TODAY'S TECHNICIAN™

AUTOMOTIVE BRAKE SYSTEMS

5TH EDITION CLASSROOM MANUAL

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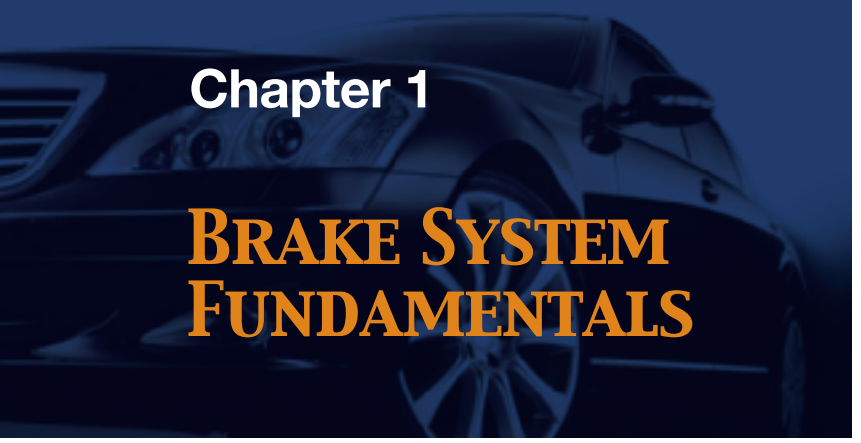

Chapter 1

Brake System Fundamentals

Upon completion and review of this chapter, you should be able to:

- List and describe the operation of the basic parts of a brake system.
- Describe the operation of the brake system during and after pedal application.
- Discuss the increasing use of disc brakes instead of drum brakes.
- Describe a typical brake hydraulic system.
- Describe the use of valves and lines to direct and control the hydraulic fluid.
- Discuss the purpose of brake power boosters and the parking brake.
- Discuss the general operation of electronic and active braking systems.
- Discuss the general operation of trailer brakes and air brakes.

Introduction

The brake system is one of the most important systems on a vehicle. It has four basic functions:

1. It must slow a moving vehicle.
2. It must bring a vehicle to a stop.
3. It must hold a vehicle stationary when stopped.
4. It allows directional control during maximum braking.

If the brake system does not operate properly, the driver and passengers could be injured or killed in an accident. Technicians who service the brake system must be highly skilled experts because the work they do can save lives. In this chapter, we start our study of the brake system by presenting the basic concepts and parts of all brake systems.

This chapter also highlights some of the dynamics associated with braking and controlling a vehicle. If all of the various dynamics are not considered during the design stage, most braking systems will under brake or over brake. When the brake system is not designed or operating correctly, it will be up to the driver to compensate, usually with poor results. In many cases, the human response is either too slow or too quick to react to a braking situation. In both cases, a loss of vehicle control is probably unavoidable.

Brake System Overview

The complete brake system consists of the major components shown in Figure 1-1. The complete brake system can be divided into the **service brakes**, which slow and stop the moving vehicle, and the **parking brakes**, which hold the vehicle stationary. On most late-model vehicles, the antilock brake system (ABS) is a third major subsystem; and many cars now also include traction control as part of the brake system functions.

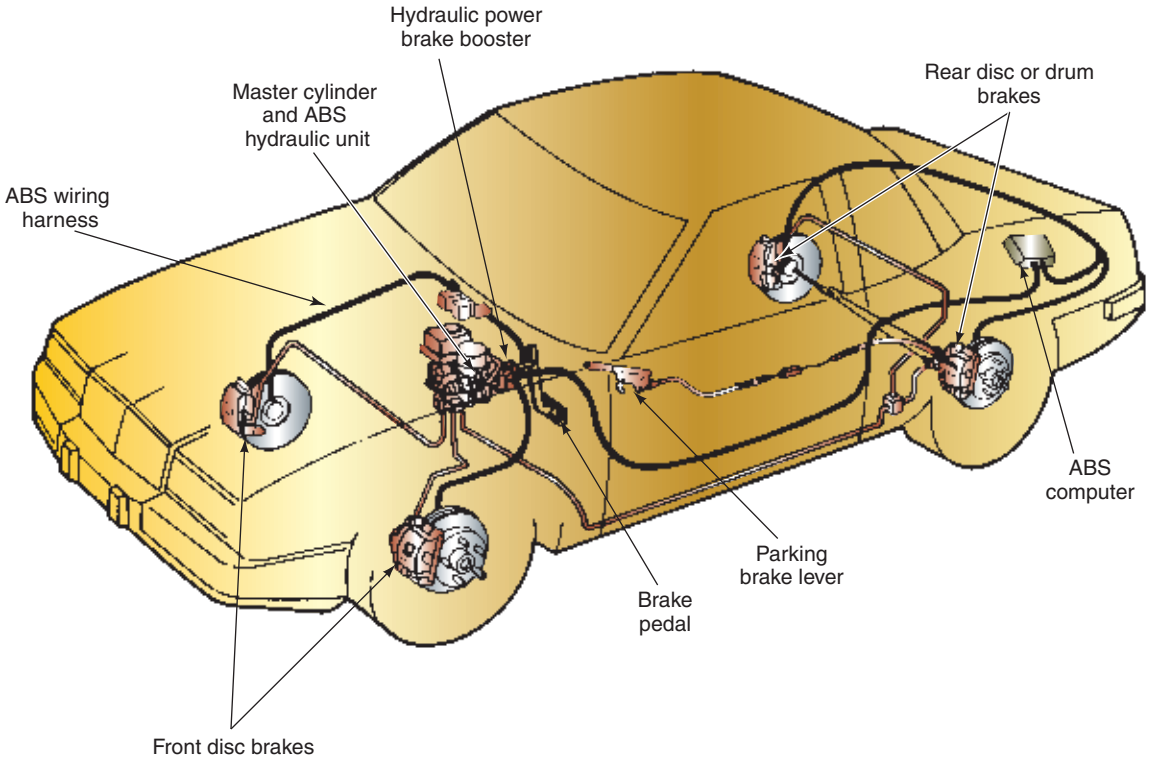

FIGURE 1-1 **A typical automotive brake system comprises these major components and subsystems.**

Leverage and the Brake Pedal Design

AUTHOR'S NOTE: A fulcrum is the point at which one lever pivots or sits to apply force to another lever or device. A seesaw pivots on a fulcrum.

Braking action on an automobile begins with the driver's foot on the brake pedal. The driver applies **force** to the pedal (which we learn more about later), and the pedal transfers that force to the master cylinder pistons. The brake pedal also multiplies the force of the driver's foot through leverage.

The brake pedal is mounted on a lever with a pivot near the top of the lever. The movement of the pedal causes a pushrod to move against a master cylinder. The master cylinder is mounted inside the engine compartment on the rear **bulkhead**. The master cylinder is a hydraulic pump that is operated by the driver through the brake pedal.

The **bulkhead** may be referred to as the firewall.

Most brake pedal installations are an example of what is called a second-class lever. In the science of physics, a second-class lever has a pivot point (or **fulcrum**) at one end and force applied to the other end. A second-class lever transfers the output force in the same direction as the input force, and multiplies the input force, depending on where the output load is placed. The brake pedal installation shown in Figure 1-2 has a 10-inch lever, and the load (the master cylinder pushrod) is 2 inches from the fulcrum (8 inches from the pedal). The pedal ratio, or the force multiplying factor, is the length of the lever divided by the distance of the load from the fulcrum. In this case, it is:

$$\frac{10}{2} = 5{:}1$$

If the driver applies 50 pounds of force to the pedal, the lever increases the force to 250 pounds at the master cylinder. When the driver applies 50 pounds of input force, the pedal may travel about 2.5 inches. When the lever applies 250 pounds of output force, the

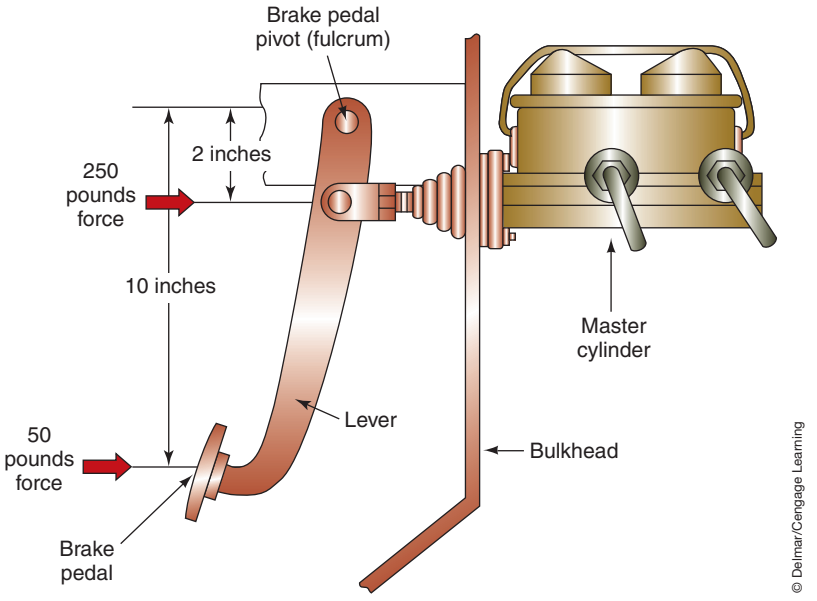

FIGURE 1-2 **The brake pedal assembly uses leverage to increase force applied to the master cylinder.**

pushrod moves only 0.5 inch. Thus, as **leverage** in a second-class lever increases force, it reduces distance by the same factor:

$$\frac{2.5 \text{ inches}}{5} = 0.5 \text{ inch}$$

Leverage is the use of a lever and fulcrum to create a mechanical advantage, usually to increase force applied to an object.

Service Brake History and Design

Modern automobile brakes evolved from the relatively crude brakes of horse-drawn vehicles. The earliest motor vehicle brakes were pads or blocks applied by levers and linkage to the outside of a solid tire on a wooden-spoked wheel. The same principles of leverage that work in modern brake pedal installations increased the force of the brake pad applied to the solid tire. These brakes worked well with speeds of 10 mph to 20 mph and little traffic. Higher performance (30 mph and beyond) and pneumatic tires meant that early wagon brakes were short-lived on automobiles.

By the end of the first decade of the twentieth century, automobiles were using either external-contracting band brakes or internal-expanding drum brakes. A few internal-expanding band brakes were tried on some early motor vehicles. External-contracting brakes have a band lined with **friction** material wrapped around a drum located on the driveline or on the wheels. The band is anchored at one end or at the center; levers and linkage tighten the band around the drum for braking force. The service brakes on Ford's famous Model T were a single contracting band applied to a drum inside the transmission.

Friction is the force that resists motion between the surfaces of two objects or forms of matter.

Band brakes, either internal or external, lose their effectiveness when higher braking force is needed. When you study **drum brakes**, you will learn about the mechanical servo action of brake shoes. It is very difficult to develop servo action with an internal band brake, and higher brake force is thus needed. Servo action on an external band brake tends to make the brake grab at high brake forces and high drum speed. Other problems associated with band brakes included dirt and water damage and loss of friction with external bands and the tendency of these brakes to lock if the drum overheated and expanded too much. Internal band brakes also suffered from band and drum overheating and reduced braking force.

A **drum brake** is a brake in which friction is generated by brake shoes rubbing against the inside surface of a brake drum attached to the wheel.

As drum brakes evolved, internal-expanding shoe-and-drum brakes became the standard. External-contracting band brakes were used as parking brakes until the late 1950s, but their days as service brakes were over by the late 1920s.

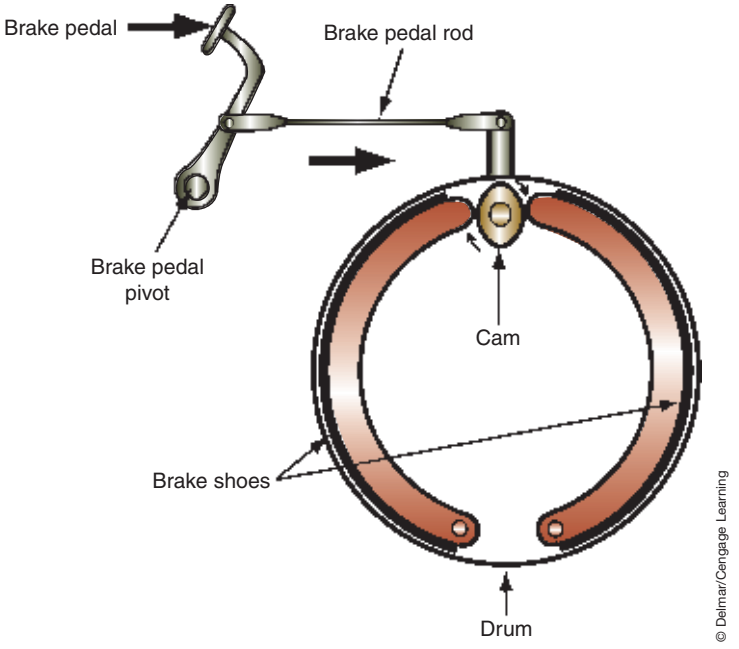

FIGURE 1-3 **Simple mechanical drum brake.**

Drum Brakes. By the mid-1920s, drum brakes with internal-expanding shoes were the general rule. Early drum brakes were operated mechanically by levers and linkage (Figure 1-3). Expensive luxury cars such as the 1921 Duesenberg Model A were among the first to have hydraulic drum brakes. Hydraulic brakes started to appear on lower-priced cars in the mid-1920s with Chrysler's Light Six, which became the Plymouth. Ford Motor Company, however, used mechanical brakes through the 1938 model year.

AUTHOR'S NOTE: There were two major reasons for the increased use of hydraulic-applied brakes over the mechanically-applied ones: 1) The four brakes never seem to apply the same amount of braking force at the same time because 2) the brake linkages required almost constant re-adjustment to make the brake work at all.

The rigid brake shoes used with drum brakes could be made stronger than the flexible bands of earlier brake designs. This eliminated breakage problems that occurred with greater braking forces that were required as automobiles got more powerful and faster. With hydraulic actuation, four-wheel drum brakes remained the standard braking system for most cars into the middle and late 1960s. With the coming of Federal Motor Vehicle Safety Standards (FMVSS) 105 in 1967, brake systems had to pass specific performance tests that made front disc brakes the general rule in the 1970s. Even at the beginning of the twenty-first century, however, drum brakes are still used on the rear wheels of many cars and light trucks.

AUTHOR'S NOTE: The larger the vehicle, the more likely it is to have drum brakes on the rear axles. Over-the-road trucks (semis) have drum on the trailer axles, usually drums on the tractor's drive axles, and about a 50/50 split between drums and discs on the steering axles.

Disc Brakes. Modern automotive **disc brakes** were developed from aircraft brakes of World War II. Known originally as "spot" brakes, disc brakes work by applying pressure to two brake pads on opposite sides of a spinning rotor attached to the wheel hub (Figure 1-4).

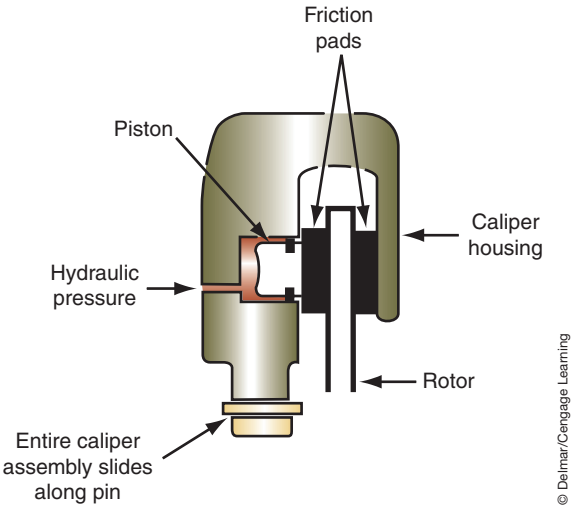

FIGURE 1-4 **Hydraulic pressure in the caliper forces the disc brake pads against the spinning motor.**

A **caliper** is a major component of a disc brake system that houses the piston(s) and supports the brake pads.

Disc brake pads are mounted in a **caliper** that sits above the spinning rotor. The caliper is either fixed or movable on its mounting. With a fixed caliper, hydraulic pressure is applied to pistons on both sides to force the pads against the rotor (Figure 1-5). With a movable caliper, pressure is applied to a piston on the inboard side only. This forces the inboard pad against the rotor, and the reaction force moves the outboard side of the caliper inward so that both pads grip the rotor (Figure 1-6).

All the friction components of a disc brake are exposed to the airstream, which helps to cool the brake parts and maintain braking effectiveness during repeated hard stops from high speeds. This, in turn, leads to longer pad life and faster recovery from brake fade. Disc brakes do not develop the mechanical servo action that you will learn about as you study drum brakes. Therefore, disc brakes require higher hydraulic pressure and greater force to achieve the same stopping power as a comparable drum brake. These pressure and force requirements for disc brakes are met easily, however, with large caliper pistons and power brake boosters. Because their advantages far outweigh any disadvantage, disc brakes have become the universal choice as the front brakes on all cars and light trucks built since the 1970s. Additionally, four-wheel disc brakes became standard equipment on high-performance automobiles, SUVs, and some light trucks.

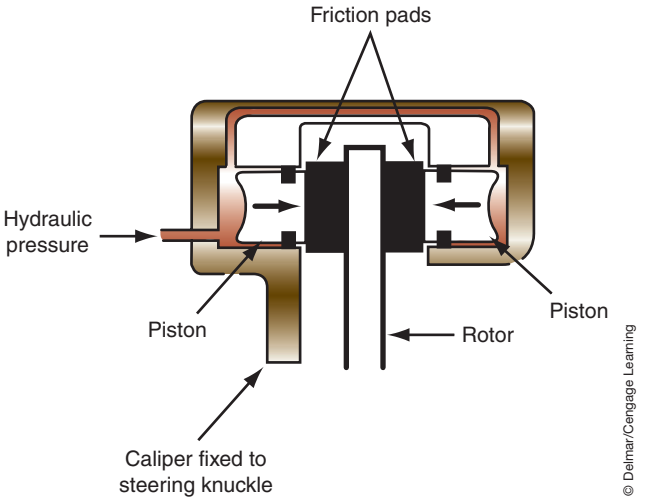

FIGURE 1-5 **Hydraulic pressure is applied equally to pistons on both sides of a fixed caliper.**

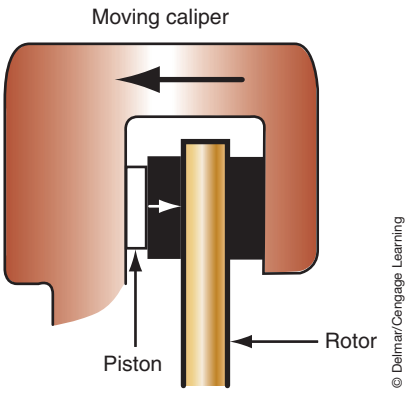

FIGURE 1-6 **Hydraulic pressure in a movable caliper forces the piston in one direction and the caliper body in the other. The reuslting action and reaction force the pads against the rotor.**

A Bit of History

Hydraulic brakes were invented in 1918 in the California shop of Malcolm Loughead. He later changed the spelling of his name to Lockheed, and he and his brother founded the aircraft company of that name. The Lockheed hydraulic brake first appeared on the 1921 Duesenberg Model A.

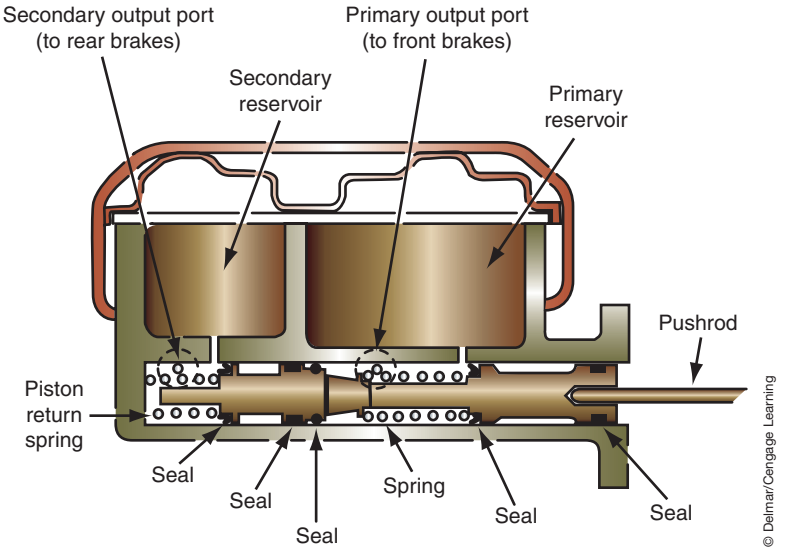

FIGURE 1-7 **The master cylinder is a cylindrical pump with two pistons that develop pressure in the hydraulic lines to the front and rear brakes.**

Brake Hydraulic Systems

The **master cylinder** is the liquid-filled cylinder in the hydraulic brake system or clutch in which hydraulic pressure is developed when the driver depresses a foot pedal.

Hydraulic operation of service brakes has been the universal design for more than 60 years. The complete hydraulic system consists of the **master cylinder**, steel lines, rubber hoses, various pressure-control valves, and brake apply devices at each wheel.

Master Cylinder. The master cylinder is the start of the brake hydraulic system. It actually is a cylindrical pump. The cylinder is sealed at one end, and the movable pushrod extends from the other end (Figure 1-7). The pushrod moves a pair of in-line pistons that produce the pumping action. When the brake pedal lever moves the pushrod, it moves the pistons to draw fluid from a reservoir on top of the master cylinder. Piston action then forces the fluid under **pressure** through outlet ports to the brake lines.

Pressure is the force exerted on a given unit of surface area—force divided by area—measured in pounds per square inch (psi) or kilopascals (kPa).

All master cylinders for vehicles built since 1967 have two pistons and pumping chambers as shown in Figure 1-7. Motor vehicle safety standards require this dual-brake system to provide hydraulic system operation in case one hose, line, or wheel brake assembly loses fluid. Because the brake hydraulic system is sealed, all the lines and cylinders are full of fluid at all times. When the master cylinder develops system pressure, the amount of fluid moved is only a few ounces.

Split Systems. Modern-day vehicles have split brake systems. The pre-1970s vehicle had a single hydraulic system serving all four wheels. A leak anywhere in the system resulted in a complete braking failure. The split system was designed to prevent a total system failure. This required the use of a dual-piston master cylinder and the inclusion of various valves. A split system is fed by one piston in the master cylinder and feeds two wheel brakes of the vehicle. There are two types of split systems: diagonal and front/rear. The diagonal has one system feeding a front-wheel brake and the rear, opposing-side wheel brake, that is, left front and right rear (Figure 1-8). The second diagonal split is to the other wheel brakes. The front/rear split is exactly as it sounds. One side or split feeds the rear-wheel brakes and the other feeds the front wheels (Figure 1-9). Both types of split have advantages and disadvantages, but each prevents complete system failure from a single leak.

Brake Lines and Hoses. The rigid lines or pipes of a brake hydraulic system are made of steel tubing for system safety. Flexible rubber hoses connect the wheel brakes to the rigid

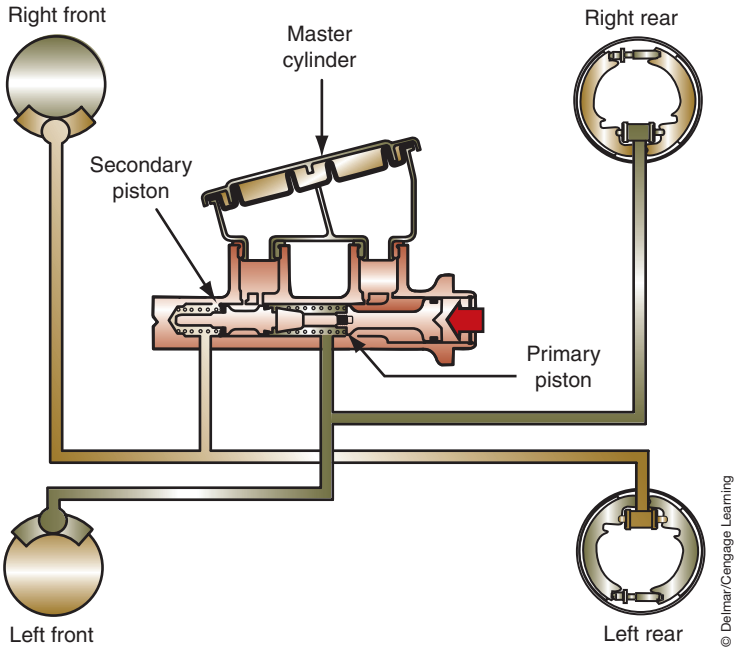

FIGURE 1-8 **Each master cylinder piston feeds one system of a split hydraulic brake system. Shown is a diagonally split system.**

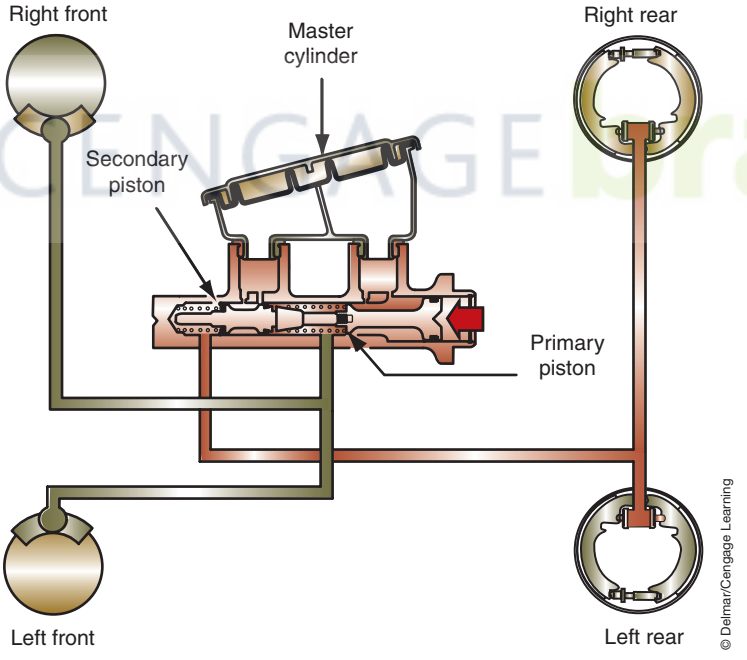

FIGURE 1-9 **A front/rear split system.**

lines on the vehicle body or frame (Figure 1-10). The front brakes have a rubber hose at each wheel to allow for steering movement. Rear brakes may have separate hoses at each wheel or a single hose connected to a line on the body or frame if the vehicle has a rigid rear axle. Brake lines and hoses contain the high-pressure fluid, and the fluid acts as a solid rod to transmit force to the wheel cylinders and caliper pistons.

Pressure Control Valves. Almost all brake hydraulic systems built since 1967 have one or more valves to control system pressure. Metering and proportioning valves modulate hydraulic pressure to front disc or rear drum brakes to provide smooth brake application and

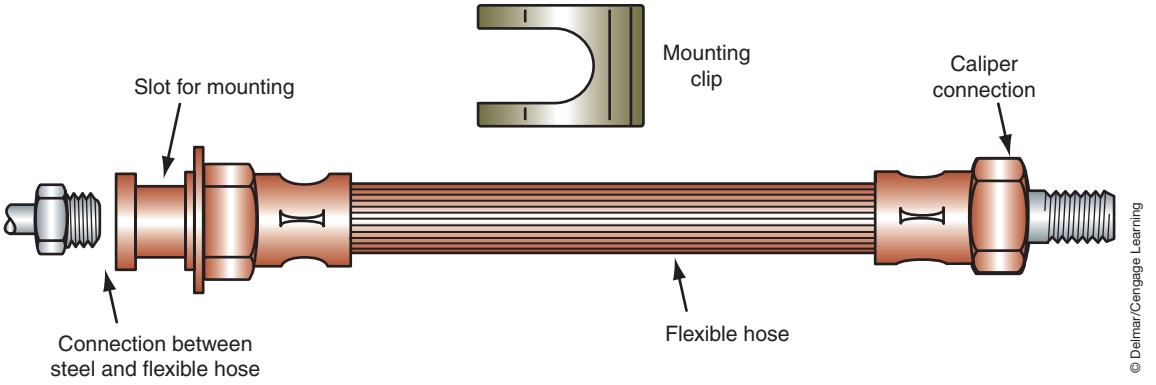

FIGURE 1-10 **A flexible hose provides a connection between the vehicle's rigid frame and the movement of the wheel and suspension assemblies.**

An **antilock brake system (ABS)** is a service brake system that modulates hydraulic pressure to one or more wheels as needed to keep those wheels from locking during braking.

reduce the tendency to lock the brakes. A pressure differential switch is a type of valve used in most systems to turn on the instrument panel warning lamp if half of the hydraulic system loses pressure.

The hydraulic system may have several individual valves or a single combination valve with multiple functions (Figure 1-11). Details on pressure control valves are in subsequent chapters.

Although pressure control valves have been part of brake systems for more than 60 years, **antilock brake systems (ABSs)** may make some valves obsolete. An ABS electronic control module can modulate hydraulic pressure for normal braking better than metering and proportioning valves can. As ABS installations become more widespread, some older hydraulic functions may be given over to the electronic computer.

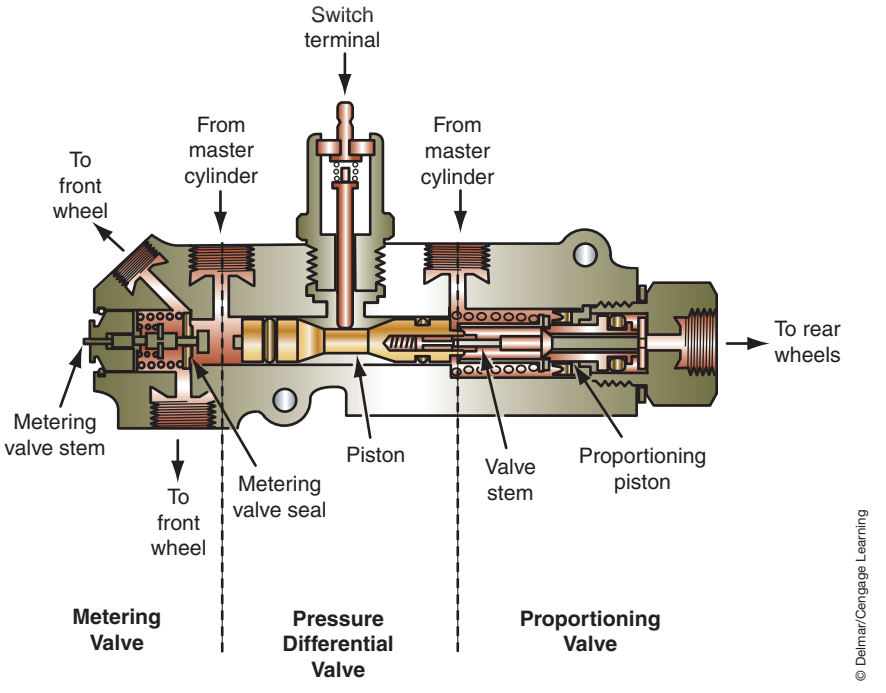

FIGURE 1-11 **This combination valve performs three hydraulic functions and switches on the brake warning light within a single housing.**

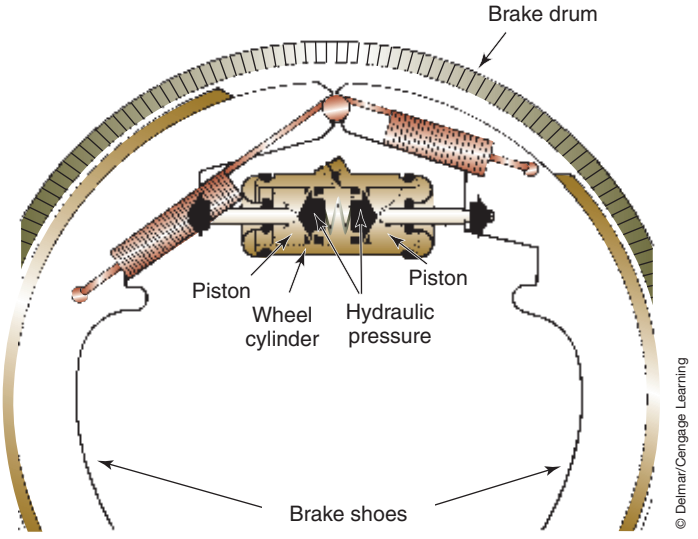

FIGURE 1-12 **Hydraulic pressure in the wheel cylinder moves the two pistons outward to force the shoes against the drum.**

The increasing use of four-wheel disc brake systems instead of the front disc/rear drum systems has also reduced the need for some brake valves.

Wheel Cylinders and Caliper Pistons. Technically, the **wheel cylinders** of drum brakes and the caliper pistons of disc brakes are "slave" cylinders because they operate in response to the master cylinder. These hydraulic cylinders at the wheels change hydraulic pressure back into mechanical force to apply the brakes.

A **wheel cylinder** is the hydraulic slave cylinder mounted on the backing plate of a drum brake assembly.

Most late-model systems with drum brakes have a single, two-piston cylinder at each wheel (Figure 1-12). Hydraulic pressure enters the cylinder between the two pistons and forces them outward to act on the brake shoes. As the shoes move outward, the lining contacts the drums to stop the car. Wheel cylinder construction and operation of drum brakes are covered in Chapter 8 of this manual.

The caliper pistons for disc brakes also act in response to hydraulic pressure that enters a fluid chamber in the caliper. Hydraulic pressure in a stationary caliper is applied to one or two pistons on each side of the caliper to force the pads against the rotor as shown in Figure 1-5. Pressure is applied to a single piston in a movable caliper on the inboard side to force the inboard pad against the rotor. As explained later in Chapter 2, hydraulic pressure is equal in all directions in a sealed chamber. This equal pressure creates a reaction force that moves the outboard side of the caliper inward so that both pads grip the rotor as shown in Figure 1-6. More details about caliper construction and operation of disc brakes are found in Chapter 7 of this manual.

Power Boosters

Almost all late-model brake systems have a power booster that increases the force of the driver's foot on the pedal (Figure 1-13). Most cars and light trucks use a vacuum booster that uses the combined effects of engine vacuum and atmospheric pressure to increase pedal force. Some vehicles have a hydraulic power booster that may be separate from the brake system and supplied with fluid by the power steering system, or may be a part of the brake system and driven by an electric motor. Chapter 6 in this *Classroom Manual* explains power boosters in detail.

FIGURE 1-13 **The power brake booster increases the brake pedal force applied to the master cylinder.**

Parking Brakes

After the service brakes stop the moving car, the parking brakes help to hold it stationary. Parking brakes are often mistakenly called "emergency" brakes, but their purpose is not to stop the vehicle in an emergency. The amount of potential stopping power available from parking brakes is much less than from the service brakes. Because the parking brakes work on only two wheels or on the driveline, much less friction surface is available for braking energy. In the rare case of total hydraulic failure, the parking brakes can be used to stop a moving vehicle, but their application requires careful attention and skill to keep the vehicle from skidding or spinning.

Electronic Braking Systems

ABS. Electronic braking covers all systems from antilock brake systems (ABSs) and **Traction Control Systems** (TCSs up to and including **Vehicle Stability Systems** [VSSs]). While there are different terms used by the various manufacturers for the same operation, all operate with electronic sensors and actuators with little or no input from the vehicle operator. Some systems like VSS are in the second and third stage of development and application but all of the ones discussed in this text will soon be offered as standard equipment on most vehicles. They will only become more complex and more common over the next several years.

Lockup or **negative wheel slip** is a condition in which a wheel stops rotating and skids on the road surface.

Whenever the brakes are applied with heavy pressure, the wheel may totally stop rotating. This condition is called wheel **lockup** or **negative wheel slip**, which does not help the car stop. Rather, the tire loses some frictional contact with the road and slides or skids. As the tires slide, the car is no longer stopping under control and the driver is in a dangerous situation. Experienced drivers try to prevent wheel lockup by pumping the brake pedal up and down rapidly. This stops and starts hydraulic pressure to the brakes and gives the driver control during hard braking.

Most late-model cars have an ABS. The ABS does the same thing as an experienced driver would, only it does it faster and more precisely. It senses when a wheel is about to lock up or skid. It then rapidly interrupts the braking pressure to the brakes at that wheel. Speed sensors at the wheels monitor the speed of the wheels and send this information to an on-board computer. The computer then directs the ABS unit to pulse the pressure going to the wheel that is starting to lock up.

Active Braking

Mass-produced **active braking** systems were first introduced by Ford in 1999. In the context here, "active" means the brake system will perform some functions without input from the operator. The ABS could be considered as the first active braking system, but it functioned only if the driver had applied the brakes and certain conditions, such as wheel skid, were present. The active braking systems of today take it one step further. The active braking system works with components from the ABS, traction control system (TCS), **electronic steering** and **automatic ride control (ARC)**. Most of those components are **wheel speed sensors**, **yaw** sensors, **actuators**, and the shared wiring. Each of the systems listed normally has its own controller or computer module. Before going further, it is best to understand what each of the noted systems does.

Wheel speed sensors are mounted at selected (or all) wheels to monitor wheel speed during vehicle operation.

The TCS controls wheel spin or **positive wheel spin** during hard acceleration or slippery road conditions. This is accomplished by shifting the power from a "spinning" drive wheel to a wheel with more traction or by reducing engine power. Shared components among active braking, ABS, and TCS are the wheel speed sensors and hydraulic modulator. TCS is an outgrowth of the ABS.

Yaw is the deviation in the line of travel commonly referred to as roll or lean during cornering.

ARC is an electronic suspension system designed to provide a more comfortable ride to the passengers and allow better control of the vehicle during cornering. To some extent it can command reduced engine power, thereby slowing the vehicle. The major component shared between ARC and active braking is the yaw sensor.

Active braking systems take the data from shared components, perform certain calculations, and apply the brakes to one or several wheels without any driver input at all. This, in effect, can help control the vehicle during some cornering and steering situations. It can be expected that, as electronic steering systems become more available, more cooperation between systems will increase and active braking will be more enhanced. There are more details on active braking in Chapter 10.

Trailer Brakes

Normally a textbook of this type does not deal with trailer brakes. However, with the advent of active braking systems and the increasing sales and usage of ¾- and 1-ton pickups, it is important that some information be provided. Consult local and state laws for specific requirements.

Older trucks used to tow trailers heavy enough to warrant a brake system always used an add-on system. This system was not efficient in some cases, and its efficiency in many cases was based on "you got what you paid for." If the trailer was lightly loaded or the road was slick, the trailer brakes could lock and the trailer would probably jack-knife. Heavy trucks over 1 ton did have a trailer brake system that was either "hard-wired" at the factory or at least had to meet stringent Department of Transportation (DOT) standards. The newest ¾- and 1-ton truck models offer a factory-installed trailer brake system. This system borrows from the ABS and active braking systems. Trailer brake systems are usually divided into two types: hydraulic surge and electric.

Hydraulic Surge

A hydraulic surge brake system is completely mounted on the trailer. It may be a disc or drum type and operates hydraulically and mechanically in a very similar manner to the drum brakes on the tow vehicle. There is a pressure differential valve mounted somewhere in the tow vehicle's rear brake system, usually at or near the vehicle's master cylinder. This valve operates so the pressure supplied to the trailer's master cylinder is in direct proportion to the pressure being directed to the tow vehicle's rear brake. The valve works very similarly to the regular proportioning valve found on almost every roadworthy vehicle. The pressure delivered to the trailer's master cylinder applies a mechanical pushrod, which, in turn, creates the correct pressure to apply the trailer brake. Trailer drum brakes may be uniservo with

FIGURE 1-14 **This is a typical add-on trailer brake controller.**

one wheel cylinder and one pushrod or duo servo with one wheel cylinder and two pushrods. The uniservo type is the most common because of cost. The disc-brake type operates almost exactly like the disc brakes on a standard vehicle.

Electric Brakes

Electric trailer brakes are most commonly used on utility and RV units, whereas boat trailers or others that are designed to be submerged underwater use the hydraulic surge. This is because water severely shortens the life expectation of electric brake components.

A trailer electric brake system requires a brake controller mounted in the tow vehicle within hand control of the vehicle driver. It is usually mounted on the dash near the steering column (Figure 1-14). The driver may reduce or increase the power of the trailer brakes or lock them down as a kind of parking brake. The controller is not readily switched between different tow vehicles, so each tow unit must be equipped with its own controller. There are three types of controllers, but each performs basically the same function. For detailed information on the controllers and troubleshooting trailer brakes, investigate Champion Trailers at its Web site at http://www.championtrailers.com/techsup.html. The regulated electric power from the controller is sent to magnets within the wheel drum. The energized magnets are pulled toward a specially machined flat surface of the drum. As the magnets move, they, in turn, move a lever(s) attached to the brake shoe. The brake shoe is applied against the rotating drum in direct proportion to the braking action of the rear brakes of the tow vehicle.

Trailer Breakaway Condition

The DOT requires that any trailer with its own braking system have a method to apply its brakes in case the trailer disconnects from its tow vehicle. On an electric system, an emergency power battery is mounted on the trailer. If a breakaway condition occurs, the pull pin at the trailer/vehicle hitch is pulled loose, triggering a switch that connects the full power of the emergency battery to the wheel magnets. This effectively locks the wheels. The hydraulic surge system uses a slightly different method to accomplish the same result. A chain or cable runs from the tow vehicle to a lever positioned to apply force to the piston in the trailer's master cylinder. When a disconnect situation occurs, the lever is moved by the chain/cable

and applies the trailer brakes. In either case, both breakaway systems may be used as parking brakes when the trailer is stored or being loaded/unloaded.

Reverse Braking

Trailer brakes do not recognize reverse braking from forward braking. Usually it is best if the trailer does not have braking during reverse operation. To prevent this, the hydraulic surge brake may be standard or free backing (Figure 1-15). The standard type requires a reversing solenoid that is triggered when the tow vehicle backup lights are activated (Figure 1-16). The solenoid is plumbed into the system at the outlet of the trailer's master cylinder. With the solenoid energized, pressurized fluid from the master cylinder is blocked from the wheels and is directed back into the master cylinder's reservoir. Free backing operation recognizes that the wheels are rotating backward and deactivates the brakes. The brake system reactivates when the wheels rotate forward. This is the system of choice for most trailers because it can be manufactured into the system. It should be noted that disc brakes on trailers must have a free backing (reversing) solenoid. Electric brake systems use only a reverse solenoid to prevent the trailer brakes from functioning in reverse. The solenoid is triggered by the backup lights circuit.

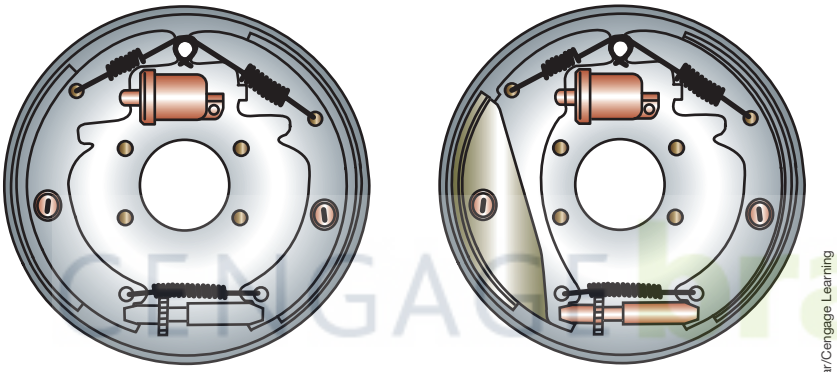

FIGURE 1-15 **The free backing brake on the right recognizes reverse movement and the brake cannot be applied.**

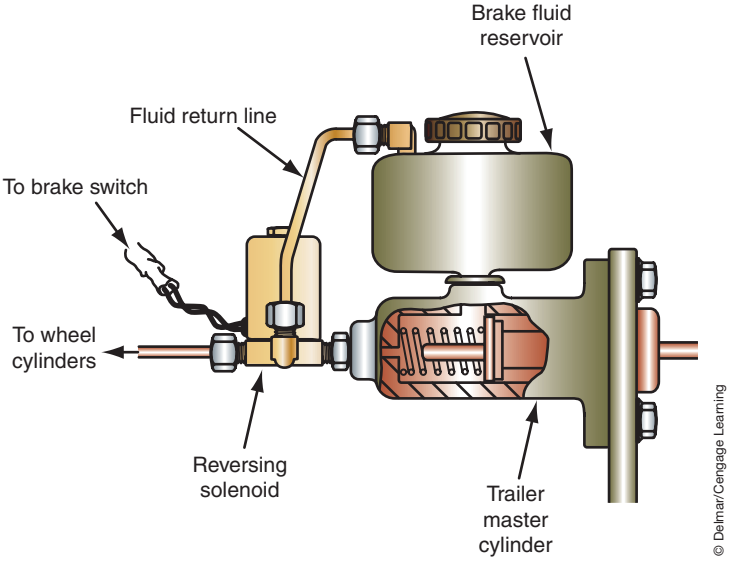

FIGURE 1-16 **The reversing solenoid is needed with the standard brakes in Figure 1-15 to prevent braking in reverse.**

AUTHOR'S NOTE: Technicians or do-it-yourselfers can get into difficulties if they do not understand how to connect an add-on trailer brake system. Also, if the add-on system is on the less expensive side, the rule "you get what you pay for" applies. There are some add-on units that meet DOT standards but have no leeway if the trailer is loaded or too heavy for the brake system.

AUTHOR'S NOTE: Go to http://www.ford.com for information on one of the first production factory-installed trailer brake systems.

Before installing an add-on system, read the specifications carefully and talk to the customer about the weight and number of axles on the trailer. On multiple-axle trailers, braking components may be installed at each wheel or only on one axle. The total weight of the loaded trailer, not just the payload of one axle, must be considered when selecting the capacity of the braking system.

AUTHOR'S NOTE: I bought a used 1999 Dodge Dakota in 2000 at very low cost. The tailgate and fender were crushed in on the left side. Because I am curious (and cheap), I convinced the salesperson to get me in contact with the previous owner. The owner had bought the Dakota because it pulled his 32-foot cabin cruiser easily on the road and was reasonable on fuel. However, one day he had to make an emergency downhill stop on the way to the boat ramp. Because the boat and trailer were too much for the little truck, the trailer lifted the back of the truck. The ABS on the truck was working, but there was no ABS on the trailer. In a classic example of lost friction, the boat and trailer tried to pass the truck. The boat made it to the truck's left rear fender before crushing a hole in its side and damaging the fender and tailgate. So the owner traded up to a Dodge B3500 with dual wheels and a Cummins diesel—one extreme to another. Moral of the story: If your customer is looking for a Dakota-size truck to pull the cabin cruiser, you would do well to brief him/her on the difference between towing power and stopping power.

Air Brakes

AUTHOR'S NOTE: This short section on air brakes is to give an overview to the reader should he or she end up working for a fleet or having to provide some type of emergency assistance to an air brake–equipped vehicle. Remember that more in-depth training will be required to provide air brake maintenance and repair. Air brake systems must comply with DOT requirements and inspection procedures.

Air brakes require at least 100 psi to operate correctly. This pressure is provided by a belt-driven air compressor, and the compressed air is held in one or two air reservoirs (tanks). A governor mounted on the compressor limits the amount of pressure to about 125 psi. The reservoirs and the brakes are connected via steel tubing to a manifold valve (foot valve) usually mounted on the engine side of the bulkhead. A three-way valve directs the air dependent on the action of the driver.

The wheel brake friction components, drum or disc, are actually applied by a spring-operated diaphragm within a brake chamber at each wheel. The diagrams are held off (brakes released) by air pressure on the brake side of the diaphragm. Slack adjusters are placed between the chamber pushrod and the S-cam in the wheel brake mechanism. Slack adjusters allow the operator or technician to adjust the brakes for wear and are one of the first items checked during a DOT inspection.

When the brakes are applied, some portion of the air pressure retaining the diaphragm is released and the spring pushes the diaphragm thereby moving the pushrod (Figure 1-17). The pushrod in turn rotates the S-cam and applies a proportional amount of movement to the brake shoes in relation to the amount of air released. A red button on the dash labeled PARK applies the parking brakes by releasing all of the air in all of the brake chambers. Anytime the vehicle is parked, the parking brakes should be engaged. On the steering column is a lever that allows the driver to apply only the trailer brakes from full lock to a moderated braking effect. The hissing noise commonly heard around air brake vehicles is from brakes being applied, parking brakes being applied, or a release of excess pressure from the air reservoirs.

When the tractor is attached to a trailer, two flexible air lines connect the tractor and trailer brakes. A tractor protection valve is located on the tractor to prevent a loss of

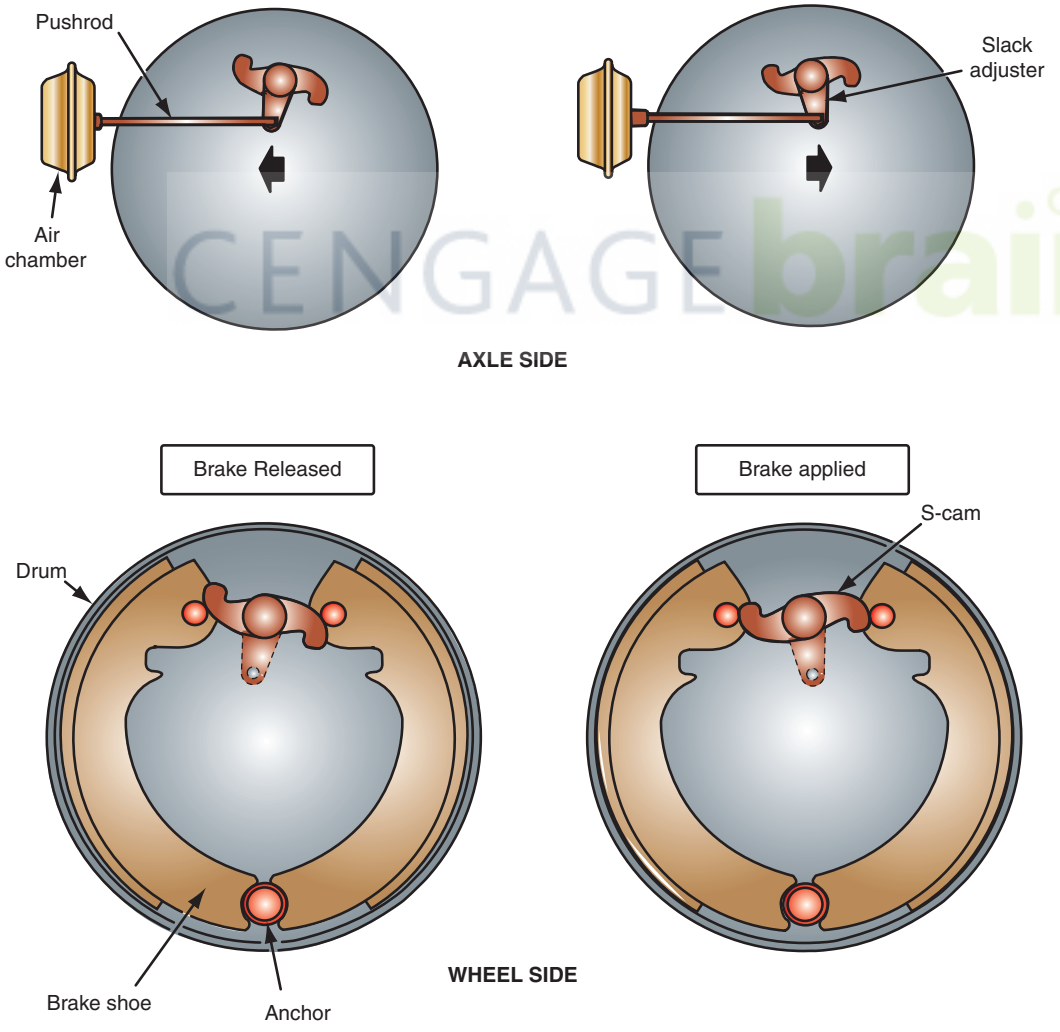

FIGURE 1-17 **The S-cam is rotated by actions of the air chamber. As the "S" turns, the wings of the "S" push the brake shoe outward.**

TERMS TO KNOW

Active brakes
Actuators
Air brakes
Ampere (A)

Terms to Know (continued)

Antilock brake system (ABS)
Automotive ride control (ARC)
Bulkhead
Caliper
Disc brake
Drum brake
Electronic steering
Force
Friction
Fulcrum
Leverage
Lockup
Master cylinder
Negative wheel slip
Parking brakes
Positive wheel spin
Pressure
Service brakes
Traction control system (TCS)
Vehicle stability system (VSS)
Wheel cylinder
Wheel speed sensors
Yaw

brakes on the tractor should the trailer brake system develops a leak or becomes disconnected. The lines extending from the tractor are self-sealing while the connections on the trailer side are not. When the hoses are disconnected, the trailer brakes lock down (park mode).

Since this overview does not provide sufficient information to become an air brake technician, there is still enough information for the average automotive technician to make a quick safety inspection. With the system fully charged at 100 psi or more, shut down the engine and perform a walk-around inspection. Any hissing sound at this time usually denotes an air leak and the leak can be traced by following the sound. At this point in your training, do not attempt a repair. Notify a trained heavy truck technician of your findings. If the air pressure does not reach 100 psi, there are several devices that can cause this problem and repairs are best left to a properly trained technician.

If more information on air brakes is desired, try http://www.youtube.com/watch?v=qJa5_ExsBE. It is an old U.S. Army black and white video dated 1967, but is actually one of the better explanations of how air brakes work.

Summary

- An automotive brake system consists of a master cylinder connected hydraulically through lines to disc and drum brake units that stop the wheels.
- A hydraulic or vacuum power assist is used on most cars to decrease the braking effort required from the driver.
- A mechanical brake, operated by levers and cables, is used for parking.
- Many cars have an ABS to improve brake operation during emergency stopping.
- Active braking systems may function with or without driver input.
- Active braking systems share components with the ABS, TCS, and ARC to provide better vehicle control and comfort.
- Trailer brakes may now be controlled or regulated by components similar to those used in active braking systems.
- Air brake systems use compressed air to control the movement of a diaphragm.
- Regardless of the type of braking system, mechanical/hydraulic or electronic, the final braking action occurs between the tire and the road.

Review Questions

Short-Answer Essays

1. List the main parts of a basic brake system and explain their purposes.
2. Discuss the general operation of drum brakes. Confine the answer to the components mounted at the wheel.
3. Discuss the operation of disc brakes. Confine the answer to the components mounted at the wheel.
4. Explain why a parking brake system is not viable for stopping a moving vehicle.
5. Explain the reasons for having a split brake system and the two types of split systems.
6. List some of the components shared among active braking systems, ABS, TCS, and ARC.
7. Explain the purpose of flexible hoses within the brake system.
8. Discuss the general interaction between a towing vehicle and its trailer brake.
9. Explain how the outboard disc brake pad is applied against the rotor with a typical movable caliper.
10. Explain why ABS is an important system in controlling a vehicle.

Fill in the Blanks

1. A brake system can have a _____ or _____ type of power assist.
2. An _____ prevents tires from skidding during braking.
3. The _____ _____ system is designed to hold the vehicle stationary.
4. On a 2:1 ratio, the driver's input of 75 pounds of force is boosted to _____ pounds of force.
5. During braking, the driver's input mechanical force is converted into _____ pressure by the master cylinder.
6. The lines of a brake system are primarily designed for _____ _____.
7. Brake valves are used to provide _____ _____ _____ and reduce wheel lockup.
8. Active braking systems share components with ABS, ARC, and _____.
9. Trailer brakes do not recognize _____ from forward braking.
10. A breakaway condition exists when the _____ from the tow vehicle.

Multiple Choice

1. Parking brake systems may share components with which of the listed brake systems?
   A. driveline brake
   B. disc brakes
   C. drum brakes
   D. both B and C
2. The brake pedal mechanism is
   A. always mounted from the top.
   B. a fulcrum.
   C. a lever.
   D. both A and B.
3. On a pedal mechanism with a 4:1 ratio, applying 250 pounds of force and moving the brake pedal 2 inches results in a pushrod movement of
   A. 8 inches.
   B. 0.5 inch.
   C. 0.25 inch.
   D. 2.5 inches.
4. Disc brake calipers may (are)
   A. be fixed on their mounts.
   B. be moveable on their mounts.
   C. mechanically activated.
   D. both A and B.
5. The typical mechanical components of a hydraulic brake system include
   A. pedal, master cylinder, wheel cylinders.
   B. pedal, disc calipers, control valves.
   C. brake shoes, brake pads, master cylinder.
   D. pedal, brake pads, brake drums.
6. The brake caliper
   A. sits above/over the rotor.
   B. is fixed with a single pad.
   C. uses a moveable caliper support.
   D. all of the above.
7. Split brake systems require
   A. dual-piston master cylinders.
   B. separate lines from the master cylinder to each wheel.
   C. control valves.
   D. both A and C.
8. An Active Brake System normally works with components of the
   A. ABS.
   B. TCS.
   C. ARC.
   D. all of the above.
9. The two electronic systems that may restrict engine performance are
   A. ABS and TCS.
   B. ABS and ARC.
   C. TCS and ARC.
   D. none of the above.
10. The major hydraulic components of a typical light vehicle brake system include
    A. master cylinder.
    B. wheel cylinder.
    C. valves.
    D. all of the above.

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Delmar
5 Maxwell Drive
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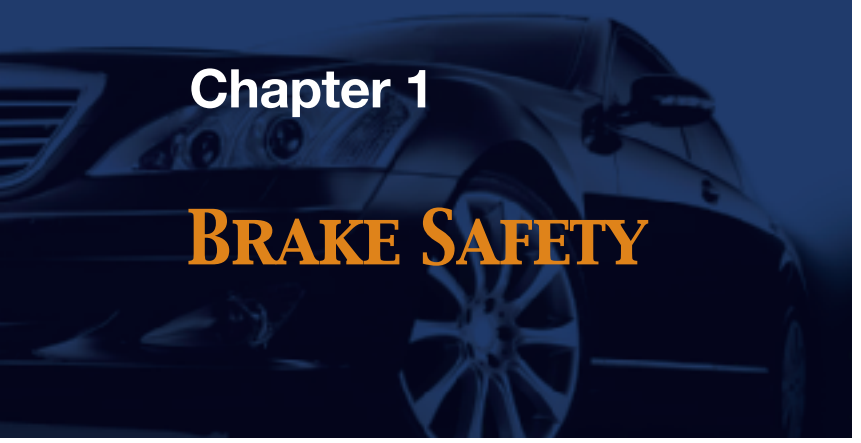


Chapter 1

Brake Safety

Upon completion and review of this chapter, you should be able to:

- Explain the need and methods for maintaining a safe working area.
- List and discuss some safety issues dealing with vehicle operation in the shop.
- Explain some of the commonsense rules for working with power equipment.
- Wear proper clothing and equipment in a shop.
- Explain the first-aid step to remove chemicals from the eyes.
- Explain the purpose for government regulations of brake performance and standards.
- List the safety requirements for working with brake fluid.
- Describe the hazards of asbestos materials.
- Explain the safety concerns with solvents and other chemicals.
- Explain the general functions of the safety and environmental agencies of the United States and Canada.
- Discuss the principles of hazardous communications.
- Discuss some of the safety concerns associated with antilock brake and air bag systems.
- Discuss technician training and certification.

Introduction

Personal protection from injury involves not only what the technician is wearing, but also making and keeping the work area safe. The twofold advantage here is if one technician is protecting himself by wearing personal protection equipment *and* keeping the shop clean and safe, then all the other employees or visitors stand a good chance of avoiding accidents or injury. This chapter discusses those practices and equipment that will provide overall and personal safety.

BASIC TOOLS

Safety glasses or goggles
Respirator
Vacuum with HEPA filter
Wet-clean system
Carbon monoxide vent system
Fire extinguisher(s)

Housekeeping

Good housekeeping is a safety issue. A cluttered shop is a dangerous shop. Each employee is responsible for keeping the work area and the rest of the shop clean and safe.

All surfaces must be kept clean, dry, and orderly. Any oil, coolant, or grease on the floor can cause slips that could result in injury. Use a commercial oil absorbent to clean up oil or brake fluid spills (Figure 1-1). Store dirty or oily rags in a sealed metal container to be disposed of properly. Keep all water off the floor; remember that water is a conductor of electricity. A serious shock hazard will result if a live wire falls into a puddle in which a person is standing.

FIGURE 1-1 **Use a commercial absorbent to soak up a spill.**

Some oil dry or absorbent compounds have to be treated as hazardous waste after being used. They should not be thrown in the trash bin.

When a vehicle is raised with a hand-operated jack, always set the car down on safety stands and remove the jack (Figure 1-2). Do not leave the jack handle sticking out from under the car where someone can trip over it.

Creepers also must be used and stored safely. When not in use, stand the creeper on end against a wall. Pushing it completely under the vehicle gets it out of the way, but it is easy to forget that it is there and drive over it after the job is completed.

Air hoses and power extension cords should be neatly coiled and hung. Do not leave a tangled mess in walkways or on the shop floor.

Keep all exits open. A blocked exit violates fire codes and leaves the shop liable to legal action if people become trapped in a fire or dangerous situation. Memorize the route to the nearest exit in case of a fire or hazardous material spill.

FIGURE 1-2 **Support a vehicle on safety stands such as these and move the jack out of the way.**

Vehicle Operation

WARNING: Use extra caution when moving a vehicle that requires brake repairs. The brakes may be poor or completely inoperative. Damage to the vehicle or shop or injury to yourself or others could result.

Test the brakes on the car to make sure they work before you start the engine. Push the car into the shop if it has a complete brake failure. After completing a brake repair and before moving the vehicle, always check the service brakes. There have been several small but embarrassing and expensive incidents where brakes were replaced but not seated. The first time the brakes were applied, there were no brakes.

Be very careful when driving a car in the shop. Be watchful of other workers or customers. Drive slowly and carefully, and get someone to act as a guide if visibility is blocked. Leave a window cranked down so instructions from someone can be heared outside the car.

Once the car is in the service area, place the automatic transmission shift lever in PARK. If the car has a manual transmission, put it in reverse gear with the engine off. Engage the parking brake by pulling the lever or setting the parking brake pedal.

The engine must often be operated in the shop to check for problems and to check your repairs. Several safety precautions should be followed when working on a running engine:

- Use wheel blocks to block the front and back of one of the wheels (Figure 1-3).
- Never get under a car when someone else is working on it or when the engine is running.
- Do not stand in front of or behind an automobile when the engine is running.
- Be careful of hot manifolds and moving engine parts if working under the hood.
- Many cars use electric cooling fans. Keep hands, tools, and test equipment clear of electric fans because they can start up at any time, even when the engine is not running.

Carbon Monoxide

Running an engine inside a shop can be very hazardous. Engine exhaust contains large amounts of **carbon monoxide**, a deadly gas that is odorless and colorless. Carbon monoxide poisoning begins with headaches and drowsiness. High exposure can lead to coma and death. Never run an engine in the shop without properly venting the exhaust fumes to the outside or to a dedicated ventilation system for exhaust gas (Figure 1-4) and make sure the ventilation system is working properly.

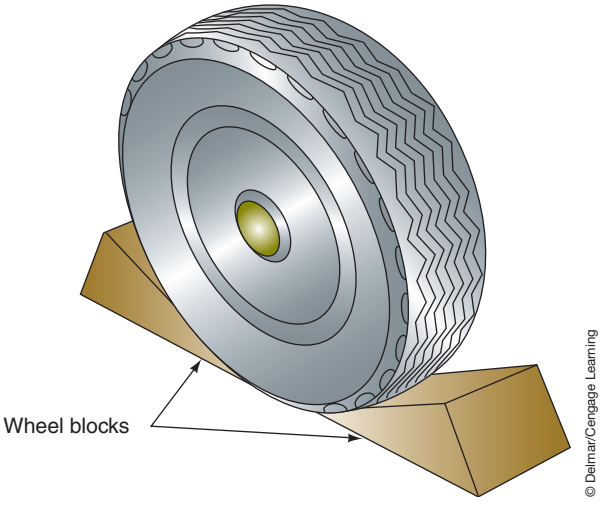


FIGURE 1-3 **Block at least one wheel both in front and behind before raising the other end of the vehicle.**

FIGURE 1-4 **When running an engine in a shop, always connect the exhaust to the ventilation system.**

CAUTION:
Do not use compressed air to clean brake components. Brake dust will be present and can be blown into the eyes, embedded into the skin, and, at least, will contaminate the surrounding air. Use only authorized low-pressure washers or vacuum-cleaner-type equipment.

Housekeeping and Brake Dust

There are special tools and equipment designed to be used to collect and contain brake dust. This special equipment is discussed in detail in Chapter 2 of this manual, but some common sense should always be used when working on and around vehicles undergoing brake service.

The first and probably most critical is to *never* use compressed air to blow dust from the braking components. This, obviously, moves and suspends the dust in the air. Use only the equipment or their equivalents listed in Chapter 3 to clean the brake components and surrounding area. A second commonsense rule is the wearing of safety glasses and gloves. As discussed earlier, brake fluid and cleaning solvents are hazardous materials and can cause injuries. If a vacuum cleaner is not available to clean the floor around the work area, mop the floor with water. When the mop is rinsed, the rinse water and the material it collects must be stored and treated as hazardous waste. This may seem to present some work problems, but like many things in the automotive repair business it must be done to protect the employees, the environment, and the community in general. Smokers or persons with some type of respiratory problems must be considered when dealing with brake dust. Even with so-called clean air, those individuals may suffer an extreme reaction to what we technicians consider everyday conditions. A technician should make every attempt to prevent the spread of brake dust while working on a vehicle.

Eye and Face Protection

The most frequent causes of eye injuries are flying objects, corrosive chemical splash, dangerous light rays, and poisonous gas or fumes. The most important point about eye injuries is that almost all of them are preventable.

WARNING: Grinds and cutting tools can be dangerous, even to a person not in the immediate area of the work. Ensure that the area is cleared of personnel as much as possible before metal-shaping work.

The best way to prevent eye injuries is to wear the correct type of eye protection (Figure 1-5). When you are performing jobs such as grinding metal, cutting metal, or driving a punch or chisel, the eyes are at risk from flying objects.

Occupational safety glasses (Figure 1-5) are the best protection against flying objects. These safety glasses are especially designed to provide the most protection. The glass or plastic lens provides maximum protection against an impact in the eye. The frames are constructed

FIGURE 1-5 **Occupational safety glasses provide protection from flying objects that ordinary eyeglasses do not.**

to prevent the lens from being pushed out of the frame during impact. They must have side shields to prevent objects from entering the eye from the side. They are available in prescriptions for people who need corrective lenses.

WARNING: Wear occupational safety glasses when working in the shop, especially when performing any grinding or cutting operations. Ordinary prescription dress glasses are made to standards that provide impact protection, but the impact protection and the frame strength of dress glasses are much lower than occupational safety glasses.

The face shield (Figure 1-6) provides protection for the entire face and is a good choice when the danger is from flying objects or splashing liquids.

Goggles can be used for nearly every type of eye hazard, and they can be used over ordinary dress glasses. Goggles have another advantage over occupational safety glasses because they fit against the head, which allows them to distribute an impact better. Clear-cover goggles provide protection against flying objects or liquid splash. Some goggles have vents and baffles on top to prevent harmful vapors or fumes from getting into the eyes. When using goggles, do not overtighten the straps. They need be only taut enough to hold the goggles in place. As with all other clothing, they have to be worn for a while to become adapted to their weight and viewing area. When taking off goggles or a face shield, close the eyes. Small

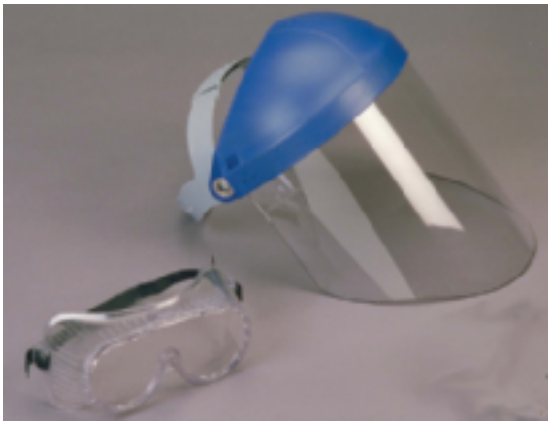


FIGURE 1-6 **A face shield protects your entire face.**

particles of sharp metal may have attached themselves to the outside of the goggles or face shield and may drop into the eyes.

Initial First Aid

Most shops and all schools require an accident report to be completed and filed.

Make sure the location and contents of the shop's first-aid kit is known. There should be eyewash solution or eyewash stations in the shop so the eyes can be rinsed thoroughly should hydraulic fluid, battery acid, asbestos dust, or other irritants in them (Figure 1-7). See Photo Sequence 1 for details. After eyewashing, seek medical attention. Find out if there is a resident nurse in the shop or at the school, and locate the nurse's office. If there are specific first-aid rules in the school or shop, find out what they are and abide by them. In a school, a report is required for any injuries to a student.

If someone is overcome by carbon monoxide, move the person to fresh air immediately. Rinse burns immediately in cold water or apply an ice pack. To stop bleeding from a deep cut or puncture wound, apply pressure on or around the wound and get medical help. Never move someone you suspect has broken bones or a back injury unless the person is in danger from another hazard such as fire or carbon monoxide gas. Call for medical assistance.

Hand Protection

Hands are one of the most frequently injured parts of the body. This fact is not surprising when you think of how often the hands are used doing automotive repair. There are two parts to protecting the hands. One is to keep hands out of dangerous areas. Rotating parts, such as the belts on the front of an engine, are hand danger areas. Make an effort to keep the hands out of those areas as much as possible.

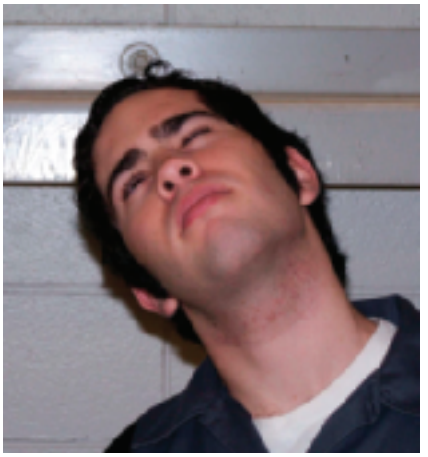
The second part of hand safety is to wear hand protection when necessary. Special protective gloves are available for many jobs that require hand protection. There are heavy work gloves for metal working, rubber gloves for electrical shock protection, and nitrile gloves for handling used oil, brake fluid, and chemicals such as those used to clean parts. Always use the correct type of glove for the hand hazards in the work area.

FIGURE 1-7 **An eyewash solution will flush contaminants from your eyes.**

USING EYE WASH

P1-1 **Remove the eyewash bottle from the wall holder. The injured person may require assistance.**

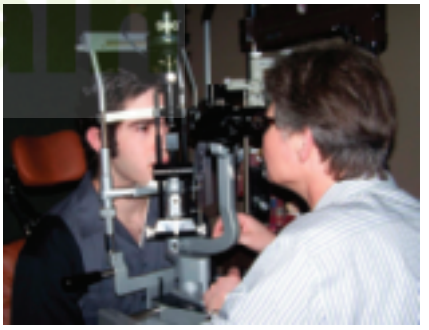
P1-2 **Open the bottle. Attempt not to touch the mouth of the bottle once it is opened. The injured person may require assistance.**



P1-3 **Tilt the head back and over so the injured eye is lower than the other eye.**

P1-4 **Pour the water so the flow goes from the nose bridge, over the eye, and down the cheek. Keep both eyes open and looking upward during the flushing. The injured person may require assistance.**

P1-5 **If necessary, cover the injured eye with a sterile dressing and seek medical assistance. If the eye is covered, it is recommended that someone guide/transport the person to the nearest medical resource. A person loses depth perception and some vision when an eye patch is first used.**



P1-6 **The injured eye should be examined by a medical technician for injuries that may not be immediately apparent.**

Do not wear a wristwatch or rings while working. Watches can get caught in rotating machinery. Rings can get caught in machinery or provide a path for an electrical shock. Long hair can get caught in rotating machinery. Many bad injuries have been caused by the hair pulling the face into a rotating part. Always tie up long hair or wear a hat over it.

Always wear safety shoes in the shop. Safety shoes have metal or fiberglass protection over the toe to prevent an injury if a heavy object falls on your foot. Safety shoes should at least have oil-resistant soles that grip slippery floors better than casual dress shoes.

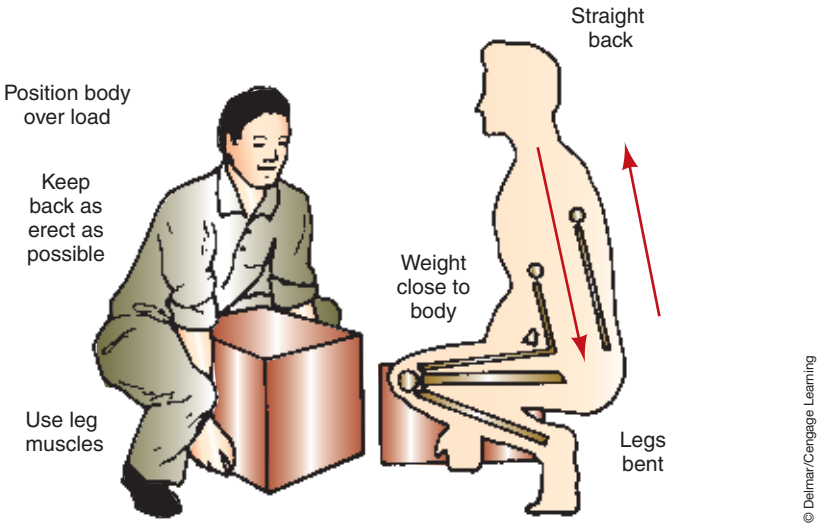


FIGURE 1-8 **Keep your back straight and bend your legs to lift heavy objects safely.**

Lifting and Carrying

If you lose control of a lifted object, do not attempt to catch it. Step back and let the object drop.

The back is one of the most often injured parts of the body. The most frequent kind of back injury at work is caused by improper lifting. Not all back injuries are caused by lifting too much weight but by lifting relatively small, light objects. The problem occurs while lifting the object and twisting the body or lifting when the load is unbalanced. Most back injuries can be prevented by following these ten simple rules:

1. Do not lift any heavy object by yourself. Get someone to share the load or get some equipment such as a chain hoist to do the lifting.
2. Study the load before you attempt to lift it. Use your head before you use your back.
3. Place your body close to the object as shown in Figure 1-8. Keep your legs close to the load and positioned for good balance.
4. Bend your legs, not your back.
5. Get a strong grip on the object with your hands.
6. Lift with your legs, keeping your back as straight as possible.
7. Keep the load close to your body as you lift it up.
8. Keep a tight grip on the object and do not try to change your grip while lifting.
9. Do not twist your body to change direction. Move your feet in the new direction.
10. When you are ready to set the load down, do not bend forward. Keep the load close to your body and lower it by bending your legs. When placing the object on a shelf, place the edge of the load on the surface of the shelf and slide it forward. When setting an object on the floor, lower it by bending your knees and keeping your back straight. Bending forward strains your back muscles.

Having the body out of position can lead to painful injury even if nothing is being lifted. The most common muscle sprain or injury happens when the person is lifting a small weight but the body is twisted off center.

Brake System Safety Regulations

In the United States, brake systems are regulated by Part 571 of the **Federal Motor Vehicle Safety Standards (FMVSS)**. These regulations are established and enforced by the U.S. **Department of Transportation (DOT)**. The standards that relate to brake systems are:

- FMVSS 105 Hydraulic Brake Systems
- FMVSS 106 Brake Hoses

- FMVSS 108 Lamps, Reflective Devices, and Associated Equipment
- FMVSS 116 Motor Vehicle Brake Fluids
- FMVSS 121 Air Brake Systems
- FMVSS 122 Motorcycle Brake Systems
- FMVSS 211 Wheel Nuts, Wheel Discs, and Hub Caps

Many U.S. states and Canadian provinces also have regulations that govern the brake's safety, condition, and operation. Several of the federal standards apply to specific components included in this text. General performance requirements for service brakes and parking brake systems are governed by FMVSS 105. This standard became effective in 1967, was revised significantly in 1976, and has undergone several smaller changes since then. FMVSS 105 spells out the "requirements for hydraulic service brake and associated parking brake systems to ensure safe braking performance under normal and emergency conditions … for passenger cars, multipurpose passenger vehicles, trucks, and buses with hydraulic service brakes."

FMVSS 105 does not prescribe the design of brake systems; it establishes brake performance requirements. By so doing, however, it also establishes the baseline for system safety. The standard regulates four major features of brake systems: instrument panel warning lamps, the fluid reservoir and its labeling, automatic adjustment, and mechanically operated friction parking brakes.

Although FMVSS does not dictate brake system hardware and design, one of its first major effects that car owners saw was the introduction of dual-chamber master cylinders and split hydraulic systems on 1967 model-year cars. Also, the increased performance requirements in the 1976 revision made it impractical to use drum brakes on the front wheels of cars. The standard did not specify front disc brakes, but discs were the most practical way to meet the performance requirements.

Brake systems are not designed just to meet minimum legal standards, however. They are designed in relation to the performance and intended use of a vehicle. Trucks have larger brakes than passenger cars, for example, to stop a vehicle with a heavier payload. A high-performance car will have high-performance brakes, but an economy compact car will not. Every vehicle has a brake system that meets motor vehicle safety requirements and matches the performance capabilities and intended use of that vehicle. Thus, brake systems reflect both safety regulations and sound engineering practices.

Department of Transportation (DOT) is the U.S. government executive department that establishes and enforces safety regulations for motor vehicles and for federal highway safety and oversees, inspects, and regulates all interstate transportation including road, rail, and water facilities; commercial operators training/certification; and commercial vehicles. They are assisted by state-funded transportation departments.

Brake Performance Test

The brake performance test of FMVSS 105 defines the minimum requirements for the hydraulic brake system on any vehicle driven on the highway. The technician should know a bit about the performance test, not for the sake of being able to quote government regulations, but because parts of the test define the kind of performance a brake system should deliver after the vehicle is serviced.

The brake performance test is divided into eighteen stages and begins with a new set of brakes on a test vehicle. The first stage of testing is discussed as an example of the other seventeen. The first stage is to install the test instruments on the vehicle and verify that they operate correctly. The vehicle then goes through what is called the "first effectiveness test." This test is performed with fresh brake linings before they have had a chance to burnish in. The vehicle makes six stops from 30 mph and six stops from 60 mph. At least one of the stops from 30 mph must be made in 57 feet or less, and one stop from 60 mph must be in 216 feet or less (Figure 1-9). These stopping distances and stopping distances in other stages of the test are absolute requirements for any vehicle of any size and weight. Remember that FMVSS 105 defines minimum brake performance. It is up to the engineers to design the vehicle and the brake system to meet the performance standards.

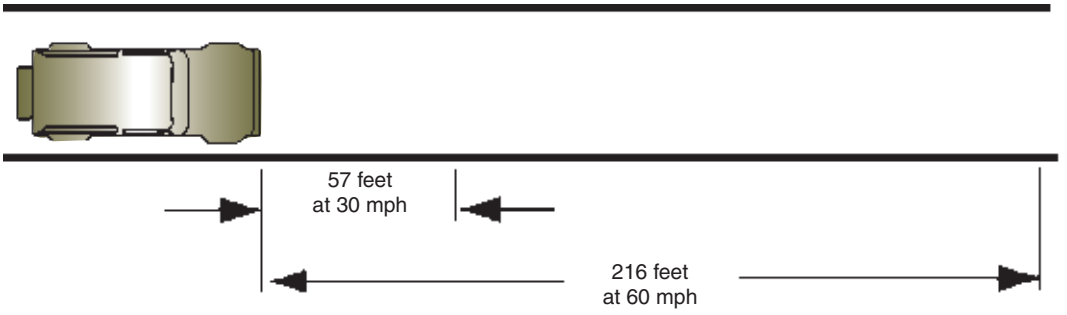


FIGURE 1-9 **One of the 18 stages of the brake performance test in FMVSS 105 requires one stop from 30 mph in 57 feet or less and one stop from 60 mph in 216 feet or less.**

Complete U.S. brake testing procedures and standards can be found on the Web at http://www.nhtsa.dot.gov/cars/rules/import/FMVSS/index.html. At the same Web location, information can be found for tires, wheels, and other vehicle safety equipment. The Canadian government has a similar site at http://www.Nasdpts.org/documents/PubSBMTCMiniGuide 04.pdf.

While the governments set the minimal rules and regulations for design and manufacturing, the technician should understand the ramifications if a brake system is not returned to its designed capability. Failure to follow correct repair procedures could cause a vehicle accident, resulting in damage, injuries, and lawsuits. It takes less time to do it right, rather than to take a shortcut that saves time and labor in the short term but may result in much greater loss of time and money later.

Brake Service Laws and Regulations

After new vehicles are first sold, the responsibility for maintaining safe brake operation falls on the vehicle owners. The owners, in turn, rely on the service technician to keep the brakes in proper operating condition. Many states and provinces have laws that govern brake system operation and brake service.

Some states require periodic vehicle safety inspection, either every year or every 2 years. These safety inspections usually include at least an inspection of brake components. Some also include dynamic stopping tests, done on a brake system analyzer or on a measured course. If a vehicle fails any part of the safety inspection, its registration cannot be renewed until all defects are fixed. Some states require that a vehicle that has failed a brake test or inspection or that has been cited for unsafe brakes by a police officer can only be repaired at a state-authorized repair facility.

In addition, some states, provinces, counties, or cities have regulations for the licensing or certification of brake service technicians. Some areas conduct their own certification programs; others rely on Automotive Service Excellence (ASE) certification in brake service. ASE is a nonprofit organization that technically certifies automotive technicians with a series of standardized written tests. Automotive business leaders, technicians, and educators select and write the test questions.

Working in an area that has brake service regulations, the technician will find that safety is not only good common sense, it is good business. Service technicians who pass all certification requirements for brake systems will get more of the service business, have more secure employment, and earn higher wages. In addition, any technician who provides high-quality brake service can take satisfaction in knowing that he or she is contributing to driving safety.

TABLE 1-1 **A Sample of brake warnings and cautions. Other components and subsystems of the brake system will also have specific alert messages similar to those listed here.**

Pertaining to brake fluids:
CAUTION: Brake fluid is corrosive to body finish. Do not allow fluid to spill onto the paint or components. The fluid will damage the finish and possibly damage some components.
WARNING: Brake fluid can damage the eyes and skin. Wear safety glasses and chemical-resistant gloves when handling brake fluid. Damage to the eyes or skin can be caused by direct contact with brake fluids.
WARNING: Never mix different types of brake fluids unless specifically authorized by the vehicle manufacturer. Mixing different types of brake fluid may result in a loss of braking ability and cause damage or injury.
Pertaining to disc brake calipers:
WARNING: Do not hang the caliper from its brake hose. Damage to the hose could occur that may result in poor braking ability. Damage or injuries could result.
CAUTION: Do not use a sharp object to remove the caliper seal. Scratches or nicks could prevent proper sealing around the piston. Damage to the caliper bore or the piston could result.

Brake Warnings and Cautions

At the beginning of many manufacturers' service manuals and at appropriate points throughout the manuals are various cautions and warnings to alert the technician to some dangers inherent in brake repair. Some of the most common manufacturers' warnings and cautions are paraphrased and listed in Table 1-1. Within this text and the *Classroom Manual*, there are also warnings and cautions pertaining to servicing brake systems. To prevent damage both to the vehicle and vehicle equipment, and possible injury, it is imperative that the technician adhere to the information contained in the alert messages. As further chapters are read and studied, the reader will become more conversant with the warnings and cautions and why they are necessary.

Asbestos Health Issues

One of the greatest safety concerns in any shop doing brake service is personnel exposure to **asbestos** dust. Exposure to asbestos was a greater problem in automotive service many years ago than it is today. The importance of avoiding asbestos exposure and the concern for asbestos safety have not decreased in the slightest, however.

Asbestos is a silicate compound that is very resistant to heat and corrosion. Its excellent heat dissipation abilities and coefficient of friction make it ideal for automotive friction materials such as clutch and brake linings. Unfortunately, asbestos has other characteristics that make it an extreme health hazard.

Asbestos contains millions of small, linked fibers that give it both strength and flexibility. Because asbestos does not deteriorate or decompose naturally, inhaling asbestos fibers lodges them in the respiratory passages and the lungs. Once inhaled, these fibers are in place forever. Even moderate quantities of inhaled asbestos fibers can lead to serious diseases. The most serious are asbestosis and lung cancer.

Asbestosis is a progressive lung disease caused by asbestos fibers continually lodging in the lungs and inflaming the lung air sacs. The inflammation of **asbestosis** can heal, but it leaves scar tissue in the lungs that thickens the air sacs and makes it increasingly more difficult for oxygen to enter the bloodstream. Over a period of years, breathing becomes increasingly more difficult. Once started, asbestosis is irreversible. Lung cancer is the most deadly of

Occupational Safety and Health Administration (OSHA) is a division of the U.S. Department of Labor that establishes and enforces workplace safety regulations.

any asbestos-related disease. Asbestos exposure combined with other respiratory irritations, such as tobacco smoke, can accelerate the development of cancer and produce more severe effects. It is possible for a person to develop both asbestosis and lung cancer from severe asbestos exposure. Heavy exposure to asbestos also can lead to other cancers of the respiratory and digestive systems.

Asbestos Control Laws and Regulations

Regulations of the U.S. **Occupational Safety and Health Administration (OSHA)** control asbestos exposure and handling of materials that contain asbestos. OSHA regulations state that fibers of 5 microns or larger are hazardous. These regulations further say that no worker can be exposed to more than 0.1 fiber per cubic centimeter of air during an 8-hour period. That is an extremely small exposure to an extremely small amount of material. These low exposure limits can be maintained in a brake service shop, however, through the proper use of brake cleaning equipment and respiratory safety devices.

A respirator designed specifically for protection against asbestos inhalation is your best personal protection. The respirator shown in Figure 1-10 is approved by the National Institute for Occupational Safety and Health (NIOSH) and has replaceable filters for maximum protection. A brake dust vacuum cleaning enclosure (Figure 1-11) and a brake washing system will keep asbestos dust within safe limits for the entire shop area.

Along with OSHA, the U.S. **Environmental Protection Agency (EPA)** regulates some aspects of asbestos safety. EPA regulations are concerned primarily with handling and disposal of asbestos waste. These regulations state that any waste material containing more than 1 percent asbestos must be disposed of by rigidly controlled methods that do not endanger public health.

Technicians' concern with asbestos safety does not end with prescribed cleaning of brake systems and respiratory safety. They must dispose of cleaning residue according to EPA regulations. Because brake dust may contain more than 1 percent asbestos, any vacuum cleaner bags, filters, and cloths used to wipe up brake dust must be sealed in double plastic bags or a

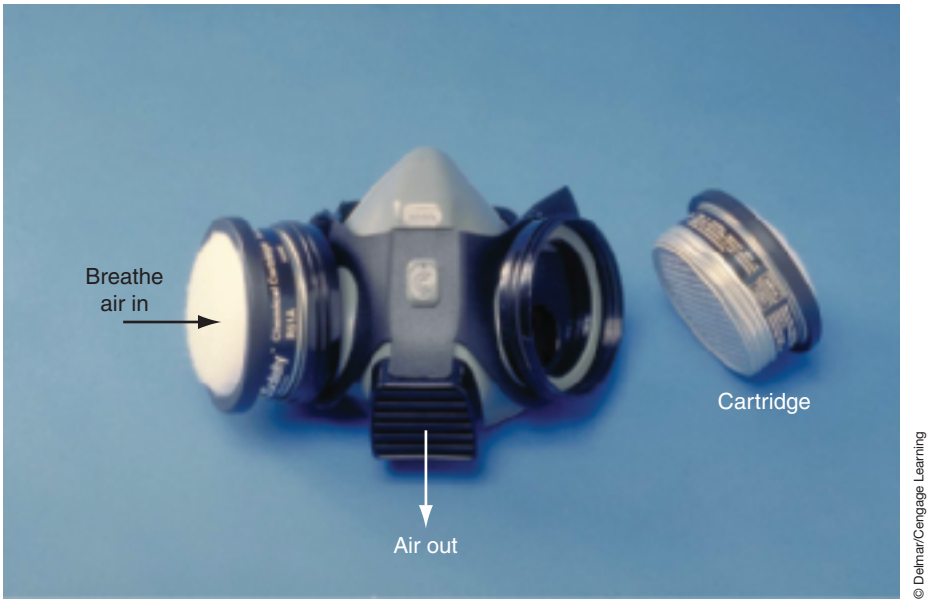


FIGURE 1-10 **This NIOSH-approved filter-type respirator is ideal for break work.**

A BIT OF HISTORY

The Occupational Safety and Health Act (OSHA), which regulates workers safety, was passed into federal law in 1970.

Environmental Protection Agency (EPA) is the U.S. government executive department that establishes and enforces regulations to protect and preserve the physical environment, through the control of hazardous materials and waste, including landfills. It is best known for regulations relating to air quality. Many times OSHA and EPA authority overlap in large incidents.

CAUTION:

Hazardous Materials

This container holds asbestos fibers. Avoid creating dust when moving or opening. Breathing protection should be worn when unsealing/sealing container. Asbestos fibers are hazardous and can cause cancer and lung disease.

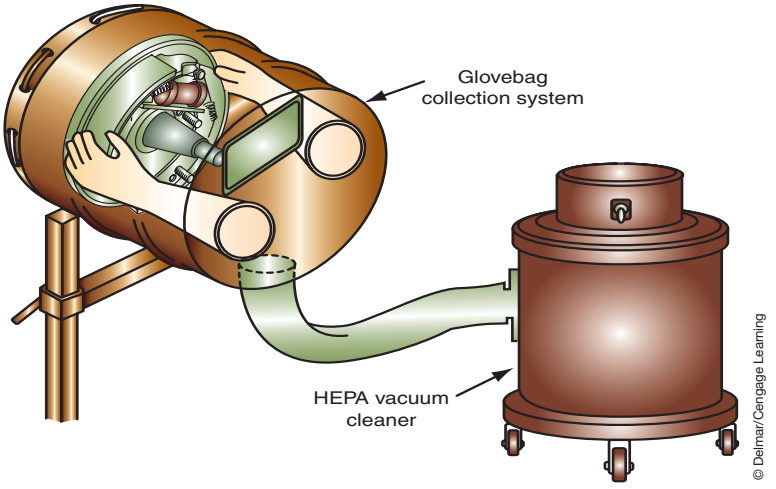


FIGURE 1-11 **This full-enclosure asbestos vacuum system traps brake dust and helps keep the shop's air free of dust.**

AUTHOR'S NOTE: All containers in which you store hazardous material or waste must be labeled as to contents. The text can be handwritten or printed with other methods as long as it cannot be easily wiped off or will not fade during the time the container is used for this purpose.

similar nonpermeable container. The bag or container must then be labeled with an asbestos exposure warning, similar to the following:

In most areas of the country, it is acceptable to turn over properly contained asbestos residue to local sanitation agencies for burial in a landfill. This eliminates the hazard of airborne fibers. Local asbestos disposal regulations may vary, however, and some may require additional special handling. It is the technician's responsibility to know the local regulations and to ensure that they are observed in the workplace.

Additional Respiratory Safety

Concern for the health hazards of asbestos exposure has led to a reduction of its use in automotive components. For many years, asbestos has been eliminated from the brake linings of new cars and light trucks sold in North America and from replacement brake linings made in the United States and Canada. These restrictions do not apply, however, to replacement brake linings manufactured outside North America and imported into the United States or Canada. Furthermore, the asbestos content of imported brake linings may not be identified clearly on packaging.

As asbestos content was reduced in brake linings, other materials took its place. Today, many brake linings are made primarily of organic or semimetallic compounds. As with asbestos, however, these materials wear and create airborne dust. Semimetallic brake linings, for example, may contain copper or iron compounds, and these materials become part of the brake dust. Although exposure to these metals may not be as hazardous as asbestos exposure, it cannot be good for a person to inhale copper or iron dust.

For all of these reasons, proper use of brake cleaning equipment and respiratory safety devices is as important today as it has ever been. Do not think for a moment that the reduced

A BIT OF HISTORY

Health concerns were one good reason to remove asbestos from brake linings, but there was an equally good engineering reason. Modern brake friction materials work better than asbestos. Asbestos was still common in some friction materials in the early 1990s, but higher temperatures of smaller disc brakes caused the asbestos pads to wear faster than was acceptable. Moreover, even the best asbestos material will start to glaze at temperatures as low as 250°F (122°C). Modern semimetallic and organic linings are safer not only from a health standpoint, but they also provide better braking performance than asbestos did.

use of asbestos in automotive materials has reduced the requirements for safe material handling. All personnel must take the proper steps to protect themself and create a safe work environment.

Chemical Safety

Most new automotive cleaning solvents no longer contain chlorine. Chlorine is suspected of causing damage to the ozone layer and is banned from common use by the EPA.

Asbestos is not the only hazardous material found in auto service facilities. Solvents, cleaners, brake fluids, gasoline, oils, and other chemicals all present hazards if not handled properly. They may be flammable, emit harmful vapors, or be irritating to the eyes or skin.

Brake Cleaning Solvents

Chlorinated hydrocarbon solvents are a class of chemical compounds that contain various combinations of hydrogen, carbon, and chlorine atoms.

One reason liquid solvents were developed for brake cleaning was to reduce the hazard of blowing off brake assemblies with compressed air and creating clouds of airborne fibers and dust. Wetting the dirt and dust residue on the brakes with solvent keeps the toxic materials out of the air.

Always work with cleaning solvents in a well-ventilated area that is free of sparks or flames. The fumes from aerosol cleaners and open part washers are heavier than air and will settle to the lower part of the work area such as below floor-level dynamometers and alignment pits. Solvent vapors may also be harmful if inhaled, particularly in large quantities for prolonged periods. If necessary, use a respirator to prevent inhaling the vapors. Chlorinated hydrocarbon solvents may be absorbed through the skin with toxic effects. Always wear gloves when using any cleaning solvent. The best first aid for skin and eye contamination is flushing with large amounts of water and contacting medical personnel. Inhalation exposure requires quick removal to clean air and medical attention.

Trichloroethane is a chlorinated cleaning solvent often used in aerosol brake cleaner.

Although they are a lesser health hazard than asbestos, various cleaning solvents used on brake systems must be handled with specific precautions. Among the most significant from a safety standpoint are those that contain **chlorinated hydrocarbon solvents** such as **1,1,1-trichloroethane**, **trichloroethylene**, and **tetrachloroethylene** (Figure 1-12). These are all colorless solvents with a strong odor of ether or chloroform. The vapors from these solvents can cause drowsiness or loss of consciousness. Very high levels of exposure, even for a short time, may be fatal. Although these hydrocarbon solvents are not flammable, they decompose when exposed to flame and release toxic gases such as **phosgene**, carbon monoxide, and hydrogen chloride.

Trichloroethylene is a chlorinated toxic cleaning solvent often used in aerosol brake cleaner and as an insecticide fumigant.

This family of chlorinated hydrocarbon solvents reacts in the atmosphere and depletes the Earth's ozone layer. Their manufacture has been restricted since January 1, 1996. Other solvents such as hexane, heptane, and xylene are replacing chlorinated hydrocarbons in brake cleaners (Figure 1-13). Hexane and heptane are flammable, however, so all fire safety precautions must be observed when using these solvents.

Causes and Effects of Chemical Poisoning

Phosgene is a poisonous gas that is formed when certain other gases are exposed to flame; it is also known as mustard gas, the principal poison gas used in World War I.

A person may be exposed to chemical health hazards in three ways: by ingestion, by inhalation, and by contact with the skin. Material safety data sheets (MSDS), discussed in more detail in subsequent paragraphs, describe any poisoning hazards and how to counteract poisonous effects. An MSDS for every solvent used in the shop should be readily available to every worker.

Obviously, swallowing any solvent—even soap—can be hazardous, but this does not happen very often. Solvents can be ingested, however, by a smoker who lights a cigarette while working with the solvent. Solvents must always be handled carefully and kept in properly

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FIGURE 1-12 **This aerosol brake cleaner contains tetrachloroethylene. You should know and practice the safe use of all solvents in the shop.**

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FIGURE 1-13 **Nonchlorinated cleaning solvents also require specific handling and safety precautions.**

labeled containers. When not in use, the containers must be stored away from untrained personnel and children.

Contact with solvents occurs most often through inhalation or absorption through the skin. Inhalation probably is the more serious and has the more immediate effect. Absorption can be just as dangerous, however, and its effects may not be noticeable for several days after exposure.

Current OSHA standards for exposure to airborne trichloroethylene say that more than 100 parts per million (ppm) in the air during 8 hours is dangerous. To give you an idea of how small the allowable exposure is, 100 ppm equal 0.0001 percent.

WARNING: Always wear nitrile gloves when working with chemicals. Exposure can lead to skin injuries and, sometimes, ingestion through the skin into the bloodstream. Serious injury could result.

There is no current standard for physical contact with these solvents, but the immediate effect is the removal of natural skin oils, which causes drying of the skin and redness and irritation. Prolonged skin contact with solvent can have the same effects as inhalation.

Exposure to chlorinated hydrocarbons and other solvents by any means can cause nausea, drowsiness, headache, dizziness, and eventually unconsciousness. Prolonged exposure can lead to liver and kidney damage.

Safety and Envirnomental Agencies

Environment Protection Agency

The Environment Protection Agency, or EPA, is a federal agency charged with instituting and enforcing regulations that assist in protecting the environment. It was formed in the early 1970s to reduce air pollution caused by vehicle and manufacturing emissions. Inherent within that charter was the control and disposal of waste products from almost all businesses, including the local automotive repair shop and individuals. The main issue with the EPA is the storage and disposal of hazardous waste from major manufacturers, plants, the local garbage dump, and everything in between. Although its formation met with much resistance, the results some 50 years later are cleaner air and less ground and water pollution. Unless something changes, the agency will be in operation for the foreseeable future. The EPA's Web site is http://www.epa.gov.

Occupational Safety and Health Administration (OSHA)

OSHA was formed to help protect employees and, ultimately, employers. It has the legal authority to inspect businesses and ensure that working areas are safe for the employees. Some safety concerns of utmost interest are the control of chemicals within the workplace, the equipment/facility in which to store or use those chemicals, the equipment and tools used within the facility, and the general working environment. It should be noted that since the formation of OSHA, accidents resulting from unsafe working environments have been reduced, with an increase in production associated with lowered loss of man-hours and fewer accidents. A suggested Web site for OSHA is http://www.osha.gov/SLTC/index.html.

Environmental Canada

Environmental Canada is the Canadian version of the U.S. EPA. It has requirements that relate to Canada's more northern environment and citizens. Within its organization are subagencies, such as the Canadian Environmental Assessment Agency, that may not be directly related to subagencies of the U.S. EPA. As far as the automotive industry is concerned,

however, the legal and environmental control requirements are almost exactly the same. Section 7 of the Canadian Environmental Protection Act specifically covers the Canadian automotive industry. The Web site best suited for information on this agency is http://www.ceaa.gc.ca/ppp/index_e.htm#1.

Canadian Center for Occupational Health and Safety (CCOHS)

The **Canadian Center for Occupational Health and Safety (CCOHS)** is similar to the U.S. OSHA with a similar mandate, responsibility, and authority. It performs inspections, determines administrative fines, may file criminal charges, and directs training programs in much the same manner as the U.S. OSHA does. The Web site is http://www.ccohs.ca/html.

It should be noted that each of the four agencies listed operates "over border" because many pollutants tend to cross borders. Automotive manufacturing, vehicle repair, and vehicle operation are shared by the United States and Canada and many associated problems are the result of actions in one country affecting the environment of its neighbor. Each of the listed Web sites has a large amount of information pertaining to almost any environmental and safety issue.

Hazardous Communications

Each of the agencies noted in the last section enforces what are known as right-to-know laws or hazardous communications. Basically, right-to-know requires the employer to notify employees of dangerous materials that are housed or used on-site. They also require the initial training of new employees; annual (or more often) refresher training of all employers; and employer-designated personnel with specific authority to train, maintain records, and, in some instances, act as first responders to fires or accidents. Of direct interest to all employees are the three main informational documents pertaining to on-site chemicals.

Important information about such materials is contained in **material safety data sheets (MSDS)**, which are multiple-page information sheets (Figure 1-14). The MSDS is issued by the manufacturer of the material; and it provides detailed information on hazardous materials, including dangerous ingredients, corrosiveness, reactivity, toxicity, fire and explosion data, health hazards, spill and leak procedures, and special precautions. Federal law requires that an MSDS be available for each hazardous material in the workplace. They are sometimes posted in the shop or available in the office. An employee must have access to all MSDS documents pertaining to his or her work area.

The MSDS often states recommended uses for the material and lists specific handling instructions and safety precautions that must be observed. Emergency treatments for accidental ingestion, inhalation, and eye and skin contact are given when applicable. Guidelines for cleaning up spills or responding to other emergencies are included. The Canadian equivalent to the MSDS is the **Workplace Hazardous Materials Information Sheet**.

The employer is responsible for obtaining all MSDS for the hazardous materials in the shop and for making this information available to all employees. The employer must also provide formal training on the safe handling of all hazardous materials and must update this training yearly.

Containers storing potentially hazardous materials must be properly labeled with regard to health, fire, reactivity, and handling hazards (Figure 1-15). The simplest way to ensure compliance is to keep materials in their original containers. If a chemical is moved into another container, it is the responsibility of the shop to see that the container is the proper type and is correctly labeled. Do not use materials in unmarked containers. They may not be what they appear to be, or they may be contaminated.

Every employer also must maintain documentation on all hazardous materials used in the shop. The employer must provide proof of training programs, keep records of all accidents

HEXANE
==========
MSDS Safety Information
==========
Ingredients
==========
Name: HEXANE (N_HEXANE)
% Wt: >97
OSHA PEL: 500 PPM
ACGIH TLV: 50 PPM
EPA Rpt Qty: 1 LB
DOT Rpt Qty: 1 LB
==========
Health Hazards Data
==========
LD50 LC50 Mixture: LD50:(ORAL,RAT) 28.7 KG/MG
Route Of Entry Inds _ Inhalation: YES
Skin: YES
Ingestion: YES
Carcinogenicity Inds _ NTP: NO
IARC: NO
OSHA: NO
Effects of Exposure: ACUTE:INHALATION AND INGESTION ARE HARMFUL AND MAY BE FATAL. INHALATION AND INGESTION MAY CAUSE HEADACHE, NAUSEA, VOMITING, DIZZINESS, IRRITATION OF RESPIRATORY TRACT, GASTROINTESTINAL IRRITATION AND UNCONSCIOUSNESS. CONTACT W/SKIN AND EYES MAY CAUSE IRRITATION. PROLONGED SKIN MAY RESULT IN DERMATITIS (EFTS OF OVEREXP)
Signs And Symptions Of Overexposure: HLTH HAZ:CHRONIC:MAY INCLUDE CENTRAL NERVOUS SYSTEM DEPRESSION.
Medical Cond Aggravated By Exposure: NONE IDENTIFIED.
First Aid: CALL A PHYSICIAN. INGEST:DO NOT INDUCE VOMITING. INHAL:REMOVE TO FRESH AIR. IF NOT BREATHING, GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN. EYES:IMMED FLUSH W/PLENTY OF WATER FOR AT LEAST 15 MINS. SKIN:IMMED FLUSH W/P LENTY OF WATER FOR AT LEAST 15 MINS WHILE REMOVING CONTAMD CLTHG & SHOES. WASH CLOTHING BEFORE REUSE.
==========
Handling and Disposal
==========
Spill Release Procedures: WEAR NIOSH/MSHA SCBA & FULL PROT CLTHG. SHUT OFF IGNIT SOURCES:NO FLAMES, SMKNG/FLAMES IN AREA. STOP LEAK IF YOU CAN DO SO W/OUT HARM. USE WATER SPRAY TO REDUCE VAPS. TAKE UP W/SAND OR OTHER NON_COMBUST MATL & PLACE INTO CNTNR FOR LATER (SU PDAT)
Neutralizing Agent: NONE SPECIFIED BY MANUFACTURER.
Waste Disposal Methods: DISPOSE IN ACCORDANCE WITH ALL APPLICABLE FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS. EPA HAZARDOUS WASTE NUMBER:D001 (IGNITABLE WASTE).
Handling And Storage Precautions: BOND AND GROUND CONTAINERS WHEN TRANSFERRING LIQUID. KEEP CONTAINER TIGHTLY CLOSED.
Other Precautions: USE GENERAL OR LOCAL EXHAUST VENTILATION TO MEET TLVREQUIREMENTS. STORAGE COLOR CODE RED (FLAMMABLE).
==========
Fire and Explosion Hazard Information
==========
Flash Point Method: CC
Flash Point Text: _9F,_23C
Lower Limits: 1.2%
Upper Limits: 77.7%
Extinguishing Media: USE ALCOHOL FOAM, DRY CHEMICAL OR CARBON DIOXIDE. (WATER MAY BE INEFFECTIVE.)
Fire Fighting Procedures: USE NIOSH/MSHA APPROVED SCBA & FULL PROTECTIVE EQUIPMENT (FP N).
Unusual Fire/Explosion Hazard: VAP MAY FORM ALONG SURFS TO DIST IGNIT SOURCES & FLASH BACK. CONT W/STRONG OXIDIZERS MAY CAUSE FIRE. TOX GASES PRDCED MAY INCL:CARBON MONOXIDE, CARBON DIOXIDE.
==========

FIGURE 1-14 **The MSDS for any chemical lists physical and chemical properties and all necessary safety information.**

or spills, and satisfy all employee requests to review MSDS. Even if a hazardous material is phased out of use, the MSDS must be kept on file for 30 years. OSHA and other regulatory agencies are quite serious when it comes to employee safety and hazardous materials. Each employee should be too.

During the workday, a technician may use any number of materials that can be hazardous. For example, there are solvents, brake cleaners, and brake fluids. The storage containers for these and all other hazardous materials must have a label that should be read before using them (see Figure 1-15).

FIGURE 1-15 **Chemical storage cabinets must be labeled as to contents and fire hazards.**

FIGURE 1-16 **The label on a can of brake fluid lists hazards, warnings, and first-aid information.**

Figure 1-16 shows a typical container label. The label must identify the hazardous chemicals in the product and tell what the specific hazards are. For example, the label would tell the technician that the material might be poisonous or flammable and list what precautions should be taken. There might be a warning to wear eye protection or to use the material in a well-ventilated area. First-aid information is also provided on the label.

Unlabeled materials can be very dangerous. Many people have been injured when they did not know what was in a container. There may be times when a material from a labeled container is placed into another container. Always make a label for the new container that describes the contents. Other persons may use the container or material.

Many of the waste materials from shop use are also considered hazardous (Figure 1-17). Dirty solvent, used engine coolant, used batteries, used engine oil, and vacuum cleaner bags with brake dust are just a few examples of shop hazardous waste. Never throw these materials in the trash or pour them down a drain. They could end up in a place where they could injure someone. Federal laws regulate how hazardous waste materials should be handled. Automotive shops usually have contracts with companies to pick up these materials and dispose of them properly.

FIGURE 1-17 **Hazardous waste materials must be stored in clearly labeled safety containers until they can be disposed of properly.**

Handling of Hazardous Waste

When the shop is finished using a hazardous material, it becomes hazardous waste. The EPA defines hazardous waste as solid or liquid materials that have one or more of the following characteristics:

- *Ignitability*. This characteristic applies to liquids with flash points below 140°F or solids that can spontaneously ignite.
- *Corrosivity*. Materials that dissolve metals or other materials or burn the skin on contact are considered corrosive.
- *Reactivity*. Reactive materials include those that react violently with water or other materials. They may release cyanide gas, hydrogen sulfide gas, or similar gases when exposed to low-pH acid solutions. They may also generate toxic or flammable vapors.
- ***Extraction Procedures* (EP)** toxicity. Materials that leach one or more heavy metals in concentrations greater than 100 times primary drinking water standard concentrations are considered toxic.

A complete list of hazardous wastes may be found at the EPA or CCOHS Web sites. When handling any hazardous waste material, always wear the safety equipment specified in the MSDS. In many cases, this includes full eye protection, chemical-resistant gloves, and a respirator (Figure 1-18).

Cleaning Equipment Safety

Parts cleaning is an important part of any brake repair job. Be careful when using solvents. Most are toxic, caustic, and flammable. Avoid placing barer hands in solvent; wear protective gloves, if necessary. Read all manufacturer's precautions and instructions and material safety data sheets (MSDS) before using.

Do not use gasoline to clean components. This practice is very dangerous. Gasoline vaporizes at such a rate that it can form a flammable mixture with air at temperatures as low as –50°F. Gasoline also is dangerous if it gets on the skin because the chemicals in gasoline can be absorbed through the skin and get into your body.

WARNING: Never work with gasoline in a closed area. One experienced technician was working on a carburetor in his home garage. After leaving for awhile to go shopping, he re-entered the garage through a door between the kitchen

FIGURE 1-18 **Wear proper safety equipment when handling hazardous materials such as cleaning solvents.**

and garage. When he flipped the light switch on, an explosion demolished the garage and kitchen. He was killed instantly. An investigation found that he apparently left a gasoline container open and the vapors filled the two-garage sufficiently to ignite from a small electrical spark. Even a small amount of gasoline or other liquid can produce enough vapors to cause lots of damage and injuries.

Small cleaning jobs are often done with aerosol cleaners. These spray cans contain chemicals that break down dirt and grease and allow them to be removed. Do not throw empty spray containers in the trash without punching a hole in the side. Always read the warnings on the can and follow them. Wear eye protection, proper gloves, and a shop coat to prevent exposure to the skin or eyes. Always do the cleaning in a well-ventilated area.

Many of the solvents used in solvent cleaning tanks are flammable. Be careful to prevent an open flame around the solvent tank. Never mix solvents. One could vaporize and act as a fuse to ignite the others.

Wear neoprene gloves when washing parts. Some solvents can be absorbed through the skin and into the body. This is especially true if there is a cut on your hand. Do not blow compressed air onto the hands if they get wet with solvent, as this can cause the solvent to go through your skin.

Wipe up spilled solvents promptly, and store all rags in closed, properly marked metal containers. Store all solvents either in their original containers or in approved, properly labeled containers. Finally, when using a commercial parts washer, be sure to close the lid when the job is finished.

A B C

FIGURE 1-19 **To relieve high ABS pressures, (A) disconnect the battery negative cable, (B) be sure the ignition is off, and (C) pump the brake pedal 25–50 times until you feel a definite increase in pedal pressure.**

Antilock Brake Hydraulic Pressure Safety

Many ABSs generate extremely high brake fluid pressures that range from 2,000 to 3,000 psi. Failure to fully depressurize the hydraulic accumulator of an ABS before servicing any part of the system could cause severe personal injury from high-pressure brake fluid escaping from a service connection. Follow the exact shop manual procedure for the vehicle being serviced. A typical repressurizing procedure follows, with complete details in Chapter 10.

1. Disconnect the negative (−), or ground, battery cable (Figure 1-19A).
2. Be sure the ignition key is off (Figure 1-19B).
3. Pump the brake pedal at least 25 to 50 times, using about 50 pounds of pedal force (Figure 1-19C).
4. Continue pumping until you feel a definite increase in pedal pressure. Pump the pedal a few more times to ensure complete relief of hydraulic pressure from the system.
5. Proceed with system service.

AIR BAG SAFETY

WARNING: Most late-model cars and light trucks have supplemental inflatablerestraint systems (SIRSs), known as air bags. To avoid accidental deployment of the air bag and possible injury or vehicle damage, always disconnect the battery ground (negative) cable, then the positive battery cable and wait a minimum of 20 minutes before working near any of the impact sensors, steering column, or instrument panel. Do not use any powered electrical test equipment on any of the air bag system wires or tamper with them in any way unless specifically directed by the instructor or supervisor. Do not use memory saver devices.

Most vehicles built since the early 1990s have a **supplemental inflatable restraint system (SIRS)**, more commonly called an air bag. This system is designed to protect the driver and other passengers from injury in case of a collision. The system consists of an air bag module in the center of the steering wheel, another in the right side of the instrument panel, and possibly others in the side panels and headrests.

When working on brake system components under the instrument panel or near any of the air bag sensors or actuators, it is a good idea to deactivate the air bag system as described in the warning above. Exact procedures may vary from one vehicle to another, so consult the specific vehicle service manual for details.

Automotive manufacturers installed side and headrest air bags in the 2000 and later model vehicles. Some side bags are in the doors, whereas others are in the side of the seat backrest. They are protection during a side impact. The headrest bags are designed to reduce head and neck injuries during a collision from the rear. It is an accepted fact that SIRSs of this type can be dangerous to automotive and emergency technicians. The newest SIRSs are disarmed in a manner similar to that for driver and passenger bags. Always consult the service manual before beginning work in or around any SIRS components.

Fire Control

There are four general classifications of fires and a type of fire extinguisher to match the burning materials (Figure 1-20). Each class of fire is matched with a type of fire extinguisher containing the best material for controlling or extinguishing that fire. The automotive repair

	Class of Fire	Typical Fuel Involved	Type of Extinguisher
Class A Fires (green)	**For Ordinary Combustibles** Put out a Class A fire by lowering its temperature or by coating the burning combustibles.	Wood Paper Cloth Rubber Plastics Rubbish Upholstery	Water*[1] Foam* Multipurpose dry chemical[4]
Class B Fires (red)	**For Flammable Liquids** Put out a Class B fire by smothering it. Use an extinguisher that gives a blanketing, flame-interrupting effect; cover whole flaming liquid surface.	Gasoline Oil Grease Paint Lighter fluid	Foam* Carbon dioxide[5] Halogenated agent[6] Standard dry chemical[2] Purple K dry chemical[3] Multipurpose dry chemical[4]
Class C Fires (blue)	**For Electrical Equipment** Put out a Class C fire by shutting off power as quickly as possible and by always using a nonconducting extinguishing agent to prevent electric shock.	Motors Appliances Wiring Fuse boxes Switchboards	Carbon dioxide[5] Halogenated agent[6] Standard dry chemical[2] Purple K dry chemical[3] Multipurpose dry chemical[4]
Class D Fires (yellow)	**For Combustible Metals** Put out a Class D fire of metal chips, turnings, or shavings by smothering or coating with a specially designed extinguishing agent.	Aluminum Magnesium Potassium Sodium Titanium Zirconium	Dry powder extinguishers and agents only

**Catridge-operated water, foam, and soda-acid types of extinguishers are no longer manufactured. These extinguishers should be removed from service when they become due for their next hydrostatic prerssure test.*

Notes:
(1) Freezes in low temperatures unless treated with antifreeze solution, usually weighs over 20 pounds (9 kg), and is heavier than any other extinguisher mentioned.
(2) Also called ordinary or regular dry chemical (sodium bicarbonate).
(3) Has the greatest initial fire-stopping power of the extinguishers mentioned for class B fires. Be sure to clean residue immediately after using the extinguishers so sprayed surfaces will not be damaged (potassium bicarbonate).
(4) The only extinguishers that fight A, B, and C classes of fires. However, they should not be used on fires in liquefied fat or oil of appreciable depth. Be sure to clean residue immediately after using the extinguisher so sprayed surfaces will not be damaged (ammonium phosphates).
(5) Use with caution in unventilated, confined spaces.
(6) May cause injury to the operator if the extinguishing agent (a gas) or the gases produced when the agent is applied to a fire is inhaled.

FIGURE 1-20 **Class B- and C-type fires present the greatest fire concern in an automotive shop. A multiple-purpose fire extinguisher will work on each type.**

shop is normally in danger of fire from fuel, mostly gasoline, or from electrical fires. Electrical fires can sometimes be easily extinguished by disconnecting the battery, but do not go in harm's way trying to do this. Fuel fires will continue to burn as long as there is fuel. One thing not to use on fuel fires is spraying water. That will only spread the fuel and the fire. A Class B or a multiple-purpose fire extinguisher is the best tool for stopping a fuel fire. Most automotive shops have multiple-purpose-type extinguishers because they will work on different types of fire.

The first thing that should be done when a fire is discovered is to sound the alarm, then locate and remove the extinguisher from its mount. Using a fire extinguisher is fairly simple provided that the employer and employee have done their routine checks. Each fire extinguisher in the shop must have a tag where the date and time of inspection have been completed. This inspection is performed and the tag initialed each month. Usually the local fire marshal will conduct an annual inspection visit of each facility, and this is one of the things that will be checked. Before placing the fire extinguisher into action, check the small gauge near the handle. The needle should be in the green zone. If it is not, then the extinguisher is no longer charged and will not function.

Exercise extreme caution when fighting a fire. If at any point it appears out of control, immediately evacuate the building or area and allow the first responders to control the situation.

Terms to Know

Asbestos
Asbestosis
Canadian Center for Occupational Health and Safety (CCOHS)
Carbon monoxide
Chlorinated hydrocarbon solvents
Department of Transportation (DOT)
Environmental Canada
Environmental Protection Agency (EPA)
Extraction Procedures (EP)
Federal Motor Vehicle Safety Standards (FMVSS)
Material safety data sheet (MSDS)
Occupational Safety and Health Administration (OSHA)
Phosgene
Supplemental inflatable restraint system (SIRS)
Tetrachloroethylene
Trichloroethane
Trichloroethylene
Workplace Hazardous Materials Information Sheet

Technician Training and Certifications

Technician training can start as early as the early teens, helping family or friends repair personal vehicles. In many ways, this is one of the best ways to start a career in automotive service. Back in the good old days, before electronics, a person who was known for working on his or her personal vehicle and keeping it operational could get a job in almost any automotive repair center. With the highly sophisticated vehicles of today, that backyard experience does not count for much with today's service managers. It is almost imperative that any person desiring to be an automotive service technician receive formal training. This training may start in high school and continue through a postsecondary technical school or college. A diploma or degree from a postsecondary school at least will get an applicant a job, but the training will not stop there. All dealerships and most independent shops will require additional training throughout the technician's career. Before selecting a postsecondary automotive program, check out its job placement program. A job placement in the 90th percentile level means the employers served by that program trust the content of the program and the instructors. Based on this trust won over many years, they will hire graduates or near-graduates, knowing that the new employees have the will and knowledge to be successful.

Another key to success, or at least to proving success, are certification programs for the technician. The most well known for automotive technicians is the Automotive Institute for Excellence (ASE), Figure 1-21. This is a nonprofit organization that conducts semiannual written tests on the eight system areas of the vehicle. More information can be gained through its Web site at http:// www.asecert.org. ASE has a subagency named the National Automotive Technician Education Foundation (NATEF). NATEF certifies automotive training programs ranging from high school to postsecondary and manufacturer-specific schools. Another thing to consider during postsecondary program selection may be: Is it NATEF certified?

FIGURE 1-21 **ASE-certified technicians may wear these shoulder patches.**

ASE-Style Review Questions

1. Which of the following items is the LEAST preferred method to clean the floor of oil or dust?
   A. using a straw broom
   B. wiping with a rag
   C. using a vacuum cleaner
   D. using a damp mop

2. *Technician A* says that the Workplace Hazardous Materials Information Sheet is published by the Canadian government.
   Technician B says that the MSDS is published by the chemical manufacturer.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. Wearing jewelry around the shop is being discussed:
   Technician A says that jewelry can become dangerous when working on electrical systems.
   Technician B says that jewelry is dangerous when working around moving machinery.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. All of the following are usually part of the firefighting procedures in an automotive shop EXCEPT
   A. selecting a Class B or multiple-purpose fire extinguisher.
   B. using a fire extinguisher with the gauge needle in the green.
   C. moving the spray back and forth at the base of the fire.
   D. remaining about 6 to 8 feet downwind of the fire.

5. An air hose is found to have a bulge in its outer lining. This means
   A. the hose is in danger of blowing out.
   B. the hose is good to use if there is no air escaping.
   C. the hose is no good and should be disconnected from the compressed air source.
   D. both A and C.

6. Trichloroethylene, 1,1,1-trichloroethane, and tetrachloroethylene are classified as what type of solvents?
   A. emulsifying soaps
   B. chlorinated hydrocarbons
   C. fluorocarbons
   D. polyglycol solvents

7. A brake system is being disassembled and cleaned for service:
   Technician A says to use a full-enclosure vacuum unit to keep dust out of the air.
   Technician B says to wear a breathing respirator for personal safety.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

8. Chemical poisoning can occur by any of the following EXCEPT
   A. inhalation.
   B. refraction.
   C. absorption.
   D. ingestion.

9. Legal responsibility for safe operation of a brake system on a vehicle in use rests with the
   A. vehicle owner.
   B. service technician.
   C. vehicle manufacturer.
   D. federal government.

10. *Technician A* says that skin contact with brake fluid is not harmful.
    Technician B says that brake fluid can harm the vehicle's finish.
    Who is correct?
    A. A only
    B. B only
    C. Both A and B
    D. Neither A nor B