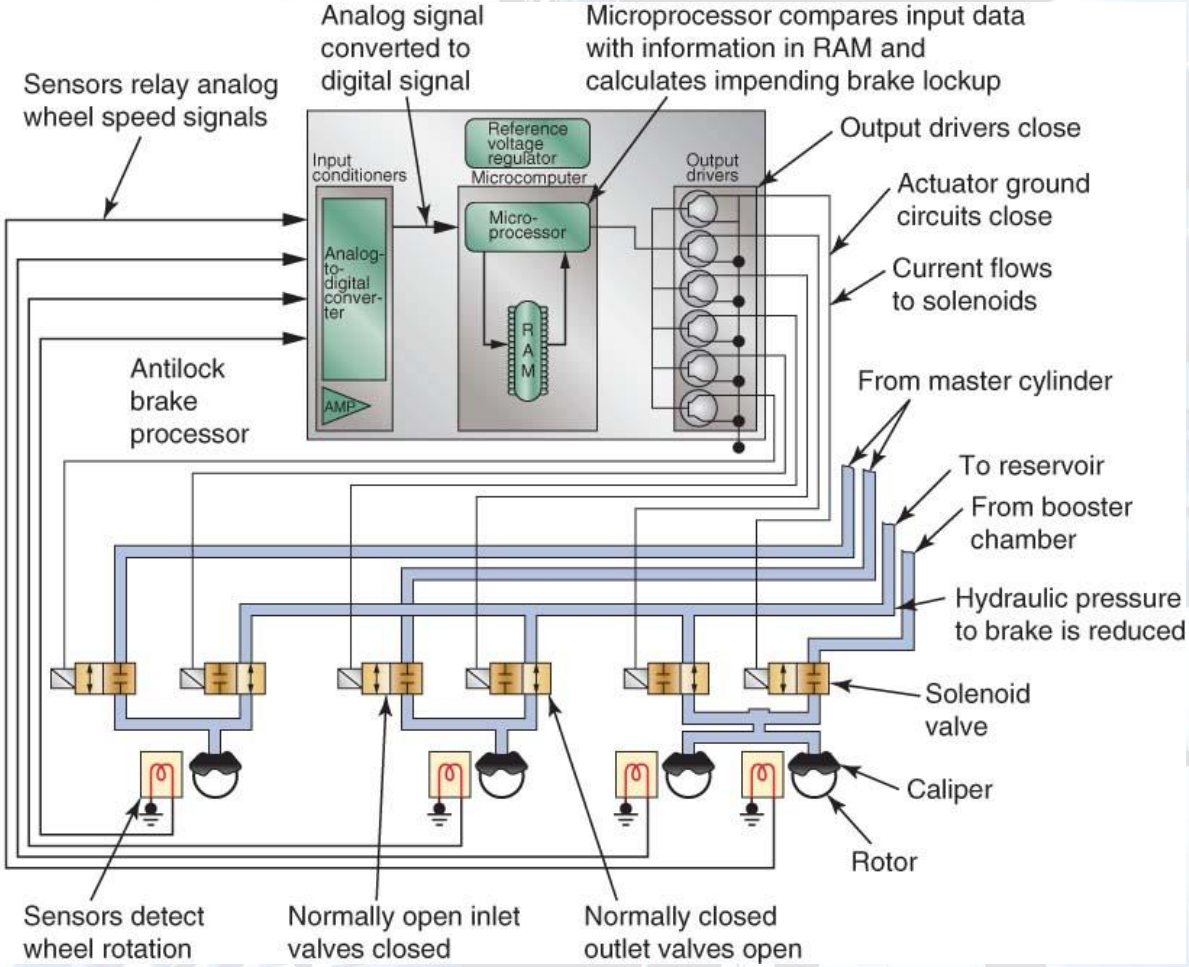
Pressure bleeder



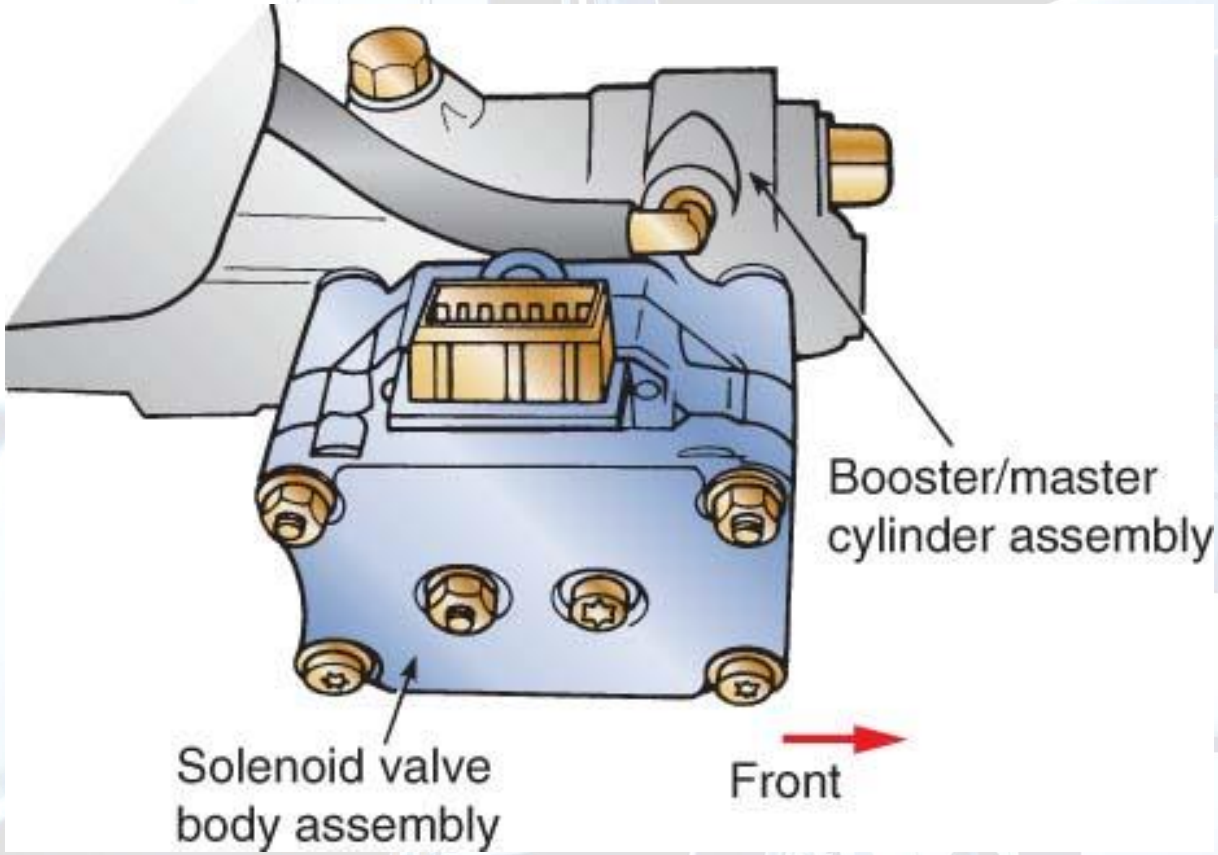
Location of ABS components on a 4S/4M small truck or school bus chassis

Typical ABS wheel sensors: (A) front and (B) rear.





ABS operation: potential brake lock condition



Typical ABS hydraulic control unit

ABS OPERATION

Wheel speed sensors continuously input wheel speed data to the ABS ECU. The system ECU monitors individual wheel speed data and compares it with average wheel speed. During braking, when the ECU senses that a high rate of wheel deceleration is occurring in a wheel, the modulator solenoid for the wheel first functions not to increase hydraulic pressure to the affected wheel.

System Redundancy

In the event of a system failure, hydraulic ABS is required to default to normal, that is, non-ABS, hydraulic braking. Should a single wheel speed sensor fail, ABS electronics will alert the driver to the fact that an ABS malfunction has occurred and operate the system in partial ABS mode. Systems are designed with a threshold of ABS failure fields that, once exceeded, results in defaulting to non-ABS operation. This is known as full redundancy operation.

CVSA OOS

Commercial Vehicle Safety Alliance (CVSA) **out of service (OOS)** standards are not maintenance standards. They define the point at which highway equipment becomes dangerous to operate. OOS are used to issue citations during safety inspections.

Summary

- Hydraulic brakes tend to be used only on lighter-duty highway trucks and off-highway applications.
- Hydraulic brakes are based on a principle that a liquid does not compress. Pressure applied to one portion of the circuit is transmitted equally to all parts of the circuit.

Summary

- In hydraulic braking systems, the mechanical force of the driver stepping on the brake pedal is converted to hydraulic pressure usually assisted by some type of power boost.
- At the wheel, the hydraulic force is once again changed back into the mechanical force required to brake the truck.

Summary

- Drum brakes can be servo, in which the action of one shoe is governed by input from the other, or non-servo, in which the shoes are separately anchored.
- Hydraulic disc brakes can be of the fixed caliper or floating/sliding caliper type.

Summary

- When the brake pedal is depressed, the master cylinder forces brake fluid to the calipers or wheel cylinders, changing mechanical force into hydraulic pressure; the wheel cylinders and calipers change hydraulic pressure back into mechanical force, braking the vehicle.

Summary

- Pressure differential valves, metering valves, proportioning valves, combination valves, and load proportioning valves are all operational components of a hydraulic brake system.
- In hydraulic brake systems, a hydraulic power booster is used to assist the master cylinder in applying the brakes. This means that the mechanical force applied by the driver's boot is amplified hydraulically.

Summary

- Some Class 6 and older Class 7 trucks are equipped with air-over-hydraulic brake systems. This combines some of the advantages of air and hydraulic brake systems.
- A hydraulic ABS is designed to modulate hydraulic application pressures to the wheel cylinders to permit maximum braking force without locking the wheels.

Summary

- A typical hydraulic ABS consists of wheel speed sensors, an electronic control module, and a modulator assembly.
- Hydraulic ABS is capable of modulation cycles at up to 15 times per second.
- All hydraulic ABS are required to default to full redundancy mode in the event of a complete system failure. Some systems permit operation in partial ABS in the event of subsection failure.