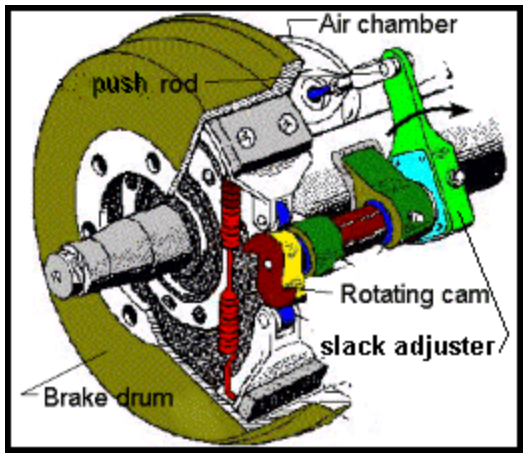
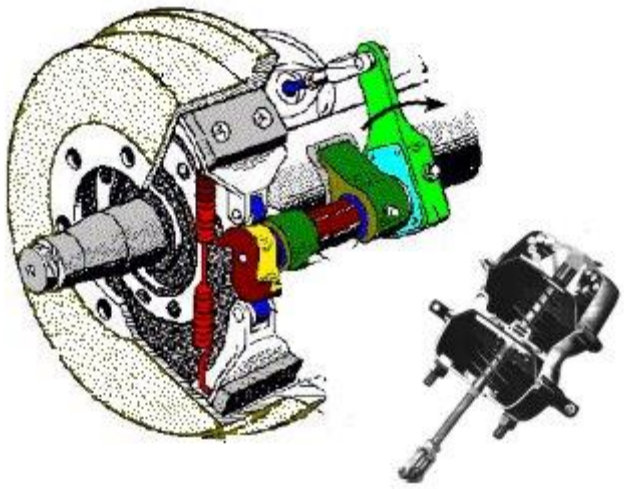
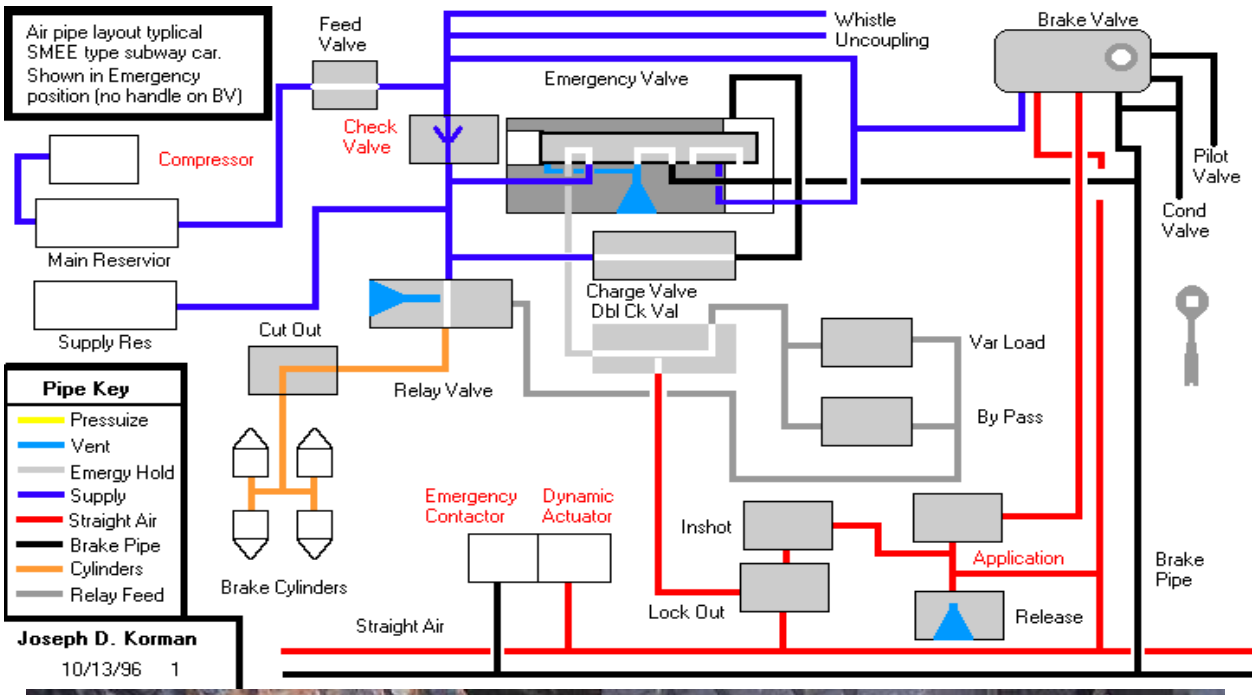
BRAKES

Air brakes

Air brakes are used in trucks, buses, trailers, and semi-trailers. George Westinghouse first developed air brakes for use in railway service. A safer air brake was patented by him on March 5, 1872. Originally constructed for use on trains, and still in common use as such, Westinghouse made many alterations to improve his invention, leading to various forms of the automatic brake, thus, its use was expanded to include road vehicles.






Air pipe layout typical SMEE type subway car. Shown in Emergency position (no handle on BV)
Feed Valve
Whistle
Uncoupling
Brake Valve
Emergency Valve
Check Valve
Compressor
Pilot Valve
Cond Valve
Main Reservior
Charge Valve
Dbl Ck Val
Supply Res
Cut Out
Var Load
Relay Valve
By Pass
Pipe Key
Pressuize
Vent
Emergy Hold
Supply
Straight Air
Brake Pipe
Cylinders
Relay Feed
Emergency Contactor
Dynamic Actuator
Inshot
Application
Brake Cylinders
Lock Out
Release
Brake Pipe
Straight Air
Joseph D. Korman
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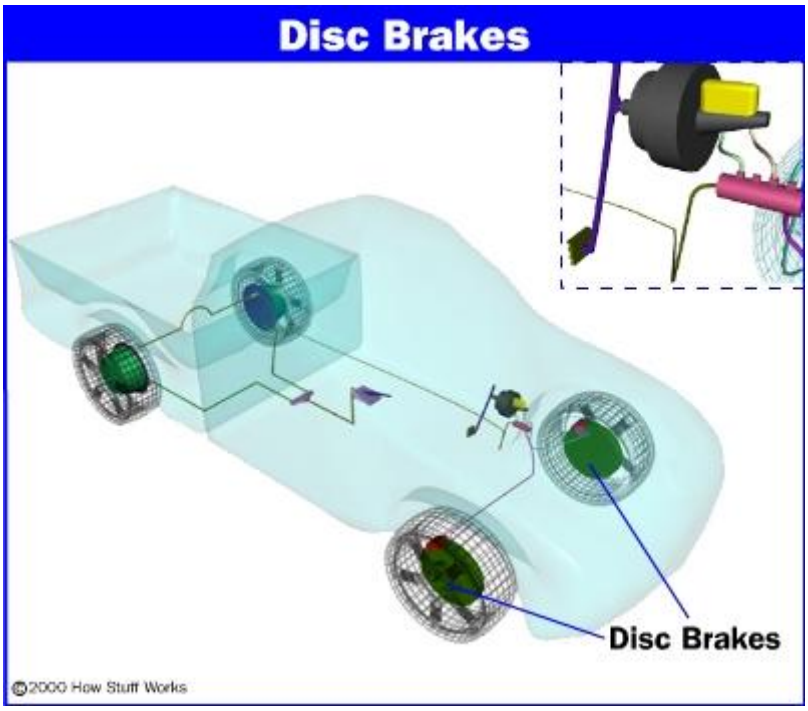
How Disc Brakes Work

Disc Brake Basics

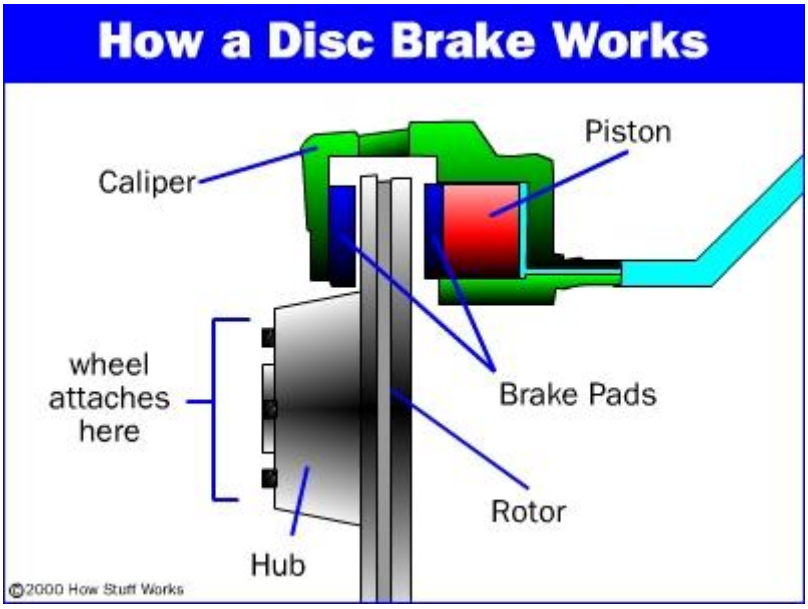
Here is the location of the disc brakes in a car:



Disc brake location

The main components of a disc brake are:

- The **brake pads**
- The **caliper**, which contains a piston
- The **rotor**, which is mounted to the hub



Parts of a disc brake

The disc brake is a lot like the brakes on a bicycle. Bicycle brakes have a caliper, which squeezes the brake pads against the wheel. In a disc brake, the brake pads squeeze the **rotor** instead of the wheel, and the force is transmitted hydraulically instead of through a cable. Friction between the pads and the disc slows the disc down.

A moving car has a certain amount of kinetic energy, and the brakes have to remove this energy from the car in order to stop it. How do the brakes do this? Each time you stop your car, your brakes convert the kinetic energy to heat generated by the friction between the pads and the disc. Most car disc brakes are **vented**.

Disc brake vents

Vented disc brakes have a set of vanes, between the two sides of the disc, that pumps air through the disc to provide **cooling**.

Most modern cars have disc brakes on the front wheels, and some have disc brakes on all four wheels. This is the part of the brake system that does the actual work of stopping the car.

The most common type of disc brake on modern cars is the **single-piston floating caliper**. In this article, we will learn all about this type of disc brake design.

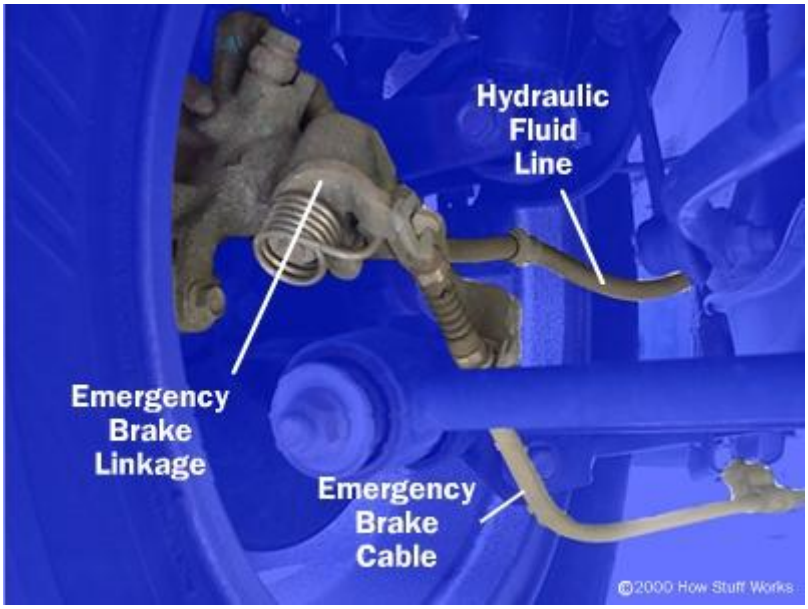
Self-Adjusting Brakes

The single-piston floating-caliper disc brake is **self-centering** and **self-adjusting**. The caliper is able to slide from side to side so it will move to the center each time the brakes are applied. Also, since there is no spring to pull the pads away from the disc, the pads always stay in light contact with the rotor (the rubber piston seal and any wobble in the rotor may actually pull the pads a small distance away from the rotor). This is important because the pistons in the brakes are much larger in diameter than the ones in the master cylinder. If the brake pistons retracted into their cylinders, it might take several applications of the brake pedal to pump enough fluid into the brake cylinder to engage the brake pads.

Older cars had dual or four-piston fixed-caliper designs. A piston (or two) on each side of the rotor pushed the pad on that side. This design has been largely eliminated because single-piston designs are cheaper and more reliable.

Emergency Brakes

In cars with disc brakes on all four wheels, an emergency brake has to be actuated by a separate mechanism than the primary brakes in case of a total primary brake failure. Most cars use a **cable** to actuate the emergency brake.



Disc brake with parking brake

Some cars with four-wheel disc brakes have a separate drum brake integrated into the hub of the rear wheels. This drum brake is only for the emergency brake system, and it is actuated only by the cable; it has no hydraulics.

Other cars have a **lever** that turns a screw, or actuates a cam, which presses the piston of the disc

Servicing Your Brakes

The most common type of service required for brakes is **changing the pads**. Disc brake pads usually have a piece of metal on them called a **wear indicator**.

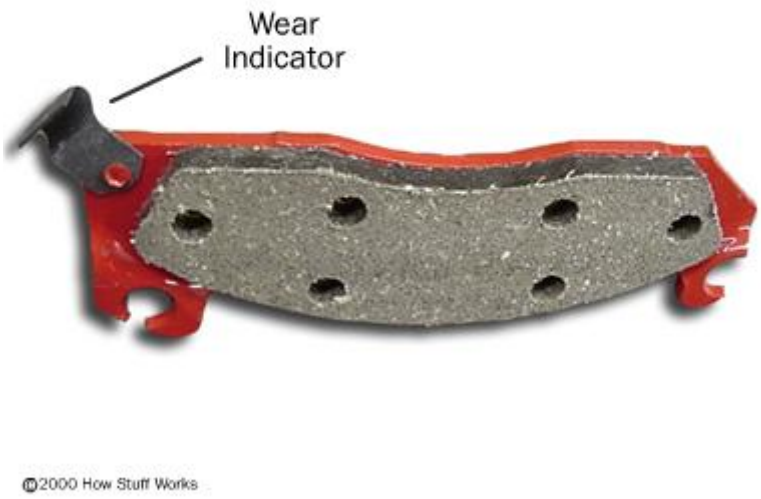
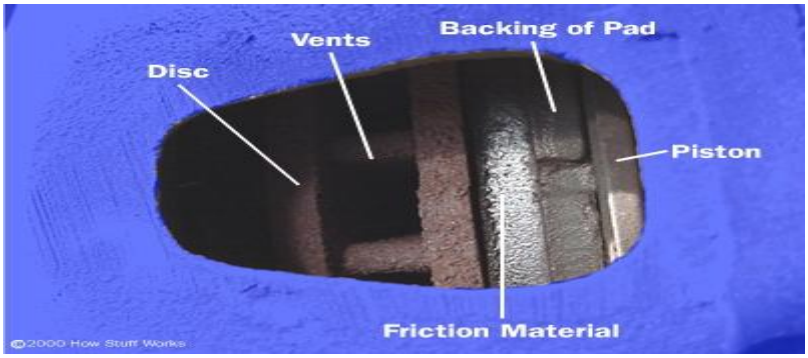


Photo courtesy of a local **Autozone** store

Disc brake pad

When enough of the friction material is worn away, the wear indicator will contact the disc and make a squealing sound. This means it is time for new brake pads.

There is also an **inspection opening** in the caliper so you can see how much friction material is left on your brake pads.



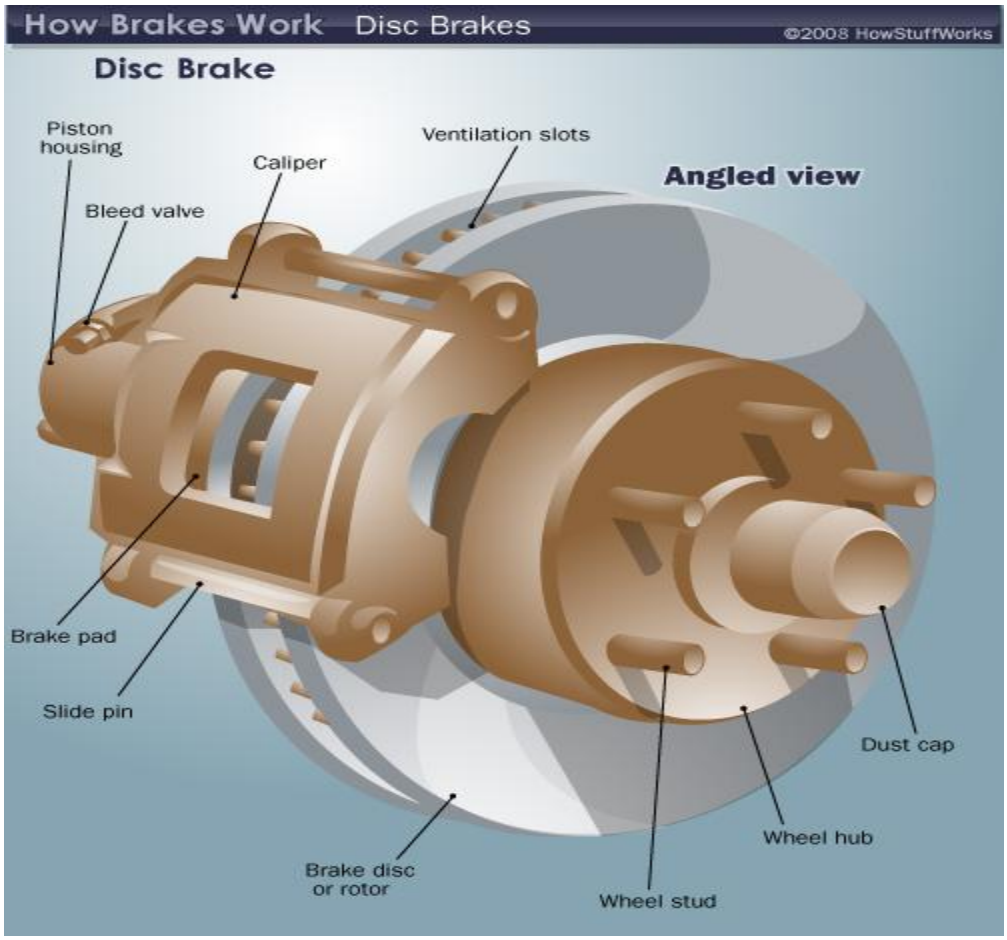
Disc brake inspection opening

Sometimes, deep scores get worn into **brake rotors**. This can happen if a worn-out brake pad is left on the car for too long. Brake rotors can also warp; that is, lose their flatness. If this happens, the brakes may shudder or vibrate when you stop. Both of these problems can sometimes be fixed by **refinishing** (also called turning or machining) the rotors. Some material is removed from both sides of the rotors to restore the flat, smooth surface.

Refinishing is not required every time your brake shoes are replaced. You need it only if they are warped or badly scored. In fact, refinishing the rotors more often than is necessary will reduce their life. Because the process removes material, brake rotors get thinner every time they are refinished. All brake rotors have a specification for the minimum allowable thickness before they need to be replaced. This spec can be found in the shop manual for each vehicle.

Disc Brake Diagram

Now let's put the parts together to see how disc brakes work as a whole. This diagram shows the basic parts that make up a disc brake system.



How Drum Brakes Work

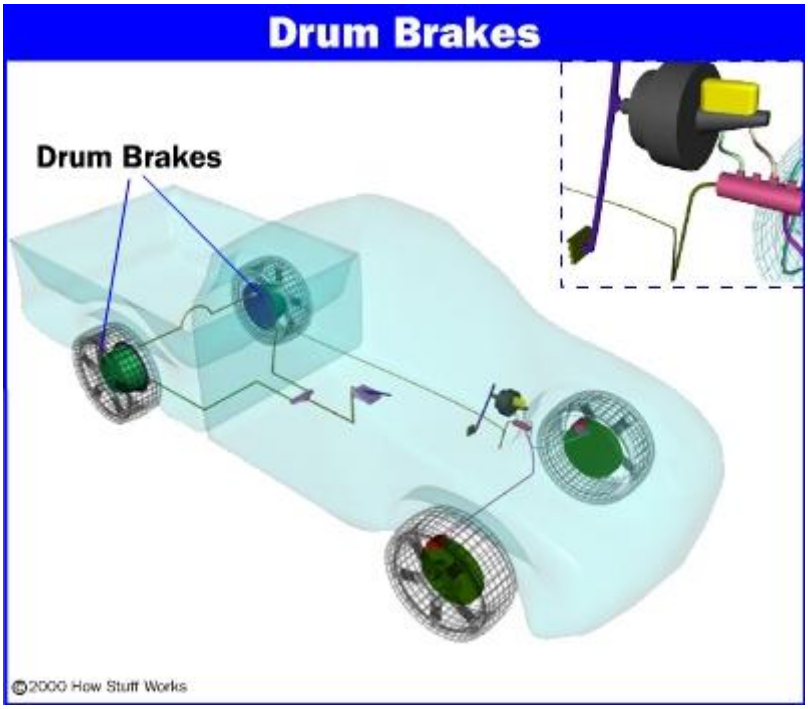
Drum brakes work on the same principle as disc brakes: **Shoes press against a spinning surface**. In this system, that surface is called a drum.

Many cars have drum brakes on the rear wheels and disc brakes on the front. Drum brakes have more parts than disc brakes and are harder to service, but they are less expensive to manufacture, and they easily incorporate an emergency brake mechanism.

In this edition of **HowStuffWorks**, we will learn exactly how a drum brake system works, examine the emergency brake setup and find out what kind of servicing drum brakes need.

Figure 2. Drum brake with drum in place

Figure 3. Drum brake without drum in place



The Drum Brake

The drum brake may look complicated, and it can be pretty intimidating when you open one up. Let's break it down and explain what each piece does.

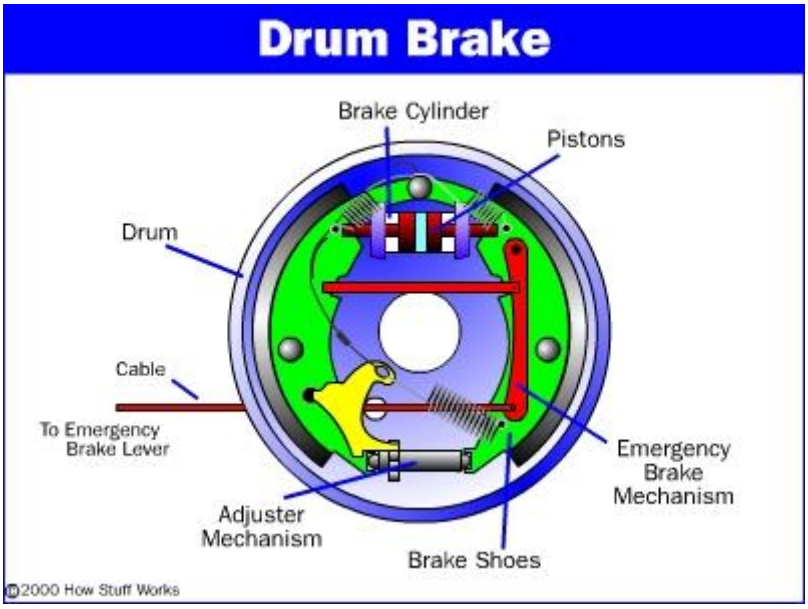


Figure 4. Parts of a drum brake

Like the disc brake, the drum brake has two brake shoes and a piston. But the drum brake also has an **adjuster** mechanism, an **emergency brake** mechanism and lots of **springs**.

First, the basics: **Figure 5** shows only the parts that provide stopping power.

When you hit the brake pedal, the piston pushes the brake shoes against the drum. That's pretty straightforward, but why do we need all of those springs?

This is where it gets a little more complicated. Many drum brakes are **self-actuating**. Figure 5 shows that as the brake shoes contact the drum, there is a kind of wedging action, which has the effect of pressing the shoes into the drum with more force.

The extra braking force provided by the wedging action allows drum brakes to use a smaller piston than disc brakes. But, because of the wedging action, the shoes must be pulled away from the drum when the brakes are released. This is the reason for some of the springs. Other springs help hold the brake shoes in place and return the adjuster arm after it actuates.

Brake Adjuster

For the drum brakes to function correctly, the brake shoes must remain close to the drum without touching it. If they get too far away from the drum (as the shoes wear down, for instance), the piston will require more fluid to travel that distance, and your brake pedal will sink

closer to the floor when you apply the brakes. This is why most drum brakes have an **automatic adjuster**.

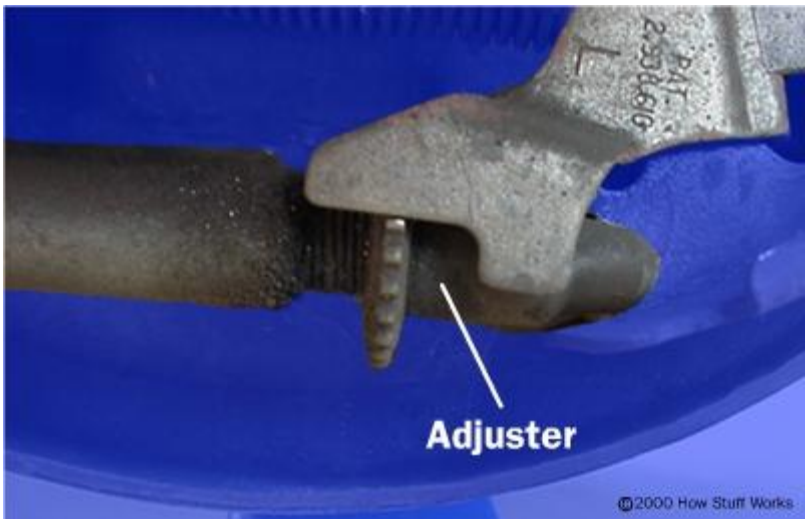


Figure 6. Adjuster mechanism

Now let's add in the parts of the adjuster mechanism. The adjuster uses the self-actuation principle we discussed above.

In **Figure 7**, you can see that as the pad wears down, more space will form between the shoe and the drum. Each time the car stops while in reverse, the shoe is pulled tight against the drum. When the gap gets big enough, the adjusting lever rocks enough to advance the adjuster gear by one tooth. The adjuster has threads on it, like a bolt, so that it unscrews a little bit when it turns, lengthening to fill in the gap. When the brake shoes wear a little more, the adjuster can advance again, so it always keeps the shoes close to the drum.

Some cars have an adjuster that is actuated when the emergency brake is applied. This type of adjuster can come out of adjustment if the emergency brake is not used for long periods of time. So if you have this type of adjuster, you should apply your emergency brake at least once a week.

Servicing

The most common service required for drum brakes is **changing the brake shoes**. Some drum brakes provide an inspection hole on the back side, where you can see how much material is left on the shoe. Brake shoes should be replaced when the friction material has worn down to within 1/32 inch (0.8 mm) of the rivets. If the friction material is bonded to the backing plate (no rivets), then the shoes should be replaced when they have only 1/16 inch (1.6 mm) of material left.

Photo courtesy of a local AutoZone store

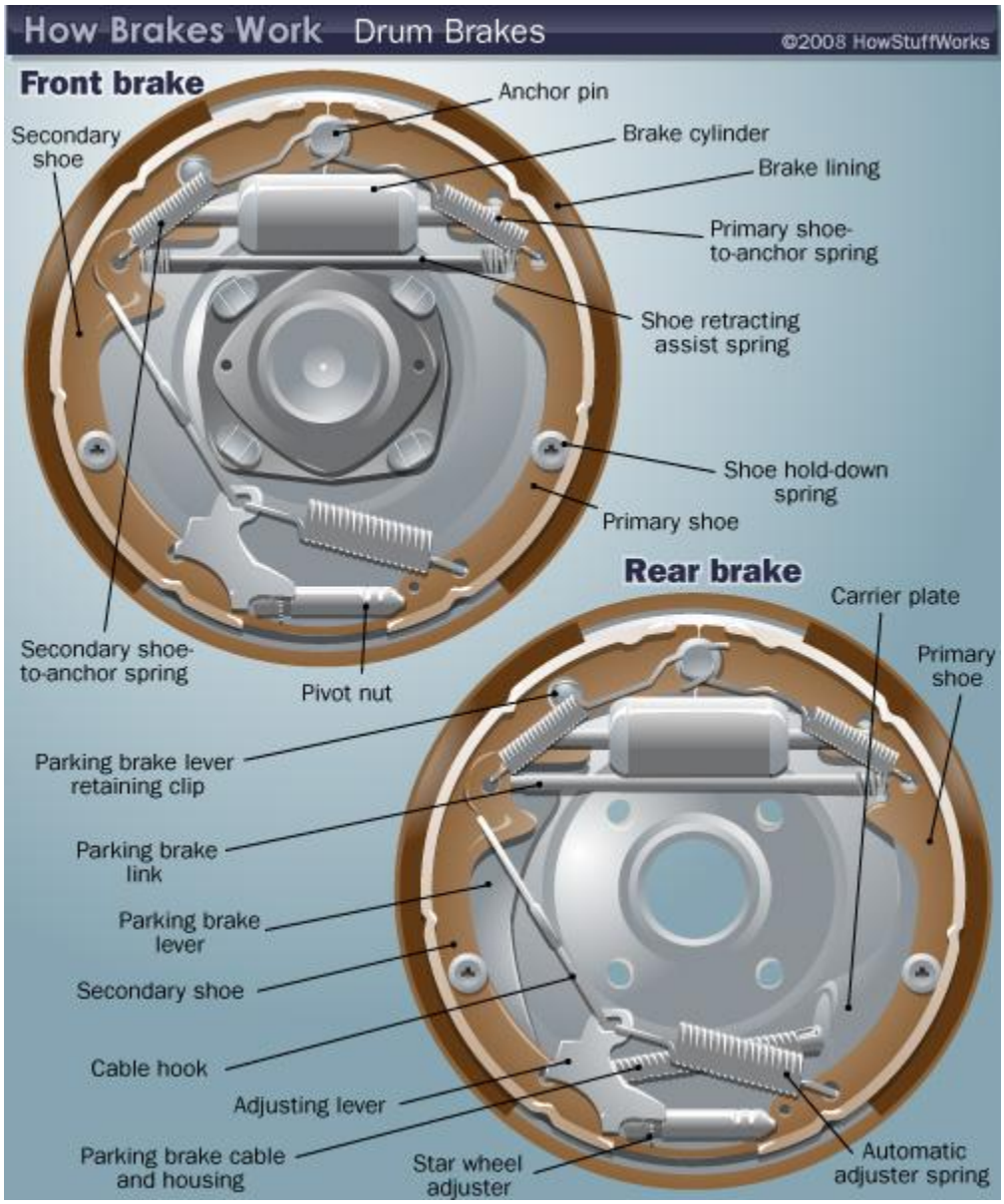
Figure 9. Brake shoe

Just as in disc brakes, deep scores sometimes get worn into brake drums. If a worn-out brake shoe is used for too long, the rivets that hold the friction material to the backing can wear grooves into the drum. A badly scored drum can sometimes be repaired by refinishing. Where disc brakes have a minimum allowable thickness, drum brakes have a **maximum allowable diameter**. Since the contact surface is the inside of the drum, as you remove material from the drum brake the diameter gets bigger.

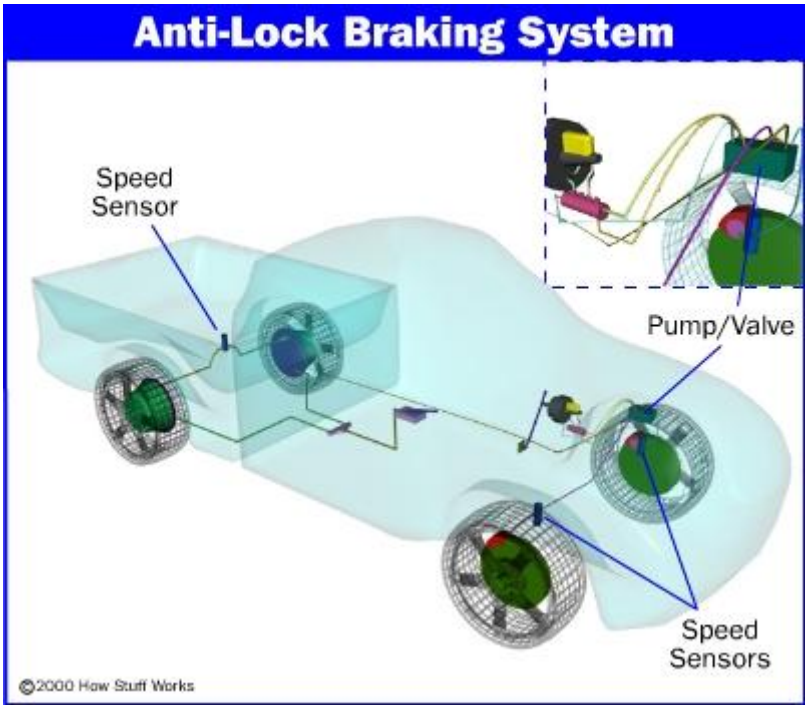
Figure 10. Brake drum

Drum Brake Diagram

Now let's put it all together. The drum brake diagram below shows how all the parts of the brake work together.



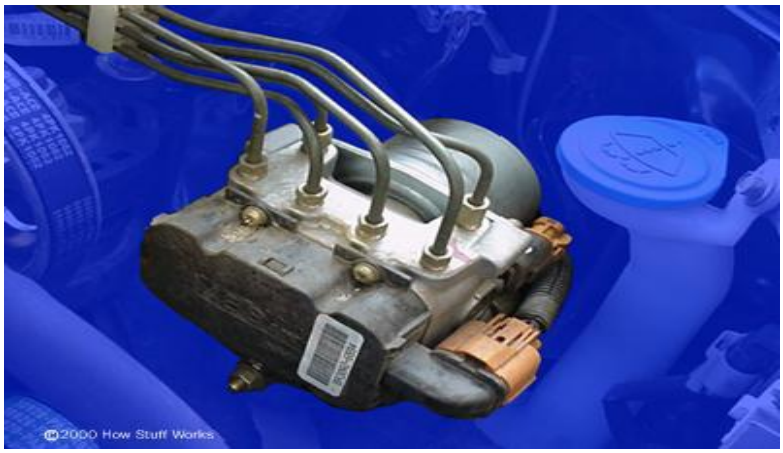
How Anti-Lock Brakes Work



Stopping a car in a hurry on a slippery road can be very challenging. Anti-lock braking systems (ABS) take a lot of the challenge out of this sometimes nerve-wracking event. In fact, on slippery surfaces, even professional drivers can't stop as quickly without ABS as an average driver can with ABS.

In this article, the last in a six-part series on brakes, we'll learn all about anti-lock braking systems -- why you need them, what's in them, how they work, some of the common types and some associated problems.

The ABS System



Anti-lock brake pump and valves

The theory behind anti-lock brakes is simple. A **skidding wheel** (where the tire contact patch is sliding relative to the road) has less **traction** than a non-skidding wheel. If you have been stuck on ice, you know that if your wheels are spinning you have no traction. This is because the contact patch is sliding relative to the ice (see Brakes: How Friction Works for more). By keeping the wheels from skidding while you slow down, anti-lock brakes benefit you in two ways: You'll stop faster, and you'll be able to steer while you stop.

There are four main components to an ABS system:

- Speed sensors
- Pump
- Valves
- Controller

Speed Sensors
The anti-lock braking system needs some way of knowing when a wheel is about to lock up. The speed sensors, which are located at each wheel, or in some cases in the differential, provide this information.

Valves
There is a valve in the brake line of each brake controlled by the ABS. On some systems, the valve has three positions:

- In position one, the valve is **open**; pressure from the master cylinder is passed right through to the brake.
- In position two, the valve **blocks** the line, isolating that brake from the master cylinder. This prevents the pressure from rising further should the driver push the brake pedal harder.
- In position three, the valve **releases** some of the pressure from the brake.

Pump
Since the valve is able to release pressure from the brakes, there has to be some way to put that pressure back. That is what the pump does; when a valve reduces the pressure in a line, the pump is there to get the pressure back up.

Controller
The controller is a computer in the car. It watches the speed sensors and controls the valves.

ABS at Work
There are many different variations and control algorithms for ABS systems. We will discuss how one of the simpler systems works.

The controller monitors the speed sensors at all times. It is looking for **decelerations** in the wheel that are out of the ordinary. Right before a wheel locks up, it will experience a rapid deceleration. If left unchecked, the wheel would stop much more quickly than any car could. It might take a car five seconds to stop from 60 mph (96.6 kph) under ideal conditions, but a wheel that locks up could stop spinning in less than a second.

The ABS controller knows that such a rapid deceleration is impossible, so it reduces the **pressure** to that brake until it sees an acceleration, then it increases the pressure until it sees the deceleration again. It can do this very quickly, before the tire can actually significantly change speed. The result is that the tire slows down at the same rate as the car, with the brakes keeping the tires very near the point at which they will start to lock up. This gives the system maximum braking power.

When the ABS system is in operation you will feel a **pulsing** in the brake pedal; this comes from the rapid opening and closing of the valves. Some ABS systems can cycle up to 15 times per second.

Anti-Lock Brake Types

Anti-lock braking systems use different schemes depending on the type of brakes in use. We will refer to them by the number of channels -- that is, how many valves that are individually controlled -- and the number of speed sensors.

Four-channel, four-sensor ABS
This is the best scheme. There is a speed sensor on all four wheels and a separate valve for all four wheels. With this setup, the controller monitors each wheel individually to make sure it is achieving maximum braking force.

Three-channel, three-sensor ABS
This scheme, commonly found on pickup trucks with four-wheel ABS, has a speed sensor and a valve for each of the front wheels, with one valve and one sensor for both rear wheels. The speed sensor for the rear wheels is located in the rear axle.

This system provides individual control of the front wheels, so they can both achieve maximum braking force. The rear wheels, however, are monitored together; they both have to start to lock up before the ABS will activate on the rear. With this system, it is possible that one of the rear wheels will lock during a stop, reducing brake effectiveness.

One-channel, one-sensor ABS
This system is commonly found on pickup trucks with rear-wheel ABS. It has one valve, which controls both rear wheels, and one speed sensor, located in the rear axle.

This system operates the same as the rear end of a three-channel system. The rear wheels are monitored together and they both have to start to lock up before the ABS kicks in. In this system it is also possible that one of the rear wheels will lock, reducing brake effectiveness.

This system is easy to identify. Usually there will be one brake line going through a T-fitting to both rear wheels. You can locate the speed sensor by looking for an electrical connection near the differential on the rear-axle housing.

ABS Questions

Should I pump the brake pedal when stopping in slippery conditions?
You absolutely should not pump the brake pedal in a car with ABS. Pumping the brakes is a technique that is sometimes used in slippery conditions to allow the wheels to unlock so that the vehicle stays somewhat straight during a stop. In a car with ABS the wheels should never lock in the first place, so pumping the brakes will just make you take longer to stop.

In an emergency stop in a car with ABS, you should apply the brake pedal firmly and hold it while the ABS does all the work. You will feel a pulsing in the pedal that may be quite violent, but this is normal so don't let off the brake.

Do anti-lock brakes really work?
Anti-lock brakes really do help you stop better. They prevent wheels from locking up and provide the shortest stopping distance on slippery surfaces. But do they really prevent accidents? This is the true measure of the effectiveness of ABS systems.

The Insurance Institute for Highway Safety (IIHS) has conducted several studies trying to determine if cars equipped with ABS are involved in more or fewer fatal accidents. It turns out that in a 1996 study, vehicles equipped with ABS were overall no less likely to be involved in fatal accidents than vehicles without. The study actually stated that although cars with ABS were less likely to be involved in accidents fatal to the

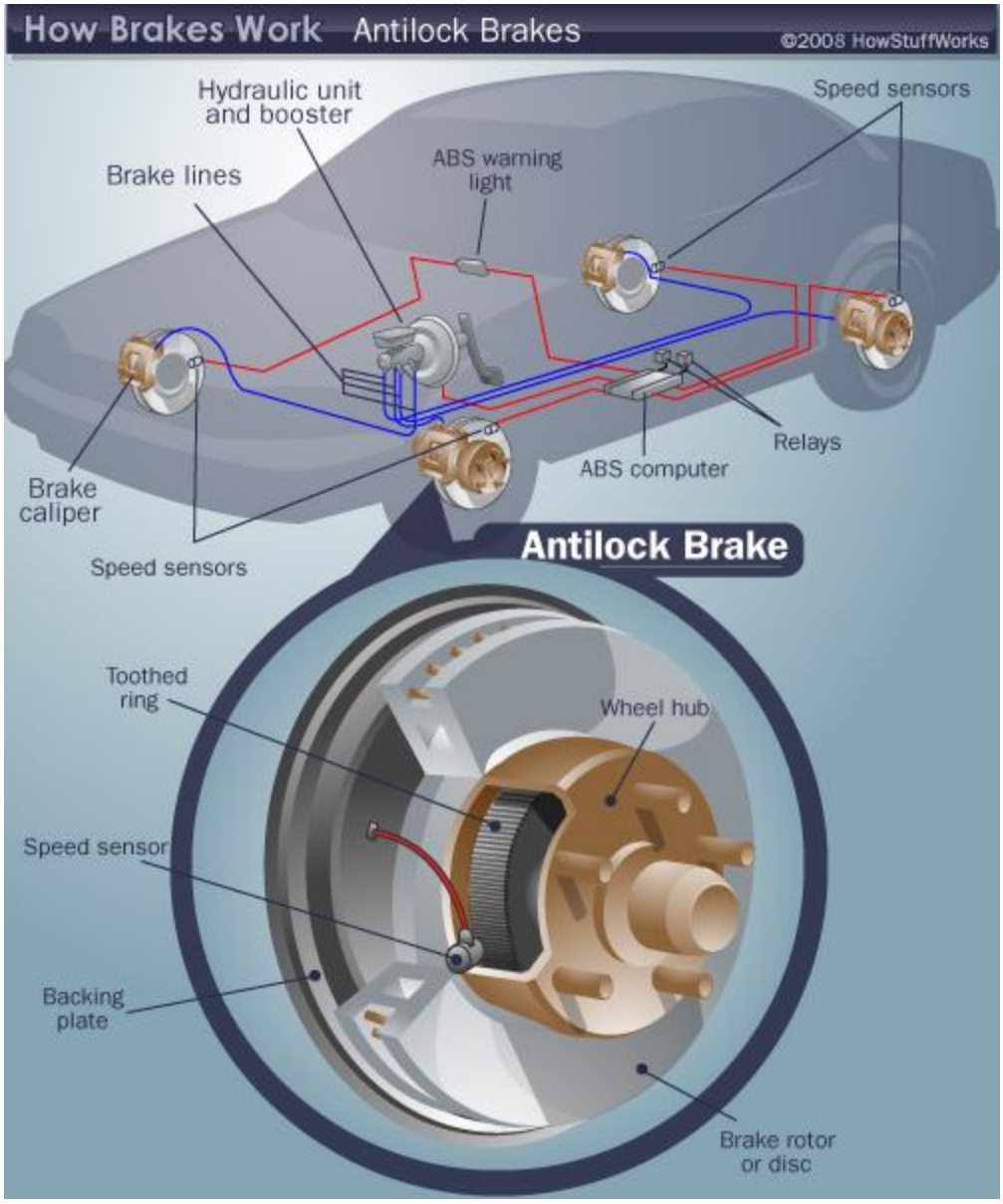
occupants of other cars, they are more likely to be involved in accidents fatal to the occupants of the ABS car, especially single-vehicle accidents.

There is much speculation about the reason for this. Some people think that drivers of ABS-equipped cars use the ABS incorrectly, either by pumping the brakes or by releasing the brakes when they feel the system pulsing. Some people think that since ABS allows you to steer during a panic stop, more people run off the road and crash.

Some more recent information may indicate that the accident rate for ABS cars is improving, but there is still no evidence to show that ABS improves overall safety.

Anti-Lock Brake Diagram

Now let's put the parts together to see how anti-lock brakes work as a whole. This diagram provides both a closeup view and an example of where the brakes are located in your vehicle.


How Brakes Work Antilock Brakes
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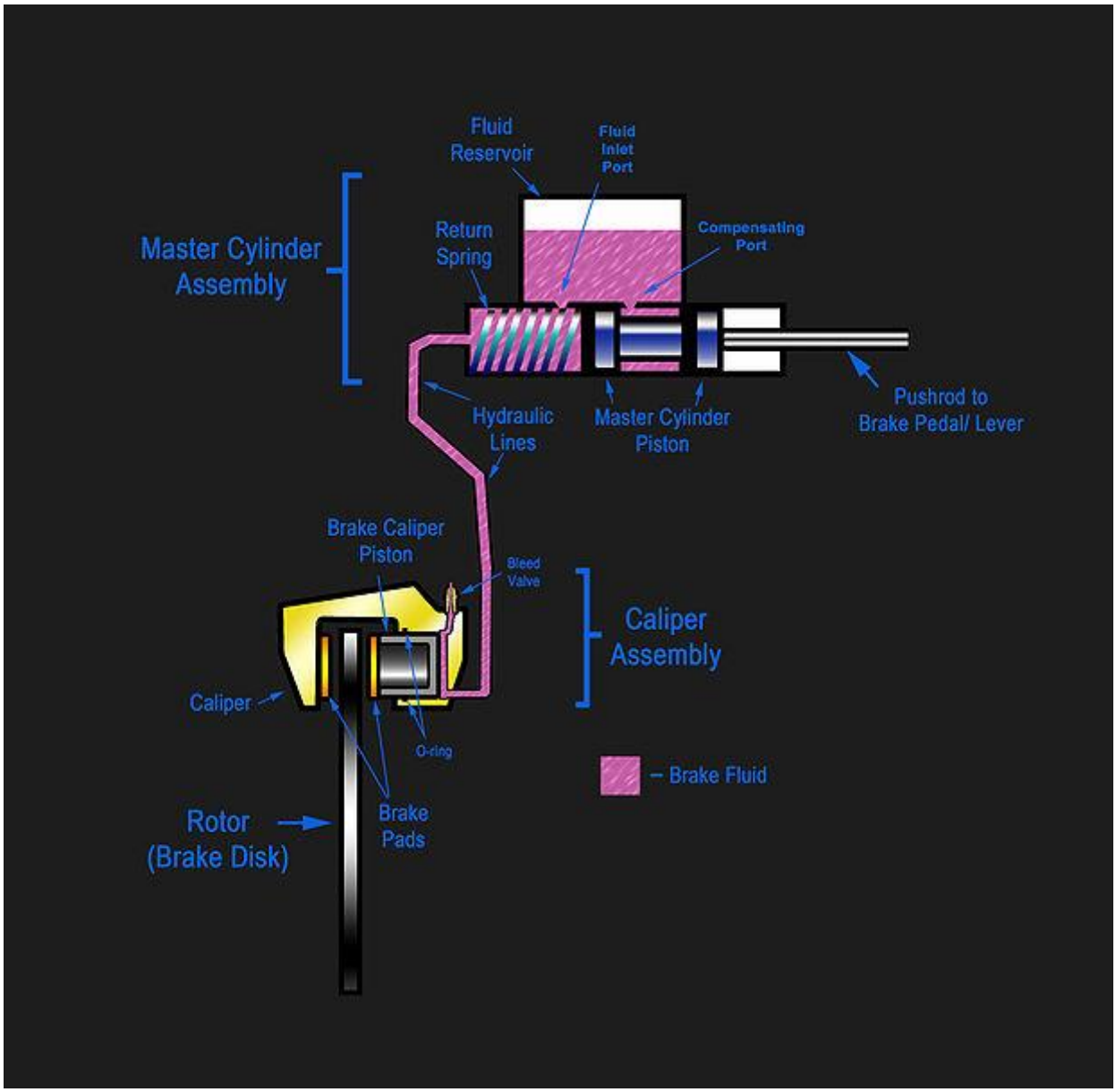
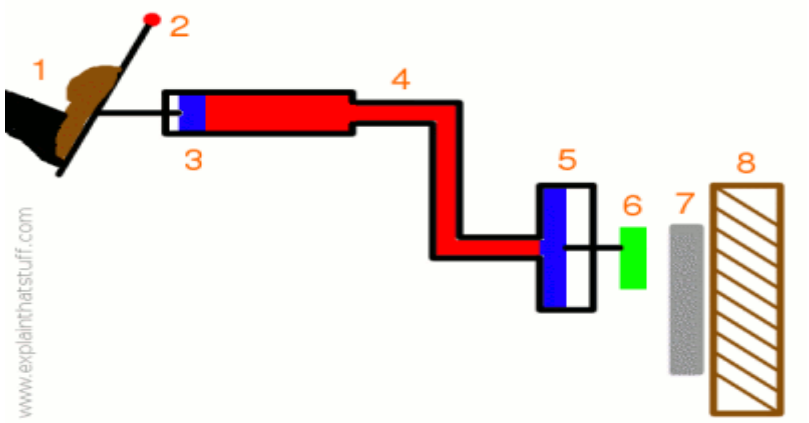
Hydraulic unit and booster
Brake lines
ABS warning light
Speed sensors
Relays
ABS computer
Brake caliper
Speed sensors
Antilock Brake
Toothed ring
Wheel hub
Speed sensor
Backing plate
Brake rotor or disc

Hydraulic Brakes

Definition

The hydraulic brake is an arrangement of braking mechanism which uses brake fluid, typically containing ethylene glycol, to transfer pressure from the controlling unit, which is usually near the operator of the vehicle, to the actual brake mechanism, which is usually at or near the wheel of the vehicle.

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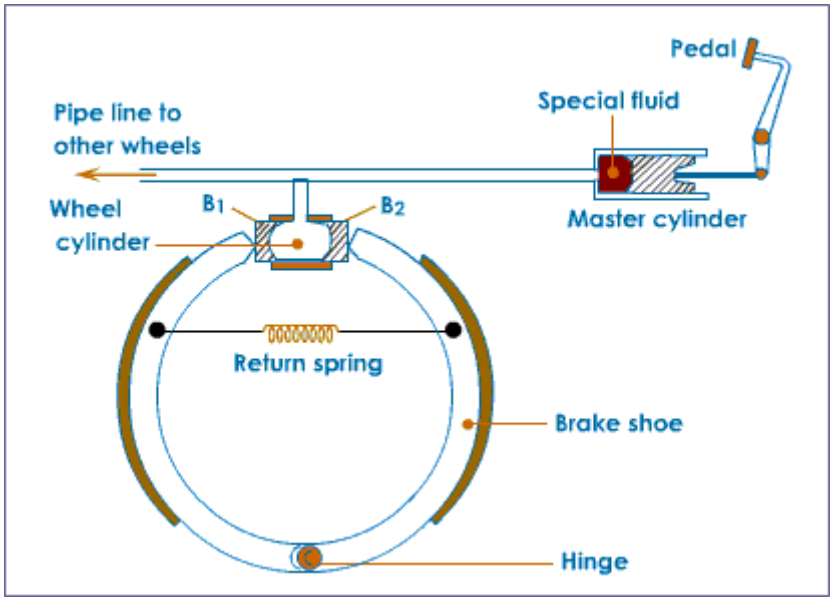
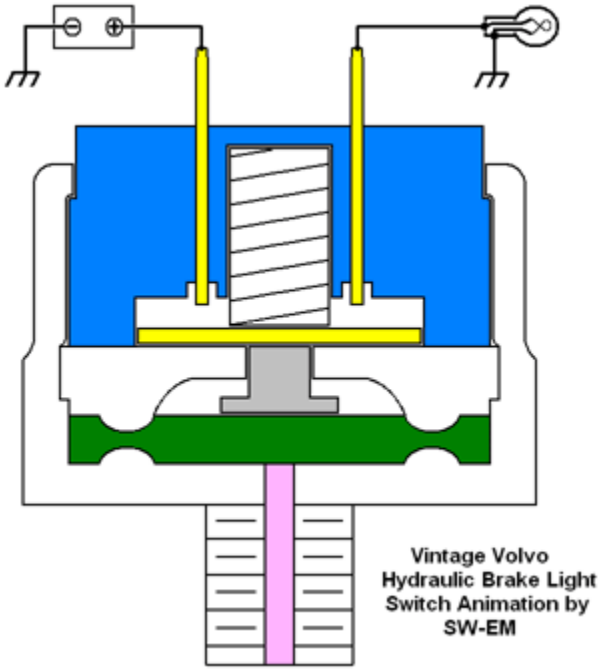

Pedal
Special fluid
Pipe line to
other wheels
Wheel
cylinder
B1
B2
Master cylinder
Return spring
Brake shoe
Hinge

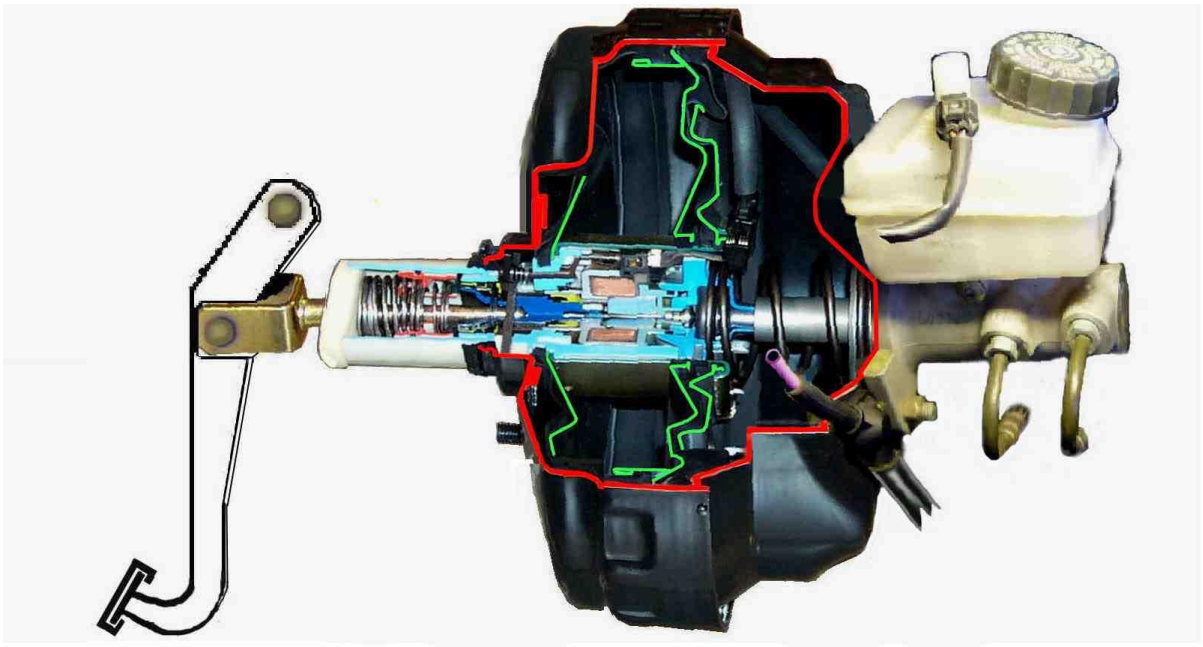


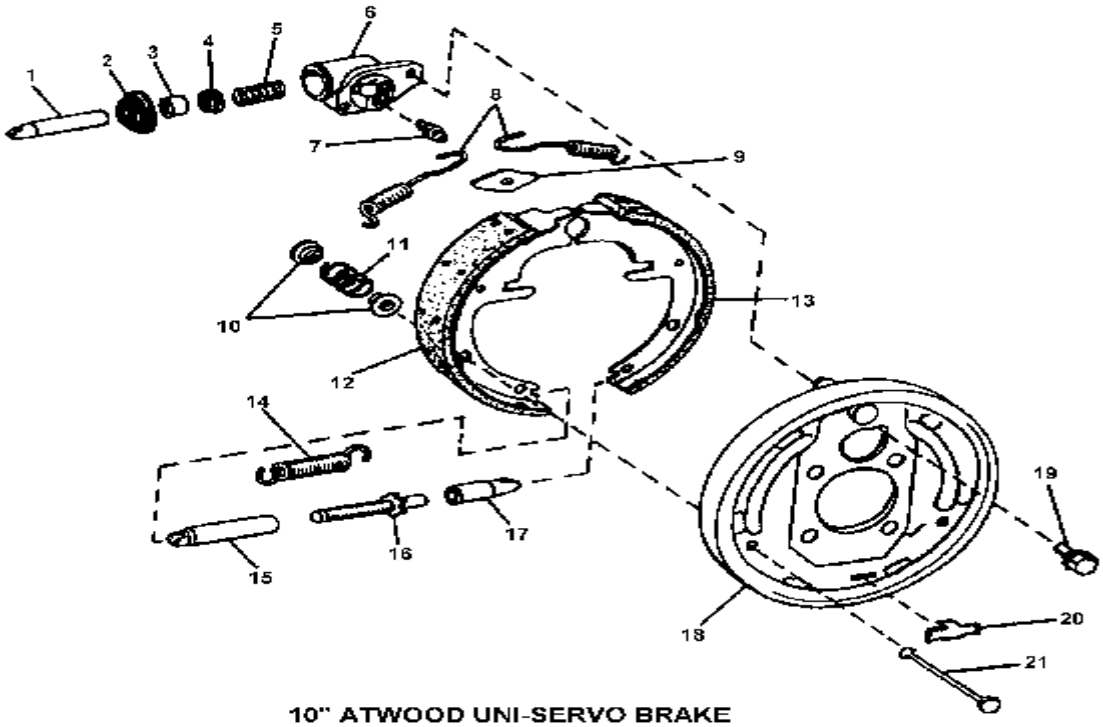
Servo brakes

Defintion

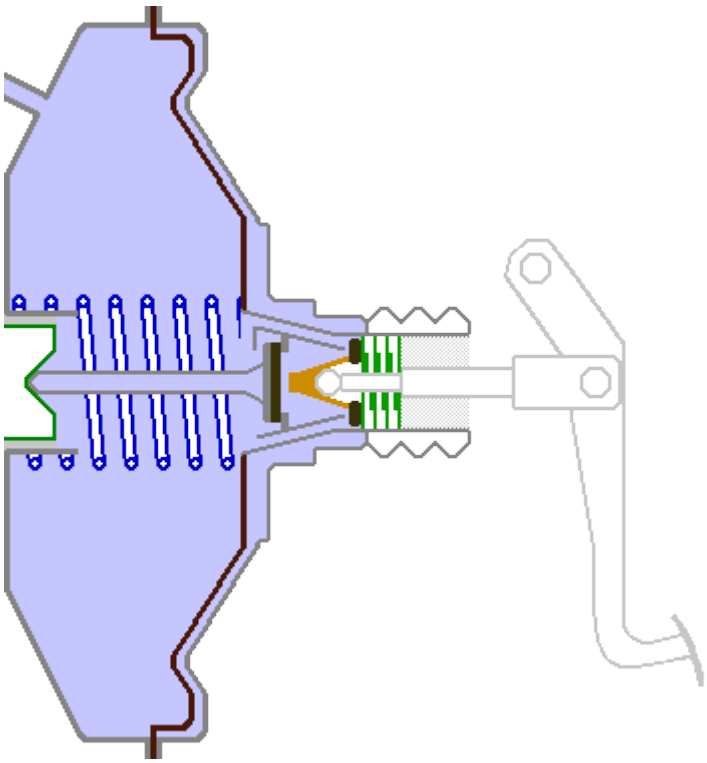
If the vehicle is equipped with an Otto engine with a throttle plate, the negative pressure in the intake pipe is usually sufficient to operate the brake servo unit. All other engine types, including the Diesel engine, have to have a vacuum pump. In both cases, while the engine is running, the negative pressure is directed through a one way valve into both chambers of the brake servo unit. As long as the brake is not operated both chambers are connected with each other via channels. There is a movable diaphragm in between the chambers.

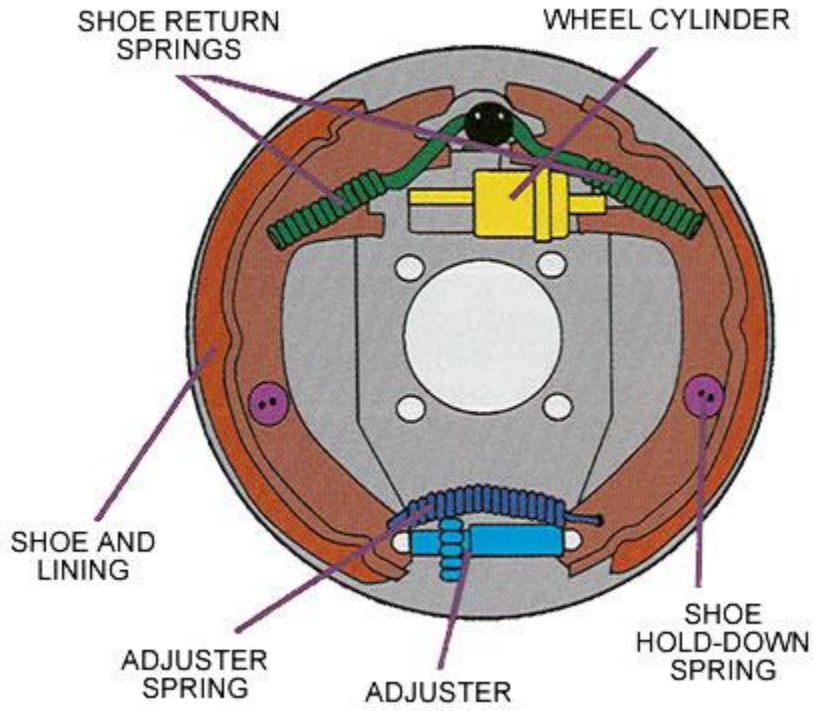
If the driver starts braking, the connecting rod moves left, pressing the seal of the double valve against the valve seat, thereby closing the connection between the two chambers. In accordance with the brake pedal force, more or less air at atmospheric pressure gets into the right chamber via an air cleaner (see arrows!), intensifying the brake force. The pressure in the right working chamber is bigger than in the left vacuum chamber. The diameter of the servo unit, still indicated in inches, determines the maximum braking force. For heavier vehicles one might make use of three or four chambers if there is not enough space for one sufficiently large unit. If there is a hydraulic system already present, the support work might be taken over by a substantially smaller hydraulic servo brake.





10" ATWOOD UNI-SERVO BRAKE




SHOE RETURN SPRINGS
WHEEL CYLINDER
SHOE AND LINING
ADJUSTER SPRING
ADJUSTER
SHOE HOLD-DOWN SPRING

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