SECTION XI Brakes

chapter 92

BRAKING SYSTEM COMPONENTS AND PERFORMANCE STANDARDS

OBJECTIVES: After studying this chapter, the reader will be able to: • Describe the fundamentals of brake systems. • Describe brake design requirements. • List the six brake system categories. • State the purpose and function of an antilock brake system. •

KEY TERMS: Adjustable pedals 1019 • Antilock braking system (ABS) 1018 • Apply system 1017 • Base brakes 1016 • Boost system 1017 • Brake balance control system 1017 • Brake pedal 1017 • Brake warning lights 1017 • Disc brakes 1016 • DOT 1019 • Drum brakes 1016 • EAP 1019 • FMVSS 1019 • Foundation brakes 1016 • GVWR 1020 • Hydraulic system 1017 • LLVW 1020 • Parking brake 1017 • Red brake warning lamp 1017 • Service brakes 1016 • Wheel brakes 1017

FUNDAMENTALS OF BRAKE SYSTEMS

Brakes are by far the most important mechanism on any vehicle because the safety and lives of those riding in the vehicle depend on proper operation of the braking system. It has been estimated that the brakes on the average vehicle are applied 50,000 times a year!

Brakes are an energy-absorbing mechanism that converts vehicle movement into heat while stopping the rotation of the wheels. All braking systems are designed to reduce the speed and stop a moving vehicle and to keep it from moving if the vehicle is stationary. **Service brakes** are the main driver-operated brakes of the vehicle. Service brakes are also called **base brakes** or **foundation brakes.** ● **SEE FIGURE 92–1.**

BRAKE SYSTEM PARTS

Most vehicles built since the late 1920s use a brake on each wheel. To stop a wheel, the driver exerts a force on a brake pedal. The force on the brake pedal pressurizes brake fluid in a master cylinder. This hydraulic force (liquid under pressure) is transferred through steel lines and flexible brake lines to a wheel cylinder or caliper at each wheel. Hydraulic pressure to each wheel cylinder or caliper is used to force friction materials against the brake drum or rotor. The friction between the stationary friction material and the rotating drum or rotor (disc) causes the rotating part to slow and eventually stop. Since the wheels are attached to the drums or rotors, the wheels of the vehicles also stop.

The heavier the vehicle and the higher the speed, the more heat the brakes have to be able to absorb. Long, steep hills can cause the brakes to overheat which results in the brakes not being able to produce the friction necessary to slow or stop a vehicle.

DRUM BRAKES. **Drum brakes** are used on the rear of many rear-wheel-drive, front-wheel-drive, and four-wheel-drive vehicles. When drum brakes are applied, brake shoes are moved outward against a rotating brake drum. The wheel studs for the wheels are attached to the drum. When the drum slows and stops, the wheels also slow and stop.

Drum brakes are economical to manufacture, service, and repair. Parts for drum brakes are generally readily available and reasonably priced. On some vehicles, an additional drum brake is used as a parking brake on vehicles equipped with rear disc brakes. ● **SEE FIGURE 92–2.**

DISC BRAKES. **Disc brakes** are used on the front of most vehicles built since the early 1970s and on the rear wheels of many vehicles.

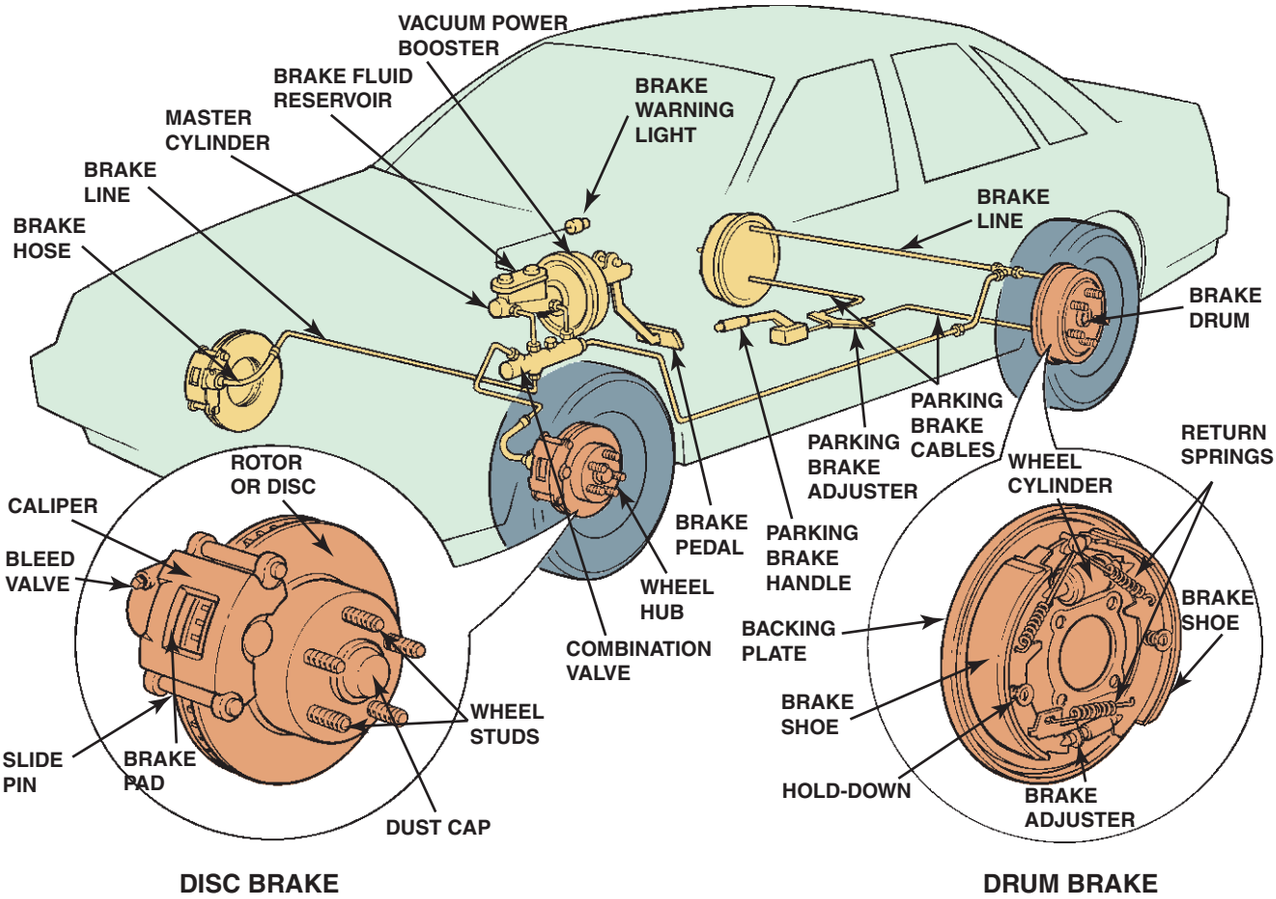

FIGURE 92–1 Typical vehicle brake system showing all typical components.

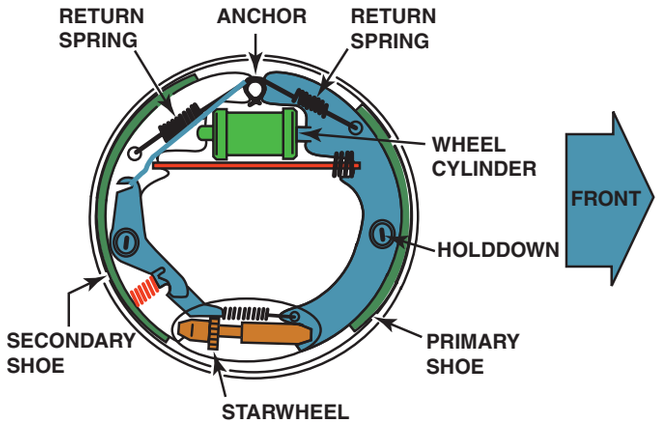

FIGURE 92–2 Typical drum brake assembly.

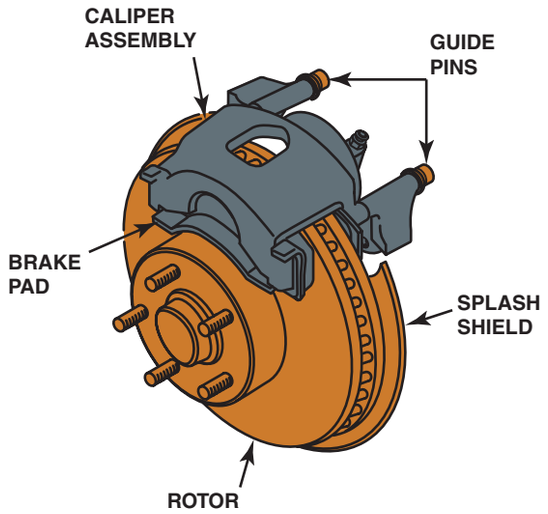

FIGURE 92–3 Typical disc brake assembly.

A disc brake operates by squeezing brake pads on both sides of a rotor or disc that is attached to the wheel. ● **SEE FIGURE 92–3.**

Type of Brake	Rotating Part	Friction Part
Drum brakes	Brake drum	Brake shoes
Disc brakes	Rotor or disc	Brake pads

Due to the friction between the road surface and the tires, the vehicle stops. To summarize, the sequence of events necessary to stop a vehicle include the following:

1. The driver presses on the brake pedal.
2. The brake pedal force is transferred hydraulically to a wheel cylinder or caliper at each wheel.
3. Hydraulic pressure inside the wheel cylinder or caliper presses friction materials (brake shoes or pads) against rotating brake drums or rotors.
4. The friction slows and stops the drum or rotor. Since the drum or rotor is bolted to the wheel of the vehicle, the wheel also stops.
5. When the wheels of the vehicle slow and stop, the tires must have friction (traction) with the road surface to stop the vehicle.

BRAKE DESIGN REQUIREMENTS

All braking forces must provide for the following:

- Equal forces must be applied to both the left and right sides of the vehicle to assure straight stops.
- Hydraulic systems must be properly engineered and serviced to provide for changes as vehicle weight shifts forward during braking. Hydraulic valves must be used in the hydraulic system to permit the maximum possible braking forces but still prevent undesirable wheel lockup. Antilock braking systems (ABS) are specifically designed to prevent wheel lockup under all driving conditions, including wet or icy road conditions.
- The hydraulic system must use a fluid that will not evaporate or freeze. The fluid has to withstand extreme temperatures without boiling and must not damage rubber or metal parts of the braking system.
- The friction material (brake shoes or brake pads) must be designed to provide adequate friction between the stationary shoes or pads and the rotating drum or rotor. The friction material should be environmentally safe. Nonasbestos lining is generally considered to be safe for the environment and the technician.
- The design of the braking system should secure the brake lining solidly to prevent the movement of the friction material during braking. It is this movement of the friction material that causes brake noise (squeal).
- Most braking systems incorporate a power assist unit that reduces the driver's effort but does not reduce stopping distance. The most commonly used brake booster is vacuum operated.

BRAKE SYSTEM CATEGORIES

Brake system components can be classified and placed into six subsystem categories, depending on their function. ● **SEE FIGURE 92–4** for an overall view of the entire braking system.

1. **Apply System.** The driver starts the operation of the braking system by pressing on the **brake pedal** or applying the **parking brake.** The apply system includes all the levers, pedals, or linkage needed to activate a braking force.
2. **Boost System.** The boost (power brake) system is used on most vehicles to reduce the force that the driver must exert on the brake pedal.
3. **Hydraulic System.** The brake pedal force is transferred to the hydraulic system, where the force is directed through lines and hoses to the wheel brakes.
4. **Wheel Brakes.** Hydraulic pressure from the hydraulic system moves a piston, in either a disc or drum brake system, which uses friction to press material against a rotating drum or rotor. The resulting friction slows the rotation of the wheels.
5. **Brake Balance Control System.** Mechanical, electrical, and hydraulic components are used to ensure that brakes are applied quickly and with balanced pressure for safe operation. Components in this category include metering valves, proportioning valves, and antilock braking system components.
6. **Brake warning lights.** There are two brake system-related warning lights.
   - The **red brake warning lamp (RBWL)** lights whenever a hydraulic system failure occurs. The red brake warning

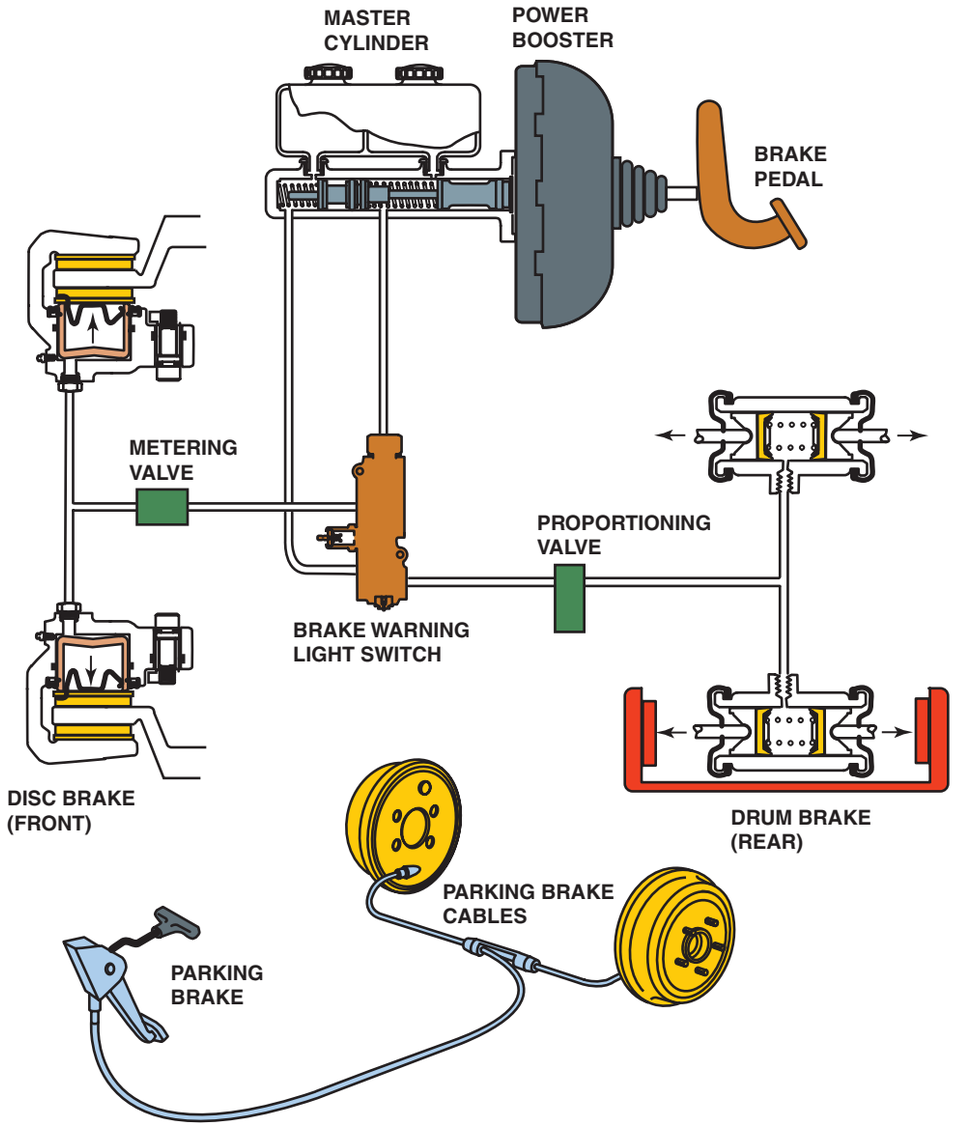

FIGURE 92–4 Typical brake system components.

lamp lights when the ignition is turned on as a bulb check then goes out unless a hydraulic fault has been detected. ● **SEE FIGURE 92–5**.

CAUTION: Do not test-drive a vehicle if the red brake warning light is on.

- The amber ABS warning lamp or dim red brake light indicates an ABS self-test and/or a possible problem in the ABS system. This warning light will usually flash several times during a self-test when the engine is first started and then go out unless a fault with the antilock braking system was detected.

FIGURE 92–5 The red brake warning light will remain on after a bulb test if there is a fault with the hydraulic part of the brake system.

ANTILOCK BRAKE SYSTEM OVERVIEW

The purpose of an **antilock braking system (ABS)** is to prevent the wheels from locking during braking, especially on low-friction surfaces such as wet, icy, or snowy roads. Remember, it is the friction between the tire tread and the road that does the actual stopping of the vehicle. Therefore, ABS does not mean that a vehicle can stop quickly on all road surfaces. ABS uses sensors at the wheels to measure the wheel speed. If a wheel is rotating slower than the others, indicating possible lockup (e.g., on an icy spot), the ABS hydraulic controller will reduce the brake fluid pressure to that wheel

for a fraction of a second. *A locked wheel has less traction to the road surface than a rotating wheel.*

The ABS controller can reapply the pressure from the master cylinder to the wheel a fraction of a second later. Therefore, if a wheel starts to lock up, the purpose of the ABS system is to pulse the brakes on and off to maintain directional stability with maximum braking force. Many ABS units will cause the brake pedal to pulse if the unit is working in the ABS mode. The pulsating brake pedal is a cause for concern for some drivers. However, the pulsing brake pedal informs the driver that the ABS is being activated. Some ABS units use an isolator valve in the ABS unit to prevent brake pedal pulsations during ABS operation. With these types of systems, it is often difficult for the driver to know if and when the ABS unit is working to control a locking wheel. ● **SEE FIGURE 92–7** for an overview of a typical ABS on a rear-wheel-drive vehicle.

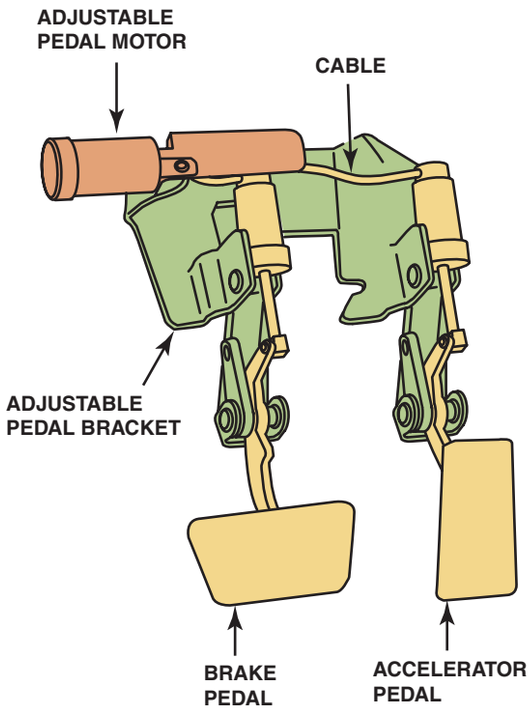

FIGURE 92–6 A typical adjustable pedal assembly. Both the accelerator and the brake pedal can be moved forward and rearward by using the adjustable pedal position switch.

? FREQUENTLY ASKED QUESTION

How Do Adjustable Pedals Work?

Adjustable pedals, also called **electric adjustable pedals (EAP),** place the brake pedal and the accelerator pedal on movable brackets that are motor operated. A typical adjustable pedal system includes the following components:

- **Adjustable pedal position switch,** which allows the driver to position the pedals.
- **Adjustable pedal assembly,** which includes the motor, threaded adjustment rods, and a pedal position sensor. ● **SEE FIGURE 92–6.**

The position of the pedals, as well as the position of the seat system, is usually included as part of the memory seat function and can be set for two or more drivers.

Another symptom of normal ABS unit operation is the activation of the hydraulic pressure pump used by many ABS units. In some ABS units, the hydraulic pump is run every time the vehicle is started and moved. Other types of units operate randomly or whenever the pressure in the system calls for the pump to operate.

FEDERAL BRAKE STANDARDS

The statutes pertaining to automotive brake systems are part of the **Federal Motor Vehicle Safety Standards (FMVSS)** established by the United States **Department of Transportation (DOT).** Several standards apply to specific components within the brake system. The overall service and parking brake systems are dealt within standard 135.

FMVSS 135 was first mandated on September 1, 2000, for passenger vehicles, and September 1, 2002, for multipurpose vehicles, trucks, and buses with a gross vehicle weight rating (GVWR) of

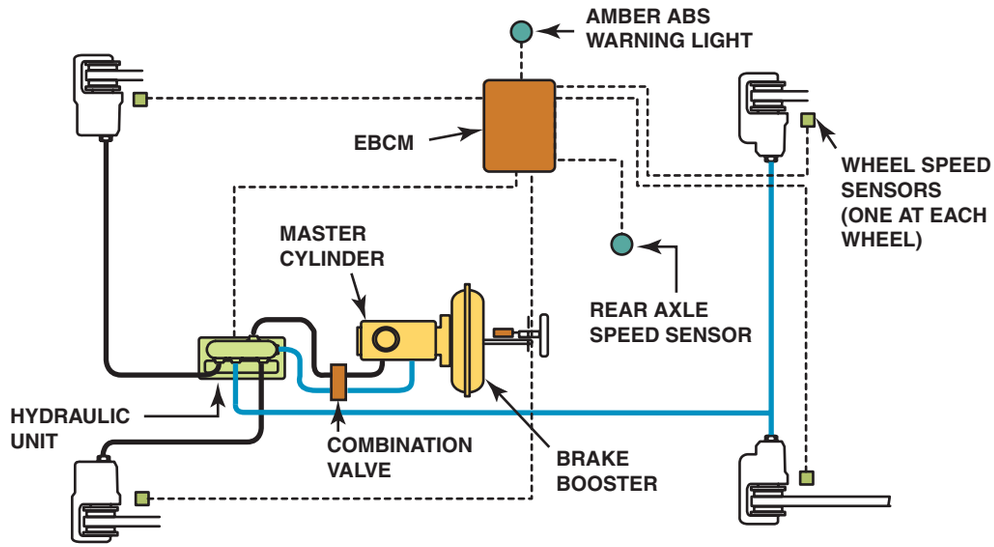

FIGURE 92–7 Typical components of an antilock braking system (ABS) used on a rear-wheel-drive vehicle.

7,716 pounds (3,500 kilograms). Its purpose is to "ensure safe braking performance under normal and emergency conditions." FMVSS 135 applies to "passenger vehicles, multipurpose passenger vehicles, trucks, and buses."

FMVSS 135 deals with brake system safety by establishing specific brake performance requirements. It does not dictate the *design* of the system, although some requirements may make older technologies impractical or obsolete. Only four parts of the brake system are specifically regulated:

- Fluid reservoir and labeling
- Dashboard warning lights
- A method of automatic adjustment
- A mechanically engaging, friction-type parking brake system

The FMVSS 135 tests are used by manufacturers to certify the braking performance of all new vehicles available for public purchase.

FMVSS 135 BRAKE TEST

The overall FMVSS 135 brake test procedure consists of up to 24 steps, depending on the vehicle's configuration and braking system. The actual performance tests are made with the vehicle loaded to both the manufacturer's specified **gross vehicle weight rating (GVWR)** and the **lightly loaded vehicle weight (LLVW),** with certain applied brake forces. There are precise instructions for every step of the test, including the number of times the tests must be repeated, the sequence of the testing, and the allowable stopping distance for the particular type of vehicle. Some highlights of the testing procedure include:

- **Burnish Procedure.** The brakes are burnished by making 200 stops from 50 mph (80 km/h) at a fixed rate of deceleration with a controlled cool-down period after each stop. This procedure conditions the friction material.
- **Adhesion Utilization (torque wheel method).** For vehicles not equipped with ABS, this test is to determine if the brake system will make adequate use of the road surface in stopping the vehicle.
- **Cold Effectiveness.** This test is performed to determine if the vehicle will have sufficient stopping power when the brake lining materials are not preheated by previous stops.
- **High Speed Effectiveness.** This test is performed to determine if the brake system will provide adequate stopping power for all loading conditions. The allowable stopping distance is calculated from the maximum speed the vehicle can attain.
- **Stops With the Engine Off.** This test is for vehicles equipped with brake power assist units. The vehicle, loaded to GVWR, must stop within 230 ft (70 m), from a speed of 62 mph (100 km/h). This test must be repeated six times.
- **Antilock Functional Failure.** This test ensures that service brakes will function correctly in the event of an antilock functional failure, and the brake system warning indicator is activated when an ABS electrical function failure occurs.
- **Variable Brake Proportioning System.** This test is performed on vehicles equipped with either a mechanical or an electrical variable proportioning system. It ensures that, in the event of a failure, the vehicle can still come to a stop in an acceptable distance.
- **Hydraulic Circuit Failure.** This test is performed to ensure that the driver will be alerted via the brake warning system indicator that a failure has occurred, and that the vehicle can still be stopped in an acceptable distance.

? FREQUENTLY ASKED QUESTION

Do the FMVSS 135 Standards Apply to Replacement Brake Part Performance?

No. The Federal Motor Vehicle Safety Standard 135 applies to new vehicles. Replacement parts used during a brake repair or replacement may or may not permit the vehicle to achieve the same standards as when new.

To help ensure like-new braking performance, the service technician should always use quality brake parts from a known manufacturer.

- **Brake Power Assist Unit Inoperative.** This test makes sure the service brake can stop the vehicle in an acceptable distance with the brake power assist unit in an inoperative state. It is performed on vehicles with brake power assist units turned off or inoperative.
- **Parking Brake.** The parking brake alone will hold the vehicle stationary in either the forward or reverse direction on a 20% grade for a period of at least 5 minutes.
- **Brake Heat Test.** This procedure heats the brake system by making a series of 15 stops from a high speed. The vehicle is loaded to GVWR, with rapid acceleration between each stop to minimize cooling the brakes.
- **Hot Performance.** After the brake system has been heated by a series of controlled stops, the hot performance test is immediately performed. The vehicle is loaded to GVWR and two stops are made. The stopping distance must be within acceptable limits as specified in the test. This test ensures that the brake system on the vehicle will not fade following a series of high-speed stops at GVWR.

Although these tests may seem extreme, these tests are only a minimum standard of performance. Any brake repair work should also leave the brake system capable of meeting FMVSS 135.

BRAKE REPAIR AND THE LAW

Once an automobile leaves the factory, the responsibility for maintaining the designed-in level of braking performance falls on the owner of the vehicle. Owners look to trained automotive technicians to service their brake systems. Many states have laws that regulate brake work to help ensure safe repairs. These laws vary from one area to another, but they may require special licensing for brake technicians, or special business practices when selling brake work. In some cases, the laws provide the consumer with specific warranties and the right to outside arbitration in cases of defective or substandard repairs.

Regardless of whether there are specific laws governing brake repair, a technician is always liable for damage or injuries resulting from repairs performed in an unprofessional or unworkman-like manner. Considering the lives and property that depend on good brakes, there is only one acceptable goal when making brake system repairs: to restore the system and its component parts so they perform to original specifications. In other words, *the purpose of any repair is to restore like-new performance.*

REVIEW QUESTIONS

1. List the differences between drum brakes and disc brakes.
2. List the six brake subsystem categories.
3. Explain how ABS units prevent wheel lockup.
4. List ten of the brake tests performed under the Federal Motor Vehicle Safety Standard (FMVSS) 135.

CHAPTER QUIZ

1. Disc brakes use replaceable friction material called _____.
   a. Linings **c.** Core
   b. Pads **d.** Web
2. Drum brakes use replaceable friction material called _____.
   a. Shoes **c.** Core
   b. Pads **d.** Web
3. Technician A says that a power-assisted brake reduces stopping distances compared with a nonpower-assisted brake system. Technician B says that the power-assisted brake system reduces the force that the driver must exert on the brake pedal. Which technician is correct?
   a. Technician A only **c.** Both Technicians A and B
   b. Technician B only **d.** Neither Technician A nor B
4. A locked wheel _____ to the road surface than a rolling wheel.
   a. Has less traction
   b. Has greater traction
5. Technician A says that all vehicles equipped with ABS will experience a pulsating brake pedal even during normal braking. Technician B says that ABS will result in quicker stops on all road surfaces. Which technician is correct?
   a. Technician A only **c.** Both Technicians A and B
   b. Technician B only **d.** Neither Technician A nor B
6. The FMVSS 135 standards determine _____.
   a. The design of the braking system
   b. The performance of the braking system
   c. The materials used in the braking system
   d. All of the above
7. An owner of a vehicle equipped with ABS brakes complained that whenever he tried to stop on icy or slippery roads, the brake pedal would pulse up and down rapidly. Technician A says that this is normal for many ABS units. Technician B says that the ABS unit is malfunctioning. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
8. Electric adjustable pedals operate _____.
   a. Parking brake only
   b. Accelerator pedal only
   c. Brake pedal only
   d. Both the accelerator and brake pedal
9. All of the following are specified by the FMVSS 135 *except*:
   a. Brake burnish procedure
   b. Variable brake proportioning system
   c. Brake noise levels
   d. Cold effectiveness
10. What is the purpose of any brake repair?
    a. Reduce noise during braking
    b. Replace pads and linings
    c. Restore proper brake pedal height
    d. Restore like-new performance