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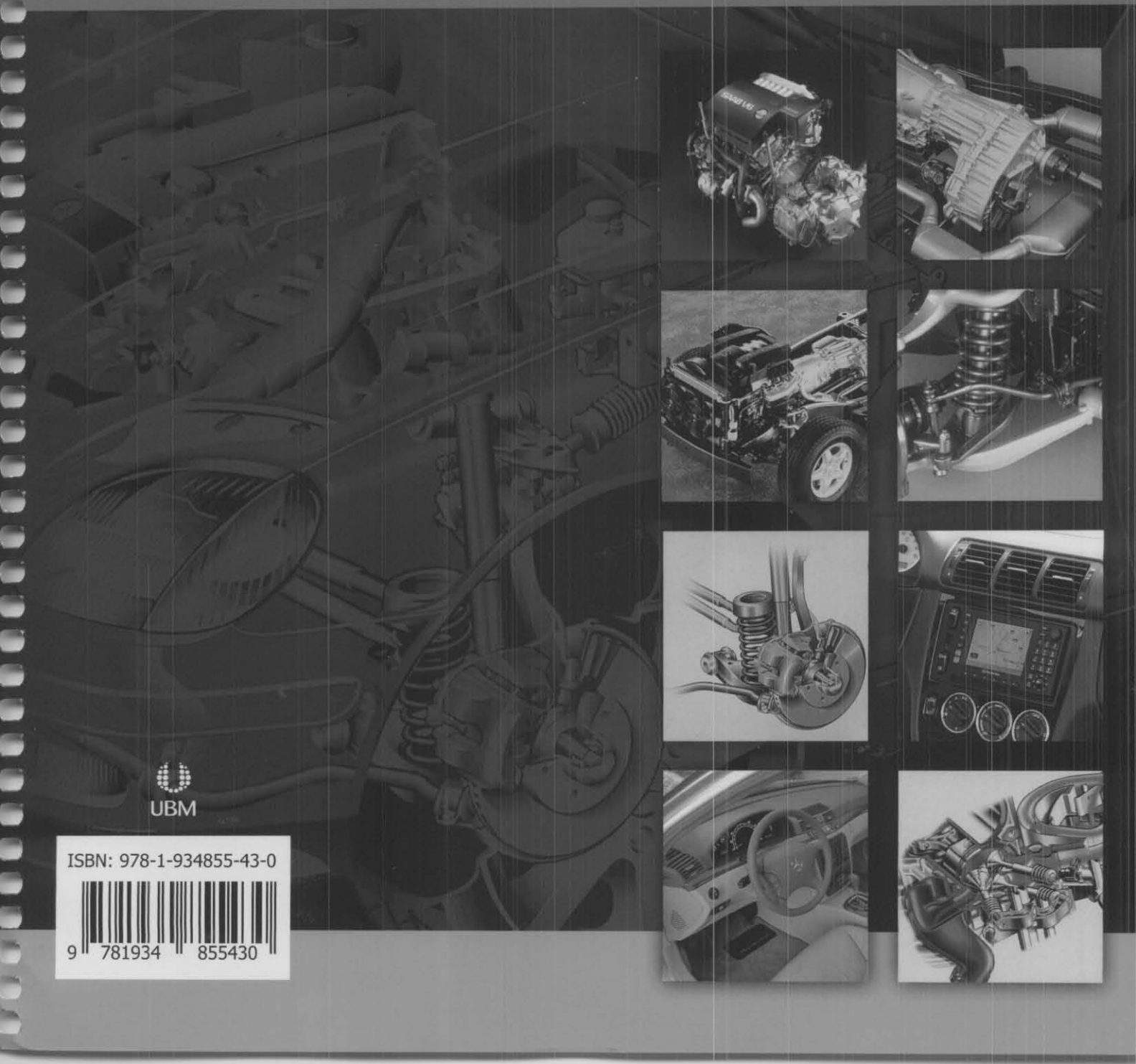
# A5 Brakes



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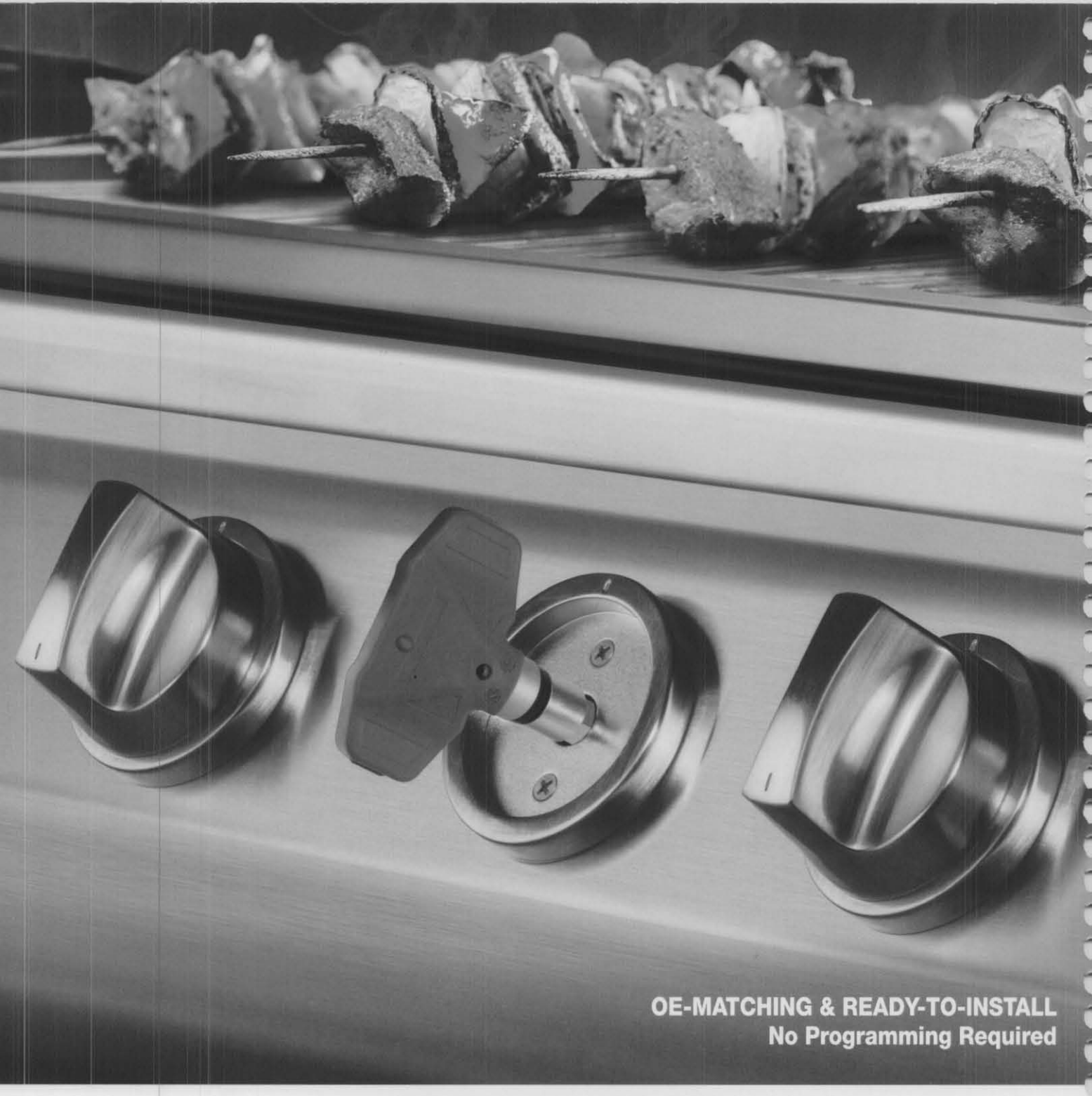


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# Taking An ASE Certification Test

This study guide will help prepare you to take and pass the ASE test. It contains descriptions of the types of questions used on the test, the task list from which the test questions are derived, a review of the task list subject information, and a practice test containing ASE style questions.

## ABOUT ASE

The National Institute for Automotive Service Excellence (ASE) is a nonprofit organization founded in 1972 for the purpose of improving the quality of automotive service and repair through the voluntary testing and certification of automotive technicians. Currently, there are over 400,000 professional technicians certified by ASE in over 40 different specialist areas.

ASE certification recognizes your knowledge and experience, and since it is voluntary, taking and passing an ASE certification test also demonstrates to employers and customers your commitment to your profession. It can mean better compensation and increased employment opportunities as well.

ASE not only certifies technician competency, it also promotes the benefits of technician certification to the motoring public. Repair shops that employ at least one ASE technician can display the ASE sign. Establishments where 75 percent of technicians are certified, with at least one technician certified in each area of service offered by the business, are eligible for the ASE Blue Seal of Excellence program. ASE encourages consumers to patronize these shops through media campaigns and car care clinics.

To become ASE certified, you must pass at least one ASE exam and have at least two years of related work experience. Technicians that pass specified tests in a series earn Master Technician status. Your certification is valid for five years, after which time you must retest to retain certification, demonstrating that you have kept up with the changing technology in the field.

## THE ASE TEST

An ASE test consists of forty to eighty multiple-choice questions. Test questions are written by a panel of technical experts from vehicle, parts and equipment manufacturers, as well as working technicians and technical education instructors. All questions have been pre-tested and quality checked on a national sample of technicians. The questions are derived from information presented in the task list, which details the knowledge that a technician must have to pass an ASE test and be recognized as competent in that category. The task list is periodically updated by ASE in response to changes in vehicle technology and repair techniques.

There are five types of questions on an ASE test:

- **Direct, or Completion**
- **MOST Likely**
- **Technician A and Technician B**
- **EXCEPT**
- **LEAST Likely**

### Direct, or Completion

This type of question is the kind that is most familiar to anyone who has taken a multiple-choice test: you must answer a direct question or complete a statement with the correct answer. There are four choices given as potential answers, but only one is correct. Sometimes the correct answer to one of these questions is clear, however in other cases more than one answer may seem to be correct. In that case, read the question carefully and choose the answer that is most correct. Here is an example of this type of test question:

A compression test shows that one cylinder is too low. A leakage test on that cylinder shows that there is excessive leakage. During the test, air could be heard coming from the tailpipe. Which of the following could be the cause?
A. broken piston rings
B. bad head gasket



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A5 - BRAKES

C. bad exhaust gasket
D. an exhaust valve not seating

**There is only one correct answer to this question, answer D.** If an exhaust valve is not seated, air will leak from the combustion chamber by way of the valve out to the tailpipe and make an audible sound. Answer C is wrong because an exhaust gasket has nothing to do with combustion chamber sealing. Answers A and B are wrong because broken rings or a bad head gasket would have air leaking through the oil filler or coolant system.

## MOST Likely

This type of question is similar to a direct question but it can be more challenging because all or some of the answers may be nearly correct. However, only one answer is the most correct. For example:

When a cylinder head with an overhead camshaft is discovered to be warped, which of the following is the most correct repair option?
A. replace the head
B. check for cracks, straighten the head, surface the head
C. surface the head, then straighten it
D. straighten the head, surface the head, check for cracks

**The most correct answer is B.** It makes no sense to perform repairs on a cylinder head that might not be usable. The head should first be checked for warpage and cracks. Therefore, answer B is more correct than answer D. The head could certainly be replaced, but the cost factor may be prohibitive and availability may be limited, so answer B is more correct than answer A. If the top of the head is warped enough to interfere with cam bore alignment and/or restrict free movement of the camshaft, the head must be straightened before it is resurfaced, so answer C is wrong.

## Technician A and Technician B

These questions are the kind most commonly associated with the ASE test. With these questions you are asked to choose which technician statement is correct, or whether they both are correct or incorrect. This type of question can be difficult because very often you may find one technician's statement to be clearly correct or incorrect while the other may not be so obvious. Do you choose one technician or both? The key to answering these questions is to carefully examine each technician's statement independently and judge it on its own merit. Here is an example of this type of question:

A vehicle equipped with rack-and-pinion steering is having the front end inspected. Technician A says that the inner tie rod ends should be inspected while in their normal running position. Technician B says that if movement is felt between the tie rod stud and the socket while the tire is moved in and out, the inner tie rod should be replaced. Who is correct?
A. Technician A
B. Technician B
C. Both A and B
D. Neither A or B

**The correct answer is C;** both technicians' statements are correct. Technician B is clearly correct because any play felt between the tie-rod stud and the socket while the tire is moved in and out indicates that the assembly is worn and requires replacement. However, Technician A is also correct because inner tie- rods should be inspected while in their normal running position, to prevent binding that may occur when the suspension is allowed to hang free.

## EXCEPT

This kind of question is sometimes called a negative question because you are asked to give the incorrect answer. All of the possible answers given are correct EXCEPT one. In effect, the correct answer to the question is the one that is wrong. The word EXCEPT is always capitalized in these questions. For example:

All of the following are true of torsion bars **EXCEPT**:
A. They can be mounted longitudinally or transversely.
B. They serve the same function as coil springs.
C. They are interchangeable from side-to-side
D. They can be used to adjust vehicle ride height.

**The correct answer is C.** Torsion bars are not normally interchangeable from side-to-side. This is because the direction of the twisting or torsion is not the same on the left and right sides. All of the other answers contain true statements regarding torsion bars.

## LEAST Likely

This type of question is similar to EXCEPT in that once again you are asked to give the answer that is wrong. For example:

Blue-gray smoke comes from the exhaust of a vehicle during deceleration. Of the following, which cause is **LEAST** likely?
A. worn valve guides
B. broken valve seals
C. worn piston rings
D. clogged oil return passages

**The correct answer is C.** Worn piston rings will usually make an engine smoke worse under acceleration. All of the other causes can allow oil to be drawn through the valve guides under the high intake vacuum that occurs during deceleration.

# PREPARING FOR THE ASE TEST

Begin preparing for the test by reading the task list. The task list describes the actual work performed by a technician in a particular specialty area. Each question on an ASE test is derived from a task or set of tasks in the list. Familiarizing yourself with the task list will help you to concentrate on the areas where you need to study.

The text section of this study guide contains information pertaining to each of the tasks in the task list. Reviewing this information will prepare you to take the practice test.

Take the practice test and compare your answers with the correct answer explanations. If you get an answer

wrong and don't understand why, go back and read the information pertaining to that question in the text.

After reviewing the tasks and the subject information and taking the practice test, you should be prepared to take the ASE test or be aware of areas where further study is needed. When studying with this study guide or any other source of information, use the following guidelines to make sure the time spent is as productive as possible:

- Concentrate on the subject areas where you are weakest.
- Arrange your schedule to allow specific times for studying.
- Study in an area where you will not be distracted.
- Don't try to study after a full meal or when you are tired.
- Don't wait until the last minute and try to 'cram' for the test.

## REGISTERING FOR ASE COMPUTER-BASED TESTING

Registration for the ASE CBT tests can be done online in myASE or over the phone. While not mandatory, it is recommended that you establish a myASE account on the ASE website (www.ase.com). This can be a big help in managing the ASE certification process, as your test scores and certification expiry dates are all listed there.

Test times are available during two-month windows with a one-month break in between. This means that there is a total of eight months over the period of the calendar year that ASE testing is available.

Testing can be scheduled during the daytime, night, and weekends for maximum flexibility. Also, results are available immediately after test completion. Printed certificates are mailed at the end of the two-month test window. If you fail a test, you will not be allowed to register for the same test until the next two-month test window.

## TAKING THE ASE TEST – COMPUTER-BASED TESTING (CBT)

On test day, bring some form of photo identification with you and be sure to arrive at the test center 30 minutes early to give sufficient time to check in. Once you have checked in, the test supervisor will issue you some scratch paper and pencils, as well as a composite vehicle test booklet if you are taking advanced tests. You will then be seated at a computer station and given a short online tutorial on how to complete the ASE CBT tests. You may skip the tutorial if you are already familiar with the CBT process.

The test question format is similar to those found in written ASE tests. Regular certification tests have a time limit of 1 to 2 hours, depending on the test. Recertification tests are 30 to 45 minutes, and the L1 and L2 advanced level tests are capped at 2 hours. The time remaining for your test is displayed on the top left of the test window. You are given a warning when you have 5 minutes left to complete the test.

Read through each question carefully. If you don't know the answer to a question and need to think about it, click on the "Flag" button and move on to the next question. You may also go back to previous questions by pressing the "Previous Question" button. Don't spend too much time on any one question. After you have worked through to the end of the test, check your remaining time and go back and answer the questions you flagged. Very often, information found in questions later in the test can help answer some of the ones with which you had difficulty.

Some questions may have more content than what can fit on one screen. If this is the case, there will be a "More" button displayed where the "Next Question" button would ordinarily appear. A scrolling bar will also appear, showing what part of the question you are currently viewing. Once you have viewed all of the related content for the question, the "Next Question" button will reappear.

You can change answers on any of the questions before submitting the test for scoring. At the end of the examination, you will be shown a table with all of the question numbers. This table will show which questions are answered, which are unanswered, and which have been flagged for review. You will be given the option to review all the questions, review the flagged questions, or review the unanswered questions from this page. This table can be reviewed at any time during the exam by clicking the "Review" button.

If you are running out of time and still have unanswered test questions, guess the answers if necessary to make sure every question is answered. Do not leave any answers blank. It is to your advantage to answer every question, because your test score is based on the number of correct answers. A guessed answer could be correct, but a blank answer can never be.

Once you are satisfied that all of the questions are complete and ready for scoring, click the "Submit for Scoring" button. If you are scheduled for more than one test, the next test will begin immediately. If you are done with testing, you will be asked to complete a short survey regarding the CBT test experience. As you are leaving the test center, your supervisor will give you a copy of your test results. Your scores will also be available on myASE within two business days.

To learn exactly where and when the ASE Certification Tests are available in your area, as well as the costs involved in becoming ASE certified, please contact ASE directly for registration information.

**The National Institute for Automotive Service Excellence**
**101 Blue Seal Drive, S.E. Suite 101**
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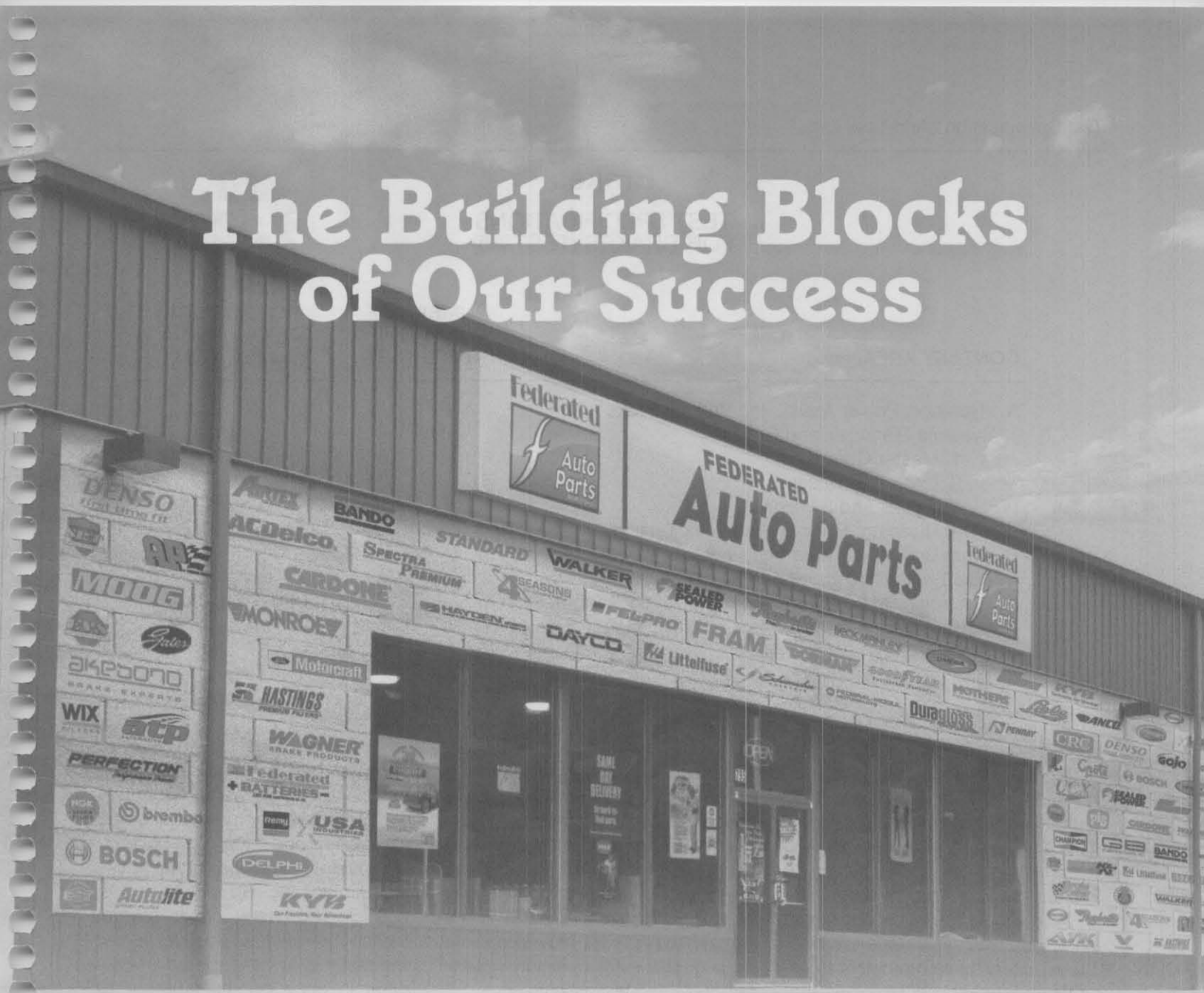
# Table of Contents
## A5 - Brakes

# The Building Blocks of Our Success

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# Brakes

## TEST SPECIFICATIONS FOR BRAKES (TEST A5)

| CONTENT AREA | NUMBER OF QUESTIONS IN ASE TEST | PERCENTAGE OF COVERAGE IN ASE TEST |
|---|---|---|
| **A.** Hydraulic, Power Assist, and Parking Brake Systems Diagnosis and Repair<br>**1.** Master Cylinder<br>**2.** Lines And Hoses<br>**3.** Valves And Switches<br>**4.** Bleeding, Flushing And Leak Testing | 19 | 43% |
| **B.** Drum Brake Diagnosis And Repair | 5 | 11% |
| **C.** Disc Brake Diagnosis And Repair | 11 | 24% |
| **D.** Electronic Brake Control Systems: Antilock Brake System (ABS), Traction Control System (TCS), and Electronic Stability Control system (ESC); Diagnosis and Repair | 10 | 22% |
| **Total** | **45** | **100%** |

The test could contain additional *questions* that are included for statistical research purposes only. Your answers to these questions will not affect your test score, but since you do not know which ones they are, you should answer all questions in the test. The 5-year Recertification Test will cover the same content areas as those listed above. However, the number of questions in each content area of the Recertification Test will be reduced by about one-half.

The following pages list the tasks covered in each content area. These task descriptions offer detailed information to technicians preparing for the test, and to persons who may be instructing technicians in Brake Repair. The task list may also serve as a guideline for question writers, reviewers and test assemblers.

It should be noted that the number of questions in each content area may not equal the number of tasks listed. Some of the tasks are complex and broad in scope, and may be covered by several questions. Other tasks are simple and narrow in scope; one question may cover several tasks. The main purpose for listing the tasks is to describe accurately what is done on the job, not to make each task correspond to a particular test question.

## BRAKES TEST TASK LIST

### A. HYDRAULIC, POWER ASSIST, AND PARKING BRAKE SYSTEMS DIAGNOSIS AND REPAIR

(19 questions)

**1. Master Cylinder**

**Task 1** - Diagnose poor stopping, dragging, high or low pedal, hard or spongy pedal caused by the master cylinder; determine needed repairs.

**Task 2** - Measure and adjust master cylinder pushrod length.

**Task 3** - Check master cylinder for failures by depressing brake pedal; determine needed repairs.

**Task 4** - Diagnose the cause of master cylinder external fluid leakage.

**Task 5** - Remove and replace master cylinder; bench bleed and test operation and install master cylinder; verify master cylinder function.

**2. Lines And Hoses**

**Task 1** - Diagnose poor stopping, pulling or dragging caused by problems in the lines and hoses; determine needed repairs.

**Task 2** - Inspect brake lines and fittings for leaks, dents, kinks, rust, cracks or wear, inspect for loose fittings and supports; determine needed repairs.

**Task 3** - Inspect flexible brake hoses for leaks, kinks, cracks, bulging, wear or corrosion; inspect for loose fittings and supports; determine needed repairs.

**Task 4** - Replace brake lines, hoses, fittings and supports; fabricate brake lines using proper material and flaring procedures

(double flare and ISO types).
**Task 5** - Inspect brake lines and hoses for proper routing and support.

**3. Valves And Switches**
**Task 1** - Diagnose poor stopping, pulling or dragging caused by problems in the hydraulic system valve(s); determine needed repairs.
**Task 2** - Inspect, test and replace metering, proportioning, pressure differential and combination valves.
**Task 3** - Inspect, test, replace and adjust load or height sensing-type proportioning valve(s).
**Task 4** - Inspect, test and replace brake warning lights, indicators, switches, sensors, and circuits; test, adjust and repair or replace brake stop light/brake pedal position switch sensor, lamps and related circuits.

**4. Bleeding, Flushing And Leak Testing**
(3 questions)
**Task 1** - Diagnose poor stopping, pulling, dragging or incorrect pedal travel caused by problems in the brake fluid; determine needed repairs.
**Task 2** - Bleed and/or flush hydraulic system using manual, pressure, vacuum or gravity method(s).
**Task 3** - Pressure test brake *hydraulic* system.
**Task 4** - Select, handle, store and install proper brake fluids (including silicone fluids). Fill master cylinder to proper level.

**5. Power Assist Units**
**Task 1** - Inspect and test brake pedal linkage for binding, looseness, and adjustment; determine needed repairs.
**Task 2** - Test pedal free travel with and without engine running to check power booster operation.
**Task 3** - Check vacuum supply (manifold or auxiliary pump) to vacuum-type power booster.
**Task 4** - Diagnose vacuum-type power booster unit for vacuum leaks and proper operation; inspect the check valve for proper operation; repair, adjust, or replace parts as necessary.
**Task 5** - Diagnose hydro-boost system for leaks and proper operation; repair or replace parts as necessary; refill and bleed system following manufacturer's specifications.

**6. Parking Brake**
**Task 1** - Diagnose parking brake system operation (including electronic parking brakes); inspect cables and parts for wear, rust and corrosion; clean or replace parts as necessary; lubricate assembly.
**Task 2** - Adjust parking brake assembly; check operation.
**Task 3** - Test the parking brake indicator light, switch and wiring.
**Task 4** - Retract the integral and/or electronic parking brake caliper piston(s) according to manufacturers' specifications.
**Task 5** - Adjust calipers with integrated parking brakes according to manufacturers' recommendations.

**B. DRUM BRAKE DIAGNOSIS AND REPAIR**
(5 questions)
**Task 1** - Diagnose poor stopping, pulling, dragging or incorrect pedal travel caused by drum brake hydraulic problems; determine needed repairs.
**Task 2** - Diagnose poor stopping, noise, pulling, grabbing, dragging, pedal pulsation or incorrect pedal travel caused by drum brake mechanical problems; determine needed repairs.
**Task 3** - Remove, clean, inspect and measure brake drums; follow manufacturers' recommendations in determining need to machine or replace.
**Task 4** - Machine drums according to manufacturers' procedures and specifications.
**Task 5** - Using proper safety procedures, remove, clean, and inspect mechanical brake components, such as: shoes/linings, springs, pins, self adjusters, levers, clips, brake backing (support) plates, and other related brake hardware; determine needed repairs.
**Task 6** - Lubricate brake shoe support pads on backing (support) plate, self-adjuster mechanisms and other brake hardware.
**Task 7** - Inspect wheel cylinder(s) for leakage, operation and mounting: remove and replace wheel cylinder(s).
**Task 8** - Following manufacturers' specifications, install brake shoes and related hardware.
**Task 9** - Pre-adjust brake shoes and parking brake before installing brake drums or drum/hub assemblies and wheel bearings.
**Task 10** - Reinstall wheel, torque lug nuts and make final checks and adjustments.
**Task 11** - Diagnose wheel bearing noises and vibration problems; determine needed repairs.
**Task 12** - Remove, clean, inspect, repack wheel bearings, or replace wheel bearings and races; replace seals; replace hub and bearing assemblies; adjust wheel/hub bearings according to manufacturers' specifications.

**C. DISC BRAKE DIAGNOSIS AND REPAIR**
(11 questions)
**Task 1** - Diagnose poor stopping, pulling, dragging or incorrect pedal travel caused by disc brake hydraulic problems; determine needed repairs.
**Task 2** - Diagnose poor stopping, noise, pulling, grabbing, dragging, pedal pulsation or incorrect pedal travel caused by disc brake mechanical problems; determine needed repairs.
**Task 3** - Retract brake caliper piston(s) according to manufacturers' recommendations.
**Task 4** - Remove caliper assembly from mountings; inspect for leaks and damage to caliper housing.
**Task 5** - Clean and inspect caliper

mountings, slides/pins, and threads for wear and damage.

**Task 6 -** Remove, clean and inspect pads and retaining hardware; determine needed repairs, adjustments and replacements.

**Task 7 -** Clean caliper assembly; inspect external parts for wear, rust, scoring and damage; replace any damaged or worn parts; determine the need to repair or replace caliper assembly.

**Task 8 -** Clean, inspect and measure rotor with a dial indicator and a micrometer; follow manufacturers' recommendations in determining need to index, machine or replace the rotor.

**Task 9 -** Remove and replace rotor.

**Task 10 -** Machine rotor, using on-car or off-car method, according to manufacturers' procedures and specifications.

**Task 11 -** Install pads, calipers, and related attaching hardware; lubricate components following manufacturers' procedures and specifications; bleed system and inspect for leaks.

**Task 12 -** Reinstall wheel, torque lug nuts, and make final checks and adjustments.

**Task 13 -** Road test vehicle and burnish/break-in pads according to the manufacturer's recommendations.

**Task 14 -** Diagnose wheel bearing noises and vibration problems; determine needed repairs.

**Task 15 -** Remove, clean, inspect, repack wheel bearings, or replace wheel bearings and races; replace seals; replace hub and bearing assemblies; adjust wheel/hub bearings according to manufacturers' specifications.

**Task 16 –** Distinguish between brake component vibration and tire/wheel vibration; determine needed repairs.

**D. ELECTRONIC BRAKE CONTROL SYSMTES**
**ELECTRONIC BRAKE CONTROL SYSTEMS: ANTILOCK BRAKE SYSTEM (ABS), TRACTION CONTROL SYSTEM (TCS) AND ELECTRONIC STABILITY CONTROL SYSTEM (ESC) DIAGNOSIS AND REPAIR**
(10 questions)

**Task 1 -** Follow the manufacturers' service and safety precautions when inspecting, testing and servicing electronic brake control system hydraulic, electrical and mechanical components.

**Task 2 -** Diagnose poor stopping, wheel lock up, false activation, pedal feel and travel, pedal pulsation and noise concerns associated with the electronic brake control system; determine needed repairs.

**Task 3 -** Observe electronic brake control system indicator light(s) at startup and during road test; determine if further diagnosis is needed.

**Task 4 -** Diagnose electronic brake control system, electronic control(s), components, and circuits (with or without DTCs) using on-board diagnosis and/or recommended test equipment such as: scan tool, digital multimeter (DMM), digital storage oscilloscope (DSO); determine needed repairs.

**Task 5 -** Bleed and/or flush the electronic brake control hydraulic system following manufacturers' procedures.

**Task 6 -** Remove and install electronic brake control system components following manufacturers' procedures and specifications; perform module set up/initialization.

**Task 7 -** Test, diagnose and service electronic brake control system sensors (such as speed, yaw, steering angle, brake pedal position, etc.) and circuits following manufacturers' recommended procedures (includes output signal, resistance, amperage, shorts to voltage/ground and frequency data).

**Task 8 -** Diagnose electronic brake control system braking concerns caused by vehicle modifications (wheel/tire size, curb height, final drive ratio, etc.) and other vehicle mechanical and electrical/electronic modifications (communication, security and radio, etc.).

**Task 9 -** Repair wiring harness and connectors following manufacturers' procedures.

**Task 10 -** Diagnose brake problems resulting from failures of interrelated systems (for example: electronic stability control, antilock brake, traction control).

**Task 11 -** Clear diagnostic trouble codes (DTCs) and verify the repair.

The preceding Task List Data details all of the relevant subject matter you are required to know in order to sit for this ASE Certification Test. Your own years of experience as a professional technician in the automotive service industry should provide you with additional background.

Finally, a conscientious review of the self-study material provided in this ASE Training for Certification unit will help you to be adequately prepared to take this test.

# Brakes

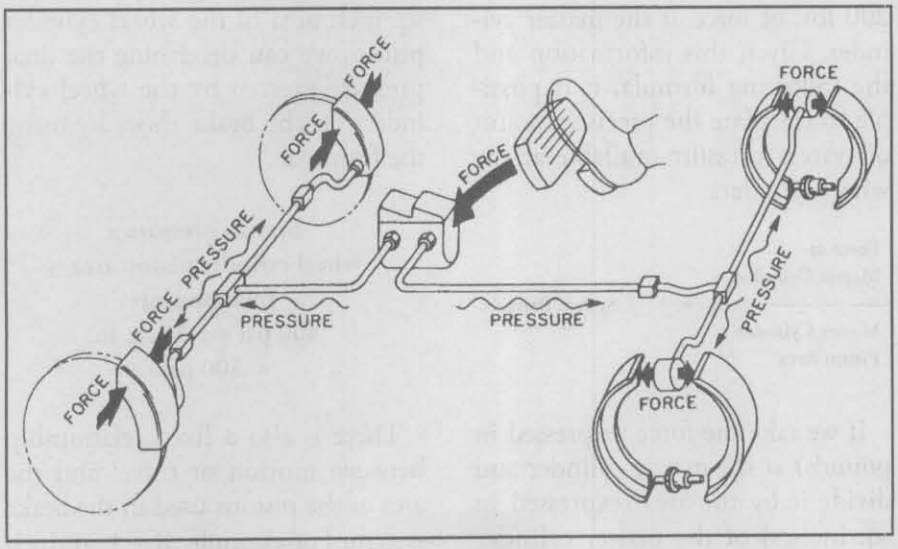
The purpose of the brake system is to slow and stop a moving vehicle, and hold the vehicle stationary when parked. This is accomplished using friction between the lining material on non-moving pads and shoes, and rotors and drums that are attached to and rotate with the road wheels. When the brakes are applied, the vehicle's kinetic (moving) energy is converted into heat.

The brake pads and shoes are applied against the rotors and drums through a hydraulic system that transfers and multiplies the force applied by the driver on the brake pedal. The hydraulic system consists of the master cylinder, connecting brake lines and hoses, and calipers and wheel cylinders that apply pressure to the brake pads and shoes. The brake pedal is connected to the master cylinder and converts the mechanical force from the driver into hydraulic fluid pressure. The brake caliper is installed over the disc brake rotor and when the brakes are applied, the caliper piston(s) clamps the pads against the rotating rotor. The wheel cylinder is attached to the brake backing plate and the wheel cylinder pistons push the brake shoes against the inside of the brake drum when the brakes are applied.

Almost all vehicles manufactured today are equipped with power brakes, a booster system used to decrease the effort required by the driver for brake application. Power assist is provided using a vacuum booster, which uses engine vacuum to apply the brakes, or with a hydro-boost system, where fluid pressure, usually generated by the power steering pump, is used to help the driver apply the brakes.

The parking brake is applied mechanically through a system of cables and levers. When the parking brake lever is pulled or the pedal pushed, a cable pulls on linkage, mechanically applying the rear brakes.

Many vehicles are equipped with an Anti-lock Brake System (ABS). The ABS allows the vehicle to be controlled under heavy braking by releasing hydraulic pressure to wheels that are about to lock up and skid. Sensors located at the wheels monitor rotating wheel speed in relation to other wheels and send the information to a control module that in turn controls a hydraulic modulator, which regulates hydraulic fluid pressure to each brake assembly.




Some vehicles with ABS also have a Traction Control System (TCS). The TCS uses the same ABS wheel speed sensors to monitor wheel speed. If the system detects that a wheel is spinning faster than the others, the brakes are applied at that wheel to slow the wheel and reduce wheel slip. Some systems also reduce power to slipping wheels.

Electronic Stability Control (ESC) is a further variation of ABS. The control module monitors not only the wheel speed sensors but also sensors that report steering angle and the lateral movement (side skidding) of the vehicle. If the control module determines that the vehicle is rotating too much in a turn, it will activate the brakes and sometimes control the throttle until it determines the vehicle is stable.

Begin brake diagnosis by interviewing the customer. Have them explain, in as much detail as possible, the brake problem(s) they are experiencing. Information on driving habits may help determine the cause of the problem and indicate what kind of parts should be installed to meet their needs. Do they tow a trailer or drive aggressively? Do they drive mostly on the highway or is it usually stop-and-go city driving?

Check for TSBs (Technical Service Bulletins) that may reveal updated repair information regarding the symptoms or system in question. Check for recalls and service campaigns. Doing research at this point could save valuable time that would otherwise be needlessly spent trying to achieve a diagnosis. Then perform a road test to verify the customer's complaint.

# Hydraulic System Diagnosis And Repair

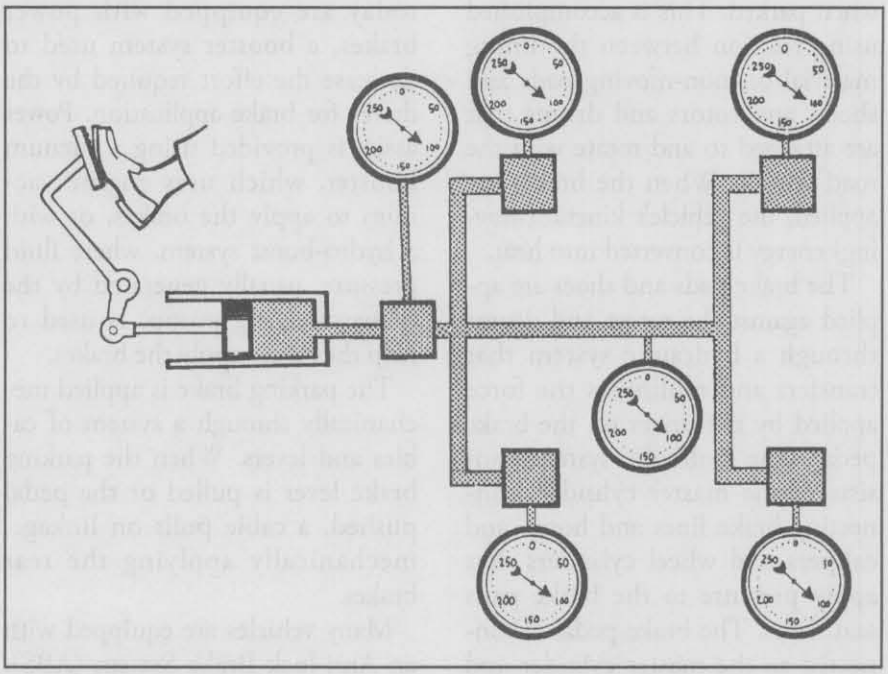
## HYDRAULIC FUNDAMENTALS

Perhaps the most well known principle common to the operation of any automotive brake system is Pascal's Law. Blaise Pascal, a 17th century scientist, discovered two primary characteristics about the behavior of liquids contained within a closed space. First, liquids cannot be compressed. Second, when pressure is applied to a liquid within a closed space, pressure is exerted equally in all directions.

Since liquids have no definite form of their own and are non-compressible, they will conform to the shape of the container in which they reside. This property offers a distinct advantage for the automotive engineer who must design a complex network of curved pipes and hoses to transport brake fluid throughout the system.

To illustrate Pascal's second discovery concerning the pressure of liquids within a closed space, let's fill a 1 sq. in. cylinder with fluid and apply a force of 1 lb. to the top of the liquid's surface. According to Pascal's Law, we have not only exerted a force of one pound per sq. in. (1 psi) on the liquid's surface, but to *all* areas of the container as well. Consequently, if a pressure of 100 psi is generated in the master cylinder, that same pressure will be transmitted to each caliper or wheel cylinder, regardless of the number or location.

A distinct relationship exists between force and piston area within a sealed hydraulic system. For example, take a typical master cylinder and wheel cylinder arrangement. In this system, the surface



According to Pascal's Law, if a pressure of 100 psi is generated in the master cylinder, the same pressure will be applied to any point in the hydraulic brake system.

area of the master cylinder piston is 0.50 sq. inch, while the surface area of the wheel cylinder piston is 1.25 sq. inches. Through a series of linkages and levers we'll say that a 50-lb. force applied by the driver to the brake pedal is augmented to 200 lbs. of force at the master cylinder. Given this information and the following formula, it is possible to calculate the precise amount of system pressure available at the wheel cylinders.

$$\frac{\text{Force at Master Cylinder}}{\text{Master Cylinder Piston Area}} = \text{System Pressure}$$

If we take the force (expressed in pounds) at the master cylinder and divide it by the area (expressed in sq. inches) of the master cylinder piston, we end up with:

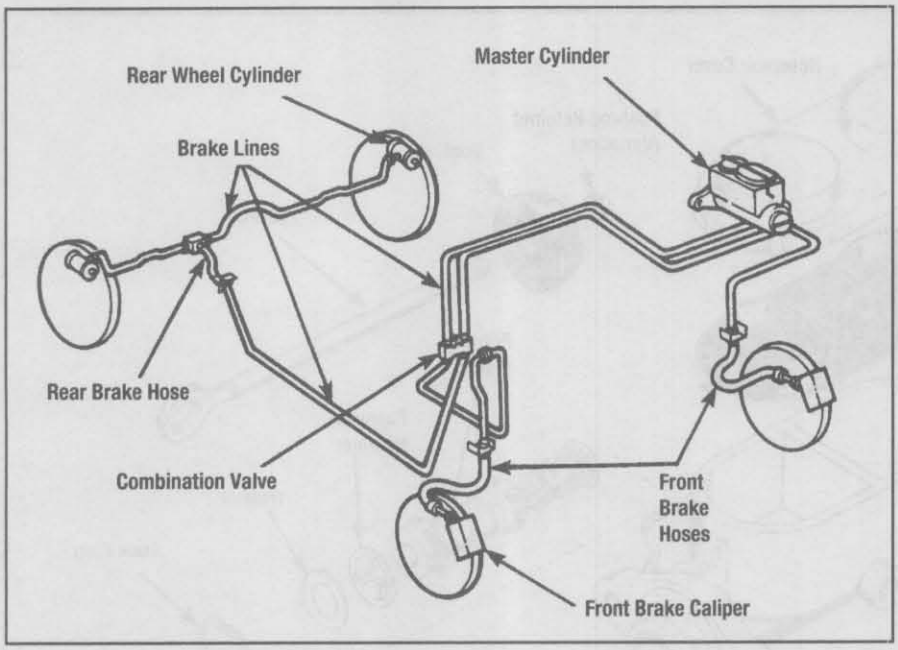
$$\frac{\text{200 lbs.}}{\text{.50 sq. in.}} = \text{400 psi}$$

Now, if we multiply the system pressure of 400 psi by the 1.25 sq. inch area of the wheel cylinder piston, we can determine the final pressure exerted by the wheel cylinders on the brake shoes by using the formula:

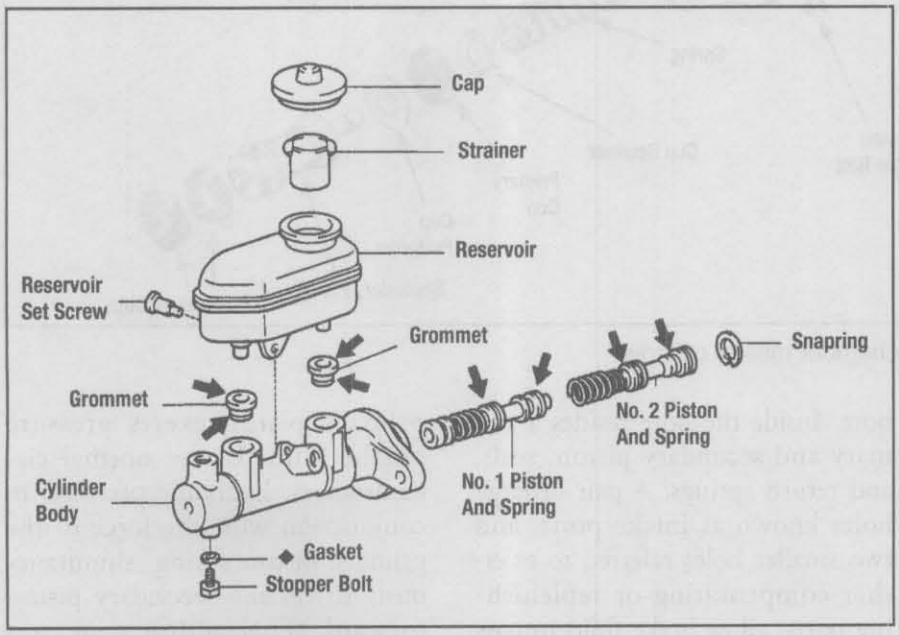
**System pressure × wheel cylinder piston area = final pressure**

**400 psi × 1.25 sq. in. = 500 psi**

There is also a fixed relationship between motion or travel and the area of the pistons used in the brake system. For example, if a 1 sq. inch




Typical hydraulic brake system layout.




Exploded view of a typical aluminum master cylinder with separate plastic brake fluid reservoir. *(Courtesy: Toyota Motor Corp.)*

master cylinder piston moves 1 inch, and the wheel cylinder piston is the same size, then the maximum travel of the wheel cylinder piston will be 1 inch. However, the larger the wheel cylinder piston, the less distance it will travel.

Since the pistons used in wheel cylinders and calipers are always larger than the ones inside the master cylinder, their motion is extremely limited. Even in a panic stop situation, when pedal travel is greatest, caliper and wheel cylinder pistons move very little. As you can see, it only takes a small initial pressure to generate the enormous amount of force needed to stop a moving vehicle.

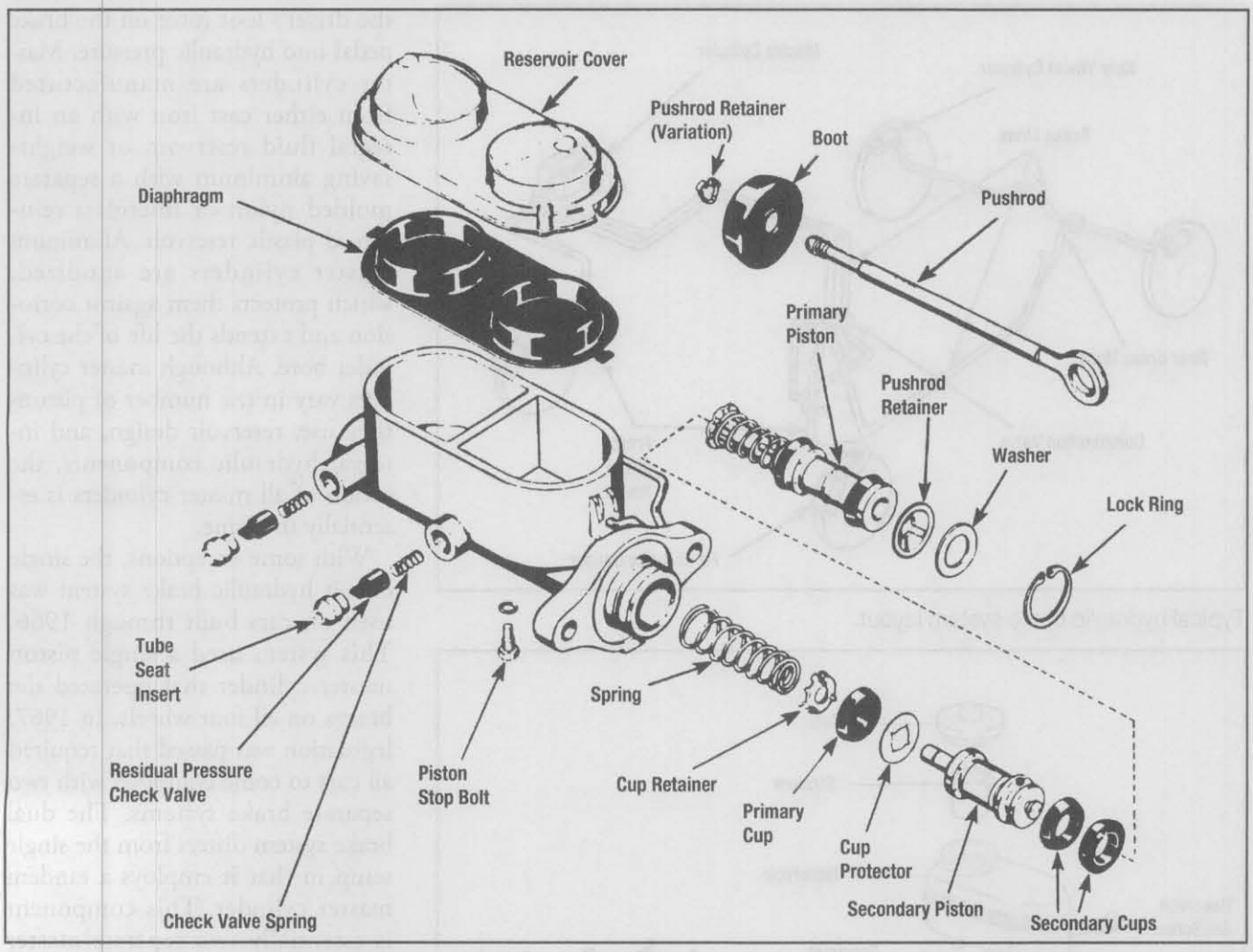
## MASTER CYLINDER

The centerpiece of the hydraulic brake system is the master cylinder. Its purpose is to transform the driver's foot force on the brake pedal into hydraulic pressure. Master cylinders are manufactured from either cast iron with an integral fluid reservoir, or weight-saving aluminum with a separate molded nylon or fiberglass reinforced plastic reservoir. Aluminum master cylinders are anodized, which protects them against corrosion and extends the life of the cylinder bore. Although master cylinders vary in the number of pistons they use, reservoir design, and integral hydraulic components, the action of all master cylinders is essentially the same.

With some exceptions, the single circuit hydraulic brake system was used on cars built through 1966. This system used a single piston master cylinder that operated the brakes on all four wheels. In 1967, legislation was passed that required all cars to come equipped with two separate brake systems. The dual brake system differs from the single setup in that it employs a tandem master cylinder. This component is essentially two separate master cylinders that utilize one cylinder bore, by incorporating a pair of pistons and fluid reservoirs. Consequently, each piston applies hydraulic pressure to two wheels only. This way, in the event one of the hydraulic circuits fails, the other will provide enough braking power to stop the car.

In early dual systems, the hydraulic circuits were divided front and rear. Both front wheels were on one hydraulic circuit and both rear wheels on another. However, since the front brakes do most of the braking work, a failure in the front system would leave little braking power in reserve. This problem was solved, however, with the advent of the diagonally-split brake system.

The diagonally-split system works on the same principle as the



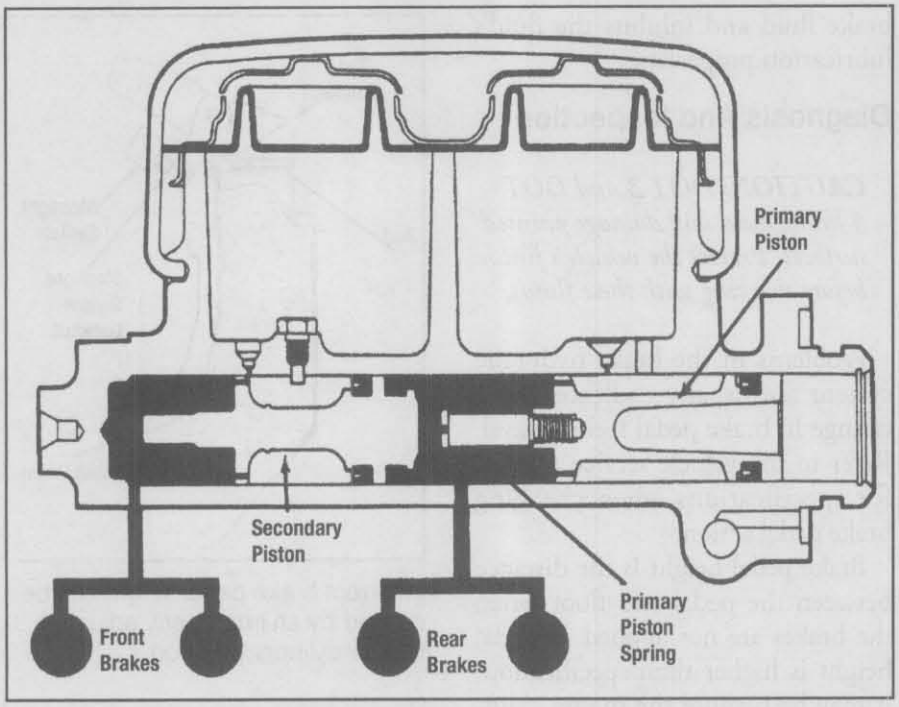

Exploded view of a typical cast iron dual chamber master cylinder.

front and rear split design, except that the hydraulic lines on this system are arranged differently. In the event of a circuit failure, the good remaining circuit will provide braking power to one front wheel and the opposite rear wheel. This arrangement leaves at least 50% of the braking power at the driver's disposal. The diagonal circuit split can occur either inside the master cylinder or externally, at a proportioning valve or pressure differential switch.

To understand how a master cylinder functions, let's examine the operation of a dual master cylinder in detail. As its name indicates, the dual master cylinder provides two individual pressure chambers housed within a single bore. Inside the bore resides a primary and secondary piston, seals, and return springs. A pair of large holes known as intake ports, and two smaller holes referred to as either compensating or replenishing ports, allow brake fluid to pass back and forth from the reservoir to each piston chamber. A pushrod, on the brake pedal end of the cylinder, transfers the driver's foot pressure directly to the master cylinder's primary piston.

At rest, the piston return spring holds the piston at the back of the bore so that the lip of the piston's sealing cup is just behind the intake port. As the brake pedal is depressed, the sealing cup closes off the intake port, followed by the compensating port, and the primary piston exerts pressure on the fluid. Under normal circumstances, hydraulic pressure, in conjunction with the force of the primary piston spring, simultaneously drives the secondary piston forward. This action generates pressure within the cylinder, which causes fluid to flow from the outlet ports into the system's hydraulic circuits, thereby applying the brakes.

When the pedal is released, fluid is forced back through the lines to the master cylinder. However, since the return springs cause the master cylinder pistons to reach their rest position faster than fluid can fill the chambers, a momentary vacuum is created. This causes the lip of the seal cup to move away from



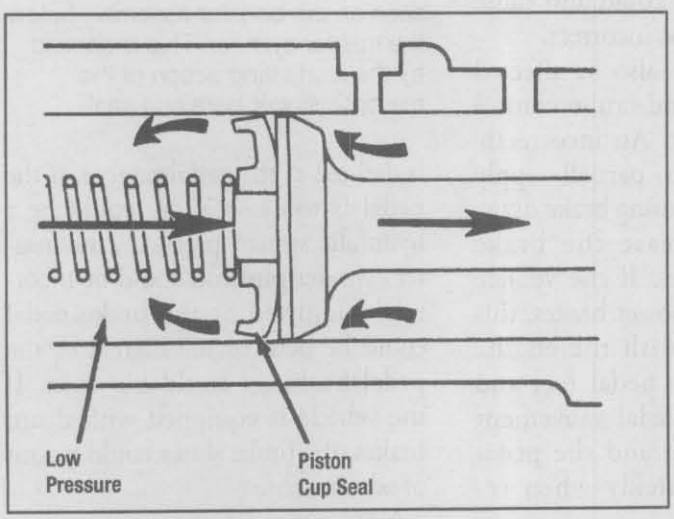

Cross section of a typical dual chamber master cylinder. In this view, the intake port for the secondary chamber cannot be seen due to the piston stopbolt.

the cylinder bore walls allowing fluid to pass forward from around the piston, keeping the cylinder full. As the wheel cylinders are forced inward by the shoe return springs, and/or the caliper pistons are retracted by the elastic action of the internal piston seals, fluid returns from the lines through the master cylinder outlet ports. Since return pressure in the hydraulic circuits is now greater than the pressure in the master cylinder, fluid from the brake lines returns to the reservoir via the compensating ports until pressure is equalized.

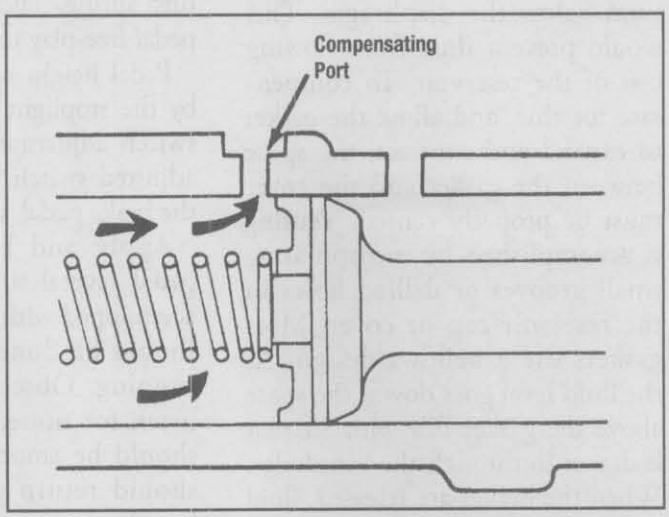
A residual pressure check valve is often used in the outlet port of drum brake systems. It is used to maintain a slight pressure in the brake lines and wheel cylinders, which keeps wheel cylinder pistons tight against their bores. This prevents air entry into the system. A residual pressure check valve is never used in disc brake systems, since it would cause brake drag.

If a leak develops in front of the secondary piston, it will move forward until it bottoms against the front of the master cylinder bore. The fluid trapped between the pistons will then operate one side of the split system. If the other side of the system develops a leak, the primary piston will move forward until it makes direct contact with the secondary piston. It will then force the secondary piston to actuate the other hydraulic circuit of the split system. In either case, brake pedal travel will increase as the brakes are applied, resulting in less available braking power.

In an effort to reduce fuel consumption, low-drag calipers are used on some vehicles. Since this




The master cylinder has return springs at each of the pistons. These springs force the pistons back to their released positions more quickly than the hydraulic fluid can return. As this occurs, the piston cup deflects to allow brake fluid to flow around the outside of the piston lands and the edges of the piston cup.




When the brake shoe return springs and caliper piston seals cause the wheel cylinder and caliper pistons to retract, the retracting pistons return hydraulic fluid to the master cylinder pressure chamber. From there, excess fluid returns to the reservoir via the compensating port.

type of caliper is designed to improve fuel efficiency by providing extra clearance between the brake pads and rotor, a different type of master cylinder design is used to prevent excessive brake pedal travel. The step-bore, or quick take-up, master cylinder, uses a larger rear cylinder bore and quick take-up valve. This arrangement provides a large volume of fluid at low pressure (light pedal application) during the initial part of the pedal stroke. The low pressure fluid quickly provides the displacement requirements of the system created by the seal-retracting pistons in the front calipers and retraction of the rear drum brake shoes.

A vital, but often overlooked part of a typical dual master cylinder is the reservoir gasket. When the cap or cover is installed, the gasket underneath maintains an airtight seal on the master cylinder while simultaneously allowing the reservoir to breathe. The gasket acts like a diaphragm, in that it expands and contracts as the fluid pressure rises and falls. As the brakes are applied, the demand for fluid could create a vacuum below the diaphragm. This would prevent fluid from flowing out of the reservoir. To compensate for this, and allow the gasket to expand and contract, the space between the gasket and the cover must be properly vented. Venting is accomplished by incorporating small grooves or drilled holes in the reservoir cap or cover. Most gaskets use a bellows design. As the fluid level goes down, the space above the gasket fills with air that is drawn in through the vent holes. When the brakes are released, fluid returns to the master cylinder reservoirs and air is expelled out the vent holes. Additionally, the gasket keeps moisture from entering the system. Moisture contamination lowers the boiling point of the brake fluid and inhibits the fluid's lubrication properties.

## Diagnosis And Inspection

***CAUTION:*** *DOT 3 and DOT 4 brake fluid will damage painted surfaces. Protect the vehicle's finish before working with these fluids.*

Problems in the brake hydraulic system are usually indicated by a change in brake pedal feel or travel. Refer to the vehicle service manual for specifications when checking brake pedal action.

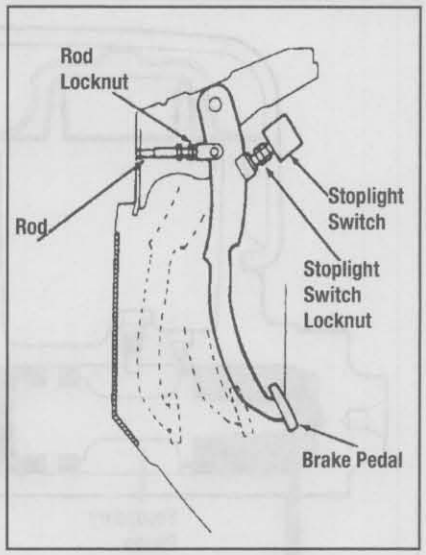
Brake pedal height is the distance between the pedal and floor when the brakes are not applied. If pedal height is higher than specification, it may be because the master cylinder pushrod is adjusted incorrectly, which could also cause the brakes to be partially applied, resulting in brake drag and premature brake lining wear. Brake pedal free-play will also be incorrect if the master cylinder pushrod is incorrectly adjusted.

Brake pedal height that is lower than specification could be caused by a bent or misaligned pedal, worn pedal bushings or a weak pedal return spring. These could also cause pedal free-play to be incorrect.

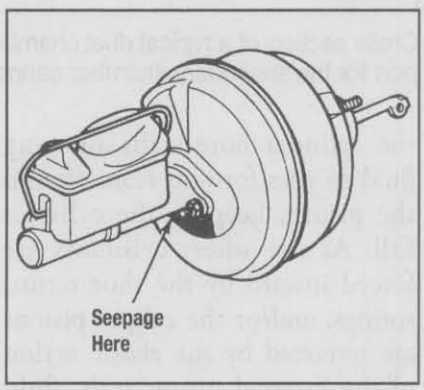
Pedal height can also be affected by the stoplight and cruise control switch adjustment. An incorrectly adjusted switch can partially apply the brake pedal, causing brake drag.

Apply and release the brake pedal several times. If the vehicle is equipped with power brakes, this should be done with the engine running. Observe pedal feel and listen for noise. Pedal movement should be smooth and the pedal should return quickly when released.

Apply the pedal with heavy pressure. It should be firm and at least 1 to 2 inches above the floor (refer to the vehicle service manual for exact specifications). This distance




Incorrect brake pedal height can be caused by an improperly adjusted master cylinder pushrod.




It is normal for a trace of fluid to be seen on the booster assembly below the master cylinder. This is caused by the lubricating action of the master cylinder bore end seal.

is defined as the pedal reserve. If the pedal is too low, there could be a hydraulic system problem, the master cylinder pushrod could be incorrectly adjusted or the brake pedal could be bent or misaligned or the pedal bushings could be worn. If the vehicle is equipped with drum brakes, the brake shoes could be out of adjustment.

Now turn off the engine, and maintain light pedal pressure for approximately 15 seconds. You should not notice any pedal movement during this time. Any travel indicates a leak, so check the fluid level

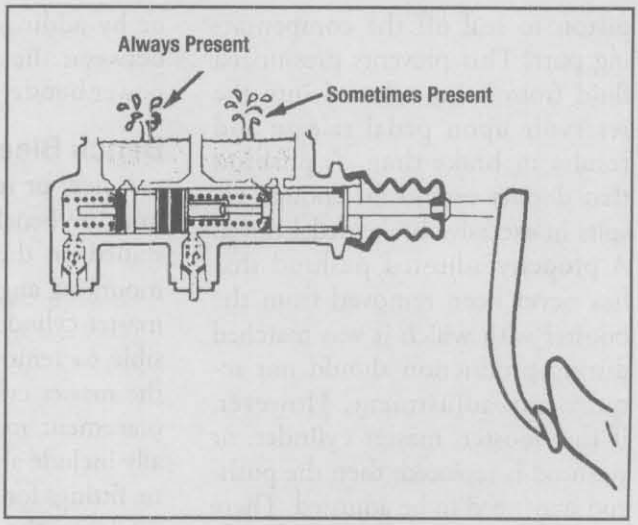
in the master cylinder.

If the master cylinder fluid level is low, it may be due to normal brake pad wear or an external leak. Add fluid to the reservoir as necessary and note the level, then apply the brakes several times. A drop in fluid level will confirm an external leak. Inspect the master cylinder for dampness caused by a cracked or porous bore. Also, check the area where the pushrod enters the master cylinder through the firewall or booster. A small amount of fluid present here is normal due to the lubricating action of the master cylinder bore end seal. The brake fluid is kept from leaking back into the power booster by a seal on the pushrod. If a large amount of fluid is present, unbolt the master cylinder from the booster and look for signs of leakage. If the master cylinder is not leaking, check for leaks at the calipers, wheel cylinders, control valves, brake hoses and brake lines.

If there is excessive pedal movement, but the fluid level is normal and there are no external leaks, then the master cylinder is leaking internally. Fluid is leaking past the piston cups and the master cylinder must be rebuilt or replaced.

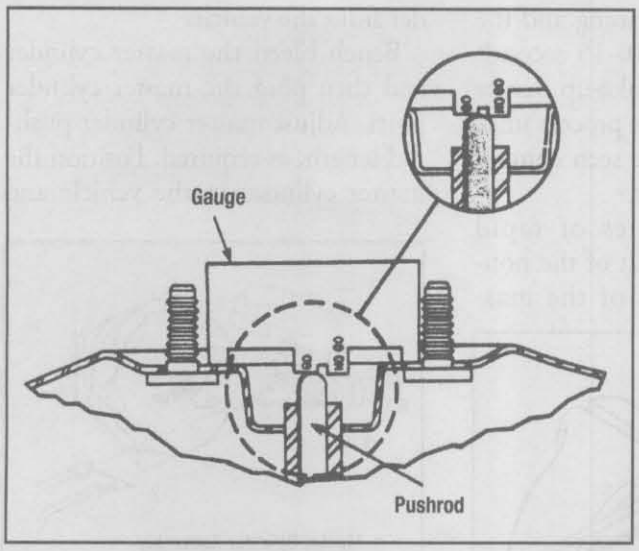
On step-bore master cylinders, a hard pedal may be caused by a restricted center orifice in the quick take-up valve. Conversely, if the quick take-up valve opens prematurely, brake fluid in the primary low-pressure chamber will bleed off into the reservoir. This is typically the result of a broken or weak check-ball spring, and will cause a low pedal condition. If the right front brake pads wear prematurely on a front-wheel-drive vehicle, the quick take-up valve is most likely plugged. This condition will keep pressure on the right front caliper piston, and requires master cylinder replacement.

Air that is trapped in the hydraulic system can cause the brake pedal to be low, bottom or feel spongy. Make sure the reservoir is filled to the proper level, then loosely replace the cover. Have an assistant pump the brake pedal rapidly 20 times and then hold the pedal down. Remove the cover and have the assistant release the pedal quickly. A geyser coming from either reservoir chamber indicates that air is trapped in the system. Pumping the brakes compresses the air and when the pedal is released, the compressed air pushes the hydraulic fluid back through the lines, causing it to squirt. Make sure the rear brake shoes are adjusted properly before performing this test, as incorrectly adjusted rear brakes could also cause the fluid to squirt. Bleed the brake system and repeat the test.




One or more squirts of fluid should be seen in the master cylinder reservoir when the brake is applied. This is caused by fluid being pushed through the compensating ports.
*(Courtesy: Ford Motor Co.)*

A closed compensating port in the master cylinder could be the cause if there is no brake pedal free-play or the brakes are dragging. To check for open compensator ports in the master cylinder, first make sure the reservoir is filled to the proper level. Then, have an assistant slowly apply the pedal fully as you observe the reservoir with the cover removed. A small squirt of fluid should appear over one or both chambers, indicating that fluid is being forced out of the cylinder bore through the compensating ports.




If the power booster, master cylinder or pushrod is replaced, the pushrod may require adjustment. Here pushrod length is being checked with a gauge.

## PUSHROD ADJUSTMENT

In order to ensure correct power brake system operation, the master cylinder pushrod must be properly adjusted. A pushrod that extends too far causes the master cylinder

piston to seal off the compensating port. This prevents pressurized fluid from being released into the reservoir upon pedal release and results in brake drag. A pushrod that doesn't extend far enough results in excessive brake pedal travel. A properly adjusted pushrod that has never been removed from the booster with which it was matched during production should not require any adjustment. However, if the booster, master cylinder, or pushrod is replaced, then the pushrod may need to be adjusted. There are two methods used to confirm the correct adjustment for proper pushrod length and installation: the gauge method and the air method.

In the majority of vacuum assisted power brake boosters the master cylinder pushrod length is fixed, and pushrod length is typically only checked after the unit has been overhauled or replaced.

After overhauling the vacuum booster assembly, position a GO-NO-GO gauge over the piston rod. If the piston rod height is not within the gauge limits, adjust the pushrod or use a service adjustable piston rod to obtain the proper height, as required. Refer to the vehicle service manual for specific instructions.

The air testing method involves the application of compressed air to the hydraulic outlet of the master cylinder. The air pressure is regulated to a value of approximately 5 psi to prevent brake fluid from spraying out of the master cylinder reservoir. If air bubbles are seen coming from the compensating port, which is the smaller of the two holes in the bottom of the master cylinder reservoir, then the adjustment is satisfactory. However, if air does not flow through the compensating port, pushrod adjustment will be required. This is accomplished either by means of an adjustment screw (if provided), or by adding the necessary shims between the master cylinder and power booster.

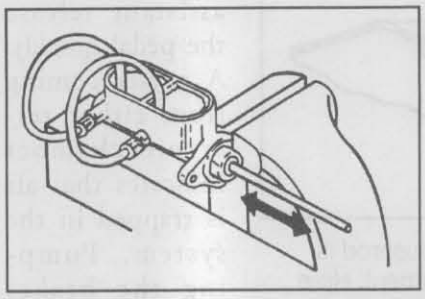
## Bench Bleeding

A new or rebuilt master cylinder must be bench bled before it is installed on the vehicle. Due to the mounting angle and design of some master cylinders, it is nearly impossible to remove all of the air once the master cylinder is installed. Replacement master cylinders generally include a pair of hoses and plastic fittings for this procedure.

Clamp the master cylinder in a vise by placing one of its ears between the jaws and secure firmly. Make sure it is level. Next, attach the plastic fittings to each of the outlet ports on the master cylinder. Connect one end of each hose to each of the fittings, and place the other end of the hoses into the master cylinder reservoir (one hose into each chamber for dual units). Fill the reservoir(s) with the specified brake fluid from a sealed container, and make sure that the hoses are fully submerged.

Using a drift, push in on the piston and release. Start with long slow strokes that completely bottom the piston cups in the bore. Pause about 5 seconds at the beginning and the end of each stroke (10-15 seconds at the end for quick take-up master cylinders). Repeat this process until no air bubbles can be seen coming from the bleeder tubes.

Next, start a series of rapid strokes to move air out of the non-pressurized sections of the master cylinder, moving the piston in about 1/2-in. and back about 1/4-in. without going to full rest. Bubbles should be visible coming up from the ports at the bottom of the reservoir. Continue until no more bubbles are visible.



Bench bleeding a master cylinder.

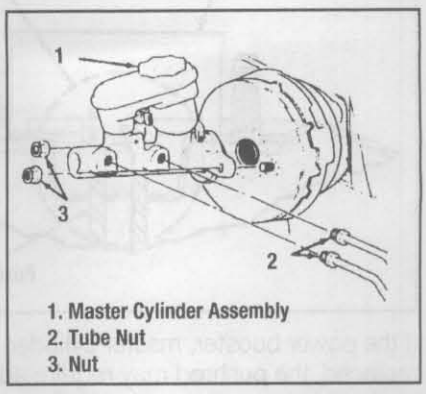
Follow up by going back to long strokes from the full return position approximately 6 times. Mount the master cylinder in the vehicle and bleed the brake system.

## Removal And Installation

***CAUTION:*** *DOT 3 and DOT 4 brake fluid will damage painted surfaces. Protect the vehicle's finish before working with these fluids.*

Using a flare nut wrench, disconnect the brake lines from the master cylinder. Cap the lines and plug the master cylinder ports to prevent dirt from entering the system and unnecessary fluid loss. If equipped, disconnect the brake fluid level or warning switch electrical connector. On manual brake vehicles, disconnect the master cylinder pushrod from the brake pedal. Remove the nuts attaching the master cylinder to the power brake booster or firewall and remove the master cylinder from the vehicle.

Bench bleed the master cylinder and then plug the master cylinder ports. Adjust master cylinder pushrod length, as required. Position the master cylinder in the vehicle and




Master cylinder installation.

secure the mounting nuts. Connect the brake lines and electrical connector (if equipped). On manual brake vehicles, connect the master cylinder pushrod to the brake pedal. Bleed the brake system.

## LINES AND HOSES

Most brake line tubing is made up of copper-fused, double-wall steel tubing ranging in diameters from 1/8-in. to 3/8-in. Some OEM brake tubing is manufactured with soft steel strips sheathed with copper. These strips are rolled into a double-wall assembly before being placed into a high-temperature furnace, which bonds the strips together. Corrosion protection is then added by tin-plating the tubing.

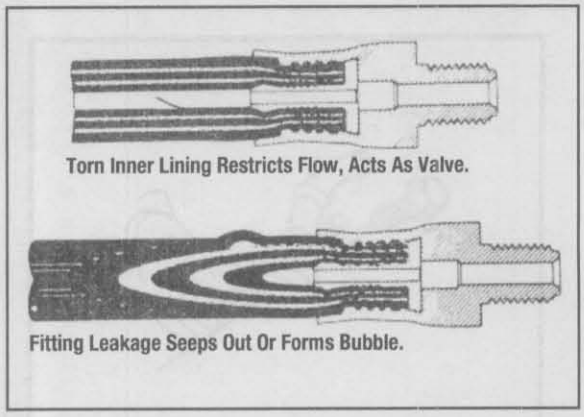
Brake hoses make it possible for steering and suspension components to operate without damaging the brake system, by providing a flexible connection to the wheels. Generally, brake hoses are 10-30 inches in length, and consist of multiple layers of fabric, impregnated with a synthetic rubber.

Brake hoses and lines are connected to each other and to other brake system components with various fittings. Fittings are made of steel or brass and come in the traditional SAE inverted flare style and the ISO style flare. These fitting styles are not interchangeable.

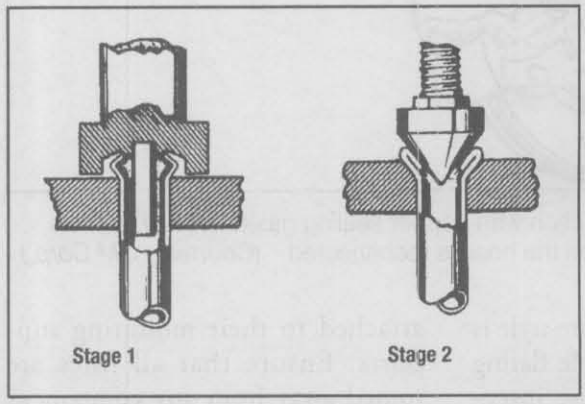
### Inspection

Inspect the brake lines for leaks, kinks, dents and corrosion. Make sure the lines are properly routed and fastened to the chassis.

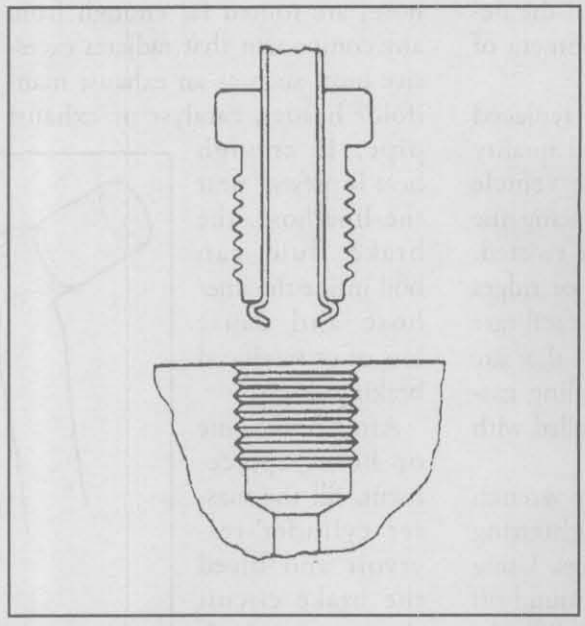
Inspect brake hoses for cracks, leaks, twists and internal damage. Have an assistant pump the brake pedal and feel the hoses for bulging. A bulging hose can cause the brake pedal to be spongy. A restricted hose or brake line can cause brake drag or brake pull. Check for wear marks due to rubbing/chafing against other components and check for signs of stress due to being overstretched, twisted or kinked from improper installation. Any lines or hoses with defects must be replaced.




An example of internal defects that can develop in a brake hose. To check for internal damage, have an assistant pump the brake pedal while you watch for any bulging or expansion of the hose. (Courtesy: Bendix Corp.)




Forming a double flare. *(Courtesy: Bendix Corp.)*



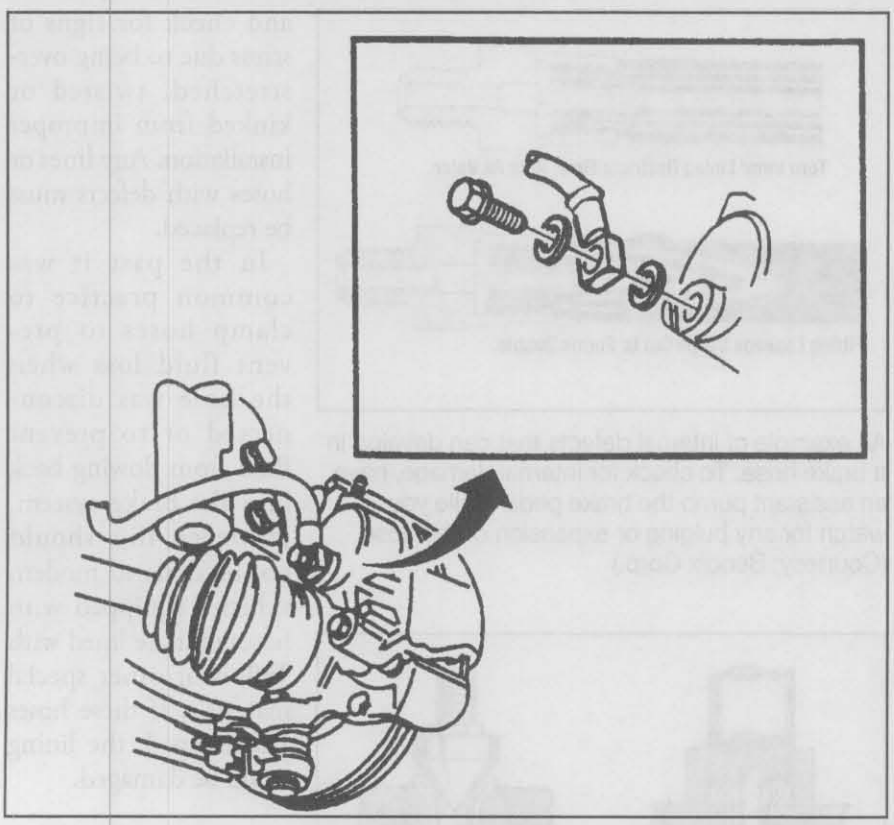
An ISO style flare. *(Courtesy: GM Corp.)*

In the past it was common practice to clamp hoses to prevent fluid loss when the hose was disconnected or to prevent fluid from flowing back into the brake system. However, this should not be done to modern vehicles equipped with hoses that are lined with Teflon or other special materials. If these hoses are clamped, the lining could be damaged.

### Brake Line And Hose Replacement

Always replace brake line tubing with tubing that meets the OEM specifications. Brake tubing must be replaced with the EXACT length tubing as the OEM. If tubing is used that is too short, the tubing may break when a movable component reaches its travel limit. Tubing that is too long could rub on the frame, a suspension component, or on the chassis.

When replacing a brake line, your first choice should always be to use a pre-bent and flared part made for the specific application. However, if one is not available, a replacement can be bent and flared using a suitable tubing bender and flaring tool.



A typical brake hose connection with copper sealing gaskets. New gaskets should always be used when the hose is reconnected. *(Courtesy: GM Corp.)*

The double or inverted flare style is the most common. Double flaring is vital in maintaining the integrity of the system. Single flare, or sleeve compression fittings will not provide adequate service in the demanding operating environment of a vehicle brake system.

Brake hoses should be replaced with the same length and quality hose as equipped by the vehicle manufacturer. When replacing the hose, make sure it is not twisted. Most hoses have a stripe or ridges running their length to facilitate proper installation. Hoses that are attached using copper sealing gaskets should always be installed with new gaskets.

Always use a flare nut wrench when loosening and tightening brake line and hose fittings. Using an open-end wrench can round off the fitting, making removal difficult.

All brake lines and hoses must be properly routed and securely attached to their mounting supports. Ensure that all lines are routed away from any component that could cause damage. In addition, make sure that all lines/hoses are routed far enough from any component that radiates excessive heat, such as an exhaust manifold/ header, catalyst or exhaust pipe. If enough heat is present near the line/hose, the brake fluid can boil inside the line/hose and cause loss of or sacrificed braking ability.

After brake line or hose replacement, fill the master cylinder reservoir and bleed the brake circuit that was serviced. Check the repair for leaks.

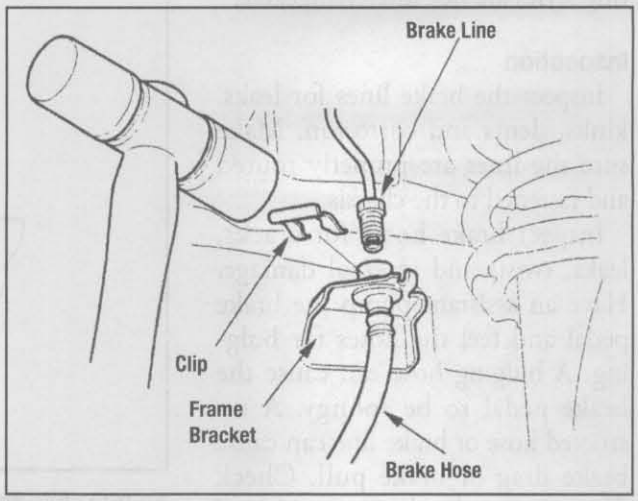

Using a flare nut wrench on a brake line fitting. *(Courtesy: Bendix Corp.)*

## VALVES AND SWITCHES

### Description And Operation

#### Metering Valve

A metering valve is used on front disc/rear drum brake systems for the purpose of providing a simultaneous application of the front and rear friction materials. Located in the front brake hydraulic circuit, the metering valve delays front disc brake operation until the rear brake shoes overcome the return spring tension. By the time the rear brake shoes start to make contact with the drum, hydraulic pressure in the front circuit is high enough to open the metering valve. Once the valve opens, pressurized fluid flows to the front calipers and the disc



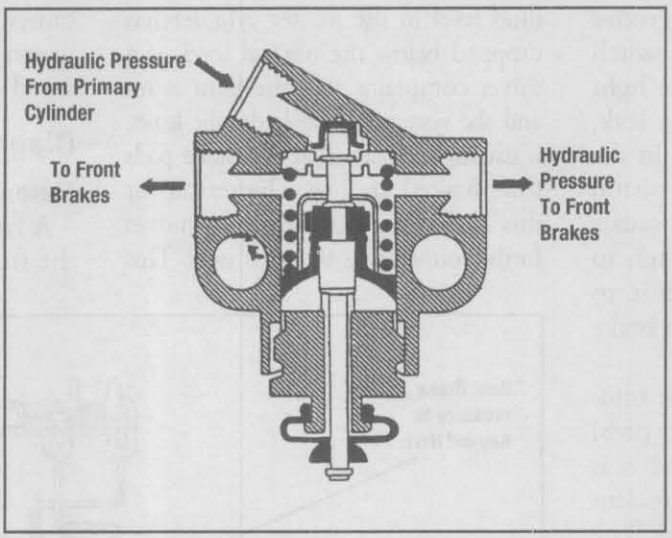

Brake hoses are typically secured to the frame bracket with retaining clips. *(Courtesy: Honda Motor Co., Ltd.)*

brakes apply. By providing this hydraulic equilibrium, the metering valve prevents the front disc brakes from applying too quickly. If the metering valve opens too soon, the front brakes would engage long before the rear shoes could catch up. This condition would cause the nose of the vehicle to dive when the brakes are applied.

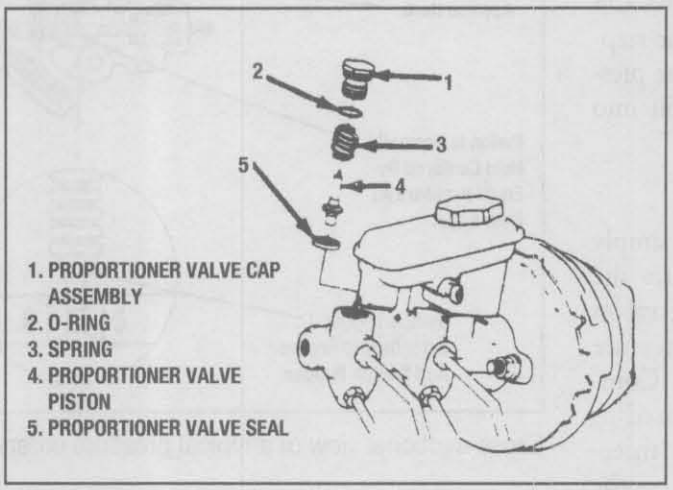
### Proportioning Valve

The proportioning valve improves front-to-rear brake balance under high deceleration or panic-type braking. Under hard stopping conditions, a percentage of the vehicle's rear weight is transferred to the front wheels. As the rear end of the vehicle becomes lighter, the tendency for the rear brakes to lock increases significantly. Therefore, the proportioning valve is used to control rear brake pressures, particularly during hard stops. When the pressure to the rear brakes reaches a predetermined level, the proportioning valve overcomes the force of its spring-loaded piston and stops the flow of fluid to the rear brakes. This action maintains rear brake system pressure at a lower level than the front brakes, keeping the front and rear braking forces in harmony.

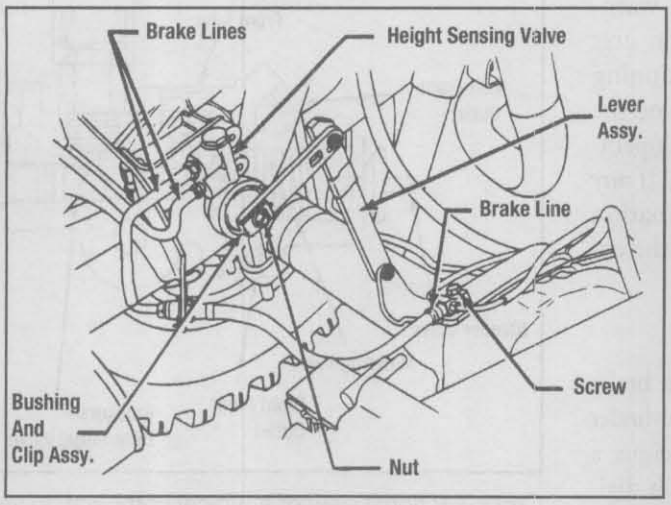
While most systems use a single proportioning valve located in line with the rear wheels, front-wheel drive vehicles equipped with the step-bore, quick take-up master cylinder use two proportioners. One proportioning valve is threaded into each of the master cylinder outlet ports.




Cross-sectional view of a typical metering valve.




Disassembled view of a master cylinder mounted proportioning valve. *(Courtesy: GM Corp.)*




Height-sensing proportioning valve and linkage mounted on a rear axle.

Many vehicles today use what is known as a height-sensing proportioning valve. This type of proportioner provides maximum braking balance based on varying vehicle payloads. Located on the frame, the valve responds to changes in the vehicle's trim height based on the rear axle load. As the load increases, brake fluid pressure to the rear wheels is increased. The valve is linked to a bracket on the axle through mechanical linkage. Be aware that any modification made to the vehicle, such as a load leveling kit, air shocks, or a suspension lift/lowering kit, will alter the distance between the axle and the frame without changing the load. Consequently, these kinds of add-on accessories will trick the proportioning valve into adjusting hydraulic pressures incorrectly.

### Pressure Differential Valve And Switch

All dual-circuit brake systems use a pressure differential warning switch to alert the driver of a pressure loss in one of the hydraulic circuits. Since each brake hydraulic system functions independently, it's possible that the driver may not immediately observe that brake function has deteriorated.

Under normal operating conditions, the hydraulic pressure on both sides of the pressure differential piston is balanced and the piston is centered. In this position, a spring-loaded

plunger sits in the tapered groove of the piston. This leaves the switch contacts open and the brake light off. If one circuit develops a leak, however, the higher pressure in the other circuit will drive the piston to one side (off-center). This causes the pressure differential switch to close, completing the circuit to ground and illuminating the brake warning light.

On some vehicles, the piston automatically re-centers as the brake pedal is released. In this case, the driver is only warned of a hydraulic problem when the brakes are applied. The pressure differential switch may be mounted separately, or be incorporated into a combination valve. On some master cylinders, like the step-bore, quick take-up design, the pressure differential switch is built into the master cylinder.

### Combination Valve

The combination valve is simply a single unit that incorporates the metering and proportioning valves in conjunction with the pressure differential valve and switch. Combination valves are categorized as being either two-function or three-function devices, depending on the number of functions they perform. A three-function valve provides all of the aforementioned capabilities of metering, proportioning and warning. However, the two-function unit combines either the proportioning and warning light functions or the metering and warning light operations into a single component. If any of the functions in a combination valve fails to operate properly, the entire unit must be replaced.

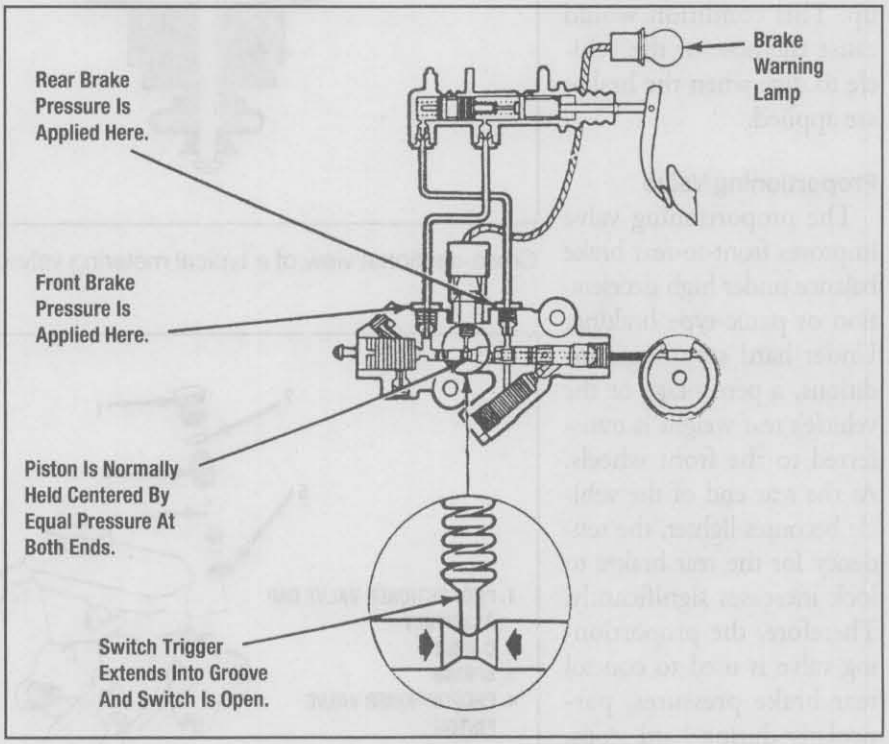
### Brake Fluid Level Sensor

Some vehicles incorporate a brake fluid level sensor in the master cylinder reservoir. The sensor activates either a dash warning light, or signals a digital message display (depending on the vehicle), which tells the driver that the fluid level in the master cylinder has dropped below the normal level. If a driver complains that the light is on and the system has no hydraulic leaks, it usually indicates that the brake pads (disc brakes) are low. The reason for this is that the caliper piston moves further outward as the pads wear. This causes the fluid level to drop in the master cylinder as extra fluid is now stored in the caliper.

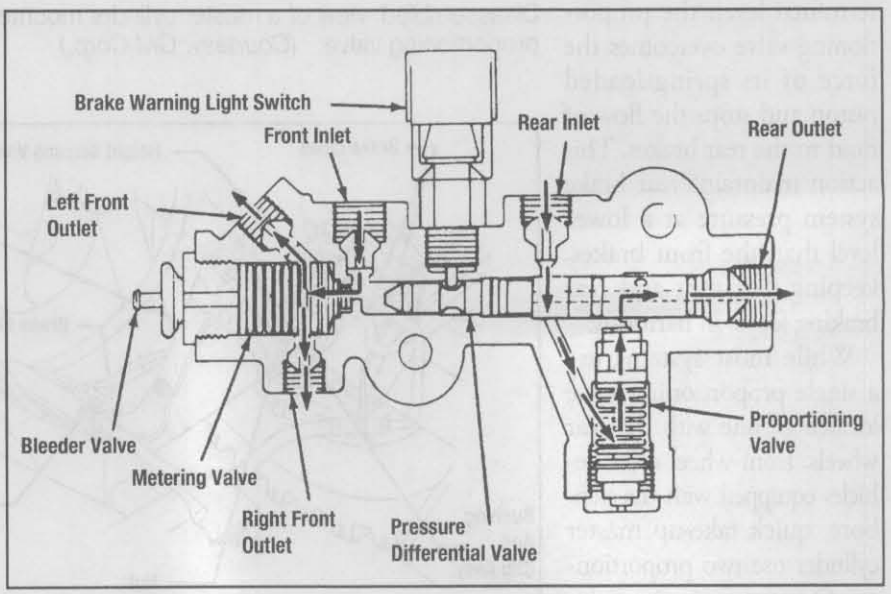
## Diagnosis And Inspection

### Metering Valve

A faulty metering valve can cause the front wheels to lock up during




Cross-sectional view of a typical pressure differential valve and switch.




Cross-sectional view of a typical combination valve. This unit incorporates the metering valve, pressure differential valve, warning light switch and the proportioning valve.

hard braking, resulting in loss of vehicle control, and can cause premature front disc pad wear from carrying all or most of the braking load during mild braking. Inspect the metering valve for leaks. A slight amount of moisture is acceptable, but excessive fluid means the valve is defective.

To check metering valve function, gently apply the brakes (if equipped with power brakes, the engine should be running). If the metering valve is operating properly, a very small change in pedal effort should be felt at about 1 in. of pedal travel. This is due to the additional hydraulic pressure necessary to open the valve.

The metering valve can be more precisely tested using a pair of pressure gauges with a range of 0-500 psi. One gauge should be connected into the line between the master cylinder and the metering valve and the other is connected to one of the metering valve outlets. Observe the gauges while an assistant slowly applies the brake pedal.

The pressure reading on both gauges should initially rise at the same rate, then the outlet pressure gauge should stop rising as the metering valve moves to its hold-off position. The inlet pressure gauge reading should continue to rise and when it reaches approx. 75-120 psi., the metering valve should open and the outlet pressure gauge should start to rise again until it is the same as the inlet pressure.

Replace the metering valve if it does not perform as described.

### Proportioning Valve

A malfunctioning proportioning valve can cause the rear wheels to lock up under hard braking, resulting in loss of vehicle control. Inspect the valve for leaks and proper operation. A pair of pressure gauges that read 0-2000 psi. are necessary to test the proportioning valve. On vehicles with diagonally-split hydraulic systems and dual proportioning valves, the test will need to be performed in each half of the system.

Connect one gauge into the line between the master cylinder and the proportioning valve. The other gauge is connected to the valve outlet for the rear brakes. Observe the gauges while an assistant slowly applies the brake pedal.

The pressure reading on both gauges should rise until the transition pressure is reached, at which time the pressure reading on the gauge connected to the rear brake outlet should rise at a slower rate. Refer to the vehicle service manual for the transition pressure specification.

If the proportioning valve does not function properly, it must be replaced.

### Height-Sensing Proportioning Valve Adjustment

As the payload increases, the height-sensing proportioning valve increases brake fluid pressure to the rear wheels. If a customer complains of front wheel lockup when the vehicle is operated near the GVWR (Gross Vehicle Weight Rating) with light pedal pressure, the height-sensing proportioning valve may require adjustment.

The following is a description of the adjustment procedure for a typical height-sensing proportioning valve: Raise the vehicle and make sure that the axle is hanging free (use a frame contact lift). Remove the nut from the valve shaft and disconnect the lever arm. Rotate the valve shaft to allow the placement of the specified adjustment gauge. The center hole of the adjustment gauge must seat on the 'D' shape of the valve shaft and the gauge tang must seat in the valve mounting hole. Place the lever on the valve shaft by pushing the plastic bushing and clip assembly over the valve shaft serrations using a 'C' clamp or channel lock pliers. Once installed correctly, the serrations on the valve shaft should fully engage the plastic bushing. Install the nut and torque to specification, then sever the tang on the adjustment gauge to permit the valve assembly to rotate freely.

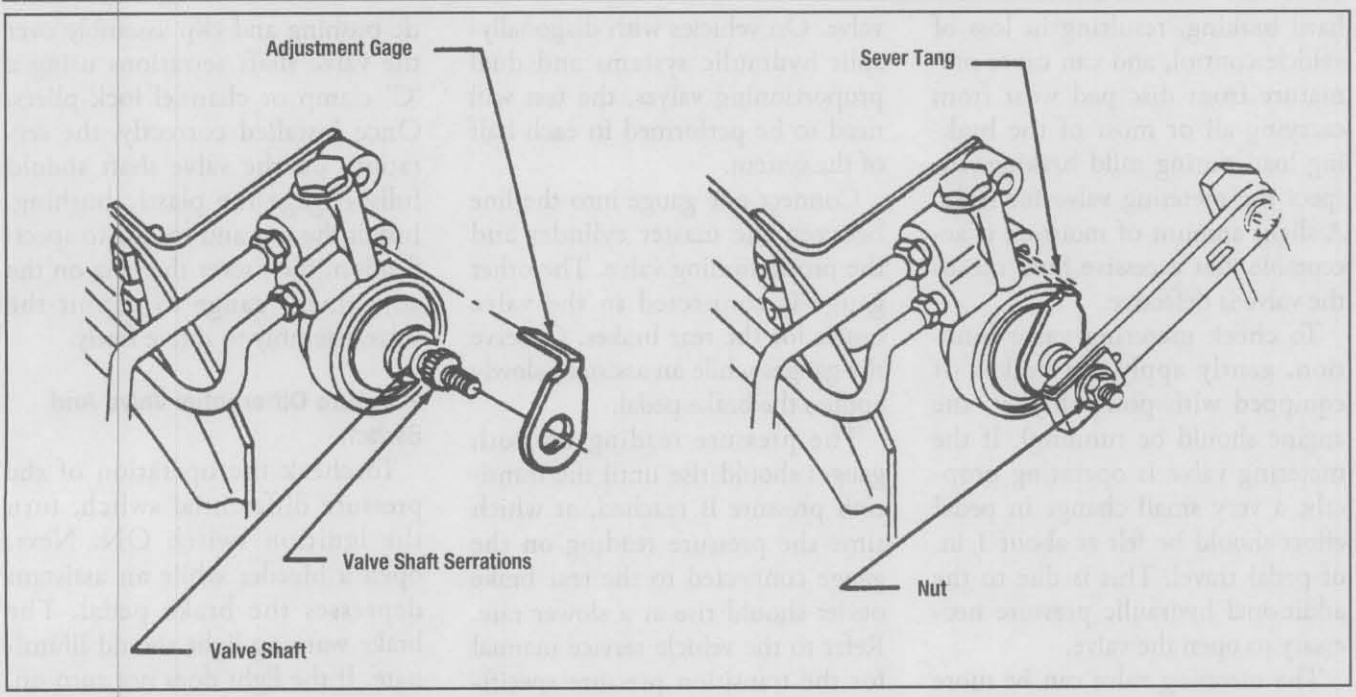
### Pressure Differential Valve And Switch

To check the operation of the pressure differential switch, turn the ignition switch ON. Next, open a bleeder while an assistant depresses the brake pedal. The brake warning light should illuminate. If the light does not turn on, remove the wire from the switch or combination valve and jump it to a good ground. If the light glows now, the problem is in the switch assembly. If the light still does not come on, check the electrical circuit back to the dash light.

After a vehicle has been repaired for a hydraulic brake problem that caused the warning light to come on, the valve must be reset. Actually, this should occur automatically once the system is properly bled since the balance of hydraulic pressure in the system forces the piston to self-center.

However, if the light does not go out, the piston in the valve may have to be recentered. There are 3 different types of pressure differential valves. In the first type, the piston in the valve is recentered by spring pressure when the brakes are released. With this type of valve/switch, the brake warning light only illuminates during brake application.

On another type of valve, the electrical switch plunger locks in the ON position when there is a brake system imbalance and the switch must be removed to allow spring pressure to recenter the piston. If the piston sticks, apply the




Adjusting a typical height-sensing proportioning valve.

brakes with the switch removed and open a bleeder screw in the other half of the hydraulic system, to force the piston over.

On some valves the piston is not spring loaded. To recenter the piston, open a bleeder screw on the side of the hydraulic system that was not serviced. Turn on the ignition switch to light the brake warning light. Gently apply the brake pedal just until the light goes out, then tighten the bleeder screw.

### Brake Warning Light

On most vehicles, the brake warning light is activated by the parking brake switch and the pressure differential valve switch. It may also light in response to the brake fluid level sensor or if there is a malfunction in the ABS. However, some vehicles have a separate warning light for low fluid level and all vehicles with ABS have a separate amber warning light.

With the parking brake released, turn the ignition switch to the ON position. The brake warning light should illuminate for a few seconds and then go off. When the parking brake is applied the light should come on and then go off when the brake is released. If the light stays on, there is a problem in the hydraulic system, the parking brake is not releasing properly or the switch is faulty, the fluid level is low in the master cylinder reservoir, or there is an ABS problem.

Inspection of the pressure differential valve is covered earlier in this section. Diagnosis of the parking brake switch and ABS system are covered in other sections of this study guide.

If the dash warning light does not come on when the fluid level is low in the master cylinder reservoir, disconnect the sensor and connect a jumper wire between the signal circuit of the sensor and the ground circuit of the sensor. Turn the ignition switch to the ON position. If the light still does not come on, check for an open or high resistance in the fluid level sensor signal circuit. If the light comes on, check for poor connections at the sensor harness connector. If OK, replace the fluid level sensor.

### Brake stop light and pedal position switches/sensors

Vehicles may be equipped with one or two switches to monitor brake pedal position. One is typically used to activate the rear brake lights and inform the electronic braking control modules (ABS, TCS, and ESC systems) that the driver has applied the brakes. The second is usually used as an input to the cruise control system (if equipped) to deactivate it if engaged. This second switch is typically incorporated into the first, but may be an independent switch that may be mounted near the first or on the master cylinder itself. On some makes, a sensor takes the place of the switch and the signal from the sensor is directed to the parent control module and shared on the vehicle's bus network.

Nearly every vehicle made after 1996 will have a scan tool Parameter Identifier (PID) for the brake pedal position, and this should be the first place you look to test whether or not it is working. On models using two switches or sensors, be sure that the two are in

synch with one another and that there is no separation or delay between the two signals. You can check this by watching the PIDs in your scan tool's graphing mode.

If the switch or sensor is not working properly, you'll need to check the integrity of the entire circuit. Use the wiring schematic to identify the circuit's paths and components. Since most electrical circuit failures are a result of either a failed component or unwanted resistance, using the voltage drop testing method is the best way to quickly isolate the fault. For circuits that may be difficult to access, the use of an ammeter to monitor current flow can help a technician quickly determine if a circuit is working as it should or not. Of course, follow the OEM troubleshooting guide in the service information of your choice to diagnose and repair any circuit failure that has resulted in a Diagnostic Trouble Code (DTC) to be set in any control module that uses the brake pedal position as a necessary input.

Faults in any of the indicator lamp circuits (dash warning lights, rear stop lamps, center stop lamp) can also be effectively diagnosed using a schematic and the voltage drop testing method, requiring only a quality Digital Multimeter (DMM) to perform.

## BLEEDING AND FLUSHING

### Brake Fluid

The fact that fluids are non-compressible doesn't mean that all brake fluids are the same. Because of the tremendous amount of heat generated by the brakes, a minimum boiling point needed to be established for brake fluid. In the 1940s that minimum was only 235°F. Soon after, however, it was discovered that prolonged braking would easily heat up the fluid well beyond 250°F. Today, brake fluid must meet specific standards set by DOT (Department of Transportation) and SAE (Society of Automotive Engineers) for boiling point, lubricity, corrosion protection, water tolerance, and rubber compatibility. The three grades of brake fluid include:

DOT 3 — 401°F minimum boiling point, glycol-based, hygroscopic

DOT 4 — 446°F minimum boiling point, glycol-based, hygroscopic

DOT 5 — 500°F minimum boiling point, silicone-based, non-hygroscopic.

The term hygroscopic is used to describe something that attracts moisture and both DOT 3 and DOT 4 brake fluids share this characteristic. Moisture affects brake fluid by lowering its boiling point. The minimum boiling point specifications given above are for fresh fluid, so it can be reasoned that the boiling point of a hygroscopic fluid will be continually lowered with age and use as it absorbs moisture. A vehicle can accumulate 2 to 3% water in the brake fluid over an 18 month period and absorption of 3% moisture can reduce the boiling point of DOT 3 by 25%. Under heavy braking, the heat generated can then boil and vaporize the fluid, which like any other gas is compressible, resulting in a spongy pedal or complete loss of brakes. For this reason DOT 3 and DOT 4 brake fluids should be periodically changed and some manufacturers specify that it be done yearly.

Due to their hygroscopic nature, DOT 3 and DOT 4 fluids have a limited shelf life. Once a container of fluid is opened, the contents should be used as soon as possible, as the fluid will begin to absorb moisture immediately. Always replace the cap on the container immediately after use. DOT 3 and DOT 4 brake fluids will damage paint, so the vehicle finish must be protected when working with these fluids.

The primary advantage to silicone brake fluid is that it always retains its high boiling point due to its non-hygroscopic nature. Silicone fluid also has a long shelf life and will not damage painted surfaces. The downside to silicone brake fluid is that it's prone to aeration. This means that when the fluid is agitated, tiny air bubbles, like those found in a carbonated drink, form in the fluid. For this reason, DOT 5 brake fluid should never be used in an anti-lock brake system. The tendency for aeration with DOT 5 also makes brake bleeding a little more difficult.

When adding brake fluid to the hydraulic system, always use fresh fluid from a sealed container. Never reuse old brake fluid. Do not mix glycol-based DOT 3 and DOT 4 fluid with silicone-based DOT 5 fluid. Glycol-based fluids are always clear, while silicone fluids are purple.

### Brake Fluid Inspection

Inspect the fluid in the master cylinder reservoir for moisture, dirt or contamination. Fluid that is mostly clear is in good condition. Fluid that appears cloudy contains a large amount of moisture. Dirty fluid will be dark in color.

If brake fluid is contaminated by petroleum or mineral based fluids, the rubber components in the hydraulic system will swell causing brake drag or brake failure. A sure sign that the system is contaminated is if the master cylinder cover diaphragm is distorted or swelled. Another way to tell is to put a spoonful of brake fluid from the master cylinder into a styrofoam cup filled with water. DOT 3 and DOT 4 fluid will

completely dissolve in the water in a white cloud and then turn clear. Petroleum or mineral based fluids will float on the water's surface and dissolve the Styrofoam cup at the water line.

Contaminated brake fluid must be drained and flushed from the system. All rubber components must then be replaced and the system filled and bled using fresh brake fluid.

The most accurate way to determine brake fluid condition is to take a sample from the vehicle's disc brake caliper, because the heat generated while stopping breaks down the corrosion inhibitors in the brake fluid. The brake fluid slowly corrodes the copper in the inner lining of steel brake tubing, resulting in copper ions in the fluid. The copper ions, in turn, corrode ferrous metal parts. Therefore, test strips that show the copper content in the fluid can be used to indicate fluid condition and help determine whether the fluid should be changed.

## Brake System Bleeding

In order to operate properly, the hydraulic brake system must be free of air. Air can enter the system when hydraulic parts are disconnected for servicing or replacement or when the fluid level in the master cylinder becomes too low. When air is in the system, the brake pedal will feel spongy upon application since the air bubbles in the fluid are compressible. Bleeder screws are located on each caliper and wheel cylinder as well as on some master cylinders.

Pressure bleeding and vacuum bleeding are two alternatives to the conventional manual bleeding procedure, however, both methods require the use of special equipment. Pressure bleeding forces fluid through the system while vacuum bleeding pulls the fluid through. Both of these processes eliminate the need to manually pump the brake pedal in order to expel trapped air. The most common, as well as inexpensive method used to rid the system of air, is through manual bleeding.

Depending upon the point at which the system is opened to the atmosphere, bleeding may only be required at one or two wheels or at the master cylinder. However, if the pedal still feels spongy after bleeding at the location where the repair was made, then the entire system must be bled using an approved method.

***CAUTION:*** *DOT 3 and DOT 4 brake fluid will damage painted surfaces. Protect the vehicle's finish before working with these fluids.*

## Manual Bleeding

If the master cylinder is being rebuilt or replaced, you must bench bleed the unit first before installing it back on the vehicle. After the master cylinder is bled, continue the bleeding process at the wheels.

Since almost every car you'll be servicing will be equipped with power brakes, get into the habit of first evacuating the power booster by pumping the brake pedal several times with the engine off. Next, make sure that the master cylinder reservoir is full, and also check that each of the wheel bleeder screws is unrestricted and free to turn. Older vehicles will many times have bleeders that are clogged because the bleeder caps weren't replaced after service. Another common experience on older vehicles is finding the bleeder screw seized in the wheel cylinder or caliper. If the bleeder will not loosen after applying penetrating oil or an equivalent to the threads, replacing the wheel cylinder and/or the caliper may be the only alternative.

The master cylinder must be bled first if it is suspected of having trapped air or if it has just been installed. Begin by filling the master cylinder reservoir, then disconnect the forward brake line and wait until fluid begins to flow out of the connector port. Reconnect the forward brake line, and have an assistant depress the brake pedal slowly one time and hold. Loosen the line connection and allow any trapped air to escape, retighten and have the assistant release the pedal. Repeat this process until all of the trapped air is purged. After all of the air has been discharged from the front port, bleed the master cylinder at the rear line connection in the same way.

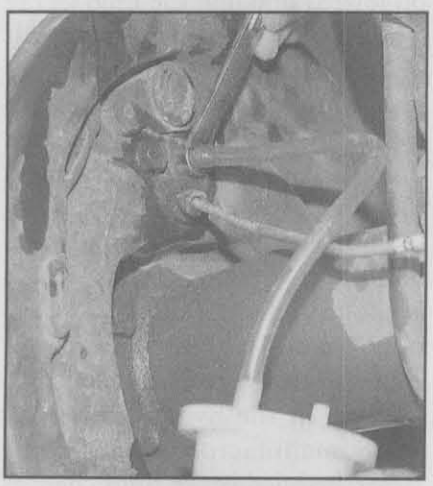
Next, bleed the combination valve and then move to the wheels. The most commonly used bleeding sequence starts at the point furthest from the master cylinder. This means that generally you will begin with the right rear wheel followed by the left rear, right front, and finally the left front wheel. However, it is strongly suggested that you consult the service manual for the particular vehicle you are working on, since a special bleeding sequence may be required.

The most efficient method of manual bleeding involves attaching a clear hose to the bleeder screw and submerging the opposite end into a clear container partially filled with brake fluid. Bleeding this way makes it easier to observe when all of the air has been expelled from the hydraulic circuit. Additionally, this setup prevents brake fluid from squirting all over the underside of the vehicle. The manual bleeding procedure requires two people: one to apply the brake pedal and the other to operate the bleeder. However, an inexpensive tool known as a one-man brake bleeder may be used successfully. This equipment consists of a

transparent plastic container with a clear hose and in-line check valve attached to the lid. By attaching the hose to the bleeder screw and opening the bleeder, the technician is now free to apply the brake pedal in the conventional manner. The check valve on the tool prevents air from being drawn back into the system when the brake pedal is released. When using this tool, periodically check the clear hose to see when all of the air bubbles have disappeared. In addition, make sure that the master cylinder remains adequately filled during the process.

In the absence of the aforementioned equipment, have an assistant depress and hold the pedal down. Open the bleeder about 1/4 turn and observe the fluid discharge. Then close the bleeder, and have the assistant release the pedal. Wait 15 seconds and repeat. Continue this process at each point in the system until all of the air bubbles have been eliminated from the fluid. With disc brakes that are stubborn to bleed, it may be necessary to tap the caliper with a rubber mallet to break up any trapped air bubbles.

Periodically check the fluid level in the master cylinder during the bleeding procedure. If the reservoir empties and air enters the brake lines through the master cylinder, you will have to start the entire bleeding procedure over again.



Opening a bleeder screw on a wheel cylinder.

## Pressure Bleeding

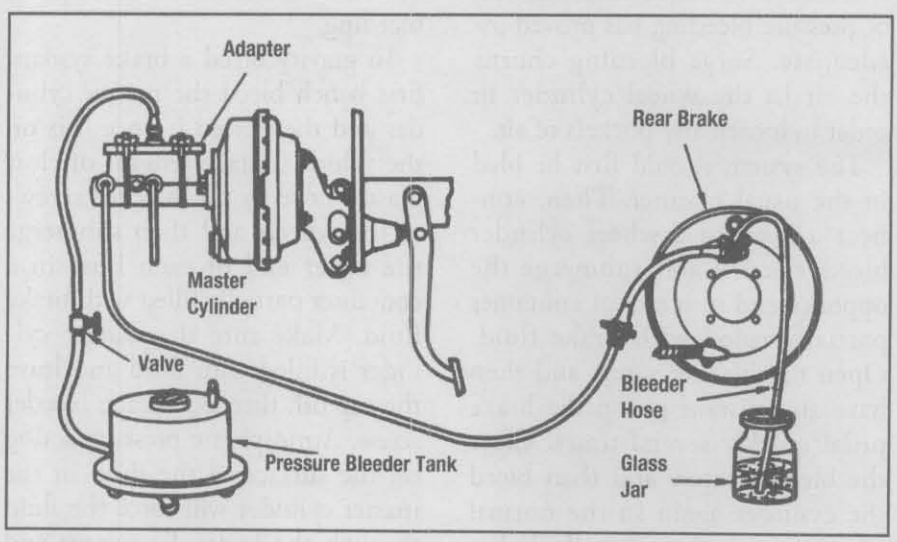
If the equipment is available, this method of bleeding not only eliminates the need for a second person, but also the need to periodically check the fluid level in the master cylinder reservoir. The pressure bleeder comes with special adapters to accommodate the specific style of master cylinder, and a bleeder ball (pressure tank). This tank must contain a rubber diaphragm between the air supply and the brake fluid. This prevents air, moisture, and other contaminants from invading the hydraulic system. A gauge is included on the equipment to indicate when the tank is sufficiently charged.

Remove the master cylinder reservoir cover and install the appropriate adapter. Using shop air, charge the pressure tank to approximately 25 psi, then connect the tank's hose to the adapter on the master cylinder. On cars with a front disc/rear drum arrangement, the metering valve must be held in the open position or else the front calipers will not bleed. The reason for this is because the input pressure of the tank is set far below the required pressure to open the metering valve. There are two different types of metering valves in use. The most common of these requires the valve stem to be held in while bleeding the brakes, while the second type requires the valve stem to be held out. Consult the service manual to identify the metering valve type as well as the proper method of holding it open during bleeding. In some cases a special tool may be required. Never use a block or clamp to hold the valve open, and never force the valve stem beyond its normal position.

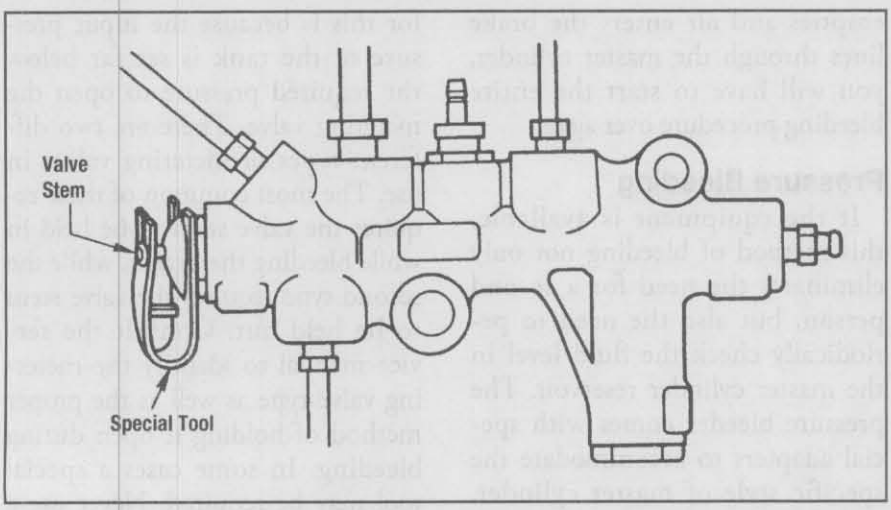
Once the pressure bleeder is ready to go, open the line valve and depress the relief valve on top of the adapter to purge any air. Keep the relief valve depressed until fluid appears. Attach a bleeder hose to the bleeder screw at the wheel, and submerge the other end into a clear container partially filled with brake fluid. Open the bleeder and permit the fluid to flow until it is completely free of air bubbles.

## Vacuum Bleeding

Vacuum bleeding works by creating low pressure at the bleeder




Pressure bleeding the hydraulic system.




If you are pressure bleeding a disc/drum system, you will need to open the metering valve. Shown here is a special tool used to hold the valve open.

screw using a vacuum pump, allowing atmospheric pressure to then push fluid through the brake lines and out the bleeder.

Attach the vacuum pump to the bleeder screw and squeeze the pump handle to create a vacuum. Loosen the bleeder screw, allowing brake fluid and air bubbles to flow into the container. Repeat until there are no more air bubbles, then move to the next wheel cylinder or caliper in the bleeding sequence.

## Surge Bleeding

Surge bleeding is a method of removing air from the hydraulic system that can be used when manual or pressure bleeding has proved inadequate. Surge bleeding churns the air in the wheel cylinder in order to loosen any pockets of air.

The system should first be bled in the usual manner. Then, connect a hose to a wheel cylinder bleeder screw and submerge the opposite end into a clear container partially filled with brake fluid. Open the bleeder screw and then have an assistant pump the brake pedal quickly several times. Close the bleeder screw and then bleed the cylinder again in the normal manner to make sure all air has been expelled.

Repeat the process at each wheel cylinder in the proper sequence.

## Gravity Bleeding

Gravity bleeding is the easiest but most time consuming method of brake bleeding. It can be advantageous for bleeding systems with DOT 5 silicone fluid because it does not agitate the fluid and generate air bubbles. However, it cannot be used on systems with residual pressure check valves or any other type valve that isolates a part of the system at low pressure, and it works best on systems that do not have a proportioning valve or combination valve that requires bleeding.

To gravity bleed a brake system, first bench bleed the master cylinder and then bleed it once it is on the vehicle. Attach lengths of clear plastic hose to the bleeder screws at the wheels and then submerge the other end of each hose in a container partially filled with brake fluid. Make sure the master cylinder is filled with fluid and leave the cap off, then open each bleeder screw. Atmospheric pressure acting on the surface of the fluid in the master cylinder will force the fluid through the hydraulic system and out through the bleeders. Maintain the fluid level in the master cylinder throughout the procedure, which may take several hours.

When no more air bubbles can be seen in the hose, close and tighten the bleeder screws and add fluid, if necessary, to bring the fluid in the master cylinder to the proper level.

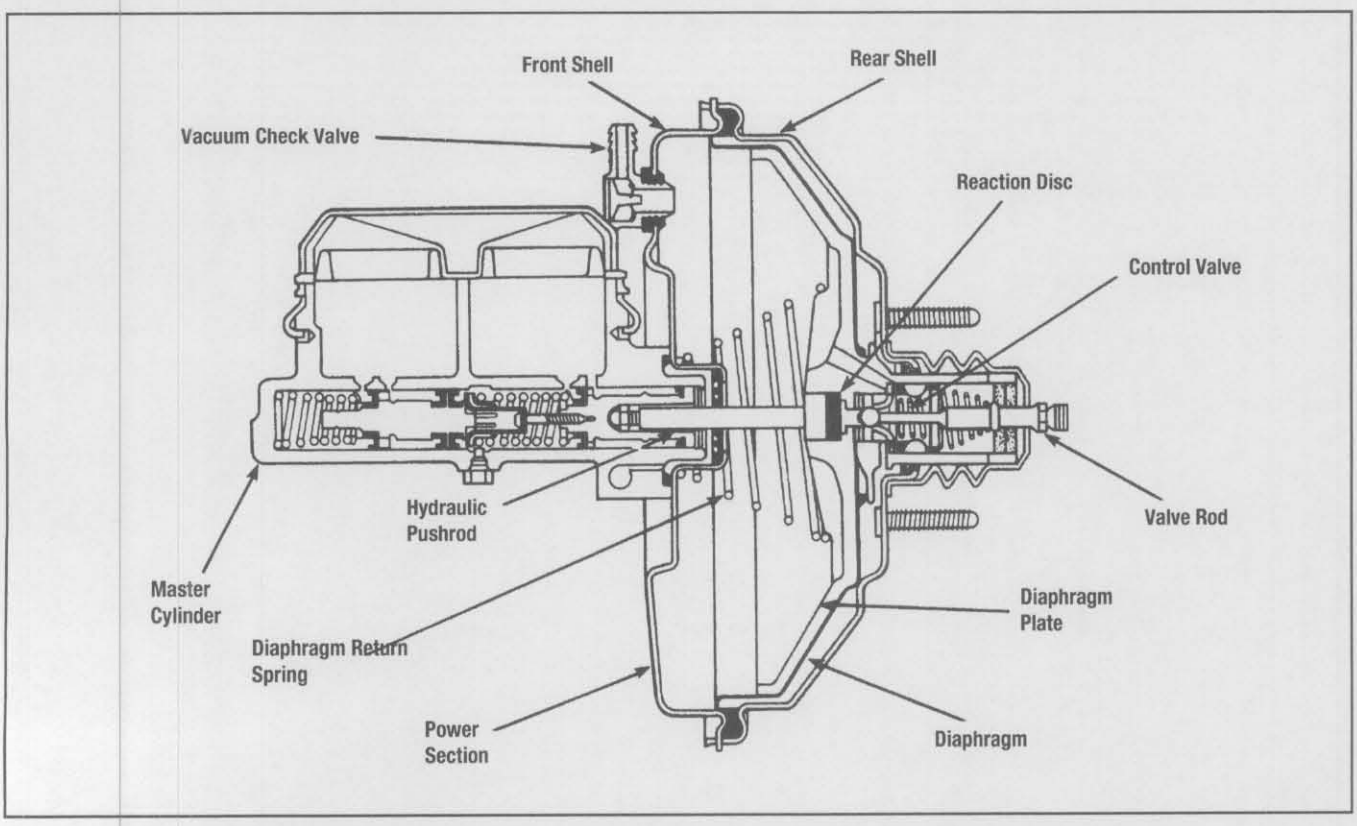
## Flushing

It is recommended that the entire hydraulic system be completely flushed with fresh brake fluid whenever new parts are installed. Approximately one quart of fluid will be required to do the job. Additionally, the system must be flushed if there is any doubt as to the grade of fluid in the system, if a glycol fluid has been mixed with a silicone-based fluid, or the fluid has been contaminated with petroleum or mineral based fluids. Any rubber parts that have been exposed to contaminated brake fluid must be replaced.

The very fact that glycol-based fluids, like DOT 3 and DOT 4, are hygroscopic, means that the hydraulic system should be flushed at least every two years, or every 30,000 miles. As the brake fluid accumulates moisture over time, the brakes may operate normally when cold. However, under heavy prolonged braking, the fluid in the wheel cylinders and calipers will boil and then vaporize. At the very least, this condition will create a spongy brake pedal. In an extreme case, the driver may experience a total loss of brakes. Besides moisture, the brake fluid accumulates a host of other contaminants, which is the reason the fluid turns dark over time. The brake fluid becomes corrosive and attacks components in the hydraulic system. Many manufacturers have regularly scheduled brake fluid changes as part of their normal scheduled maintenance routine.

## Notes

# Power Assist Units Diagnosis And Repair




Cross-sectional view of a dual chamber master cylinder and vacuum operated power booster.

## OPERATION

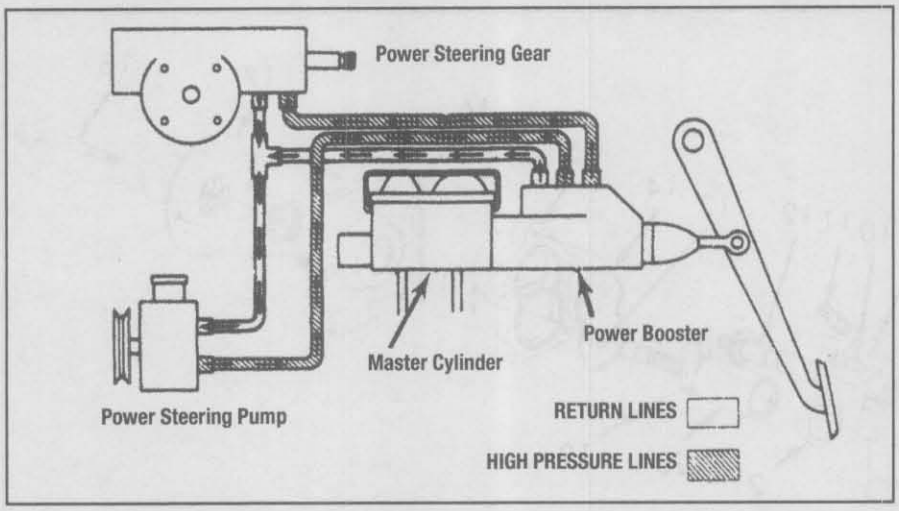
### Vacuum Operated Booster

Power brake systems offer an advantage over their manual counterparts by assisting the driver with brake application. By applying the principles of pressure differential to a diaphragm assembly, a piston can be made to move toward the master cylinder with little effort from the driver's foot.

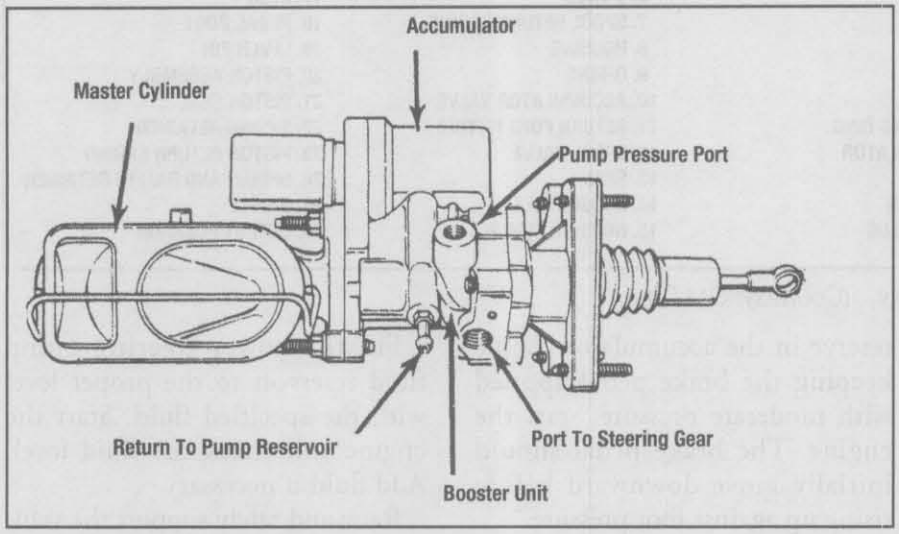
The power brake booster contains a disc-like diaphragm that separates the two halves of the booster's pie-shaped cylinder. Engine vacuum is supplied to the master cylinder side of the diaphragm, while the brake pedal operates a valve, which regulates the amount of outside air allowed to act on the firewall side of the booster diaphragm. Before the brakes are applied, the diaphragm remains in a fixed position since vacuum (negative pressure) exists on each of its sides. However, when the brakes are applied, atmospheric pressure is permitted to fill the chamber on the firewall side of the diaphragm. This action creates a pressure differential that forces the booster's power piston forward, making contact with the master cylinder. When the brake pedal is released, vacuum is once again applied to both sides of the diaphragm, and a large spring in the booster returns the diaphragm to its fixed position. The diaphragm connects to the intake manifold through a hose and a check valve. The one-way check valve is used to maintain brake assist during periods of high engine load when manifold vacuum is low.

### Hydro-Boost

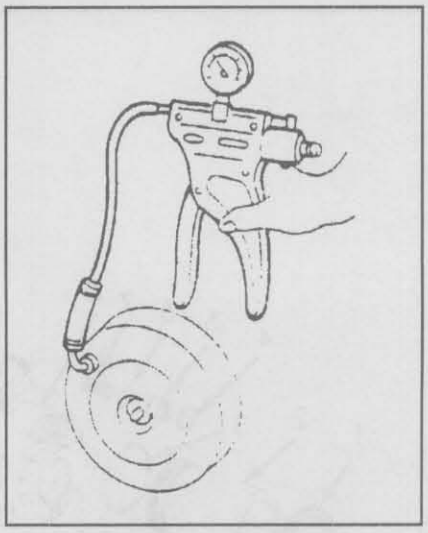
Hydro-Boost is a variation on the conventional power brake system. It operates by using power steering pump fluid pressure rather than intake manifold vacuum. The Hydro-Boost unit contains an open-center spool valve, which regulates the amount of pump pressure as the brakes are applied. A lever assembly controls the valve's position, while a boost piston provides the force necessary to operate the conventional master cylinder on the front of the booster. A reserve of at least two assisted brake applications is supplied by an accumulator, which is spring loaded on earlier models and pneumatic on later ones. When the reserve pressure is depleted, the brakes can be applied manually.




Hydro-Boost power brake system functional schematic. *(Courtesy: GM Corp.)*




Hydro-Boost power brake assembly. *(Courtesy: GM Corp.)*



Vacuum testing a power brake booster.
*(Courtesy: Nissan Motor Co., Ltd.)*

## TESTING POWER BRAKE OPERATION

### Vacuum Operated Booster

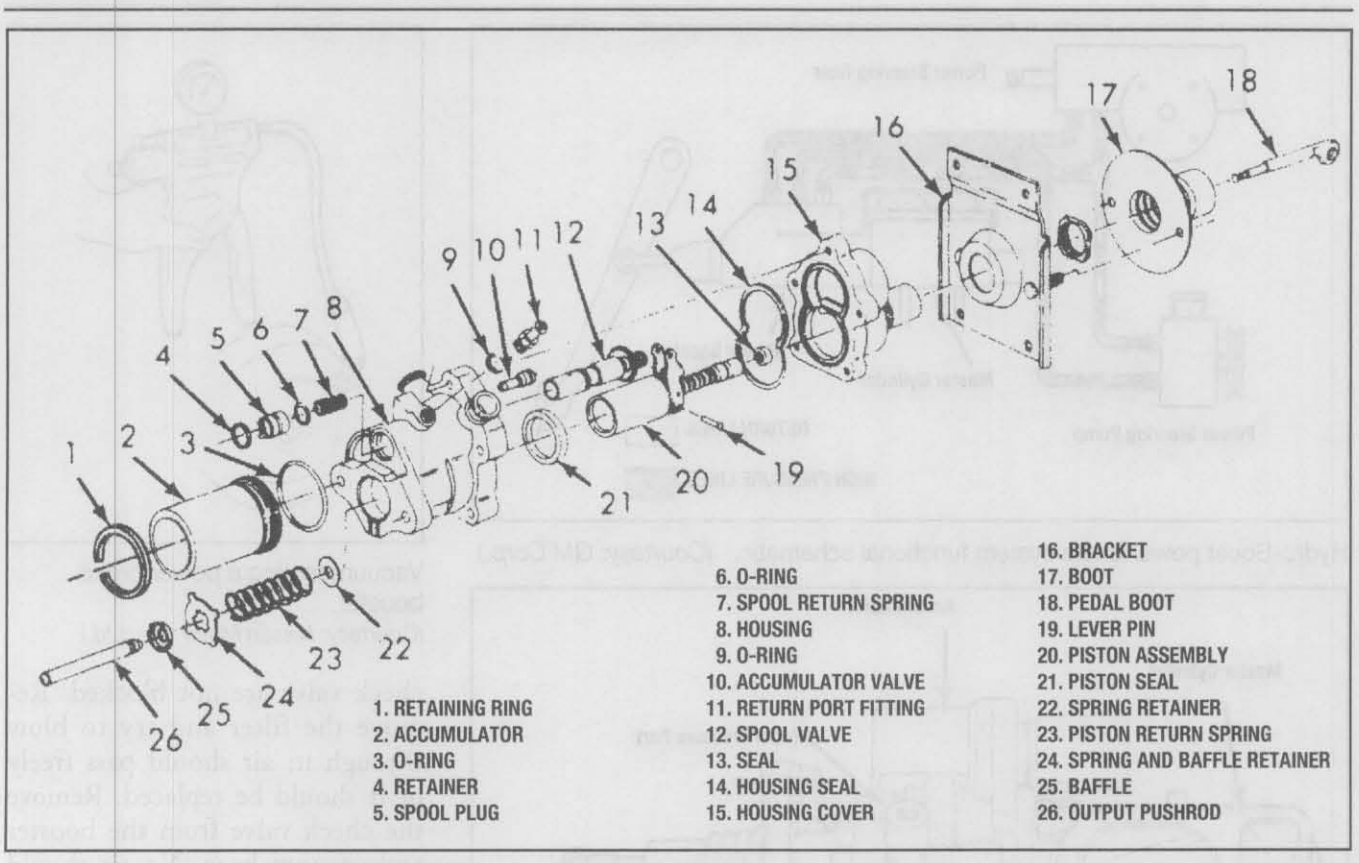
Vacuum assisted power brakes rely on a sufficient level of manifold vacuum from the engine. For this reason, if the engine is not mechanically sound, or if there are vacuum leaks anywhere in the system, the power booster will be unable to operate correctly. Vacuum leaks through the booster diaphragm or housing seams will make a hissing noise. If the vacuum leak is severe enough, it can cause a lean air/fuel mixture in the engine with attendant driveability problems. Decreased vacuum will also cause a hard brake pedal.

To check manifold vacuum, disconnect the booster vacuum hose from the intake manifold and connect a vacuum gauge to the manifold fitting. Observe the vacuum gauge reading while the engine idles; it should be 17-21 in. Hg. If vacuum is low, check for vacuum leaks elsewhere on the engine and check the overall engine condition. If the vacuum reading is within range, make sure that the booster is being supplied with the same vacuum. Check that the vacuum line leading to the booster is in good condition and is not cracked, kinked or blocked. Also make sure any in-line filters and the booster check valve are not blocked. Remove the filter and try to blow through it; air should pass freely or it should be replaced. Remove the check valve from the booster and vacuum hose. No air should pass when blowing through the valve from the intake end and the valve should hold vacuum when a vacuum pump is connected to the booster end. Replace the check valve if necessary.

To check the operation of the power brake booster, apply and release the pedal several times with the engine stopped. This will deplete the vacuum reserve in the booster. While keeping the brake pedal applied with moderate pressure, start the engine. If the vacuum booster is operating properly, the pedal should move downward when the engine starts.

Accelerate the engine momentarily and then let it return to idle. Shut off the engine and wait a few minutes. Apply the brake pedal several times. The first one or two brake applications should be power assisted, then the pedal should get hard. If there was no power assist, the check valve is faulty and must be replaced.

Disconnect the vacuum hose




Exploded view of a Hydro-Boost assembly. *(Courtesy: GM Corp.)*

from the manifold and connect a vacuum pump to the hose. Operate the vacuum pump until it draws 17-20 in. Hg. of vacuum. If that level cannot be achieved or if it drops from that level, there is a vacuum leak. Check the supply hose and the check valve. If they are OK, the booster is leaking and must be replaced.

## Hydro-Boost

On Hydro-Boost systems, an inspection should always begin by thoroughly examining the power steering belt, pump, and hose condition and connections. Unless the power steering fluid is clean and free of trapped air, the Hydro-Boost system will not function correctly. Check the entire system for fluid leaks and repair, as necessary.

A basic test of the system can be performed as follows: With the engine off, apply the brake pedal several times to deplete the fluid reserve in the accumulator. While keeping the brake pedal applied with moderate pressure, start the engine. The brake pedal should initially move downward before rising up against foot pressure.

To check the accumulator, start the engine and turn the steering wheel from stop-to-stop. Hold the steering wheel at that position for no more than five seconds and then return the wheel to center (front wheels straight ahead). Shut off the engine and then pump the brake pedal. There should be at least two or three power-assisted applications.

Again, start the engine and turn the steering wheel from stop-to-stop. Center the wheel and shut off the engine. Wait an hour and then pump the pedal again. You should still feel two or three power assisted applications. If not, the accumulator is leaking and must be replaced.

Hydro-Boost System Bleeding

Fill the power steering pump fluid reservoir to the proper level with the specified fluid. Start the engine and check the fluid level. Add fluid if necessary.

Raise and safely support the vehicle so that the front wheels are off the ground. Start the engine and let it run at approximately 1500 rpm. Apply and release the brake pedal several times and turn the steering wheel from stop-to-stop.

Shut off the engine and check the fluid level in the reservoir. If the fluid is foamy, wait until the foam clears and check the level again. Add fluid if necessary.

Lower the vehicle, start the engine and run it at approximately 1500 rpm. Apply and release the brake pedal several times and turn the steering wheel from stop-to-stop.

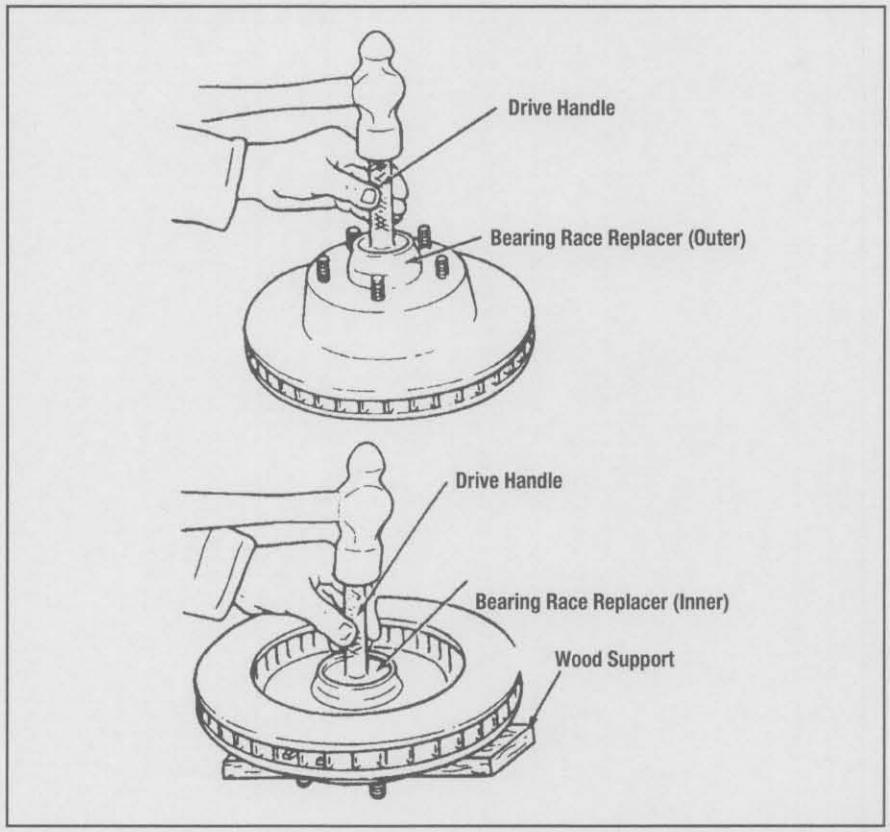
Shut off the engine and check the fluid level in the reservoir. Add fluid if necessary. If the fluid is still foamy, wait an hour and repeat the above procedure.

## Notes

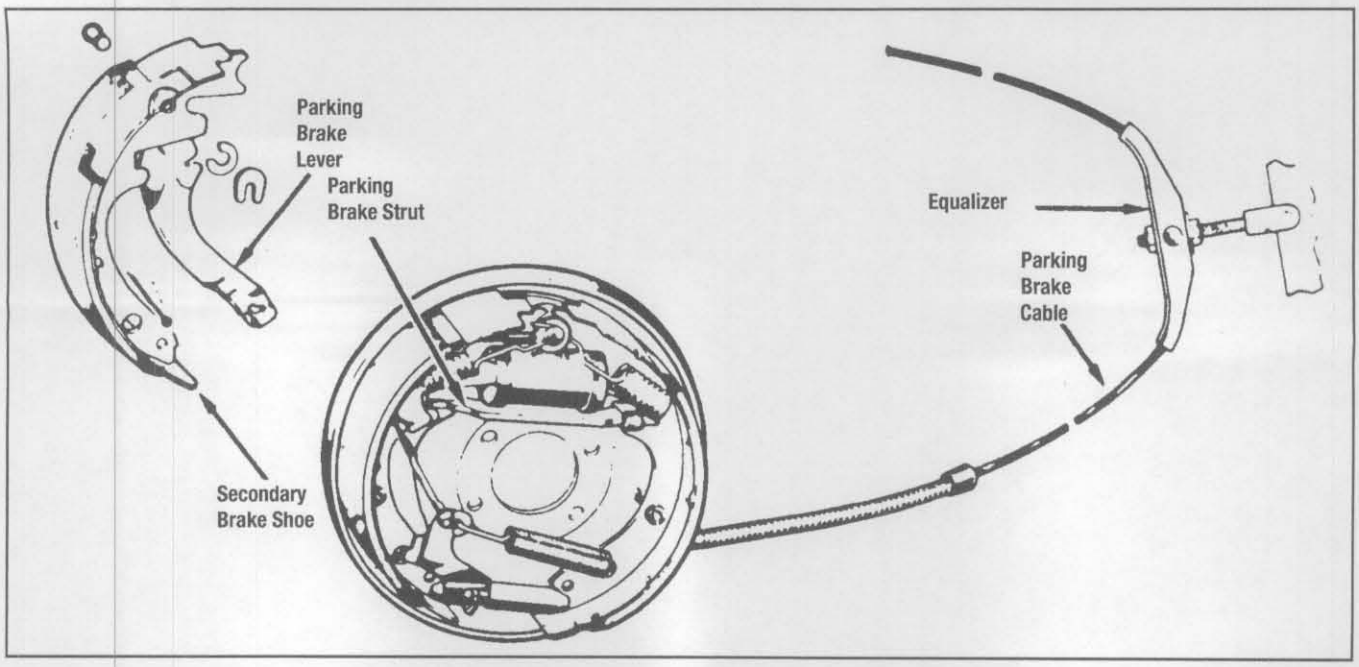
# Parking Brakes

The parking brake is not part of the hydraulic system but rather operates mechanically through a series of linkages and cables. Depending on the vehicle, the parking brake system will either be actuated using a foot pedal or a hand-operated lever. On vehicles with rear drum brakes, when the parking brake is applied, the rear brake shoes are actuated mechanically via the linkage and cables.

There are two kinds of parking brakes on vehicles with rear disc brakes. One kind has small brake shoes inside a drum that is incorporated in the disc brake rotor. The shoes are forced against the drum by the linkage and cables in the same manner as conventional drum parking brakes. The other kind uses the rear disc brake pads. The linkage and cables actuate a cam or screw mechanism inside the caliper piston to push the caliper




Installing inner and outer bearing races. *(Courtesy: Ford Motor Co.)*

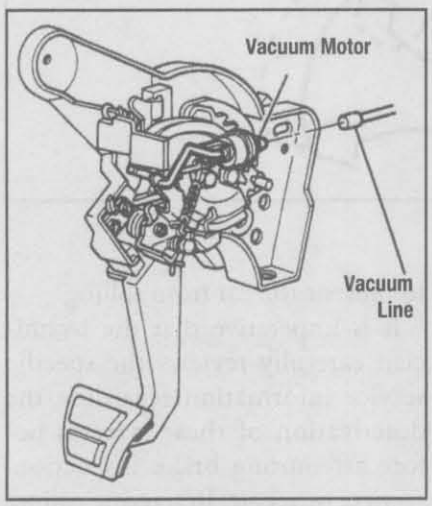



Typical drum parking brake system. *(Courtesy: EIS Brake Parts)*

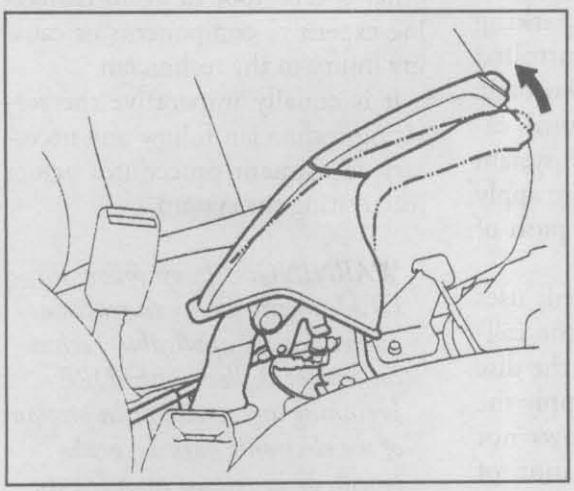
piston and pads against the rotor.

Some vehicles are equipped with an automatic parking brake release mechanism, which releases the parking brakes when the automatic transmission is shifted into drive or reverse. These systems usually consist of a vacuum motor that is attached to a release lever, and a vacuum switch that routes vacuum to the motor when the transmission is placed in drive or reverse.

When the driver selects the drive or reverse position, the switch directs engine vacuum to the vacuum motor, which releases the lever and the parking brakes. Vehicles with this system also have a manual release lever, which can be used if the automatic system fails.




Parking brake pedal assembly with vacuum release motor. *(Courtesy: GM Corp.)*



When adjusting the parking brake, engage the lever or pedal the number of clicks specified by the manufacturer or place the lever or pedal into a position that will be comfortable for the driver to operate. *(Courtesy: Honda Motor Co., Ltd.)*

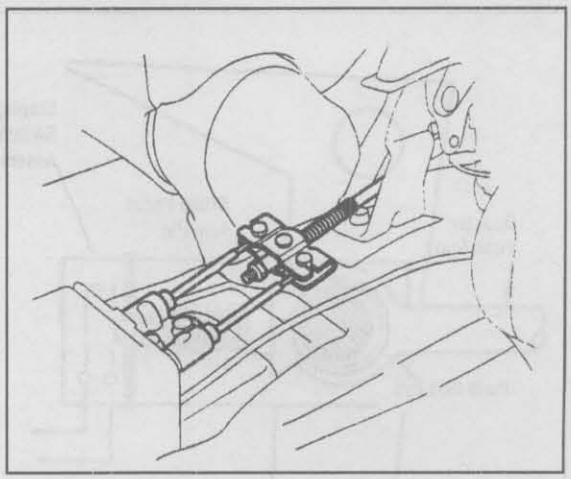
## Inspection

Make sure the rear drum or disc service brakes are in good condition and properly adjusted. Some disc brake vehicles with caliper actuated parking brakes require a caliper lever adjustment; refer to the service manual for the proper adjustment procedure.

Check the parking brake linkage and equalizer for wear, rust and damage. Check the cables for rust and fraying. Make sure the cables move freely inside the conduits. Lubricate and/or replace parts as necessary.

If the parking brake fails to release on a vehicle with an automatic release mechanism, check for vacuum to the vacuum release motor using a vacuum gauge. Refer to the manufacturer's specifications for the vacuum level at which the motor should actuate. If there is no vacuum or if vacuum is less than specification, check for cracked, kinked or split vacuum lines and loose connections.

If there is vacuum to the vacuum switch, but no vacuum from the switch when the vehicle is placed in drive or reverse, the switch is defective. If there is sufficient vacuum to the release motor, but the motor does not actuate, test the motor with a vacuum pump. Apply the necessary amount of vacuum to the motor for actuation and replace the motor if it fails to operate.



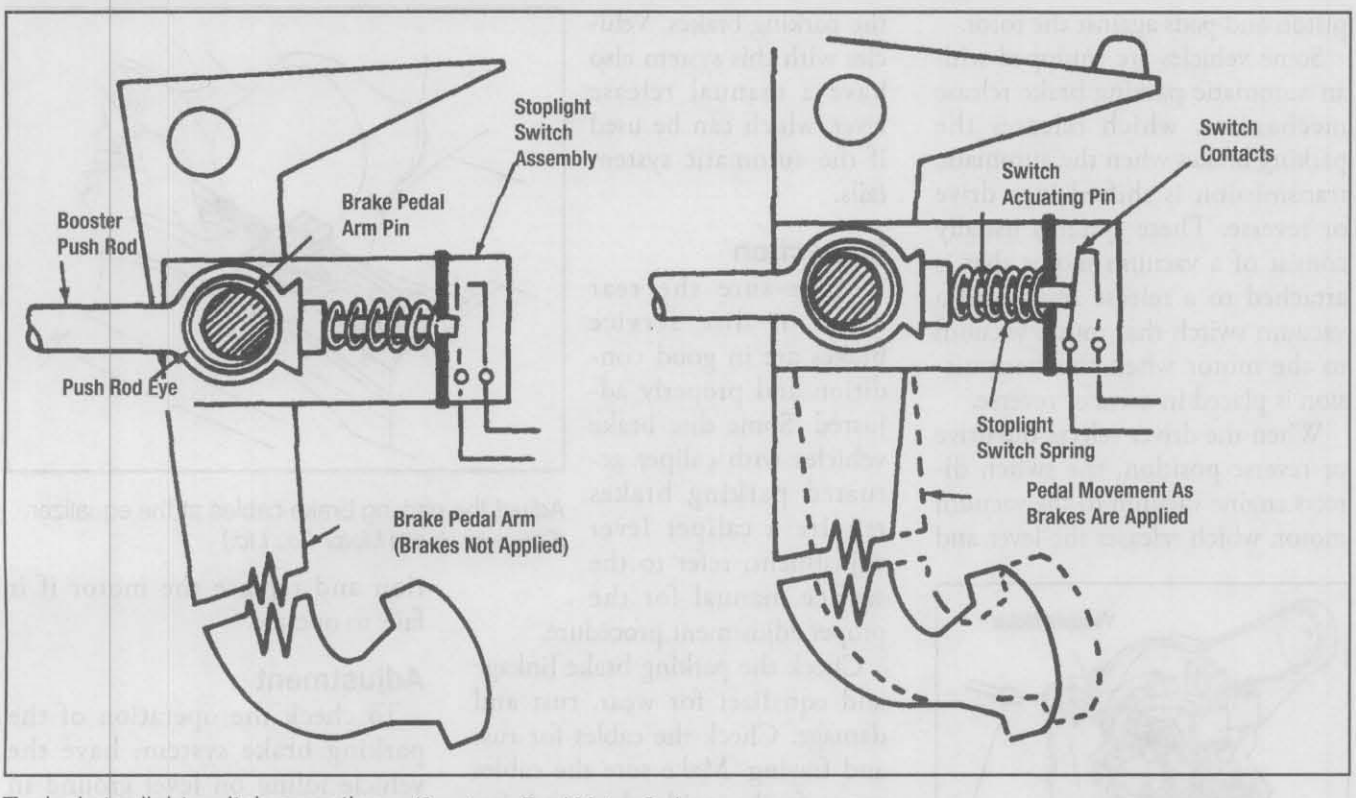
Adjust the parking brake cables at the equalizer. *(Courtesy: Honda Motor Co., Ltd.)*

## Adjustment

To check the operation of the parking brake system, have the vehicle idling on level ground in neutral with the parking brake engaged. Make sure the area is clear to the front and rear of the vehicle while performing this test. Place the gear selector in drive. The vehicle should stay still. If it does not, the parking brake cable may require an adjustment.

Adjustment is accomplished by raising and safely supporting the vehicle and engaging the parking brake a specific number of clicks as specified by the manufacturer. If this information is unavailable, then engage the foot brake or hand lever into a position that will be comfortable for the driver to operate. For example, if the foot brake is set to lock the rear wheels at only two clicks, the driver may be unable to apply enough foot pressure to the pedal for it to ratchet into position. Once the pedal or lever is properly positioned, you should not be able to rotate the rear wheels in a forward direction by hand.

If the wheels can be rotated and the rear brakes have been adjusted properly, then tighten the adjust-




Typical stoplight switch operation. *(Courtesy: Ford Motor Co.)*

ing nut at the cable equalizer or the hand lever until the wheels lock. Now release the parking brake and check that the wheels spin freely. If they do not, the equalizer or hand lever is adjusted too tight and must be backed off until the wheels spin free. If the brakes either won't adjust tight, or won't release completely, check the cables for free movement. If the cables operate properly, then check the parking brake linkage for proper installation. In the case of rear disc brakes, caliper service may be required if the parking brake does not operate correctly.

## Parking Brake Switch

The brake warning light should illuminate when the parking brake is applied.

If the light does not come on when the parking brake is applied, disconnect the switch and connect a jumper wire between the signal circuit of the switch and a good ground. Turn the ignition switch to the ON position. If the light still does not come on, check for an open or high resistance in the parking brake switch signal circuit. If the light comes on, check for a poor ground or poor connections at the switch harness connector. If these are OK, replace the parking brake switch.

## Electronic Parking Brakes

Increasingly popular, parking brakes are now being controlled electronically. There are two basic versions. One is a conventional, cable-operated parking brake system that uses an electric motor to apply the cable tension with the push of a button.

The other, more involved, uses electric motors built into the calipers themselves to activate the disc brake caliper pistons and apply the rear brake pads. This allows not only for automatic application of the parking brakes, it also allows for a driver convenience feature called "Hill Stop."In this mode, whenever the car is not moving the parking brake system is activated to prevent the car from rolling.

It is imperative that the technician carefully reviews the specific service information regarding the deactivation of these systems before attempting brake inspection, service, or repair. Retracting caliper pistons, for example, may require a vehicle-compliant scan tool or other special tool to avoid damaging expensive components or causing injury to the technician.

It is equally imperative the servicing technician follow any necessary adjustment procedures before reactivating the system.

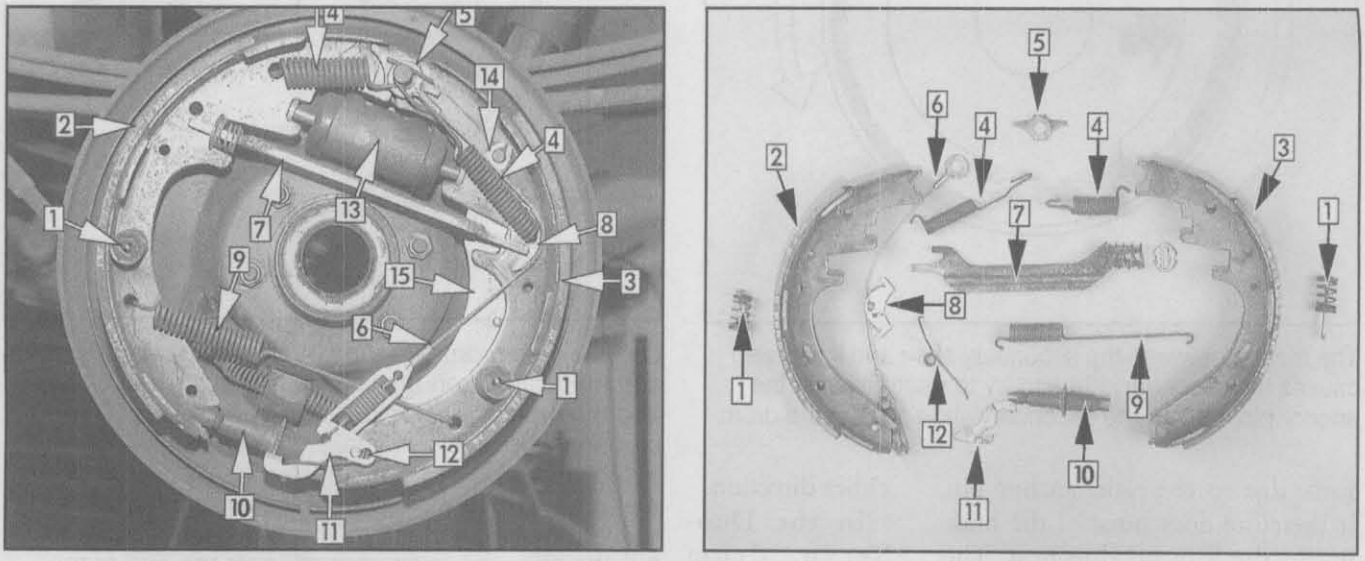
***WARNING:*** *Always follow the OEM specific service instructions and review all applicable Technical Service Bulletins BEFORE beginning any service or inspection of the electronic parking brake system, or its related components. Physical injury can result if the proper service precautions are not taken or followed.*

# Drum Brake Diagnosis And Repair

## DESCRIPTION AND OPERATION

The typical drum brake design employs one pair of brake shoes mounted on a stationary backing plate. These shoes are positioned inside a circular cast iron or aluminum drum, which rotates with the wheel assembly. The shoes are held in place by various springs. The return, or pull-back springs, secure the tops of both shoes to an anchor pin on the backing plate. These springs allow the shoes to move in and out laterally. An adjuster assembly is positioned between the primary (front) and secondary (rear) shoes at the bottom, and the shoes are linked together by a spring located right above the adjuster. The hold-down springs are used to keep the shoes secured to the backing plate. All of the springs serve to maintain correct shoe-to-drum alignment. The brake shoes are actuated by a wheel cylinder, which is mounted at the top of the backing plate. This type of drum brake arrangement is known as Duo-Servo, or self-energized brakes.

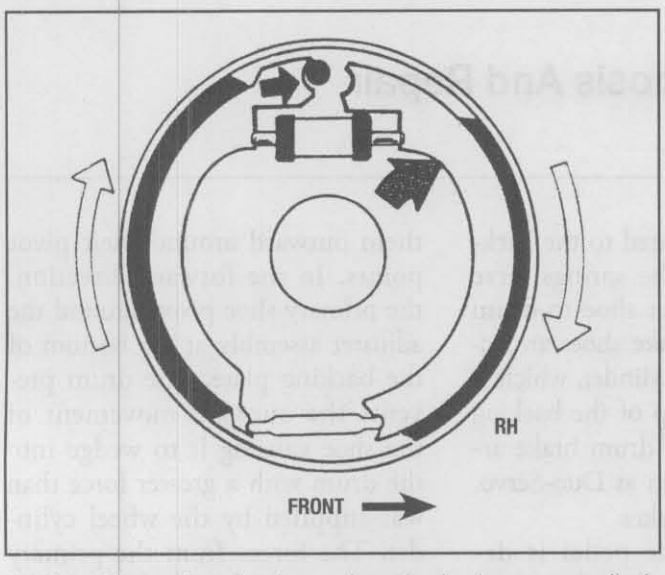
When the brake pedal is depressed, the force that the wheel cylinder applies to the shoes is augmented by the tendency of the shoes to wrap themselves into the rotating brake drum. When both brake shoes are pushed out by the wheel cylinder and contact the spinning drum, in either direction of rotation, the frictional forces between the linings and drum tend to drag the shoes along and turn them outward around their pivot points. In the forward direction, the primary shoe pivots around the adjuster assembly at the bottom of the backing plate. The drum prevents the outward movement of the shoe causing it to wedge into the drum with a greater force than was supplied by the wheel cylinder. The forces from the primary shoe are transferred through the adjuster assembly to the secondary shoe. The frictional force between the drum and the secondary shoe quickly overcomes the force of the wheel cylinder, causing the secondary shoe to return to the anchor pin at the top. The drum again wedges the secondary shoe in a similar manner to the primary shoe. Since it cannot transfer any



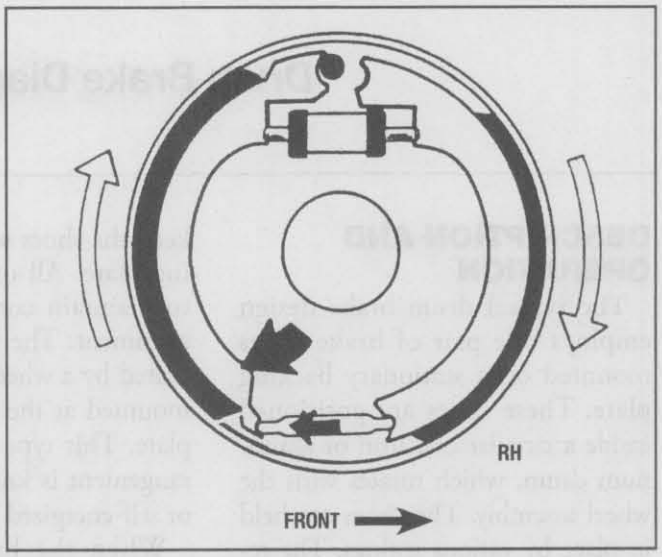
Typical Duo-Servo drum brake components.

**Rear Drum Brake Components**

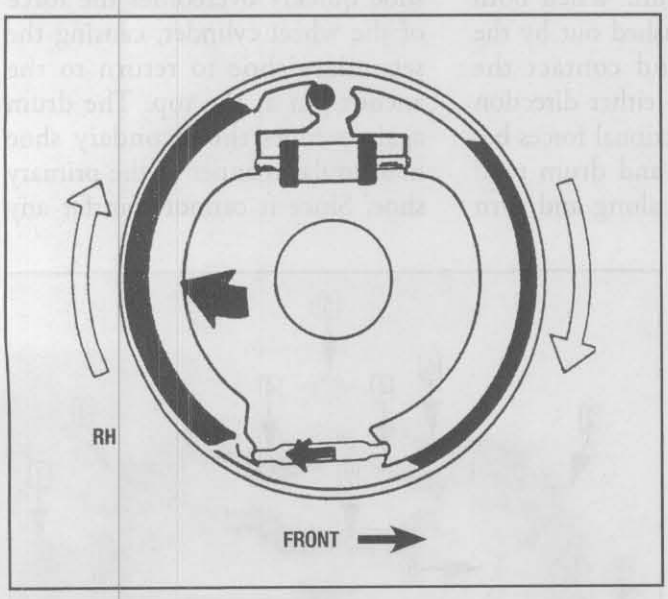
1. Shoe Hold-Down Spring And Retainer
2. Primary Brake Shoe
3. Secondary Brake Shoe
4. Brake Shoe Retracting Springs
5. Anchor Pin Guide Plate
6. Shoe Adjusting Lever Cable
7. Parking Brake Strut
8. Shoe Adjusting Lever Cable Guide
9. Brake Shoe Adjusting Screw Spring
10. Brake Adjusting Screw
11. Brake Shoe Adjusting Lever
12. Adjusting Lever Return Spring
13. Wheel Cylinder
14. Parking Brake Lever Retaining Clip
15. Parking Brake Lever



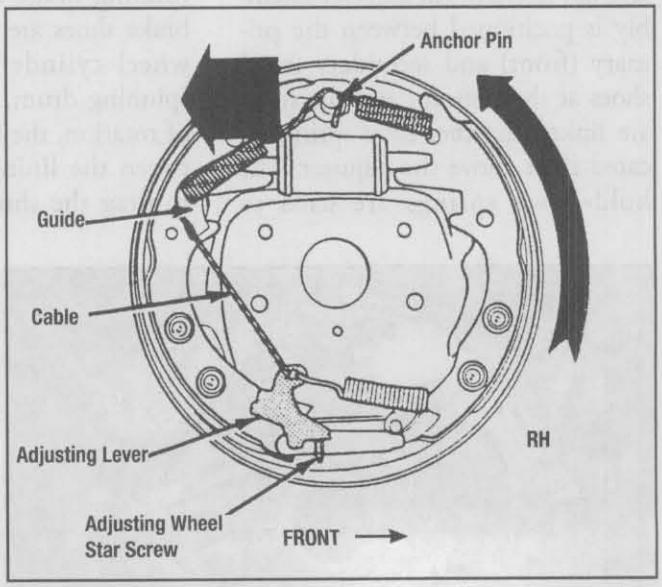

On Duo-Servo drum brakes, when the brakes are applied with the vehicle traveling forward, the shoe lining contacts the drum. The friction between the brake drum and the lining of the primary shoe causes the primary shoe to rotate a short distance.




As the thrust of the primary shoe is transmitted through the adjusting screw to the secondary shoe, the secondary shoe is driven more tightly against the lining of the drum.




The friction between the secondary shoe and lining also causes the secondary shoe to try to rotate against the anchor pin, forcing the secondary shoe against the drum.



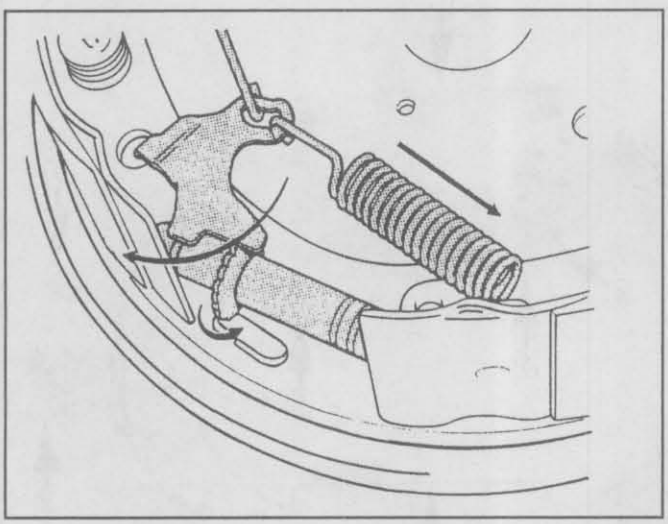

On Duo-Servo drum brakes, brake adjustment is made automatically when the vehicle is moving backward and the brakes are applied. The upper end of the primary shoe is forced against the anchor pin by frictional drag. The action of the wheel cylinder moves the upper end of the secondary shoe and cable guide away from the anchor pin. This causes the cable to pull the adjusting lever upward, over the end of the tooth on the adjuster star wheel.

force due to the rigid anchor pin, it therefore does most of the braking in the forward direction. This is why the secondary shoe is usually longer and thicker than the primary shoe. The name Duo-Servo comes from this self-energizing action that takes place as the braking force is transferred from one shoe to the other as the wheel rotates in either direction.

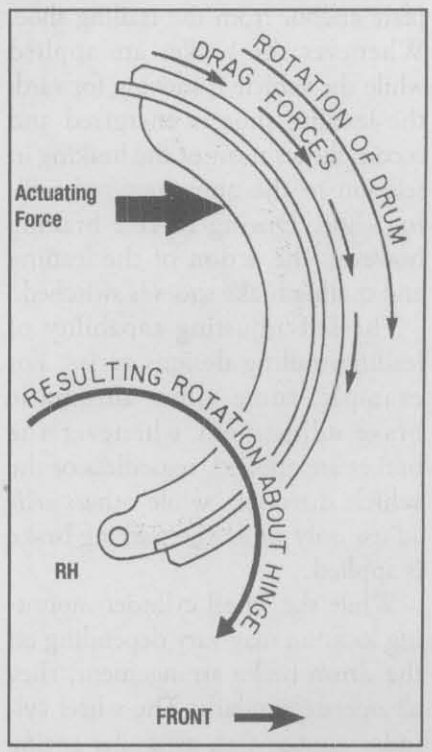
In the Duo-Servo drum brake design, the shoes will self-adjust when the brakes are applied with the vehicle traveling in reverse. This is accomplished through a series of links and levers that actuate a star wheel, which automatically compensates for lining wear. Depending on the manufacturer, the self-adjusting mechanism will either operate when the brakes are applied or when the

brake pedal is released.

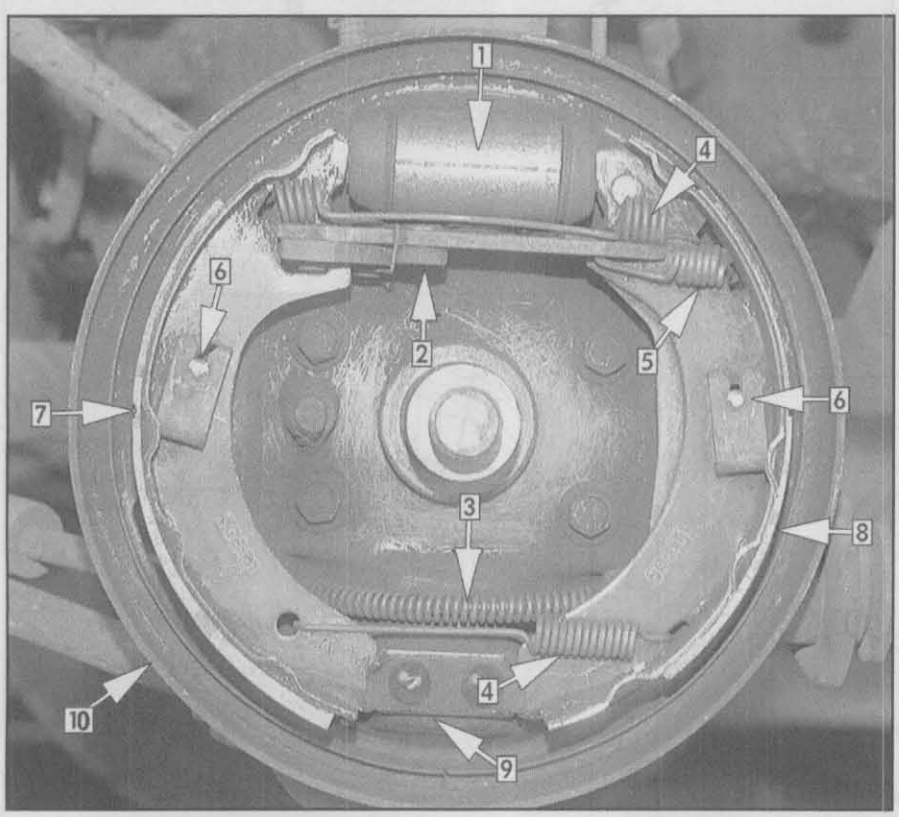
Another design, known as Leading-Trailing drum brakes, has both shoes held in place against a solidly attached anchor mounted to the bottom of the backing plate. A retaining spring links the bottom of both shoes together and keeps them in place against the anchor. During forward brake application, the friction forces of the leading (front) shoe are developed by the wheel cylinder pushing the lining into contact with the rotating brake drum. This shoe friction force works against the rigidly mounted backing plate anchor near the bottom of the shoe. The trailing (rear) shoe is also actuated by the wheel cylinder, however, it can only support a



The spring pulls the adjusting lever back down when the brakes are released, turning the adjusting wheel.

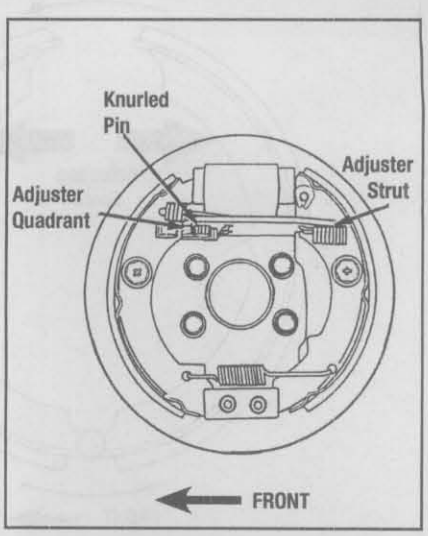



On leading-trailing drum brakes, when the brake shoe is engaged, the drag from the friction between the shoe and the drum causes the shoe to rotate at its hinge point, the anchor. Because the drum and the leading shoe are both rotating in the same direction, this drag pulls the shoe tighter against the inside of the drum.




Typical leading-trailing drum brake components—assembled

1. Wheel Cylinder
2. Adjusting Strut And Quadrant
3. Parking Brake Cable
4. Shoe Retracting Springs
5. Parking Brake Return Spring
6. Brake Shoe Retaining Pin And Spring
7. Brake Shoe
8. Brake Shoe And Parking Brake Lever
9. Anchor Block
10. Backing Plate

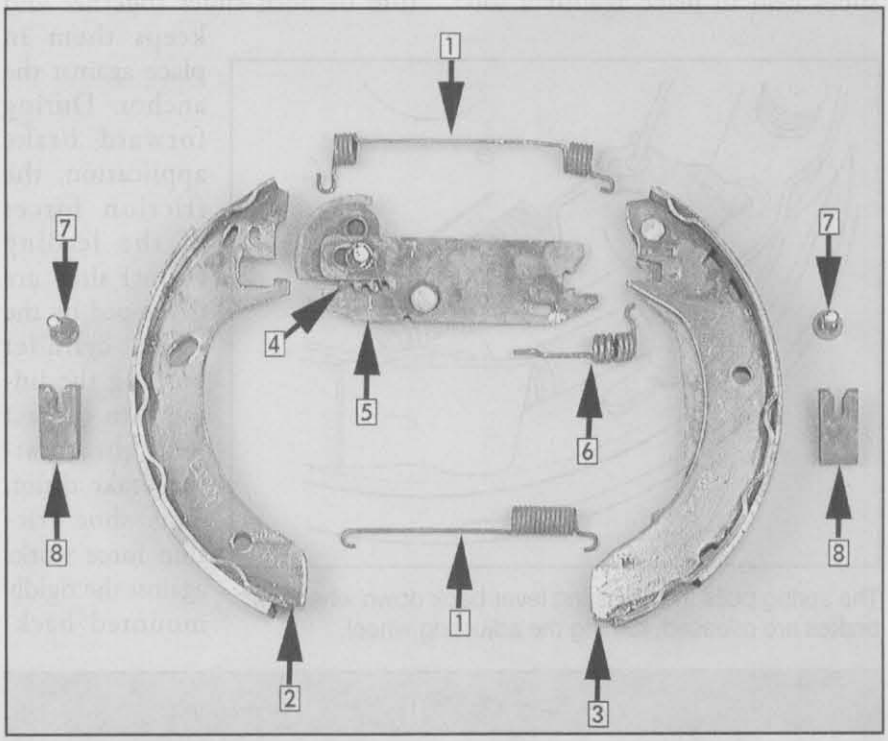



On this type of automatic adjuster mechanism, an adjustment is made when a certain distance between the lining and drum is reached.

friction force equal to force generated by the wheel cylinder piston. Under this condition, no friction force is transmitted to the backing plate anchor from the trailing shoe. Whenever the brakes are applied while the vehicle is moving forward, the leading shoe is energized and accomplishes most of the braking in relation to the non-energized trailing shoe. During reverse braking however, the action of the leading and trailing brake shoes is switched.

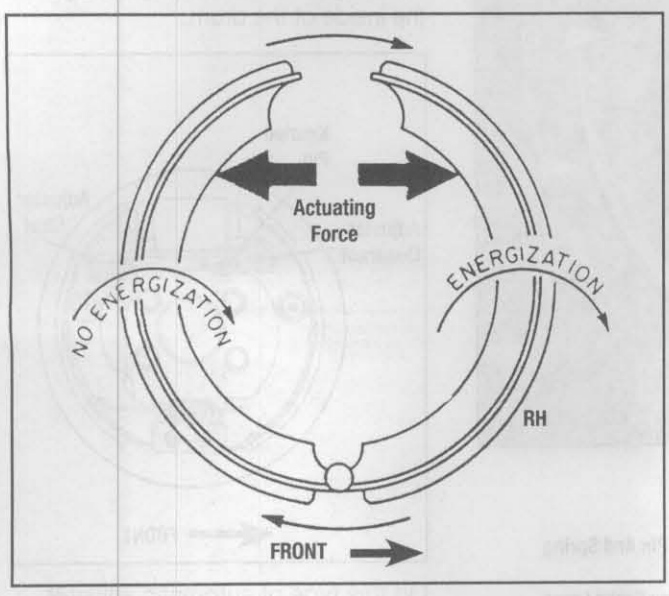
The self-adjusting capability of leading-trailing designs varies. For example, some allow automatic brake adjustment whenever the brakes are applied, regardless of the vehicle direction, while others self-adjust only when the parking brake is applied.

While the wheel cylinder mounting location may vary depending on the drum brake arrangement, they all operate similarly. The wheel cylinder contains an expander spring and cup assembly that separates a pair of pistons. The space between the cups in the cylinder bore is filled with fluid at all times. Operating in response to the master cylinder, the wheel cylinder receives pressurized fluid from the hydraulic line through its inlet port. As fluid pressure increases during brake apply, the wheel cylinder cups and pistons are forced apart within the cylinder bore. This action pushes the shoes

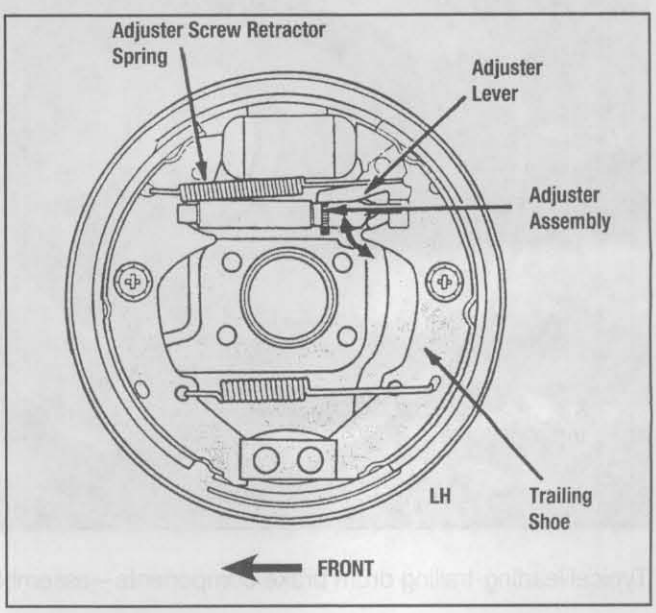



Typical leading-trailing drum brake components—disassembled.

1. Shoe Retracting Springs
2. Brake Shoe
3. Brake Shoe With Parking Brake Lever
4. Adjusting Quadrant
5. Adjusting Strut
6. Parking Brake Return Spring
7. Brake Shoe Retaining Pin
8. Brake Shoe Retaining Spring




With the leading-trailing brake design, when the brakes are applied in normal vehicle motion, the forward or 'leading' shoe is energized, while the trailing shoe is not.




On most leading-trailing drum brakes, the action of the wheel cylinder moves the two shoes away from each other, causing the adjuster screw retractor spring to pull the lever up over the end of the tooth on the adjuster wheel.

directly (or indirectly using shoe links) into contact with the drum. As a result, hydraulic pressure is converted into a mechanical force that acts on the brake shoes.

## DIAGNOSIS

While road testing the vehicle, listen for noise and check brake operation. A squeaking noise when the brakes are applied could be caused by excessive wear to or lack of lubrication on the brake backing plate shoe support pads. A squealing noise could be caused by glazed brake linings or foreign material embedded in the lining. A grinding noise could be caused by metal-to-metal contact of the rivets or brake shoe against the brake drum if the linings are worn.

If the brake pedal is low, there is excessive clearance between the brake linings and drum or there is a leak in the hydraulic system. Excessive clearance between the linings and drum can be caused by malfunctioning automatic adjuster mechanisms or if the driver does not back up enough to allow the adjuster mechanisms to keep pace with lining wear.

If the pedal is spongy, it could be due to a hydraulic brake hose bulging under pressure, or cracked or thin drums. A hard pedal could be caused by glazed linings, or grease or brake fluid on the linings. Grease or brake fluid contamination can also cause the brakes to grab. Pedal pulsation could be caused by drums that are out of round. Dragging brakes could be caused by broken or weak return springs, frozen parking brake cables, a restricted brake hose or swelled rubber components due to contaminated brake fluid.

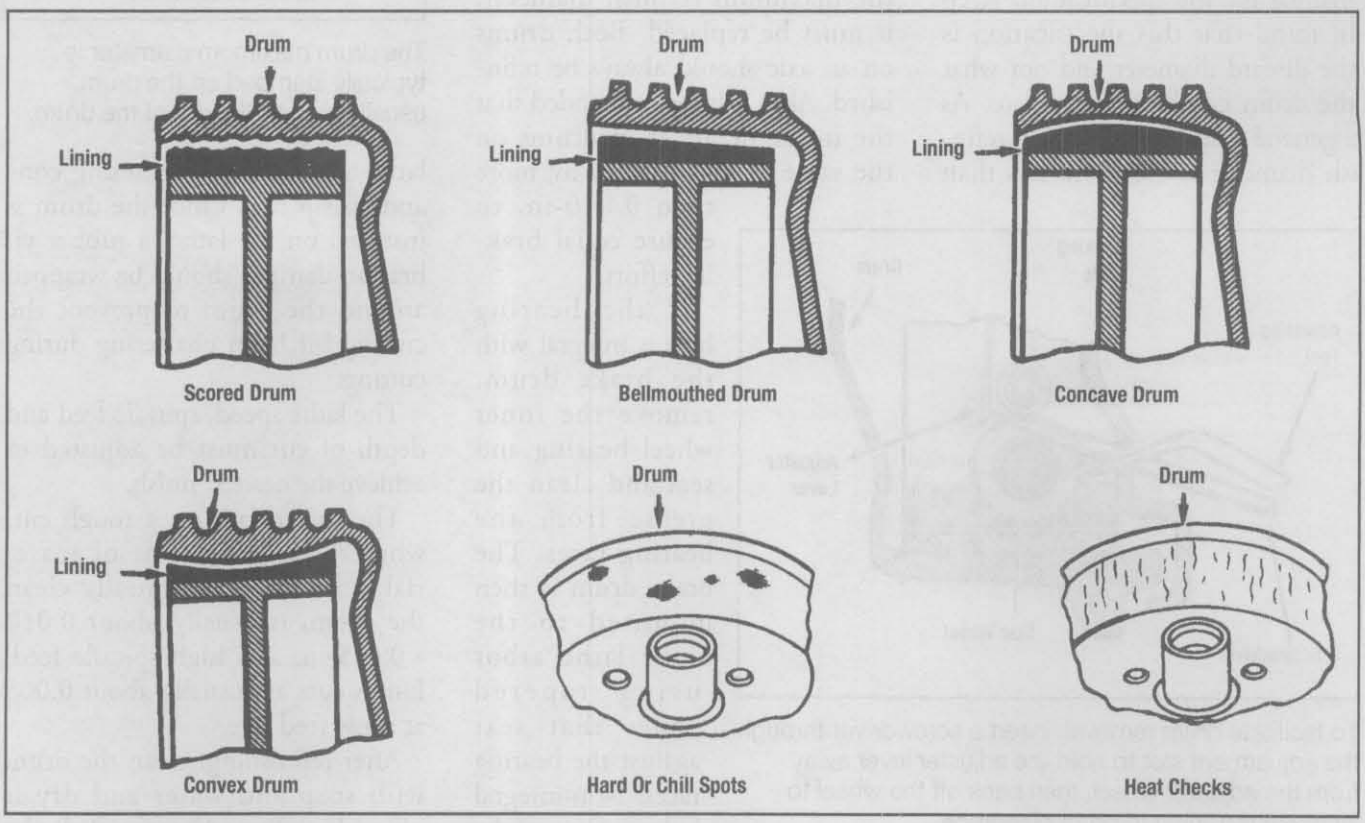
## REMOVAL AND INSPECTION

### Brake Drum

If the wheel bearing hub is integral with the drum, remove the dust cap, cotter pin, retaining nut and washer. Pull the drum from the spindle, being careful not to drop the outer wheel bearing. Most all other brake drums can be removed by pulling the drum from the axle once the wheel is removed, however, some drums may be retained by small screws that thread into the axle flange.

If the drum is difficult to remove, it may be because wear has caused a lip to form at the edge of the machined surface, outside of the lining contact area. In this case, back off the brake adjuster to increase the lining-to-drum clearance, so the drum can be removed.

Inspect the drum for cracks, scoring, heat checks or hard spots. Cracks are caused by stress and most often appear in the drum mounting area. A cracked drum must be replaced. Scoring can be caused by dust, dirt or foreign material between the linings and drum




Types of brake drum defects. *(Courtesy: Bendix Corp.)*

or if the linings wore to the point that the rivets or shoe steel contacted the drum. A scored drum can be reused if the scoring can be removed without machining past the maximum drum refinishing diameter. Heat checks are caused by extreme operating temperatures. They may be difficult to remove with standard drum machining equipment and in such cases the drum should be replaced. Hard spots are also caused by heat and usually appear during the drum machining process. Even if hard spots appear to have been removed by machining, they can reappear once the drum is heated again, causing chatter, noise and a hard pedal. Therefore, a drum with hard spots should be replaced.

Measure the drum for wear and out-of-roundness using an inside micrometer. The maximum drum diameter is cast into the outside of the drum; however, if it is not legible, consult the vehicle service manual for the specification. Keep in mind that this specification is the discard diameter and not what the drum can be machined to. As a general rule, the maximum refinish diameter is 0.030-in. less than the maximum diameter, but refer to the vehicle service manual to be sure.

Measure the drum at several points around the circumference to pick up out-of roundness and distortion. Take the measurements at the center and at the inside and outside edges of the machined surface to detect concave, convex, bellmouth and taper wear. A drum that is out-of-round by more than 0.010-in. will cause a pulsation in the brake pedal. The drum can probably be made true by machining, but drum balance may be affected and when the drum is heat stressed, it may become out-of-round again. Therefore, drums that are severely out-of-round should be replaced.

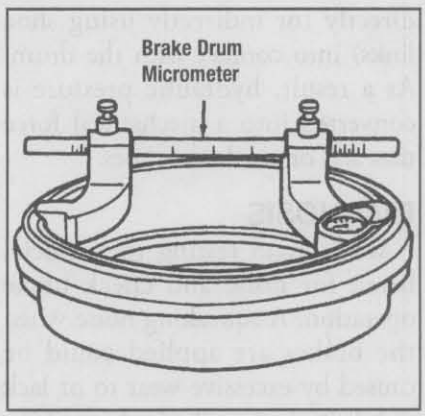
Brake drums can be refinished by grinding or turning on a brake lathe. When machining the drum, remove only enough metal to obtain a smooth surface. If the drum does not clean up when turned to the maximum refinish diameter, it must be replaced. Both drums on an axle should always be refinished. Also, it is recommended that the inside diameter of drums on the same axle not differ by more than 0.010-in. to ensure equal braking effort.

If the bearing hub is integral with the brake drum, remove the inner wheel bearing and seal and clean the grease from the bearing races. The brake drum is then mounted to the brake lathe arbor using tapered cones that seat against the bearing races. Non-integral hubs mount to the lathe arbor using a centering cone and clamp cup. Once the drum is installed on the lathe, a rubber vibration damper should be wrapped around the drum to prevent the cutting bit from chattering during cutting.

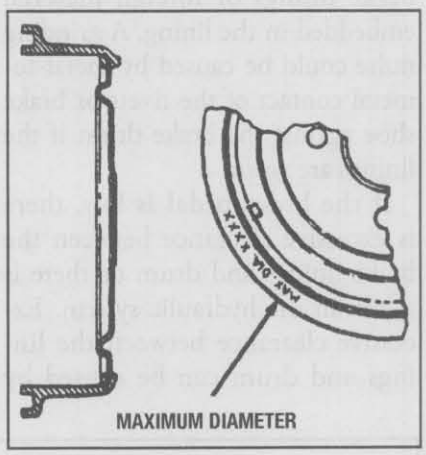
The lathe speed, spindle feed and depth of cut must be adjusted to achieve the desired finish.

The tool depth on a rough cut, where a large amount of material is removed to initially clean the drum, is usually about 0.010 - 0.015-in. at a high spindle feed. Finish cuts are usually about 0.005 at a low feed rate.

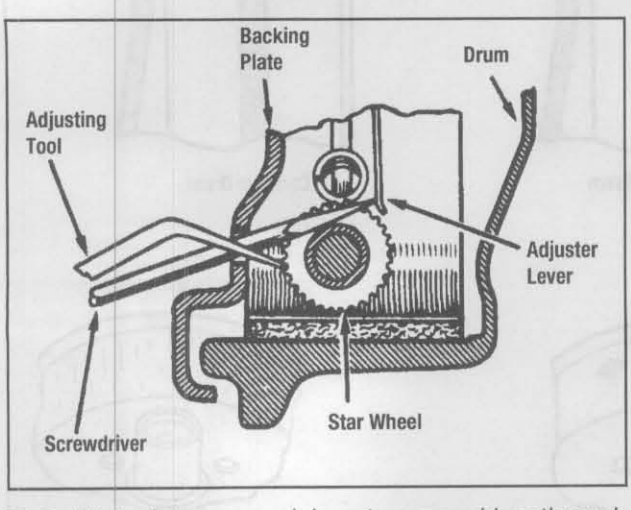
After refinishing, clean the drum with soap and water and dry it off with a clean shop towel. Brake




A brake drum micrometer is necessary to measure the diameter of a brake drum.




The drum maximum diameter is typically stamped on the drum, usually around the rim of the drum.




To facilitate drum removal, insert a screwdriver through the adjustment slot to hold the adjuster lever away from the adjuster wheel, then back off the wheel to increase the lining to drum clearance. *(Courtesy: Bendix Corp.)*

cleaning solvent may not remove all of the fine particles left over from the machining process, and these can become imbedded in the new linings and cause brake noise and drum scoring.

## Brake Shoes And Hardware

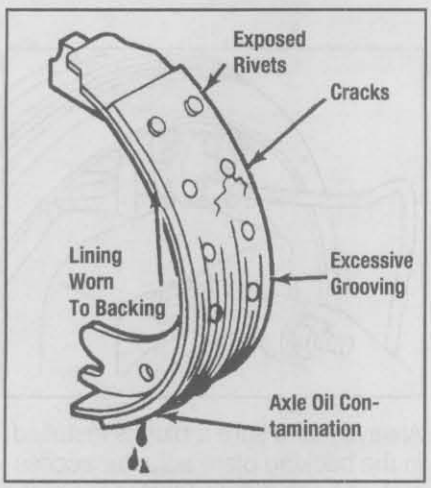
Inspect the brake shoe linings for exposed rivets, cracks, contamination, glazing, unusual wear patterns or discoloration due to overheating. If the brakes have overheated, the brake springs will have lost their tension and should be replaced.

Measure the lining thickness; it must be at least 0.030-in. above the brake shoe on bonded shoes or rivet head on riveted shoes.

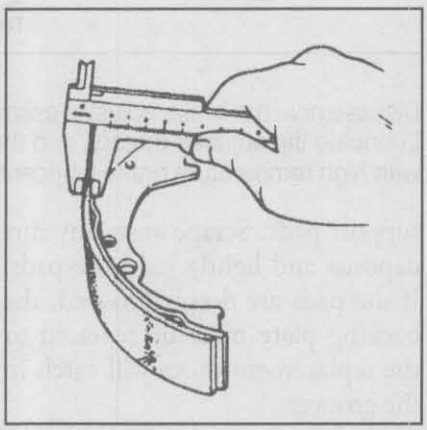
If the brake shoe linings are contaminated or there is evidence of wetness on the brake backing plate, it could be grease, gear oil or brake fluid. A bad wheel seal could allow wheel bearing grease to leak onto the brake assembly. A worn axle seal would let gear oil leak from the axle housing. Pull back the wheel cylinder boots to check for a brake fluid leak. A small amount of moisture is normal, however if a large amount of fluid is present, the wheel cylinder must be rebuilt or replaced.

Before removing the brake shoes, note how the return and hold-down springs are attached and how the automatic brake adjuster and parking brake assemblies are installed. Remove the return springs using a brake spring tool (Duo-Servo brakes) or needle nose pliers (leading-trailing brakes) and remove the automatic adjuster assemblies. Remove the hold-down springs and remove the brake shoes from the backing plate. Disconnect the parking brake cable and remove the shoes from the vehicle.

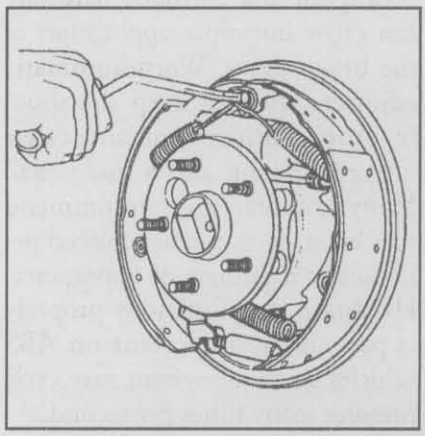
Remove the wheel cylinder if it is to be rebuilt or replaced. Some wheel cylinders can be rebuilt while mounted on the backing plate. Loosen the brake line fitting at the wheel cylinder with a flare nut wrench and disconnect the brake line from the wheel cylinder. Plug the line to keep dirt out of the sys-



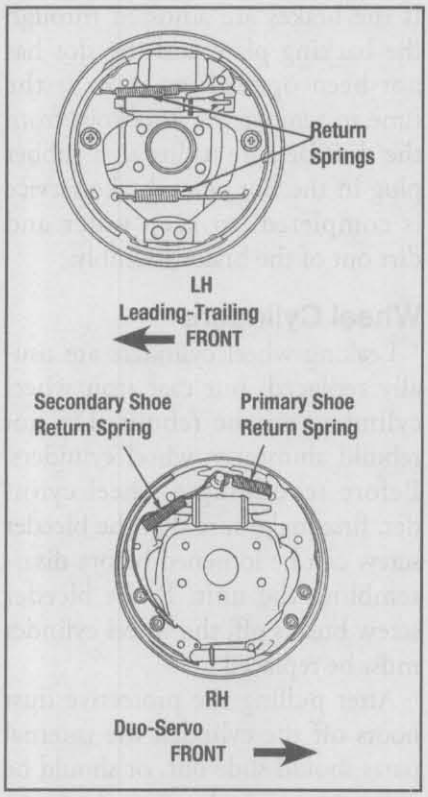

Types of brake shoe defects. *(Courtesy: Raybestos)*



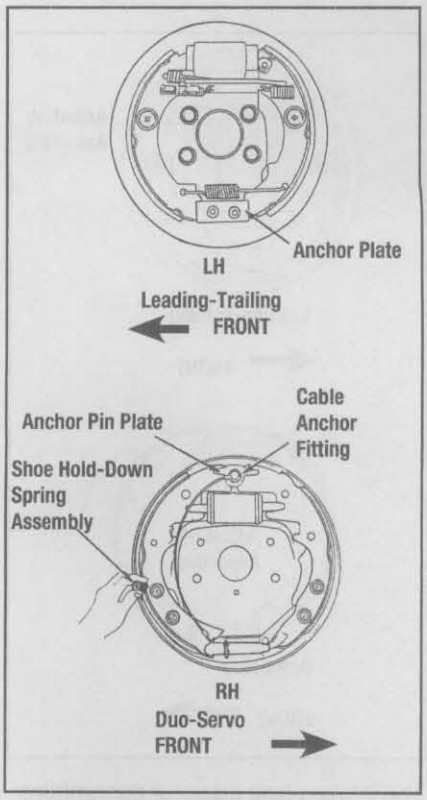
Measuring brake shoe lining thickness.



Removing brake shoe return springs from a Duo-Servo brake assembly.




Brake shoe return spring design differences of leading-trailing and Duo-Servo drum brakes.



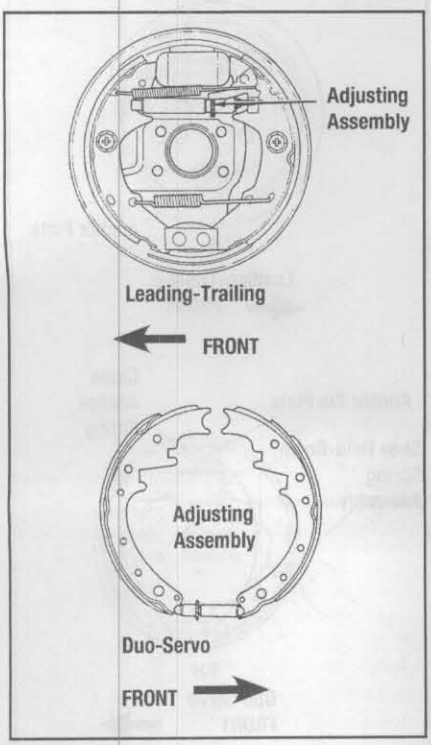

Hold-down spring and anchor plate design differences of leading-trailing and Duo-Servo drum brakes.

tem. Remove the wheel cylinder mounting bolts and remove the wheel cylinder.

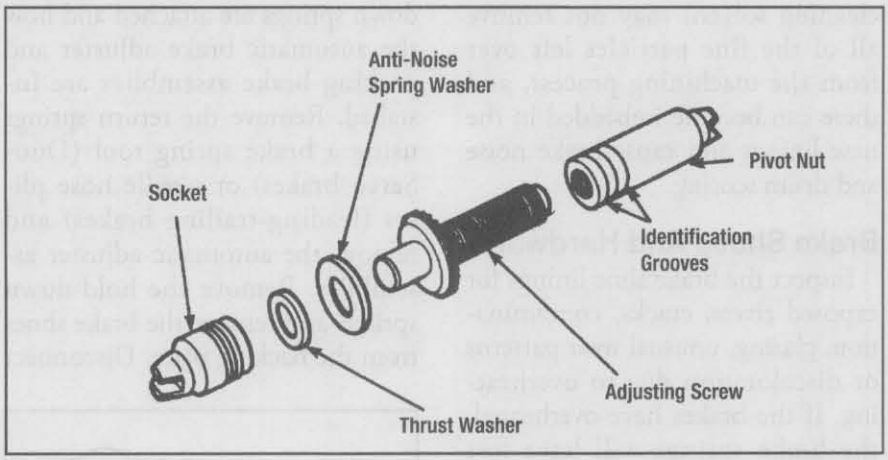
Clean all of the brake assembly hardware with brake cleaning solvent. Disassemble the adjuster screw assembly, thoroughly clean the threads, and make sure it turns freely. Replace any damaged or worn parts and stretched or distorted springs.

Fatigued and corroded hardware can cause improper application of the brake shoes. Worn automatic adjusters will not keep the shoes in proper adjustment and cause uneven braking and a low pedal. Many manufacturers recommend that brake hardware be replaced periodically regardless of appearance. Hardware that functions properly is particularly important on ABS vehicles since the system may cycle pressure many times per second.

Clean the brake backing plate with brake cleaning solvent, paying particular attention to the shoe support pads. Scrape away any dirt deposits and lightly sand the pads. If the pads are deeply grooved, the backing plate must be replaced or the replacement shoes will catch in the grooves.

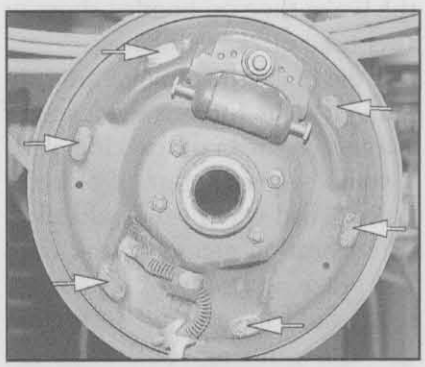



The brake shoe adjuster assemblies of Duo-Servo and leading-trailing drum brake systems are slightly different.




Disassemble the brake adjuster assembly and clean the threads thoroughly. Lubricate the adjuster threads and the inside of the socket and socket face with high temperature brake lubricant before assembling.

At this time, check the brake backing plate and brake drum for the presence of an adjustment slot. If the brakes are adjusted through the backing plate and the slot has not been opened yet, now is the time to remove the knockout from the slot. Be sure to install a rubber plug in the slot when brake service is completed, to keep water and dirt out of the brake assembly.

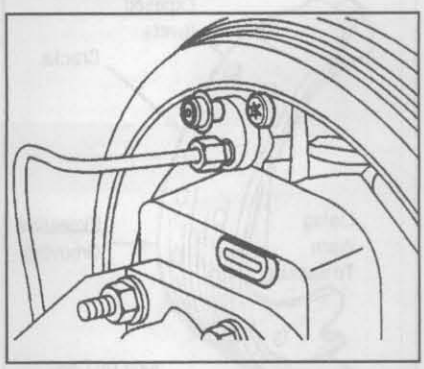


Clean the brake shoe support pads and examine them for wear. Slight wear is normal, but deeply grooved pads mean the backing plate must be replaced. Lubricate the pads with high temperature brake lubricant before installing the brake shoes.

## Wheel Cylinders

Leaking wheel cylinders are usually replaced, but cast iron wheel cylinders can be rebuilt. Do not rebuild aluminum wheel cylinders. Before rebuilding a wheel cylinder, first make sure that the bleeder screw can be loosened before disassembling the unit. If the bleeder screw breaks off, the wheel cylinder must be replaced.

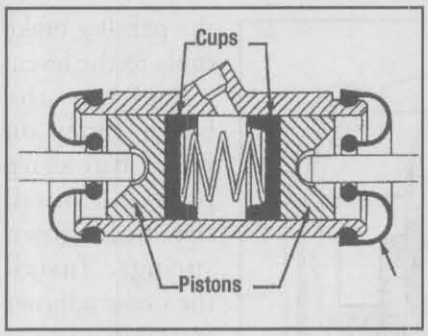
After pulling the protective dust boots off the cylinder, the internal parts should slide out, or should be able to be picked out easily. Stubborn parts can be driven out with a wooden dowel, or blown out at low



Always make sure a plug is installed in the backing plate adjuster access slot, to keep dirt and water out of the brake assembly.

pressure by applying compressed air to the fluid inlet port. With the wheel cylinder apart, clean the bore with brake cleaning solvent. Never use petroleum-based solvents, even in small amounts, since they will damage rubber components. Light roughness or deposits can be removed with crocus cloth or a wheel cylinder hone. Hone the bore at low rpm with a steady back and forth motion. Periodically submerse the honing stones into fresh brake fluid during the procedure, being careful to never hone with a dry stone. Clean the freshly honed cylinder with soap and water, and then dry using a lint-free cloth. After the cylinder has been honed, inspect it for excessive piston clearance. To check the maximum clearance, place a 0.003 inch feeler shim lengthwise in the cylinder bore. If the piston can be inserted with the shim in place, the cylinder is oversize and should be discarded.

Coat the wheel cylinder bore and pistons and cups with clean brake fluid and assemble the wheel cylinder. Insert the cups and pistons from each end of the cylinder; do not slide them through the cylinder. Cup lips should always face inward.



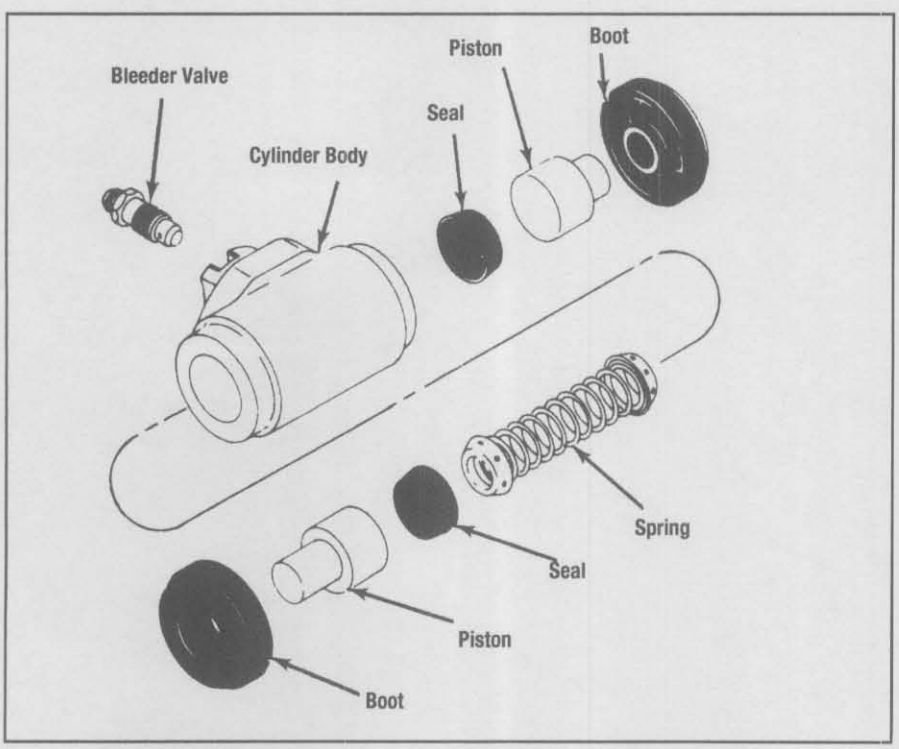

Cross-sectional view of a typical wheel cylinder.

## Installation

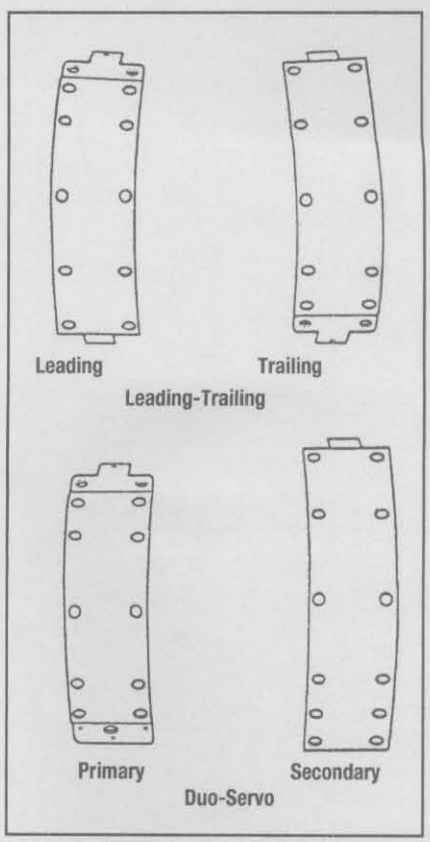
If removed, position the wheel cylinder on the brake backing plate and start the brake line fitting into the wheel cylinder port. Once the fitting is started, install and tighten the wheel cylinder mounting bolts. Tighten the brake line fitting using a flare nut wrench.

Lubricate the brake shoe support pads and the brake shoe anchor pin on the backing plate with high temperature brake lubricant. Also lubricate the adjuster threads and socket, parking brake lever pivot, adjuster lever pivot, parking brake linkage-to-brake shoe contact points and adjuster assembly-to-brake shoe contact points. Use a minimal amount of lubricant in all areas to keep from contaminating the brake shoe linings. Wash all grease and oil from your hands before handling the new brake shoes.

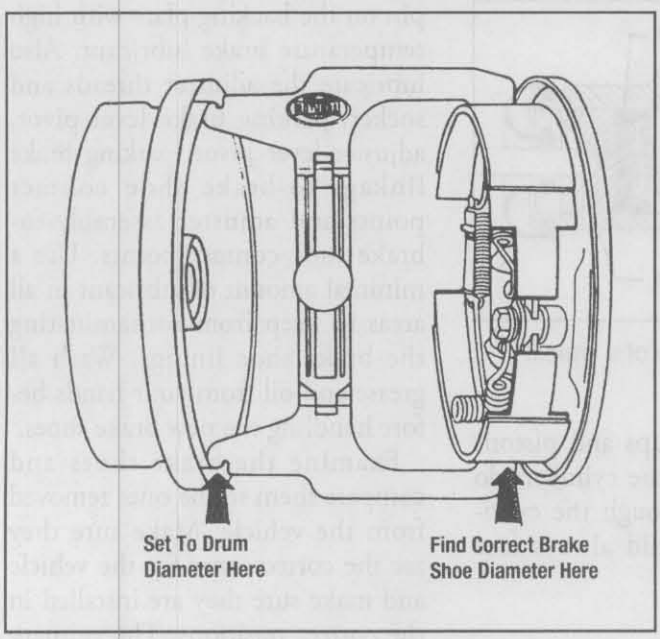
Examine the brake shoes and compare them to the ones removed from the vehicle. Make sure they are the correct ones for the vehicle and make sure they are installed in the correct positions. The primary shoe on a Duo-Servo brake system usually has a smaller lining and is always installed facing the direction of forward motion. Attach the




Disassembled view of a typical wheel cylinder. *(Courtesy: GM Corp.)*




There is a noticeable difference in the shoe designs of a Duo-Servo and leading-trailing drum brake system. Always make sure the shoes are installed in the correct position.




This tool should be used to adjust the brakes prior to installing the drum over the brake shoes.

parking brake lever to the secondary or trailing shoe and connect the parking brake cable to the lever.

Position the brake shoes on the backing plate and install the hold-down springs. Install the brake adjuster assembly and the parking brake linkage. Install the brake shoe return springs, being careful not to overstretch or distort them.

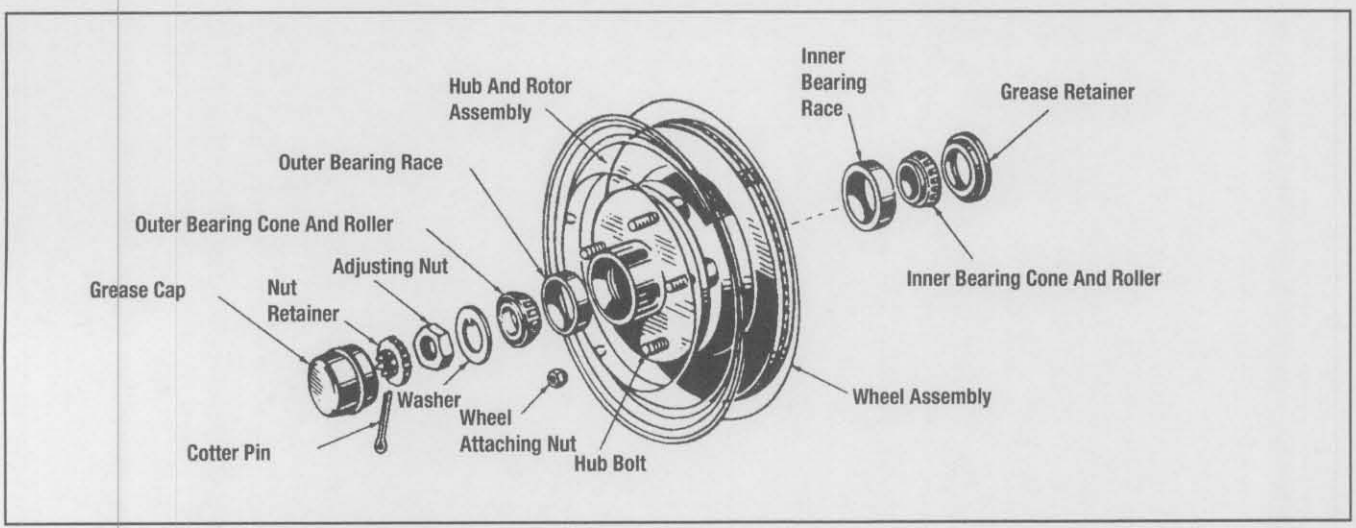
Make sure the inside of the brake drum is clean. If the brake drum is integral with the wheel bearing hub, pack the hub cavity and wheel bearings with high temperature bearing grease. Install the inner wheel bearing and install a new wheel seal.

Position a brake shoe adjustment gauge in the brake drum and set the gauge to the inside drum diameter. Position the gauge over the brake shoes and turn the adjuster wheel until the shoes lightly contact each end of the gauge.

Install the brake drum over the brake shoes. If the brake drum is integral with the wheel bearing hub, install the outer wheel bearing, washer and nut. Adjust the wheel bearings and install a new cotter pin, then install the dust cap.

If the wheel cylinder was rebuilt or replaced, fill and bleed the hydraulic system. Install the wheel and torque the lug nuts to specification. Road test the vehicle.

## WHEEL BEARINGS

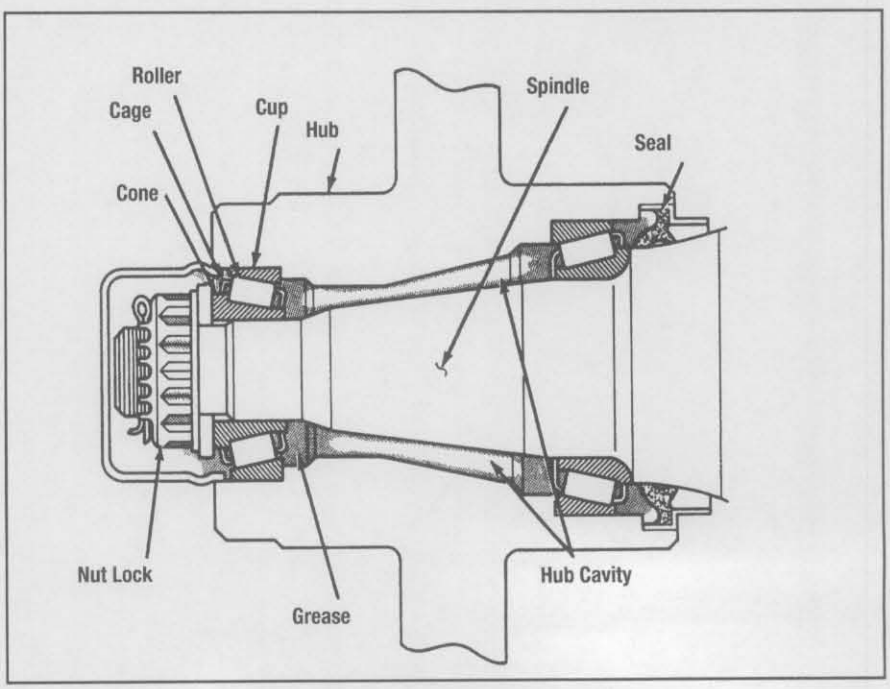



Tapered roller wheel bearing assembly. *(Courtesy: Ford Motor Co.)*

### Description

There are two different wheel bearings systems used on late model vehicles. The first system uses adjustable tapered roller bearings that are mounted between a hub and fixed spindle. This system is commonly used on non-drive axles. The roller bearing and inner race assemblies are removed from the hub after it is removed from the spindle. The bearings are then cleaned, repacked with grease and adjusted during installation.

The other system uses non-adjustable roller or ball bearings that are pressed into a hub. On some vehicles the hub is bolted to the knuckle, however on others the entire knuckle must be removed to press out the bearings. On some vehicles these bearings are sealed, however on other applications the bearings must be packed with grease and a new grease seal installed during installation. This system is commonly used on drive axles but can also be used on non-drive axles.

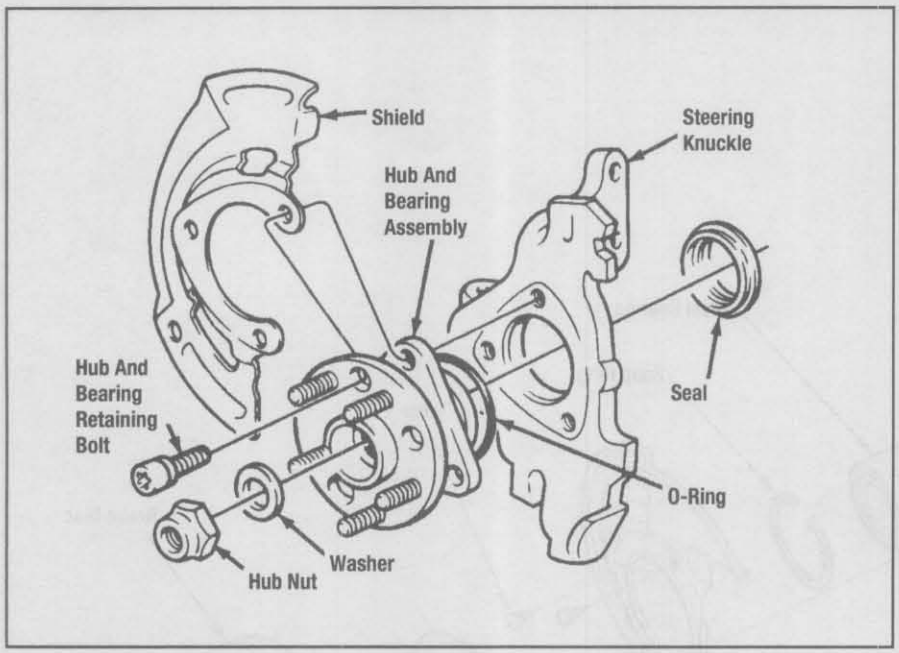



Cutaway view of a tapered roller bearing assembly on a spindle. Inner bearings are usually larger than outer bearings due to weight distribution and loading.

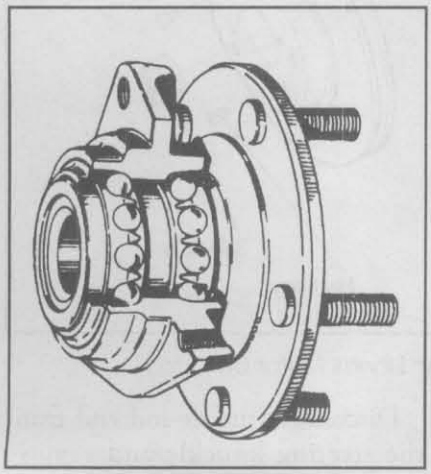
### Inspection

Wheel bearings can wear due to excessive use or from lack of lubrication. When wheel bearings wear, the balls or rollers and races become grooved, pitted, scored or otherwise damaged. These deformities can cause a humming or growling noise as the wheel turns during vehicle operation.

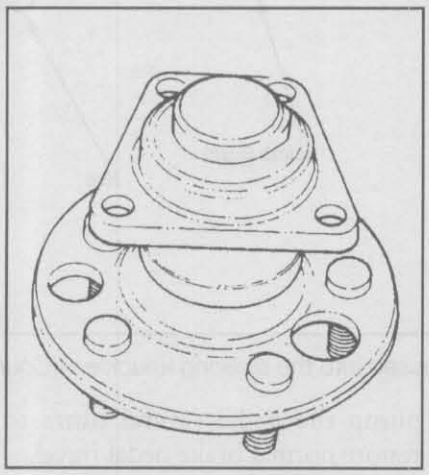
Raise and safely support the vehicle, then listen and feel for roughness as the wheel is rotated. Grasp the tire at the top and bot-




An integral hub and wheel bearing assembly on a drive axle. *(Courtesy: GM Corp.)*



Cutaway view of an integral hub and wheel bearing assembly for a drive axle.



An integral hub and wheel bearing assembly for a non-drive axle. *(Courtesy: GM Corp.)*

tom and check for excessive play in the bearing. If in doubt, remove the wheel and secure the brake rotor to the wheel hub using the lug nuts. Mount a dial indicator on the steering knuckle, with the stylus resting on the wheel hub. If equipped with disc brakes, push the caliper piston into the bore just enough to free the pads from the disc. Push in on the hub, then position the indicator foot on the hub and zero the dial indicator. Pull out on the hub to get the bearing play reading.

Compare the reading to the specification in the vehicle service manual. Tapered roller bearings can be adjusted, but if not within specification, plain roller or ball bearings, or the entire bearing hub must be replaced.

## Tapered Wheel Bearing Service

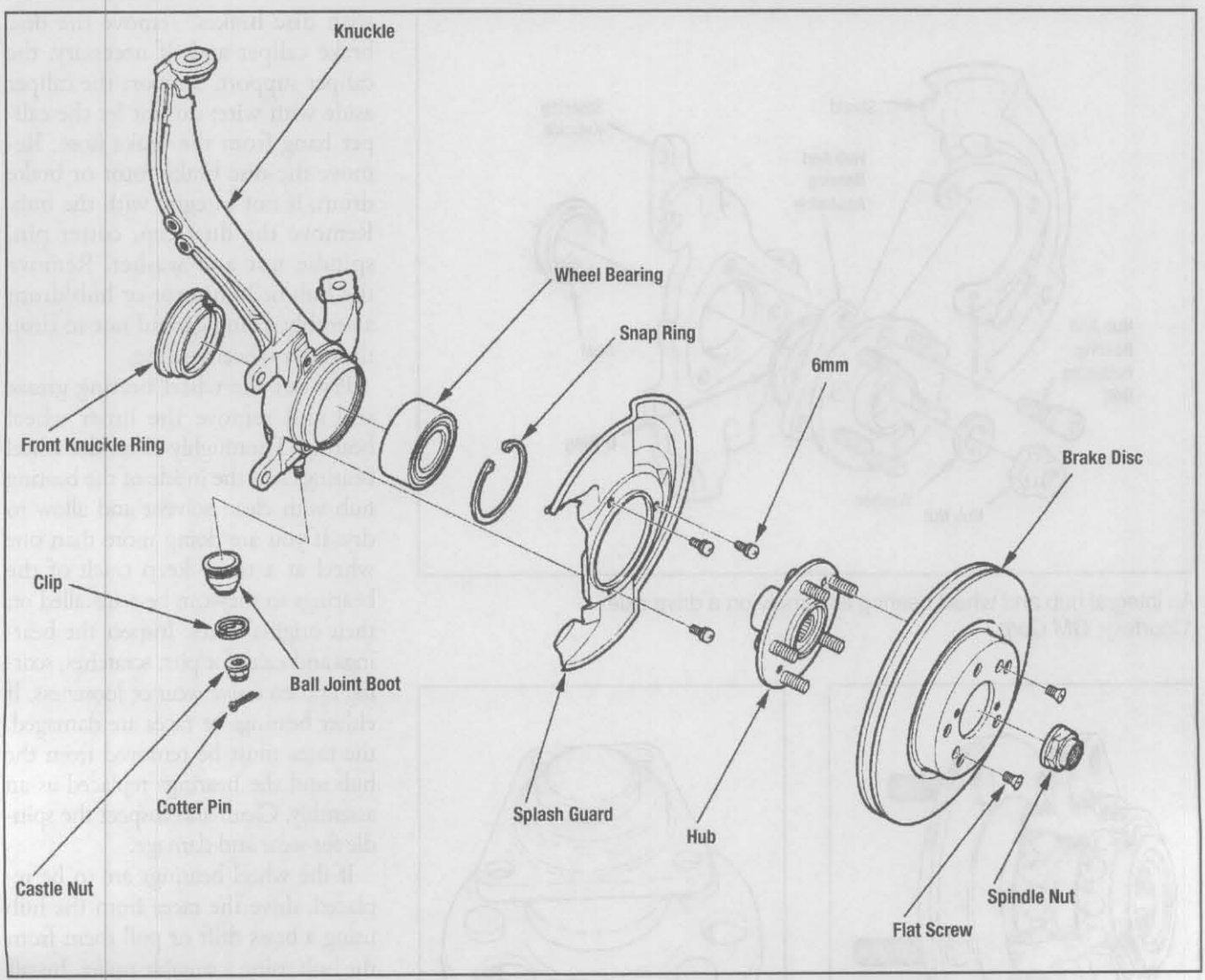
Raise and safely support the vehicle. Remove the wheel. If equipped with disc brakes, remove the disc brake caliper and, if necessary, the caliper support. Support the caliper aside with wire; do not let the caliper hang from the brake hose. Remove the disc brake rotor or brake drum, if not integral with the hub. Remove the dust cap, cotter pin, spindle nut and washer. Remove the hub or hub/rotor or hub/drum assembly, being careful not to drop the outer wheel bearing.

Pry out the wheel bearing grease seal and remove the inner wheel bearing. Thoroughly clean the wheel bearings and the inside of the bearing hub with clean solvent and allow to dry. If you are doing more than one wheel at a time, keep track of the bearings so they can be reinstalled on their original races. Inspect the bearings and races for pits, scratches, scoring and excessive wear or looseness. If either bearings or races are damaged, the races must be removed from the hub and the bearings replaced as an assembly. Clean and inspect the spindle for wear and damage.

If the wheel bearings are to be replaced, drive the races from the hub using a brass drift or pull them from the hub using a suitable puller. Install the new races using a suitable bearing race installer.

Pack the bearings with high temperature wheel bearing grease. If available, use a bearing packer to force the grease into the bearing. If not, work as much grease as possible between the rollers, inner bearing race and cage as possible. Coat the inner surface of the hub, the bearing races and the spindle with grease.

Install the inner wheel bearing into the hub. Use a suitable seal installer to install a new grease seal in the hub. Lubricate the lip of the seal with a light film of grease, and then install the hub, hub/disc or hub/drum assembly over the spindle, being careful not to damage the grease seal. Install the outer wheel bearing, washer and spindle nut.




An example of a wheel bearing that is pressed into the steering knuckle. *(Courtesy: Honda Motor Co., Ltd.)*

Adjust the wheel bearings according to the manufacturers instructions. Usually this involves tightening the spindle nut to a specific torque while the hub is turned, then the nut is backed off. It is then either torqued to an inch lb. specification or the nut is turned to set bearing play, which is checked with a dial indicator, and then locked in place.

Install a new cotter pin and the dust cap. Install the brake rotor or drum if not integral with the hub. Install the disc brake caliper support, if removed, and caliper. Install the wheel, torque the lug nuts to specification and lower the vehicle. If a brake caliper was removed, pump the pedal several times to restore normal brake pedal travel.

Non-Adjustable Roller Or Ball Bearing Service

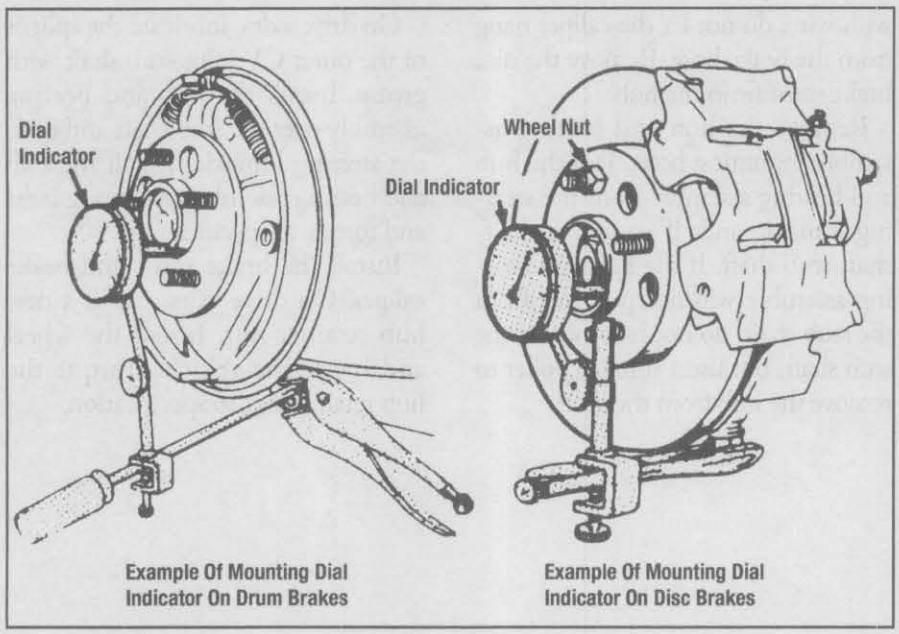
***NOTE:*** *The following descriptions are of typical procedures. However, due to the variety of suspension and wheel bearing designs, always consult the service manual for specific procedures and specifications.*

## Non-Integral Hub And Bearing

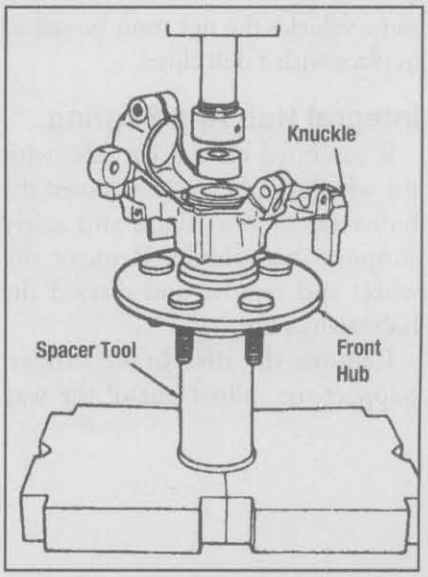
With the wheels on the ground, loosen the hub retainer nut. Raise and safely support the vehicle. Remove the wheel and remove and discard the hub retainer nut.

Disconnect the tie-rod end from the steering knuckle and remove the disc brake caliper. Support the caliper out of the way with wire; do not let the caliper hang from the brake hose.

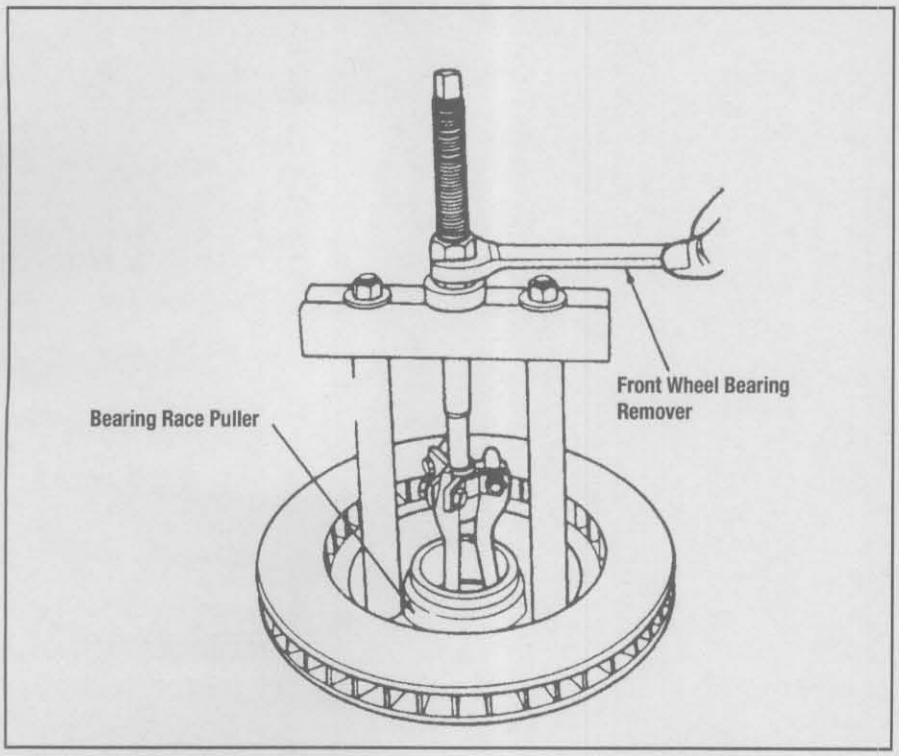
Support the suspension so that tension is removed from the ball joint(s). Support the steering knuckle and separate it from the lower ball joint. Separate the knuckle from the upper ball joint or strut. On some strut vehicles, the strut-to-knuckle bolts also are used for camber adjustment. In this case, mark the position of the fasteners or the strut in the knuckle so that the camber setting will be the same after installation.




Checking wheel bearing end-play with a dial indicator.




Pressing a wheel hub into the wheel bearing and steering knuckle using a press and suitable fixtures.




Removing the inner bearing race using a puller. *(Courtesy: Ford Motor Co.)*

Pull outward on the steering knuckle while pulling the halfshaft stub shaft from the hub. If the stub shaft will not pull free, do not hammer on the stub shaft, but use a suitable puller to remove the shaft from the hub. Do not allow the halfshaft to hang unsupported. If necessary, wire it up to keep it from hanging.

Using a suitable prybar, pry the grease seal from the steering knuckle. Using a shop press and suitable fixtures, press the hub from the steering knuckle. Remove the snapring from the steering knuckle and using a suitable puller, remove the wheel bearing from the knuckle.

Using a shop press and suitable fixtures, press the wheel bearing into the steering knuckle. Press on the outer race of the bearing during installation. Install the snapring.

Lubricate the lip of a new grease seal with grease and install using a seal installer. Using a shop press and suitable fixtures, press the hub into the steering knuckle. Support the inner bearing race as the hub is pressed in.

Lubricate the splines of the outer CV-joint stub shaft with grease. Install the outboard CV-joint stub shaft into the hub. If the stub shaft will not seat in the hub, use a suitable puller tool to draw it into place; do not use the hub retainer nut.

Connect the lower ball joint to the steering knuckle. Connect the upper ball joint or position the knuckle in the strut, aligning the marks made at removal. Connect the tie-rod end. Install the brake caliper. Install the wheel and install a new hub retainer nut.

Lower the vehicle. Torque the hub retainer nut to specification. On

some vehicles the nut must be staked in place with a dull chisel.

### Integral Hub And Bearing

If mounted on a drive axle, with the wheels on the ground, loosen the hub retainer nut. Raise and safely support the vehicle. Remove the wheel and remove and discard the hub retainer nut.

Remove the disc brake caliper. Support the caliper out of the way with wire; do not let the caliper hang from the brake hose. Remove the disc brake rotor from the hub.

Remove the hub and bearing assembly mounting bolts. Pull the hub and bearing assembly from the steering knuckle and, if equipped, half-shaft stub shaft. If the hub and bearing assembly will not pull free from the stub shaft, do not hammer on the stub shaft, but use a suitable puller to remove the hub from the shaft.

On drive axles, lubricate the splines of the outer CV-joint stub shaft with grease. Install the hub and bearing assembly over the stub shaft and onto the steering knuckle. Install the hub and bearing assembly mounting bolts and torque to specification.

Install the brake rotor and brake caliper. On drive axles, install a new hub retainer nut. Install the wheel and lower the vehicle. Torque the hub retainer nut to specification.

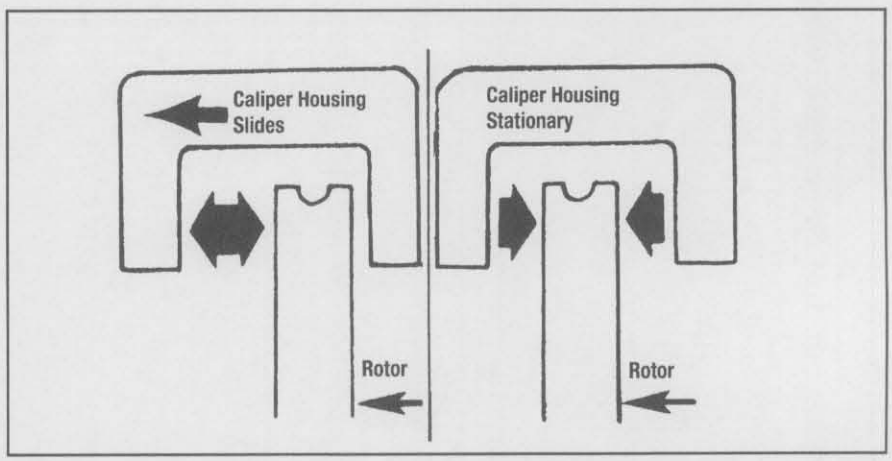
## Notes

# Disc Brake Diagnosis And Repair

## DESCRIPTION AND OPERATION

The disc brake system utilizes a disc (rotor), a caliper assembly, and frictional material (pads). The pads, which are positioned on either side of the rotor, are forced against the disc by hydraulic pressure acting on the caliper piston(s). Braking action is achieved in a manner similar to squeezing a spinning phonograph record between your fingers. The rotor is made of cast iron with each side machined smooth to accept the friction material. While most rotors are a one-piece casting, many newer vehicles use composite rotors, which use a cast iron disc mated to a steel hub. In either case, most front rotors are ventilated, which means they incorporate cooling fins between the two braking surfaces. This enables air to circulate inside the rotor, maintaining lower operating temperatures. This makes the disc less sensitive to heat buildup, which causes brake fade and rotor distortion.

The pads are secured to metal plates with either rivets or adhesive, and are kept in close contact with the rotor at all times, making them inherently self-adjusting. However, when the brakes are not applied, there is no frictional contact between the pads and rotor. Since contaminants are either thrown off by the centrifugal action of the spinning rotor, or scraped off by the pads, dirt and water do not adversely affect braking action.




Both floating and sliding calipers (left) move laterally as the brakes are applied, resulting in an equal force against the rotor from both sides. Fixed calipers (right) use a piston(s) on both sides to force the pads against the rotors, and therefore do not move.

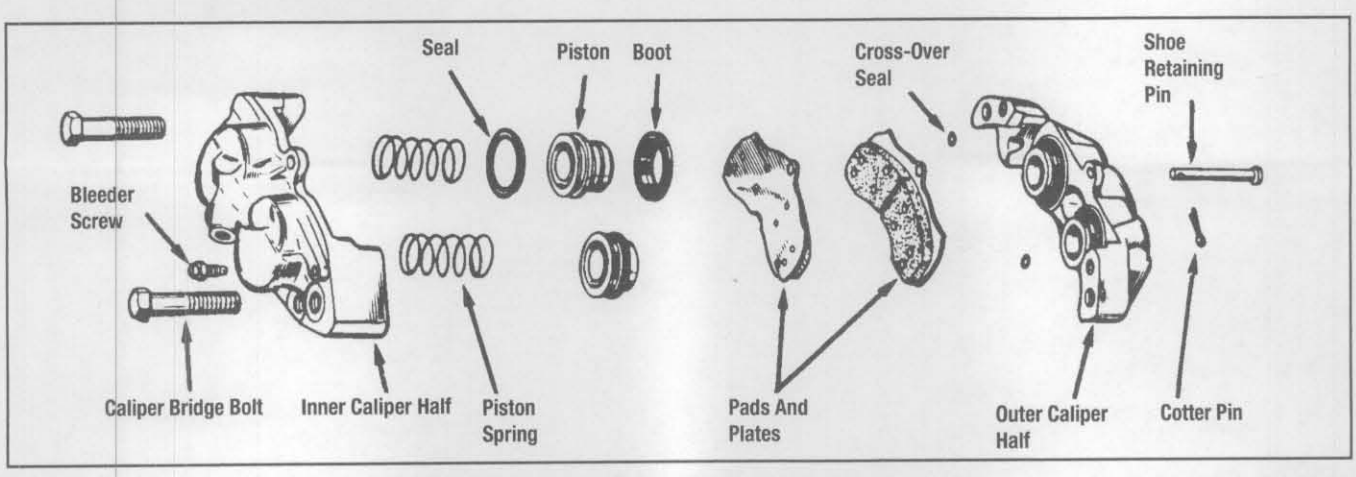
There are three general types of disc brake calipers:

**Fixed Caliper:** 2-piston, 4-piston or 6-piston

**Sliding Caliper:** single-piston or double-piston

**Floating Caliper:** single-piston or double-piston.

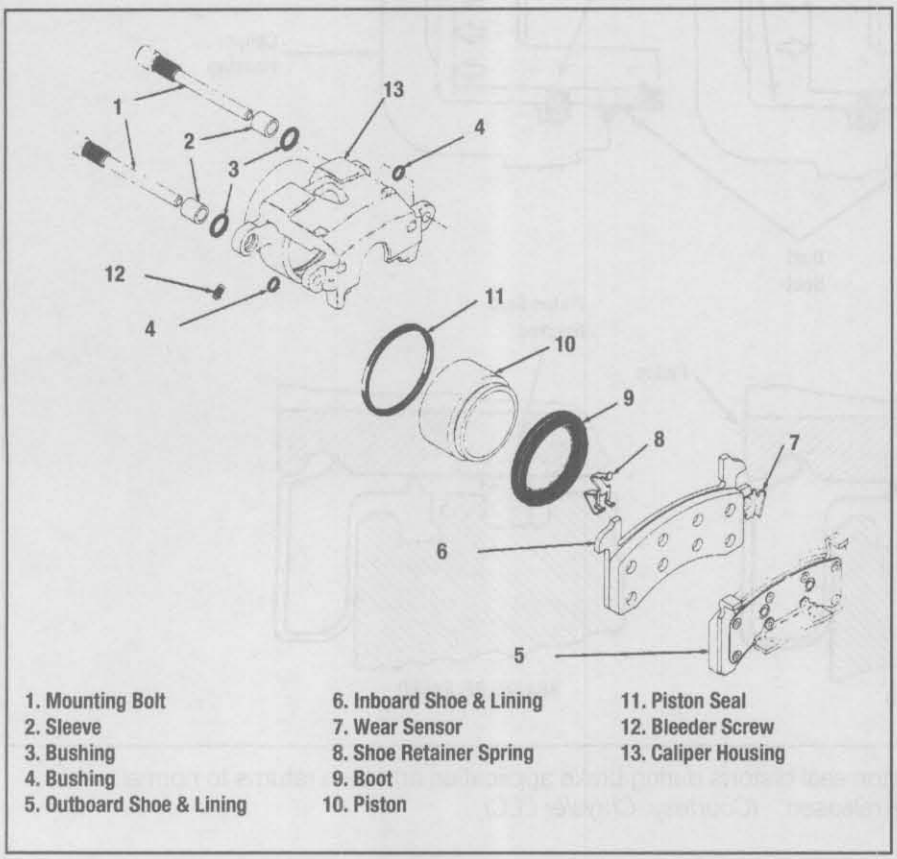
The fixed caliper design contains one or more pistons positioned on either side of the rotor. With this arrangement, the caliper is rigidly attached to the spindle and the pads are applied with equal hydraulic pressure from both sides. The floating caliper design uses an adapter, or anchor plate, that is bolted to



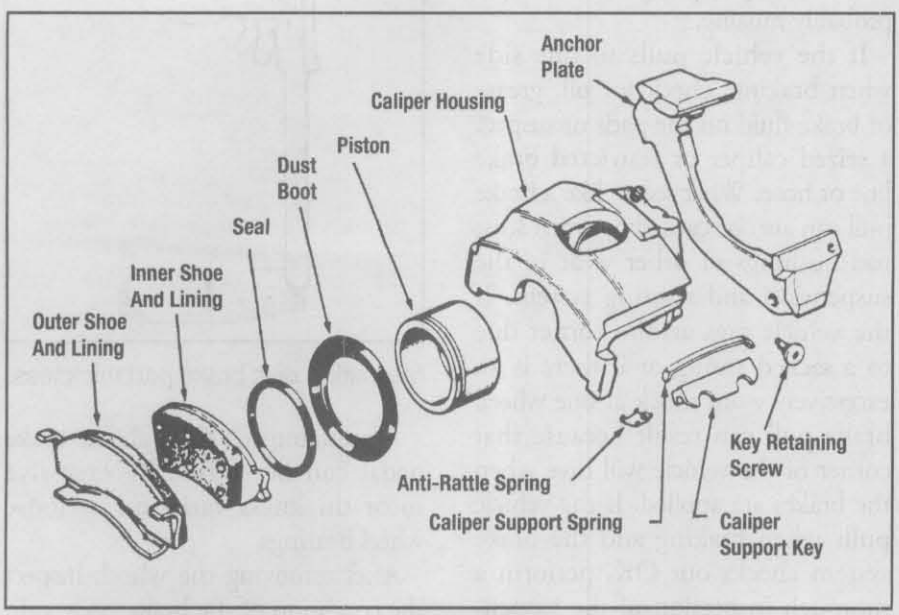

Exploded view of a fixed disc brake caliper assembly. *(Courtesy: Bendix Corp.)*

the spindle. The caliper floats laterally across a pair of special bolts that are screwed into the adapter. As hydraulic pressure is applied to the piston(s), the inboard pad is forced against the rotor. This pressure causes the caliper to move inboard until an equal pressure is applied by the outside pad to the outer disc surface. The sliding caliper operates similarly to the floating design, however, it attaches to the anchor plate using only one attachment point. Since no return springs are used to retract the caliper piston, it's the elastic action of the internal piston seal that draws the piston back after the brakes are released.

Caliper pistons are typically chrome-plated steel, however, some manufacturers have used phenolic (composite plastic) pistons since the 1970s. Phenolic pistons are lighter than steel and also have superior heat dissipation characteristics.



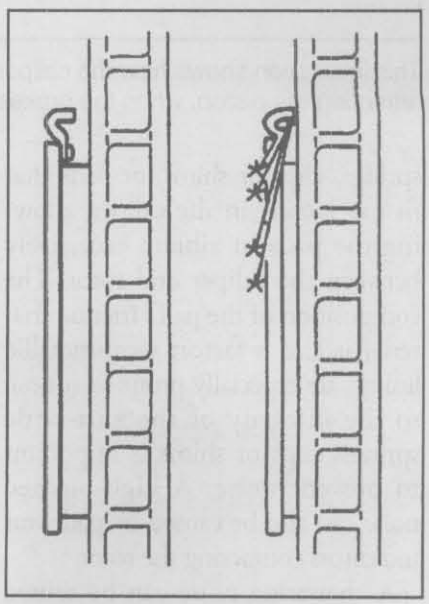

Exploded view of a typical floating disc brake caliper assembly. Mounting bolt sleeves and bushings should be replaced along with worn pads.



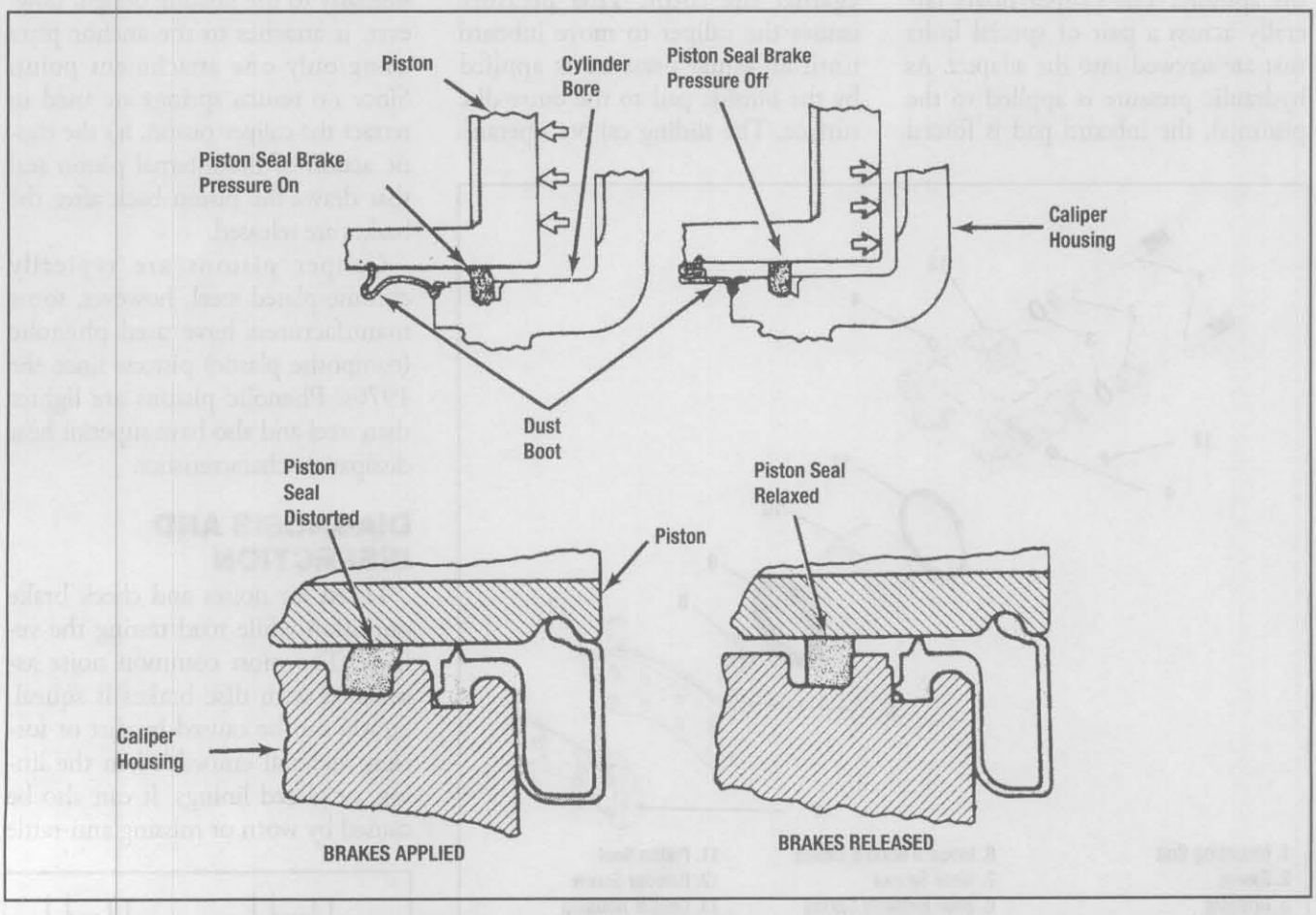

Layout of single-piston sliding caliper disc brakes.

## DIAGNOSIS AND INSPECTION

Listen for noises and check brake operation while road testing the vehicle. The most common noise associated with disc brakes is squeal. Squeal can be caused by dirt or foreign material embedded in the lining, or glazed linings. It can also be caused by worn or missing anti-rattle



Some disc brake pads have wear indicators, which are positioned to contact the rotor when the minimum lining thickness is near. The resulting high pitched noise warns the driver that the pads should be replaced before continued use causes metal-to-metal contact between the pad backing plates and the rotors. *(Courtesy: GM Corp.)*

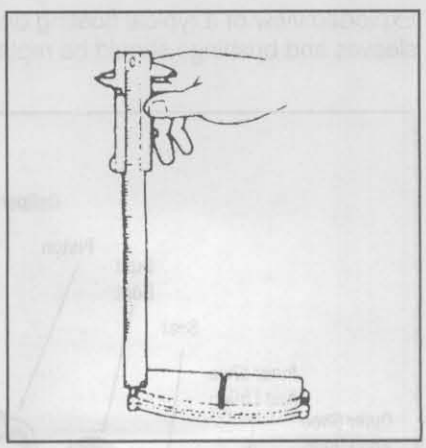



This illustration shows how the caliper piston seal distorts during brake application and then returns to normal, retracting the piston, when the brakes are released. *(Courtesy: Chrysler LLC)*

springs, clips or shims, or pads that fit too loosely in the caliper, allowing the pads to vibrate excessively between the caliper and rotor. The composition of the pad's friction material is also a factor; semi-metallic linings are especially prone to squeal, so the integrity of the anti-rattle springs, clips or shims is important to prevent noise. A high-pitched noise can also be caused by pad wear indicators contacting the rotor.

A chattering noise can be caused by excessive rotor runout or loose wheel bearings. This is usually accompanied by a pulsation through the brake pedal. Scraping or grinding noise usually means that the pads are worn to the point where there is metal-to-metal contact between the pad backing plate and the rotor. A rattle sound that is heard when traversing a rough road without the brakes applied means that the ant-rattle clips, springs or shims are probably missing.

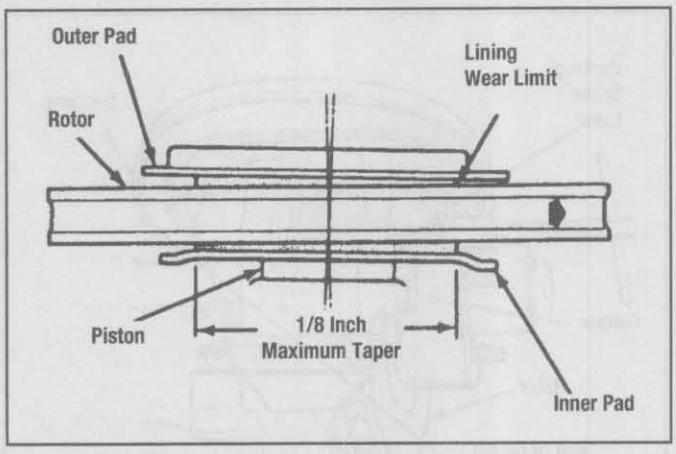
If the vehicle pulls to one side when braking, check for oil, grease or brake fluid on the pads or suspect a seized caliper or restricted brake line or hose. What seems like a brake pull can also be caused by worn strut rod bushings or other wear in the suspension and steering system. If the vehicle sags at one corner due to a sacked spring or if there is an excessively worn shock at one wheel, brake pull can result because that corner of the vehicle will dive when the brakes are applied. If the vehicle pulls when braking and the brake system checks out OK, perform a thorough inspection of the suspension and steering system.



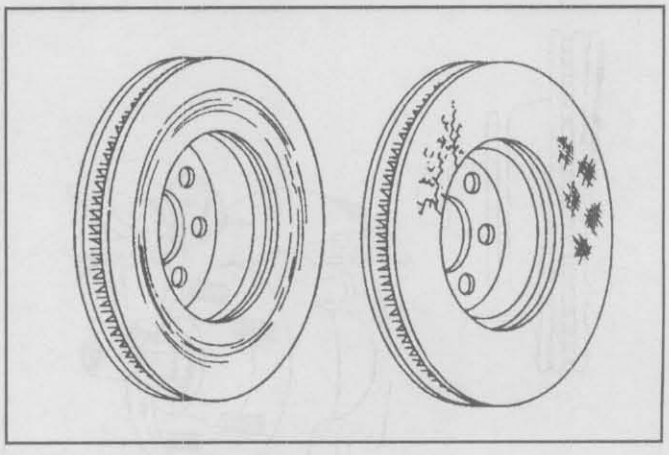
Measuring disc brake pad thickness.

A pulsation felt through the brake pedal can be caused by excessive rotor thickness variation or loose wheel bearings.

After removing the wheel, inspect the condition of the brake pads, caliper and rotor. Check the thickness




An example of disc brake pad taper wear.
*(Courtesy: EIS Brake Parts)*



Types of brake rotor defects.
*(Courtesy: EIS Brake Parts)*

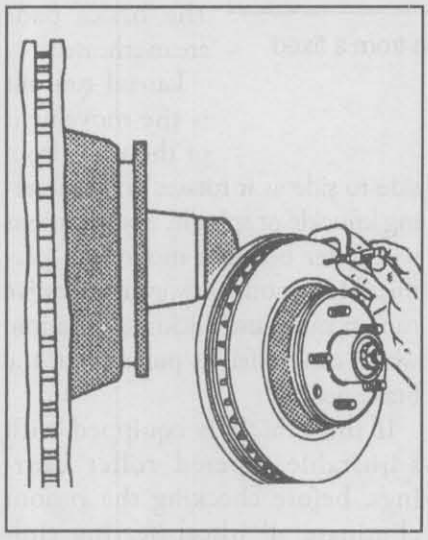
of the brake pads through the caliper inspection hole and at the leading and trailing edges of the pad. It may be necessary to remove the pads to get an accurate measurement. Refer to the vehicle service manual for minimum pad thickness specifications. If the pads are below specification or have severe taper wear (more than 1/8 in.), or are cracked, glazed or contaminated, they must be replaced. Also check the caliper mounting if there is excessive taper wear.

If the inboard pad on a floating or sliding caliper is worn more than the outboard pad, the caliper should be rebuilt or replaced and/or the slides replaced. If the outboard pad shows more wear, the sliding mechanism may be sticking or damaged.

If the front brake pads are worn prematurely on a vehicle with rear drum brakes, it is most likely because the rear shoes are out of adjustment. The misadjusted rear brakes cannot contribute the designed amount of brake force, thereby forcing the front brakes to have to work harder.

Inspect the caliper for physical damage and leaks and check the condition of the dust boot. If the caliper is not leaking, appears OK, and the piston can be bottomed in its bore with moderate force, it can be returned to service. However, if the caliper is damaged, leaking or requires excessive force to bottom, or will not bottom the piston in the bore, it must be rebuilt or replaced.

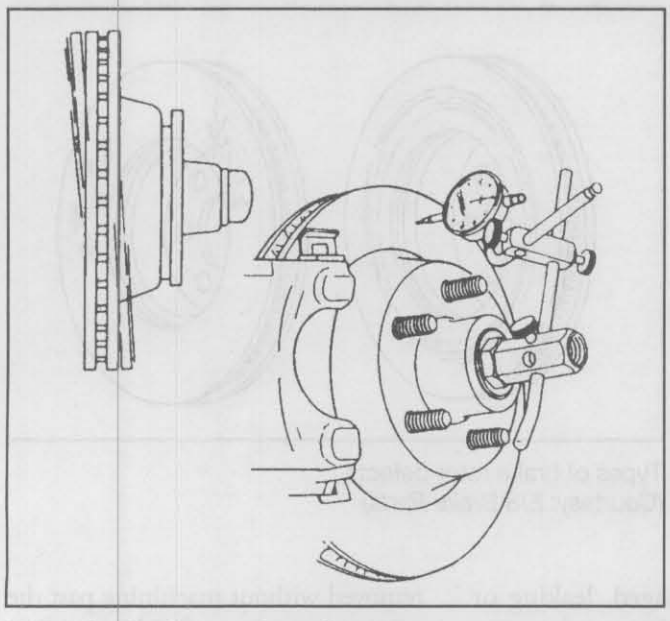
Visually inspect the brake rotor for cracks, scoring, heat checks, hard spots and lining deposits. If there are small heat checks and surface cracks, the rotor can be reused providing they are removed by resurfacing, however, large cracks are cause for rotor replacement. Scoring can be caused by dirt or foreign material between the linings and rotor or if the linings wore to the point that the rivets or pad backing plate contacted the rotor. A scored rotor can be reused if the scoring can be removed without machining past the minimum rotor refinishing thickness. Hard spots can cause uneven wear and pedal pulsation, and are also a reason for rotor replacement, since resurfacing seldom removes the entire hard spot.



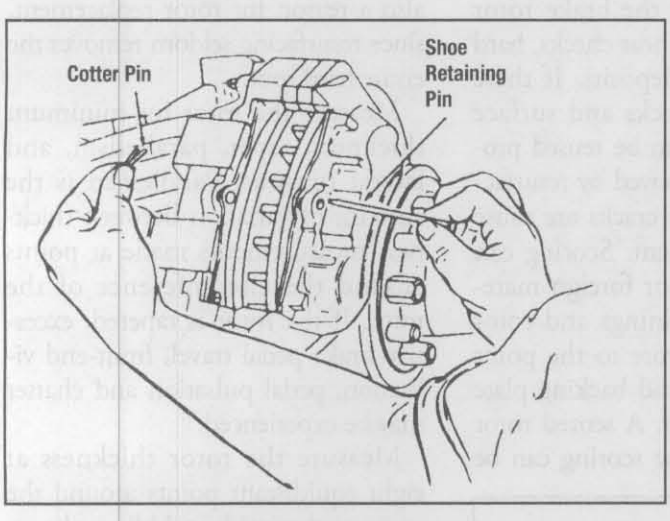
Measuring brake rotor parallelism (thickness variation).

Measure the rotor for minimum thickness, taper, parallelism, and lateral run-out. Parallelism is the amount of variation between thickness measurements made at points around the circumference of the rotor. If the rotor is tapered, excessive brake pedal travel, front-end vibration, pedal pulsation and chatter may be experienced.

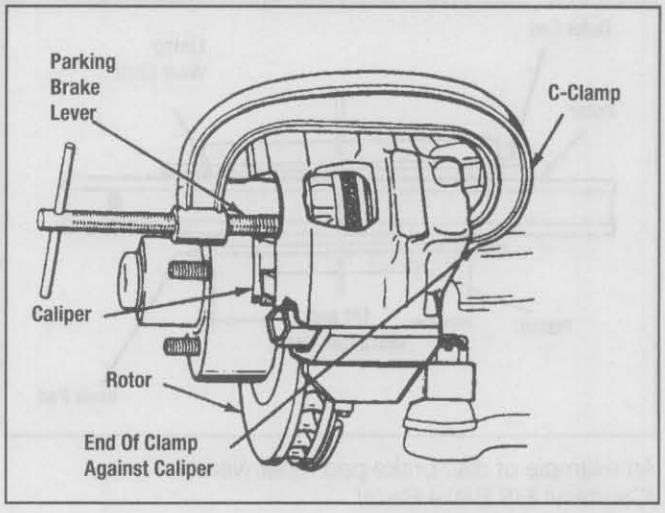
Measure the rotor thickness at eight equidistant points around the rotor, at the inside, middle and outside areas of the brake pad contact surface. Use a disc brake micrometer to perform this procedure. Unlike a standard micrometer that uses a flat surface on the anvil and movable spindle tips, a disc brake micrometer uses pointed tips. The reason for this is so the instrument can fit into the grooves of scored rotors to accurately measure the thickness. Most rotors come with the "discard" or "machine to" dimension cast into them, however, if this cannot be found or is illegible, consult the vehicle service manual for the specification. A rotor should be replaced if it is worn below



Measuring brake rotor lateral runout. *(Courtesy: EIS Brake Parts)*




Removing the disc brake pad retaining pin from a fixed caliper. *(Courtesy: EIS Brake Parts)*




Using a C-clamp to bottom the piston in a floating disc brake caliper. *(Courtesy: Ford Motor Co.)*

the "discard" thickness or if it cannot be resurfaced without exceeding the "machine to" dimension.

Parallelism (thickness variation) is much harder to measure, since in many cases, only 0.001-in. variation is beyond specification (always consult the vehicle service manual for the exact specification). Although this a very small amount, any more can cause a noticeable pedal pulsation. Thickness variation can be caused by excessive lateral runout (wobble). As the rotor turns, the brake pads wear the high spots on each side of the rotor, gradually wearing the rotor until those areas are thinner than the rest of the rotor. Thickness variation can also be caused by the uneven transfer of lining material to the brake disc that can occur if the brake pads are overheated.

Lateral run-out is the movement of the rotor from side to side as it rotates on the steering knuckle or spindle. Specifications will differ between models on permissible runout, however, excessive runout can cause thickness variation, which can be felt as pulsation at the brake pedal.

If the vehicle is equipped with adjustable tapered roller bearings, before checking the runout eliminate all wheel bearing endplay with the wheel spindle nut. Secure non-integral rotors to the hub using the lug nuts installed backwards. Mount a dial indicator on the suspension at a convenient place so that the indicator stylus contacts the rotor face in the middle of the brake pad contact area. Set the dial to zero. Check the total indicator reading while turning the rotor one full revolution. If the rotor is warped excessively, it is unlikely that it can be successfully resurfaced since too much metal would need to be removed from the disc.

Excessive lateral runout can be caused by improper lug nut torquing, a poor previous resurfacing job, rust buildup between the hub and rotor or manufacturing defects.

## REMOVAL

### Disc Brake Pads

On fixed calipers, remove the clip(s) from the pad retaining pin(s) and remove the pin(s) and retaining spring, if equipped. Use a suitable prying tool to force the pads away from the rotor, then use pliers on the backing plate to pull the pads from the caliper. Remove any anti-rattle shims, clips or springs.

On sliding and floating calipers, connect a hose to the caliper bleeder screw and insert the other end of

the hose into a suitable container. Open the bleeder screw, then use a C-clamp or pliers to slowly bottom the piston in the caliper.

In the past it was common practice to just remove half of the fluid in the master cylinder reservoir before retracting the piston, however with this method dirty brake fluid is forced back into the system when the caliper piston is bottomed. Since the caliper is the lowest point in the system, dirt and corrosion naturally accumulate there. If the bleeder screw is not opened, brake fluid and these contaminants are forced backward into the system. When these contaminants find their way into an ABS hydraulic control unit, they can cause valves and accumulators to stick and plug compensator ports. This can result in pulling during braking, low pedal and brake drag.

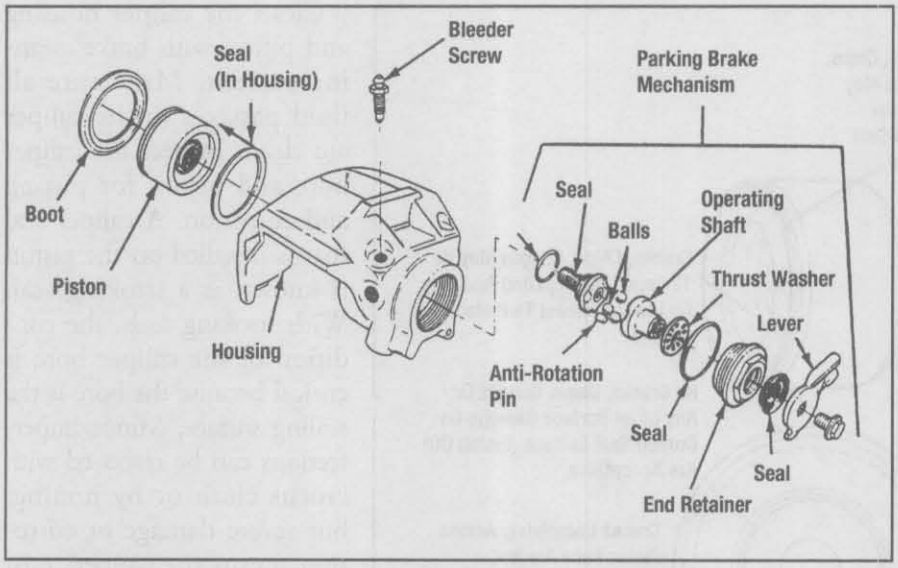
Vehicles with rear disc brakes that incorporate the parking brake mechanism, require a special tool to bottom the caliper piston. This tool is usually installed in the caliper after the pads are removed, then the tool is turned until it engages holes or slots in the caliper piston. The tool is then turned until the piston retracts into the caliper bore.

Remove the caliper fasteners and pivot or remove the caliper from the anchor bracket. Remove the outboard brake pad from the caliper and remove the inboard brake pad from the caliper or anchor bracket. Remove any anti-rattle shims, clips or springs. Wire the caliper out of the way to support it while it is removed from the anchor bracket. Never let the caliper hang from the brake hose.

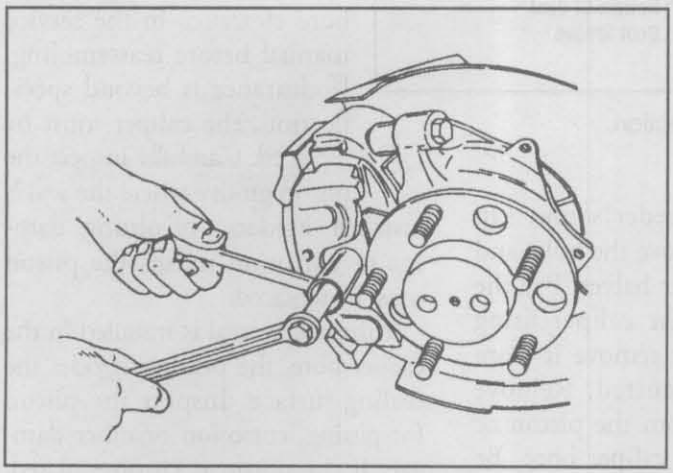
## Disc Brake Caliper

If the caliper is to be overhauled or replaced, disconnect the brake hose from the caliper. If the hose is connected using a banjo fitting, remove the banjo bolt and remove the hose from the caliper. Plug the hose to prevent dirt from entering the system and unnecessary fluid loss. If the brake hose is threaded into the caliper, the caliper must be removed before loosening the hose so the hose is not twisted, or the hose can be disconnected from the brake line at the frame bracket instead. Discard the copper sealing gasket(s) that were used to seal the hose connection; new ones should be installed during caliper installation.

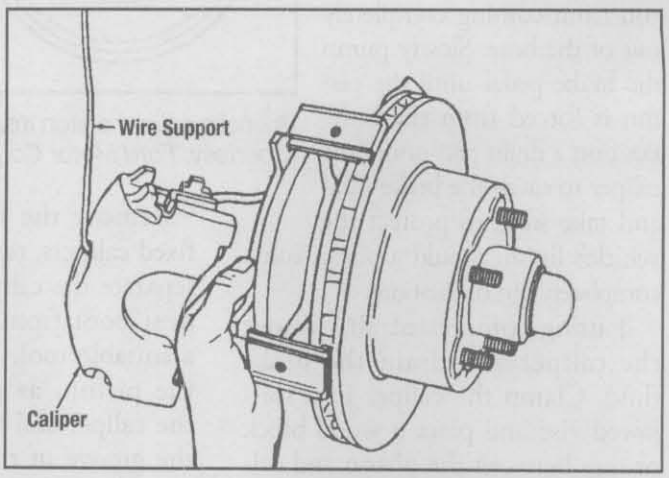
Floating and sliding calipers are removed when the brake pads are removed. Fixed calipers can be removed



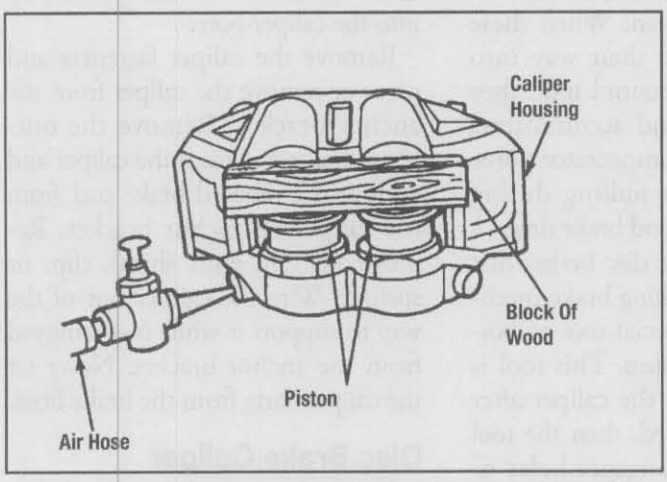

Exploded view of a caliper with an integral parking brake mechanism.



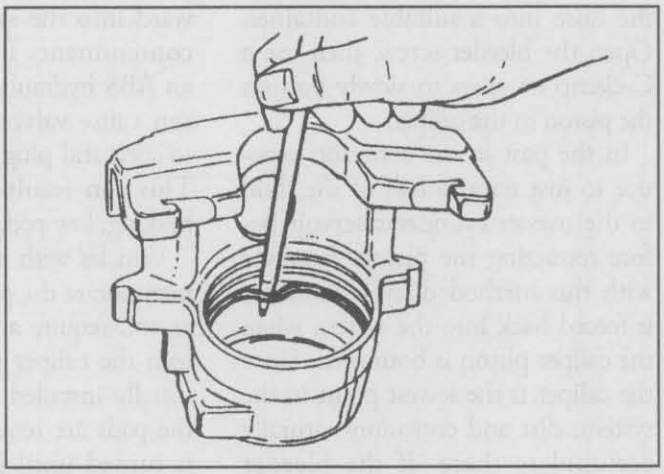
Retracting the caliper piston into the bore on a caliper with an integral parking brake mechanism. *(Courtesy: EIS Brake Parts)*




Support the caliper with wire while it is removed from the anchor bracket. Never let it hang from the brake hose. *(Courtesy: EIS Brake Parts)*




Using compressed air to remove caliper pistons.
*(Courtesy: Ford Motor Co.)*



Removing the seal from the caliper bore.
*(Courtesy: EIS Brake Parts)*

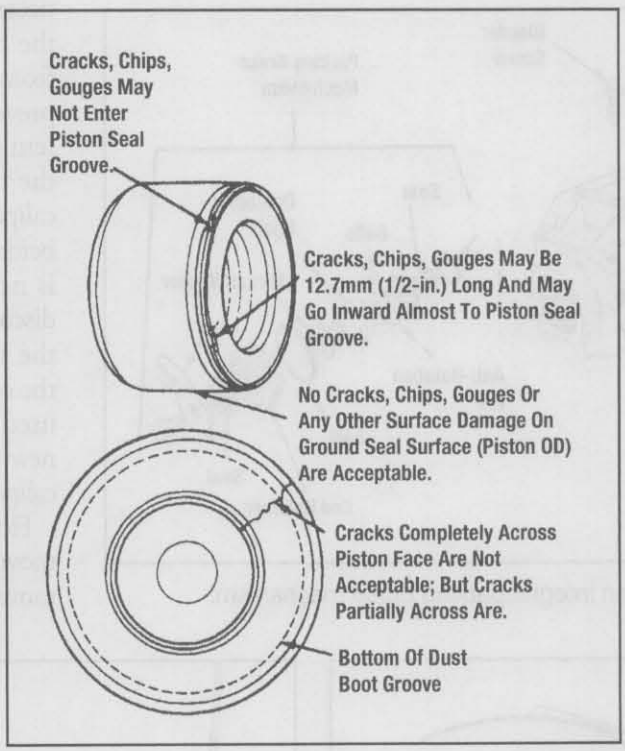
with or without the pads in place.

## Caliper Overhaul

Before overhauling the caliper, attempt to loosen the bleeder screw. If the bleeder screw is frozen or breaks off, the caliper should be replaced.

The caliper piston can be removed either with brake system hydraulic pressure or with compressed air. If using hydraulic pressure, remove the caliper but leave the brake hose connected. Properly support the caliper and place a wood block between the piston and caliper body to prevent the piston from coming completely out of the bore. Slowly pump the brake pedal until the piston is forced from the bore. Position a drain pan under the caliper to catch the brake fluid and take steps to protect the vehicle's finish, should a piston come completely out of the bore.

If using compressed air, remove the caliper and drain the brake fluid. Clamp the caliper in a soft-jawed vise and place a wood block or rags between the piston and caliper body. Apply air pressure to the brake fluid inlet to force the piston from the bore.

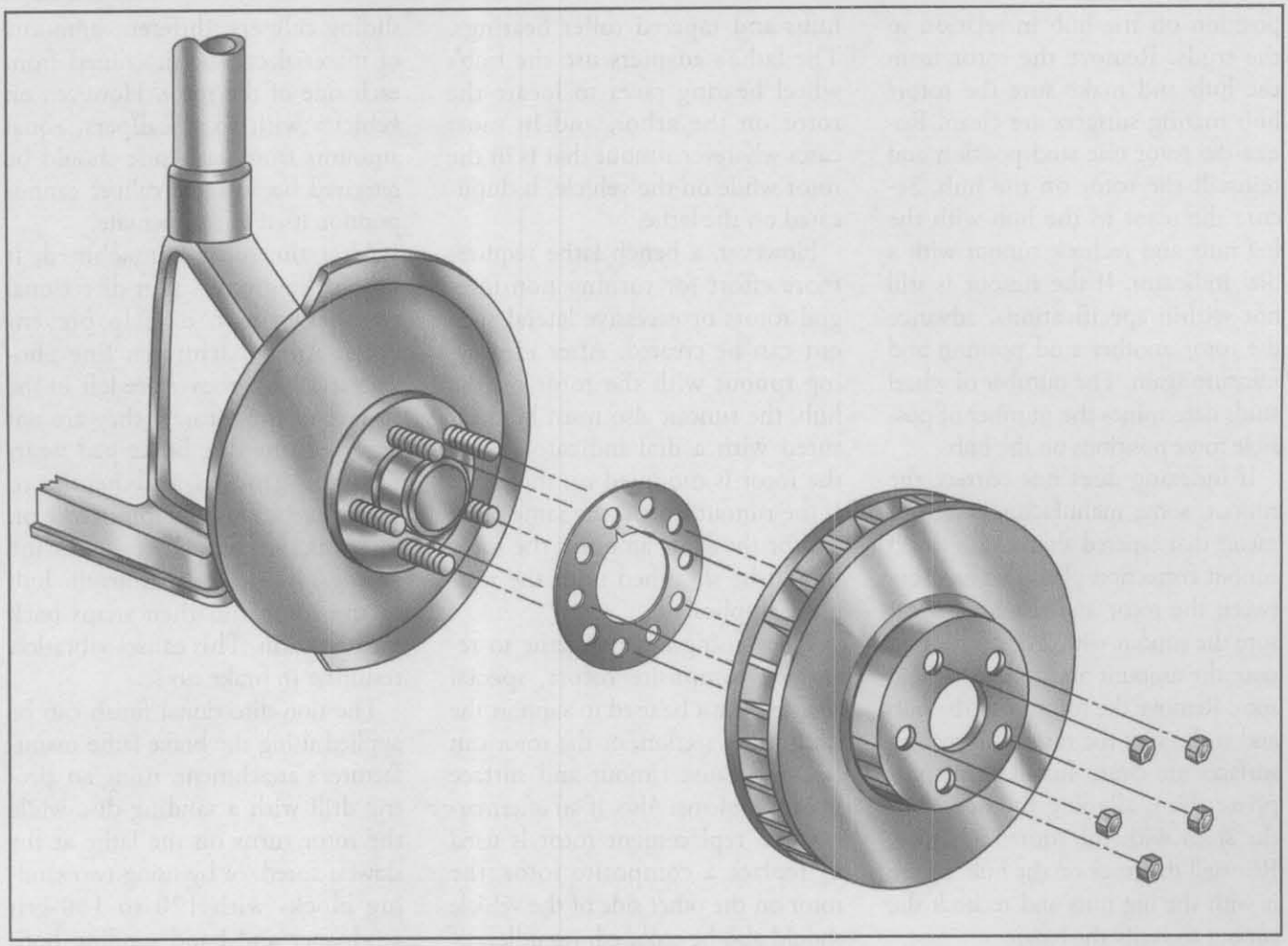



Phenolic caliper piston inspection.
*(Courtesy: Ford Motor Co.)*

Remove the bleeder screw. On fixed calipers, remove the bolts and separate the caliper halves. Pry the dust boot from the caliper using a suitable tool, or remove it from the piston, as required. Remove the caliper seal from the piston or the groove in the caliper bore. Be careful not to damage the piston or caliper bore when removing the dust boot or seal.

Clean the caliper housing and piston with brake cleaning solvent. Make sure all fluid passages in the caliper are clean. Inspect the caliper bore and piston for pitting and corrosion. A caliper seal that is installed on the piston is known as a stroking seal. With stroking seals, the condition of the caliper bore is critical because the bore is the sealing surface. Minor imperfections can be removed with crocus cloth or by honing, but severe damage or corrosion means the caliper must be replaced. If the caliper bore is honed, check the piston-to-bore clearance in the service manual before reassembling. If clearance is beyond specification, the caliper must be replaced. Carefully inspect the piston groove where the seal is installed. Evidence of pitting, damage or corrosion means the piston must be replaced.

If the caliper seal is installed in the caliper bore, the piston provides the sealing surface. Inspect the piston for pitting, corrosion or other damage. If the piston is chrome plated, make sure the chrome is not peeling. Examine phenolic pistons for cracks, chips or gouges (refer to the illustra-



One way to maintain rotor runout within specifications is to use a tapered shim, or runout correction plate, that fits over the wheel studs and between the hub and rotor. *(Courtesy: Brake Align, Inc.)*

tion). Replace a piston that is defective. Examine the seal groove for corrosion and damage that could cause an imperfect seal. The condition of the caliper bore is not as critical as with stroking seals, however the bore should be smooth enough to allow free movement of the piston. Replace the caliper assembly if the seal groove or bore is damaged.

On calipers with stroking seals, lubricate the seals and caliper bores with clean brake fluid. Stretch the seals and dust boots over the pistons, then install the pistons into the caliper bores, being careful not to damage the lips of the seals. Use a suitable tool to seat the dust boot on the caliper.

On calipers with fixed seals, lubricate the caliper seal, groove and bore with clean brake fluid and install the seal in the groove in the caliper. Lubricate the piston with clean brake fluid and install it in the bore. Push it past the seal until it bottoms in the bore. It may be necessary to use a C-clamp to install the piston. If using a C-clamp on phenolic pistons, protect the piston with a block of wood. Stretch the dust boot over the piston and use a suitable tool to seat the dust boot on the caliper.

On fixed calipers, reattach the caliper halves using new O-rings. Install the attaching bolts and torque to specification.

## Disc Brake Rotor

Although many consider disc brake rotor machining a regular part of disc brake service, if the rotor is not damaged and measures within specification, machining is unnecessary. Many auto manufacturers have issued bulletins in recent years providing guidelines for disc brake servicing. In these bulletins they've indicated that brake rotors should not be refinished during routine brake pad replacement if the rotor dimensions are within specification. Resurfacing the rotor unnecessarily removes material and makes the rotor thinner, lessening its ability to absorb and dissipate heat and shortening the rotor's useable lifespan.

Even if rotor runout is not within specification, there are methods of correcting it without machining or discarding the rotor. The first method is indexing: If a non-integral rotor has excessive runout, mark its

position on the hub in relation to the studs. Remove the rotor from the hub and make sure the rotor/hub mating surfaces are clean. Rotate the rotor one stud position and reinstall the rotor on the hub. Secure the rotor to the hub with the lug nuts and recheck runout with a dial indicator. If the runout is still not within specifications, advance the rotor another stud position and measure again. The number of wheel studs determines the number of possible rotor positions on the hub.

If indexing does not correct the runout, some manufacturers recommend that tapered shims, also called runout correction plates, be used between the rotor and the hub. Measure the runout with a dial indicator, note the amount and mark the high spot. Remove the rotor from the hub and make sure the rotor/hub mating surfaces are clean. Install the appropriate shim, aligning the notch on the shim with the rotor high spot. Reinstall the rotor on the hub, secure it with the lug nuts and recheck the runout to verify the repair.

To remove a rotor that is integral with the brake hub, remove the dust cap and cotter pin, then remove the spindle nut and washer. Remove the rotor/hub assembly, being careful not to let the outside wheel bearing fall from the hub.

Non-integral rotors are removed by unbolting them from the bearing hub. On some vehicles the hub must first be removed from the vehicle.

Vehicles with floating or sliding calipers may require that the caliper anchor bracket be removed, to allow rotor removal.

### Rotor Machining

If inspection and measurement determined that resurfacing is necessary, there are two alternatives: the traditional bench lathe or an on-car brake lathe.

A traditional bench lathe is ideal for resurfacing rotors with integral hubs and tapered roller bearings. The lathe's adapters use the hub's wheel bearing races to locate the rotor on the arbor, and in most cases whatever runout that is in the rotor while on the vehicle, is duplicated on the lathe.

However, a bench lathe requires more effort for turning non-integral rotors or excessive lateral runout can be created. After measuring runout with the rotor on the hub, the runout also must be measured with a dial indicator when the rotor is mounted on the lathe. If the runout isn't in the same place and/or the same amount, the rotor should be shimmed until the runout is duplicated.

When using a bench lathe to resurface composite rotors, special adapters must be used to support the steel center section, or the rotor can flex and cause runout and surface finish problems. Also, if an aftermarket cast replacement rotor is used to replace a composite rotor, the rotor on the other side of the vehicle should also be replaced, regardless of its condition. Composite and cast rotors should not be mixed on the same axle or a brake pull can result.

On-car brake lathes refinish the rotor without removing it from the vehicle. They are ideal for refinishing rotors on vehicles where the rotor is difficult to remove from the vehicle. Many vehicle manufacturers specify on-car brake lathes for use on their vehicles.

When setting up either type lathe, be sure to use a vibration dampening device. Proper set-up of the rotor is crucial to the finish surface of the rotor; ensure that the proper set-up is used for the type of rotor being resurfaced. The degree of perfection of the rotor's surface will determine how the new pads will wear and how well the brakes will operate. When machining, only remove the amount of material necessary to restore the surface. On vehicles with floating or sliding calipers, different amounts of material can be machined from each side of the rotor. However, on vehicles with fixed calipers, equal amounts from each side should be removed because the caliper cannot position itself to compensate.

After the rotor is machined, it should be given a non-directional swirl-like finish to help prevent noise. After machining, fine phonograph like grooves are left in the surface of the rotor. If they are not removed, the disc brake pad wears into the grooves and begins to track, like a phonograph needle on a record. As the pad tracks in the grooves, it rides away from the hub of the rotor and then snaps back into position. This causes vibration resulting in brake noise.

The non-directional finish can be applied using the brake lathe manufacturer's attachment, using an electric drill with a sanding disc while the rotor turns on the lathe at the slowest speed, or by using two sanding blocks with 120 to 150-grit sandpaper and hand sanding both sides of the rotor while it turns at the lathe's slowest speed. Apply the non-directional finish until the machined finish that was created by the cutting bit begins to disappear, about one minute per side.

When rotor resurfacing is completed, wash the rotor with soap and water and wipe it off with a clean shop towel. Brake cleaning solvent may not remove all of the fine particles left over from the machining process, and these can become imbedded in the new pads and cause brake noise. Always make sure the inside of a non-integral rotor and the hub flange are clean and free of corrosion, dirt or burrs that could cause runout when reassembled.

## INSTALLATION

Thoroughly clean the disc brake rotor. Install non-integral rotors onto the wheel hub and install the

hub, if removed. On integral rotors, pack the wheel bearing cavity and the wheel bearings with high temperature wheel bearing grease, then install the inner wheel bearing and a new wheel seal. Install the rotor over the spindle and install the outer wheel bearing, washer and spindle nut. Adjust the wheel bearings and install a new cotter pin and the dust cap. Install the caliper anchor bracket, if removed.

Before installing the brake pads, make sure they are the correct ones for the vehicle. Many newer vehicles are equipped with ceramic compound brake pads, which generally provide quieter braking and generate less brake dust. Semi-metallic pads may be available for the same application, but if these are installed, the customer may complain about noise or brake dust on their wheels.

Install the brake pads into fixed calipers and secure them with the pin(s) and clips. Install any anti-rattle springs, clips or shims. Install the caliper over the brake rotor and install the caliper mounting bolts. Torque the bolts to specification.

Clean the caliper bushings, pins or keys, as required. On sliding calipers, thoroughly clean the mating surfaces of the caliper and anchor bracket. Replace defective parts as required. On sliding calipers, lubricate the mating surfaces of the caliper and anchor bracket with high temperature brake lubricant. On floating calipers, lubricate the caliper bushings and pins with high temperature brake lubricant.

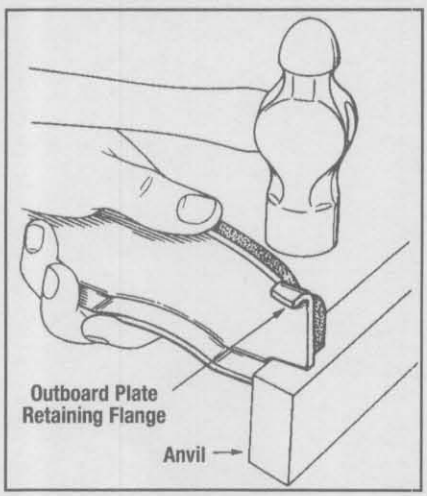
Install the inner brake pad with its anti-rattle springs, clips or shims into the caliper anchor bracket or caliper, as required. Install the outboard pad with its ant-rattle springs, clips or shims into the caliper. On some applications, the flanges on the pad must be bent to make sure the pad fits tightly in the caliper, using slip-joint pliers or a hammer and drift. Install the caliper over the rotor and secure it to the anchor bracket with the mounting bolts. Torque the bolts to specification.

Connect the brake hose using new sealing washers. If the caliper was removed, fill the master cylinder and bleed the system. If the caliper was not removed, apply the brakes a few times to set the caliper piston, then check the fluid level in the master cylinder. Top off the fluid level, as required.

Install the wheel and torque the lug nuts to specification in the proper sequence. Improperly tightening or overtightening the lug nuts can distort the rotor and create excessive runout.

## Disc Brake Pad Burnishing

Whenever new brake pads are installed, they must undergo a burnishing, or break-in procedure before the vehicle can be operated normally. This is to ensure that the bonding resins used during the manufacturing process are slowly burned off rather than quickly boiling to the surface and glazing over or leaving deposits on the rotor, and to ensure that the pads seat and make full contact with the rotor. The latter is particularly important if the rotors were not machined, since even a rotor that was deemed serviceable will not have a perfectly smooth surface.




The retainer flange on some outboard disc brake pads must be bent so the pad is not loose in the caliper. A loose fitting pad can cause brake noise.
*(Courtesy: Bendix Corp.)*

Burnishing procedures will vary somewhat according to application and pad material. The procedure for pads on a high-performance sports car may be different than one for a standard passenger car, so always follow the brake pad and/or vehicle manufacturer's instructions. Generally, the procedure will entail making multiple stops from a certain speed, with cooling off periods in between stops, as in the following example:

1. On a smooth road with little or no traffic, accelerate the vehicle to 30 mph.
2. Using moderate to firm pressure, bring the vehicle to a stop, but do not allow the brakes to lock.
3. Repeat steps 1 and 2 approximately 20 times, driving the vehicle for 30-60 seconds in between stops to let the brake pads cool.

In addition to the above, the driver should be advised to avoid severe braking for several hundred miles.

## Wheel Bearing Service

Refer to the wheel bearing service section under "Drum Brake Diagnosis and Repair" for information on servicing, inspection and replacement of tapered and hub-style wheel bearings.

## Diagnosing Vibration Complaints

Vibration complaints caused by the braking system are generally felt as a rapid pulsation in the brake pedal when the brakes are applied. The pulsation is caused by excessive lateral run-out (side-to-side) of the brake rotor. As the pads try to follow this excessive run-out, the caliper piston is forced in against the pressure being applied by the driver, and the pedal bounces in response.

Lateral run-out should be verified in specification (usually listed in units of ten thousands of an inch)

any time brake work is performed or a customer complaint of vibration is being diagnosed. Remove the wheel and secure the rotor to the hub. Use a dial indicator mounted to the steering knuckle. Place the probe of the indicator so that it is perpendicular to the rotor "hat" at its outer edge and then zero the gauge. Rotate the rotor slowly and note the total deflection.

Often, excessive run-out is caused in the relining process by technicians not following proper service procedure. Improper rotor machining, failure to remove rust buildup from the hub face and the mating surface of the rotor, and even improper lug nut torque. Resurfacing the rotor using an "on car" lathe is one way to help insure that the rotor is running true to the spindle.

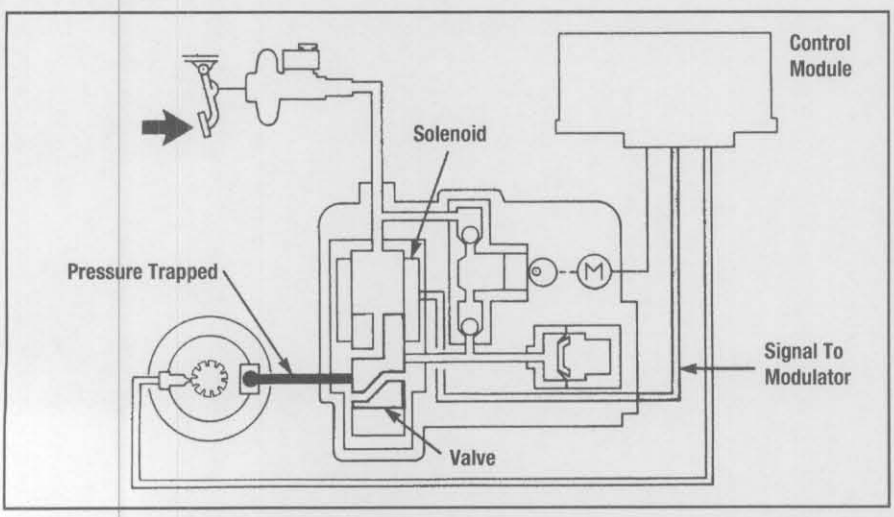
If the vibration exists whether the brake is applied or not, suspect and inspect for a different cause like tire imbalance/damage, wheel run-out/damage, etc.

## Notes

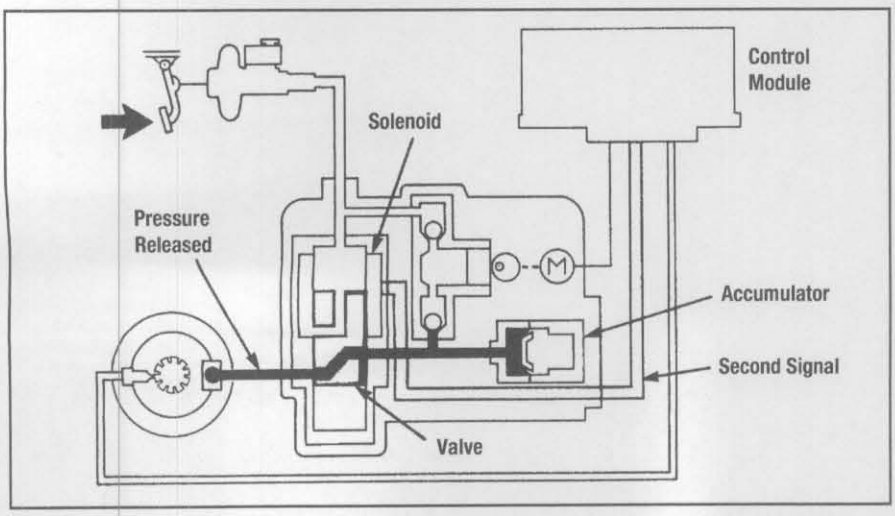
# Electronic Brake Control Systems: Anti-Lock Brake System (Abs), Traction Control System (Tcs) And Electronic Stability Control System (Esc) Diagnosis And Repair

## DESCRIPTION AND OPERATION

The normal reaction of the average driver encountering an emergency braking situation is to slam down on the brake pedal and keep it depressed. While this reaction may be normal, it will result in an uncontrolled skid and possibly a serious accident. Before the advent of ABS, drivers were taught to pump the brake pedal during a panic stop, in order to avoid wheel lockup and maintain vehicle control. ABS does this pumping for the driver, at a rate much faster and in a manner more precise than is humanly possible.




When the control unit senses impending wheel lockup, the pressure maintain phase is engaged. Here the fluid pressure is cut off from the master cylinder by the action of the solenoid valve in the modulator. At the same time, the solenoid valve keeps fluid from flowing out of the caliper or wheel cylinder, thus maintaining residual line pressure in an attempt to lower tire slip.

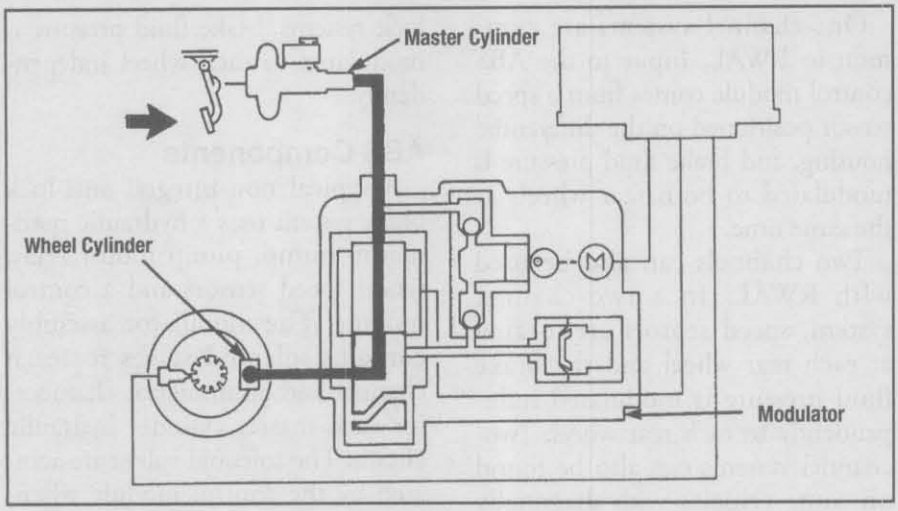



If tire slip does not diminish sufficiently in the pressure maintain phase, the control unit enters the pressure decrease phase. Here the solenoid valve in the modulator moves into a position that allows the residual line pressure to bleed off into an accumulator chamber. At this point, the pump is activated and fluid is returned to the master cylinder.

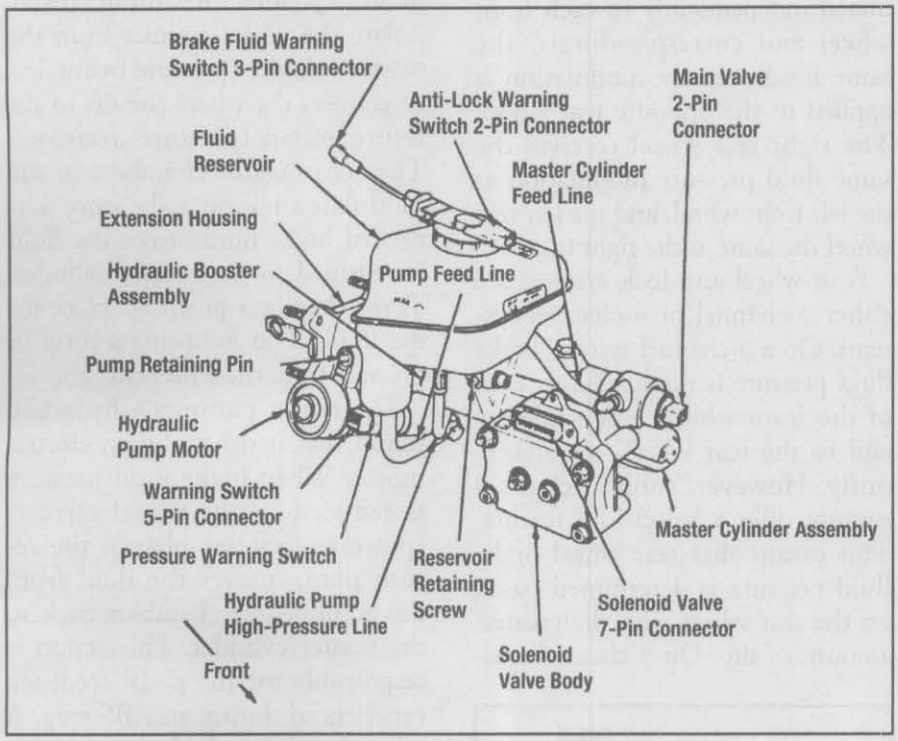
Anti-lock systems use a control module in conjunction with a group of wheel speed sensors to establish the deceleration rate of the vehicle's wheels during braking. If the control module determines that wheel lockup is about to take place, it will issue the necessary commands to a hydraulic modulator that regulates fluid pressure to the wheels as instructed.

There are three phases of hydraulic control that occur during an ABS stop. The first of these is called the pressure maintain phase. This means that any further brake fluid pressure to the slipping wheel or wheels is cut off. Phase two is known as the pressure decrease function. If wheel slip continues to increase in the pressure maintain phase, hydraulic pressure to the wheel(s) is then decreased until wheel slip approaches zero. This means that wheel speed equals vehicle speed. At this point the pressure maintain phase is re-engaged.

The final phase is referred to as the pressure increase phase. If wheel slip approaches zero in the pressure maintain phase, hydraulic pressure to the wheel(s) is increased until wheel slip begins to occur. This means that wheel speed is less than vehicle speed. The pressure increase phase is another name for normal brake operation, since maximum master cylinder pressure is applied to the wheels.




Fluid flow in a typical anti-lock system during the pressure increase (non-ABS) mode. Notice that fluid flows through the hydraulic modulator to the wheel at full master cylinder pressure.




Typical integral ABS hydraulic unit.

## Tire Slip & Steering Control

Tire (wheel) slip is a term used to describe the amount of drag (measured in percentage) that occurs between the tire and road surface. At zero percent slip the tire rotates freely, while at 100 percent slip the tire is completely locked. In a maximum slip situation, the brakes stop the wheels but not the vehicle. Under this condition the weight of the vehicle pushes the non-rotating tires along the road. Brake engineers have concluded that maximum braking force is achieved when tire slip is maintained between 10 percent and 20 percent. This means some tire rotation is absolutely necessary in order to attain optimum braking performance. It is the purpose of ABS to maintain tire slip within the aforementioned range. However, the best brake system in the world cannot develop adequate stopping force unless the tires are in good condition. Proper tire traction provides the counterforce for the brakes to work against.

The forces involved in stopping a vehicle are enormous. Consider that bringing a two-ton vehicle to a stop from 60 mph requires the brakes to generate about 640 horsepower of braking or heat energy. At wheel lockup or 100 percent slip, the forward energy of the vehicle is turned into heat energy between the tire and the road. While this friction will ultimately bring the car to a stop, the problem is that the stopping distance will be excessive since rubber against pavement is not a good high temperature friction material. Brake linings are able to produce much more efficient stopping force than the road can against non-rotating tires.

ABS does what a driver cannot; modulate brake pressure with the precision and speed necessary to maintain the correct percentage of tire slip under adverse road surface conditions.

Like braking, steering control also depends on tire traction. A locked tire (100 percent slip) delivers more than just poor braking, it also limits its directional control. Watching a vehicle slide on ice (wheels locked), demonstrates that the position the front tires are pointing in, has little effect on the direction the vehicle is headed.

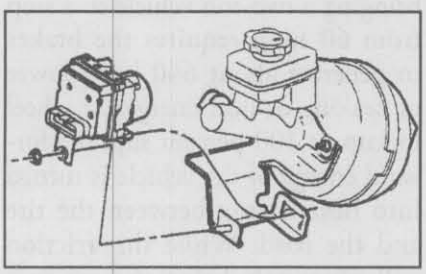
## ABS Types

Anti-lock brake systems can be categorized according to system type (integral and non-integral), number of wheels covered (two-wheel and four-wheel) and number of channels (one-, two-, three- or four-channel).

### Integral & Non-Integral Systems

Most early anti-lock brake systems were the integral type. Integral

ABS uses a special hydraulic unit that combines the functions of the master cylinder and power booster into one component. This self-contained device houses the necessary electrical and mechanical parts that provide not only ABS control, but power assist to the brakes as well.



On a non-integral anti-lock system, the hydraulic control unit is separate from the conventional master cylinder and power booster. *(Courtesy: GM Corp.)*

Integral anti-lock brake systems are high-pressure designs.

A non-integral anti-lock system is added on to the vehicle's existing hydraulic brake system, and is generally a low-pressure arrangement. Non-integral systems make use of the vehicle's master cylinder and power booster, however, special components are added to the conventional brake system that provide the anti-lock capabilities. Most newer vehicles are equipped with non-integral ABS.

### Two-Wheel & Four-Wheel Systems

Two-wheel anti-lock brake systems provide anti-lock control for the rear wheels only and are usually only found on light trucks. These systems are usually referred to as Rear-Wheel Anti-Lock (RWAL). Four-wheel anti-lock systems are the most common type and control all four wheels of the vehicle.

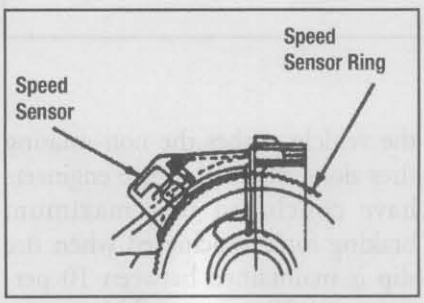
## Channels

The term "channel" refers to the number of independent hydraulic paths to each wheel in the brake system; not to the number of wheel speed sensors a system has.

One-channel systems are common to RWAL. Input to the ABS control module comes from a speed sensor positioned on the differential housing, and brake fluid pressure is modulated to both rear wheels at the same time.

Two channels can also be used with RWAL. In a two-channel system, speed sensors are located at each rear wheel and the brake fluid pressure is modulated independently to each rear wheel. Two-channel systems can also be found on some vehicles with diagonally split brake systems. These vehicles have speed sensors at each front wheel. Brake fluid pressure is modulated independently to each front wheel and correspondingly, the same fluid pressure modulation is applied to the opposite rear wheel. The right rear wheel receives the same fluid pressure modulation as the left front wheel, and the left rear wheel the same as the right front.

Four-wheel anti-lock systems are either 3-channel or 4-channel systems. On a 3-channel system, brake fluid pressure is modulated to each of the front wheels independently and to the rear wheels simultaneously. However, some 3-channel systems offer a 'select-low' feature. This means that rear wheel brake fluid pressure is determined based on the rear wheel with the greatest amount of slip. On 4-channel anti-lock systems, brake fluid pressure is modulated to each wheel independently.



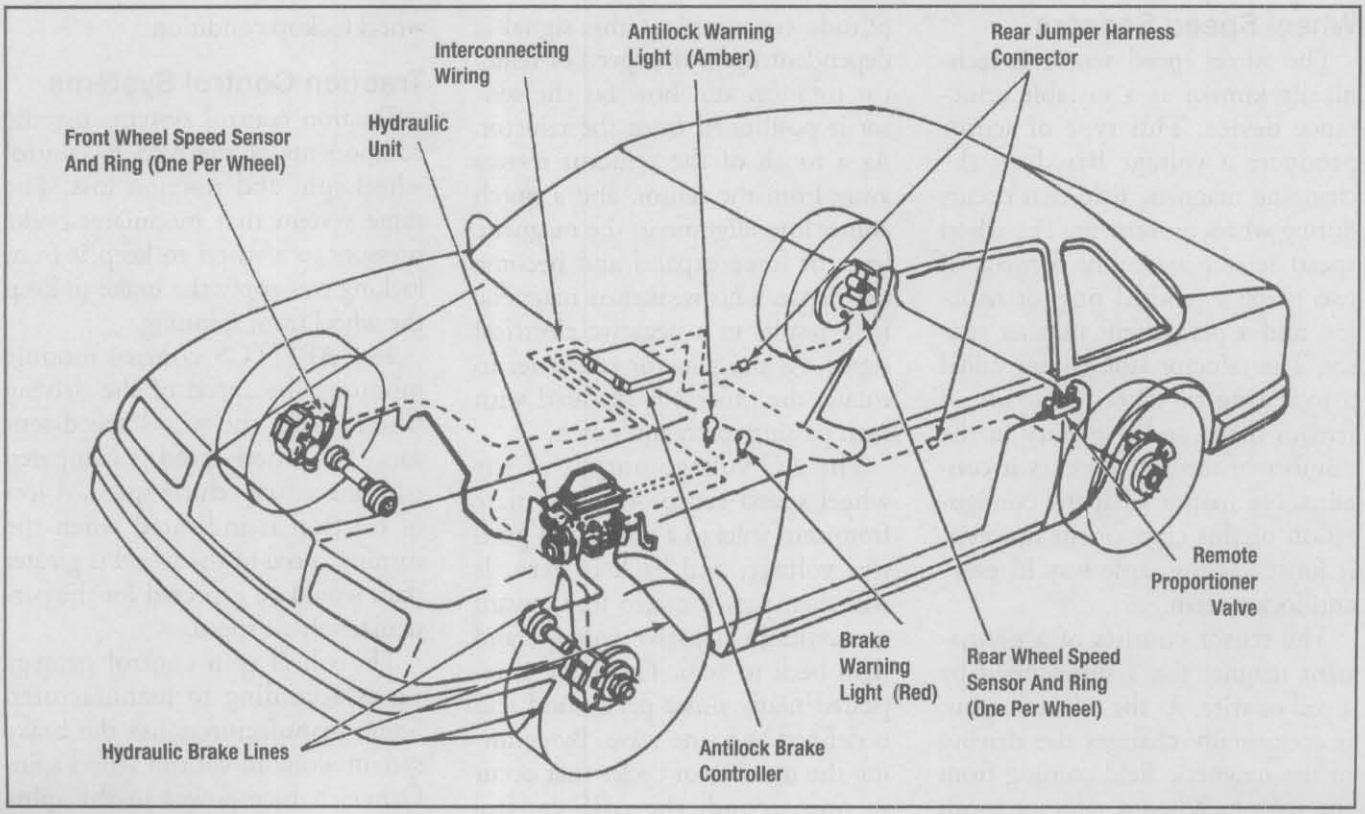

A one-channel rear-wheel anti-lock brake system uses input from one speed sensor. The sensor is usually located on the differential housing and the reluctor, or toothed ring, is mounted on the differential carrier. *(Courtesy: Ford Motor Co.)*

## ABS Components

A typical non-integral anti-lock brake system uses a hydraulic modulator, pump, pump motor relay, wheel speed sensors and a control module. The modulator assembly contains solenoid valves for each channel and accumulator chambers for each master cylinder hydraulic circuit. The solenoid valves are actuated by the control module whenever ABS braking is required. These 3-position valves either connect the wheel hydraulic circuits to the master cylinder (pressure increase), isolate the wheel circuits from the master cylinder (pressure maintain), or connect the wheel circuits to the return pump (pressure decrease). The accumulator chambers in the modulator temporarily store unneeded brake fluid before the fluid is returned to the master cylinder. These chambers provide a place for the fluid to go following a drop in pressure from the wheel circuits.

The return pump is a hydraulic pump that is driven by an electric motor. When brake fluid pressure is reduced in the wheel circuits (pressure decrease phase), the return pump moves the fluid from the accumulator chambers back to the master cylinder. This action is responsible for the pedal feedback experienced during an ABS stop. A relay is used to provide power to the return pump due to its high current demand.

An integral anti-lock brake system replaces the traditional master cylinder and power booster with an electro-mechanical unit. This device contains a high-pressure accumulator, which provides fluid pressure to the rear wheels as well as power assist to the entire brake system. The front brakes are applied by the action of the pedal pushrod against a booster piston.

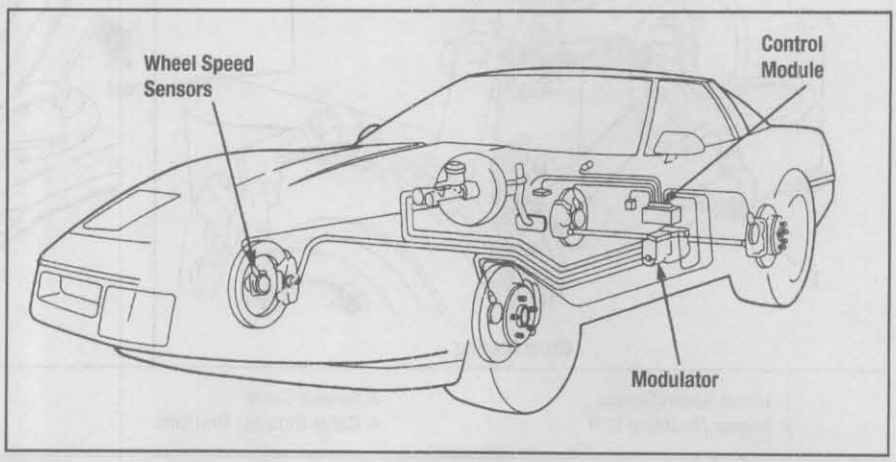



Typical integral ABS component layout.

The accumulator is used to store fluid under high pressure and contains a thick flexible diaphragm that separates brake fluid from high-pressure nitrogen gas. This gas is charged to 600-1300 psi. When pressure drops below a predetermined amount, the pump will force fluid into the accumulator. This action compresses the diaphragm against the high-pressure nitrogen gas. The nitrogen gas acts like a heavy spring by offering resistance to the incoming fluid. When the pump begins to run, the amount of accumulator pre-charge represents the amount of resistance the pump has to work against. If the accumulator begins to fail, the pump will run for longer periods in an effort to maintain sufficient charge pressure. Because the control module monitors pump run times, a trouble code will typically be stored under this condition.

Three pressure switches are used to sense accumulator pressure. The first pressure switch is used to control the operation of the pump. The pump motor will run when the ignition switch is turned on and the pressure switch is closed. The switch closes when accumulator pressure falls below 2000 psi and opens when pressure rises above 2600 psi. A second pressure switch controls the operation of a brake warning light and will close when pressure drops below 1500 psi. The switch contacts will open when pressure exceeds 1900 psi. The third pressure switch is used to signal the control module to illuminate the ABS warning light on the dash when accumulator pressure becomes too low.

The integral system modulates brake fluid pressure in much the same way as the non-integral system, using pulse-width modulated solenoid valves controlled by the ABS control module.




Typical non-integral ABS component layout.

## Wheel Speed Sensors

The wheel speed sensor is technically known as a variable reluctance device. This type of sensor produces a voltage based on the changing magnetic field that occurs during wheel movement. The wheel speed sensor assembly consists of two parts: a toothed ring, or reluctor, and a permanent magnet sensor. The reluctor (sometimes called a tone ring or wheel) is made of ferrous metal and may vary in the number of teeth or notches it contains. No matter what the configuration of this component however, it functions the same way in every anti-lock system.

The sensor consists of a permanent magnet that's surrounded by a coil of wire. As the reluctor spins, it continually changes the density of the magnetic field coming from the sensor. When a reluctor tooth aligns with the permanent magnet sensor, the lines of magnetic force around the sensor are squeezed and become denser. This movement generates a positive electrical signal to the ABS control unit. The amplitude (strength) of this signal is dependent upon the speed of reluctor rotation and how far the sensor is positioned from the reluctor. As a tooth of the reluctor moves away from the sensor, and a notch comes into alignment, the magnetic lines of force expand and become less dense. This weakened magnetic field results in a negative electrical signal. As the reluctor continues to rotate, the process is repeated with each passing tooth and notch.

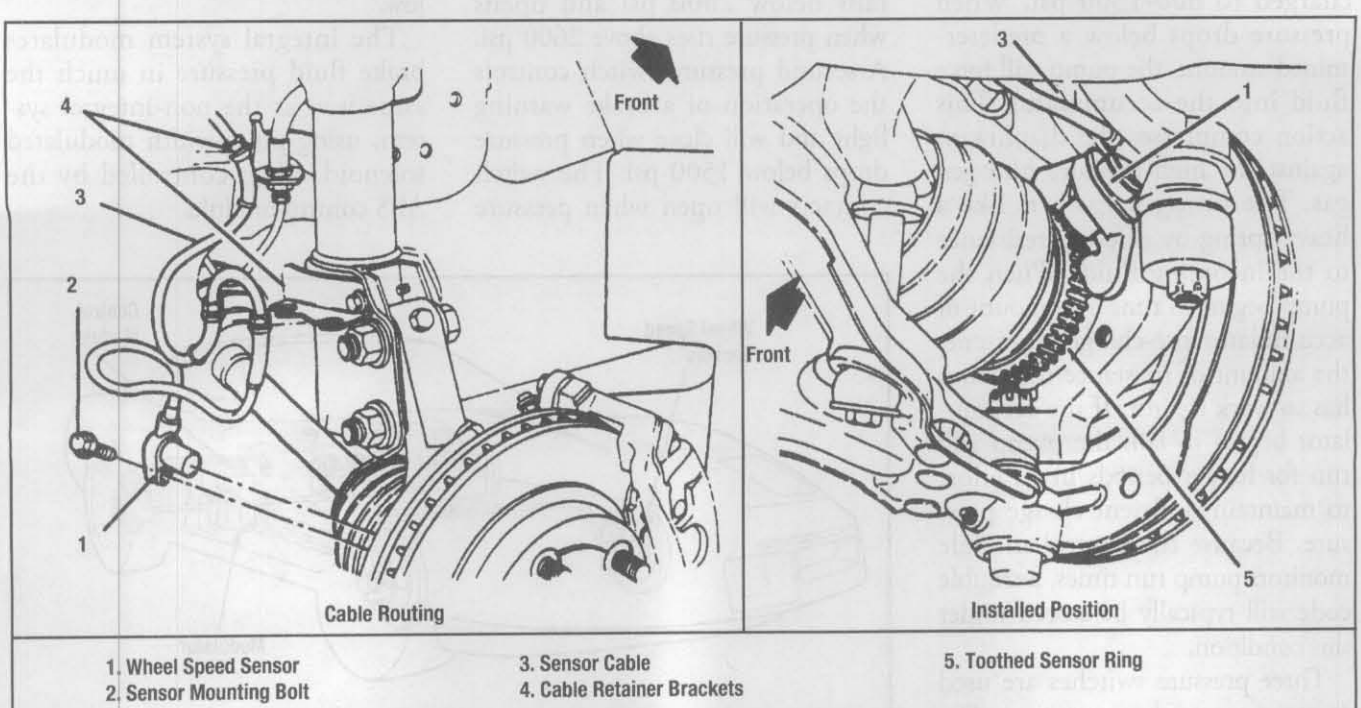
The AC voltage output of the wheel speed sensor will alternate from zero volts to a maximum positive voltage, and back to zero. It will then pass the zero line toward a maximum negative voltage, and then back to zero. This cycle is repeated many times per second and is defined as a sine wave. By counting the number of cycles that occur in one second, the ABS control unit can determine the sensor's frequency. By comparing the frequencies of the wheel speed sensors to one another, the control unit can detect changes in wheel deceleration rates that indicate an impending wheel lockup condition.

## Traction Control Systems

Traction control systems use the components of the ABS to control wheel spin and traction loss. The same system that modulates brake pressure to a wheel to keep it from locking can apply the brake to keep the wheel from spinning.

The ABS/TCS control module monitors the speed of the driving wheels using the wheel speed sensors. The wheel speed is compared with the actual vehicle speed. A loss of traction is indicated when the turning speed of the wheel is greater than would be expected for the particular vehicle speed.

The wheel spin control strategy varies according to manufacturer. Some manufacturers use the brake system alone to control wheel spin. Others reduce power to the spinning wheel by retarding the ignition timing, cutting off fuel injection to certain cylinders and/or mechanically closing the throttle, and only apply the brakes if the wheel continues to spin.




Reluctor to speed sensor relationship shown here on the right front wheel of a front-wheel drive vehicle.

Most traction control systems use the same components as the antilock brake system. There are usually some variations in the hydraulic control system but the main difference between an ABS and ABS/ TCS vehicle is the programming in the brake and engine control system modules.

## Electronic Stability Control Systems

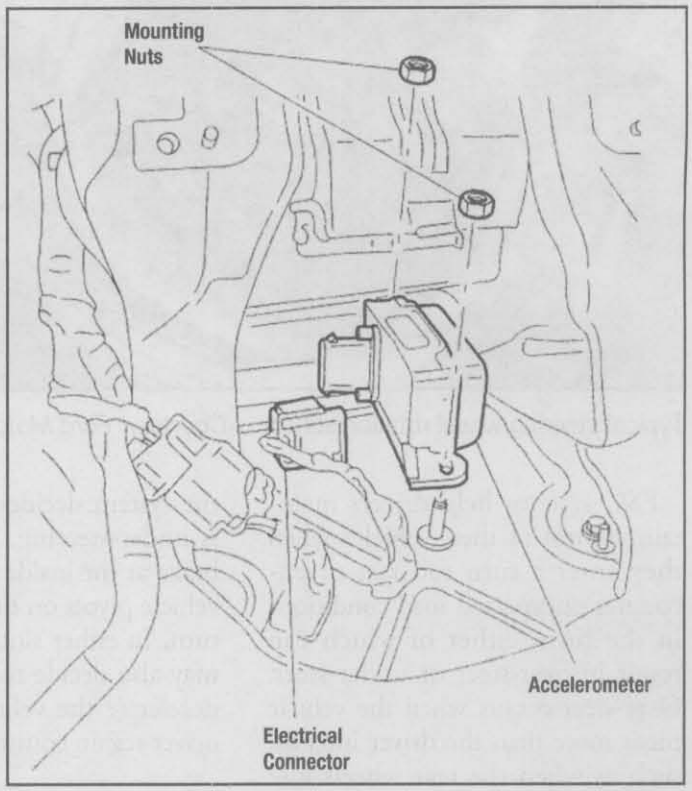
Electronic Stability Control (ESC) is a further variation of ABS/ TCS. Like an ABS/ TCS, the control module in an ESC system uses input from the wheel speed sensors to modulate brake pressure at the wheels and control power output from the engine. However, an ESC system control module also receives additional inputs from a lateral acceleration sensor, a yaw rate sensor and steering wheel angle, or rotation, sensor.

The lateral acceleration sensor measures vehicle lateral force as it corners through a turn; the speed at which the vehicle slides sideways in a skid. It varies the signal voltage to the control module based on vehicle lateral (side-to-side) forces. As lateral force increases to one side, the voltage increases, while lateral force to the other side will decrease the voltage.

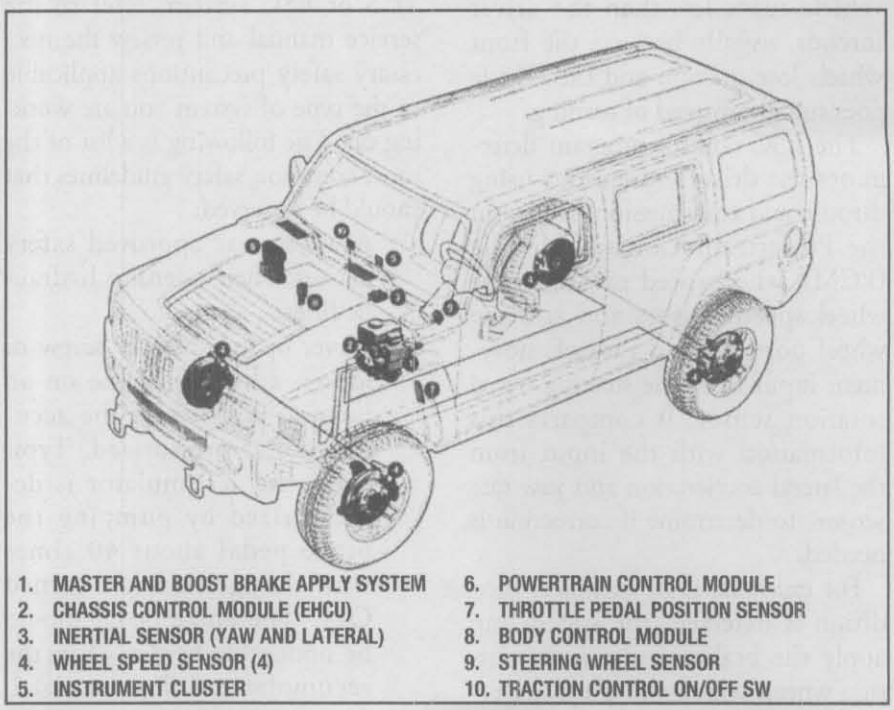
The yaw rate sensor measures a vehicle's rotational speed around its vertical axis; the speed at which an end of the vehicle swings during a skid. Signal voltage to the control module is constant when the vehicle travels straight ahead, but increases when the vehicle turns to one side and decreases if it turns in the other direction.

The lateral acceleration and yaw rate sensors are often housed together in one unit, which on some vehicles is called the sensor cluster, or accelerometer. The accelerometer is typically mounted as close as possible to the vehicle's center of mass.

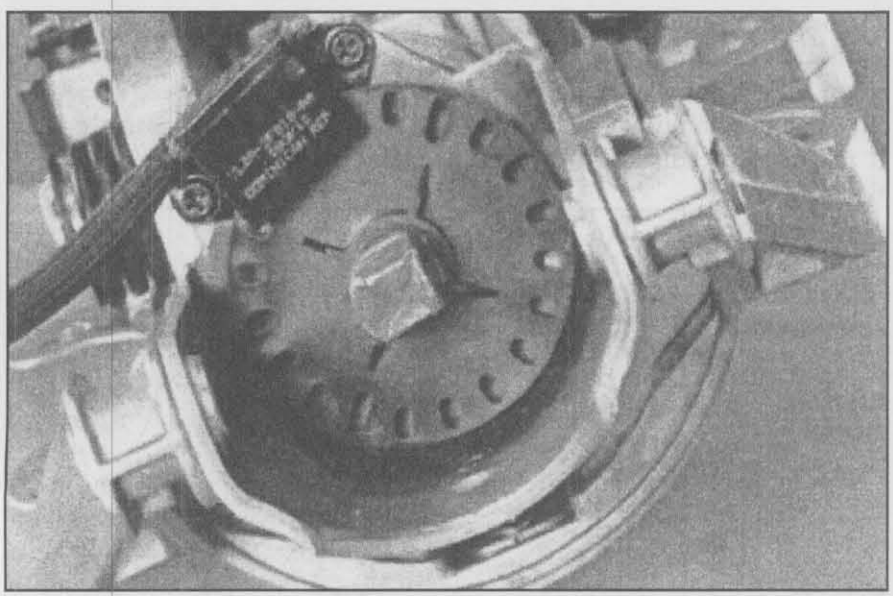
The steering wheel rotation sensor provides input to the control module regarding driver steering input. The sensor is mounted on the steering column housing, where it measures the direction of rotation and speed of rotation of a sensor ring attached to the column shaft. The signal is used by the control module to determine which way the wheel is being turned and how far and fast it is being turned. The control module calibrates the sensor output so it indicates zero when the steering wheel is centered and the vehicle is traveling straight ahead. It does this by comparing the steering wheel position with the lateral acceleration, yaw rate and wheel speed sensor signals to determine a relative straight ahead position.




Typical accelerometer installation. *(Courtesy: Ford Motor Co.)*




Layout of a typical electronic stability control system. *(Courtesy: GM Corp.)*



Typical steering wheel rotation sensor. *(Courtesy: Ford Motor Co.)*

ESC systems help drivers maintain control of their vehicles when they enter a turn too fast or encounter unexpected road conditions in the turn, either of which can result in over-steer or under-steer. Over-steer occurs when the vehicle turns more than the driver intends, such as when the rear wheels lose traction and the rear of the vehicle slides out. During under-steer, the vehicle turns less than the driver intends, usually because the front wheels lose traction and the vehicle goes straight instead of turning.

The ESC control program determines the driver's intentions using throttle and transmission data from the Powertrain Control Module (PCM), wheel speed rate from the wheel speed sensors and steering wheel position and rate of movement input from the steering wheel rotation sensor. It compares this information with the input from the lateral acceleration and yaw rate sensors to determine if correction is needed.

For example, if an over-steer condition is detected, the system can apply the brake on the front outside wheel, which will push the vehicle in the opposite direction of the slide until it straightens out. If the system decides that the vehicle is under-steering, it can apply the brake at the inside rear wheel so the vehicle pivots on that wheel into the turn. In either situation, the system may also decide to reduce power to decelerate the vehicle and help the driver regain control.

## SAFETY GUIDELINES

Before servicing an ABS, ABS/TCS or ESC system, refer to the service manual and review the necessary safety precautions applicable to the type of system you are working on. The following is a list of the most common safety guidelines that should be observed:

- Always wear approved safety glasses when opening hydraulic lines.
- Never open a bleeder screw or loosen a hydraulic line on an integral ABS while the accumulator is pressurized. Typically, the accumulator is depressurized by pumping the brake pedal about 40 times with the ignition key turned OFF. The brake pedal should be noticeably harder when the accumulator is depressurized. Always consult service manual for the exact procedure.
- Never connect or disconnect any ABS, ABS/TCS or ESC system electrical connectors while the ignition key is turned ON. Doing so may resdamage the ABS, ABS/TCS or ESC system control unit.
- Never tap on speed sensor components. Reluctors must be pressed into wheel hubs where applicable and not hammered into place. Striking these components can cause de-magnetization or polarization, which will affect the accuracy of the speed signal to the ABS, ABS/TCS or ESC system control unit.
- Never mix tire sizes. While increasing the tire width within acceptable limits is fine, the diameter must remain the same for all four tires in order to maintain accurate wheel speed signals
- Make sure all tires are worn evenly and inflated properly. Excessively worn or under inflated tires have the same negative effects as different diameter tires.
- Make sure that grease does not come into contact with the wheel speed sensor assembly unless specifically indicated by the manufacturer.
- Never use DOT 5 (silicone) brake fluid in an ABS, ABS/TCS or ESC system.
- Never bleed the hydraulic system on an ABS, ABS/TCS or ESC system equipped vehicle without consulting the vehicle service manual.

## DIAGNOSIS & TESTING

Before testing any ABS, ABS/TCS or ESC system, make sure you have the relevant factory service information on hand, including a wiring diagram. It is important to know the particulars and have specifications for the system in question, and to follow the manufacturer's

diagnostic procedure.

Begin diagnosis by discussing the complaint with the driver. He may be experiencing a problem that may or may not be related to the ABS, ABS/TCS or ESC system, or maybe the only indication he has that there is a problem is a warning light that won't go out.

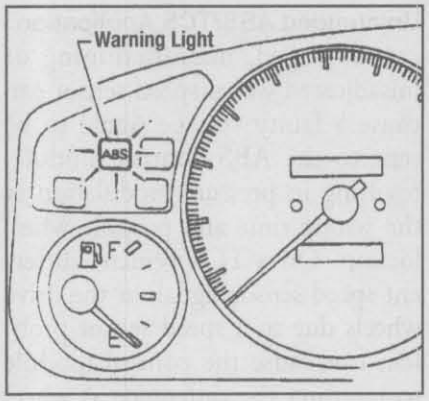
ABS vehicles usually have an amber ABS warning light and a red brake warning light. The amber light will come on when there is a malfunction in the ABS system. The red light may also come on, but this light usually means that there is a problem with the basic brake hydraulic system. On many vehicles, the red light also comes on when the parking brake is applied.

If the ABS light is illuminated, then the system should be checked for Diagnostic Trouble Codes (DTCs). If only the brake warning light is on, then the hydraulic system and parking brake circuit should be checked. If both lights are on, there is a loss of brake fluid pressure or the brake fluid level is low in the reservoir.

A dash light will also come on if there is a malfunction in the TCS or ESC system. This may be an ABS/TCS or ESC system warning light or it may be a separate warning light. TCS vehicles and some ESC system vehicles also usually have a manual override switch that the driver can use to disengage the system. When the system is disengaged, an amber warning light will illuminate on the dash. Some systems also illuminate a light on the dash when the system is actively controlling wheel spin or vehicle stability.

## Preliminary Checks

Perform a visual inspection of the brake system before performing any tests. A thorough visual inspection can often uncover the problem and eliminate the need for further diagnosis.

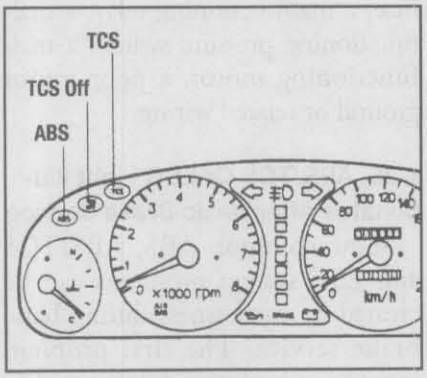



If a malfunction in the ABS is detected by the ABS control module, the ABS warning light will be illuminated.
*(Courtesy: Nissan Motor Co., Ltd.)*

- Check the brake fluid level in the reservoir.
- Inspect all hoses, lines, fittings and hydraulic system components for leaks and damage.
- Make sure all components of the basic brake system are in good condition and operating properly.
- Inspect all electrical wiring and connections for damage and corrosion.
- Check the condition of the wheel speed sensors and reluctors (toothed rings). Make sure there is no debris between the sensors and reluctors and check that air gaps are correct.

## Self Diagnosis

All ABS, ABS/TCS and ESC systems have self-diagnostic capabilities. When the ignition key is turned to the ON position, the amber ABS, ABS/TCS or ESC system light illuminates and the control module performs a basic resistance check of all ABS, ABS/ TCS or ESC system circuits. If a circuit is found to be out of specification, the light will stay on, otherwise the light will turn off after a few seconds.



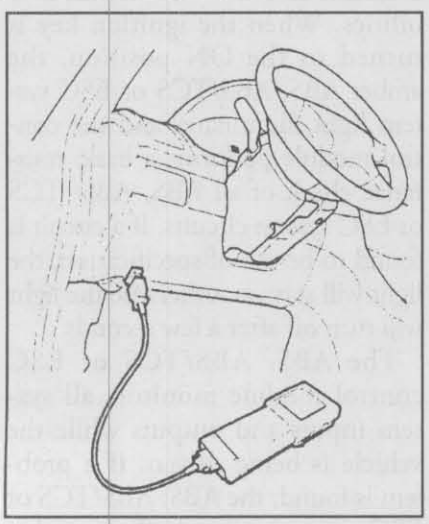

A traction control system will add one or two lights to the instrument panel.
*(Courtesy: Hyundai Motor Co.)*

The ABS, ABS/TCS or ESC control module monitors all system inputs and outputs while the vehicle is being driven. If a problem is found, the ABS, ABS/TCS or ESC system is turned off, the amber warning light illuminates and a DTC is set in the control module's memory. On some vehicles, if a problem specific to the TCS or ESC system is detected, such as a failed yaw rate sensor, the TCS or ESC system will be disabled but the ABS will continue to function.

While most RWAL systems offer flash-code diagnostics, most four-wheel ABS, ABS/TCS and ESC systems require the use of a scan tool to extract stored DTCs. Flash-code diagnostics requires you to count the pulses of the warning light to identify specific code number(s). This is accomplished by jumping specific pins in the diagnostic connector, or jumping a pigtail wire to ground with the key turned on.

A Diagnostic Link Connector (DLC) is used to connect a scan tool to the ABS, ABS/TCS or ESC system control module. The scan tool may require an adapter to connect to the DLC, particularly on older vehicles, and it must be loaded with the proper software applicable to the year, make and model of the vehicle being serviced. The actual number of the fault code, and in many cases a brief description of the malfunctioning circuit, will be displayed right on the scan tool's screen.

Each ABS, ABS/TCS and ESC system has a specific number of



To obtain ABS, ABS/TCS or ESC system DTCs from most vehicles, a scan tool must be connected to the diagnostic link connector. (Courtesy: Honda Motor Co., Ltd.)

codes that are assigned to various circuits and components. Each code number corresponds to a diagnostic chart in the factory service information. The diagnostic charts will describe the circuit and the fault that the code represents and contain troubleshooting procedures and tests that must be performed, to determine the cause of the malfunction. These tests will require a scan tool to monitor component operational values, or PIDs (Parameter IDs), and describe various voltage and resistance measurements that are made using a Digital Multi Meter (DMM).

A bi-directional scan tool or dedicated ABS/TCS/ESC tester can be used to perform tests on ABS, ABS/TCS and ESC system components. These are particularly useful for diagnosing an intermittent problem, which may not set a DTC. With these tools, a technician can activate solenoids and valves while observing the change in current for that circuit.

## Common ABS/TCS/ESC Problems

Each of the following symptoms may or may not set a DTC.

### Unintended ABS/TCS Application

A damaged, malfunctioning or misadjusted wheel speed sensor can cause a faulty voltage signal to be sent to the ABS control module, resulting in pressure modulation at the wrong time and possible wheel lockup. On a TCS vehicle, different speed sensor signals at the drive wheels due to a speed sensor problem can cause the control module to interpret the difference as wheel spin and engage the traction control when it is not needed.

Different diameter tires can cause wheel speed sensors to generate different signals, and the ABS control module could interpret this as wheel slip and activate the pressure control solenoids. Tires that are the same size, but made by different manufacturers can have different diameters, as can tires that have more tread than others or under inflated tires.

### ABS Pump Continues To Run

If there is a leak in the hydraulic control unit, the ABS pump may continue to run in order to try to maintain operating pressure. A malfunction in the hydraulic pump, stuck valves and defective accumulators are possible causes. A shorted pressure switch can also cause this condition.

### ABS Pump Does Not Run

This can be caused by a blown fuse, a malfunctioning relay, a malfunctioning pressure switch, a malfunctioning motor, a poor motor ground or related wiring.

### ABS, ABS/TCS Or ESC Light Illuminates After Basic Brake Service

Some common ABS, ABS/TCS and ESC system problems can be created by carelessness during basic brake service. The first problem involves wheel speed sensors that are accidentally damaged or misadjusted during repairs. As stated earlier, a damaged or misadjusted sensor can cause a faulty voltage signal to be sent to the ABS, ABS/TCS or ESC system control module. Another problem related to wheel speed sensors occurs because the sensors are magnetic. They can collect large amounts of debris from the road and also collect metal shavings from a freshly turned rotor if the rotor was not cleaned properly. Any debris that collects on the sensor can affect the sensor-to-reluctor gap and the signal to the control module. It is good practice to clean the sensors and reluctors and check the air gap between them during a brake job.

Another problem involves foreign material being forced into the hydraulic control unit. This is caused by bottoming the caliper piston in the caliper bore without opening the caliper bleeder screw. Since the caliper is the lowest point in the system, dirt and corrosion naturally accumulate there. If the bleeder screw is not opened, brake fluid and these contaminants are forced backward into the system. When these contaminants find their way into the hydraulic control unit, they can cause valves and accumulators to stick and plug compensator ports. This can result in pulling during braking, low pedal and brake drag.

## Wheel Speed Sensor Testing

Make a visual inspection of the reluctor and sensor. A bridged air gap or excessive air gap can cause faulty voltage signals. Inspect for road debris that may be trapped between the air gap and clean as necessary. Check for corrosion build up beneath the speed sensor mount, which can jack the sensor up, increasing the air gap. This can often be misdiagnosed as a faulty sensor. Remove the sensor, clean the mounting surface and retest before condemning the sensor. Also, check the reluctor for chipped or broken teeth.

The simplest test for the wheel speed sensor is to measure the resistance of the sensor coil winding using an ohmmeter. Compare your readings with the manufacturer's specification. Another check of the sensor is to see if it is still magnetized. This can be done by simply placing a paper clip or other metallic object near the sensor's tip. While these tests are valid, they are static checks only, and do not confirm the dynamic operation of the sensor.

While the output voltage of the sensor can be monitored with a voltmeter set to the AC scale, the voltmeter only averages the reading by sampling the signal a few times per second. Similarly, while a scan tool can actually display the individual wheel speed in mph, it too has a low sampling rate. Both of these methods are fine for measuring the quantity of the voltage, but not necessarily the quality of the signal.

If the customer complains of intermittent ABS problems, it could be due to an erratic wheel speed sensor signal that doesn't show up under conventional test procedures. In these cases a DSO (Digital Storage Oscilloscope) is required. This equipment samples the electrical signal over 250,000 times per second. Consequently, if a glitch occurs during operation, you'll be able to see it on the scope screen.

## ABS/TCS/ESC SERVICE

### Checking Brake Fluid Level

The brake fluid level on a vehicle with a non-integral ABS, ABS/TCS or ESC system is checked just like a vehicle without ABS. However, on vehicles with integral ABS, it may be necessary to pressurize or depressurize the system. Always consult the vehicle service manual.

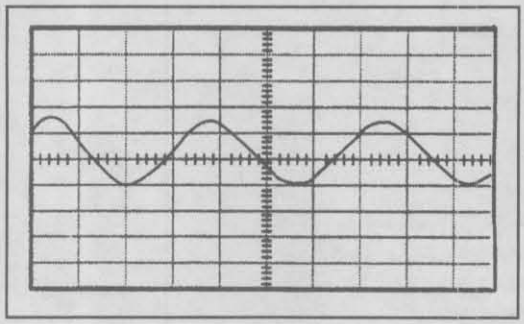
### Bleeding

Bleeding an ABS, ABS/TCS or ESC system will involve a variety of different methods depending upon the manufacturer. In many cases a bi-directional scan tool will be required. This type of scan tool is not only able to receive information, but send it as well. On certain systems, solenoid valves or other components may need to be in specific positions in order to bleed the system successfully. A bi-directional scan tool accomplishes this by commanding the ABS, ABS/TCS or ESC system control unit to perform certain tasks prior to bleeding.

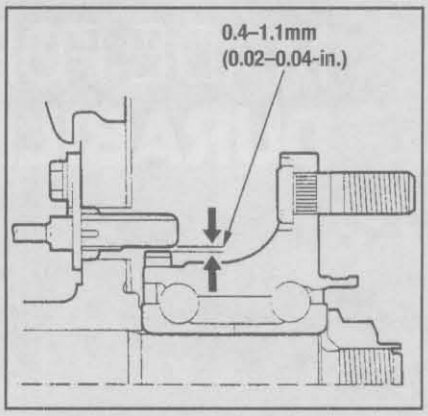
Many non-integral ABS, ABS/TCS and ESC systems can be bled using traditional techniques, while on most integral designs only the front circuits can be bled in the conventional manner. A fully charged accumulator or pressure bleeding equipment is necessary to properly bleed the rear circuit(s) on most integral designs. Always consult the service manual before attempting to bleed any ABS, ABS/TCS or ESC system.

### Wheel Speed Sensor Replacement

Raise and safely support the vehicle. Remove the necessary components to facilitate sensor removal. Disconnect the sensor from the wiring harness. Remove the sensor mounting fasteners and remove the sensor.



The ABS/TCS/ESC wheel speed sensor is a variable reluctance device, which produces a sine wave pattern visible on an oscilloscope display screen.




Typical wheel speed sensor-to-reluctor gap specification. (Courtesy: Honda Motor Co., Ltd.)

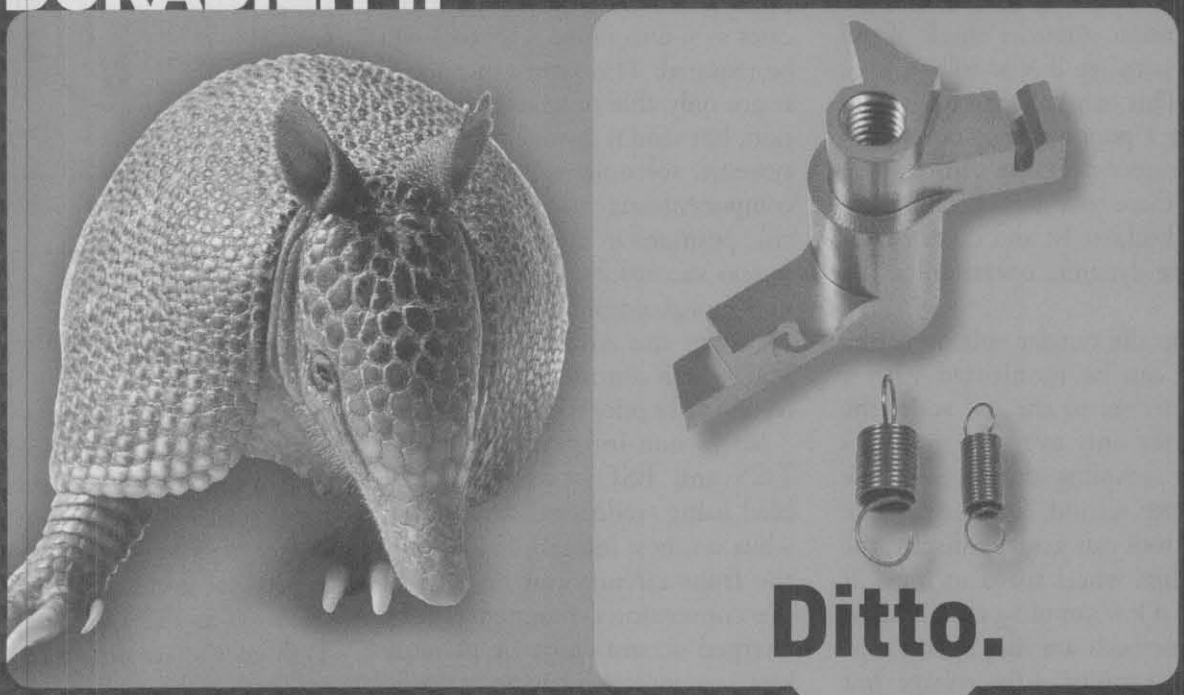
Install the sensor and adjust the sensor-to-reluctor gap, if required. This is usually accomplished with a paper spacer or non-magnetic feeler gauge. New sensors come with the paper spacer installed, which will wear off as the vehicle is driven. Tighten the sensor mounting fastener when the gap is correct.

Connect the sensor to the wiring harness, install all remaining components and lower the vehicle. Check sensor operation by driving the vehicle and checking the ABS, ABS/TCS or ESC system warning light to see if it illuminates.

### Wiring And Connectors

Handle wiring and connectors on ABS, ABS/TCS and ESC systems with care. It is not recommended to backprobe any connectors on the system. Testing/diagnosis of the ABS, ABS/TCS and ESC system wiring/connectors should be accomplished using basic techniques and safety precautions as with the rest of the vehicle. If any wiring harnesses require service, ensure that the replacement or repair meets all of manufacturer specifications. If a connector is the faulty component, never fabricate a connector. Always replace it (if possible and available) with one that meets the manufacturer's specs. Otherwise, replace the harness.

# MADE FOR **DURABILITY.**

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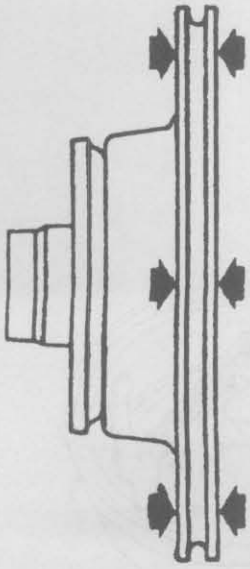
# Prepare yourself for ASE testing with these questions on BRAKES

**NOTE: The following questions are written in the ASE style. They are similar to the kinds of questions that you will see on the ASE test. However, none of these questions will actually appear on the test.**

1. On a car with disc/drum brakes, the front brakes grab quickly when light pedal pressure is applied. This problem could be caused by a bad:
   A. proportioning valve
   B. pressure safety switch
   C. metering valve
   D. residual check valve

2. The driver of a vehicle with power disc/drum brakes says that the brake pedal moves slowly to the floor while maintaining pedal pressure at a stoplight. What could cause this problem?
   A. leaking primary piston cup in master cylinder
   B. leaking power brake booster
   C. leaking residual check valve in master cylinder
   D. internal leak in the combination valve



**Check rotor parallelism (thickness variation) at eight equidistant points around the rotor.**

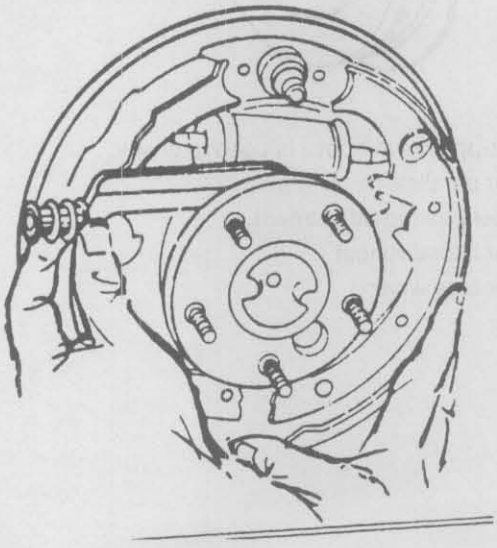
3. Which of the following would **MOST LIKELY** happen if the measurements taken from the check shown above varied from the manufacturer's specifications?
   A. noisy brake operation
   B. brake grab or pull
   C. pulsating brake pedal
   D. low brake pedal

4. What is the purpose of the master cylinder residual check valve(s) on vehicles equipped with drum brakes?
   A. allows the driver to pump up the brakes
   B. prevents air from entering the hydraulic system
   C. prevents wheel lockup by reducing the hydraulic pressure
   D. reduces pedal pulsation by controlling hydraulic pressure

5. A technician has just overhauled the front brakes on a vehicle with front disc and rear drum brakes. However, when he attaches a pressure bleeder (pressurized to about 25 psi) to the master cylinder, he cannot get any fluid to come out of the disc brake caliper bleeder screws. Which of the following is **MOST LIKELY** the cause?
   A. bad proportioning valve
   B. bad pressure differential valve
   C. proportioning valve release button not activated
   D. metering valve release button not activated

6. On a vehicle with single piston floating caliper front disc brakes, the brake pads on the left side of the vehicle are almost completely worn while the right side is almost new. Technician A says that too much rotor runout could be the cause. Technician B says that a binding caliper piston could be the cause. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

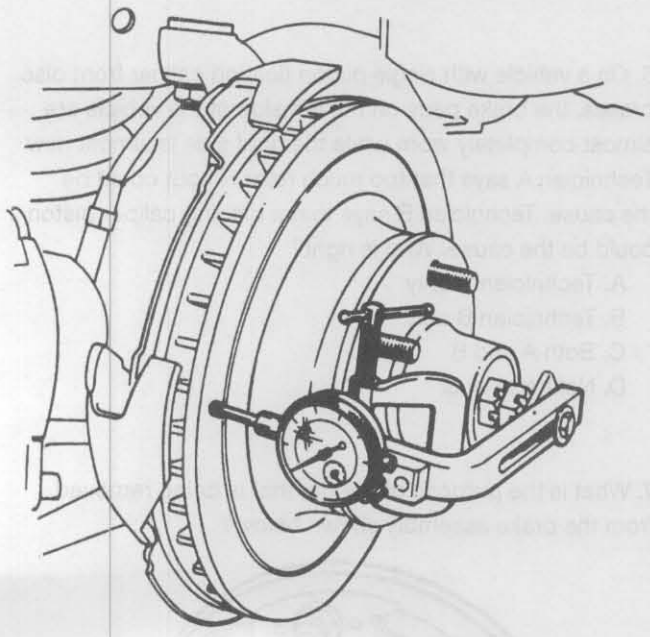
7. What is the purpose of the bar that is being removed from the brake assembly shown below?



# Prepare yourself for ASE testing with these questions on BRAKES

A. to equalize the braking force between the shoes during normal braking
B. to center the shoes after each brake application
C. to force the shoes into the drum when the parking brakes are applied
D. to reduce the distance between the shoes and the drum

8. A hydraulic brake line is leaking. Which of the following is the correct repair procedure?
A. Cut out the bad section and replace with new steel tubing using compression fittings.
B. Replace the leaking line with double-flared, seamless copper tubing.
C. Cut out the bad section and replace with single-flared steel tubing using flare nuts and unions.
D. Replace the leaking line with double-flared steel tubing.

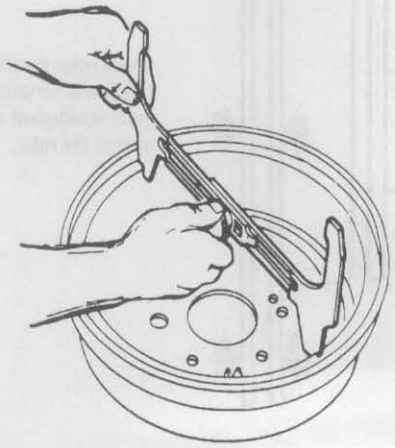


9. The set-up shown above is used to check:
A. rotor parallelism
B. wheel bearing adjustment
C. rotor lateral runout
D. rotor face wear

10. Which of the following problems would be caused by using a residual check valve in a disc brake master cylinder?
A. reduced brake pedal travel
B. reduced brake system pressure
C. increased brake pad wear
D. increased rotor runout

11. A customer complains that their vehicle pulls to the right when the brakes are applied. Technician A says a restricted brake line to the left caliper can cause this problem. Technician B says a malfunctioning proportioning valve is probably the cause. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

12. With foot pressure applied, the brake pedal on a vehicle with vacuum assisted power brakes moves down slightly when the engine is started. Technician A says that this condition can be caused by a leaking power brake booster diaphragm. Technician B says that the cause could be a faulty power brake booster check valve. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B



13. Technician A says that the tool shown above is used to adjust the brake shoes. Technician B says that the tool shown above is used to determine the inside diameter of the drum. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

# Prepare yourself for ASE testing with these questions on BRAKES

14. The hydraulic system on a vehicle with integral ABS is to be bled. Technician A says that the front brakes can be bled in a conventional manner. Technician B says that both front and rear brakes can only be bled using the pressure from a fully charged accumulator. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

15. A driver complains that the ABS system on his car engages every time he applies the brakes on a cobblestone roadway he uses going back-and-forth to work. This condition means that:
   A. The system is operating normally.
   B. The wheels are traveling at different speeds.
   C. A wheel speed sensor(s) is faulty.
   D. both A and B

16. Two technicians are discussing the duo-servo type drum brake design. Technician A says the brake lining on the secondary shoe is usually longer and thicker than the brake lining on the primary shoe. Technician B says the primary shoe is installed toward the rear of the vehicle. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

17. All of the following statements about leading-trailing type drum brakes are true **EXCEPT:**
   A. The leading shoe does most of the forward braking.
   B. Both brake shoes are held against a fixed anchor on the backing plate.
   C. They are self-energizing.
   D. The trailing shoe does most of the reverse braking.

18. Technician A says that DOT 5 brake fluid has a lower boiling point than DOT 4. Technician B says that DOT 4 brake fluid is silicone-based and should never be used in an ABS system. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

19. Brakes that drag or fail to release can be caused by which of the following conditions in the master cylinder?
   A. leaking primary cup
   B. leaking secondary cup
   C. failure of the residual pressure check valve
   D. clogged compensating port

20. All of the following could cause a hard brake pedal on a vehicle with power brakes **EXCEPT:**
   A. an engine with the valves adjusted too tight
   B. brake fluid on the linings
   C. a leak in the brake hydraulic system
   D. a frozen caliper

21. Technician A says that a caliper seal installed in the caliper bore is called a stroking seal. Technician B says that when the brake pedal is released, the piston in the caliper moves back in its bore due to the action of the piston seal. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

22. When replacing disc brake pads, you must bottom the caliper piston in its bore to create room for the new pads. Which of the following is the proper procedure?
   A. Use a C-clamp or pliers to slowly bottom the piston in the caliper.
   B. Remove half the fluid from the master cylinder reservoir, then use a C-clamp or pliers to slowly bottom the piston in the caliper.
   C. Connect a hose to the caliper bleeder screw and insert the other end of the hose into a suitable container, open the bleeder screw, then use a C-clamp or pliers to slowly bottom the piston in the caliper.
   D. Remove the caliper from the vehicle, then use a C-clamp or pliers to slowly bottom the piston in the caliper.

23. Technician A says that all 3-channel ABS systems use only 3 wheel speed sensors. Technician B says that a 4-channel ABS system means that fluid pressure is independently regulated to each of the wheels during an ABS stop. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

# Prepare yourself for ASE testing with these questions on BRAKES

24. Technician A says that when a rotor is machined, an equal amount of material must always be removed from both sides. Technician B says that the minimum thickness dimension cast into the rotor is the dimension that the rotor can be machined to. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

25. The purpose of an anti-lock brake system is to maintain tire (wheel) slip at what level?

A. a level between 50-75%
B. 100%
C. 0%
D. a level between 10-20%

26. While on a road test, a technician notices that the rear wheels lockup and the car skids when attempting to stop quickly from a high speed. The **MOST LIKELY** cause of this problem is a defective:

A. residual pressure check valve
B. pressure differential valve
C. metering valve
D. proportioning valve

27. Excessive slack in the parking brake cables can be eliminated on most vehicles by making an adjustment at the:

A. equalizer
B. star wheel adjusters
C. strut rod
D. pushrod

28. A customer complains that the brake warning light comes on whenever the brake pedal is depressed while driving. All of the following could cause this to occur **EXCEPT:**

A. a leak in the rear half of the hydraulic system
B. a short to ground in the warning light circuit
C. a leak in the front half of the hydraulic circuit
D. a leaking pressure differential switch

29. The MOST common cause for premature front brake pad wear in a disc/drum system is:

A. seized calipers
B. faulty master cylinder
C. improperly adjusted rear shoes
D. malfunctioning metering valve

30. Technician A says that DTCs can be accessed from any ABS system using flash diagnostics. Technician B says that ABS system tests can be performed with a bi-directional scan tool. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

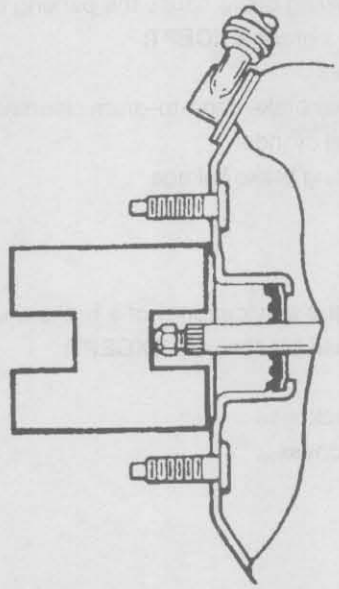
31. To determine if an intermittent ABS problem is related to an erratic wheel speed sensor signal, which of the following should be used?

A. ohmmeter
B. voltmeter
C. scan tool
D. digital storage oscilloscope

32. A few minutes after the engine was turned off on a vehicle with vacuum power assist, the brake pedal is applied and it is hard to push. Technician A says that this is a normal condition. Technician B says that the booster check valve is leaking. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

# Prepare yourself for ASE testing with these questions on BRAKES



33. The above measurement is made when replacing all of the following components **EXCEPT:**
   A. master cylinder
   B. vacuum power booster
   C. brake caliper
   D. master cylinder pushrod

34. During a brake inspection, an area of the vacuum brake booster below the master cylinder is found to be damp. Technician A says that this is a normal condition. Technician B says that any evidence of fluid indicates a leak and the master cylinder must be replaced. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

35. Technician A says that tapered roller bearings can be adjusted using a torque wrench. Technician B says that tapered roller bearings are adjusted using a dial indicator. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

36. All of the following could cause a pulsation to be felt in the brake pedal **EXCEPT:**
   A. brake drum out of round
   B. normal ABS operation
   C. lateral rotor runout
   D. seized caliper piston

37. Technician A says that, when testing a proportioning valve, the pressure at the outlet port to the rear brakes should rise at a faster rate, once transition pressure is reached. Technician B says that vehicles with diagonally-split hydraulic systems must have the proportioning valve tested twice. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

38. All of the following disc brake rotor measurements can be performed using a micrometer **EXCEPT:**
   A. parallelism
   B. thickness
   C. runout
   D. taper

39. Which of the following disc brake caliper designs usually allow the brake pads to be removed without removing the caliper?
   A. fixed
   B. floating
   C. sliding
   D. all of the above

40. After applying the brake pedal several times to deplete the fluid reserve in the accumulator of a Hydro-Boost system, a technician applies the brake pedal with moderate pressure and starts the engine. What should the technician feel at the pedal if the Hydro-Boost system is operating properly?
   A. The pedal should initially rise before moving downward.
   B. The pedal should initially move downward before rising up.
   C. The pedal should move downward.
   D. The pedal should rise.

# Prepare yourself for ASE testing with these questions on BRAKES

41. All of the following can cause disc brake squeal **EXCEPT:**
   A. loose or missing anti-rattle springs
   B. grease on the linings
   C. glazed linings
   D. dirt embedded in the linings

42. Technician A says that when rebuilding a caliper with a stroking seal, the condition of the caliper bore surface is critical. Technician B says that when rebuilding a caliper with a fixed seal, the condition of the piston surface is the most important consideration. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

43. All of the following can cause a vehicle to pull to one side when the brakes are applied **EXCEPT:**
   A. seized caliper piston
   B. worn strut rod bushings
   C. blocked master cylinder compensating port
   D. brake fluid soaked linings

44. Technician A says that ABS wheel speed sensor gap should be adjusted with a non-magnetic feeler gauge. Technician B says that a paper spacer can be used to adjust ABS wheel speed sensor gap but the paper must be removed before the vehicle is operated. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

45. When discussing wheel bearings, all of the following statements are true **EXCEPT:**
   A. Tapered wheel bearings are most commonly used on drive axles.
   B. Sealed ball bearings are not adjustable.
   C. A new grease seal should be installed when bearings are repacked.
   D. The races on tapered wheel bearings cannot be interchanged.

46. All of the following could cause the parking brake to not hold a vehicle on a grade **EXCEPT:**
   A. seized cables
   B. excessive rear brake shoe-to-drum clearance
   C. seized wheel cylinder
   D. broken parking brake linkage

47. To determine the serviceability of a brake drum, all of the following should be checked **EXCEPT:**
   A. diameter
   B. minimum thickness
   C. out-of-roundness
   D. taper wear

48. A vehicle's brake pedal is pumped rapidly 20 times and then held down. The master cylinder cover is then removed and when the pedal is released, a geyser is seen coming from the reservoir. Technician A says that this indicates that air is trapped in the system. Technician B says that this means that fluid is being forced out of the cylinder bore through the compensating ports and is normal master cylinder operation. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

49. Technician A says that RWAL ABS systems must be diagnosed using a scan tool. Technician B says that the ABS warning light will only come on when there is a fault in the system. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

50. Technician A says that any imperfection found in a phenolic caliper piston warrants replacement. Technician B says that a phenolic caliper piston should be protected with a block of wood when installing it into the caliper bore with a C-clamp. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

# Prepare yourself for ASE testing with these questions on BRAKES

51. Which of the following should be used to measure the thickness of a scored rotor?
   A. vernier caliper
   B. outside micrometer with flat anvil and spindle
   C. inside micrometer
   D. outside micrometer with pointed anvil and spindle

52. During routine vehicle maintenance, the fluid level in the master cylinder reservoir is checked. When the reservoir cap is removed, purple colored fluid is found in the reservoir. Technician A says that this means the fluid should be topped off with DOT 4, which has a higher boiling point than regular brake fluid. Technician B says that this means that the fluid is contaminated; all rubber parts in the system must be replaced and the system flushed. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

53. A complete front brake service has just been performed on a vehicle with disc brakes: rotors turned, calipers rebuilt, new brake pads, bearings repacked and adjusted. However, when the vehicle is road tested, a pulsation can be felt through the pedal. Which of the following is the **MOST LIKELY** cause of the pulsation?
   A. non-directional finish not applied to rotors
   B. wrong lining compound chosen
   C. over-torqued lug nuts
   D. incorrect bleeding sequence

54. Brake fluid leaking from a cracked brake line causes the brake light on the dashboard to come on in response to the loss of hydraulic pressure. Which of the following valves in the hydraulic system switched on the light?
   A. metering valve
   B. pressure differential valve
   C. proportioning valve
   D. residual check valve

55. Technician A says that an integral ABS system is an add-on system. Technician B says that a non-integral ABS system is a high-pressure system. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

56. The diameter of drums mounted on the same axle should measure within how many thousands of an inch of one another?
   A. 0.001
   B. 0.005
   C. 0.010
   D. 0.020

57. Absorption of 3% moisture can reduce the boiling point of DOT 3 brake fluid by what percentage?
   A. 10%
   B. 20%
   C. 25%
   D. 50%

58. All of the following are procedures for removing air from a hydraulic system **EXCEPT:**
   A. bench bleeding
   B. power bleeding
   C. manual bleeding
   D. vacuum bleeding

59. All of the following can be used to apply a non-directional finish to a disc brake rotor **EXCEPT:**
   A. sanding block
   B. fine file
   C. lathe attachment
   D. sanding disc

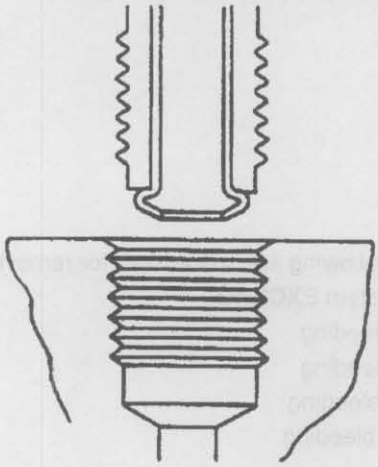
60. All of the following can cause a problem in the Hydro-Boost system **EXCEPT:**
   A. loose power steering pump belt
   B. leaking power steering hoses
   C. low power steering pump pressure
   D. leaking check valve

61. A customer says that he has just replaced his front disc brake pads himself and now the ABS warning light is on. Which of the following could be the cause?
   A. damaged wheel speed sensor
   B. incorrect wheel speed sensor gap
   C. stuck ABS solenoid valve
   D. all of the above

# Prepare yourself for ASE testing with these questions on BRAKES

62. Drum brake drag can be caused by all of the following **EXCEPT:**

A. frozen parking brake cables
B. frozen star wheel
C. restricted brake hose
D. swelled wheel cylinder cups



63. Technician A says the type of fitting shown above is common to all brake systems. Technician B says the flare shown was formed with an inverted flaring tool. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

64. Technician A says the rear brake shoes should be properly adjusted before adjusting the parking brake. Technician B says the parking brake lever should be disengaged before adjusting the equalizer. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

65. Which of the following should be used to clean a disc brake rotor after it is machined?

A. compressed air
B. solvent tank
C. soap and water
D. brake cleaning solvent

66. A front brake hose is being replaced. On this type of hose, the male end threads directly into the caliper. Technician A says the end of the hose that attaches to the steel brake line should be connected first. Technician B says that a new copper sealing washer should be used when the hose is connected to the caliper. Who is right?

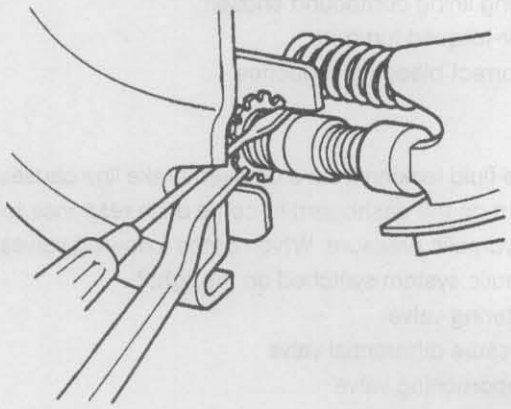
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

67. Technician A says that surge bleeding is used in conjunction with manual or pressure bleeding. Technician B says that surge bleeding is used to remove air that is trapped in the brake hydraulic system. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

68. All of the following are cause for brake rotor refinishing **EXCEPT:**

A. hard spots
B. heat checks
C. scoring
D. thickness variation



69. In the above illustration, Technician A says that new brake shoes are being adjusted after installation. Technician B says that the procedure shown above is being done so the brake drum can be removed. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

# Prepare yourself for ASE testing with these questions on BRAKES

70. The front disc brake pads are being replaced on a vehicle with composite rotors. The left front rotor is scored below the 'machine to' but not the 'discard' thickness. The right front rotor has minor heat checks but otherwise checks out OK. If cast rotors are the only available replacements, which of the following is the proper course of action?

A. Machine both rotors, being careful not to exceed the 'discard' thickness.
B. Replace the left front rotor and machine the right front.
C. Replace both rotors.
D. Replace the left front rotor and leave the right front alone.

71. Which of the following brake symptoms can be caused by wheel bearing problems?

A. pedal pulsation
B. brake pull
C. grabbing
D. all of the above

72. Which component in the Hydro-Boost system provides power assist if there is a loss of hydraulic pressure to the system?

A. boost piston
B. check valve
C. accumulator
D. open-center spool valve

73. A customer complains that the parking brake will not keep his car stationary. The car has four-wheel disc brakes. Technician A says the caliper levers could be out of adjustment. Technician B says the brake shoes could need adjustment. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

74. When replacing an integral hub/bearing assembly on a front wheel drive vehicle, all of the following must be removed **EXCEPT:**

A. brake rotor
B. brake caliper
C. steering knuckle
D. wheel

75. A wheel cylinder has been disassembled and corrosion and light scoring have been found in the bore. Technician A says the bore can be refinished using a small hone lubricated with cutting oil. Technician B says oversize pistons and cup seals can be installed if the hone removes too much material. Who is right?

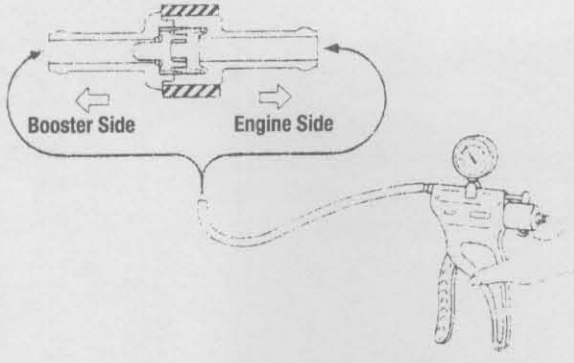
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

76. Two technicians are discussing traction control systems. Technician A says that some traction control strategies do not use the brakes to control wheel spin. Technician B says that a fault in the ABS does not affect traction control. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

77. When rough machining a brake drum, the depth of cut and spindle feed rate should be:

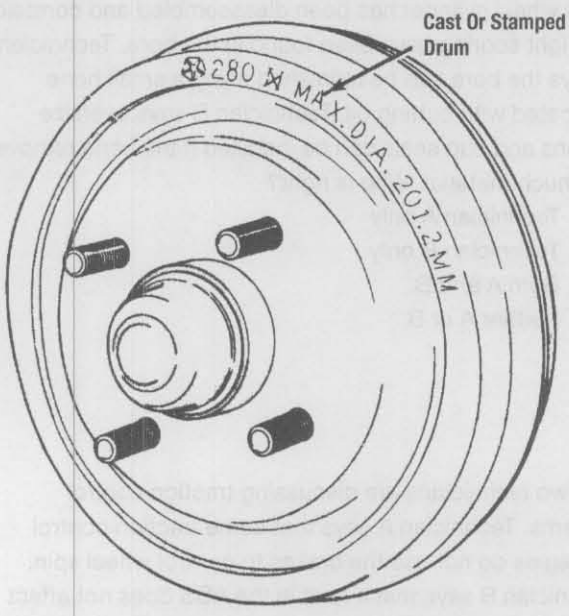
A. 0.010-0.015-in. at high feed rate
B. 0.010-0.015-in. at low feed rate
C. 0.005-in. at high feed rate
D. 0.005-in. at low feed rate




78. In the test shown above, vacuum should:

A. exist on the engine side but not on the booster side
B. exist on the booster side but not on the engine side
C. exist on both sides
D. exist on neither side

# Prepare yourself for ASE testing with these questions on BRAKES

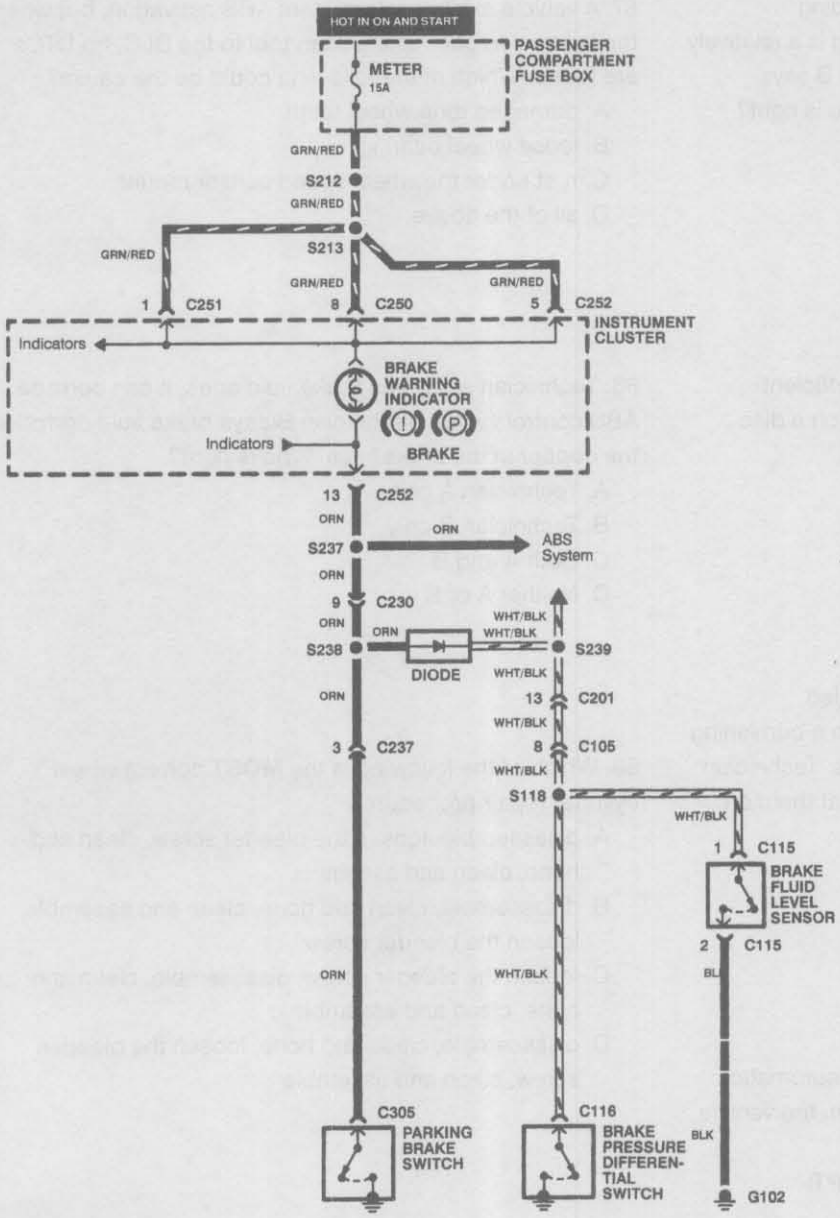



*(Courtesy: Chrysler LLC)*

79. Technician A says the number on the brake drum shown above indicates the maximum diameter, beyond which the drum should not be used. Technician B says the number indicates the maximum diameter the drum can be machined to. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

# Prepare yourself for ASE testing with these questions on BRAKES




*(Courtesy: Kia Motors America, Inc.)*

80. A vehicle's brake warning system schematic is shown above. All of the following could cause the brake warning light to stay illuminated **EXCEPT:**

A. a short to ground between C105 and C201
B. a stuck closed parking brake switch
C. an open between C237 and C305
D. a leaking wheel cylinder

81. A technician wants to check the condition of a vehicle's brake fluid. Where should he get the sample to make the most accurate determination?

A. master cylinder reservoir
B. brake caliper
C. combination valve
D. wheel cylinder

# Prepare yourself for ASE testing with these questions on BRAKES

82. Two technicians are discussing brake bleeding procedures. Technician A says gravity bleeding is a relatively quick way to bleed a brake system. Technician B says silicone brake fluid cannot be gravity bled. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

83. Which of the following is the **MOST** cost-efficient method of correcting excessive lateral runout on a disc brake rotor?

A. indexing
B. shimming
C. machining
D. replacement

84. New disc brake pads have just been installed. Technician A says the new pads must undergo a burnishing process during the road test to 'cure' the pads. Technician B says the new pads must be burnished to seat them on the rotor. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

85. The parking brake pedal on a vehicle with automatic parking brake release remains depressed when the vehicle is placed in drive.
All of the following are possible causes **EXCEPT:**

A. defective vacuum motor
B. faulty release switch
C. vacuum leak
D. seized cables

86. Two technicians are discussing Electronic Stability Control (ESC) systems. Technician A says the ESC control module uses inputs from the steering wheel rotation sensor and wheel speed sensors to calculate the driver's intended path. Technician B says the ESC control module uses inputs from the lateral acceleration and yaw rate sensors to calculate the vehicle's actual path. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

87. A vehicle exhibits intermittent ABS activation, but when the technician connects a scan tool to the DLC, no DTCs are found. Which of the following could be the cause?

A. damaged tone wheel teeth
B. loose wheel bearing
C. rust under the wheel speed sensor mount
D. all of the above

88. Technician A says as brake fluid ages, it can corrode ABS control valves. Technician B says brake fluid corrodes the copper in the brake lines. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

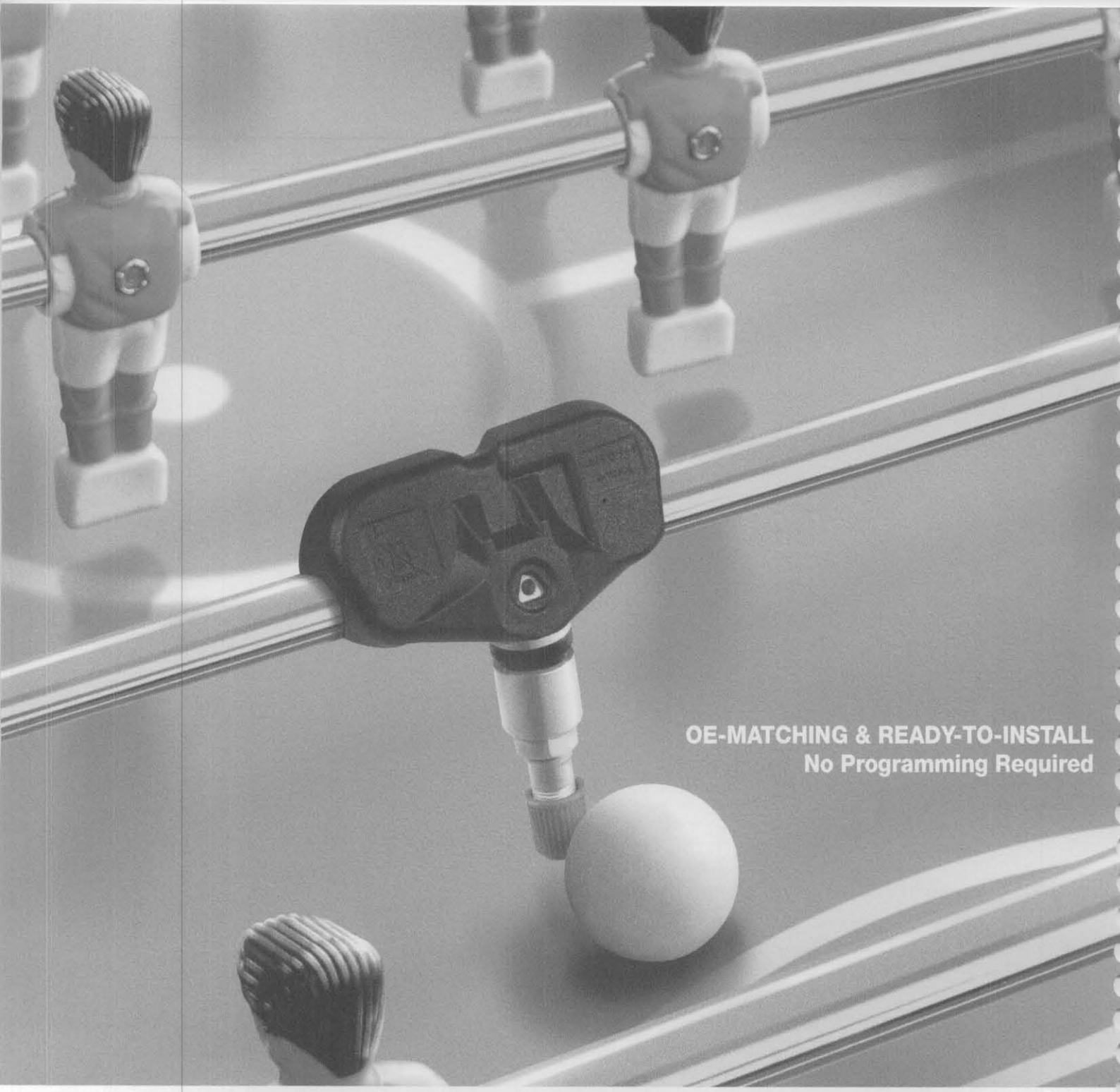
89. Which of the following is the **MOST** correct wheel cylinder repair procedure?

A. disassemble, loosen the bleeder screw, clean and hone, clean and assemble
B. disassemble, clean and hone, clean and assemble, loosen the bleeder screw
C. loosen the bleeder screw, disassemble, clean and hone, clean and assemble
D. disassemble, clean and hone, loosen the bleeder screw, clean and assemble

90. A vehicle's ABS warning light is on and a DTC for the left front wheel speed sensor is found in the computer's memory. When check with an oscilloscope, the waveform for the left wheel speed sensor is erratic and uneven. Technician A says the sensor air gap is excessive. Technician B says the tone ring is probably damaged. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

## Notes




# OE SENSOR REPLACEMENT –PERFECT

## (FOOSBALL PLAYER REPLACEMENT –BAD CALL)

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# Answers to Study-Guide Test Questions

**1. The correct answer is C.** The metering valve delays the flow of brake fluid to the front calipers until the pressure in the system rises to a point where the wheel cylinder can overcome the tension of the brake shoe return springs. The purpose is to have both front and rear brakes apply simultaneously. This prevents the front brakes from locking up during light brake applications.

**2. The correct answer is A.** If the primary piston cup in the master cylinder is leaking, pressure will not build up ahead of the primary piston to increase pressure to the rear brakes. The piston will then move forward until the spring is compressed enough to move the secondary piston. Consequently, this internal leak will cause the brake pedal to slowly drop to the floor.

**3. The correct answer is C.** Poor rotor parallelism (thickness variation) will cause a pulsating brake pedal. This is due to the caliper piston movement that occurs as the pad rides over the alternating high and low areas on the disc. This action forces brake fluid to flow back and forth from the caliper to the master cylinder, creating the pulsating pedal feedback.

**4. The correct answer is B.** Residual check valve(s) are used on drum brakes to keep residual low pressure (slight static pressure) in the brake system at all times even when the brake pedal is released. This pressure (5-20 psi) keeps the lips of the wheel cylinder piston cups tight against the cylinder walls to prevent air from entering the system when at rest (brakes released).

**5. The correct answer is D.** A metering valve requires a minimum pressure (typically between 75-125 psi) to open. At this point pressurized fluid flows to the front calipers. Since the bleeder tank is only pressurized to 25 psi, fluid pressure is too low to open the metering valve during this procedure. Therefore, when you use a pressure bleeder on a system with a metering valve, you must manually keep the valve open by either pushing the button in on the end of the valve, or pulling the stem outward on the end of the valve.

**6. The correct answer is B.** Excessive rotor runout would cause a pulsating brake pedal, but not uneven side-to-side pad wear. A frozen caliper piston on the other hand, will keep both inner and outer brake pads equally applied against the rotor even when the brake pedal is released. This constant friction will cause rapid pad wear in the affected caliper as well as a front-end pull.

**7. The correct answer is C.** The parking brake strut bar forces the brake shoes into the drum when the parking brake is applied.

**8. The correct answer is D.** Steel tubing of the same size, type, and length with double flared ends must be used when replacing a traditional SAE double inverted flare style hydraulic brake line.

**9. The correct answer is C.** Lateral runout is the movement of the rotor from side to side as it rotates on the steering knuckle spindle. The dial-indicator set-up shown in the illustration is used to make this measurement once the wheel bearing nut has been tightened (bearing play removed).

**10. The correct answer is C.** If a residual check valve was installed in a disc brake master cylinder, it would cause increased brake pad wear since the residual brake pressure would cause the caliper pistons to keep the pads applied even when the brake pedal is released.

**11. The correct answer is A.** A restriction in the brake line will cause a drop in fluid pressure to the affected caliper. This will cause the caliper to be unable to exert the same force against the pads as the unrestricted side. Because of this, the vehicle will pull to the side where the pressure is highest and brake force is greatest. In this case, that would be the right side.

**12. The correct answer is D, neither technician is right.** With the brake pedal applied while starting the engine, the pedal should move down slightly indicating that the vacuum booster is operating properly.

**13. The correct answer is A.** The illustration shows a technician setting a brake shoe adjustment gauge, or caliper, to the inside diameter of a brake drum. The other side of the gauge is then positioned over the brake shoes and the star wheel turned until the shoes lightly contact each end of the gauge. Technician B is wrong because a brake drum micrometer is used to measure the inside diameter of a brake drum.

**14. The correct answer is A.** The front hydraulic circuits in an integral ABS system can be bled in the conventional manner since it is the booster piston in the hydraulic modulator assembly that supplies fluid to the front brakes. However, the rear circuit is dependent upon boost pressure from the accumulator, which means the accumulator must be fully charged in order to bleed the rear brakes.

**15. The correct answer is D.** When a vehicle with ABS is braked on abnormally irregular road surfaces, like a cobblestone road, the wheels decelerate at different speeds. Because the signals coming from the wheel speed sensors under this condition are not in sync with each other, the ABS control unit interprets this as impending wheel lockup and responds by engaging the system.

# Answers to Study-Guide Test Questions

**16. The correct answer is A.** In a duo-servo drum brake design under normal forward braking, the friction developed by the secondary lining is greater than the primary lining. Therefore, the secondary shoe is typically longer and thicker than the primary shoe. The primary shoe is installed facing the direction of forward motion.

**17. The correct answer is C.** The leading-trailing drum brake design is not self-energizing. This is due to the fixed anchor on the backing plate, which prevents the shoes from transferring their force to one another.

**18. The correct answer is D, neither technician is right.** It is DOT 4 brake fluid that has a lower boiling point, and DOT 5 that is silicone-based and should not be used in any ABS system.

**19. The correct answer is D.** The compensating port allows for residual hydraulic line pressure to be discharged into the reservoir as the brake pedal is released. A clogged or restricted compensating port will create a pressure build-up, which will cause the brakes to drag or fail to release. The port can be clogged by foreign matter, blocked by a swollen primary cup or covered by the primary cup if the master cylinder pushrod is improperly adjusted.

**20. The correct answer is C.** A leak in the hydraulic system wouldn't cause a hard pedal, but rather create the exact opposite condition due to the hydraulic pressure loss. An engine with the valves adjusted too tight would develop low vacuum. This would adversely affect the operation of the power brake booster and cause a hard pedal. Brake fluid on the linings will cause the friction material to grab resulting in a hard pedal, while a frozen caliper would prevent retraction of the piston resulting in a similar condition.

**21. The correct answer is B.** The outward movement of the caliper piston during brake application causes the piston seal to distort. Once the brakes are released however, the seal returns to its original shape forcing the piston to retract in its bore. A caliper seal that is installed on the piston is known as a stroking seal.

**22. The correct answer is C.** By opening the bleeder screw on the caliper, contaminated fluid is not forced back into the master cylinder (or on ABS vehicles, into the hydraulic control unit). Answer B is wrong because, while it will work, doing so can cause problems in the hydraulic system. Answer A is wrong because, without checking the fluid level or opening the bleeder screw, fluid could be forced into and spill out of the master cylinder reservoir. Answer D is wrong because caliper removal is not necessary.

**23. The correct answer is B.** The number of wheel speed sensors used on an ABS system does not necessarily indicate the number of channels the system has. A channel is an independently controlled fluid path from the hydraulic modulator to the wheel. Therefore, a 3-channel system on a car can have a wheel speed sensor at each wheel, even though there are only 3 individually controlled hydraulic circuits: two in the front, and one in the rear.

**24. The correct answer is D, neither technician is right.** The minimum thickness dimension cast into the rotor is usually the discard dimension. The rotor should not be machined closer than 0.030-in. to this dimension in order to allow for wear. When machining a rotor, you do not have to remove an equal amount of material from both sides if the vehicle has floating or sliding calipers. However, on fixed calipers an equal amount must be machined from both sides.

**25. The correct answer is D.** Maximum braking effectiveness is achieved when tire slip is maintained at a level between 10-20%.

**26. The correct answer is D.** The proportioning valve reduces the pressure applied to the rear wheel cylinders in relation to the pressure applied to the front calipers under heavy braking. A defective proportioning valve can cause the rear wheels to lock and skid during sudden stops because the fluid pressure to the rear wheel cylinders would be unregulated.

**27. The correct answer is A.** On most vehicles, parking brake adjustment consists of shortening the length of one or more cables to remove excessive slack. This adjustment is generally made by tightening an adjusting nut at the equalizer.

**28. The correct answer is B.** Any leak in the hydraulic system that causes unequal pressure to be applied to one side of the pressure differential piston will cause the warning light to illuminate. The only choice here is a short to ground in the light. This failure would cause the light to stay on all the time regardless of hydraulic condition.

**29. The correct answer is C.** While all of the choices listed could cause the pads to wear prematurely, the most common cause of this condition is when the rear shoes are incorrectly adjusted. Since the majority of braking action is done by the front brakes (especially on front-wheel-drive cars), it is imperative that the rear shoes are adjusted properly. This will help balance brake action as well as lining wear.

**30. The correct answer is B.** Only a few ABS systems (primarily RWAL) offer flash code diagnostics for retrieving stored fault codes. A bi-directional scan tool can be used to perform tests on ABS system components. A technician can activate solenoids and valves while observing the change in that circuit.

**31. The correct answer is D.** Answers B and C are incorrect because the sampling rates are too low. An intermittent can be seen with the digital storage oscilloscope (DSO) because it samples the electrical signal over 250,000 times per second.

**32. The correct answer is B.** Technician A is incorrect because there should be at least one power assist before the pedal gets hard to push. Technician B is correct because the lack of power assist indicates that the check valve is leaking.

**33. The correct answer is C.** Replacing a disc brake caliper would not require measuring master cylinder pushrod length. Measuring pushrod length may be required when replacing any of the other components.

**34. The correct answer is A.** A small amount of fluid present here is normal due to the lubricating action of the master cylinder bore end seal. The brake fluid is kept from leaking back into the power booster by a seal on the pushrod. If a large amount of fluid is present, unbolt the master cylinder from the booster and look for signs of leakage.

**35. The correct answer is C, both technicians are right.** Both methods are commonly used to adjust tapered roller bearings. Consult the vehicle service manual for the specific adjustment procedure.

**36. The correct answer is D.** A seized caliper piston can cause a brake pull or a hard pedal, but it would not cause a pedal pulsation. All of the other choices can cause a pulsation to be felt through the brake pedal.

**37. The correct answer is B.** Vehicles with diagonally-split hydraulic systems have dual proportioning valves, so if a problem is suspected, both valves must be tested. Technician A is incorrect because, when testing a proportioning valve, the pressure at the outlet to the rear brakes will rise at a slower rate, once transition pressure is reached.

**38. The correct answer is C.** Lateral runout is measured using a dial indicator. All of the other measurements can be made using a micrometer.

**39. The correct answer is A.** The disc brake pads can usually be removed from fixed calipers while the caliper is mounted in place. Floating and sliding calipers require that the caliper be removed or pivoted out of the way to access the disc brake pads.

**40. The correct answer is B.** If the Hydro-Boost system is operating properly, the brake pedal should initially move downward before rising up against foot pressure.

**41. The correct answer is B.** Brake linings that are contaminated with grease, oil or brake fluid can cause the vehicle to pull when the brakes are applied, but would not cause brake squeal.

**42. The correct answer is C, both technicians are right.** A stroking seal is located in a groove in the caliper piston and moves with the piston. The lip of the seal rides against the surface of the caliper bore, so the caliper bore must be smooth to prevent leaks. A fixed seal is installed in a groove in the caliper bore. It seals against the outside surface of the caliper piston, so that surface must be in good condition to provide a good seal.

**43. The correct answer is C.** A blocked master cylinder compensating port could cause all brakes to drag but would not cause a brake pull. All of the other choices could cause brake pull.

**44. The correct answer is A.** New wheel speed sensors come with the paper spacer installed but it is not necessary to remove it; the spacer is designed to wear off during vehicle operation.

**45. The correct answer is A.** Tapered roller bearings are usually used on non-drive axles. All of the other statements are true.

**46. The correct answer is C.** The parking brake system engages the rear brakes mechanically; a seized wheel cylinder would not affect parking brake operation.

**47. The correct answer is B.** Minimum thickness is checked when inspecting a disc brake rotor. All of the other measurements mentioned should be made when inspecting a brake drum.

**48. The correct answer is A.** Pumping the brakes compresses the air and when the pedal is released, the compressed air pushes the hydraulic fluid back through the lines, causing it

to squirt. Technician B is wrong because a small squirt of fluid should appear over the reservoir, indicating that fluid is being forced out of the cylinder bore through the compensating ports, only when the pedal is applied.

**49. The correct answer is D, neither technician is right.** Technician A is wrong because, while most Rear Wheel Anti-Lock (RWAL) systems offer flash-code diagnostics, most four-wheel ABS systems require the use of a scan tool to extract stored fault codes from the computer's memory. Technician B is wrong because the 'anti-lock' warning light will come on whenever the key is turned ON, and if there are no faults in the system, will then go out after a few seconds.

**50. The correct answer is B.** A phenolic piston should be protected to keep it from being damaged when a C-clamp is used. Technician A is wrong because minor surface imperfections are OK provided they do not enter the dust boot groove area.

**51. The correct answer is D.** An outside micrometer with a pointed anvil and spindle is a disc brake micrometer. Unlike a standard micrometer that uses a flat surface on the anvil and spindle, a disc brake micrometer uses pointed tips so the instrument can fit into the grooves of scored rotors, to accurately measure the thickness.

**52. The correct answer is D, neither technician is right.** Purple is the color of silicone fluid, and only DOT 5 fluid should be used to top off the reservoir.

**53. The correct answer is C.** Over-tightening the lug nuts can distort the rotor and create excessive runout, resulting in a pedal pulsation. All of the other choices may cause other problems, but not a pedal pulsation.

**54. The correct answer is B.** The pressure differential valve and warning switch alerts the driver of a pressure loss in one of the hydraulic circuits. The residual check valve is often used in the master cylinder outlet port of drum brake systems in order to maintain a slight pressure in the brake lines and wheel cylinders, which keeps wheel cylinder pistons tight against their bores. The metering valve delays front disc brake operation until the rear brakes shoes overcome the return spring tension. The proportioning valve is used to control rear brake pressures, particularly during hard stops.

**55. The correct answer is D, neither technician is right.** The non-integral ABS system is added on to the vehicle's existing hydraulic brake system, and is generally a low-pressure arrangement.

**56. The correct answer is C.** The diameter of brake drums mounted on the same axle must be within 0.010-in. of one another.

**57. The correct answer is C.** Absorption of 3% moisture can reduce the boiling point of DOT 3 brake fluid by 25%.

**58. The correct answer is A.** Bench bleeding is a procedure for removing air from the master cylinder only. All of the other procedures remove air from the entire system.

**59. The correct answer is B.** Files are not used to apply a non-directional finish on a disc brake rotor. All of the others methods can be used to give the rotor a swirl-like finish.

**60. The correct answer is D.** A vacuum check valve is used on a vacuum power booster. The Hydro-Boost system uses power steering pump fluid pressure rather than intake manifold vacuum, so all of the other choices would apply.

**61. The correct answer is D.** Some common ABS problems can be caused by carelessness when performing basic brake service. Wheel speed sensors can be disturbed or damaged accidentally. Solenoid valves can stick if the caliper bleeder screws are not opened when the caliper pistons are retracted. Since the caliper is the lowest point in the system, dirt and corrosion naturally accumulate there. If the bleeder screws are not opened, brake fluid and these contaminants are forced backward into the system. When these contaminants find their way into the hydraulic control unit, they can cause valves to stick.

**62. The correct answer is B.** A frozen star wheel would not cause brake drag. Rather, it would prevent the automatic adjuster mechanism from working, which would gradually cause the brake shoe-to-drum clearance to increase as the linings wore. All of the other answers could cause the brake shoes to not retract from the drum, resulting in brake drag.

**63. The correct answer is D, neither technician is right.** The fitting shown is an ISO flare fitting. ISO flare fittings are used on many newer vehicles, but should never be intermixed on the same vehicle with the more common inverted flare style fittings.

**64. The correct answer is A.** The brake shoes must be correctly adjusted for the parking brake to work properly. There may not be enough adjustment in the parking brake system to overcome excessive shoe-to-drum clearance, resulting in the parking brake not being able to hold the vehicle in

place when it is applied. Technician B is wrong because the parking brake lever must be engaged a certain number of clicks before the equalizer is adjusted.

**65. The correct answer is C.** When rotor resurfacing is completed, wash the rotor with soap and water and wipe it off with a clean shop towel. Brake cleaning solvent may not remove all of the fine particles left over from the machining process, and these can become imbedded in the new pads and cause brake noise.

**66. The correct answer is B.** Technician A is wrong because the male end of the hose should be connected and tightened first. If the female end of the hose is connected to the brake line first, the hose will twist when it is threaded into the caliper.

**67. The correct answer is C, both technicians are right.** Surge bleeding is a method of removing air from the hydraulic system that can be used when manual or pressure bleeding has proved inadequate. Surge bleeding churns the air in the wheel cylinder in order to loosen any pockets of air. However, the system should first be manually or pressure bled and again after surge bleeding to make sure all air has been expelled.

**68. The correct answer is A.** Hard spots call for rotor replacement, since resurfacing seldom removes the entire hard spot. All of the other conditions can be corrected by machining, provided it can be done without machining past the minimum rotor refinishing thickness.

**69. The correct answer is B.** The screwdriver shown in the illustration is not necessary when turning the star wheel to expand the brake shoes. However, if the shoes are too tight against the drum or a lip has developed due to wear that prevents the brake drum from being removed, the shoe-to-drum clearance must be reduced. To back off the star wheel adjustment, the screwdriver is used to hold the self-adjuster lever away from the wheel, allowing it to be turned in the opposite direction.

**70. The correct answer is C.** Composite and cast rotors should not be mixed on the same axle. Answer A is wrong because, as the question indicated, the rotor is already worn past the 'machine to' dimension. Even if the rotor is not machined beyond the 'discard' thickness, this leaves no allowance for wear in the future.

**71. The correct answer is D.** Loose wheel bearings can cause excessive rotor runout, which in turn can cause pedal pulsation. A failed wheel bearing seal can allow grease to contaminate the brake linings and cause brake pull and grabbing.

**72. The correct answer is C.** The accumulator can supply enough power assist for two stops if there is a loss of hydraulic pressure in the Hydro-Boost system. The boost piston provides the force to operate the master cylinder and the open-center spool valve regulates pump pressure. The check valve is used on vacuum operated boosters.

**73. The correct answer is C, both technicians are right**. The brakes must be inspected before reaching a diagnosis, but without knowing what type of system the car had, either technician could be right. There are two kinds of parking brakes on vehicles with rear disc brakes. One kind has small brake shoes inside a drum that is incorporated in the disc brake rotor. The shoes are forced against the drum by the linkage and cables in the same manner as conventional drum parking brakes. These shoes must be properly adjusted for the parking brake to work correctly. The other kind uses the rear disc brake pads. The linkage and cables actuate a cam or screw mechanism inside the caliper piston to push the caliper piston and pads against the rotor. Some of these systems require a caliper lever adjustment.

**74. The correct answer is C.** The steering knuckle does not have to be removed when replacing an integral hub/bearing assembly. However, it must be removed when replacing the press-fit type front wheel bearing.

**75. The correct answer is D, neither technician is right.** Use only fresh clean brake fluid to lubricate the honing stones; never use petroleum-based cutting oil. After the cylinder has been honed, inspect it for excessive piston clearance. To check the maximum clearance, place a 0.003-inch feeler shim lengthwise in the cylinder bore. If the piston can be inserted with the shim in place, the cylinder is oversize and cannot be rebuilt.

**76. The correct answer is A.** Some manufacturers reduce power to the spinning wheel by retarding the ignition timing, cutting off fuel injection to certain cylinders and/or mechanically closing the throttle, and may only apply the brakes if the wheel continues to spin. Technician B is wrong because the TCS uses the same components as the ABS; if there is a fault in the ABS the TCS is turned off as well.

**77. The correct answer is A.** The tool depth on a rough cut, where a large amount of material is removed to initially clean the drum, is usually about 0.010 - 0.015-in. at a fast spindle feed rate.

**78. The correct answer is B.** The illustration shows a vacuum operated brake booster check valve being tested. Vacuum should exist at the booster side of the check valve, but not on the engine side.

**79. The correct answer is A.** The number on the drum shown in the illustration is the maximum diameter. This specification is the discard diameter and not what the drum can be machined to. As a general rule, the maximum refinish diameter is 0.030-in. less than the maximum diameter, but refer to the vehicle service manual to be sure.

**80. The correct answer is C.** For the light to illuminate, the circuit must be grounded, either intentionally or unintentionally. Answer D is an example of the former: a leak and loss of pressure in the brake hydraulic system causes the brake pressure differential switch contacts to close and complete the circuit. Answers A and B are examples of an unintentional ground: a short to ground or a switch that is stuck closed will still complete the circuit. Answer C is right because an open will not provide a ground and complete the circuit.

**81. The correct answer is B.** The most accurate way to determine brake fluid condition is to take a sample from the vehicle's disc brake caliper, because the heat generated while stopping breaks down the corrosion inhibitors in the brake fluid.

**82. The correct answer is D, neither technician is right.** Technician A is wrong because gravity bleeding is the easiest but most time consuming method of brake bleeding. Gravity bleeding relies on atmospheric pressure, acting on the surface of the fluid in the master cylinder, to force the fluid through the hydraulic system and out through the bleeders, which may take several hours. Technician B is wrong because gravity bleeding does not agitate the fluid and generate air bubbles, which is advantageous for systems with DOT 5 silicone fluid since it is prone to aeration.

**83. The correct answer is A.** Indexing involves moving the rotor position on the hub and rechecking the runout with a dial indicator. The number of wheel studs determines the number of possible positions to correct runout. This method requires little extra labor, no parts expense and no machining labor or expense. Resurfacing the rotor unnecessarily removes material and makes the rotor thinner, lessening its ability to absorb and dissipate heat and shortening the rotor's useable lifespan.

**84. The correct answer is C, both technicians are right.** Whenever new brake pads are installed, they must undergo a burnishing, or break-in procedure before the vehicle can be operated normally. Burnishing accomplishes two things: It 'cures' the resin in the friction material, which could otherwise boil to the surface and cause glazing if the vehicle was immediately subjected to hard braking; and it ensures that the pads seat and make full contact with the rotor. The latter is particularly important if the rotors were not machined, since even a rotor that was deemed serviceable will not have a perfectly smooth surface.

**85. The correct answer is D.** An automatic parking brake release mechanism releases the parking brakes when the automatic transmission is shifted into drive or reverse. These systems usually consist of a vacuum motor that is attached to a release lever, and a vacuum switch that routes vacuum to the motor when the transmission is placed in drive or reverse. When the driver selects the drive or reverse position, the switch directs engine vacuum to the vacuum motor, which releases the lever and the parking brakes. Seized cables could keep the vehicle from moving or cause severe drag, but would not keep the pedal from returning to the unapplied position. All of the other possibilities listed could keep the release lever from releasing the pedal, causing it to remain in the applied position.

**86. The correct answer is C, both technicians are right.** The ESC control program determines the driver's intentions using throttle and transmission data from the Powertrain Control Module (PCM), wheel speed rate from the wheel speed sensors and steering wheel position and rate of movement input from the steering wheel rotation sensor. It compares this information with the input from the lateral acceleration and yaw rate sensors to determine if correction is needed. If the actual path the vehicle is traveling does not match the intended path, the control module applies brake pressure to individual wheels and/or reduces engine power to correct the motion of the vehicle.

**87. The correct answer is D.** False ABS activation occurs when the ABS is engaged even though none of the wheels are slipping. The ABS control module can interpret a weak or erratic wheel speed sensor signal as wheel slip and cycle the ABS at the affected wheel. Rust under the sensor mount, loose wheel bearings and damaged tone wheel teeth can all affect the sensor gap, which in turn can cause a weak or erratic signal.

**88. The correct answer is B.** At a slow rate, over several months or years, brake fluid slowly corrodes the copper in the inner lining of steel brake tubing. The copper leaches into the brake fluid as ions, atoms with an electrical charge. When the corrosion inhibitors in the brake fluid eventually deplete, these copper ions become the oxidizer that corrodes ferrous metal parts like ABS control valves. Technician A is wrong because it is not the brake fluid that corrodes the ABS control valves, but rather the copper ions that are released by the brake fluid.

**89. The correct answer is C.** Before rebuilding a wheel cylinder, first make sure that the bleeder screw can be loosened before disassembling the unit. If the bleeder screw breaks off, the wheel cylinder must be replaced.

**90. The correct answer is B.** A tone ring with chipped or damaged teeth will cause an erratic, uneven waveform. Technician A is wrong because excessive air gap would cause a low amplitude waveform

## Notes

--a--

***abrasion*** - rubbing away or wearing of a part.

***ABS*** - see anti-lock brake system.

***accumulator*** - in a non-integral ABS system, a chamber that temporarily stores fluid during the pressure decrease phase of ABS operation. In an integral ABS system, a sealed vessel containing a thick flexible diaphragm that separates brake fluid from high-pressure nitrogen gas. In the Hydro-Boost power brake system, a component that provides a reserve of at least two power assisted stops if there is a loss of hydraulic pressure.

***actuator*** - a control device that delivers mechanical action in response to an electrical signal.

***air gap*** - a specified space between two components.

***air lock*** - a bubble of air trapped in a fluid circuit that interferes with normal circulation of the fluid.

***alternating current (AC)*** - an electric current whose polarity is constantly changing from positive to negative and then back again.

***anchor pin*** - a component located on the brake backing plate, on which the brake shoes rotate and to which the return springs are secured.

***anti-lock brake system (ABS)*** - a computer controlled system that allows the vehicle to be controlled under heavy braking by releasing hydraulic pressure to wheels that are about to lock up and skid. Sensors located at the wheels, monitor rotating wheel speed in relation to other wheels and send the information to a control module that in turn controls a hydraulic modulator, which regulates hydraulic fluid pressure to each brake assembly.

***anti-rattle spring*** - a device used with disc brake pads to keep them from moving and making noise.

--b--

***backing plate*** - the component to which the brake shoes, wheel cylinder and related components are attached.

***ball bearing*** - an anti-friction bearing that uses a series of steel balls that rotate between inner and outer bearing races.

***bearing race*** - machined circular surface of a bearing against which the roller or ball bearings ride.

***bleeder screw*** - a valve located on disc brake calipers, wheel cylinders and some master cylinders that allows air and fluid to be removed from the brake system.

***boot*** - a protective rubber cover or seal that is used to protect the inside of a caliper or wheel cylinder from contaminants.

***brake drag*** - a condition that occurs when brake pads or shoes are in continuous contact with the disc brake rotors or brake drums.

***brake drum*** - a round cast iron housing attached to an axle shaft or spindle, on which the brake shoes press to stop its rotation.

***brake fade*** - phenomenon that takes place when the temperature of the friction surfaces increases to a point where the application of heavy pedal pressure results in little braking action.

***brake fluid*** - the hydraulic fluid used to transmit hydraulic pressure through the brake lines in a brake system.

***brake flushing*** - a procedure to clean the brake hydraulic system with fresh, clean fluid that should be performed whenever new parts are installed, if there is any doubt as to the grade of fluid in the system, if a glycol fluid has been mixed with a silicone-based fluid, or if the fluid has been contaminated with petroleum or mineral based fluids.

***brake hoses*** - flexible hoses that connect the brake lines on the chassis with the calipers or wheel cylinders, or the junction block on a solid axle.

***brake lines*** - metal tubing that carries the brake fluid from the master cylinder to other brake system components.

***brake pads*** - see disc brake pads.

***brake rotor*** - see disc brake rotor.

***brake shoes*** - friction material that is bonded or riveted to curved metal structures and attached to the backing plate. The brake shoes press on the brake drum to stop its rotation.

***break-in*** - a slow wearing-in process between two mating part surfaces.

*--c--*

***caliper*** - see disc brake caliper.

***check valve*** - a gate or valve that allows passage of gas or fluid in one direction only.

***circuit*** - a path through which electricity flows before returning to its source.

***coefficient of friction*** - a relative measurement of the friction developed between two objects in contact with each other such as brake pads and brake rotors.

***continuity*** - the condition that exists in a working electrical circuit. A circuit that is unbroken, not open.

***corrosion*** - the eating into or wearing away of a substance gradually by rusting or chemical action.

***current*** - the movement or flow of electricity passing through a conductor.

*--d--*

***data link connector (DLC)*** - a means through which information about the state of the ABS control system can be extracted with a scan tool.

***diagnostic trouble code (DTC)*** - a code that represents and can be used to identify a malfunction in a computer control system.

***dial indicator*** - a tool used to measure minor variations or slight movements; a dial indicator is used to check lateral runout on a brake rotor.

***diaphragm*** - flexible, impermeable membrane on which pressure acts to produce mechanical movement, such as inside a vacuum power brake booster.

***differential case*** - housing for the differential pinion gears and side gears. Mounting point for ring gear.

***disc brake*** - a braking system that uses cast iron discs mounted on the wheel hubs, over which brake calipers are mounted. Hydraulic pressure from the brake system forces the caliper piston(s) against friction pads mounted in the calipers, which in turn clamp the brake discs, stopping their rotation.

***disc brake caliper*** - a hydraulically actuated device in a disc brake system that is mounted straddling the brake disc. The caliper contains at least one piston and is used to provide the clamping force of the brake pads on the disc.

***disc brake pad burnishing*** - a break-in procedure that should be performed after new brake pads are installed, to ensure the pads are properly 'cured' and seated on the rotor. Generally involves making multiple stops from a certain speed, with cooling off periods in between stops.

***disc brake pads*** - friction material that is bonded or riveted to metal plates and mounted in the disc brake caliper. The brake pads are clamped against the disc brake rotor to stop its rotation.

***disc brake rotor*** - a cast iron disc mounted on the wheel hub, which is clamped by the caliper and disc brake pads to slow and stop its rotation.

***DLC*** - see data link connector.

***drum brake*** - a braking system that uses cast iron drums mounted to the wheel hubs. Hydraulic pressure from the brake system forces pistons in the wheel cylinder to press friction lined brake shoes against the inside of the drum, stopping its rotation.

***duo-servo*** - a drum brake design that provides increased stopping power due to the servo or self-energizing action of the brake shoes.

*--e--*

***electromagnet*** - a magnet formed by electrical flow through a conductor.

***electromagnetic induction*** - moving a wire through a magnetic field to create current flow in the wire.

***electronic stability control (ESC) system*** - a system that determines the driver's intentions using throttle and transmission data from the Powertrain Control Module (PCM), wheel speed rate from the wheel speed sensors and steering wheel position and rate of movement input from the steering wheel rotation sensor, and then compares this information with the input from the lateral acceleration and yaw rate sensors to determine

if correction is needed. If the actual path the vehicle is traveling does not match the intended path, the control module applies brake pressure to individual wheels and/or reduces engine power to correct the motion of the vehicle.

***end-play*** - the amount of axial or end-to-end movement in a shaft due to clearance in the bearings.

***expansion*** - an increase in size.

*--f--*

***ferrous metal*** - a metal that contains iron or steel and is subject to rust.

***fixed caliper*** - a brake caliper design that contains one or more pistons positioned on either side of the rotor. The caliper is rigidly attached to the spindle and the pads are applied with equal hydraulic pressure from both sides.

***fixed seal*** - a type of brake caliper seal that is installed in a groove in the caliper bore.

***flare*** - an expanded, shaped end on a metal tube or pipe.

***floating caliper*** - a brake caliper design that uses an adapter, or anchor plate, which is bolted to the spindle. The caliper floats laterally across a pair of special bolts that are screwed into the adapter. As hydraulic pressure is applied to the piston, the inboard pad is forced against the rotor. This pressure causes the caliper to move inboard until an equal pressure is applied by the outside pad to the outer disc surface.

***flux density*** - the degree of concentration of the magnetic lines of force that emanate from a magnetic sensor; when the tooth of a reluctor aligns with the sensor tip, the magnetic lines of force are squeezed together, which increases flux density.

***foot pound*** - a unit of measurement for torque. One foot pound is the torque obtained by a force of one pound applied to a wrench handle that is 12-in. long.

***force*** - a pushing effort measured in pounds.

***free-play*** - looseness in a linkage between the start of application and the actual movement of the device, such as the movement in the steering wheel before the wheels start to turn.

***friction*** - the resistance to the motion of two moving objects in contact with each other.

***front-wheel drive (FWD)*** - the entire drivetrain is located at the front of and drives the front wheels of the vehicle.

*--g--*

***gravity bleeding*** - an easy but time consuming method of brake bleeding. Lengths of clear plastic hose are attached to the bleeder screws at the wheels and then the other ends submerged in containers partially filled with brake fluid. The master cylinder is filled with fluid and the cap left off, then each bleeder screw is opened. Atmospheric pressure acting on the surface of the fluid in the master cylinder forces the fluid through the hydraulic system and out through the bleeders, which may take several hours.

***ground*** - negatively charged side of a circuit; can be a wire, negative side of the battery or vehicle chassis.

*--h--*

***hard spot*** - areas in the friction surface of a brake drum or rotor that have become harder than the surrounding metal; this condition results from the changes in metallurgy that occur during overheating.

***hold***-down springs - springs that are used to keep the brake shoes secured to the backing plate.

***hone*** - abrasive tool for correcting small irregularities or differences in diameter in a cylinder, such as an engine cylinder or wheel cylinder; to enlarge or smooth a bore with a rotating tool containing an abrasive material.

***hub*** - mounting point for the wheel on an axle or spindle; the part of the synchronizer assembly that is splined to the transmission shaft; the center part of a wheel, gear, etc., that rides on a shaft.

***hydraulic pressure*** - pressure exerted through a liquid.

***Hydro-Boost*** - a power brake system that uses hydraulic pressure from the power steering system to provide power assist.

***hygroscopic*** - the ability of a material or substance to attract water.

--i--

***indexing*** - a disc brake rotor lateral runout correction procedure, where the rotor is placed at a different position on the hub and the runout rechecked with a dial indicator to see if it is then within specs. The number of wheel studs determines the number of possible positions to achieve correction.

***integral ABS*** - an anti-lock braking system that substitutes the traditional master cylinder and power booster with a self-contained hydraulic modulator and high-pressure accumulator.

--k--

***kinetic energy*** - energy in motion; the energy of a body that results from its motion; it's equal to half the product of its mass and the square of its velocity.

--l--

***lateral runout*** - side-to-side movement or wobble in a wheel, tire or brake rotor.

***leading-trailing drum brakes*** - a non-servo drum brake system where both brake shoes are held in place against a solidly attached anchor mounted to the bottom of the backing plate.

***lockup*** - the point at which braking power overcomes the traction of the vehicle's tires and skidding occurs. The most efficient stopping occurs just before lockup is reached. Locked wheels cause loss of control, long stopping distances, and flat spotting of the tires. The point at which friction overcomes rotating force.

***lubrication*** - reducing friction between moving parts such as applying brake fluid to the stones of a hone during wheel cylinder rebuilding.

--m--

***magnet*** - any body with the property of attracting iron or steel.

***magnetic field*** - the areas surrounding the poles of a magnet or current-carrying body (wire) where properties of attraction and repulsion are observable.

***master cylinder*** - the primary fluid pressurizing device in some hydraulic systems. In automotive use, it is found in the brake and hydraulic clutch systems and is pedal-activated, either directly or through a vacuum assist unit.

***memory*** - the part of a computer that stores or holds programs and other data.

***metering valve*** - a valve used on front disc/rear drum brake systems for the purpose of providing a simultaneous application of the front and rear friction materials. Located in the front brake hydraulic circuit, the metering valve delays front disc brake operation until the rear brakes shoes overcome the return spring tension.

***micrometer*** - a precision measuring instrument. When a micrometer measures in thousandths of an inch, one turn of its thimble results in 0.025-in. movement of its spindle. There are 40 threads per inch (1/40th inch = 0.025-in.).

***modulator*** - a component in the ABS system that contains the solenoid valves that regulate hydraulic fluid pressure to the calipers or wheel cylinders.

***module*** - an electronic control unit.

***multimeter*** - a tool that combines the functions of a voltmeter, ohmmeter and ammeter into one diagnostic instrument.

--o--

***oscilloscope*** - an instrument that displays electrical activity in the form of line patterns on a screen.

***out-of-round*** - refers to an inside or outside diameter that was originally designed to be perfectly round, but instead has varying diameters when measured at different points across its diameter, such as an out-of-round brake drum.

--p--

***parking brake*** - a system that applies the brakes mechanically through a series of linkages and cables. Depending on the vehicle, the parking brake system will either be actuated using a foot pedal or a hand-operated lever.

***Pascal's Law*** - the law of physics stating that liquids are non-compressible, and that a force applied to the top of a liquid in a closed container is exerted equally in all directions.

***pitting*** - surface irregularities caused by corrosion.

***play*** - movement between two parts.

***power booster*** - a device that uses a diaphragm, engine vacuum and atmospheric pressure to assist the driver with brake application. Also known as a vacuum booster.

***power brakes*** - a system that uses vacuum or hydraulic pressure to assist the driver with brake application.

***preload*** - thrust load applied to bearings that support a rotating part; eliminates axial play or movement.

***pressure*** - the exertion of force upon a body.

***primary shoe*** - the brake shoe in a duo-servo drum brake system that transfers part of its force to the secondary shoe. The brake shoe facing the front of the vehicle when the vehicle is moving forward.

***proportioning valve*** - the proportioning valve is used to control hydraulic pressure to the rear brakes. When the pressure to the rear brakes reaches a predetermined level, the proportioning valve overcomes the force of its spring-loaded piston and stops the flow of fluid to the rear brakes. This action maintains rear brake system pressure at a lower level than the front brakes, keeping the rear brakes from locking during hard stops.

*--q--*

***quick take-up master cylinder*** - a master cylinder design that is used to prevent excessive brake pedal travel. The quick take-up master cylinder uses a larger rear cylinder bore and quick take-up valve. This arrangement provides a large volume of fluid at low pressure (light pedal application) during the initial part of the pedal stroke. Also called a step-bore master cylinder.

***quick take-up valve*** - the valve used in a quick take-up master cylinder that controls fluid flow into the reservoir.

*--r--*

***race*** - the housing in which the balls or rollers of a bearing operate; on an integral disc or drum an inner and outer race is pressed into the hub to support the bearings.

***rear-wheel drive (RWD)*** - system where the driveline drives the rear wheels of the vehicle. Most often the engine is located in the front of the vehicle and a transmission and driveshaft connect to a drive axle, however there are also systems where the entire driveline is located toward the rear of the vehicle.

***reluctor*** - a toothed ring made of ferrous metal, which is used to change the magnetic flux density of the wheel speed sensor; mounted on the wheel hub or differential case, depending on application.

***resistance*** - the opposition offered by a substance or body to the passage of electric current.

***return springs*** - springs that secure the tops of the brake shoes to an anchor pin on the backing plate. These springs allow the shoes to move in and out laterally.

***rotor*** - a component mounted on the shaft of the distributor that transfers voltage from the distributor cap center terminal (coil wire) to the spark plug wire terminals; a cast iron disc mounted on the wheel hub, which is clamped by the caliper and disc brake pads to stop its rotation.

***runout*** - degree of wobble outside normal plane of rotation.

*--s--*

***scan tool*** - a microprocessor designed to communicate with a vehicle's on-board computer for the purpose of extracting stored trouble codes and other system data; a bi-directional scan tool can send information as well as receive it.

***score*** - a scratch, ridge or groove marring a finished surface.

***secondary shoe*** - the brake shoe in a duo-servo drum brake system that receives force from the primary shoe when the brakes are applied. The secondary shoe does most of the braking when the vehicle is traveling forward, so its lining is larger than that of the primary shoe.

***self-diagnostics*** - refers to the way in which the computer in the ABS system constantly monitors the state of each of its sensors and actuators. If one of them produces an implausible signal, or no signal at all, the system registers a fault code.

***sliding caliper*** - a brake caliper design that operates similarly to the floating design, however, it attaches to the anchor plate using only one attachment point.

***sponginess*** - the feel of a soft or mushy brake pedal usually caused by trapped air in the hydraulic system.

***star wheel*** - the star shaped wheel that is attached to the screw of a drum brake shoe adjuster. If brake shoe-to-drum clearance is excessive, the wheel is turned by the self-adjuster lever when the brakes are applied with the vehicle in reverse, moving the brake shoes closer to the drum.

***step-bore master cylinder*** - see quick take-up master cylinder.

***stroking seal*** - a type of brake caliper seal that is installed on the caliper piston, so called because it moves, or strokes, with the piston as the brakes are applied and released.

*--t--*

***taper*** - the difference in thickness of a brake pad or brake rotor between its widest and narrowest points.

***TCS*** - see traction control system.

***tire slip*** - also called wheel slip, is a measurement (in percentage) of the friction between the tire and road surface; at zero slip the tire rotates freely, while at 100% slip the tire is locked up and is pushed along the road surface by the moving vehicle.

***tone wheel*** - see reluctor.

***torque*** - a twisting force.

***traction control system (TCS)*** - a system used in conjunction with the ABS to control wheel spin and traction loss. Depending on the manufacturer's strategy, wheel spin is controlled by applying the brakes, reducing power to the wheel(s) or a combination of both.

*--u--*

***union*** - a hydraulic coupling that is used to connect pipe or tubing.

*--v--*

***vacuum booster*** - see power booster.

***variable reluctance sensor*** - a magnetic sensor that generates its own alternating current voltage based on the interference of a moving object across its tip.

*--w--*

***wheel slip*** - see tire slip.

***wheel speed sensor*** - a permanent magnetic sensor that sends information to the computer in an ABS system regarding wheel speed.