## OBJECTIVES

When you have completed this chapter you should be able to:

- Define ABS and explain how it works.
- Explain the major differences between ABS systems.
- List four ABS service procedure basics.

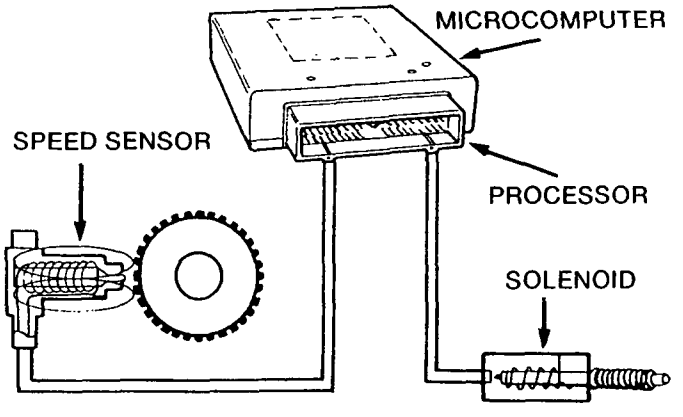
### THE ANTI-LOCK BRAKE SYSTEM

Although it only affects the system a small percentage of the time, the anti-lock brake system (ABS) is one of the most important innovations in brake systems in recent years. Because of its price — $1,000 - $1,500 for a four-wheel system — they are currently being used only on top-of-the-line cars and some Ford and GM trucks. Some light trucks are using the less expensive two-wheel systems.

ABS prevents wheel lockup, which in turn helps the driver maintain control of the car by maintaining contact between the tire tread and the road.

In bad weather, this may mean the difference between a safe stop and a collision. In good weather, it prevents dragging the tires and creating flat spots.

The ABS systems doesn't work at all during normal braking. It is activated by its sensors indicating that one wheel is slowing more quickly than the others. In the event of a malfunction in the ABS, the on-board computer disables the systems and the brakes work normally. An indicator light warns the driver that the system has been disabled.



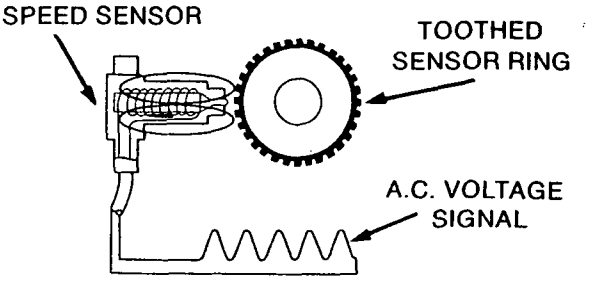

*(Figure 74) The major components of the ABS system.*

### HOW THEY WORK

Current anti-lock brake systems (Kelsey-Hayes, Bosh, and Teves) are all electronic, controlled by an on-board computer. The computer recieves data from the wheel speed sensors and the electrical components. It also checks and monitors the ABS system, disabling it in the event of a malfunction and lighting the warning light.

The systems use solenoid valves to modulate hydraulic pressure to the brakes, creating an effect similar to the driver pumping the brake pedal very quickly. The system's electrically activated solenoids, however, "pump the brakes" 10 to 14 times a second, much quicker than the driver can. The action of the solenoid, like the driver's pumping the brake, maintains traction while slowing the car.

In addition to the hydraulic brake system found on the automobiles, the ABS system has two major parts, the wheel speed sensors and the solenoids.




*(Figure 75) The wheel speed sensor uses electric current to measure wheel rpm's.*

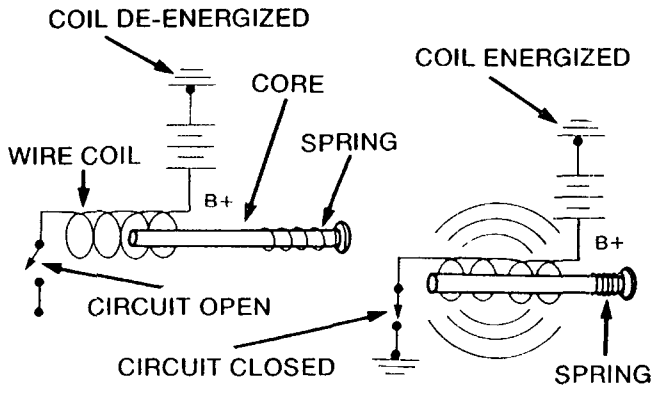
Wheel speed sensors, providing the electrical inputs to the computer, consist of magnetic pickups that have a wire wrapped around a magnetic core, creating a magnetic field around the coil. When the toothed sensor ring (see drawing above) attached to the wheels rotates through the field, it is disturbed, generating electric voltage in the wire coil.

The computer reads the input from the wheel sensor, compares it to instructions preprogrammed into its memory, and if it anticipates wheel lock, it immediately activates the solenoid connected to that wheel.

The solenoids convert the electrical current to mechanical motion by opening and closing an electric switch. The solenoid consists of a wire coil with a movable core and return spring. When the switch is closed, current flows through the coil, creating a magnetic field that causes the core to move and, by moving, compress the return spring. When the circuit is de-energized, the spring pushes the core to its original position. By alternately energizing and de-energizing the coil, the system rapidly moves the core back and forth, "pumping" the brakes.



PLAINTIFF'S EXHIBIT 35




*(Figure 76) Solenoid operation: In the drawing at left, the circuit is open (coil de-energized) and the core is in the resting position. At right, the circuit is closed, energizing the coil and causing the core to move forward.*

**TYPES OF ABS SYSTEMS**

The three types of anti-lock braking systems in use today are the Teves, the Bosch and the Kelsey Hayes. In this section we will consider the differences between the systems.

**TEVES ABS:** The Teves system uses a primary and secondary piston to each front brake, supplying the rear brakes hydraulically by a modulated booster system. Inside the Teves unit, the reaction sleeve pushes the brake pedal back during anti-lock braking.

The system's main valve is located at the end of the master cylinder and is controlled during anti-lock stops by the computer. When the solenoid is energized, accumulator pressure fills the area behind the master cylinder pistons and in front of the reaction sleeve.

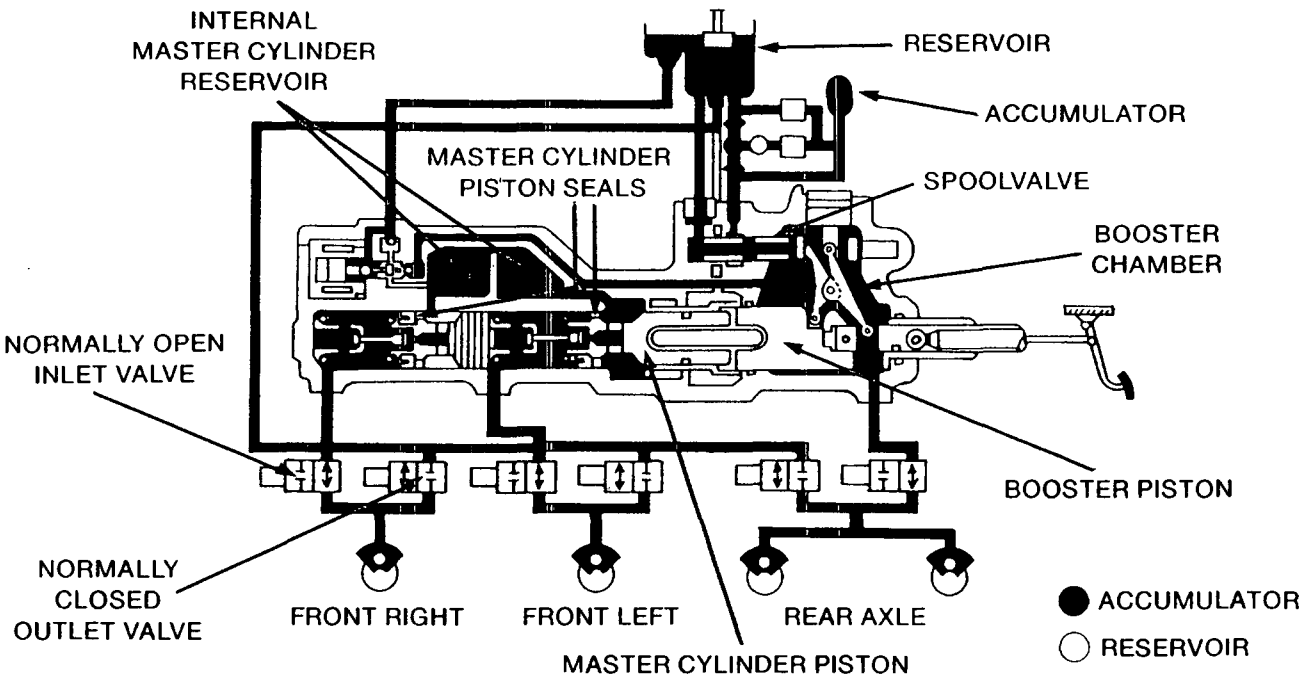
A valve block, bolted to the side of the master cylinder, contains the three pairs of solenoids controlled by the computer (one pair for each of the front wheels and the third pair for the rear wheels). Each valve pair consists of a normally open inlet valve and a normally closed outlet valve.

The hydraulic booster, consisting of an electro-hydraulic pump, pressure sensing switch and an accumulator, modulates the accumulator pressure for power brakes and rear brake applications. The booster control valve is operated by a lever mechanism connected to the brake pedal push rod.

The accumulator is charged by the pump with brake fluid pressure in the range of approximately 2200 to 2610 psi. The low pressure switch activates the hydraulic pump at pressures below 2200 psi.

In the normal unapplied position, the system is set as follows:

- The accumulator is charged and high pressure is applied to the control valve. The booster control valve blocks the accumulator pressure from the rear brake circuit and booster piston.




*(Figure 77) The Teves ABS System*

- Internal reservoirs and normally closed outlet valves are venting pressure to the reservoir.
- The master cylinder pistons are in the open position, venting pressure to the internal reservoir.

When the brakes are applied for a normal stop, the movement of the pedal is transferred through the lever mechanism to the control valve. The control valve opens and allows regulated accumulator pressure in the boost chamber. The pressure in the boost chamber goes to the rear brakes and pushes against he boost piston and reaction sleeve, actuating the master cylinder pistons. The fluid under pressure to the front and rear brakes is directed through the open solenoids. Closed solenoids trap the fluids, applying the brakes.

When the microcomputer determines that a wheel lock is about to occur, two things happen:

1. The normally open solenoid for that wheel is closed.
2. The main valve is energized, opening the area behind the master cylinder pistons to accumulator pressure. When the normally open solenoid is momentarily opened to increase pressure, accumulator pressure rushes through the holes in the master cylinder pistons, reaction sleeve, booster piston and brake pedal.

The driver must apply the right amount of pressure during the stop. Anti-lock brake pressure, like regular braking, is proportionate to pedal pressure, and the computer cannot compensate for driver error.

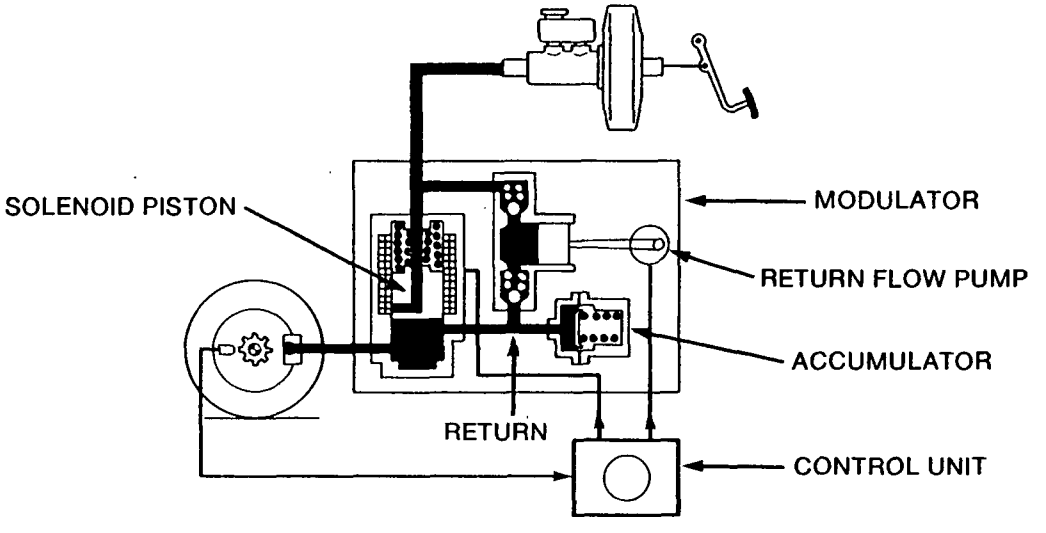
**BOSCH ABS:** The Bosch ABS II system has three solenoids, and the anti-lock system controls the front brakes independently through half the master cylinder and two solenoids. The rear brakes are controlled together through the other half of the master cylinder and one solenoid.

The Bosch III system uses four solenoids and controls each wheel independently, using half the master cylinder and two solenoids for the front and the remainder for the back.

In either of the Bosch systems, the solenoids are incorporated into the hydraulic modulator. They each have three positions — pressure building, pressure holding, and pressure drop. These pressure positions adapt to the braking requirements and control the friction between the road surface and tires.

The modulator also has two accumulators for each brake circuit. They store fluid pressure during the pressure drop cycle, and an electric motor returns brake fluid to the primary circuit from these accumulators. This allows the pressure to drop.

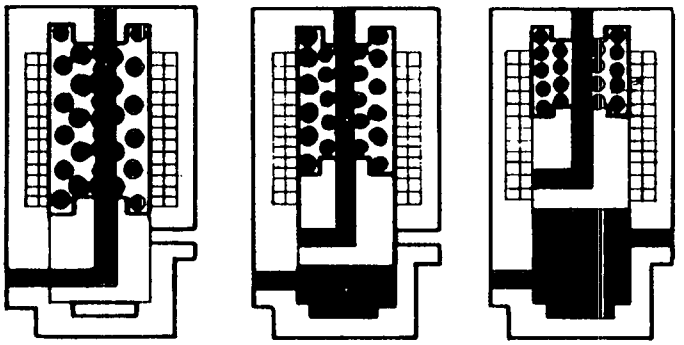
When the brakes are applied, the solenoid valves are de-energized, putting the solenoids in a pressure building position. Brake fluid is pumped from the master cylinder to the calipers. If pressure builds up and lockup is occurring, the solenoid switches to its center position (pressure holding), maintaining but not increasing pressure. If the wheel speed decreases, the solenoid reduces pressure further by moving to its third position — pres-




*(Figure 78) The Bosch system.*

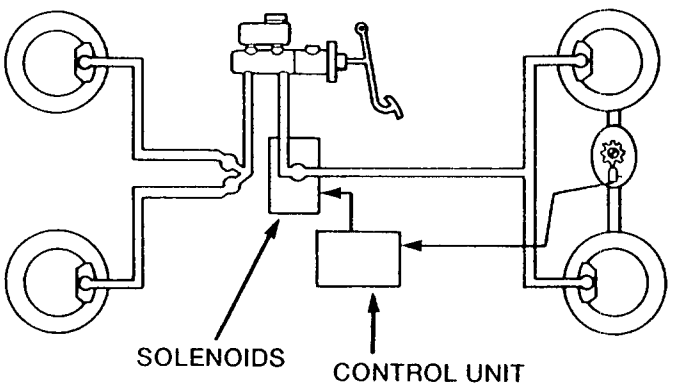
sure drop. If the wheel speed does not decrease, it moves back to its pressure build position.

Systems with one solenoid for rear brake control are set on the "select low" principle. This means that the wheel with the lower tire-to-road friction coefficient determines the level of control.




*(Figure 79) The three positions of the Bosh solenoid: 1) Pressure building 2)Pressure holding and 3) Pressure drop.*

**KELSEY-HAYES SYSTEM:** The Kelsey-Hayes system is used on certain models of Ford and GM trucks. In this system, the brake system is essentially unchanged. Added to the brake system are an electro-hydraulic control valve, a rear wheel speed sensor and the control module.




*(Figure 80) The Kelsey-Hayes ABS System*

The electro-hydraulic control valve is connected into the rear brake circuit. It has two solenoids, activated by the control module, that control the apply and release of hydraulic pressure during an ABS braking situation.

During normal operations, the control module monitors rear wheel speed through a sensor and toothed ring on the rear axle. If a lockup is going to occur, the control module activates the control valve solenoid, causing the isolation valve to close and cutting off fluid pressure to the rear wheels. The dump valve solenoid is activated by the module only if lockup is still going to occur. A series of rapid pulses of the solenoid will bleed off pressure from the wheel cylinders into a spring-loaded accumulator piston.

If a lockup no longer exists, the isolation valve solenoid opens, allowing pressure to the rear brakes is a series of re-apply pulses. When the brakes are released, the accumulator spring pushes the piston back in the bore, and the brake fluid is returned to the master cylinder.

## SERVICE CONSIDERATIONS

Each anti-lock system has its own service procedures, and each system may vary from application to application. Follow the manufacturers' recommendations for the specific system and application.

Each system may be checked if there is a malfunction. Troubleshooting does require special testers, pinout boxes, and a digital OHM/Volt meter.

At this time, original equipment manufacturers are using only DOT 3 brake fluid in the system. Silicone brake fluid is not recommended.

The control module in the ABS system may be damaged by electrical surges or heat. Potential dangers include welding with an electrical unit, and fast charging for starting the engine. In the case of welding, unplug the control module. For fast charging, the battery should be disconnected from the electrical system. However, the battery should not be disconnected while the engine is running.

Keep in mind that the foundation brake system remains unchanged and that ABS does not compensate for a poorly maintained brake system and worn, under or over inflated, or misaligned tires. For the ABS system to do its job, all of the functioning parts between the brake pedal and the road must be properly maintained.

## SUMMARY

The anti-lock brake system is an important advance in automotive safety, and will undoubtedly become standard equipment on more and more cars and trucks. In this chapter, we have covered the basic design of the three systems in common use today and examined their major components.