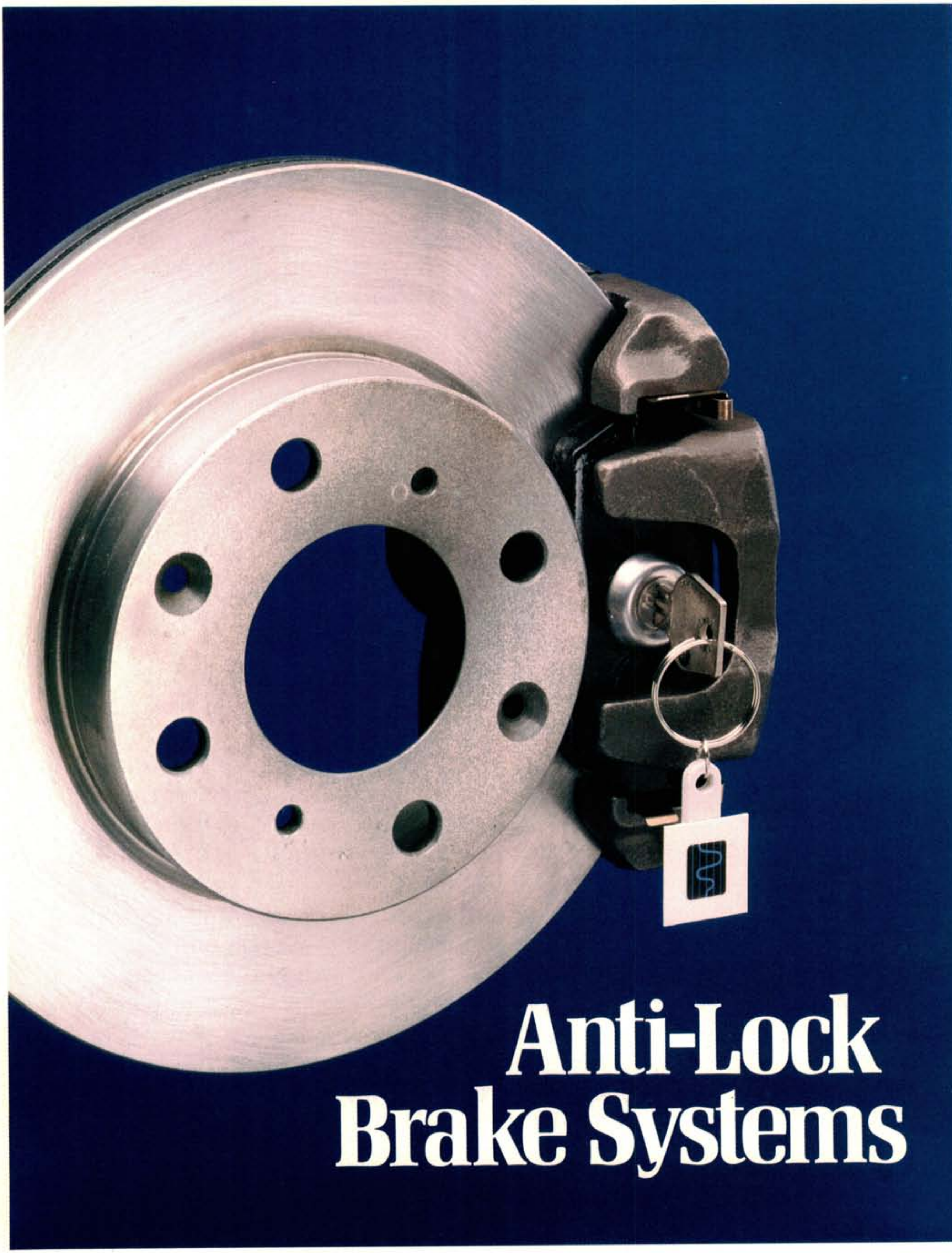
IMPORT SERVICE



Anti-Lock Brake Systems

According to an old automotive legend, the first Anti-lock Braking System (ABS) was installed on a small number of specially equipped Lincoln models back in 1954. These cars probably amounted to less than one percent of total automotive production for the year. As recently as 1988, approximately 30-40 percent of all imported cars were equipped with ABS.

The number of ABS-equipped cars is sure to climb as less expensive systems are installed on lower priced models. Because of its obvious safety advantages, ABS may be available on the majority of import and domestic cars before much longer.

If you're a full service import repair specialist, sooner or later someone is going to ask you to repair the ABS on their imported car or truck. Whether it's an ABS warning light that stays lit, or a car that just doesn't seem to stop like the owner thinks it should, it will be your job to unlock the system's secrets and repair the problem.

Ready When You Aren't

Have you ever found yourself on slick pavement when you needed to slow down in a hurry? Slamming on the brakes might buy you a one way ticket to the bottom of a ravine. An experienced driver knows that carefully pumping the brakes will usually bring the car to a safe stop under these conditions.

But what if there isn't enough time or distance to do the job yourself? What if the idiot in front of you just slammed on his brakes while traveling over the same stretch of slick pavement? If you don't slow down in a hurry, you're going to end up hitting him as he slides all over the road in front of you.

ABS can do the same thing that you might try to do with your foot, but it can do it as often as 15 times per second (faster on some systems). Try moving your foot that fast. ABS really shines when the road surface is wet or slick. Under these conditions, ABS can reduce stopping distances by as much as 25 to 40 percent. It can also decrease stopping distances by as much as 10 to 15 percent on dry pavement.

Making a comparison might help to explain why temporarily releasing, then re-applying the brakes can stop a car more quickly. Instead of rapid deceleration (braking), think about rapid acceleration for a moment.

If you've ever driven a really powerful car, you know that standing on the gas when the light turns green will give you a cloud of smoke and squealing tires. The only thing that will be going fast is the gasoline you're wasting.

Most of the engine's power isn't making it to the ground to accelerate the car, it's being wasted as wheel spin. The tires can't handle all of the engine's power all at once. You'll probably accelerate more quickly by stepping on the gas smoothly, so that more of the engine's power is transferred to the ground through the tires.

The same thing happens when you jump on the brake pedal as hard as you can. The brake system can deliver more stopping power to the wheel cylinders than the tires can transfer to road. So the tires lose their grip on the road and start to skid. The wheel cylinders have a tight hold at each wheel, but none of that grip is being transferred through the tires to the ground.

ABS temporarily holds the brake pressure steady, or releases it to the locked up wheel cylinder. This lets the wheel start turning again, giving the tire a chance to regain its grip on the road.

But remember that ABS spends most of its time waiting to do its job. Although the system is ready for work soon after the ignition switch is turned on, the ABS control unit can't do anything until you close the brake light switch contacts by stepping on the brake pedal.

Also, ABS was never intended to take the place of sensible driving habits. It's not a cure all for automotive irresponsibility. If you like to fly into corners at 90 MPH and wait until the last possible second to apply the brakes, don't count on ABS to bail you out.

How Many Channels?

It seems that each new electronic automotive system comes equipped with its own special language. ABS is no different in this respect, although the list of new vocabulary words is pretty short. Channel is one word that you should understand, and we're not talking about the white cliffs of Dover either.

- **Four Channel Systems**

Some systems control the braking at all four wheels individually. These are called four channel systems because each of the four wheels is monitored and controlled on its own separate channel.

- **Three Channel Systems**

Less complicated three channel systems have separate channels for each front wheel, but monitor and control both rear wheels as a pair. Rear wheel drive three channel systems pick up the rear wheel speed signal at the differential or driveshaft, giving the ECU an average signal for both rear wheels.

Front wheel drive three channel systems have a speed sensor at each rear wheel. But if either of the rear brakes begins to lock, ABS will control the braking to both rear wheels as a pair. This helps the driver maintain vehicle control during ABS operation.

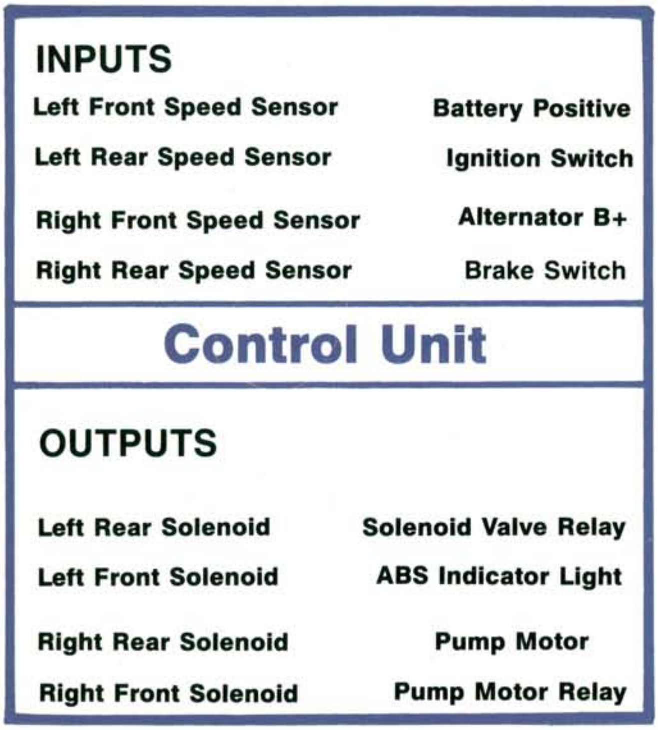
- **Single Channel Systems**

Some systems monitor and control the braking at the rear wheels only, using a single channel. Front wheel braking is not under ABS control on these systems. Single channel systems are usually found on light duty trucks and utility vehicles.

System Schematic

ABS uses operating principles that are very similar to those found in computer controlled engine management systems. The ABS electronic control unit (ECU) listens to information from its input sensors, then controls the system through its output actuators. Some ABS components even look like they were borrowed from an engine management system.

Illustration One shows a simplified ABS electrical schematic. Use this illustration to familiarize yourself with the system's main components. We'll cover some of the components in greater detail as we go along.



Fortunately, ABS has fewer inputs and outputs than you'll find in an engine management system. Take a look at the input sensors in the illustration first. The ECU monitors signals from:

- **the speed sensors**
- **the ignition switch**
- **the brake switch**
- **the alternator.**

Some systems may have more inputs than we have shown here, but these are the most important.

This simplified system has only a handful of important outputs. The ECU outputs include:

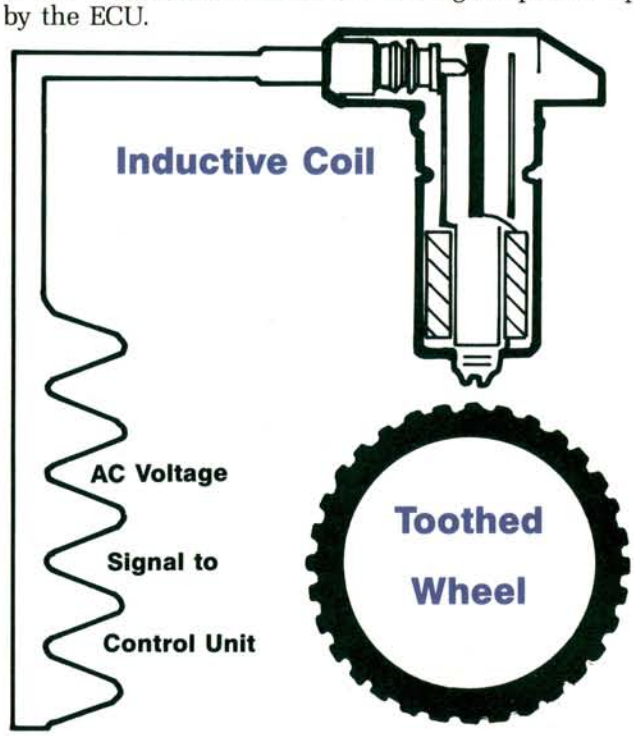
- **the four brake fluid pressure control solenoids in the ABS hydraulic modulator**
- **the solenoid valve relay**
- **the pump motor relay**
- **the ABS indicator light.**

We'll give our system self-diagnostic capability too. The light will also flash trouble codes from the ECU's memory when the system is switched into its self-diagnostic mode.

Speed Sensors

Let's take a closer look at the main input sensors in our ABS electrical schematic. The speed sensors work like small generators. Each sensor contains a permanent magnet, a winding, and a metal yoke. The speed sensor is mounted near a toothed wheel which turns along with the road wheel.

The speed sensor generates a weak alternating current as the toothed wheel moves past the sensor magnet. The frequency of the sensor current changes in direct relation to the turning speed of the toothed wheel. The sensor's electrical message is picked up by the ECU.



Correct speed sensor placement is very important. The weak alternating current generated by the sensor gets even weaker if the sensor is too far away from the toothed wheel. Toothed wheel run out may damage the sensor if it's mounted too close to the toothed wheel. Any dirt or debris between the sensor and toothed wheel will also affect the sensor's signal accuracy. Most manufacturers specify a required clearance gap between the sensor and toothed wheel.

Generation Gap

Up to this point, we've described the operation of second generation systems (ABS II). ABS II systems are produced by several different manufacturers, although their operating principles are very similar. But like anything automotive, the engineers weren't content to stick with a good thing. A new generation is beginning to take over for ABS II on newer models. We'll call these new systems ABS III.

While earlier ABS II systems were "added on" to the car's existing brake system, the latest generation ABS III systems are built right into the conventional brake system. Components are more compact, so the system actually looks less complicated.

One example is the way newer ABS III systems produce power assist. Most ABS II systems have a conventional vacuum operated brake booster. Some ABS II systems (like BMW's) substitute a hydraulic pump to make pressure for power assisted brakes.

Later ABS III systems use an electric pump to generate the power assist, so there's no need for a vacuum booster or engine driven hydraulic pump. The electric pump is located in the master cylinder assembly, and can generate pressures up to 2600 PSI.

This pressure is stored in a hollow, high pressure sphere called an accumulator. The accumulator stores the hydraulic pressure until it's needed for power assist during braking. If the accumulator pressure drops below a preset minimum, the electric pump switches on to build it back up.

Operation of the other components on ABS III systems is very similar to earlier ABS II systems.

Hydraulic Modulator

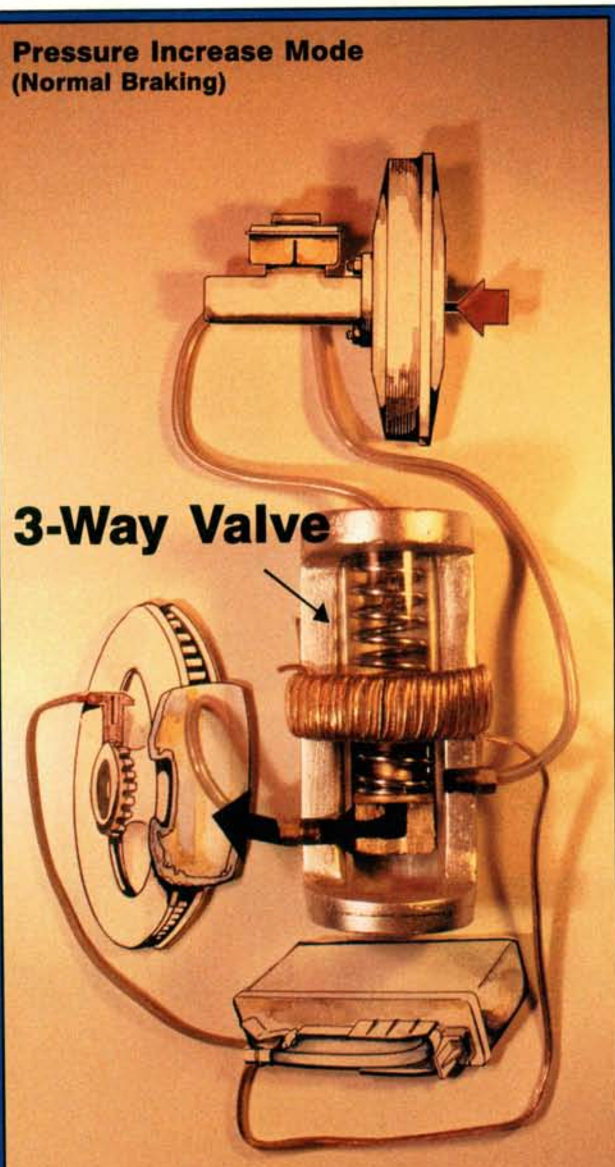
When a speed sensor tells the control unit that one wheel is braking more quickly than the others, it's time for the ABS system to respond. The wheel may be losing traction and about to lock up. The ABS control unit commands the hydraulic actuator to adjust the brake fluid pressure to the wheel that's losing traction, helping the driver maintain control of the vehicle.

The hydraulic actuator goes by different names, depending on the system's manufacturer. A couple of its more common names are the brake actuator or hydraulic modulator unit. To avoid confusion, we'll stick with hydraulic modulator unit, or modulator unit for short.

The number of three way valves contained in the modulator unit will vary, depending on the number of channels the system has. The following illustrations show how each three way valve controls the flow of brake fluid to 1) apply, 2) hold, or 3) release the brake cylinder.

During ABS operation, each of the three way valves in the hydraulic actuator could be in any of the three positions shown. The ECU can change the position of the three way valves as often as 15 times per second on most systems. These rapidly repeated apply, hold, and release cycles prevent lock up at any of the wheels controlled by the ABS control unit.

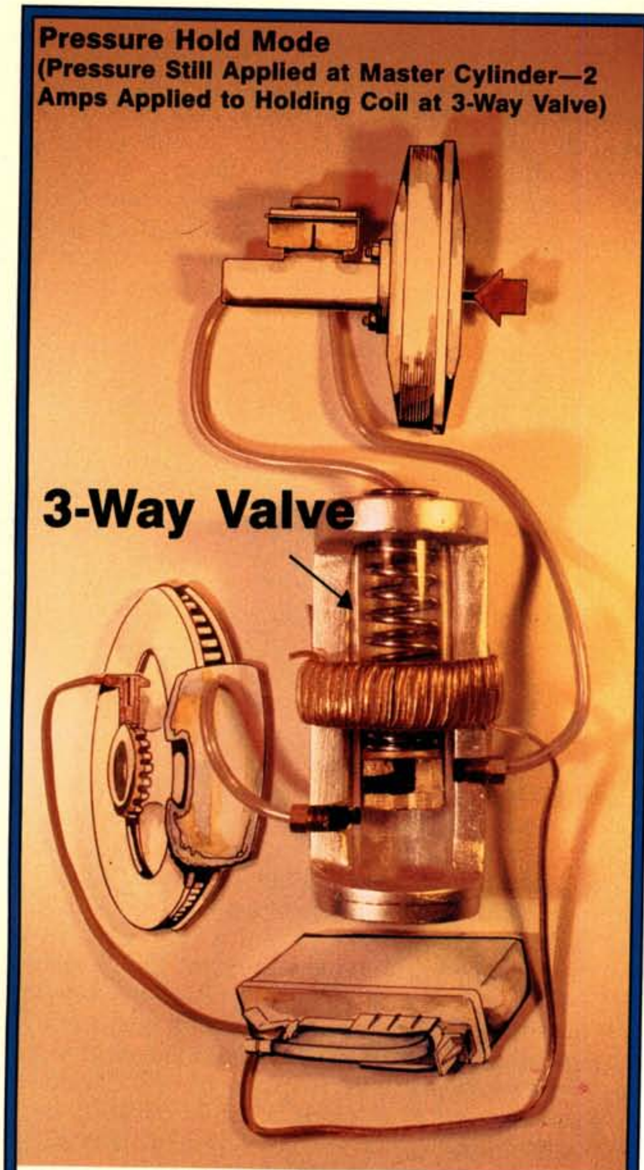
The change in valve position takes place so rapidly that the driver may not even know that the system is doing its job. His only clue might be a pulsation in the brake pedal as the three way valves apply, hold, and release the fluid pressure to each of the wheel cylinders in the system.



Pressure Increase Mode

Figure One shows the three position valve in the pressure increase mode.

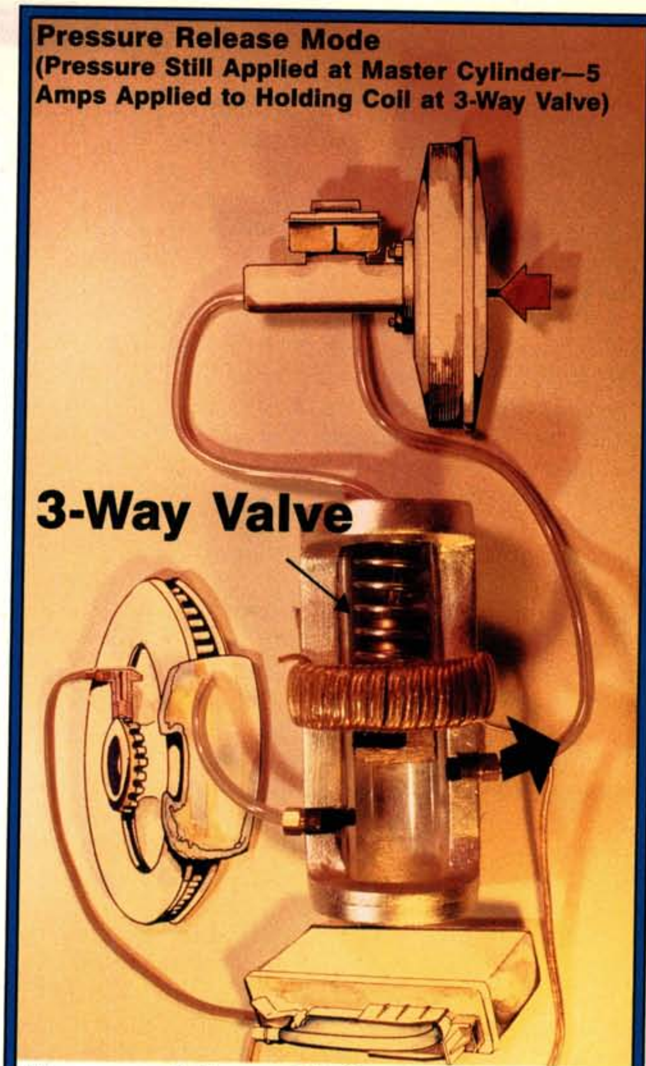
- **Hydraulic pressure from the brake master cylinder flows past the open check ball at the inlet side of the valve.**
- **No voltage is applied to the holding coil in the valve, so the passage stays open.**
- **Fluid pressure passes through an opening in the valve and passes directly to the brake line feeding the wheel cylinder.**
- **The wheel cylinder is receiving the full pressure from the master cylinder. Thiş is the position that the three way valve maintains under conditions that don't require ABS braking.**
- **The valve will also stay in this position if the ECU detects a problem in the system and switches to fail-safe operation.**



Pressure Holding Mode

When the speed sensor signal tells the ECU that the wheel is about to lock up, it switches the three way valve to the pressure holding mode shown in Figure Two.

- **A two amp current from the control unit energizes a holding coil to move the three way valve. This closes both the upper and lower passages, trapping the existing fluid pressure in the brake lines.**
- **The fluid has nowhere to go, so pressure is maintained in the line to the wheel cylinder.**
- **The fluid pressure to the wheel cylinder remains constant, and braking to the wheel is also maintained at a fixed value.**
- **The driver can press as hard as he wants on the brake pedal, but no additional fluid pressure can reach the wheel cylinder.**
- **This keeps the brake from locking and allows the wheel to keep turning, maintaining steering and braking control.**



Pressure Release Mode

Figure Three shows the three way valve in the pressure release mode. In this mode, the speed sensor signal has warned the ECU that the wheel is still trying to lock up.

- **The ECU now applies a five amp current to the holding coil, moving the three way valve to its final position.**
- **The valve continues to block the upper passage, stopping the fluid pressure from the master cylinder. Remember, the driver is still standing on the brake pedal.**
- **Residual fluid pressure in the line leading to the wheel cylinder is reduced because the three way valve also opens the vent passage.**
- **When the fluid pressure is reduced, the wheel cylinder releases, keeping the wheel from locking up.**
- **A small amount of vented brake fluid fluid leaves the three way valve during the pressure release mode. The fluid is collected by a small pump which operates whenever ABS is in use. The pump returns the vented fluid from the hydraulic actuator to the master cylinder reservoir.**

ABS Troubleshooting

The first indication of an ABS problem will probably be the ABS dashboard indicator light. The indicator light should light when the ignition is first switched on, along with the other dashboard warning lights. Once the engine is started and the ECU has run through its system checks, the warning light should go off.

If the light stays on, it means the ECU has detected a fault in the system. Some systems require dedicated test equipment to help you find where the problem is located. Other systems can store self-diagnostic codes when the ECU detects a problem. Many self-diagnostic systems can be repaired without dedicated test equipment, using the diagnostic flow charts in the service manual.

While we can't cover the diagnostic and troubleshooting procedures for every variety of ABS in one article, there are several important tips we would like to pass along. Most are common sense checks and procedures that may get overlooked because the system is still new and unfamiliar to many technicians.

Checking the following items first may save you a lot of unnecessary diagnostic time:

- **Check the brake fluid level.** It may seem obvious, but low fluid level, and/or external leaks can cause low hydraulic pressure. If the system is equipped with a fluid level sensor, low fluid will probably cause the ABS warning light to light as well.
- **Add the right brake fluid.** Always use the brake fluid recommended by the manufacturer. If the manufacturer specifies DOT 3 fluid, make sure you use only DOT 3.
- **Check for contaminated brake fluid.** Following the recommended brake fluid change intervals is an often overlooked maintenance item. Clean brake fluid is especially important on ABS-equipped cars because of the high pressures the fluid is exposed to. Any water or other contamination in the brake fluid will keep the system from operating properly, and may cause internal damage to the ABS and regular brake system components.
- **Inspect the condition of all brake system hydraulic components.** Leaking or rusted brake lines or other damaged components are bad enough on a non-ABS brake system. There's even less room for this on an ABS-equipped car. The system's high fluid pressures would quickly turn a small leak into a big problem.
- **Check for dragging brakes.** The ABS control unit can be fooled by sticking calipers or wheel cylinders, rusted or misadjusted parking brake cables, or other brake component problems. Any of these can cause uneven braking, which can trick the ECU into thinking that one of the wheels is losing traction.
- **Follow recommended service safety precautions.** ABS III systems can maintain very high line pressures, even after the engine is off. Make sure you have safely relieved this pressure, using the recommended procedures, before you open any fluid lines.
- **Use correct brake bleeding procedures.** There are many places for air bubbles to hide in an ABS brake system. Air in the lines will cause uneven braking, which will also affect ABS operation. Always bleed the brake lines using the manufacturer's recommended bleeding sequence. This may involve as many as eight or nine steps in some cases.
- **Check rotor finish and use the recommended procedures to break in new friction linings.** Anything that gives one wheel better braking ability than others can cause ABS problems. This can be something as simple as a freshly resurfaced rotor that has a different finish than the others, or a set of brake pads that hasn't been properly broken in after replacement.
- **Don't mix and match brake pads.** Mixing brake pads from different manufacturers or using pads with different friction coefficients is another possible source of ABS problems. Mixing different pads from side to side or front to rear could make the wheels decelerate at slightly different rates during braking, fooling the ECU.
- **Check for incorrect tire size.** This is probably one of the most common causes of ABS problems. Substituting the wrong size tires, or using tires that have the wrong outside diameter will cause the wheels (and toothed sensor wheel) to rotate at a speed that's different from the other wheels. The ECU will pick up this constant speed difference and throw the system into fail-safe operation, disabling the ABS function.
- **Correct any electrical supply or ground problems.** Make sure all of the fuses which protect the ABS are good. You can't expect the system to work if it's not getting power to all of its circuits. Intermittent problems may be caused by corroded or damaged electrical connectors. Poorly mated connectors can also cause intermittent problems. Also check the system's ground connections to the vehicle body. Poor ground connections can prevent relays, the hydraulic modulator, or pump motor from operating. Repair any ABS wiring that's shorted or damaged.
- **Do a thorough visual inspection to find any damaged ABS components.** The ABS speed sensors and toothed sensor wheels have to live out in the elements and can be damaged by road debris. Check for chipped, warped, or loose sensor wheels. Check the speed sensor tips for damage. Also look for speed sensor wiring connector corrosion or damage.

—By John Bradley and Karl Seyfert