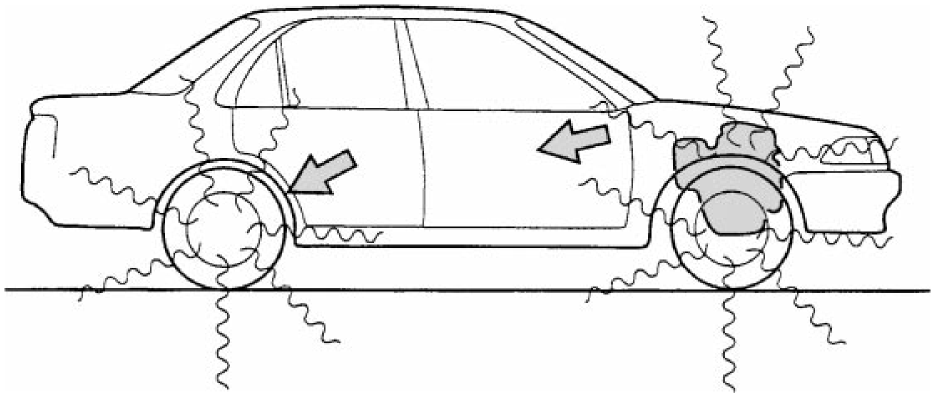
Section 1

FUNDAMENTAL PRINCIPLES



Lesson Objectives

1. Describe the cycle of heat as it applies to automotive brakes.
2. Explain the effect of heat transfer as it relates to brake fade.
3. Describe how the coefficient of friction affects the rate of heat transfer.
4. Relate the effect of hydraulic theory as it applies to a closed hydraulic circuit.
5. Explain how output force in a hydraulic circuit can be tailored for specific applications by changing the diameter of the output piston.
6. List the requirements of brake fluid in an automotive brake system.

Fundamental Principles

The most important safety feature of an automobile is its brake system. The ability of a braking system to provide safe, repeatable stopping is the key to safe motoring. A clear understanding of the brake system is essential for anyone involved in servicing Toyota vehicles.

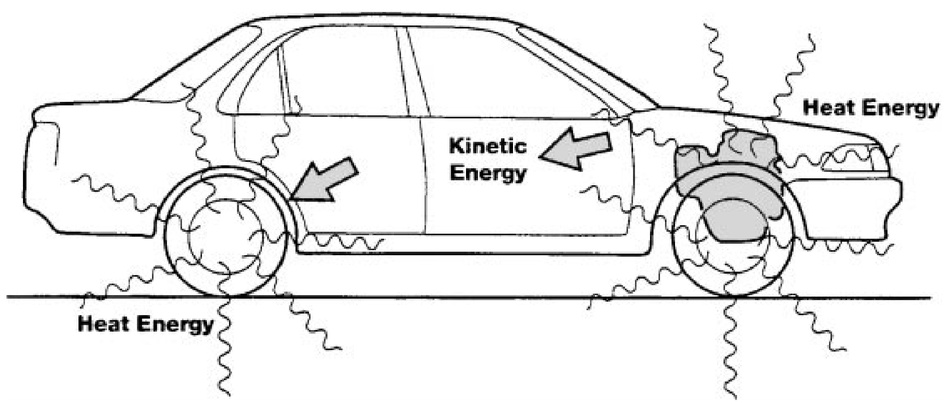
The basic principle of brake operation is the conversion of energy. Energy is the ability to do work. The most familiar forms of energy in automotive use are; chemical, electrical and mechanical. For example starting an engine involves several conversions. Chemical energy in the battery is converted to electrical energy in the starter. Electrical energy is converted to mechanical energy in the starter as it cranks the engine.

Cycle of Heat Energy

Burning hydrocarbons and oxygen in the engine creates **heat energy**. Nothing can destroy energy once it is released, it can only be converted into another form of energy. Heat energy is converted into **kinetic energy** as the vehicle is put into motion. Kinetic energy is a fundamental form of mechanical energy; it is the energy of a mass in motion. Kinetic energy increases in direct proportion to weight increase and increases by four times for speed increases.

Cycle of Heat

Heat energy converts to kinetic energy which converts back to heat energy.



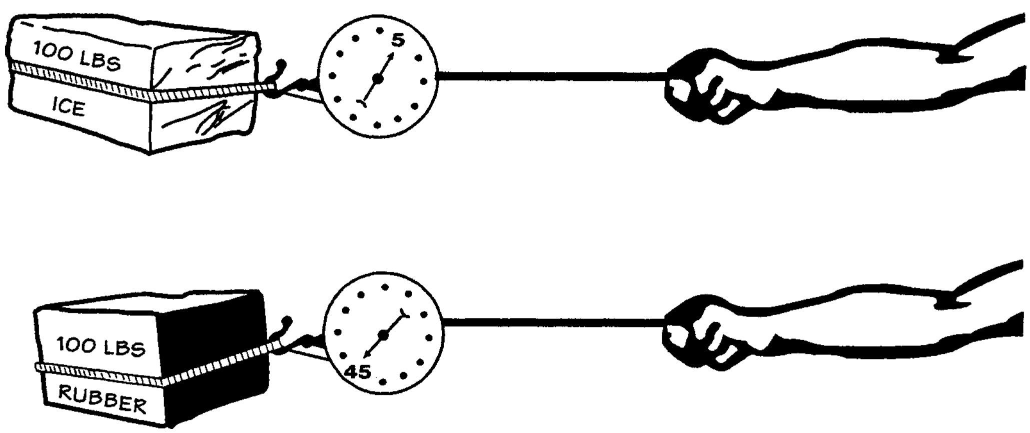
Friction is the resistance to movement between two objects in contact with each other. It also converts energy of motion to heat. If we allow the vehicle to coast in neutral on a level surface, eventually the kinetic energy would be converted to heat in the wheel bearings, drivetrain bearings, and at the tire and road surface to bring the vehicle to a complete stop. The brake system provides the means of converting kinetic energy through stationary brake shoes or pads which press against a rotating surface, generating friction and heat.

The amount of friction produced is proportional to the pressure between the two objects, composition of surface material and surface condition. The greater the pressure applied to the objects, the more friction and heat is produced. The more heat produced by friction, the sooner the vehicle is brought to a stop which results in stopping control.

The **coefficient of friction** is a measurement of the friction between two objects in contact with each other. Force is the effort required to slide one surface across the other. It is determined by dividing the force required to move an object by the weight of an object.

Coefficient of Friction

Coefficient of friction varies based on composition of material and condition of the surface.



The following example illustrates how the type of friction surface can influence the coefficient of friction (COF).

100 pounds of ice pulled across a concrete floor may require 5 pounds of force to move.

5 / 100 = 0.05
COF = 0.05

However 100 pounds of rubber pulled across a concrete floor may require 45 pounds of force to move.

45 / 100 = 0.45
COF = 0.45

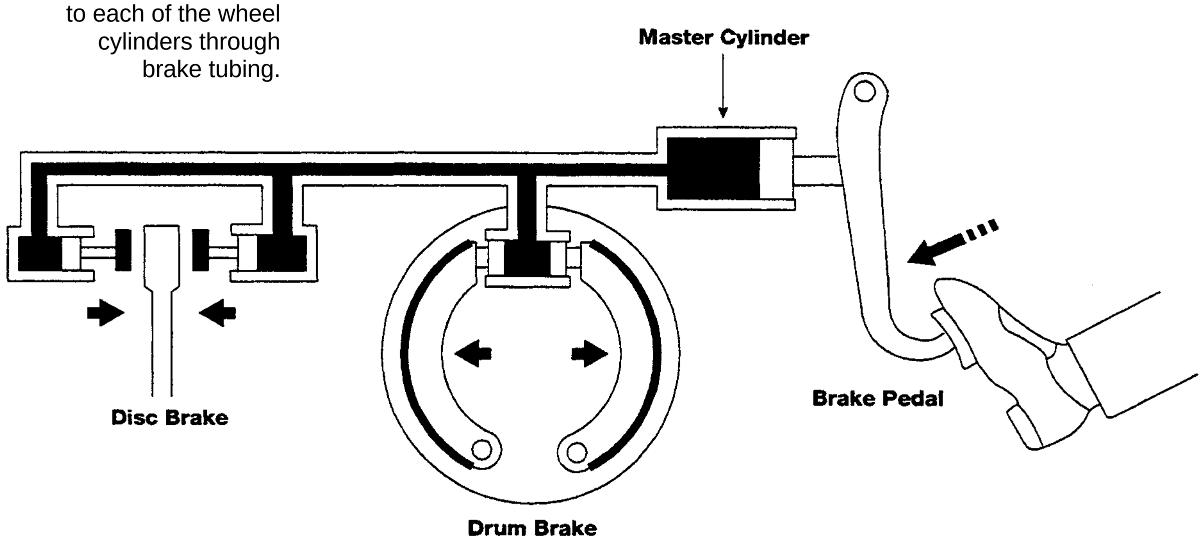
The coefficient of friction varies in the two examples above based on the materials used. The same is true in a brake system, the coefficient of friction varies on the type of lining used and the condition of the drum or rotor surface.

Basic Brake System

The most widely utilized brake systems at present are the foot operated main brake and manual type parking brake. The main brake actuates the brake assemblies at each wheel simultaneously using hydraulic pressure. Fluid pressure created at the master cylinder is transmitted to each of the wheel cylinders through brake tubing. The wheel cylinders force the shoes and pads into contact with a drum or rotor spinning with the wheels generating friction and converting kinetic energy to heat energy. Large amounts of heat is created resulting in short distance stopping and vehicle control. The converted heat is absorbed primarily by the brake drums and dissipated to the surrounding air.

Foot Operated Brake System

Fluid pressure is transmitted to each of the wheel cylinders through brake tubing.



Brake Fade

Brake drums and rotors are forced to absorb a significant amount of heat during braking. Brake fade describes a condition where heat is generated at a faster rate than they are capable of dissipating heat into the surrounding air. For example, during a hard stop the temperature of drums or rotors may increase more than 100 degrees F in just seconds. It may take 30 seconds to cool these components to the temperature prior to braking. During repeated hard stops, overheating may occur and a loss of brake effectiveness or even failure may result.

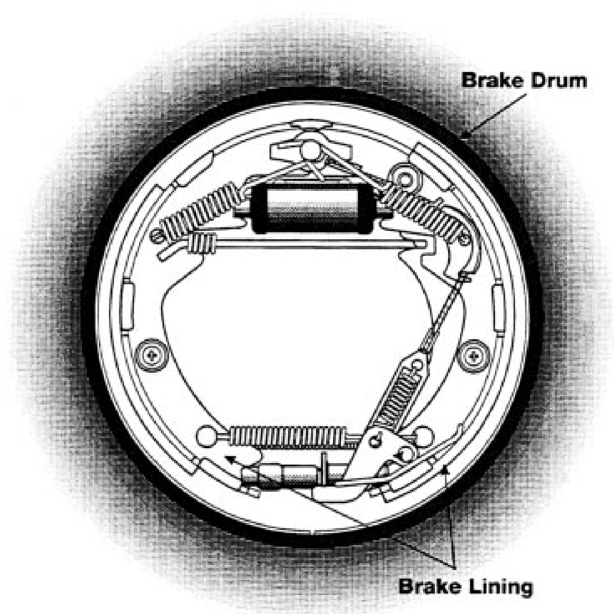
There are primarily two types of brake fading caused by heat;

- Mechanical fade.
- Lining fade.

Mechanical fade occurs when the brake drum overheats and expands away from the brake lining resulting in increased brake pedal travel. Rapidly pumping the pedal will help to keep linings in contact with the drum.

Brake Fade

Drums and rotors are forced to absorb heat during braking at a faster rate than they are capable of dissipating the heat.



Lining fade affects both drum and disc brakes and occurs when the friction material overheats to the point where the coefficient of friction drops off. When the coefficient of friction drops off, friction is reduced and the brake assemblies ability to convert added heat is reduced.

Brake fade is the primary reason for weight limits for towing and trailer brake requirement for vehicles above a given trailer weight. The added kinetic energy resulting from increased vehicle mass requires added heat conversion capacity when the brakes are applied.

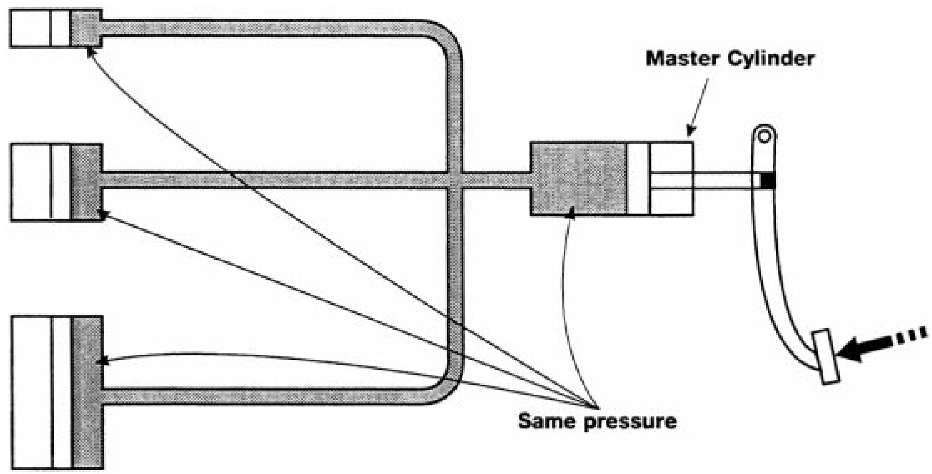
Basic Hydraulic Theory

Brake systems use hydraulic fluid in a closed system to transmit motion. The hydraulic brake system is governed by physical laws that makes it efficient at transmitting both motion and force. Blaise Pascal discovered the scientific laws governing the behavior of liquids under pressure. Pascal's Law states that pressure applied anywhere to an enclosed body of fluid is transmitted equally to all parts of the fluid. In other words, 100 psi generated at the master cylinder is the same at each wheel cylinder as well as anywhere within a static system.

A feature of hydraulic theory can be seen in the illustration below which demonstrates the pressure in the master cylinder is transmitted equally to all wheel cylinders.

Pascal's Law

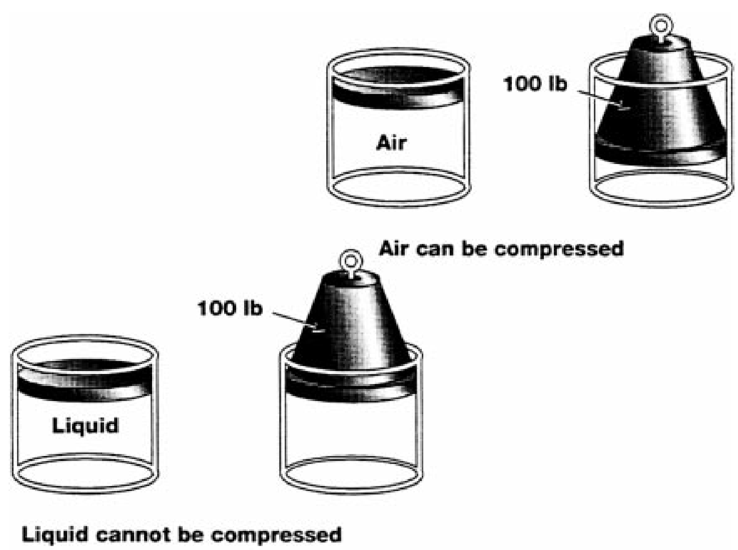
Pressure applied anywhere to an enclosed body of fluid is transmitted equally to all pans of the fluid.



Another important distinction to make is that liquids cannot be compressed, whereas, air is compressible. A hydraulic system must be free of air in order to function properly. Pedal travel will increase as air in the system is compressed.

Air is Compressible

Liquids cannot be compressed, whereas, air is compressible.



Fluid pressure is indicated in pounds per square inch (psi). It is determined by dividing the input force applied to a piston by the area of the piston. (force/area = pressure in psi) If a force of 100 pounds is applied to a master cylinder piston, an area of 2 square inches, the resulting pressure will be 50 psi. This pressure is transmitted to all parts of the fluid in the container equally.

force / area = psi
100 / 2 = 50 psi

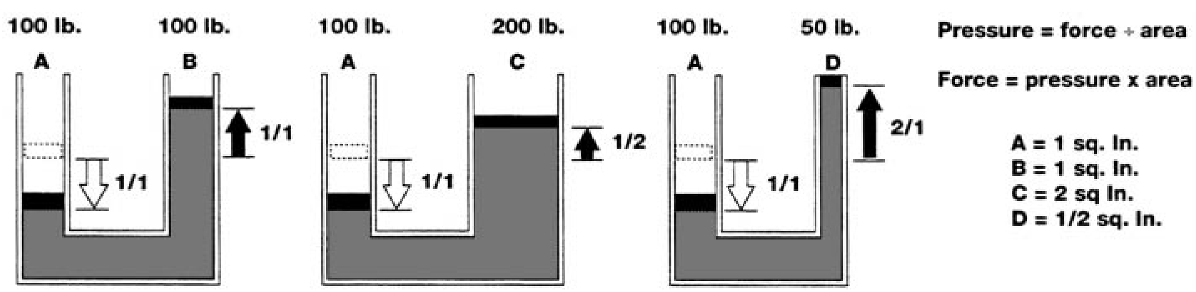
In the series of examples below we are examining working force and transfer of motion based on different working piston diameters. In each example, piston A is the same diameter (1”) and the same 100 lb. input force is applied. When the force is applied to piston A, piston B has 100 psi of output force and travels an equal distance to piston A.

By contrast piston C will have an output force of twice that of piston A because piston C has twice the area. In addition, piston C transfers only half the distance of piston A.

Yet another contrast is piston D which is half the area of piston A. The system pressure is the same as the two previous examples but since piston D is half the area of piston A, the pressure is half the apply pressure and the motion transfer is twice that of piston A.

Working Force and Transfer of Motion

The braking force varies, depending on the diameter of the wheel cylinders.



Hydraulic brakes deliver equal braking force to all wheels with a minimum of transmission loss. Hydraulic brakes have a wide design flexibility because braking force can be changed merely by changing the diameter of the master cylinder and wheel cylinders.

Brake Fluid

Brake fluid is specifically designed to be compatible with its environment of high heat, high pressure and moving parts. Standards for brake fluid have been established by the Society of Automotive Engineers (SAE) and the Department of Transportation (DOT). Requirements of a fluid used in automotive brake applications must include the following:

- remain viscous.
- have a high boiling point.
- act as lubricant for moving parts.

The Federal Motor Vehicle Safety Standard (FMVSS) states that by law, brake fluid must be compatible regardless of manufacturer. Fluids are not necessarily identical however, any DOT approved brake fluid can be mixed with any other approved brake fluid without damaging chemical reactions. Although the fluid may not always blend together into a single solution, it does not effect the properties of liquid under pressure.

Brake Fluid Types

Two types of brake fluid are used in automotive brake applications, each having specific attributes and drawbacks. **Polyglycol** is clear to amber in color and is the most common brake fluid used in the industry. It is a solvent and will immediately begin to dissolve paint. Flush the area with water if brake fluid is spilled on paint.

One of the negative characteristics of polyglycol is that it is hygroscopic, that is, it has a propensity to attract water. Water can be absorbed through rubber hoses and past seals and past the vent in the master cylinder reservoir cap. Moisture in the hydraulic circuit reduces the boiling point of the fluid and causes it to vaporize. In addition, moisture causes metal parts to corrode resulting in leakage and /or frozen wheel cylinder pistons.

Extra caution should be taken with containers of brake fluid because it absorbs moisture from the air when the container is opened. Do not leave the container uncapped and close it tightly.

Silicone is purple in color. It is not hygroscopic and therefore has virtually no rust and corrosion problems. It has a high boiling point and can be used in higher heat applications. It will not harm paint when it comes in contact with it.

Silicone has a greater affinity for air than polyglycol. Because the air remains suspended in the fluid it is more difficult to bleed air from the hydraulic system.

DOT Grades

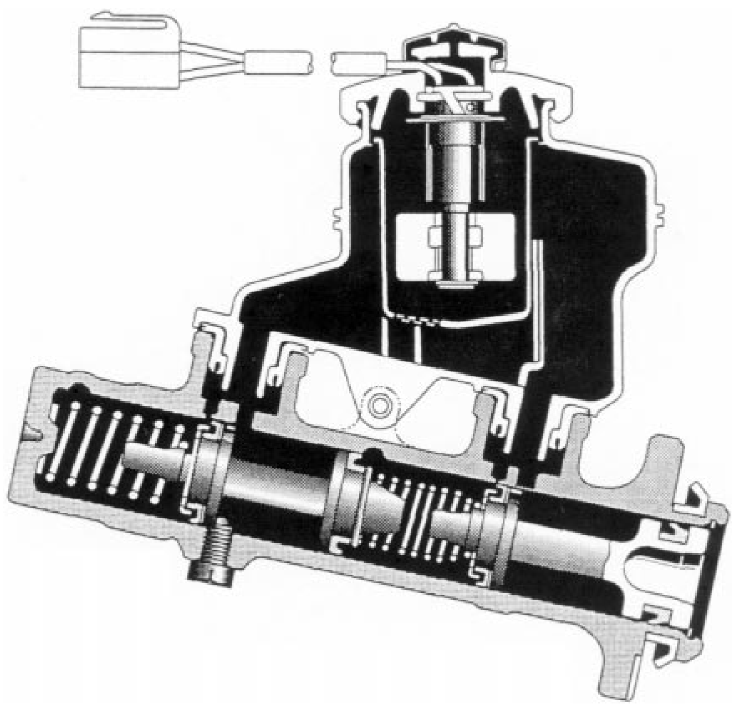
There are three grades of brake fluid which are determined by Federal Motor Vehicle Safety Standard 116. Fluid grades are rated by the minimum boiling point for both pure fluid (dry) and water contaminated fluid (wet):

- DOT 3 – Polyglycol
    - minimum boiling point – 401°F dry, 284 °F wet
    - blends with DOT 4
- DOT 4 – Polyglycol
    - minimum boiling point – 446 °F dry, 311 °F wet
    - blends with DOT3
- DOT 5 – Silicone
    - minimum boiling point – 500 °F dry, 356 °F wet
    - compatible by law with DOT 3 and 4 but will not blend with them

Toyota recommends the exclusive use of Polyglycol DOT 3 brake fluid in all its products.

Section 2

MASTER CYLINDER



Lesson Objectives

1. Explain the difference between conventional and diagonal split piping system and their application.
2. Describe the function of the compensating port of the master cylinder.
3. Explain the operation of the residual check valve on the drum brake circuit of the master cylinder.
4. Explain the safety advantage of having two hydraulic circuits in the master cylinder.
5. Describe the difference between the Portless and Lockheed master cylinders.

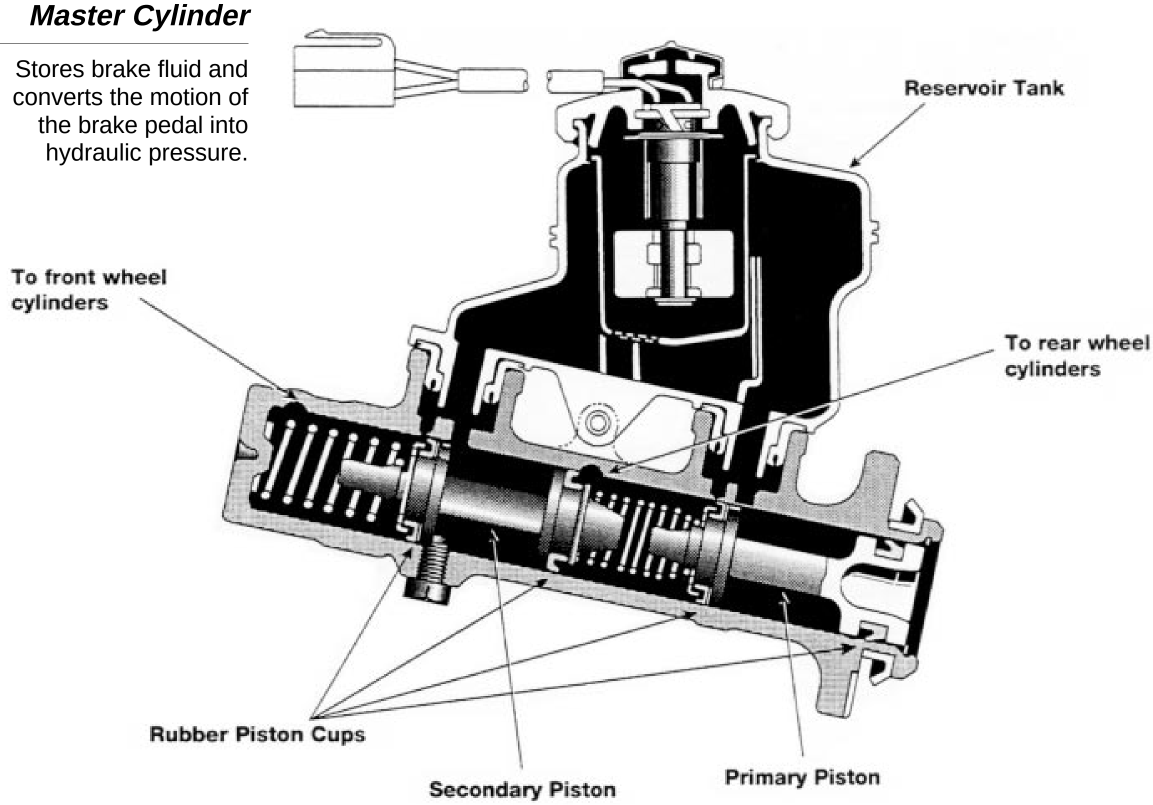
Master Cylinder

The master cylinder converts the motion of the brake pedal into hydraulic pressure. It consists of the reservoir tank, which contains the brake fluid; and the piston and cylinder which generate the hydraulic pressure.

The reservoir tank is made mainly of synthetic resin, while the cylinders are made of cast iron or an aluminum alloy.

Master Cylinder

Stores brake fluid and converts the motion of the brake pedal into hydraulic pressure.



Tandem Master Cylinder

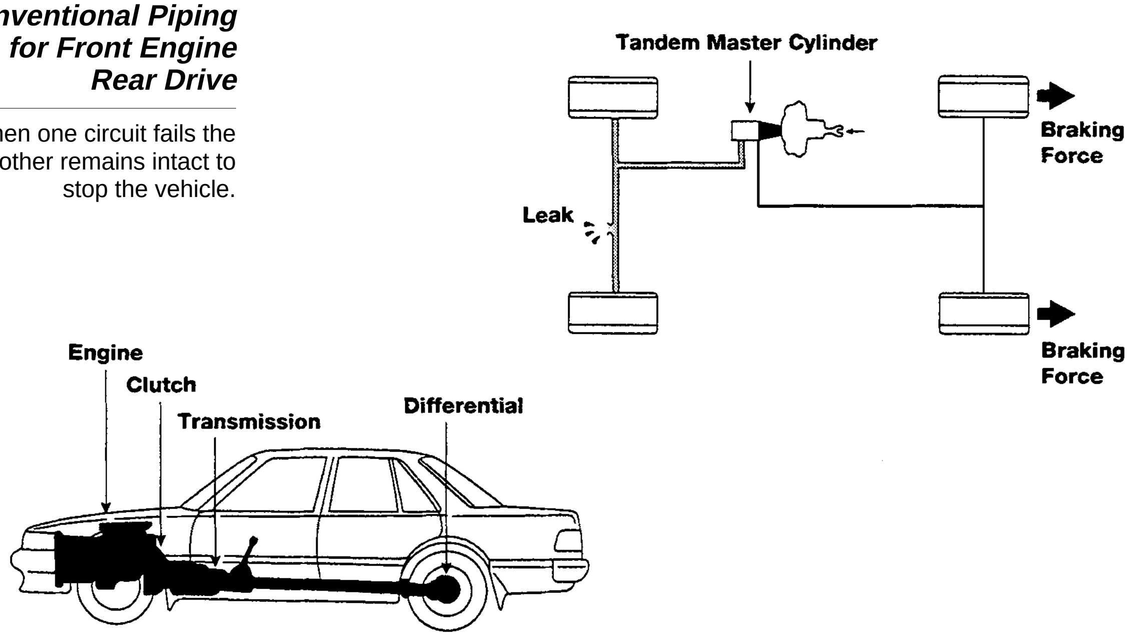
The tandem master cylinder has two separate hydraulic chambers. This creates in effect two separate hydraulic braking circuits. If one of these circuits becomes inoperative, the other circuit can still function to stop the vehicle. Stopping distance is increased significantly, however, when operating on only one braking circuit. This is one of the vehicles' most important safety features.

Conventional Piping

On front-engine rear-wheel-drive vehicles, one of the chambers provides hydraulic pressure for the front brakes while the other provides pressure for the rear.

Conventional Piping for Front Engine Rear Drive

When one circuit fails the other remains intact to stop the vehicle.

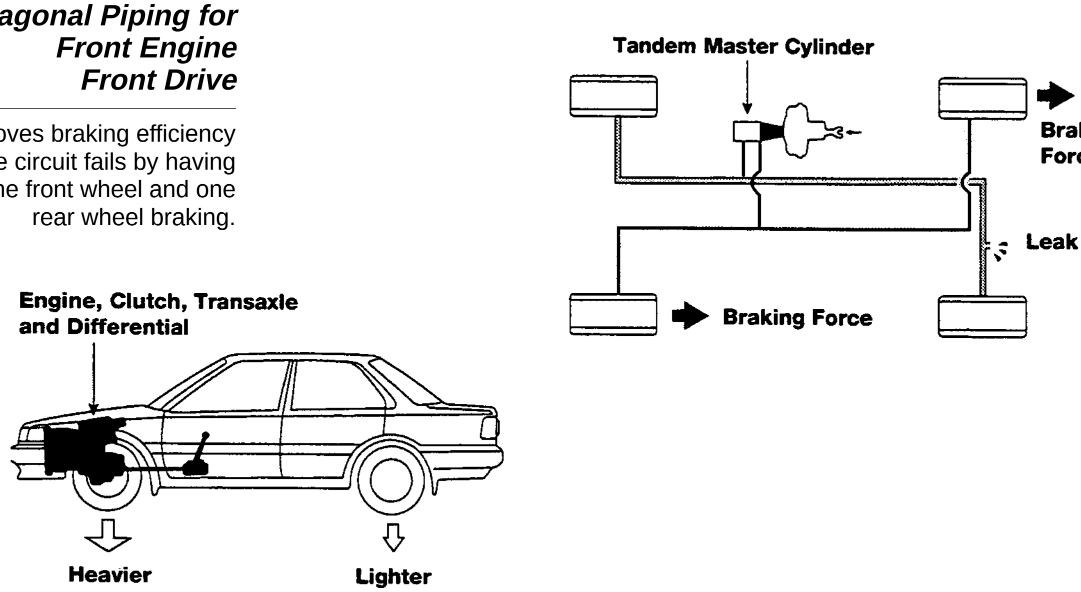


Diagonal Split Piping

On front-engine front-wheel-drive vehicles, however, extra braking load is shifted to the front brakes due to reduced weight in the rear. To compensate for hydraulic failure in the front brake circuit with the lighter rear axle weight, a diagonal brake line system is used. This consists of one brake system for the right front and left rear wheels, and a separate system for the left front and right rear wheels. Braking efficiency remains equal on both sides of the vehicle (but with only half the normal braking power) even if one of the two separate systems should have a problem.

Diagonal Piping for Front Engine Front Drive

Improves braking efficiency if one circuit fails by having one front wheel and one rear wheel braking.



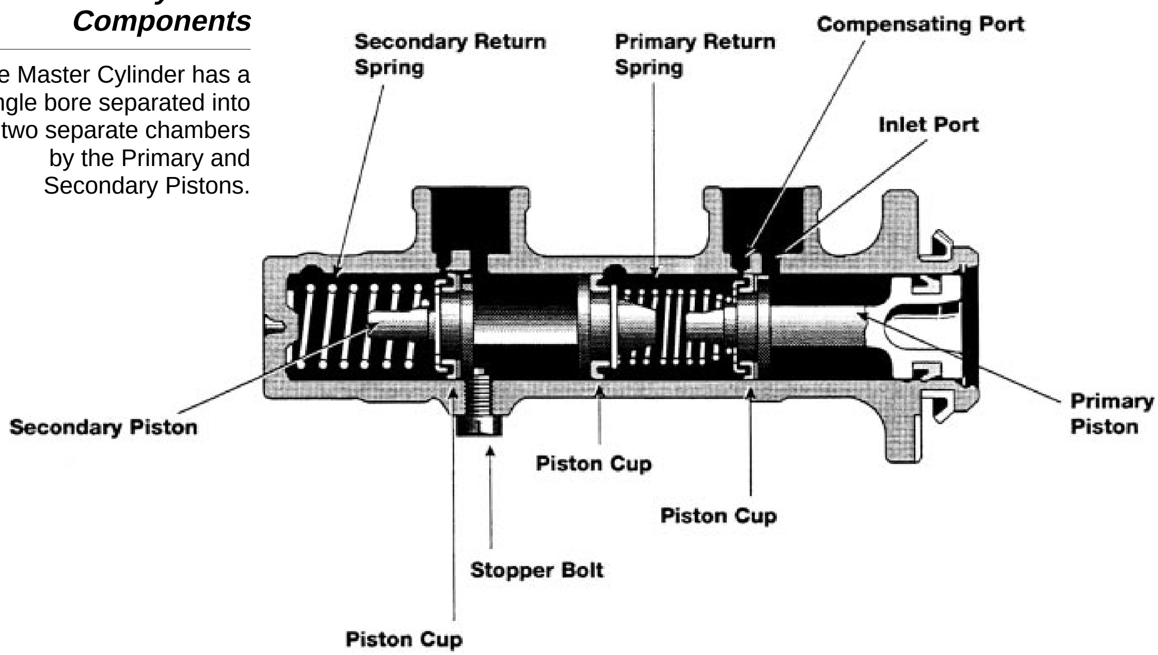
Construction

The Master Cylinder has a single bore separated into two separate chambers by the Primary and Secondary Pistons. On the front of the master cylinder Primary Piston is a rubber Piston Cup, which seals the Primary Circuit of the cylinder. Another Piston Cup is also fitted at the rear of the Primary Piston to prevent the brake fluid from leaking out of the rear of the cylinder.

At the front of the Secondary Piston is a Piston Cup which seals the Secondary Circuit. At the rear of the Secondary Piston the other Piston Cup seals the Secondary Cylinder from the Primary Cylinder. The Primary Piston is linked to the brake pedal via a pushrod.

Master Cylinder Components

The Master Cylinder has a single bore separated into two separate chambers by the Primary and Secondary Pistons.



Normal Operation

When the brakes are not applied, the piston cups of the Primary and Secondary Pistons are positioned between the Inlet Port and the Compensating Port. This provides a passage between the cylinder and the reservoir tank.

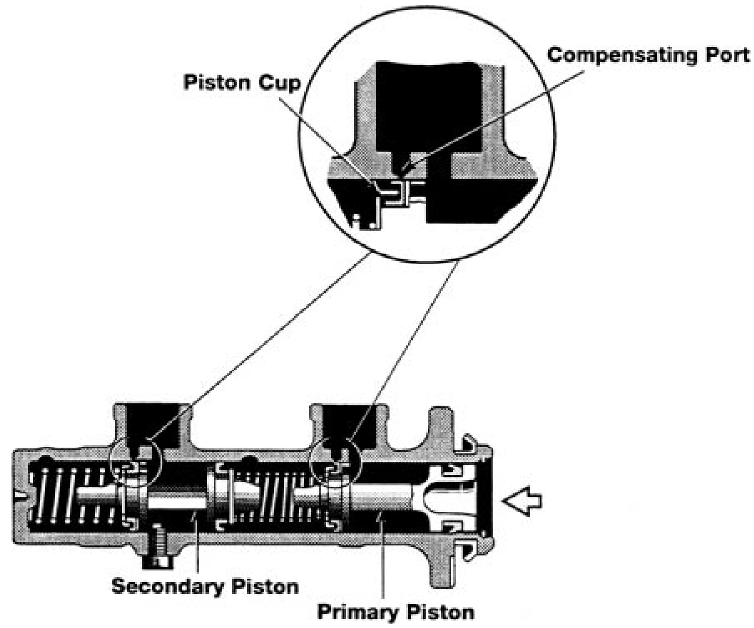
The Secondary Piston is pushed to the right by the force of Secondary Return Spring, but prevented from going any further by a stopper bolt.

When the brake pedal is depressed, the Primary Piston moves to the left. The piston cup seals the Compensating Port blocking the passage between the Primary Pressure Chamber and the Reservoir Tank. As the piston is pushed farther, it builds hydraulic pressure inside the cylinder and is applied or transmitted to the wheel cylinders in that circuit. The same hydraulic pressure is also applied to the Secondary

Piston. Hydraulic pressure in the Primary Chamber moves the Secondary Piston to the left also. After the Compensating Port of the Secondary Chamber is closed, fluid pressure builds and is transmitted to the secondary circuit.

Brake Application

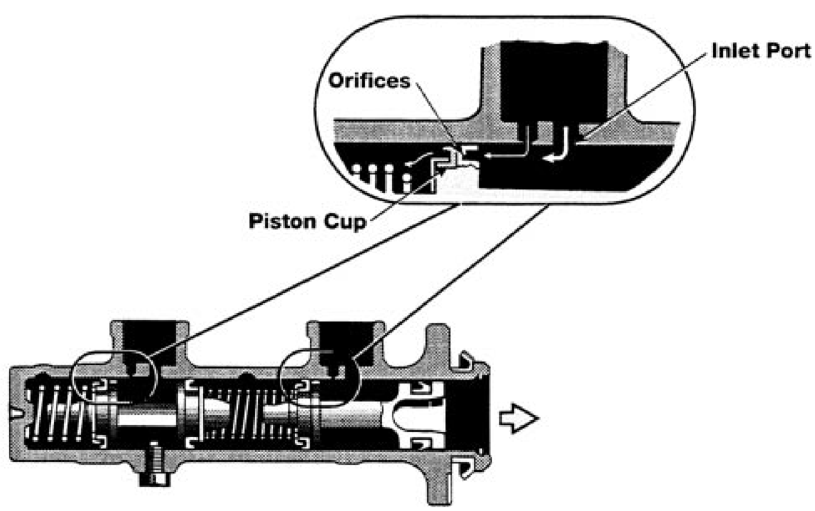
As the piston cup passes the compensating Port pressure begins to increase in the hydraulic circuit.



When the brake pedal is released, the pistons are returned to their original position by hydraulic pressure and the force of the return springs. However, because the brake fluid does not return to the master cylinder immediately, the hydraulic pressure inside the cylinder drops momentarily. As a result, the brake fluid inside the reservoir tank flows into the cylinder via the inlet port, through small holes provided at the front of the piston, and around the piston cup. This design prevents vacuum from developing and allowing air to enter at the wheel cylinders.

Brake Release

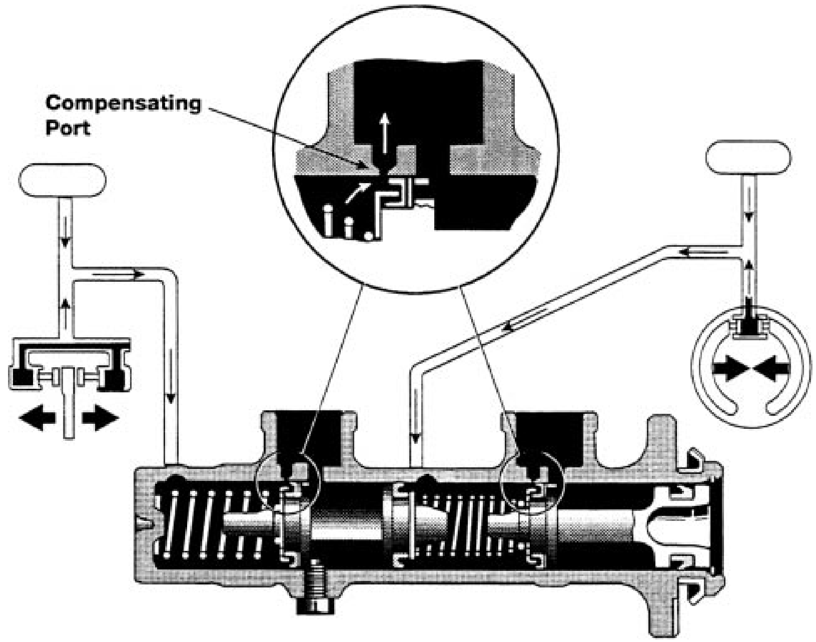
Brake fluid inside the reservoir tank flows into the cylinder via the inlet port, through small holes provided at the front of the piston, and around the piston cup.



After the piston has returned to its original position, fluid returns from the wheel cylinder circuit to the reservoir through the Compensating Port.

Fluid Return

Fluid returns to the reservoir tank through the compensating port.

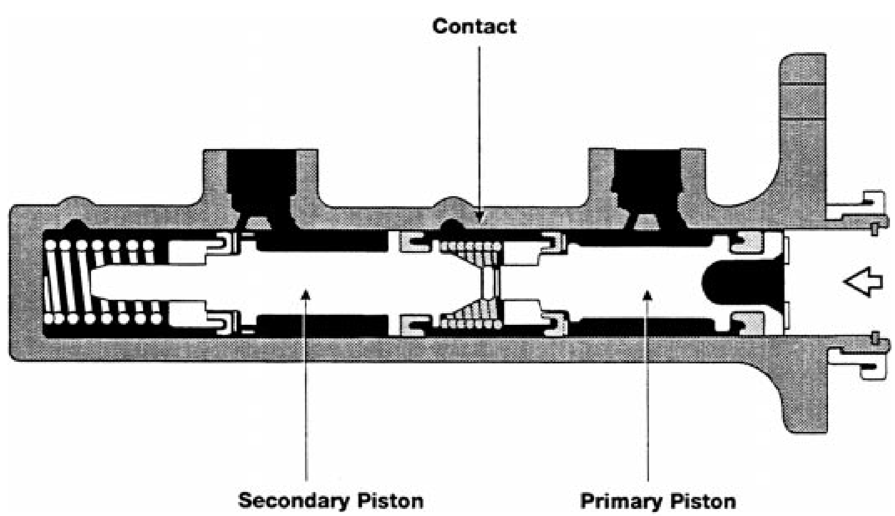


Fluid Leakage In One of the Hydraulic Circuits

When fluid leakage occurs in the primary side of the master cylinder, the Primary Piston moves to the left but does not create hydraulic pressure in the primary pressure chamber. The Primary Piston therefore compresses the Primary Return Spring, contacting the Secondary Piston and directly moving the Secondary Piston. The Secondary Piston then increases hydraulic pressure in the Secondary Circuit end of the master cylinder, which allows two of the brakes to operate.

Leakage In Primary Circuit

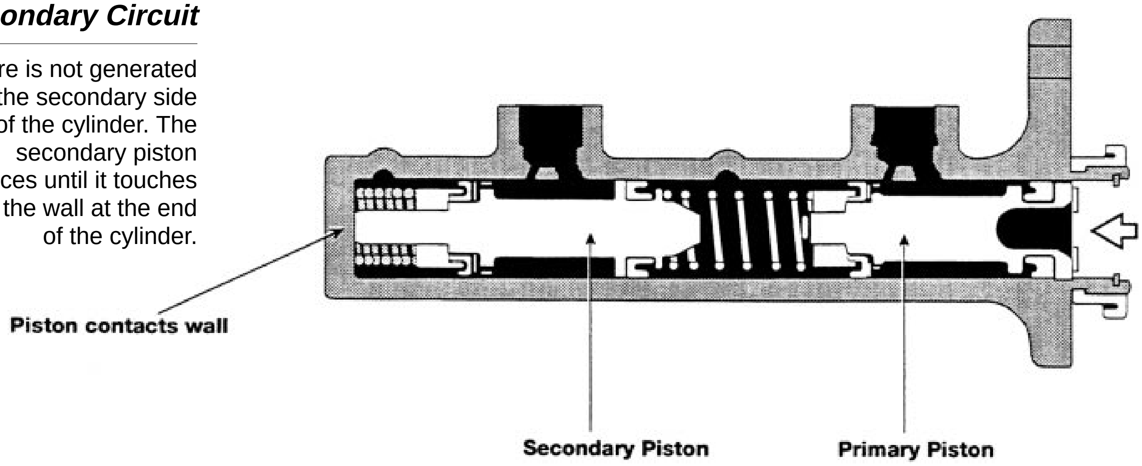
The primary piston compresses the return spring, contacts the secondary piston, and manually moves it.



When fluid leakage occurs on the secondary side of the master cylinder, hydraulic pressure in the Primary Chamber easily forces the Secondary Piston to the left compressing the return spring. The Secondary Piston advances until it reaches the far end of the cylinder.

Leakage in the Secondary Circuit

Pressure is not generated in the secondary side of the cylinder. The secondary piston advances until it touches the wall at the end of the cylinder.



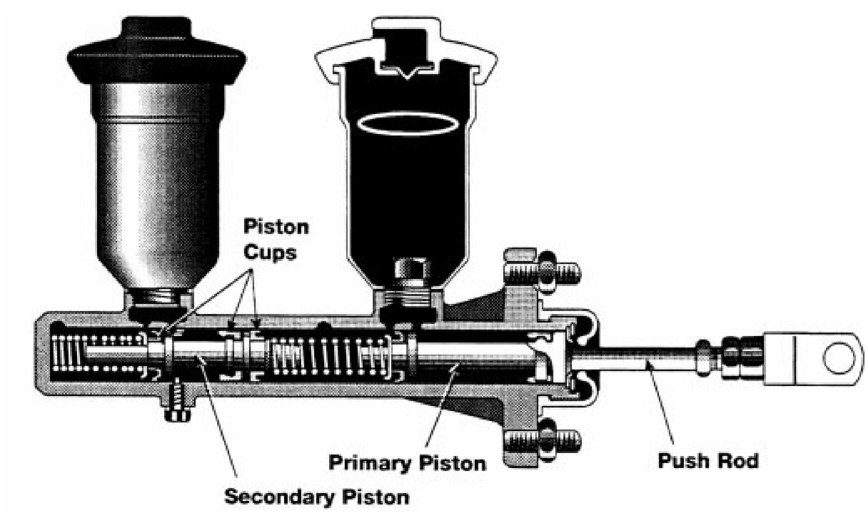
When the Primary Piston is pushed farther to the left, hydraulic pressure increases in the rear (primary) circuit or pressure chamber of the master cylinder. This allows one half of the brake system to operate from the rear Primary Pressure Chamber of the master cylinder.

Separated Reservoir Tank

The master cylinder we have been covering so far has only two piston cups on the Secondary Piston and a single fluid reservoir. A third piston cup is added to the Secondary Piston of master cylinders having separate fluid reservoirs for the primary and secondary chambers.

Dual Reservoir Master Cylinder

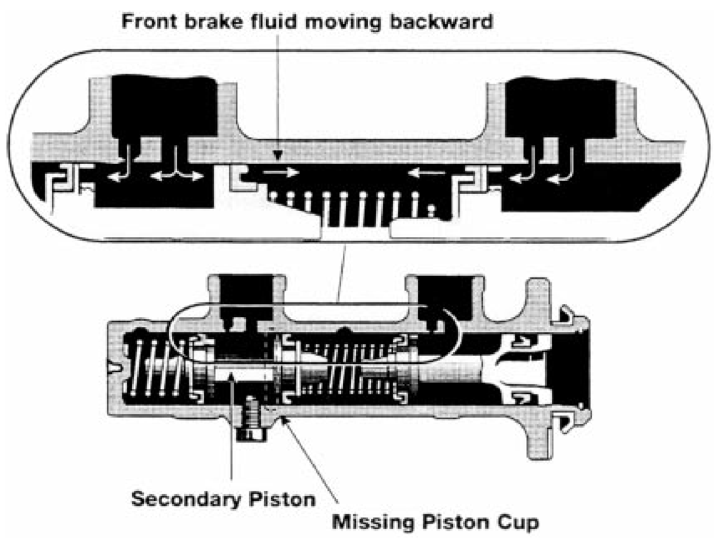
An additional piston cup is added to the secondary piston to seal the secondary cylinder from the primary cylinder.



The third piston cup is located between the front and rear piston cup of the secondary piston and seals the Secondary Chamber from the Primary Chamber. When the brakes are released after brake application, the master cylinder pistons return faster than the fluid can, momentarily creating low pressure (vacuum) in the Primary Chamber. It is the job of the third piston cup to prevent fluid passage between the Secondary Chamber and the Primary Chamber. If the piston cup were missing or worn, fluid passing the third piston cup would fill the Primary Reservoir and deplete the Secondary Reservoir. If left unchecked, the Secondary Reservoir would empty allowing air into the secondary hydraulic circuit.

Role of the Second Piston Cup of the Secondary Piston

Prevents transfer of fluid from the front tank to the rear tank.

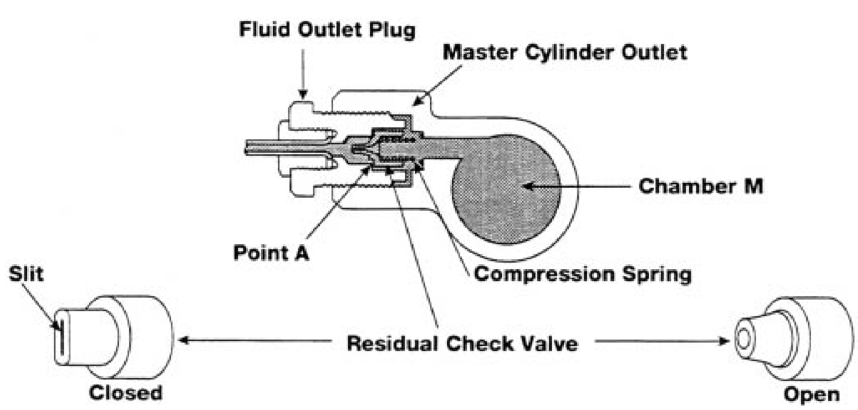


Residual Check Valve

The Residual Check Valve is located in the master cylinder outlet to the rear drum brakes. Its purpose is to maintain about 6 to 8 psi in the hydraulic circuit. When the brakes are released the brake shoe return springs force the wheel cylinder pistons back into the bore. Without the Residual Valve the inertia of fluid returning to the master cylinder may cause a vacuum and allow air to enter the system. In addition to preventing a vacuum, the residual pressure pushes the wheel cylinder cup into contact with the cylinder wall.

Master Cylinder Residual Check Valve

Maintains about 6 to 8 psi in the hydraulic circuit to prevent air from entering.



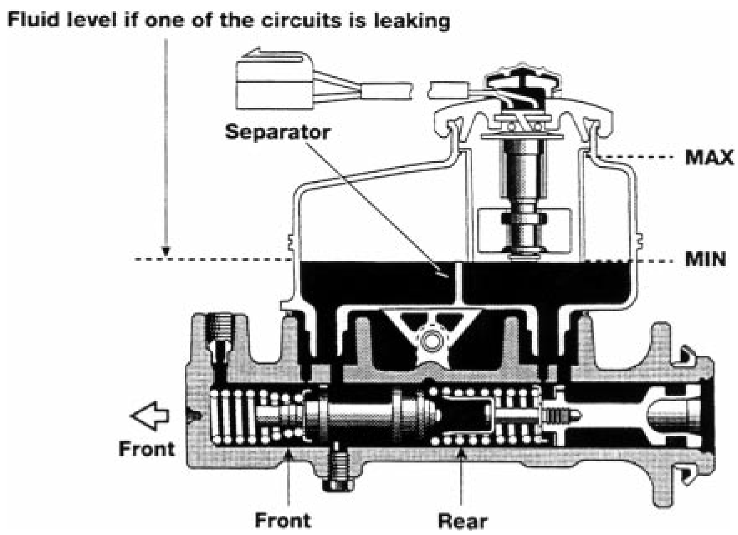
Reservoir Tank

The amount of the brake fluid inside the Reservoir Tank changes during brake operation as Disc Brake Pads wear. A small hole in the reservoir cap connects the reservoir to the atmosphere and prevents pressure fluctuation, which could result in air being drawn into the hydraulic circuit.

A tandem master cylinder having a single reservoir tank has a separator inside that divides the tank into front and rear as shown below. The two-part design of the reservoir ensures that if one circuit fails due to fluid leakage, the other circuit will still be available to stop the vehicle.

Single Fluid Reservoir Tank

A separator inside divides the tank into front and rear parts to ensure that if one circuit fails the other will still have fluid.

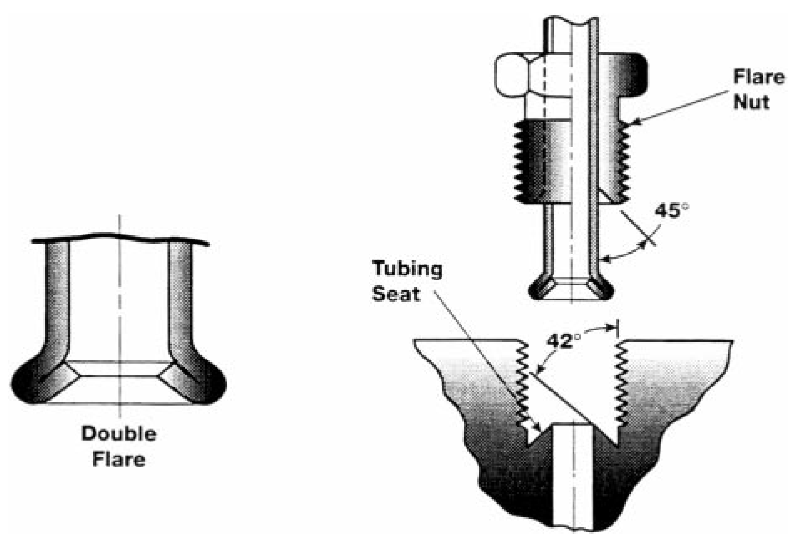


Brake Tubing

Brake hydraulic components are connected by a network of seamless steel tubes and hoses. Brake tubing is made of copper plated steel sheets rolled at least two times and brazed into a single piece and plated with tin and zinc for corrosion resistance. It is produced in different lengths and pre-bent for the specific model applications. Each end is custom flared in a two step process and fitted with a flare nut.

Double Flare Tubing

The tapered seats and double flare tube provide a compression fitting to seal the connection.



Portless Master Cylinder

The master cylinder design discussed up to this point has been the conventional compensating port and inlet port type used on most brake systems. A new style master cylinder is used on late model vehicles equipped with ABS and ABS/TRAC (Traction Control).

Initially introduced on the 1991 MR2 and Supra, which were rear wheel drive vehicles, the front piston has a port-less design. The single passage from the reservoir to the secondary piston is non-restrictive. The secondary piston provides a machined passage to the secondary circuit which is controlled with a valve. The valve is spring loaded to seal the piston passage however, a stem attached to the valve holds it from contact with the piston in the “at rest” position. When the brakes are applied the valve closes, sealing the passage and pressure is built in the secondary circuit. The front piston controls pressure to the rear brake calipers.

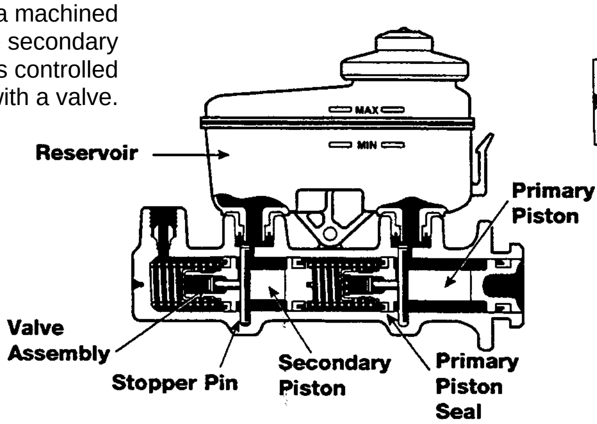
The master cylinder on the 1997 Camry and Avalon incorporates another master cylinder portless design. In this design a spring loaded valve seals the passage in the piston however, in the “at rest” position, a stem attached to the valve contacts the piston retaining pin and unseats the valve.

Three types of master cylinders are available on the 1997 Camry and Avalon depending on the brake system options.

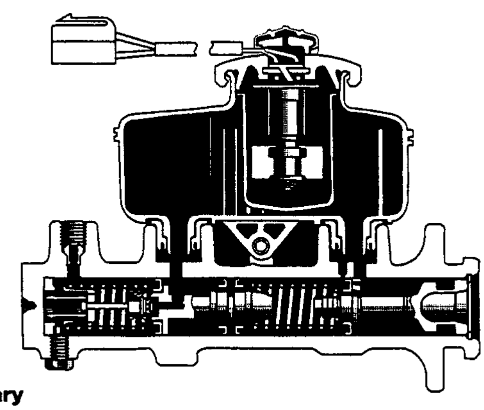
1. Non ABS Brake System - Conventional primary and secondary master cylinder.
2. ABS Brake System - Portless secondary and conventional primary master cylinder.
3. ABS and TRAC Brake System - Portless secondary and Portless primary master cylinder.

Portless Master Cylinder

The single passage from the reservoir to the secondary piston is non restrictive. The secondary piston provides a machined passage to the secondary circuit which is controlled with a valve.



Portless / Portless



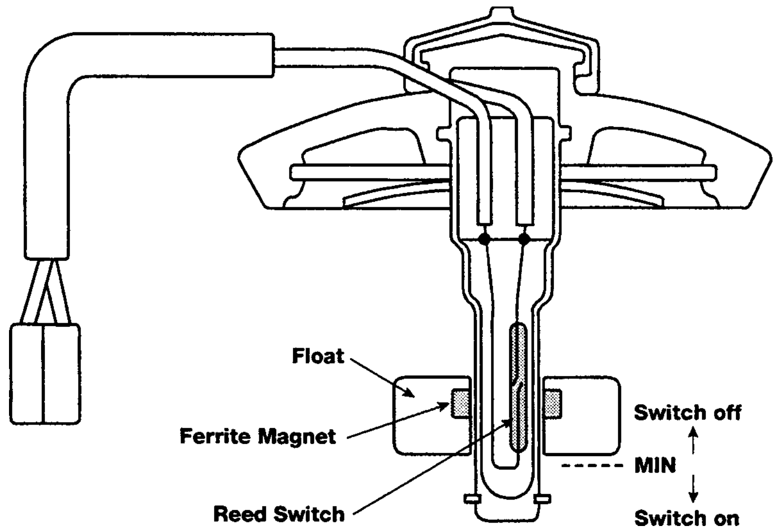
Portless / Conventional

Brake Fluid Level Warning Light Switch

The brake fluid level warning switch is located on the reservoir cap or in some models, is wired within the reservoir body. It normally remains off when there is an appropriate amount of fluid. When the fluid level falls below the minimum level, a magnetic float moves down and causes the switch to close. This activates the red brake warning lamp to warn the driver.

Brake Fluid Level Warning Switch

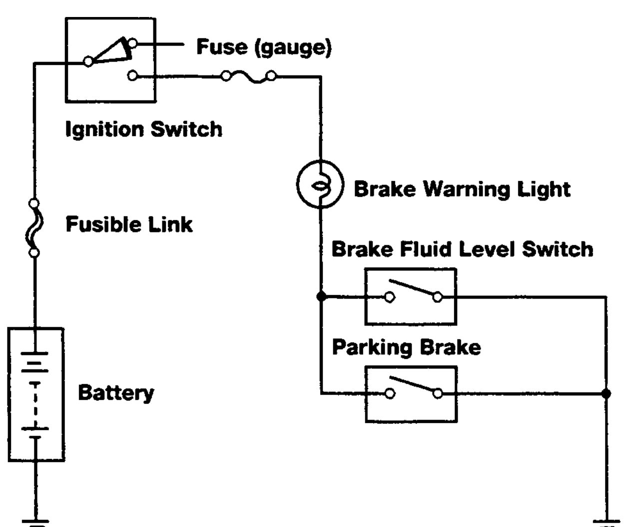
If fluid level falls below the minimum level, a magnetic float moves down and turns the switch on.



A typical brake warning lamp electrical circuit is shown below. It also turns ON when the parking brake is applied.

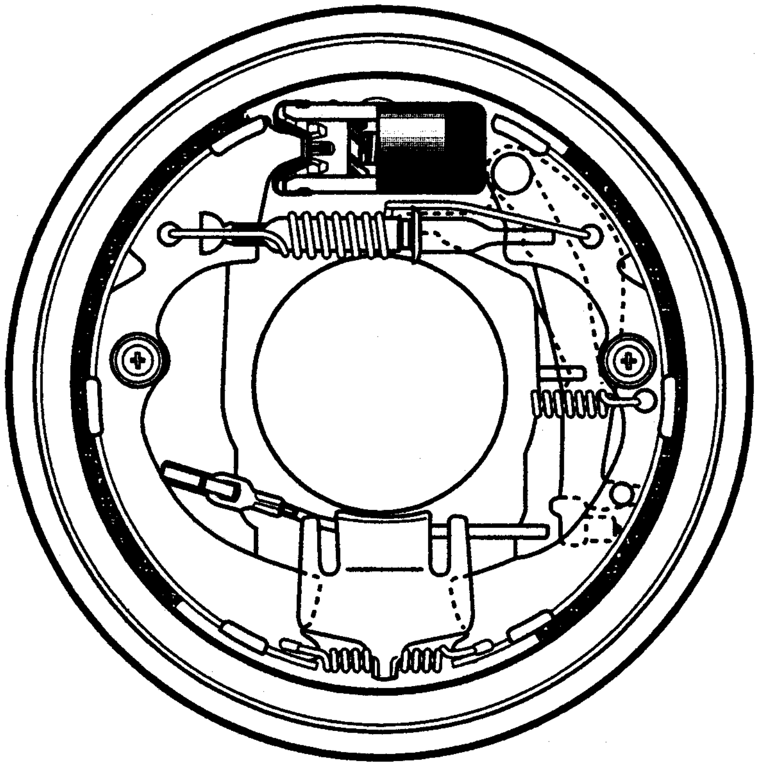
Brake Warning Light Electrical Circuit

Low brake fluid level or parking brake light turn on.



Section 3

DRUM BRAKES



Lesson Objectives

1. Identify the components of the drum brake system.
2. Explain the operation of the drum brake system during brake application.
3. Explain brake fluid flow return from the wheel cylinder to the master cylinder.
4. Describe the function and operation of the self adjuster mechanism.
5. Demonstrate the operation of adjusting the brake shoe clearance using a vernier caliper or drum caliper.

Drum Brakes

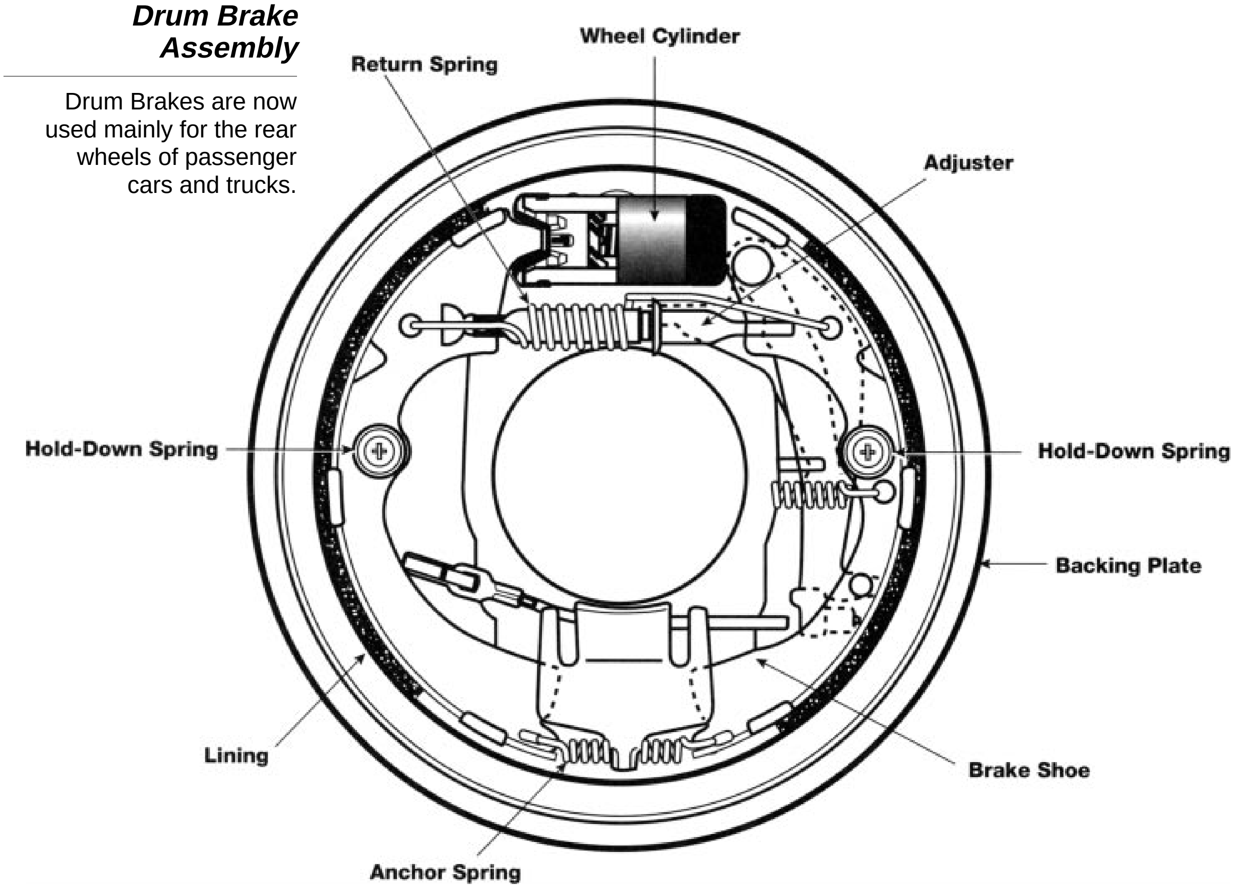
The drum brake has been more widely used than any other brake design. Braking power is obtained when the brake shoes are pushed against the inner surface of the drum which rotates together with the axle.

Drum brakes are used mainly for the rear wheels of passenger cars and trucks while disc brakes are used exclusively for front brakes because of their greater directional stability.

The backing plate is a pressed steel plate, bolted to the rear axle housing. Since the brake shoes are fitted to the backing plate, all of the braking force acts on the backing plate.

Drum Brake Assembly

Drum Brakes are now used mainly for the rear wheels of passenger cars and trucks.



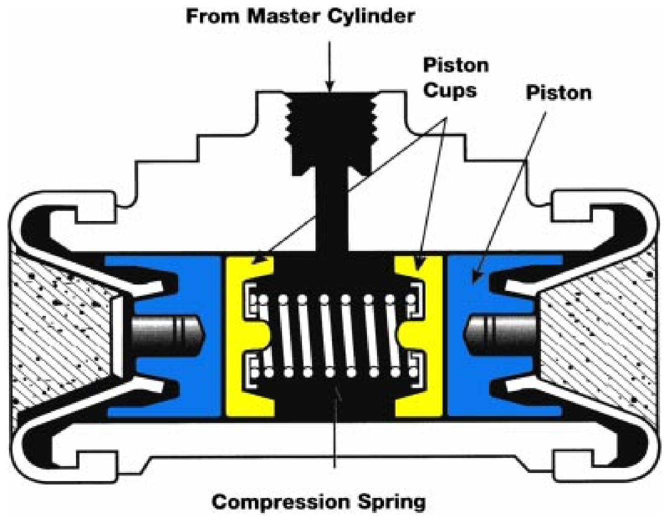
Wheel Cylinder

The wheel cylinder consists of a number of components as illustrated on the next page. One wheel cylinder is used for each wheel. Two pistons operate the shoes, one at each end of the wheel cylinder. When hydraulic pressure from the master cylinder acts upon the piston cup, the pistons are pushed toward the shoes, forcing them against the drum.

When the brakes are not being applied, the piston is returned to its original position by the force of the brake shoe return springs.

Wheel Cylinder

Hydraulic pressure acting upon the piston cup, forces the pistons outward toward the shoes.



Brake Shoes

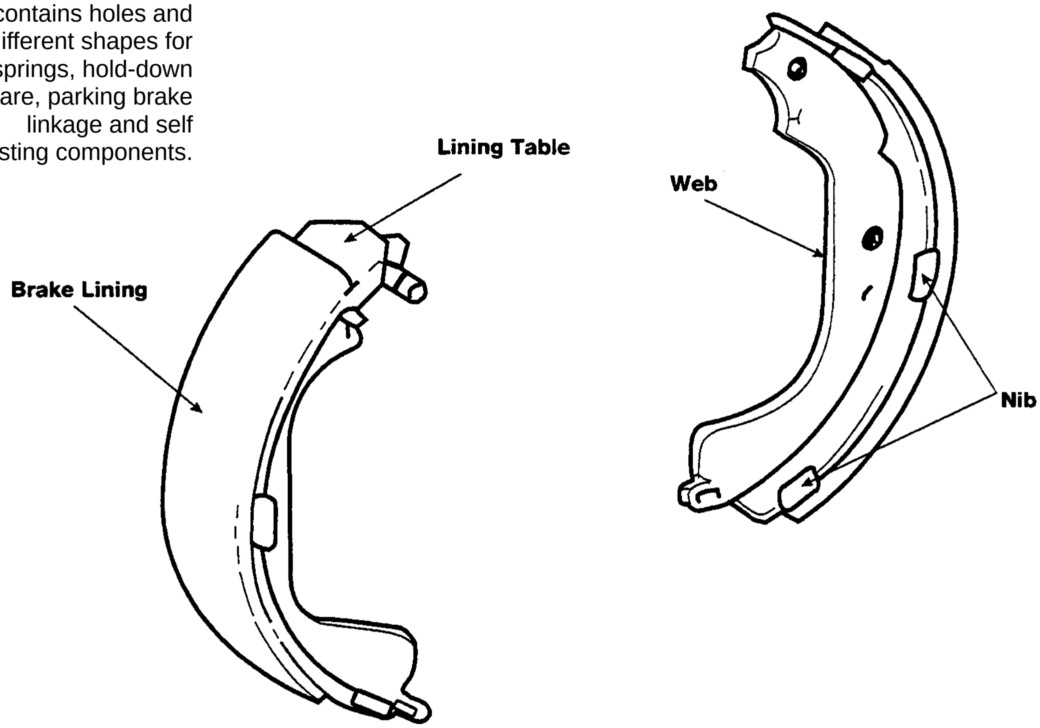
Brake shoes are made of two pieces of sheet steel welded together. The friction material is attached to the lining table either by adhesive bonding or riveting. The crescent shaped piece is called the **web** and contains holes and slots in different shapes for return springs, hold-down hardware, parking brake linkage and self adjusting components. All the application force of the wheel cylinder is applied through the web to the lining table and brake lining. The edge of the lining table generally has three "V" shaped notches or tabs on each side called nibs. The nibs rest against the support pads of the backing plate to which the shoes are installed.

Each brake assembly has two shoes, a primary and secondary. The primary shoe is located toward the front of the vehicle and has the lining positioned differently than the secondary shoe. Quite often the two shoes are interchangeable, so close inspection for any variation is important.

Linings must be resistant against heat and wear and have a high friction coefficient. This coefficient must be as unaffected as possible by fluctuations in temperature and humidity. Materials which make up the brake shoe include friction modifiers, powdered metal, binders, fillers and curing agents. **Friction modifiers** such as graphite and cashew nut shells, alter the friction coefficient. **Powdered metals** such as lead, zinc, brass, aluminum and other metals increase a material's resistance to heat fade. **Binders** are the glues that hold the friction material together. **Fillers** are added to friction material in small quantities to accomplish specific purposes, such as rubber chips to reduce brake noise.

Brake Shoes and Lining

The friction material is attached to the lining table. The crescent shaped web contains holes and slots in different shapes for return springs, hold-down hardware, parking brake linkage and self adjusting components.



Brake Drum The brake drum is generally made of a special type of cast iron. It is positioned very close to the brake shoe without actually touching it, and rotates with the wheel and axle. As the lining is pushed against the inner surface of the drum, friction heat can reach as high as 600 degrees F.

The brake drum must be:

1. Accurately balanced.
2. Sufficiently rigid.
3. Resistant against wear.
4. Highly heat-conductive.
5. Lightweight.

Drum Type Brake Adjustment

It is very important that the specified drum-to-lining clearance be accurately maintained at all times. In some types of brake systems, this is done automatically. In others, this clearance must be periodically adjusted.

An excessively large clearance between the brake drum and lining will cause a low pedal and a delay in braking. If the drum to lining clearance is too small the brakes will drag, expand with increased heat, and seizure between the drum and brake lining may occur. Furthermore, if the clearance is not equal the rear-end of the vehicle may fishtail (oscillate from side to side) as one brake assembly locks-up.

Automatic Brake Shoe Clearance Adjustment

Automatic clearance adjusting devices may be divided into two types:

- Reverse Travel Adjuster.
- Parking Brake Adjuster.

Reverse Travel Adjuster

Adjustment effected by braking effort during reverse travel is used with duo-servo type brakes. Duo-servo brake shoes have a single anchor located above the wheel cylinder. When the leading shoe contacts the drum it transfers force to the trailing shoe which is wedged against the anchor. This system uses an:

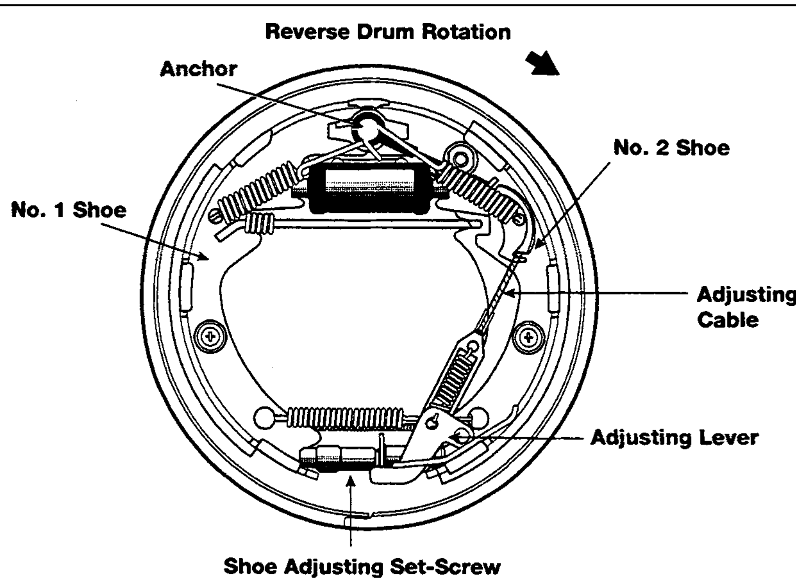
- adjusting cable assembly.
- adjusting lever.
- shoe adjusting setscrew (star wheel).
- cable guide.
- lever return spring.

The adjusting cable is fixed at one end to the anchor pin, while the other end *is* hooked to the adjusting lever via a spring.

The adjusting lever is fitted to the lower end of No. 2 brake shoe, and engages with the shoe adjusting setscrew.

Reverse Travel Brake Shoe Adjustment

The adjusting cable is fixed to the anchor pin, the other end is hooked to the adjusting lever and engages with the shoe adjusting set screw.

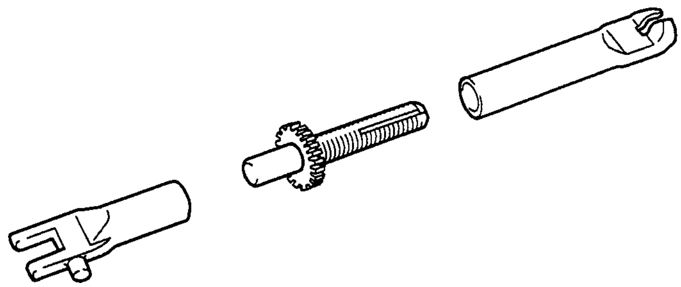


When the brake pedal is depressed while the vehicle is moving backward, the brake shoes expand and contact the drum. The shoes are forced by the drum to begin rotating; however, the upper end of No. 1 shoe is wedged against the anchor pin. Since No. 2 shoe is moving away from the anchor pin, it causes the adjusting lever to pivot and turn the shoe adjusting screw and reduce the clearance. If clearance is proper, the adjusting lever will not engage the tooth of the adjusting screw.

The shoe adjusting screw consists of a bolt and two nuts as shown below. The bolt end is marked with a “R” or “L” to indicate which side of the vehicle it is mounted on.

Shoe Adjusting Set Screw

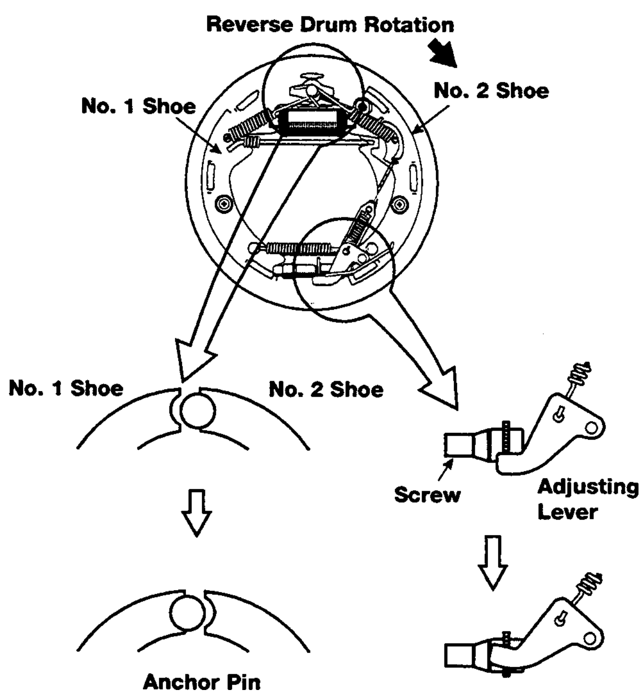
Each end of the screw is in contact with a brake shoe. Clearance decreases as the screw turns.



Since each end of the adjusting screw is in contact with a brake shoe, the brake shoe clearance decreases as the screw turns.

Adjusting Lever Action

As the No. 2 shoe moves away from the anchor pin, the adjusting lever pivots causing the adjusting screw to turn.



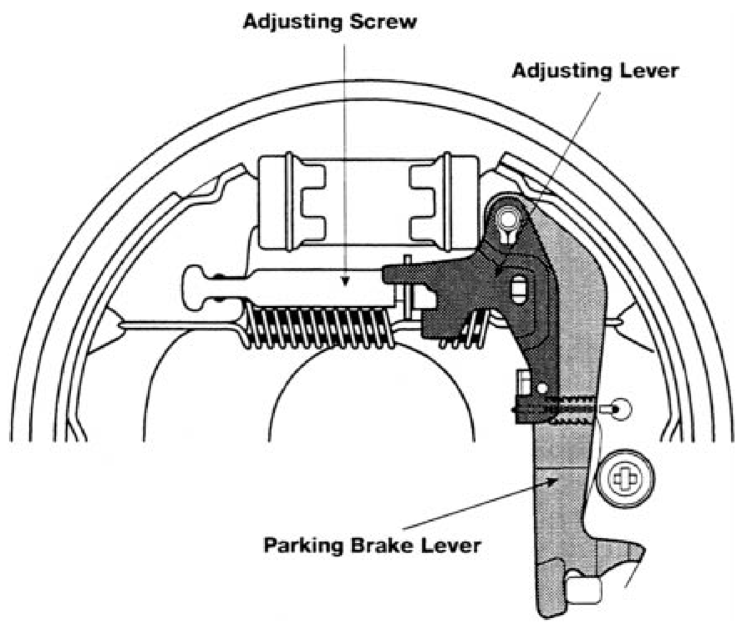
Parking Brake Automatic Adjuster

The second type of automatic clearance adjustment operates by applying the parking brake. The adjusting lever is attached, together with the parking brake lever, to the shoe. The lower end of the adjusting lever is held to the brake shoe via a spring, and the other end of the lever engages the adjusting screw pulling it downward.

When the parking brake is released, the brake lever is pushed to the right. At the same time, the adjusting lever pivots, turning the adjusting screw.

Parking Brake Shoe Adjustment

The adjusting lever is attached with the parking brake lever to the shoe. The lever engages the adjusting screw pulling it downward.

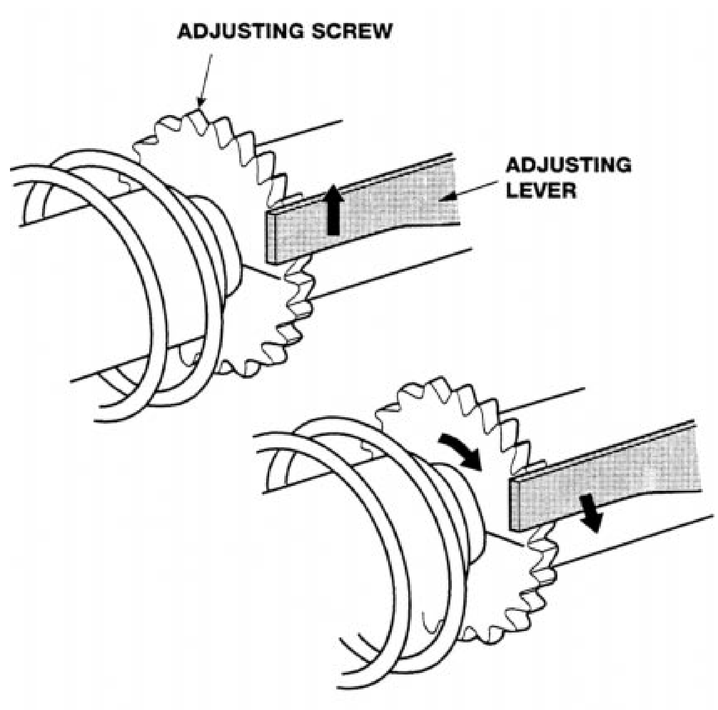


When brake shoe clearance is greater than standard and the parking brake lever is pulled, the adjusting lever moves over to the next tooth of the adjusting screw.

When the parking brake lever is released, the adjusting lever spring pulls the lever down. This causes the adjusting screw to rotate, reducing the brake shoe clearance.

Adjusting Lever Rotates Adjusting Screw

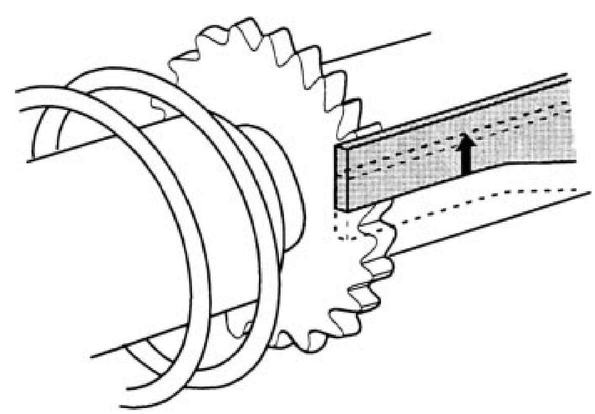
When the parking brake lever is pulled the adjusting lever engages the next tooth on the adjusting screw. When the parking brake lever is released, the adjusting lever rotates the adjusting screw.



When the brake shoe clearance is normal and the parking brake lever is pulled, the adjusting lever moves only a small distance. The adjusting lever does not move to the next tooth of the adjusting screw. Brake shoe clearance remains unchanged as a result.

Normal Brake Shoe Clearance

With proper clearance the adjusting lever does not engage the next tooth of the screw.



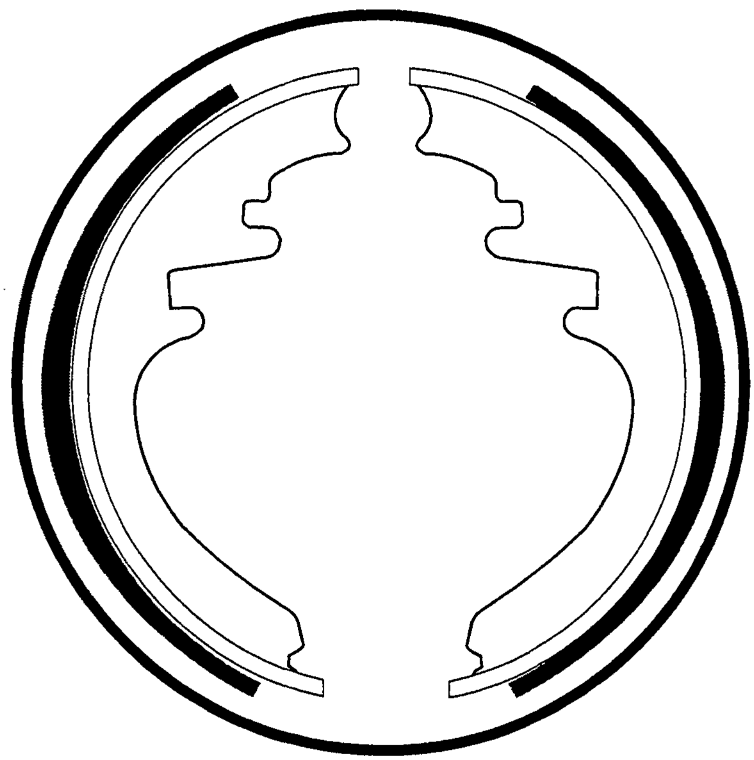
The adjusting lever is arranged in such a way as to engage with one adjusting screw tooth. Therefore, one operation of the parking brake lever only advances the adjusting screw by one tooth, reducing brake shoe clearance by approximately 0.012” (0.03mm), even when there is a large amount of brake shoe clearance.

Lining that is eccentrically ground, that is having clearance at the heel and toe when held against the drum face, can tolerate a closer drum to shoe clearance. As the brakes are applied, the center of the lining contacts the drum first. As hydraulic pressure increases, the shoe will stretch slightly and allow additional lining contact and ensures consistent pressure over a larger area of lining. As the shoes wear-in they will fit the contour of the drum more closely.

Place the lining inside the drum and press it against the contour of the drum to ensure heel and toe clearance. If the heel and toe have heavy contact it is likely that the brakes will grab and cause the wheels to lockup.

Eccentrically Ground Brake Lining

The center of the lining contacts the drum first. As pressure increases the shoe will stretch slightly and allow additional lining contact and ensures consistent pressure over a larger area of lining.



Initial Brake Shoe Adjustment

Initial clearance between the shoe and the drum must be set when new brake shoes are installed. A specific clearance of 0.60 mm, (0.024”) is stated in the Repair Manual for most models.

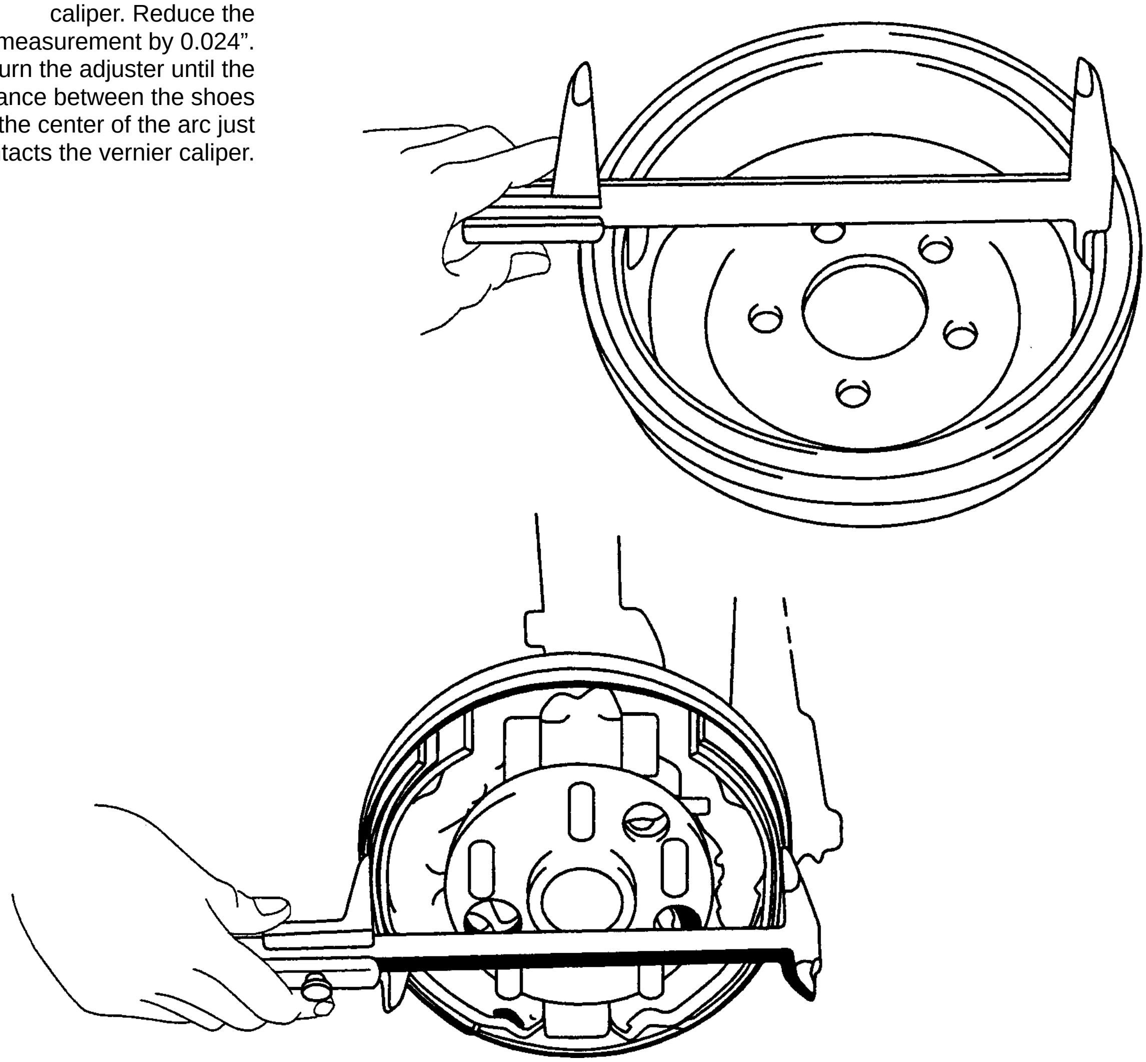
Use the following procedure to set the initial adjustment:

- Shoes must be centered on the backing plate.
- Measure the inside diameter of the drum with a vernier caliper.

- Reduce the measurement by 0.024” or (0.60 mm).
- Turn the adjuster until the distance between the shoes at the center of the arc just contacts the vernier caliper.
- When installing the drum, there should be no heavy drag of the drum and shoes as the drum is turned. Apply the parking brake several times to center the shoes and check for drag. Back-off adjustment if brakes continue to drag.

Setting the Brake Shoe Initial Adjustment

Measure the inside diameter of the drum with a vernier caliper. Reduce the measurement by 0.024”. Turn the adjuster until the distance between the shoes at the center of the arc just contacts the vernier caliper.



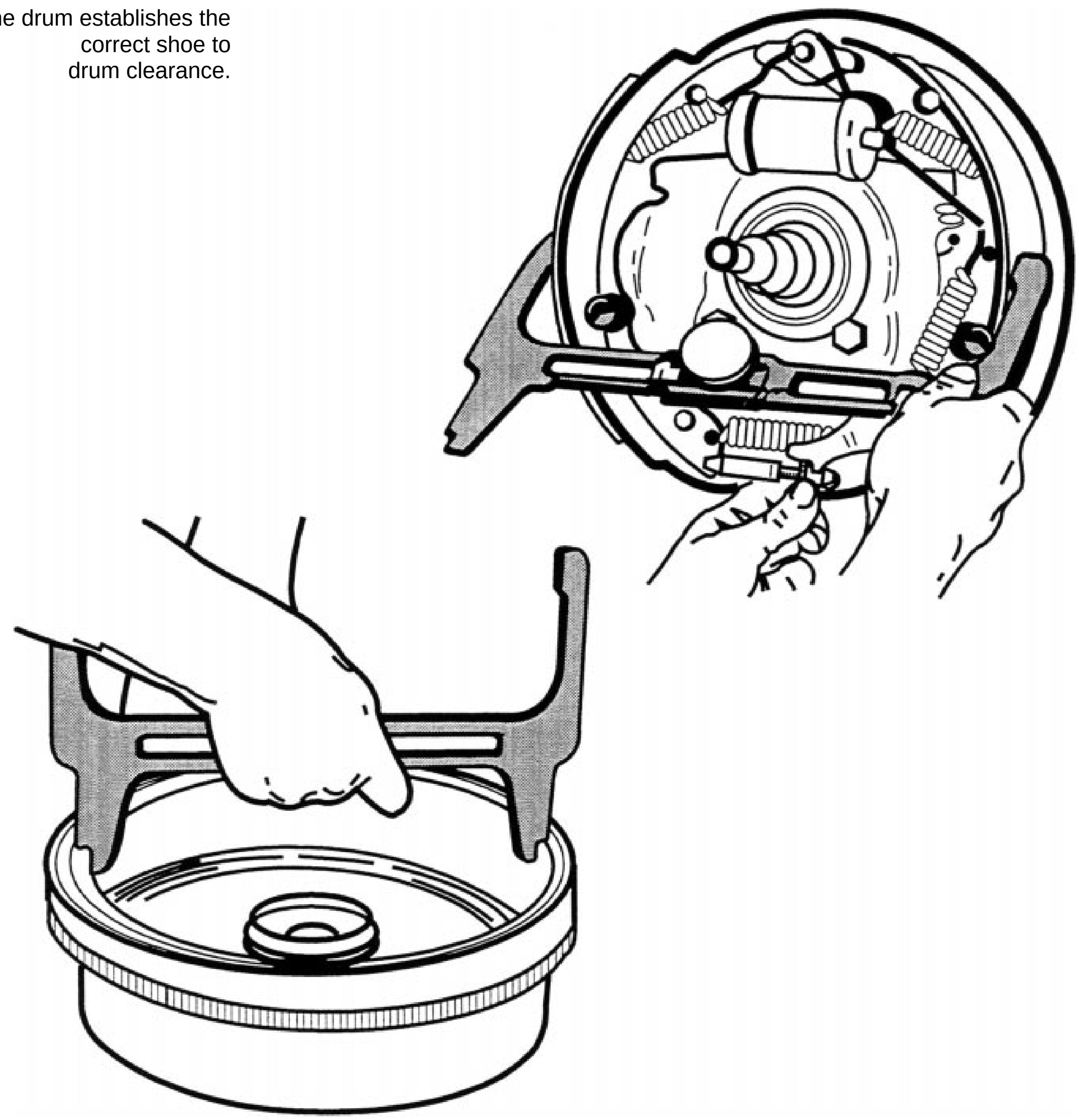
Brake Adjustment Caliper

A special gauge shown below is available from domestic tool sources which provides a built-in 0.030” clearance.

Using the narrow end of the gauge, place it in the drum and extend it the full diameter. Use the thumb screw to lock the position. Use the wide end of the gauge to set the brake shoe position. The shoe to drum clearance is preset in the tool design.

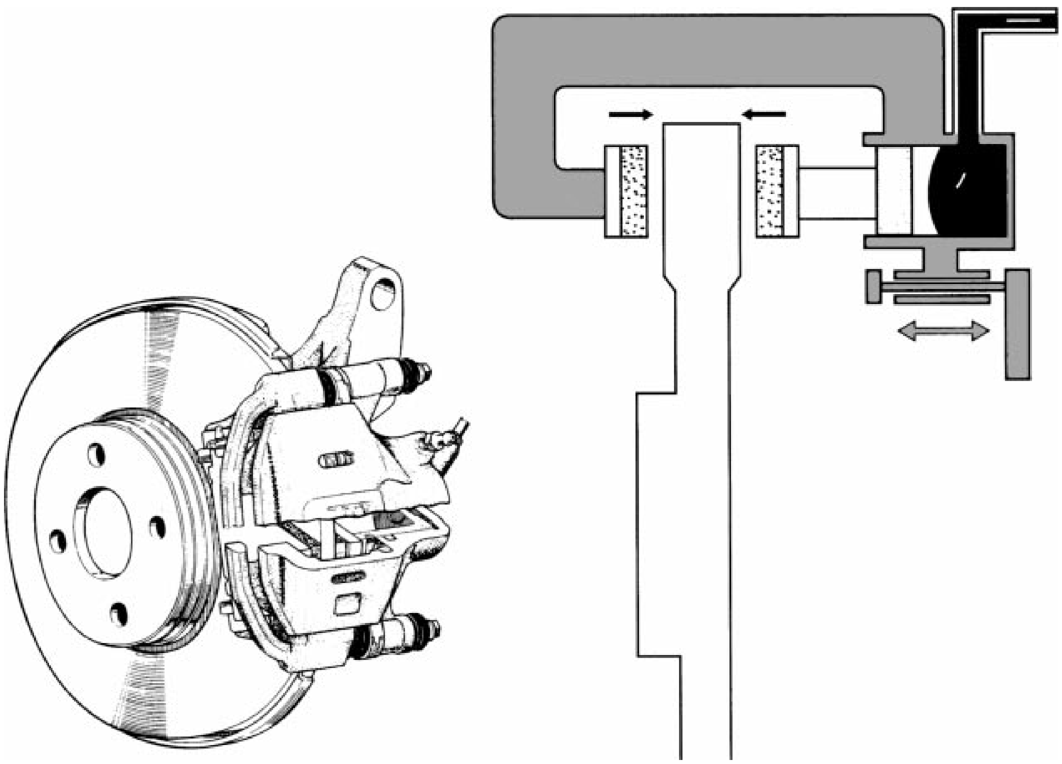
Brake Adjustment Caliper

Adjusting the caliper to the inside diameter of the drum establishes the correct shoe to drum clearance.



Section 4

DISC BRAKES



Lesson Objectives

1. Identify the components of the disc brake system.
2. List the advantages of a disc brake system over a drum brake system.
3. Describe the self-adjustment of the brake caliper piston.
4. Explain the function of anti-squeal shims and support plates for brake noise reduction.
5. List the advantages of multiple pistons on a fixed caliper design.

Components and Operation of Disc Brakes

A disc brake assembly consists of a:

- cast-iron disc (disc rotor) that rotates with the wheel.
- caliper assembly attached to the steering knuckle.
- friction materials (disc pads) that are mounted to the caliper assembly.

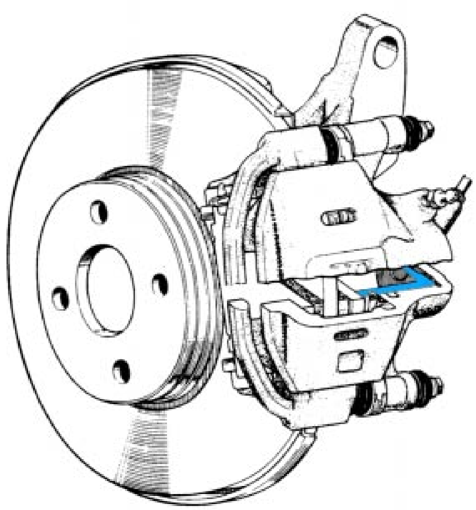
When hydraulic pressure is applied to the caliper piston, it forces the inside pad to contact the disc. As pressure increases the caliper moves to the right and causes the outside pad to contact the disc. Braking force is generated by friction between the disc pads as they are squeezed against the disc rotor. Since disc brakes do not use friction between the lining and rotor to increase braking power as drum brakes do, they are less likely to cause a pull.

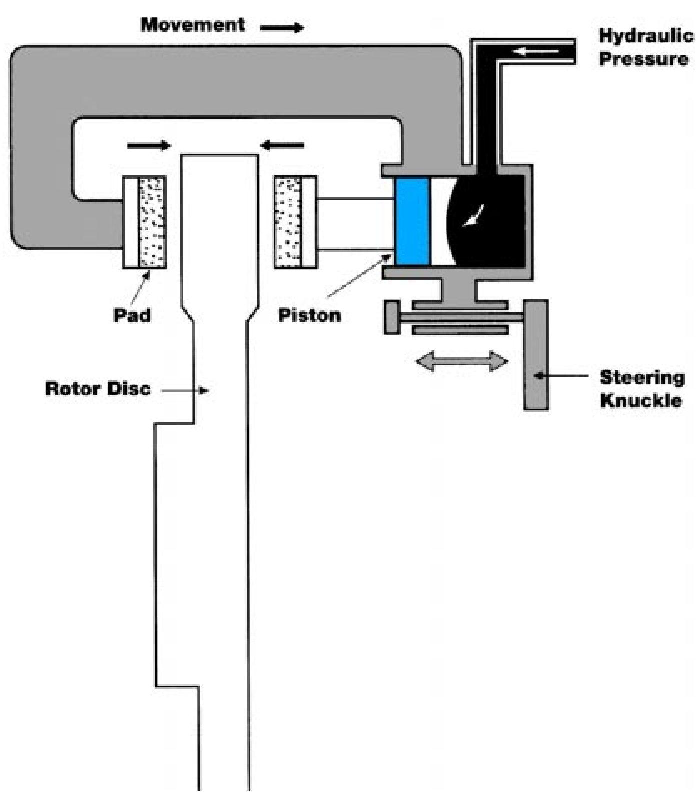
The friction surface is constantly exposed to the air, ensuring good heat dissipation, minimizing brake fade. It also allows for self-cleaning as dust and water are thrown off, reducing friction differences.

Unlike drum brakes, disc brakes have limited self-energizing action making it necessary to apply greater hydraulic pressure to obtain sufficient braking force. This is accomplished by increasing the size of the caliper piston. The simple design facilitates easy maintenance and pad replacement.

Disc Brake Assembly

Disc rotor, caliper and disc pads are the major components.





Disc Rotor

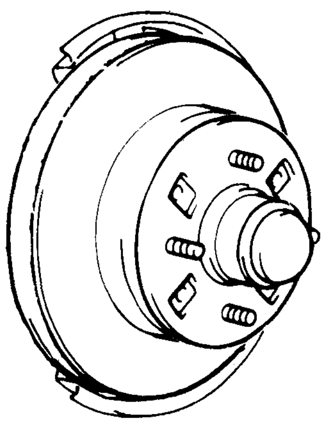
Generally, the disc rotor is made of gray cast iron, and is either solid or ventilated. The ventilated type disc rotor consists of a wider disc with cooling fins cast through the middle to ensure good cooling. Proper cooling prevents fading and ensures longer pad life. Some Ventilated rotors have spiral fins which creates more air flow and better cooling. Spiral finned rotors are directional and are mounted on a specific side of the vehicle. Ventilated rotors are used on the front of all late model Toyotas.

The solid type disc rotor is found on the rear of four wheel disc brake systems and on the front of earlier model vehicles.

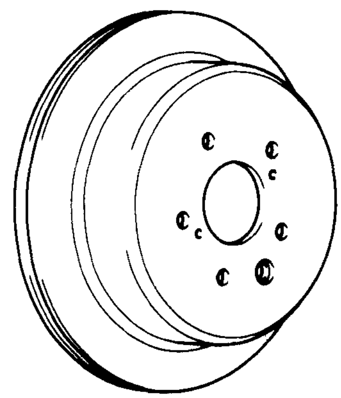
A third style rotor can be either the ventilated or solid type which incorporates a brake drum for an internal parking brake assembly.

Disc Rotor Types

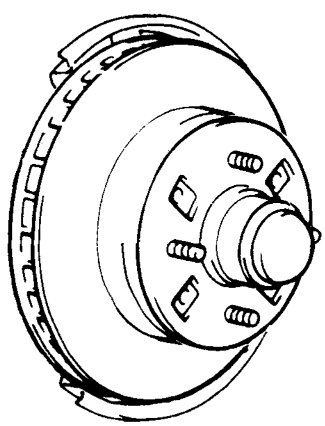
The type of rotor is determined by the vehicles intended use.



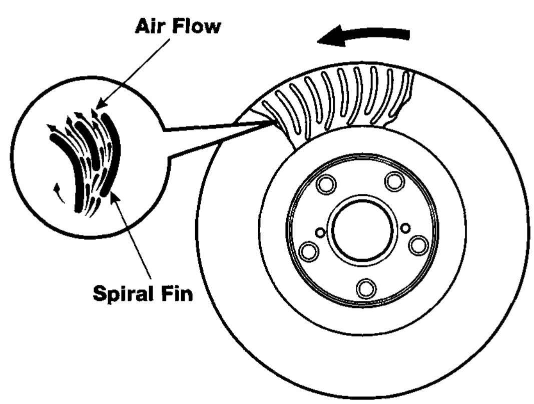
Solid Type



Solid Type With Drum



Ventilated Type



Caliper (Cylinder Body)

The caliper, also called the cylinder body, houses one to four pistons, and is mounted to the torque plate and steering knuckle or wheel carrier. It is found in floating caliper designs or fixed caliper designs on Toyotas.

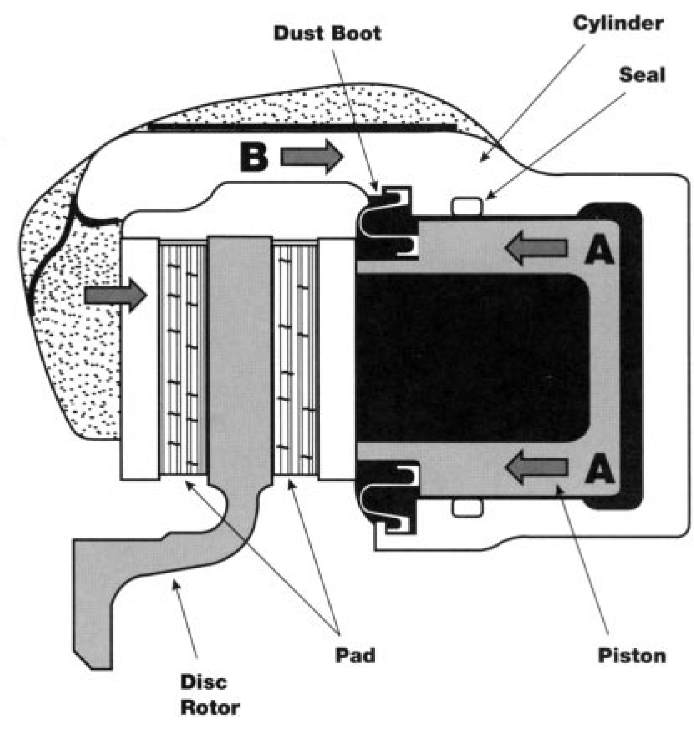
Floating Caliper Type

The floating caliper design is not only more economical and lighter weight but also requires fewer parts than it's fixed caliper counterpart. Depending on the application, the floating caliper has either one or two pistons.

The piston is located in one side of the caliper only. Hydraulic pressure from the master cylinder is applied to piston (A) and thus presses the inner pad against the disc rotor. At the same time, an equal hydraulic pressure (reaction force B) acts on the bottom of the cylinder. This causes the caliper to move to the right, and presses the outer pad located opposite the piston against the disc rotor.

Floating Caliper

The piston exerts pressure on the inside pad as well as
moving the caliper body to engage the outside pad.



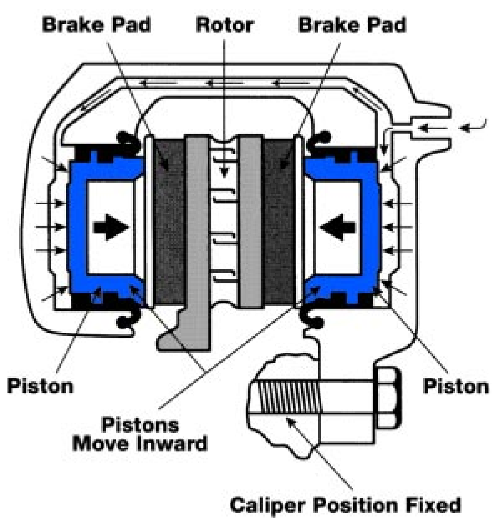
Fixed Caliper Type

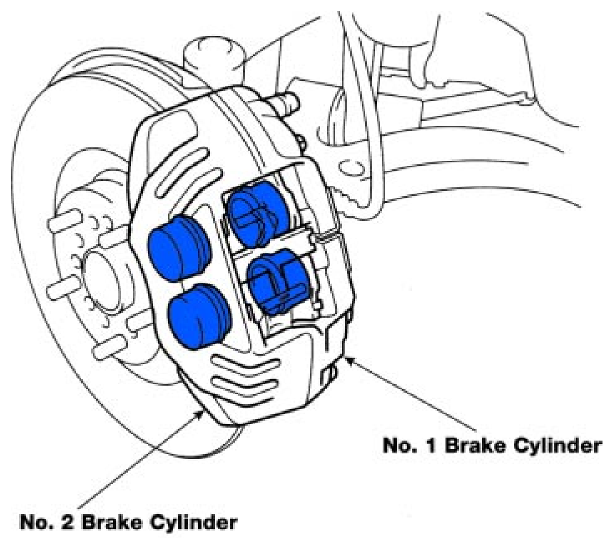
The fixed caliper design has pistons located on both sides of the caliper providing equal force to each pad. The caliper configuration can incorporate one or two pistons on each side. The ability to include multiple pistons provides for greater braking force and a compact design. Because these assemblies are larger and heavier than the floating caliper, they absorb and dissipate more heat. This design is able to withstand a greater number of repeated hard stops without brake fade.

This design is found on models which include larger engine displacement such as the V-6 Camry and Avalon as well as the Supra and four-wheel-drive Truck, T100 and Tacoma.

Fixed Caliper

The ability to include multiple pistons provides for greater braking force and a compact design.





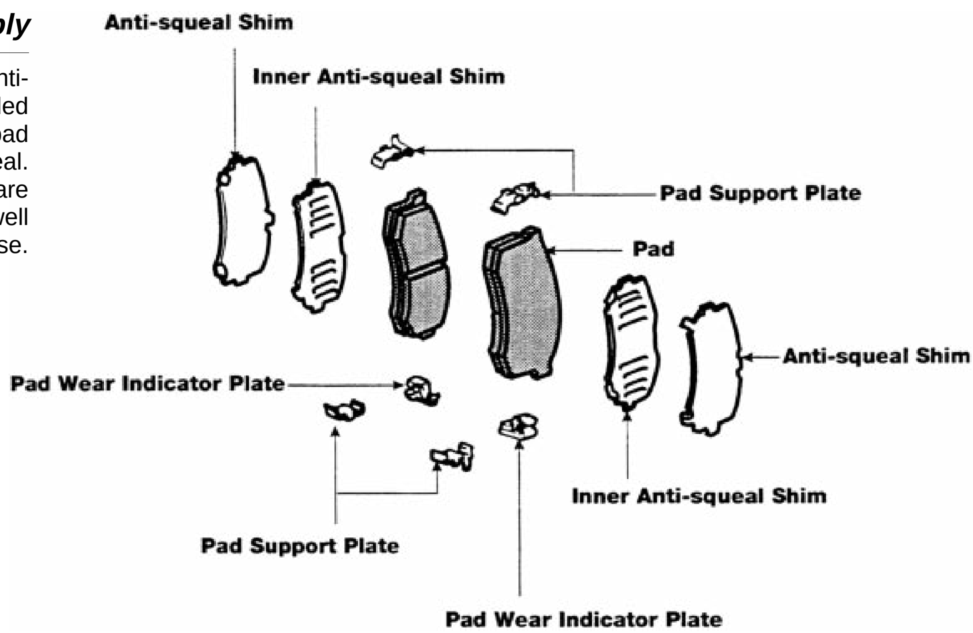
Brake Pad

Different brake design applications require different kinds of friction materials. Several considerations are weighed in development of brake pads; the coefficient of friction must remain constant over a wide range of temperatures, the brake pads must not wear out rapidly nor should they wear the disc rotors, should withstand the highest temperatures without fading and it should be able to do all this without any noise. Therefore, the material should maximize the good points and minimize the negative points.

Materials which make up the brake pad include friction modifiers, powdered metal, binders, fillers and curing agents. **Friction modifiers** such as graphite and cashew nut shells, alter the friction coefficient. **Powdered metals** such as lead, zinc, brass, aluminum and other metals increase a material's resistance to heat fade. **Binders** are the glues that hold the friction material together. Phenolic resin is the most common binder in current use. **Fillers** are added to friction materials in small quantities to accomplish specific purposes such as rubber chips to reduce brake noise.

Brake Pad Assembly

Multiple plates called anti-squeal shims, are provided on the piston side of the pad to minimize brake squeal. Various springs and clips are used to reduce rattle as well as reduce brake noise.



The brake pad material is bonded to a stamped steel backing plate with a high temperature adhesive to which heat and pressure are applied to cure the assembly. A slit is provided on the face of the pad to indicate the allowable limit of pad wear and provide a path for brake dust and gas to escape.

A metal plate, or in some applications multiple plates called anti-squeal shims, are provided on the piston side of the pad to minimize brake squeal. Various springs and clips are used to reduce rattle as well as reduce brake noise. Shims and plates should be inspected for wear and rust and can be re-used when replacing pads. Fresh approved grease should be applied to the shims prior to installation.

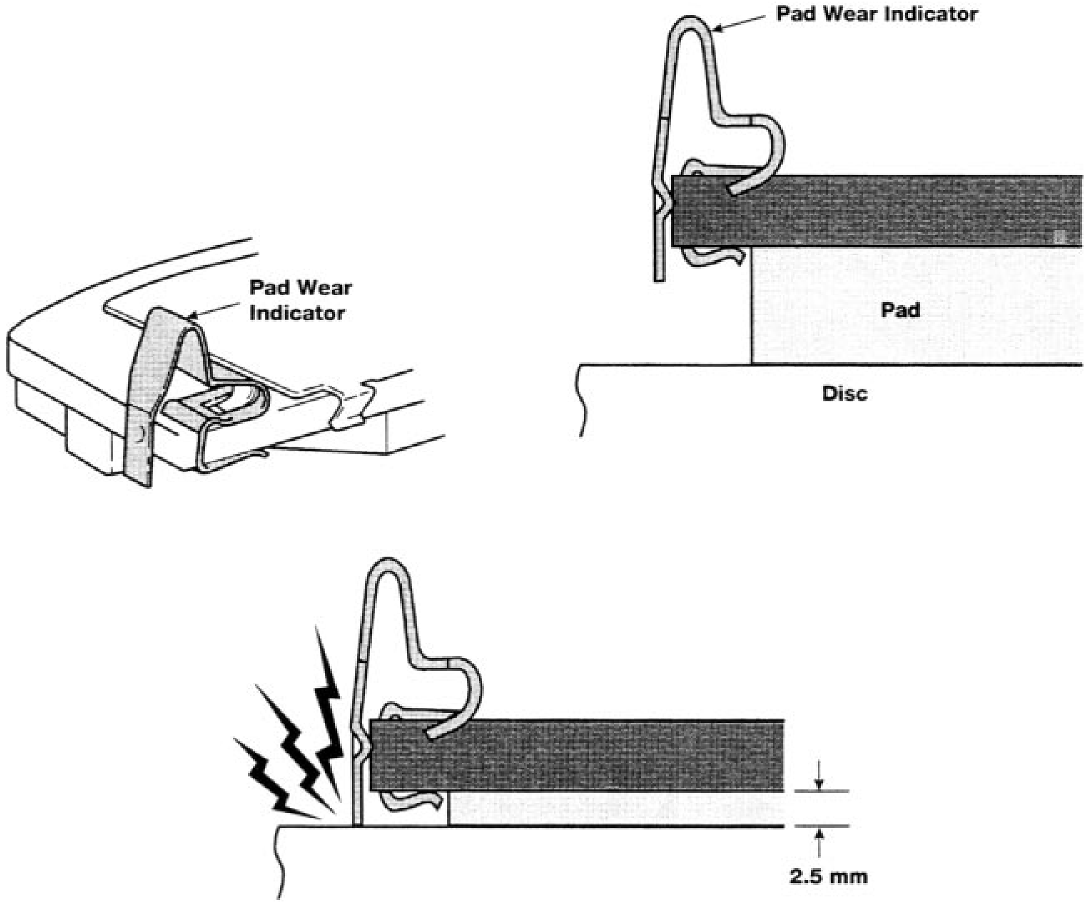
Pad Wear Indicator

A pad wear indicator has been adopted on some models that produces a high screeching noise when the pad is worn down to a predetermined thickness. The purpose of the indicator is to warn the driver and prevent damage to the rotor should the brake pad wear further. The indicator contacts the rotor while the wheel turns and the brakes are not applied. A customer may comment that the noise stops when the brakes are applied.

Be sure to install the wear indicators when new pads are installed.

Pad Wear Indicator

Produces a high screeching noise when the pad is worn down to a predetermined thickness.



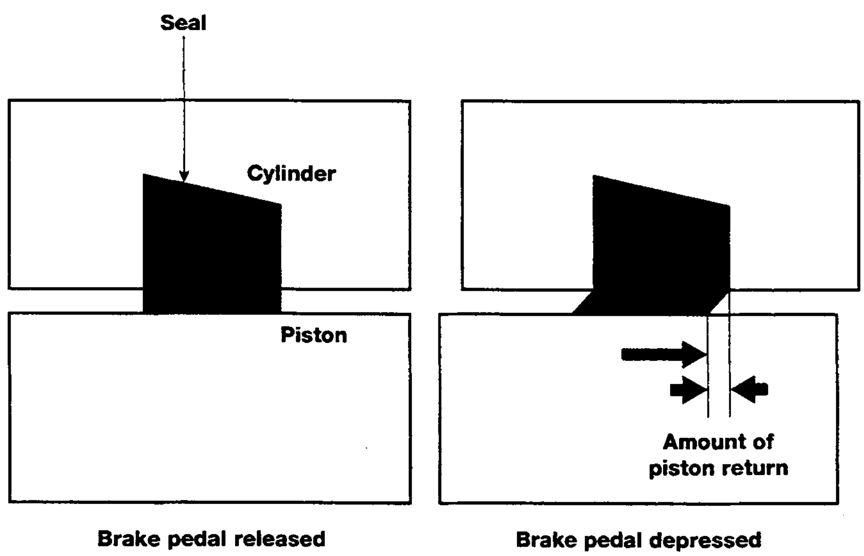
Automatic Adjustment of Rotor-to-Pad Clearance

Disc brakes also have the advantage of being self adjusting. The pads are always right next to the spinning rotor. This adjustment is maintained in all models by a square cut piston seal which is seated in a machined groove in the cylinder bore. Any wear of the lining is automatically compensated for by the action of the brake caliper.

When the brakes are applied, the caliper piston moves out toward the rotor until the brake pad contacts it. The piston seal twists or deforms elastically as shown below. When the brake pedal is released and hydraulic pressure is reduced, the piston seal returns to its original shape, pulling the piston back. As the brake pads wear, the piston continually moves outward through the seal to maintain proper pad to rotor clearance.

Self Adjusting Mechanism of the Disc Caliper

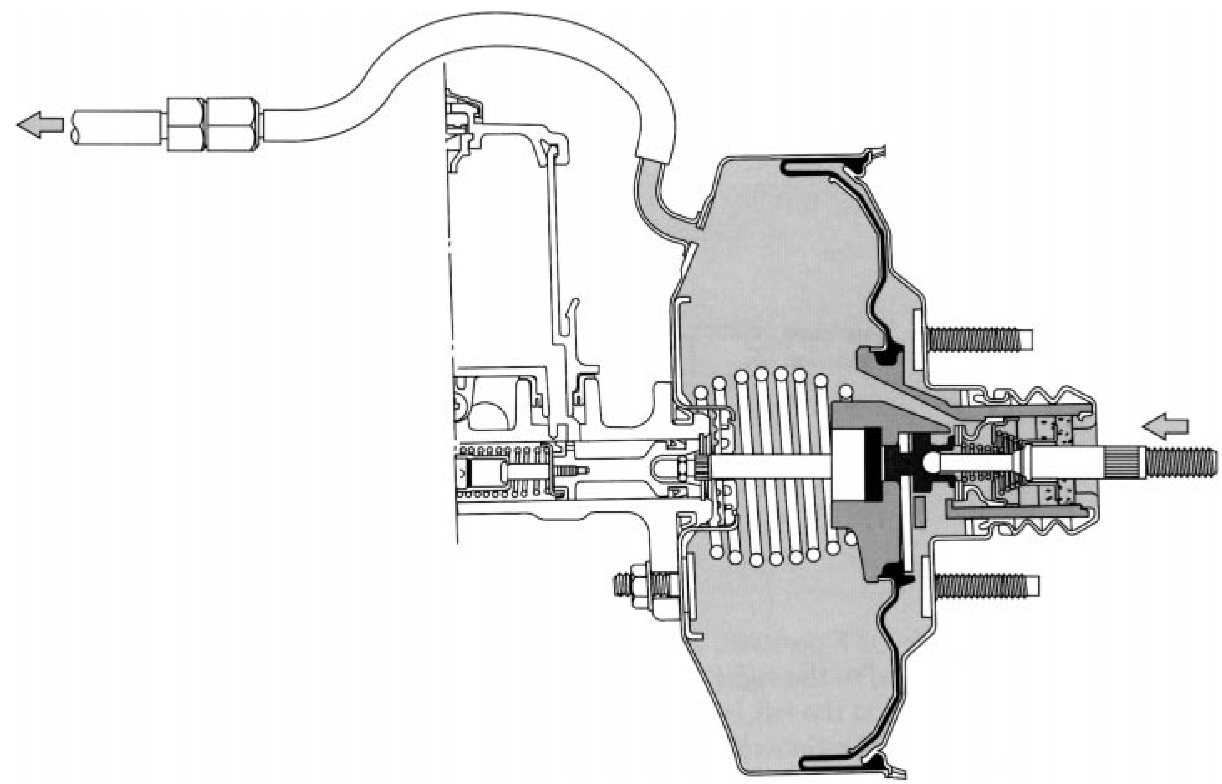
Piston seal deforms as the piston moves outward. It returns to its original shape, pulling the piston back when the brakes are released.



Notes

Section 5

BRAKE BOOSTER



Lesson Objectives

1. Explain the function of engine vacuum in providing brake assist to the master cylinder.
2. Perform the following booster tests using the brake pedal:
   - operating test
   - air tightness check
   - air tightness under load
3. Using a brake booster push rod gauge SST, measure booster push rod clearance and determine needed adjustment.
4. List the symptoms of an improperly adjusted booster push rod.

Brake Booster

The brake booster is designed to create a greater braking force from a minimum pedal effort, using a difference in atmospheric pressure and the engine's manifold vacuum. It increases the pedal force 2 to 4 times depending on the size of the diaphragm. The brake booster is located between the brake pedal and the master cylinder.

When pressure is applied to the brake pedal, pressure is exerted on the booster air valve. With pressure created by the booster the master cylinder is applied. Should the booster malfunction, the normal mechanical braking force of the master cylinder is maintained.

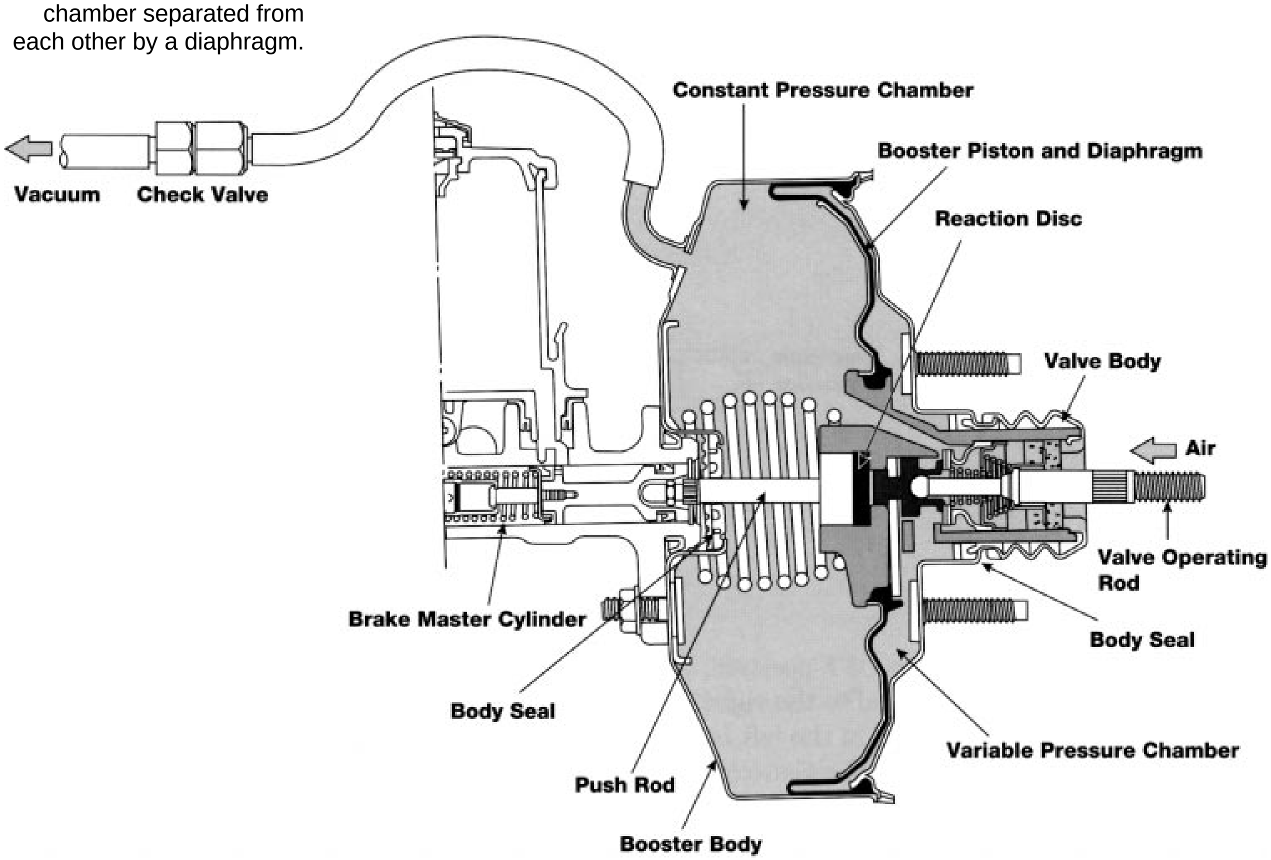
Construction

The brake booster consists of the **body, booster piston, piston return spring, reaction mechanism, and control valve mechanism**.

The body is divided into a constant pressure chamber and a variable pressure chamber. The chambers are separated from each other by a diaphragm. The control valve mechanism regulates the pressure inside the variable pressure chamber.

Single Diaphragm Booster

The body is divided into a constant pressure chamber and a variable pressure chamber separated from each other by a diaphragm.

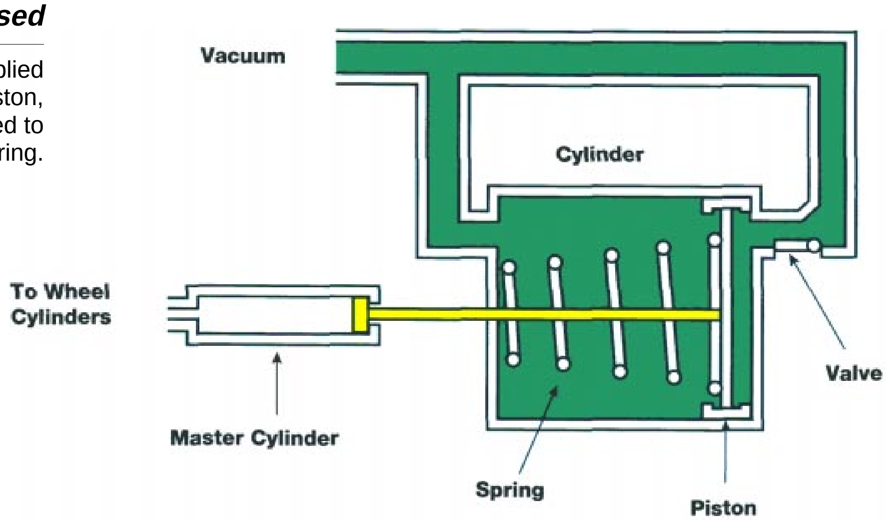


Basic Booster Operation

The basic principle of the brake booster is pressure differential. When vacuum is applied to both sides of the piston, the piston is pushed to the right by the spring and remains there.

Control Valve Closed

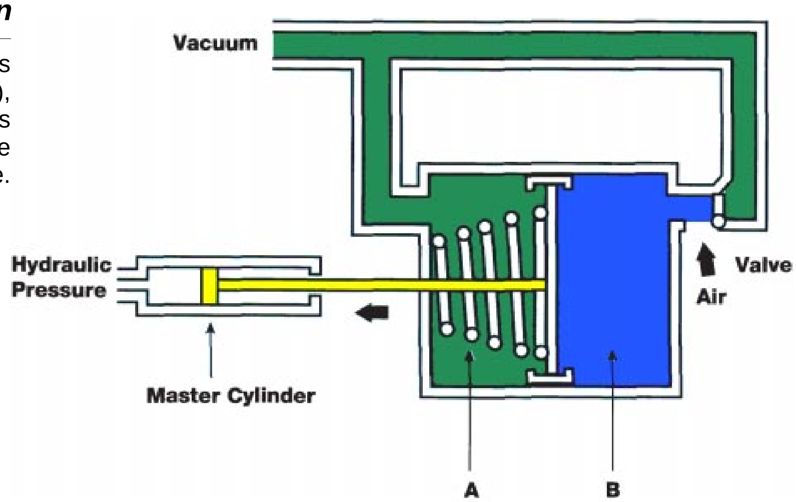
When vacuum is applied to both sides of the piston, the piston is pushed to the right by the spring.



When atmospheric air is allowed into chamber B the piston starts to compress the spring, due to the difference in pressure, and moves to the left. This causes the piston rod to move the piston of the master cylinder, generating hydraulic pressure.

Control Valve Open

When atmospheric air is allowed into chamber (A), the piston starts to compress the spring due to the difference in pressure.



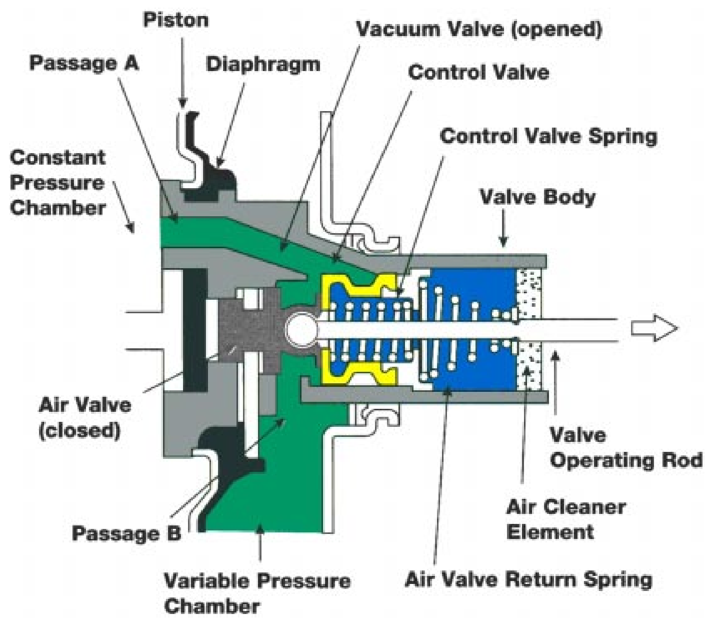
Booster Air Valve Operation

In the OFF position, the Air Valve (connected to the Valve Operating Rod) is pulled to the right by the Air Valve Return Spring. The Control Valve is pushed to the left by the Control Valve Spring. This causes the Air Valve to contact the Control Valve. Therefore, the atmospheric air that passes through the air cleaner element is prevented from entering the Variable Pressure Chamber.

The piston's Vacuum Valve is separated from the Control Valve in this position, providing an opening between passage A and passage B. Since there is always vacuum in the Constant Pressure Chamber, the opening allows vacuum into the Variable Pressure Chamber. As a result, the piston is pushed to the right by the piston return spring.

Booster Air Valve Brakes Not Applied

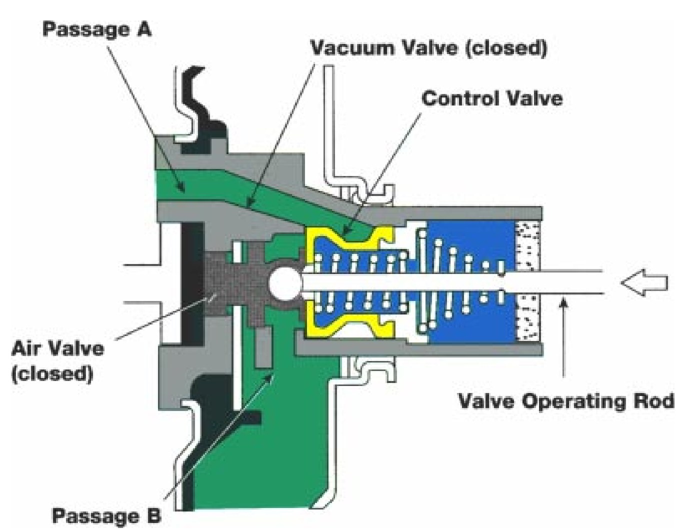
The Vacuum Valve is open allowing vacuum on both sides of the booster piston.



In the ON position, when the brake pedal is depressed, the Valve Operating Rod pushes the Air Valve to the left. The Control Valve which is pushed against the Air Valve by the Control Valve Spring, moves to the left until it touches the Vacuum Valve. This blocks off the opening between passage A and passage B (Constant Pressure Chamber (A) and Variable Pressure Chamber (B)).

Booster Air Valve Brakes Applied

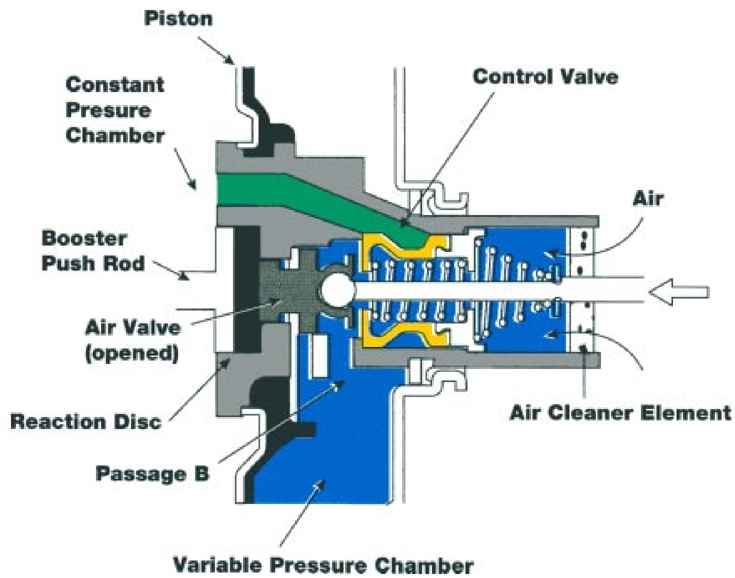
The vacuum valve is closed, cutting off the vacuum source to the variable pressure chamber.



As the Air Valve moves further to the left, it moves away from the Control Valve. This allows atmospheric pressure to enter the Variable Pressure Chamber through passage B. The pressure difference between the Constant Pressure Chamber and the Variable Pressure Chamber causes the piston to move to the left. This, in turn, causes the Reaction Disc to move the Booster Push Rod to the left and exert braking force.

Booster Air Valve Brakes Applied

Air Valve opens allowing atmospheric air to enter the variable pressure chamber.



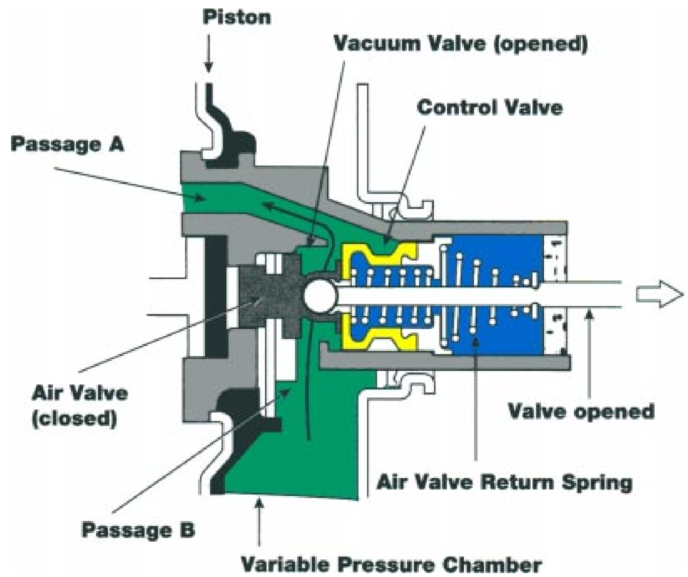
Released Position

When the brake pedal is released, the Valve Operating Rod and the Air Valve are moved to the right by the Air Valve Return Spring and reaction force of the master cylinder. This movement causes the Air Valve to contact the Control Valve, blocking atmospheric pressure from the Variable Pressure Chamber. At the same time, the Air Valve also retracts the Control Valve Spring. The Control Valve moves away from the Vacuum Valve, connecting passage A with passage B.

This allows atmospheric pressure from the Variable Pressure Chamber to flow into the Constant Pressure Chamber. The pressure difference is eliminated between the two chambers and the piston is pushed back to the right by the Diaphragm/Piston Return Spring. The booster returns to the released position.

Booster Air Valve Released Position

Pressure equalizes in the two chambers and the air valve is closed.



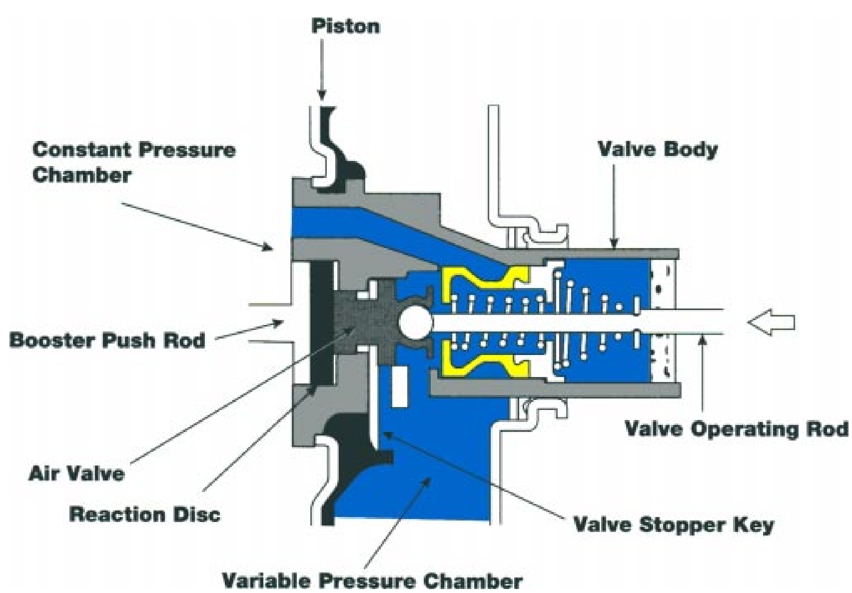
Lack Of Vacuum

If vacuum fails to act on the brake booster, for any reason, there will be no difference in pressure between the Constant Pressure Chamber and the Variable Pressure Chamber. When the brake is in the "OFF" position, the piston is returned to the right by the Piston Return Spring.

When the brake pedal is depressed, the Valve Operating Rod advances to the left and pushes the Air Valve, Reaction Disc, and Booster Push Rod. This movement causes the master cylinder piston to apply braking force to the brake system, maintaining brake system operation.

Booster Air Valve No Vacuum

Although the booster loses self-energizing force when vacuum is lost, it still generates hydraulic pressure mechanically and can maintain brake system operation.



Tandem Brake Booster

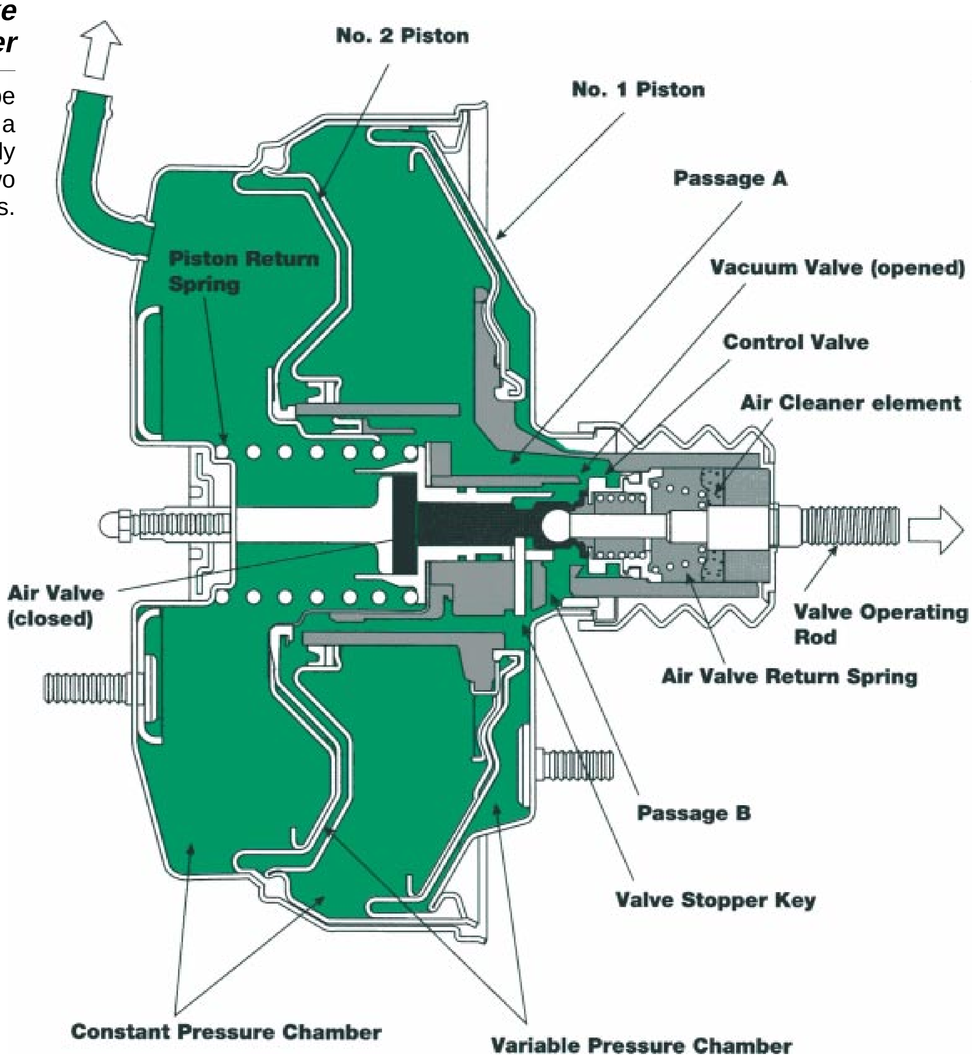
The tandem type brake booster is a compact and extremely powerful unit having two Constant Pressure Chambers and two Variable Pressure Chambers. A Piston separates each variable and constant pressure chamber. With two pistons incorporated into this design, a large surface area provides additional boost while taking up less space.

When the brakes are not applied the Air Valve and Valve Operating Rod are pushed to the right by the tension of the Air Valve Return Spring, and stop when they contact the Valve Stopper Key. Since the Air Valve pushes the Control Valve back toward the right, the passage through which atmospheric air from the air cleaner element enters the booster, is closed. Since the Vacuum Valve and the Control Valve are not in contact with each other, pressure is equalized between the two chambers through passage (A) and passage (B).

Therefore, vacuum is applied to both the Constant Pressure Chambers and the Variable Pressure Chambers; so, there is no difference in pressure between the chambers on both sides of the piston.

Tandem Brake Booster

The tandem type brake booster is a compact and extremely powerful unit having two vacuum chambers.



Brakes Applied

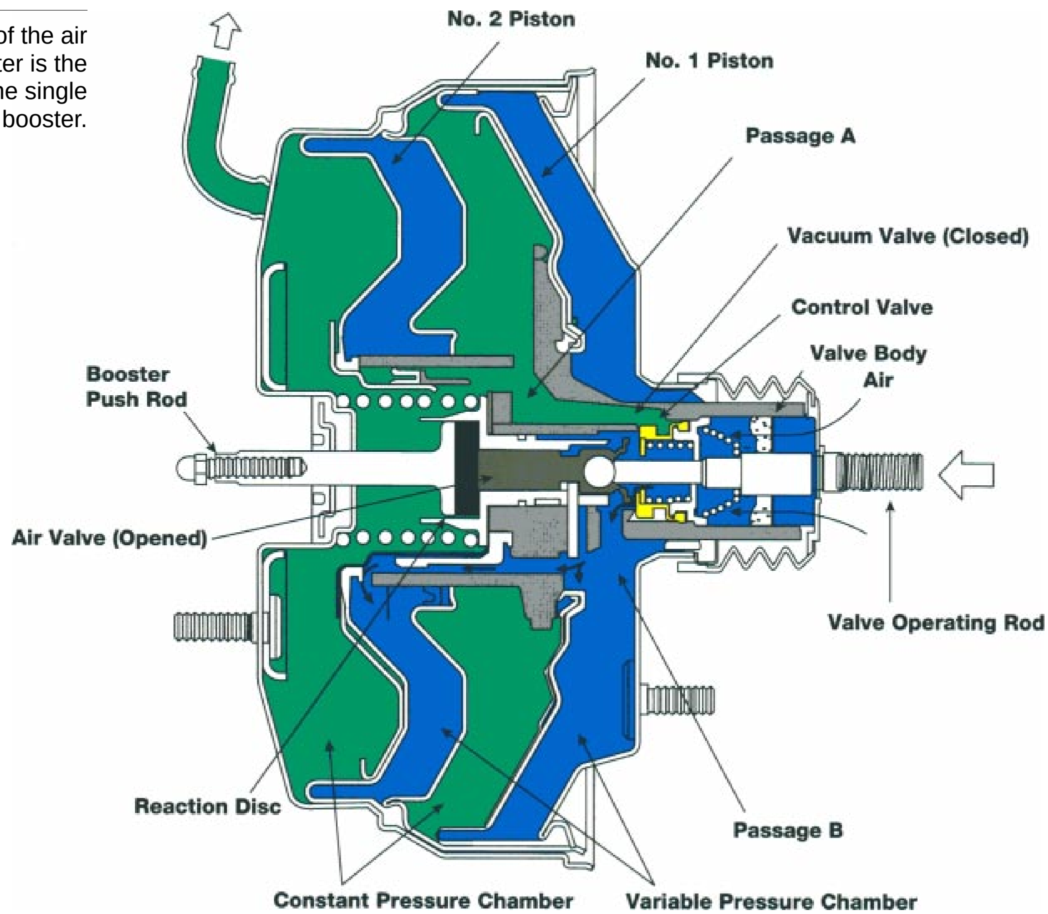
When the brake pedal is depressed, both the Valve Operating Rod and Air Valve are pushed to the left together. As a result, the Control Valve and Vacuum Valve come into contact with each other, closing passages (A) and (B) (the constant pressure chamber and variable pressure chamber).

Next, the Air Valve moves away from the Control Valve, and atmospheric air from the air cleaner element passes through passage (B) and enters the Variable Pressure Chamber. This generates a pressure difference between the Variable Pressure Chamber and the Constant Pressure Chamber, and the pistons move to the left.

The forces applied by the pistons, which occur due to the pressure difference, are transmitted to the Reaction Disc via the Valve Body. They are further transmitted to the Booster Push Rod, becoming the booster output force. The combined surface area of pistons No. 1 and No. 2, multiplied by the pressure difference between the Constant Pressure Chamber and Variable Pressure Chamber, equals the booster output force.

Tandem Brake Booster - Brakes Applied

The operation of the air valve and booster is the same as the single diaphragm booster.



Booster Diagnosis

The following steps are taken to diagnose the brake booster.

Operating Check

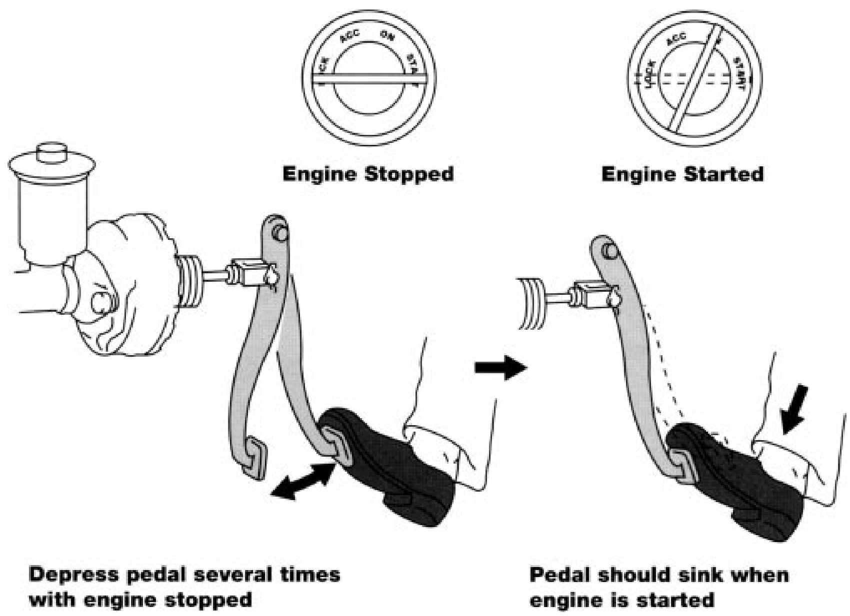
With the engine stopped, depress the brake pedal normally, several times. The brake pedal must be depressed before the engine is started in order to remove vacuum from the booster.

With the brake pedal depressed start the engine. When the engine is started, vacuum is created and operates the booster. This causes the brake pedal to go down.

If the brake pedal goes down slightly, the booster is operating normally. If the brake pedal does not move, the booster is not receiving manifold vacuum, or is malfunctioning.

Booster Operating Check

The brake pedal should sink when the engine starts.

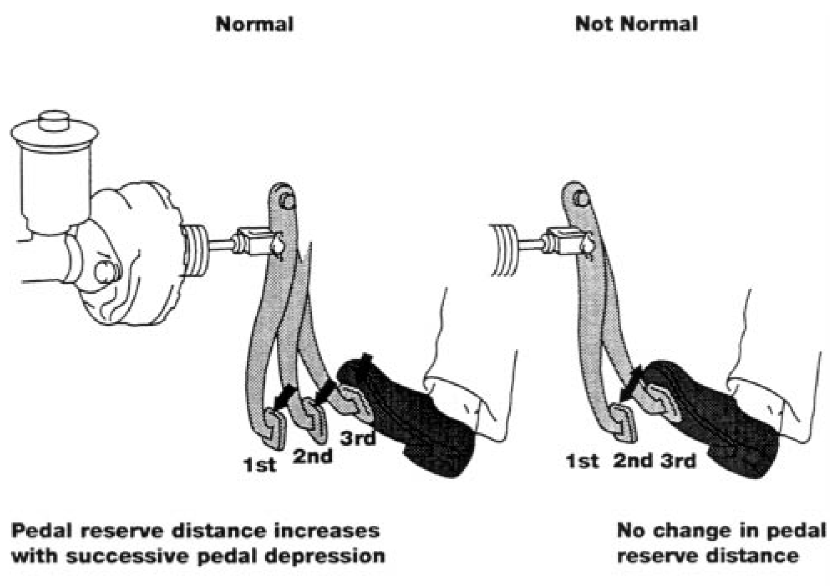


Air Tightness Check

Start the engine and let it run for one or two minutes, then shut it off. Now step on the brake pedal several times, applying normal pressure. Be sure to wait about five seconds between each depression of the pedal. If the brake pedal reserve distance increases every time the pedal is depressed, the booster has good air tightness.

Booster Air Tightness Check

Pedal reserve distance increases with successive pedal depressions.



The brake pedal reserve distance changes every time the pedal is depressed, because the vacuum that is stored in the booster is reduced every time the brake pedal is depressed.

The brake pedal reserve distance will not change if the Check Valve is defective. The check valve is located on the vacuum booster body or between the booster body and the source of engine vacuum. It's purpose is to act as a one-way valve and seal vacuum in the booster to provide at least two power assist stops should the engine stop running. To check the Check Valve and vacuum hose piping use the following procedure:

- Remove the vacuum hose and valve from the booster.
- Block the valve with a finger and start the engine.
- A strong vacuum should be felt if the piping and valve are operating.
- The vacuum must remain unchanged for approximately one minute after the engine is stopped.

Lack of vacuum indicates a malfunction in the check valve or the vacuum hose piping. If the vacuum appears normal, there may be a problem in the booster itself.

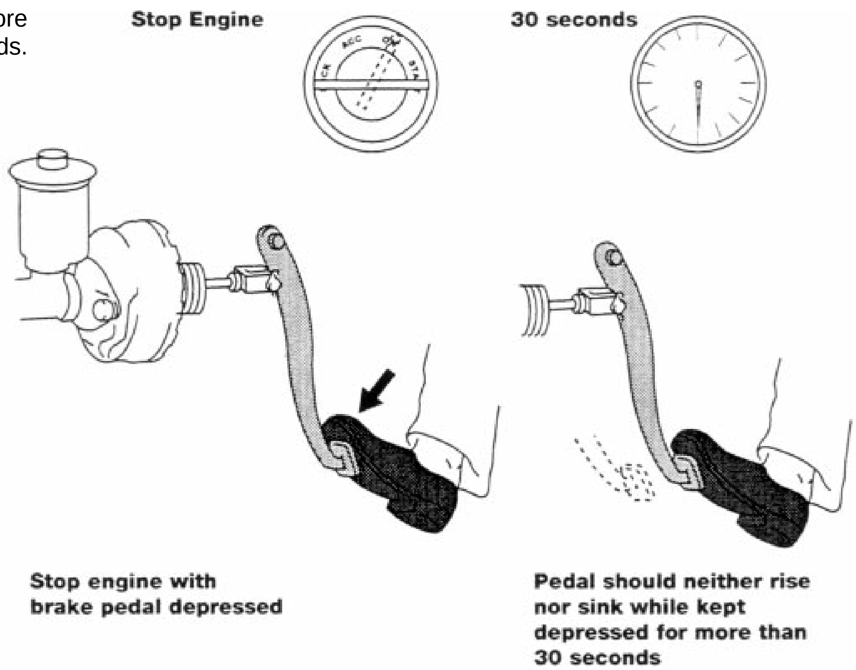
Air Tightness Test Under Load

Depress the brake pedal when the engine is running, then stop the engine and wait for about 30 seconds. If the brake pedal position does not change, the brake booster is functioning normally. It is defective if the brake pedal moves up.

The brake pedal reserve distance remains unchanged because vacuum is maintained in the Constant Pressure Chamber.

Booster Air Tightness Under Load

Stop the engine with the brake pedal depressed, the brake pedal should maintain the same height for more than 30 seconds.



Booster Push Rod Adjustment

The Booster Push Rod projects from the front of the Brake Booster and activates the master cylinder. The push rod is adjustable and the clearance must be checked any time the master cylinder or booster is replaced. This is required to ensure the correct gap between the master cylinder piston and the booster push rod.

Problems can occur if the push rod is improperly adjusted:

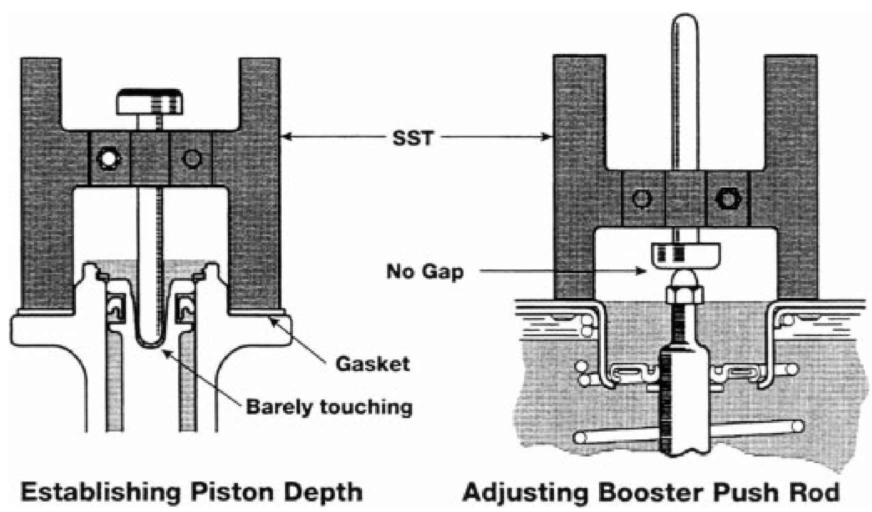
- If the gap is too small, it may cause brake drag and premature brake wear.
- If the gap is too large, it may cause brake delay and reduced pedal reserve distance.

Prior to making the adjustment:

- Check the brake pedal freeplay to ensure the booster is not partially applied.
- Make the adjustment with the engine running to ensure the booster has vacuum. The booster body will change shape when a vacuum is applied and may reduce the clearance.

Booster Push Rod Gauge

The push rod is adjustable and the clearance must be checked any time the master cylinder is replaced.



Adjusting Procedure:

1. Place a new gasket on the flange of the master cylinder. Set the push rod gauge over the end of the master cylinder with the rounded end of the tool plunger toward the piston.
2. Push the plunger down until it just touches the bottom of the piston bore.
3. Turn the gauge over and set the flat plunger end of the gauge on the booster and over the push rod. There should be no clearance between the booster push rod and the plunger.
4. Adjust the booster push rod if necessary. (If the brake pedal is depressed to expose the adjustment nut, be sure to start the engine before checking the adjusted clearance.)

Alternate Method for Booster Adjustment

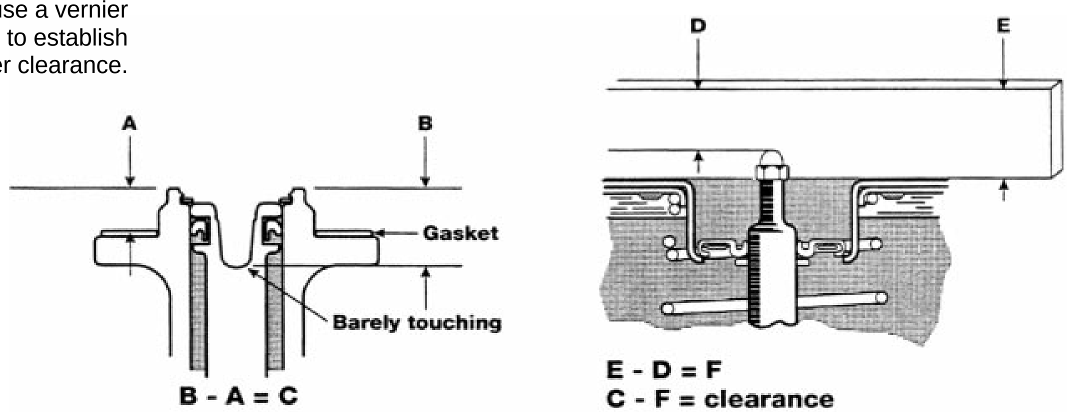
The preferred method of adjustment is the Booster Push Rod Gauge procedure just described. If the special service tool is not available the measurement procedure described here can be used to ensure a calculated clearance prior to installation of the master cylinder.

In this procedure, measure the distance between the bottom of the bore in the master cylinder primary piston to the top of the flange gasket using a depth micrometer or vernier caliper.

1. Measure from the rim of the cylinder bore to the new gasket on the flange, (measurement “A”)
2. Measure from the rim of the cylinder bore to the bottom of the bore in the primary piston, (measurement “B”)
3. Subtract A from B will give the depth of the piston bore from the master cylinder flange gasket, (measurement “C”)

Alternate Measurement Method

If the Booster Push Rod Gauge is not available, use a vernier caliper to establish proper clearance.



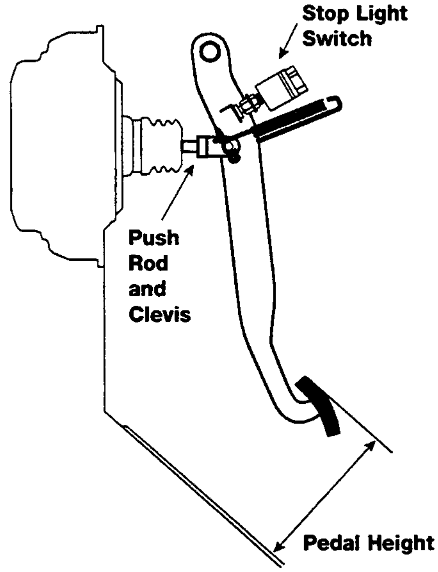
Next, measure the height of the booster push rod.

1. Place a precision straight edge across the face of the booster body adjacent to the push rod.
2. Measure from the top of the straight edge to the top of the push rod. (measurement “D”)
3. Measure the width of the straight edge, (measurement “E”)
4. Subtract measurement “D” from “E” will give the height of the push rod. (measurement “F”)
5. Clearance is determined by subtracting “F” from “C”.
6. Adjust the push rod to obtain approximately 0.1 mm to 0.5 mm clearance.

WORKSHEET 5-1 (ON-CAR)
Brake Pedal Measurement

Vehicle	Year/Prod. Date	Engine	Transmission

In this Worksheet you will practice the procedure for measuring pedal height, pedal free play and pedal reserve distance.



Tools and Equipment:

- Measuring tape.
- Assortment of open-end wrenches.
- Feeler gauge.
- Trim removal tool.

Pedal Height:

1. Pull the carpet down from the bulkhead to the foot well to reveal the asphalt melt sheet, (remove sill plate or trim as needed)
2. Using the measuring tape, measure at a right angle from the brake pedal pad to the melt sheet.
3. Record your measurement in the box below.

Measured Brake Pedal Height	Specification	Pass/Fail

1. Is the brake pedal height adjustable? If yes, explain how.

____

____

____

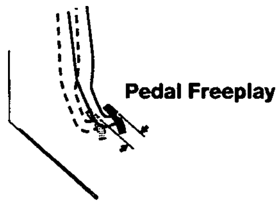
2. What effect would a low pedal height have on the brake system? Explain your answer.

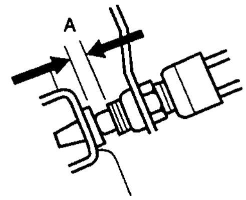
____

____

Brake Pedal Freeplay:

1. Stop the engine and depress the brake pedal several times until there is no vacuum in the booster.
2. Depress the pedal by hand until the beginning of resistance is felt. Record this measurement below.





Measured Brake Pedal Freeplay	Specification	Pass/Fail

1. Why is the vacuum booster depleted before checking brake pedal freeplay?

____

____

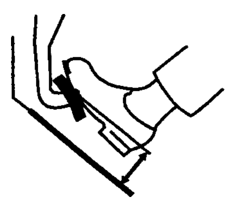
2. If brake pedal freeplay is less than specification, what possible adjustment should be checked?

____

____

Brake Pedal Reserve Distance:

1. Release the parking brake.
2. With the engine running, depress the pedal with approximately 110 pounds of force.
3. Measure the pedal reserve distance at a right angle from the pedal pad to the melt sheet.



Measured Brake Pedal Reserve Distance	Specification	Pass/Fail

1. If the brake pedal height is within specification but pedal reserve distance is insufficient, list several possible causes?

____

____

2. Is brake pedal reserve distance adjustable? If yes, explain.

____

____

WORKSHEET 5-2 (ON-CAR)
Booster Push Rod Adjustment

Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this Worksheet you will practice the procedure for measuring booster push rod to master cylinder clearance.

Tools and Equipment:

- Depth Micrometer.
- Straight Edge.
- Push Rod Gauge. (SST 09737-00010)
- 10mm combination wrench.
- Tubing Wrench set.
- Plugs for master cylinder ports.

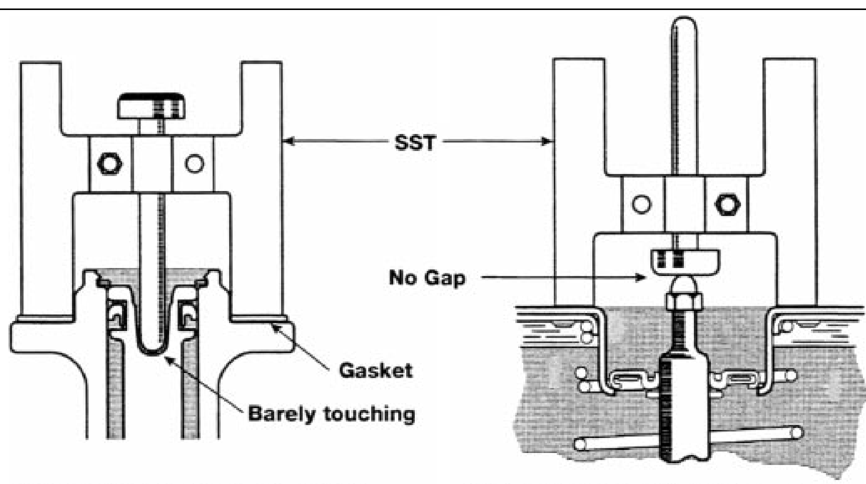
Preparation:

- With the engine off, pump the brake pedal several times to reduce vacuum in the booster.
- Loosen and remove the brake tubes from the master cylinder.
- Remove the master cylinder from the brake booster.

Measurement: (Using the special service tool)

1. Place a new gasket on the master cylinder.
2. Centering the Push Rod Gauge pin over the master cylinder piston and position the gauge on the gasket of the master cylinder.
3. Lower the pin into the piston until it lightly touches the bottom of the bore.
4. Start the engine and turn the opposite end of the gauge and center the head of the pin over the booster push rod.
5. Adjust the push rod as needed to ensure no gap between the push rod and the head of the pin.
6. Turn the engine OFF, deplete the vacuum in the booster by depressing the brake pedal several times.
7. Place the gauge over the booster push rod and push the pin toward the push rod. Did it move? Why?

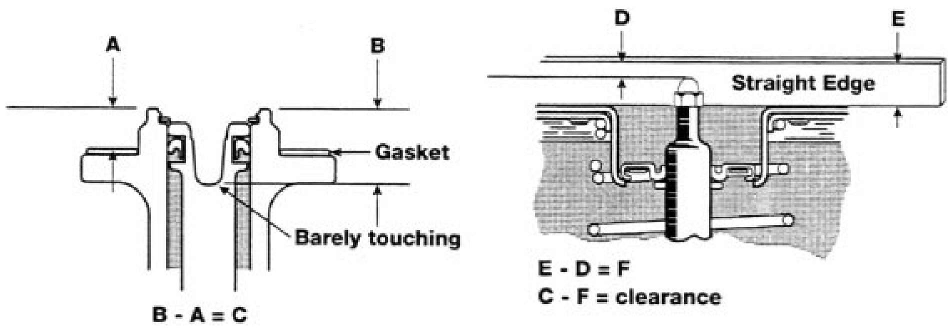
____



Establishing Piston Depth   Adjusting Booster Push Rod

Measurement: (Using the depth gauge)

- Place a new gasket on the master cylinder.
- Using a depth micrometer measure from the rim flange of the cylinder bore to the new gasket. This is measurement A.
- Using a depth micrometer measure from the rim flange of the cylinder bore to the bottom of the piston bore. This is measurement B.
- Place a straight edge over the brake booster gasket mating surface.
- Measure from the top side of the straight edge to the top of the booster push rod. This is measurement C.
- Subtract measurement C from the width of the straight edge to get measurement F. (push rod height)



Summary:

1. Using the measurements below, calculate the push rod clearance.
   A =13.76 mm
   B = 20.8 mm
   D = 28.5 mm
   E = 35.5 mm

   ____

2. List two occasions when this adjustment should be done.

   ____

   ____

3. What difference is there between performing the adjustment with the engine running and not running?

   ____

   ____

4. If the push rod was too long, what is the most likely result?

   ____

   ____

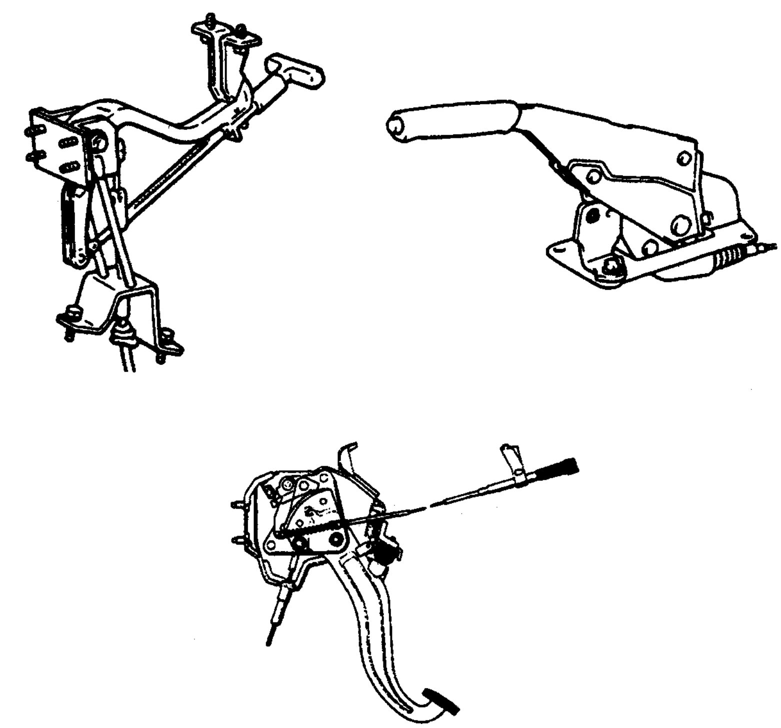
5. If the push rod is too short (the clearance between the push rod and master cylinder piston is too great), what is the most likely result?

   ____

   ____

Section 6

PARKING BRAKE



Lesson Objectives

1. Describe the purpose of the parking brake system.
2. Explain the clutch spring and sleeve nut function in maintaining the adjustment of the caliper parking brake.
3. Describe the procedure to reseat the piston of the caliper parking brake during pad replacement.
4. Explain the operation of the exclusive parking brake assembly.

Parking Brake Mechanisms

The parking brake system is a secondary braking system used to hold a parked car in position. They are applied independently of the service brakes. Since there is no inertia to overcome, less braking power is required to hold the vehicle stationary and less force is required to apply. The application of only two of the four brake assemblies are required to hold the vehicle.

There are three styles of rear parking brake systems. Two types use the service brake and the other is an exclusive parking brake design. The service type parking brake uses part of the ordinary service brake mechanism and operates the shoe or piston mechanically.

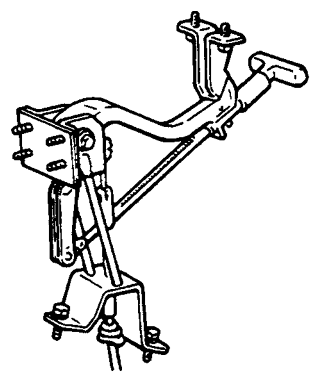
The parking brake lever is located near the driver's seat. Pulling the parking brake lever by hand or pressing the pedal with the foot, operates the brake via a cable connected to the parking brake lever of the brake assembly.

There are a number of different types of parking brake levers, as shown below. Application depends upon the design of the driver's seat and the desired operating effort.

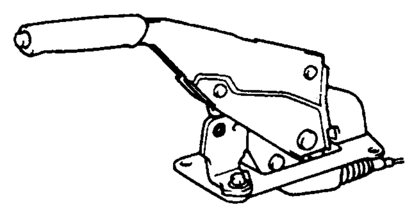
The parking brake lever is provided with a ratchet locking mechanism to maintain the lever at the position to which it was set, until released. Some parking levers have an adjusting screw near the brake lever so the amount of brake lever travel can be easily adjusted. Travel is determined by the number of clicks of the ratchet mechanism found in the Repair Manual.

Parking Brake Levers

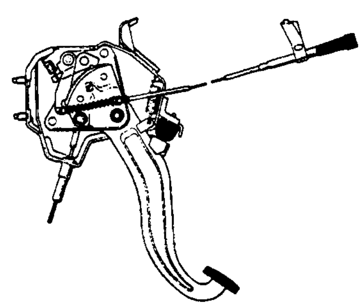
A ratchet locking mechanism holds the lever in position when set.



Stick Type



Center Lever Type



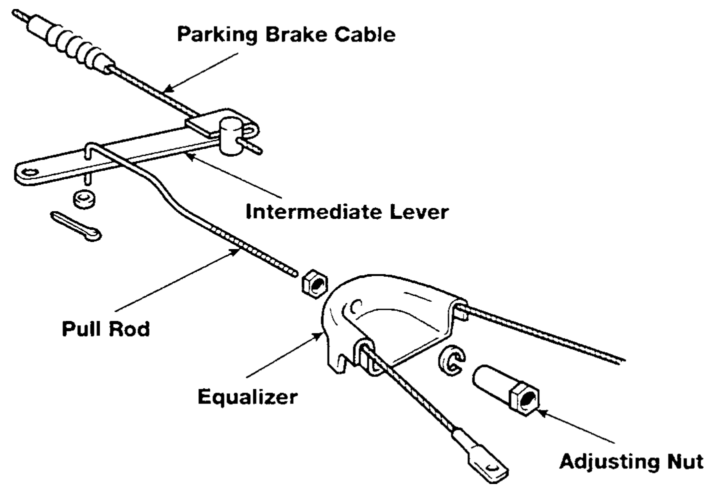
Pedal Type

Parking Brake Linkage

The parking brake cable transmits the lever movement through a typical series of components, as shown below, to the brake drum subassembly. The Intermediate Lever multiplies the operating force to the Equalizer. The Equalizer divides the lever operating force to brake assemblies at both wheels. The two major parts may vary in design however, their function remains the same.

Linkage Components

The intermediate lever multiplies the operating force to the equalizer. The equalizer divides the force to brake assemblies at both wheels.

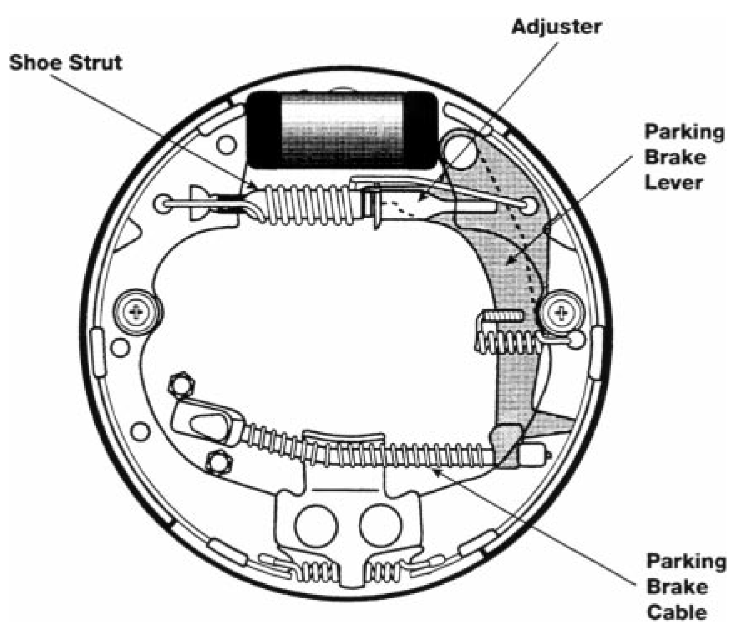


Drum Parking Brake

On all models using drum brakes on the rear, the cable pulls the parking brake lever. The lever *is* attached to the secondary shoe at the top and transfers the lever action to the primary shoe through the shoe strut. When released, the brake shoe springs return the shoes to their retracted position.

Drum Type Parking Brake Components

The cable pulls the parking brake lever and transfers the lever action to the primary shoe through the shoe strut.



Disc Parking Brakes

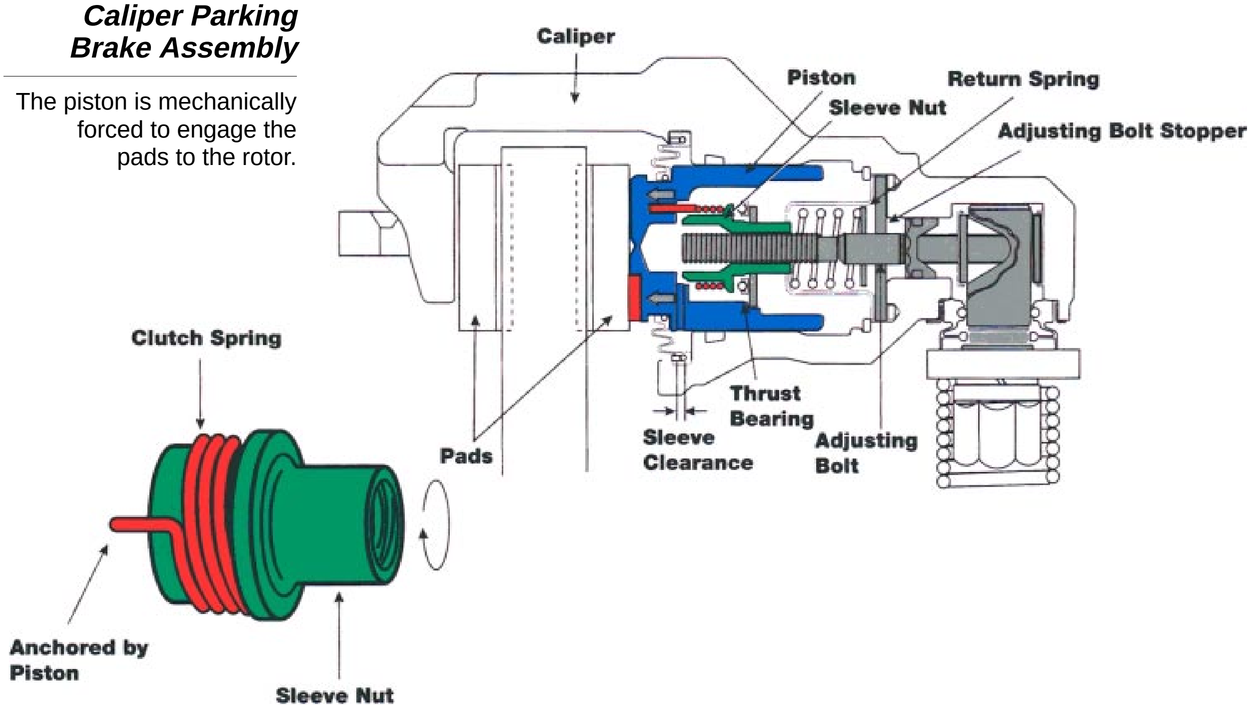
There are two types of rear wheel parking brake systems for disc brakes. The first uses the brake caliper assembly to mechanically apply pressure to the disc. The second type is an exclusive drum brake assembly that applies pressure to an inside drum, which is an integral part of the disc rotor.

Caliper Parking Brake

The parking brake is built into the caliper housing and is provided with an automatic adjusting mechanism to compensate for piston movement as the brake pads wear.

Caliper Parking Brake Assembly

The piston is mechanically forced to engage the pads to the rotor.



Automatic Adjusting Mechanism

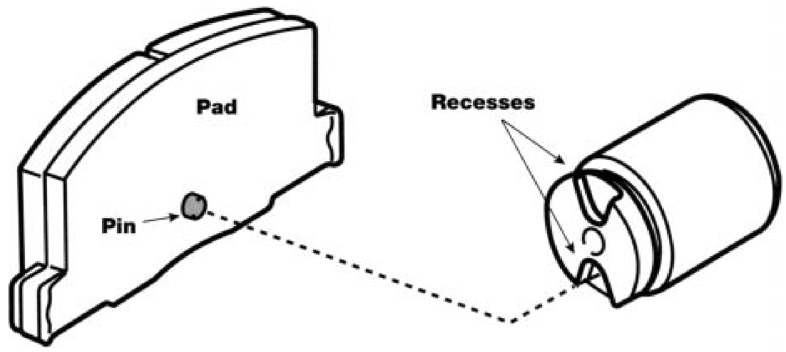
The automatic adjusting mechanism maintains the operating clearance between the pads and the rotor as the pads wear down with use. The primary assembly which makes this possible is the Sleeve Nut and Adjusting Bolt. The Sleeve Nut is held by the Clutch Spring which allows it to turn in one direction only. The diameter of the Clutch Spring is slightly smaller than the diameter of the sleeve nut and allows it to turn in the unwind direction only. The clutch spring is held stationary with one end attached to the piston.

When the brake pedal is depressed, hydraulic pressure forces the piston to move to the left. The movement of the Piston exerts pressure on the Thrust Plate and Thrust Bearing against the Sleeve Nut causing it to be screwed out from the stationary Adjusting Bolt. The Sleeve Nut can be easily screwed out because the Clutch Spring unwinds and therefore does not prevent the Sleeve Nut from rotating. The distance that the Sleeve Nut screws out from the Adjusting Bolt is equal to the amount of pad wear.

The piston head is provided with two recesses, one of which engages with a pin that protrudes from the backing plate of the brake pad. This pin prevents the piston from being rotated by the automatic adjuster. The adjusting bolt stopper prevents the adjusting bolt from rotating. The only part allowed to turn is the sleeve nut.

Piston Head Design

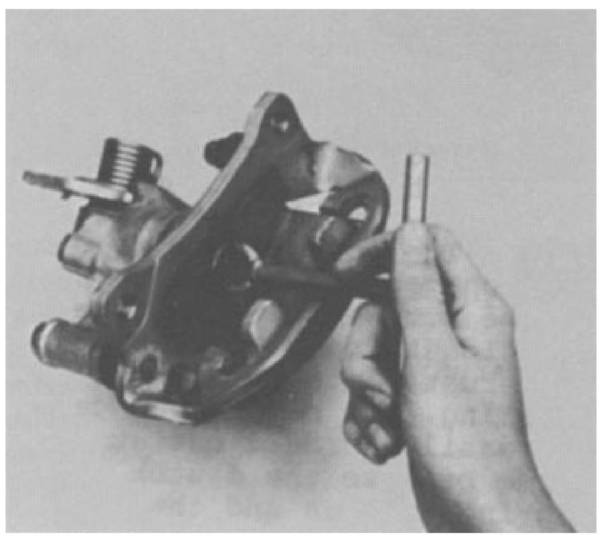
The pin on the brake pad is indexed to the recess of the piston head to prevent the piston from rotating.



When brake pads are replaced, the piston with the sleeve nut must be forcibly rotated into the cylinder with the Special Service Tool shown below (SST 09719-00020).

Rear Caliper Pad Replacement

The piston must be forcibly screwed into the cylinder with the SST.



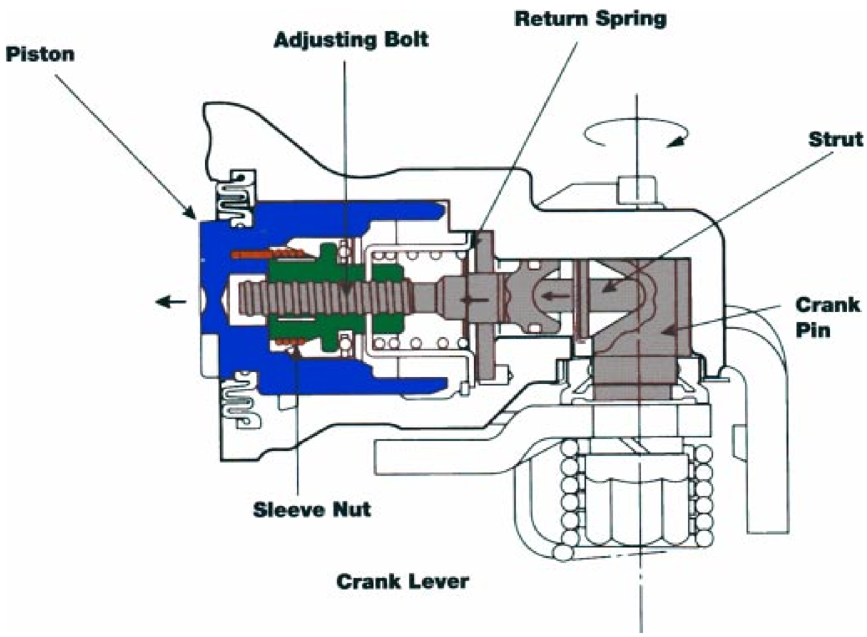
After pad replacement, the parking brake lever travel adjustment should be performed. Depress the brake pedal several times to activate the automatic adjustment within the caliper. Then adjust the cable for the proper number of clicks of the hand brake lever.

Parking Brake Operation

When the parking brake is applied, the cable attached to the parking brake lever rotates the crank lever counterclockwise. The crank pin then pushes the strut to the left. The strut moves the adjusting bolt, sleeve nut, and piston toward the left. As the strut moves to the left, it also compresses the adjusting bolt return spring. The assembly moves until it presses the pads against the disc rotor.

Parking Brake Operation

The crank pin pushes the strut and adjusting bolt, sleeve nut and piston toward the disc rotor.



When the parking brake lever is released, the compressed Return Spring pushes the Adjusting Bolt and Piston back to their previous positions. As a result, the parking brake is released.

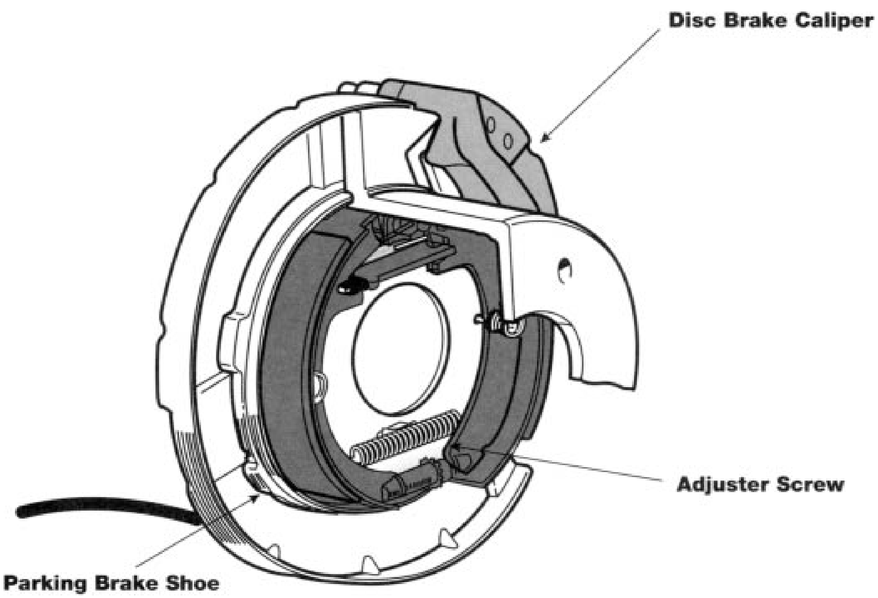
During this operation, the Clutch Spring prevents the rotation of the Sleeve Nut so that the force of the parking brake lever is transferred to the Piston via the Adjusting Bolt.

Exclusive Parking Brake

The exclusive parking brake is found on the LandCruiser, Supra, Celica, Previa, Avalon and Camry. As illustrated below, a drum brake is cast into the disc rotor. The shoes and other components are similar to a conventional dual-servo drum brake system but smaller and with no wheel cylinder.

Exclusive Parking Brake Assembly

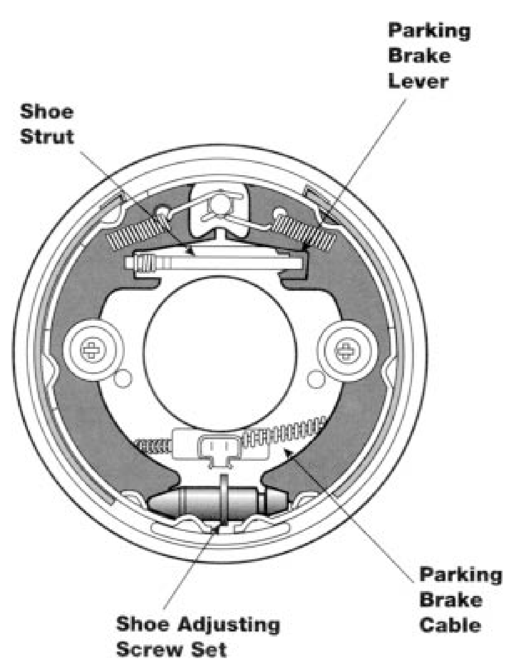
A pair of brake shoes are mounted to the backing plate and a brake drum is cast into the disc rotor.



Activating the parking brake is similar to applying the parking brake on conventional drum brakes. Adjustment to the exclusive parking brake is done manually at the Shoe Adjusting Screw Set (Star Wheel) and must be done periodically.

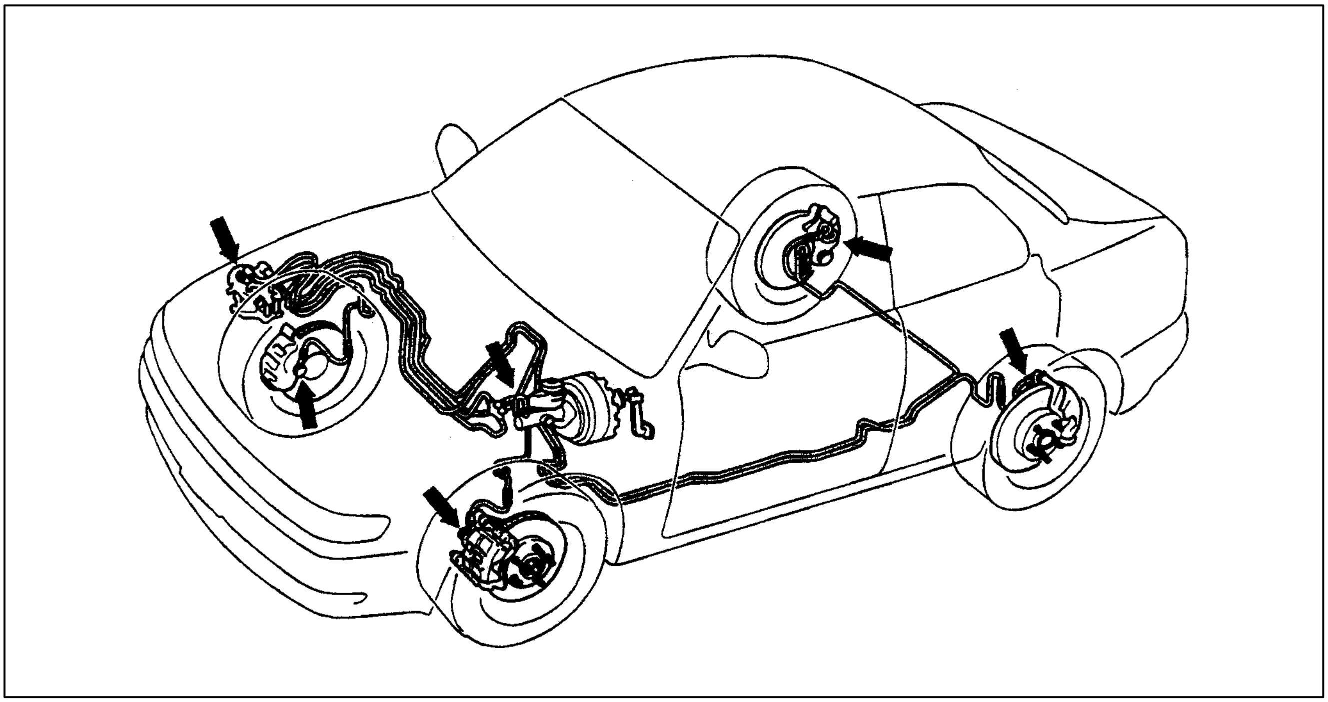
Exclusive Parking Brake Components

Manual adjustment is made at the Shoe Adjusting Screw Set.



Section 7

BRAKE DIAGNOSIS



Lesson Objectives

1. Convey the importance of verifying the customers complaint.
2. Describe road test procedures used to determine the cause of brake vibration.
3. Using the brake pedal, establish pedal height, pedal freeplay and reserve distance for initial brake system diagnosis.
4. Determine the serviceability of a drum or rotor using a measuring device and specification table.
5. Turn a rotor using the on-car brake lathe.
6. Measure hub runout and rotor runout using a dial indicator.
7. Using a dial indicator, phase-match a rotor and hub for minimum rotor runout
8. Explain the cause of rotor parallelism.
9. Using a micrometer or vernier caliper, measure rotor parallelism.
10. Using a brake drum micrometer, determine brake drum diameter and serviceability.

Diagnosing Brake Problems

Diagnosing a problem in the brake system is similar to diagnosing problems in any other system in the vehicle. The plan of action should include the following:

- verify the customers complaint.
- identify the symptoms.
- isolate the cause.
- repair the problem.
- check for proper operation.

Verify Customers Complaint

Begin by determining the symptoms based on the customer's complaint recorded on the RO. If your information is incomplete and you proceed to fix what you find to be a problem, other than what the customer complained about, you both lose. The customer has to bring the car back and you may not get paid for the work you did.

You're the expert, the customer brings the vehicle in because they perceive a problem. When you service the vehicle and don't take care of the problem, you look bad and so does the dealer. Worst of all, the customer may not return. So get more information when in doubt.

If you can't verify the customer's complaint, it may be necessary to go for a test drive with the customer so that he can point out the symptom. The problem may not be brakes at all. It could be something as simple as a bowling ball in the trunk that makes a banging noise when the brakes are hit hard, or it could be a loose suspension component or worn bushings.

Attempt to find the source of the customer's complaint: then any additional things you find to be improper can be brought to the customer's attention for their approval to repair.

Chances are you have done a previous repair for a similar symptom. That gives you an advantage in your diagnosis.

Before you take the customer's car out for a test drive, make sure it's safe. If the pedal goes to the floor sometimes but seems fine now, do some preliminary checks before you take it out on the road.

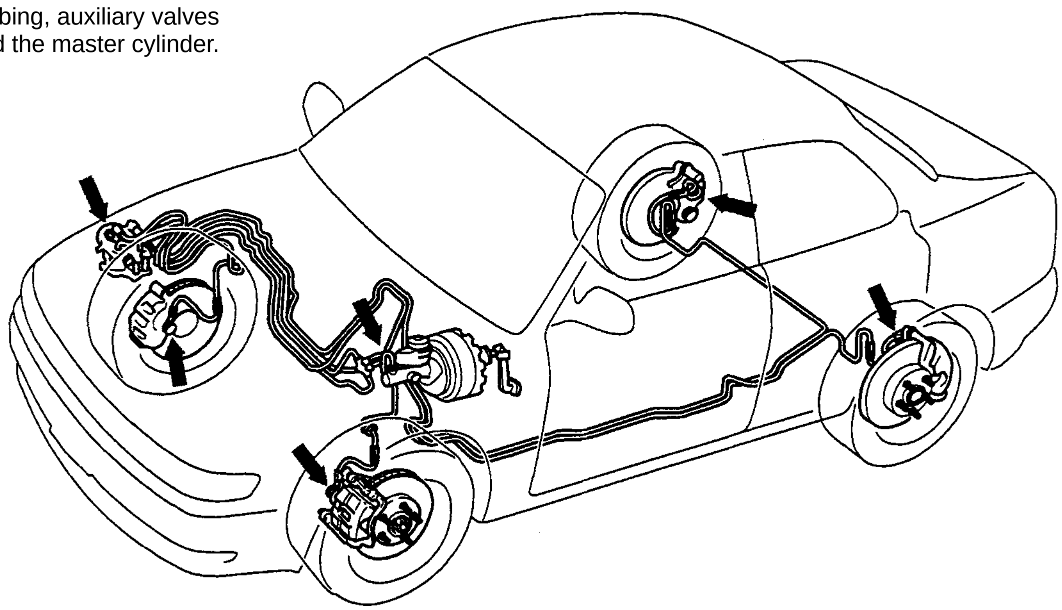
Preliminary Checks

Preliminary checks should establish that the essentials are intact and operational. Check fluid level in the master cylinder. Even though it is full, check for leaks, the reservoir may have been topped off prior to bringing it in for service. Check the following for signs of leakage:

- brake backing plate.
- flexible brake hoses.
- connections.
- brake tubing.
- auxiliary valves.
- master cylinder.

Brake System Inspection

Check for leakage at the brake backing plate, flexible brake hoses, connections, brake tubing, auxiliary valves and the master cylinder.

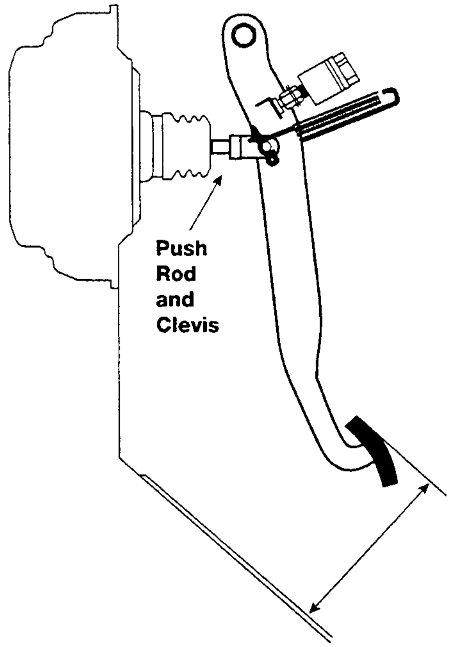


Pedal Height

When checking the brake pedal travel, start with the pedal height. It should be measured from the asphalt sheet, below the carpet, to the top of the pedal pad. Pedal height is adjusted using the push rod to establish the pedal position.

Brake Pedal Height

Measured from the asphalt sheet, below the carpet, to the top of the pedal pad. Adjusted using the push rod and clevis.

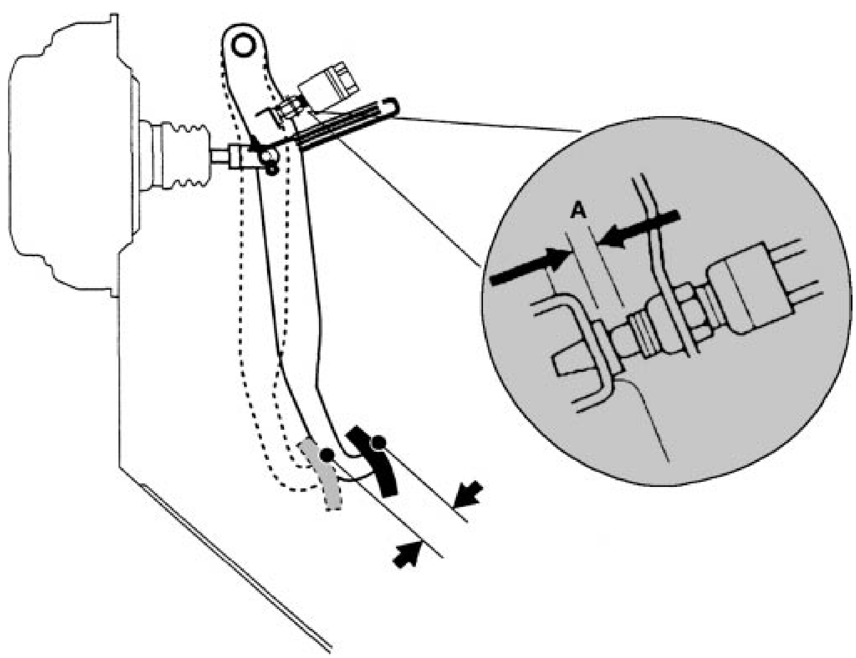


Pedal Freeplay

Make sure that the freeplay is at least 0.040” to 0.120” (1 - 3 mm). Turn the engine off and apply the brakes several times to reduce the vacuum in the booster. If freeplay is less than specified, the brakes may be lightly applied at all times, overheating the brakes and causing premature wear. If there is too little free play, check the Stop Light Switch for proper clearance as shown below.

Brake Pedal Freeplay

Turn the engine off and apply the brakes several times to reduce the vacuum in the booster.



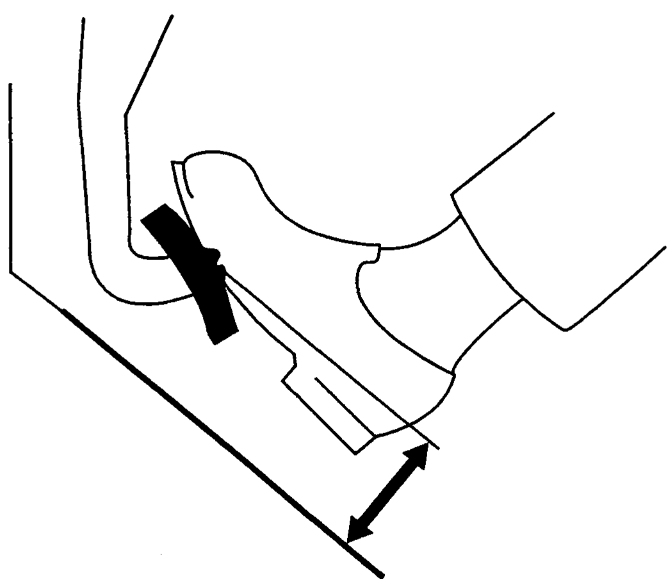
Pedal Reserve Distance

Measure the distance from the melt sheet to the top of the brake pedal while applying the brakes with the engine running. Insufficient reserve distance may be caused by:

- rotor run-out or loose wheel bearings. In either case the rotor pushes the caliper piston further into the cylinder requiring additional pedal travel to move the brake pads into contact with the rotor.
- inoperative automatic adjusters reduced reserve distance as the shoes must travel further to contact the drum.
- air in the line will also cause the pedal to go further to the floor as air in the system compresses. When air is in the lines, the pedal will also feel spongy. You may be able to verify air in the system by pumping the pedal several times compressing the air. Remove the reservoir cover and observe the brake fluid as the brake pedal is released. The compressed air will cause the returning fluid to shoot above the side of the reservoir.

Brake Pedal Reserve Distance

With the engine running apply the brakes and the distance from the top of the pedal pad to the melt sheet should be as specified in the Repair Manual.



If the pedal is hard and the braking inefficient, suspect the booster or its vacuum source. Go through the booster diagnostic steps under the booster section of this text.

Brake Pad Inspection

Worn pads or shoes may be quite obvious, but when you look closely and compare the wear side to side it may give you a clue as to their operation. If pads on one side are worn more severely than the opposite side of the vehicle, the piston may be stuck in the cylinder of the opposite caliper. If the inside pad is worn more severely than the outside pad of the same brake assembly, the caliper may not be free to float on the torque plate.

Suspension Inspection

Areas not directly related to the brake system should be inspected as they may indirectly cause noise or pull when the brakes are applied. Tire condition and inflation pressure should be considered. The pressure and tire size should be equal from side to side on the same axle. Tire condition may indicate front suspension problems.

When excessive wheel and tire run-out is present a vibration may be felt on brake application. Check the vehicle Repair Manual for the specific run-out specification. Vibration may also be felt at cruise speeds. For example, it may come in at 55 mph and be gone at 60 mph.

Worn suspension bushings or ball joints change front-end geometry and may cause a pull or drift when the brakes are applied.

Road Test - Identify the Symptoms

A road test should be completed in order to verify the customer's complaint. Because the customer perceives the problem when the brakes are applied, he naturally assumes the problem to be in the brakes. However, the brake system may be indirectly related to the complaint. It is important to determine the correct cause of the customer concern.

A series of decelerations from 50 to 20 mph, while noting the vehicle speed, intensity and location of any vibration will aid in further diagnosis of the system.

The first check is done merely by allowing the vehicle to coast down without applying the brakes to determine if the problem lies outside the brake system.

This will help to determine if driveshaft balance or angle is causing a vibration. If the vibration occurs at speeds between 40 to 25 mph, the problem is likely that the driveshaft angle varies at each end of the driveshaft. This can be confirmed by noting any vibration on moderate to heavy acceleration.

The second check involves applying light to moderate brake pressure. Information found here is used in conjunction with parking brake application to determine the area of vibration.

If the symptom occurs when the service brake is applied and not when the parking brake is applied, the problem lies in the front brake or wheel assemblies.

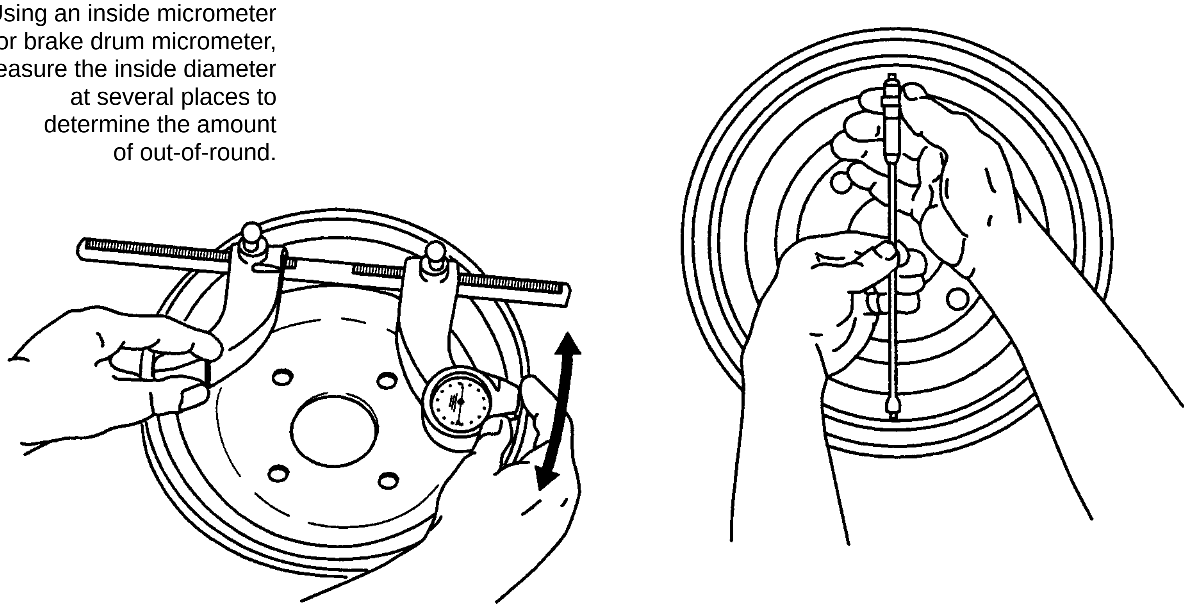
When vibration is most noticeable in the steering wheel, check the front brakes, wheel and tire condition. When vibration is most noticeable in the brake pedal, check disc rotor for parallelism. Measure the disc thickness at eight points around the circumference, about 10 mm from the outside edge.

The third check is done by using the parking brake. This check can only be done with those vehicles which share the service and parking brake assemblies. It distinguishes vibration caused by front and rear brake assemblies.

Should vibration occur while the parking brake is applied at the suspected vehicle speed, check the drum for deformation. Using an inside micrometer or brake drum micrometer, measure the inside diameter at several places to determine the amount of out-of-round. If the difference between the smallest and the largest measurement is more than 0.006”, the drum should be machined on an off-car lathe. Precautions regarding off-car lathes mentioned on page 85 should be observed.

Drum Measurement

Using an inside micrometer or brake drum micrometer, measure the inside diameter at several places to determine the amount of out-of-round.



Isolate the Cause

If the symptom is pulling when the brakes are applied, determine if the pull is erratic or whether it is consistent. The crown of the road will contribute to these symptoms, so perform several brake applications on roads with different crown surfaces.

When a pull is erratic, it will cause the vehicle to pull either left or right with no consistency. When this occurs, check the wheel alignment and suspension bushings. Excessive wear of the bushings and ball joints will change the suspension geometry while braking. Wear in the strut bar bushing allows the lower control arm to move rearward when the brakes are applied, inducing caster change which causes a pull. Caster will cause a vehicle to pull to the side of the least positive caster.

A steering gear that is out of adjustment or loose in its mounting may also contribute to an erratic pull.

When the vehicle pulls consistently in one direction, the problem is usually in the brake system. When the pull is to the left for example, check both the left and right brake assemblies. The cause of a greater amount of braking on one side may be a condition on either brake assembly. Inspection of the brake system should start with the condition of the brake drum or disc surface. The surface condition should be the same on both rotors.

Lining that is soaked with brake fluid or gear oil will cause a pull and should be replaced as an axle set after repairing the source of the leak.

The brake assembly creating the greatest heat conversion will do the greatest braking. So when a caliper is frozen on the torque plate or a piston is frozen in the caliper, the vehicle will pull to the opposite side.

Brake Noise

Brake noise is caused by friction between the pads and drum or rotor when the brakes are applied. Occasional squeal is normal, and not a functional problem and does not indicate loss of braking effectiveness.

When the brake noise occurs all the time, check the lining condition. Lining that is glazed should be replaced or cleaned using emery cloth. When sanding the lining to remove the glazed surface, be sure to cover the entire surface evenly. (See precautions under asbestos in the reference section of this book). Also check the drum or disc for a glazed condition and cleanup with emery cloth or turn on a brake lathe if the drum diameter or disc thickness permits.

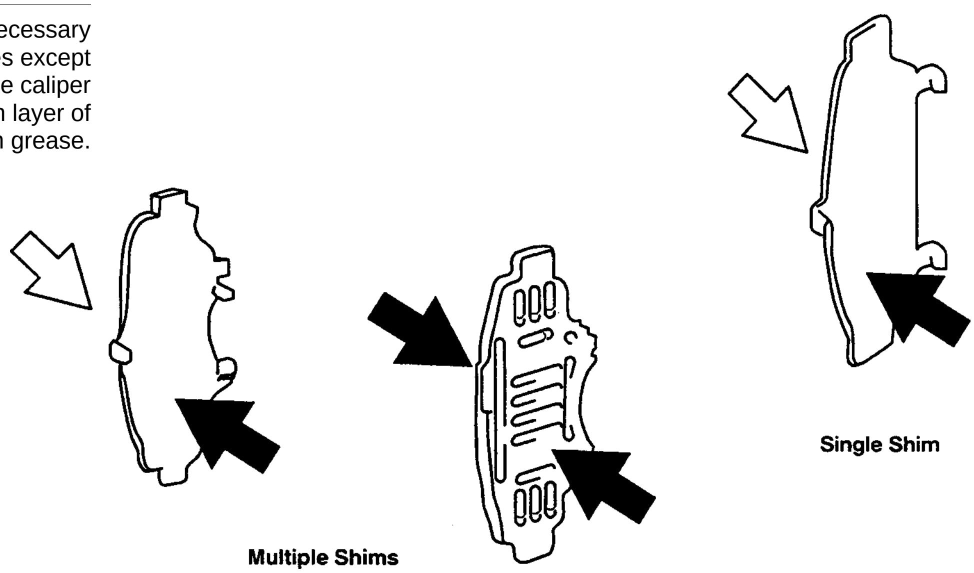
Squeal can also be caused by a weak or broken hold down spring or return spring as well as missing, damaged or improperly installed anti-squeal shims. To inspect return springs, check for space between the spring coils and nicks in the spring wire diameter. Nicks caused by tools during installation and removal may cause springs to break. Damaged springs should be replaced as a set.

Anti-squeal shims help to dampen the vibration which occurs when the pads contact the disc. Make sure that the appropriate shims are in place. Anti-rattle springs are used to position and hold the pad as rigidly as possible to reduce pad movement in the caliper assembly and thereby reduce noise caused by vibration. Make sure that they are positioned properly so they are most effective.

When assembling brake pads to the caliper assembly inspect the shims and fitting components. Anti-squeal springs and support plates may be reused if in good condition. Inspect them for proper rebound, deformation, burrs, cracks, wear, or rust. Clean the shims as necessary and lubricate all sides except the side contacting the caliper piston with a thin layer of shim grease. Shim grease can be ordered separately under part number 08887-80409. In addition, remove any rust from the caliper grooves into which the ears of the brake pad rest and coat with a thin layer of shim grease.

Shim Inspection and Lubrication

Clean the shims as necessary and lubricate all sides except the side contacting the caliper piston with a thin layer of shim grease.



When brake noise occurs on only the first few brake applications, check for corrosion on the disc rotors. Clean the rotors with emery cloth or turn the rotors if it falls within the specified requirement of rotor thickness.

When brake noise occurs just before the vehicle stops, check for glazed lining, damaged anti-squeal shims or fluid soaked lining. Correct the conditions as covered previously.

Groan or creep-groan, which occurs when the brake pedal is released slowly while the engine idles in forward gears, is caused by the pad allowing the disc to slip. Slightly increasing or decreasing the pedal effort will eliminate the noise. It does not adversely affect the braking system or braking performance.

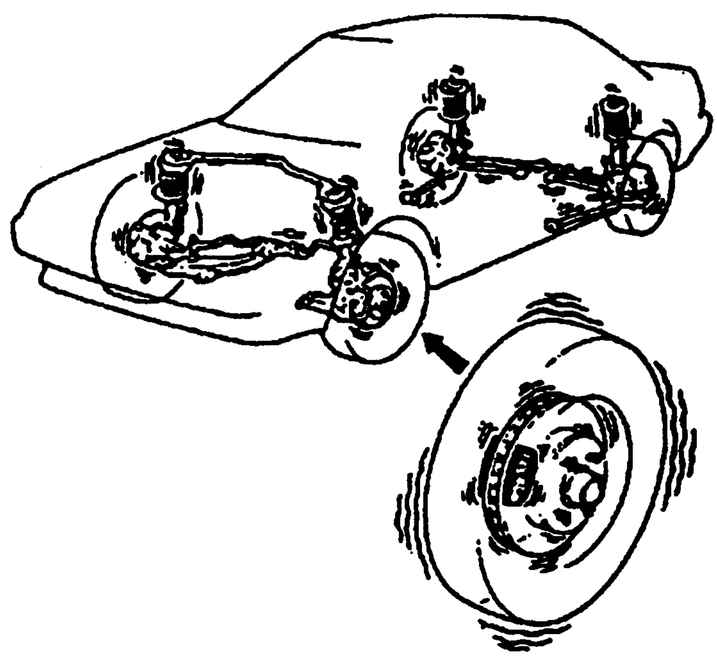
Brake Vibration Isolation

Brake vibration is a symptom which occurs during braking and is not accompanied by sound. With brakes applied at high speeds, the vibration is transmitted to the suspension system, the steering wheel, instrument panel and brake pedal. In advanced stages, vibration may also occur at lower speeds.

If the vibration causes the steering wheel to oscillate side to side, the cause is likely the front brake assemblies. The rear parking brake can be used to isolate the vibration by applying the parking brake at the speed at which the vibration occurs. If the vibration does not occur, it is likely that the front brakes are the cause. (This procedure will not work if the parking brake is an exclusive design found on rear disc brakes with a drum type parking brake.)

Isolating Brake Vibration

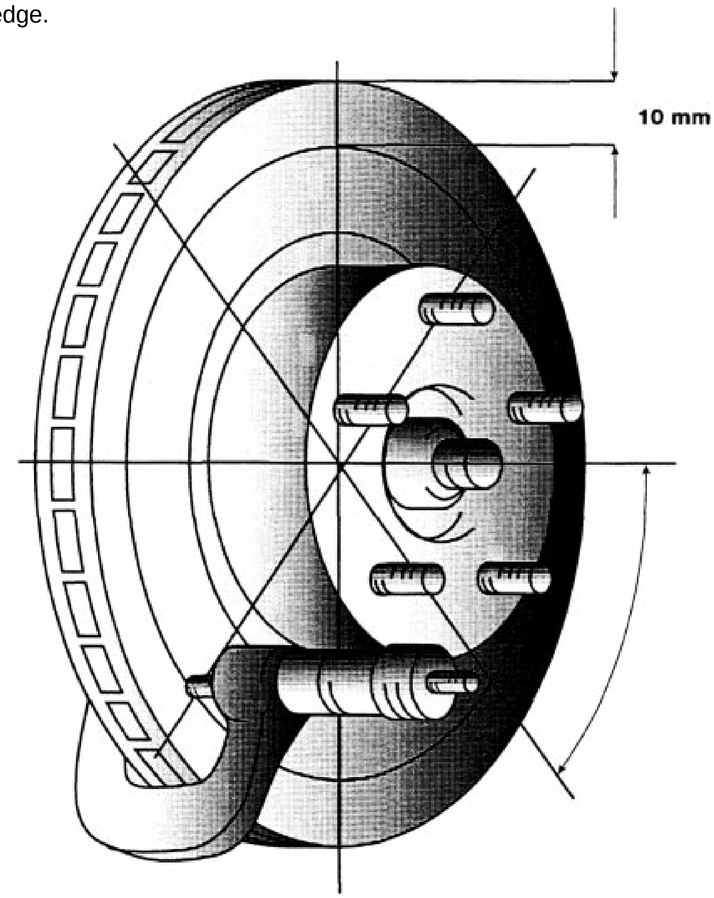
With brakes applied at high speeds. The vibration is transmitted to the suspension system, the steering wheel, instrument panel and brake pedal.



If the vibration cannot be isolated to either the front or rear brakes, measure the front disc rotors for parallelism. Using a micrometer, measure the rotor at eight different places around the diameter of the rotor about 10 mm from the outer edge. Thickness variation is determined by subtracting the smallest thickness measurement from the largest thickness. If the ; thickness variation is greater than 0.0008" (0.02 mm) the rotor is the cause and should be resurfaced or replaced.

Rotor Measurement

Using a micrometer measure the rotor at eight different places around the diameter of the rotor about 10 mm from the outer edge.



Thickness Variation

Thickness variation causes the thickest part of the rotor to push the piston back into the caliper cylinder each time it rotates past the brake pads. This increase of hydraulic pressure is transferred via the brake line tubing to the master cylinder and translated through the booster to the brake pedal.

Two conditions that cause thickness variation are:

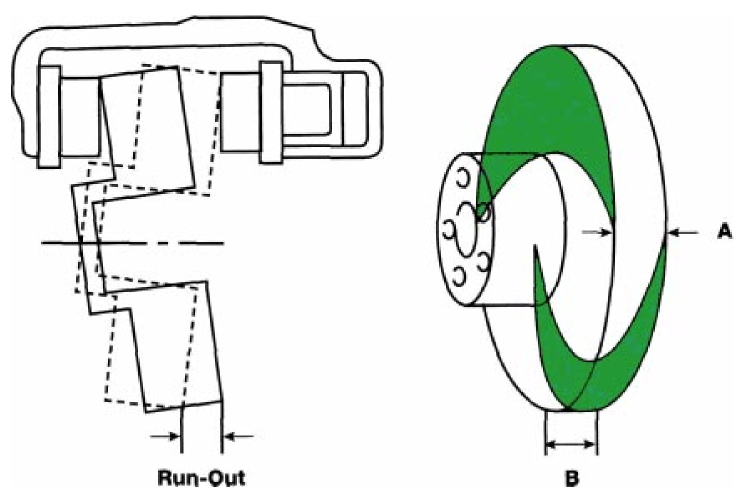
- Rotor run-out.
- Excessive rust or corrosion on rotor surface.

Rotor Run-out

Lateral run-out of the rotor is the most significant cause of rotor thickness variation and eliminating run-out is the only way to solve a pedal pulsation complaint for good. When rotor run-out is excessive, a portion of the rotor comes into contact with the brake pad with each rotor revolution. Over time the rotor will wear at the contact point causing thickness variation. Poor mating of the disc rotor and axle hub can cause excessive, run-out. The rotor is mounted to the axle hub and each is manufactured with a tolerance for allowable run-out. When the tolerances are stacked one on the other, the total run-out may exceed 0.004” (0.10 mm) and cause the situation described here.

Rotor Run-out

When rotor run-out is excessive a portion of the rotor comes into contact with the brake pad with each rotor revolution. The rotor will wear at the contact point causing thickness variation.



Excess Rust and Corrosion

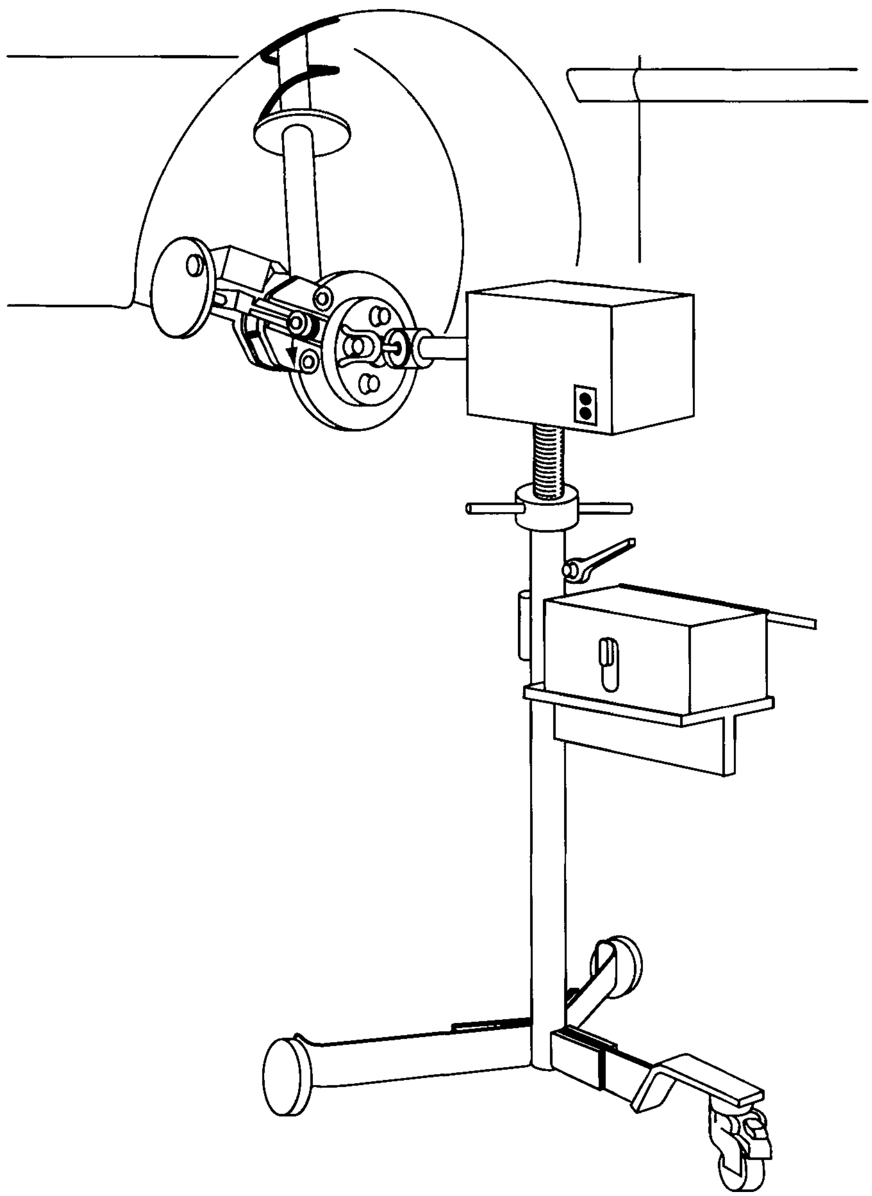
In areas where salt is applied to road surfaces during winter conditions, vehicles parked for an extended time have rust and corrosion build-up on areas of the disc surface not covered by the brake pads. When the vehicle is driven, the rusted areas wear at a different rate than the non-corroded areas, resulting in excessive thickness variation.

Repair the Problem

Resurfacing of rotors with an on-car brake lathe is the recommended operation to correct rotor run-out and thickness variation. The on-car lathe is installed in the same position as the caliper, ensuring that the rotors will be machined absolutely parallel to the brake pad and caliper assembly. An on-car lathe is designed to take into account all of the variations in the bearings, hub and rotor assembly and provides the greatest accuracy by eliminating virtually all run-out.

On-Car Brake Lathe

The on-car lathe is installed in the same position as the caliper, ensuring that the rotors will be machined absolutely parallel to the brake pad and caliper assembly.



If an on-car lathe is not available and the rotor is machined on an off-car lathe:

- check the lathe arbor for excessive run-out and correct or replace as needed.
- check the condition of the rotor mounting surfaces to ensure proper mounting.
- make certain the adapters and cones are free of burs and particles that might prevent the proper mounting of the rotor.
- check the rotor run-out with a dial indicator and correct mounting as needed.
- measure the rotor thickness to ensure it is greater than the minimum thickness.

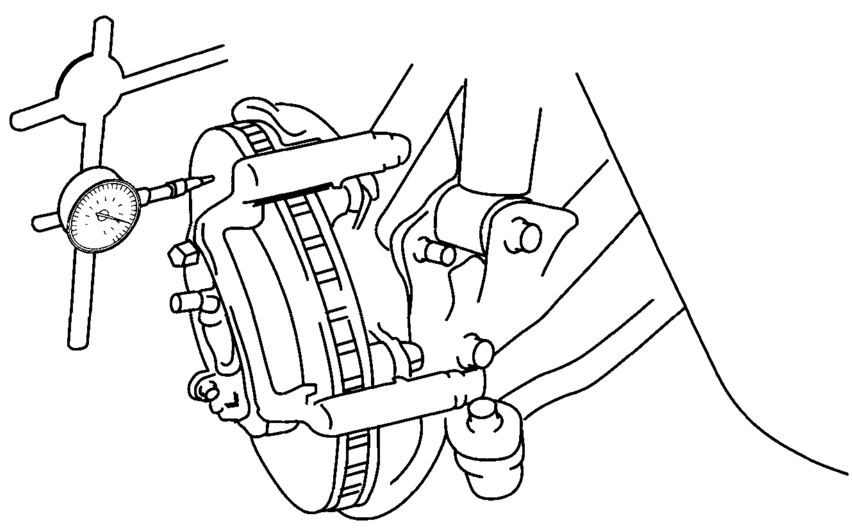
Typically when a rotor is turned on a lathe, the opposite rotor should also be turned so that they are both within 0.010” (0.25 mm) of each other. Also, if one rotor has a rougher surface finish than the other, the difference in friction may cause a pull.

Phase Match Rotor to Hub

When mounting machined rotors or replacing new rotors, check the condition of the axle bearing and be sure to seat the rotor on the axle using the lug nuts and tighten them evenly with a torque wrench. Using a dial indicator, measure the lateral run-out. Run-out should not exceed 0.002” (0.05 mm). If run-out is excessive, index the rotor one lug and measure the run-out again. Repeat the procedure, indexing the rotor one lug at a time until the minimum run-out is achieved.

Measuring Rotor Run-out

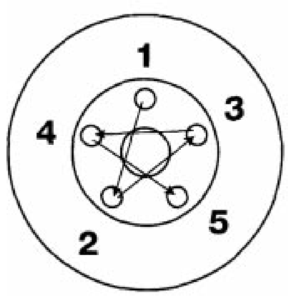
If run-out is excessive, index the rotor one lug at a time and measure the runout again until minimum run-out position is found.



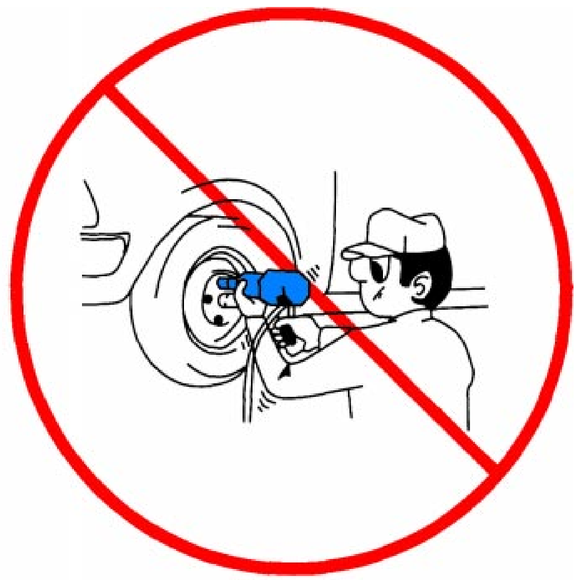
Of equal importance is the necessity of tightening all wheel lug nuts to the specified torque using a star sequence when installing the wheels. All the care and attention in machining and measurement for run-out can all be destroyed by using an impact wrench to tighten lug nuts. Improper torque or uneven torque can distort the rotor and create a comeback.

Wheel Tightening Procedure

All the care and attention in machining and measurement for run-out can all be destroyed by using an impact wrench to tighten lug nuts.



Lug Tightening Pattern



Check for Proper Operation

Following the repair, road test the vehicle to ensure that the customers concern has been eliminated. This will help to ensure customer satisfaction with your service.

WORKSHEET 7-1 (ON-CAR)
Brake Rotor Run-Out and Rotor Phase Matching

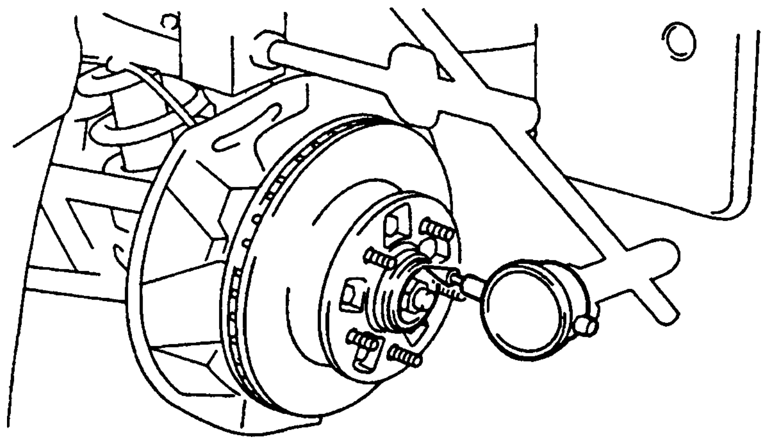
Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this Worksheet you will practice the procedure for checking for bearing wear, measuring Rotor Run-Out and Phase Match a rotor.

Tools and Equipment:

- Dial indicator and base.
- Abrasive cloth.
- Torque wrench.
- Permanent Marker.



Preparation:

- Mount the stem adapter to the indicator plunger.
- Mount the indicator to the base.
- Raise vehicle on a lift or support with jack stands.
- Mark the wheel stud nearest the valve stem to ensure wheels balance and remove the wheel.
- Mark the disc rotor and wheel stud, then remove the disc rotor and inspect for corrosion build-up and clean as needed with abrasive cloth.
- Reinstall the disc rotor and all lug nuts to the wheel studs to hold the rotor firmly in place.

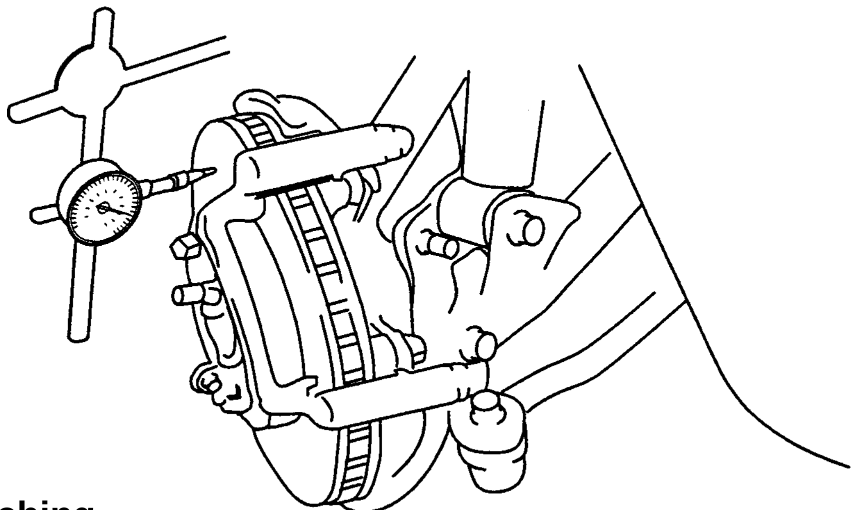
Measurement:

1. Place the indicator plunger in line with the axle near the center of the axle hub. Compress the indicator plunger stem slightly to preload the dial indicator plunger.
2. Push inward on the hub to seat the wheel bearing and zero the indicator. Pull the hub outward and note the amount of wheel bearing backlash or axial play in the box below.

Measured Wheel Bearing Free Play	Specification	Result

3. Place the indicator plunger perpendicular to the rotor braking surface, 10 mm from the outer diameter. Compress the indicator plunger stem slightly to preload the plunger.
4. Rotate the rotor slowly to locate the lowest point of indicator travel and zero the indicator.
5. Rotate the rotor several times and verify the indicator returns to zero.
6. Continue to rotate the hub noting the maximum indicated runout and compare your measured value to specification.

Measured Rotor Run-Out	Specification	Pass/Fail



Brake Rotor Phase Matching

Procedure:

1. Mark a stud and its position on the rotor for index purposes.
2. Place lugnuts flat side toward the rotor and torque evenly.
3. Measure rotor runout and record in the chart below.
4. Reposition rotor in clockwise direction to the next lug and measure runout.
5. Repeat for each lug and record.

Lug Number	Measurement

Summary:

1. How could excessive wheel bearing free play influence runout measured at the brake rotor?

2. How could excessive wheel bearing free play affect brake pedal travel?

3. What affect would a rotor with excess runout have on brake operation in the first 500 miles?

4. What happened to the rotor in question 3 if after several thousand miles of wear, the brake pedal pulsates?

5. What is the proper service procedure to correct the condition identified in question 4?

6. Referring to the measurements made for Phase Matching, what is the difference between the highest runout and the lowest runout? (Show your math calculations)

Notes

WORKSHEET 7-2 (ON-CAR)
Brake Rotor Parallelism Measurement

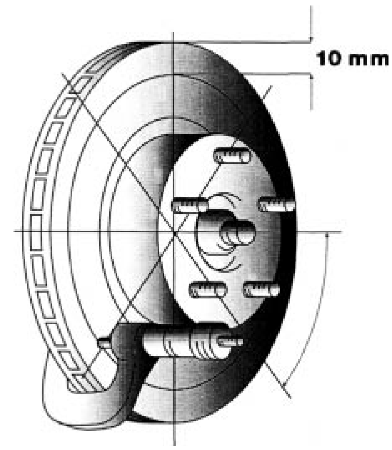
Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this Worksheet you will practice the procedure for measuring brake rotor parallelism for thickness variation.

Tools and Equipment:

- 1” Micrometer.
- Permanent Marker Pen.
- Repair Manual.
- Lug Nut Wrench.
- Straight Edge.



Preparation:

- Raise vehicle on a lift or support with jack stands.
- Mark the wheel stud nearest the valve stem and remove the wheel.
- Install all lug nuts to the wheel studs to hold the rotor firmly in place.
- Using a marker pen and straight edge, divide the rotor into eight equal parts and mark a line 10mm from the outside circumference.

Measurement:

1. Measure the rotor thickness at the intersection of the eight lines and the circular mark.
2. Record the readings in the chart below.

Measurement Point	Measured Rotor Thickness
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	

Measurement (Cont'd):

3. Record the largest and smallest thickness measurement in the chart and record the thickness variation.

Largest	
Smallest	
Thickness Variation	
Rotor Minimum Thickness	

Summary:

1. What is the specification for maximum allowable thickness variation?

____

____

2. What symptoms would be experienced with excessive thickness variation?

____

____

3. List two causes of rotor thickness variation?

____

____

____

4. What is the correct repair procedure for thickness variation?

____

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WORKSHEET 7-3 (ON-CAR)
On-Car Brake Lathe

Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this Worksheet you will practice the procedure for setup and machining a rotor using the On-Car Brake Lathe.

Tools and Equipment:

- Accu-Tum Brake Lathe with Accessories.
- Extension Cord.
- Assorted Hand Tools.
- Micrometer and Dial Indicator and Stand.
- Brake Clean.

Thickness Measurement

Preparation:

- Raise vehicle on a lift.
- Check the wheel bearings for excessive play or roughness. (Adjust or replace as necessary)
- Mark the stud nearest the valve stem and remove the wheel.
- Remove the Caliper from the steering knuckle and secure it with mechanic's wire or the “S” hook provided.
- Measure the rotor thickness to determine its serviceability. Check the minimum thickness cast into the rotor.

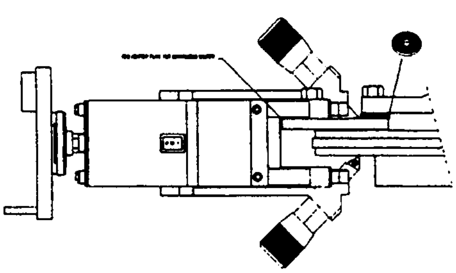
Thickness Measurement	Minimum Thickness Spec.	Allowable Cut

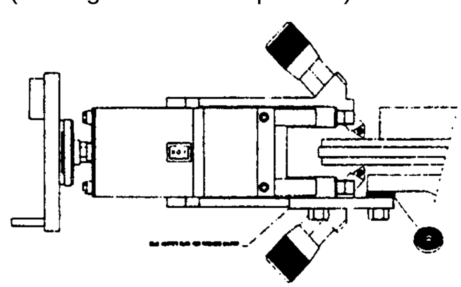
- Install the drive yoke and secure the rotor to the hub using the flat side of the vehicles lug nuts (concave receiving washers are provided for closed end lugs). Securely tighten the lug nuts. (Yoke crossbar should be centered to axle)
- Install the silencer band on the rotor.
- Remove rust and debris from the steering knuckle caliper mounting surface.
- Mount the dial indicator and measure rotor runout.

Rotor Runout Measurement

Lathe Mounting:

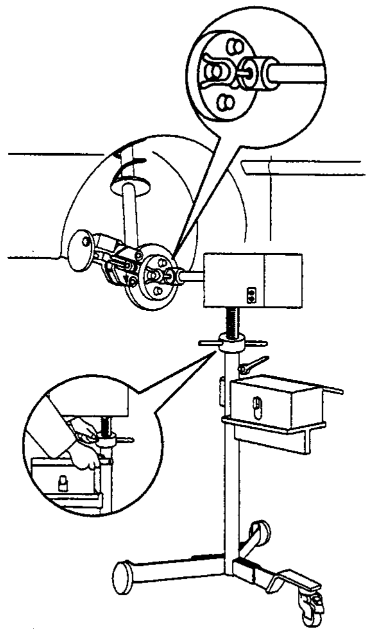
- Attach lathe to the steering knuckle caliper mounting surface using the plate specified for the vehicle.
- Use spacers to center the lathe to the rotor as needed. (See figures on set-up sheet)





Auxiliary Drive Installation:

- Rotate the rotor so that the yoke crossbar is horizontal.
- Adjust the auxiliary drive so that the shaft and nylon coupler are centered to the axle.
- Attach the nylon coupler to the yoke crossbar leaving a 1/4” gap in the rear of the slot.
- Lock the rear caster on the drive stand.
- Turn the drive unit “ON” in the direction of the arrow located on the lathe body.
- Any shaking or oscillation will smooth out with a slight height adjustment of the drive unit.



Machining the Rotor:

- Be sure to note the directional arrow on the side of the lathe to ensure that the direction of rotation is observed. (Failing to do so will result in damage to the cutting bits.)
- While the drive unit is rotating, turn the hand wheel to position the tool holders over the friction area.
- Adjust the left and right tool holders until each bit makes surface contact and record the reading on the adjusting knobs and record it in the chart below.
- Adjust the left and right tool holders until each bit just makes contact with the rotor and record the reading of the adjusting knob below. Adjust the left and right tool holders until each bit makes contact for a full 360 degrees, and record the readings of the adjusting knobs.

	Inside Reading	Outside Reading
Initial Contact		
360 Contact		

- Retract the tool holders several turns and position them past the inner friction surface near the hat section of the rotor.
- Remove any ridge at the outer edge or near the hat area if necessary, being certain not to take a cut deeper than the amount indicated at the 360 degree contact made earlier.

- Turn the adjusting knobs back to the original reading plus an additional one-half mark (0.002”).
- Push the power feed switch to the rear position.
- Rotate the clutch knob on the handwheel clockwise to engage the feed.
- After machining is complete, measure the rotor thickness to ensure it is above minimum thickness.

Rotor Thickness Measurement

- Mount the dial indicator and measure rotor runout.

Final Rotor Runout Measurement

Summary:

1. Why should wheel bearings be checked for excessive play or roughness before the rotor is turned?

___

___

___

2. Why is it important to torque the lug nuts evenly when securing the brake rotor to the hub before machining the rotor.

___

___

___

3. What advantage would there be in providing a non-directional finish on the rotor?

___

___

___

4. When a cut of .002” is made on each side of a rotor, the overall thickness of the rotor is reduced by:

___

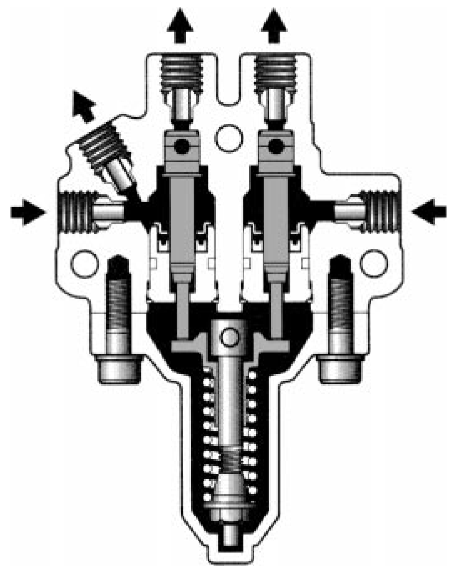
5. What is the difference between the initial rotor thickness measurement and the final thickness measurement?

___

Notes

Section 8

HYDRAULIC CONTROL



Lesson Objectives

1. Describe the purpose of a proportioning valve.
2. Describe the purpose of a load sensing proportioning valve.
3. Describe the function of the bypass valve in a LSPBV.
4. Measure front and rear brake pressure using LSPV pressure gauge set.
5. Adjust LSPBV rear brake pressure.

Hydraulic Control Valves

Hydraulic control valves regulate hydraulic pressure to the rear brakes to ensure efficient braking. Types of control valves used on Toyotas:

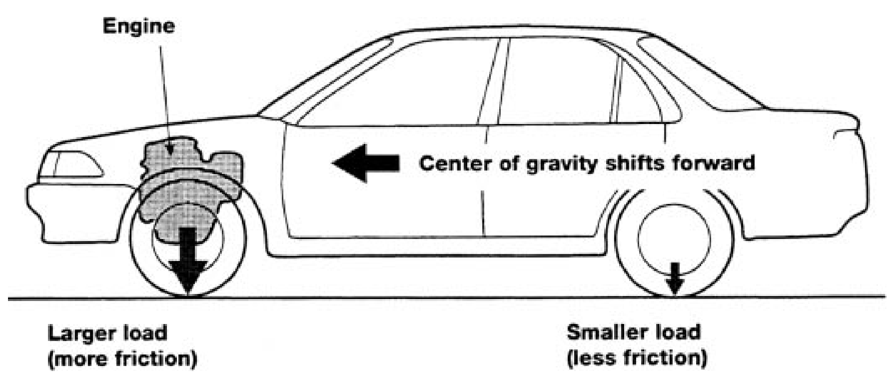
- Proportioning Valve.
- Proportioning and Bypass Valve.
- Double Proportioning Valve.
- Load Sensing Proportioning Valve.
- Load Sensing Proportioning and Bypass Valve.

Control of rear brake pressure is necessary because inertia, created when the brakes are applied, shifts vehicle weight toward the front wheels. Because the rear wheels have less weight during braking, they can lockup, causing the vehicle to lose traction and skid out of control.

The front of a front-engine vehicle is heavier than the rear, so when the brakes are applied, the vehicle's center of gravity tends to move forward because of inertia. This adds to the front load, and the rear load decreases as a result. With greater braking force, the center of gravity moves further forward and the rear load decreases even more.

Shifting Center of Gravity

When the brakes are applied, the vehicle's center of gravity tends to move forward reducing load at the rear wheels.



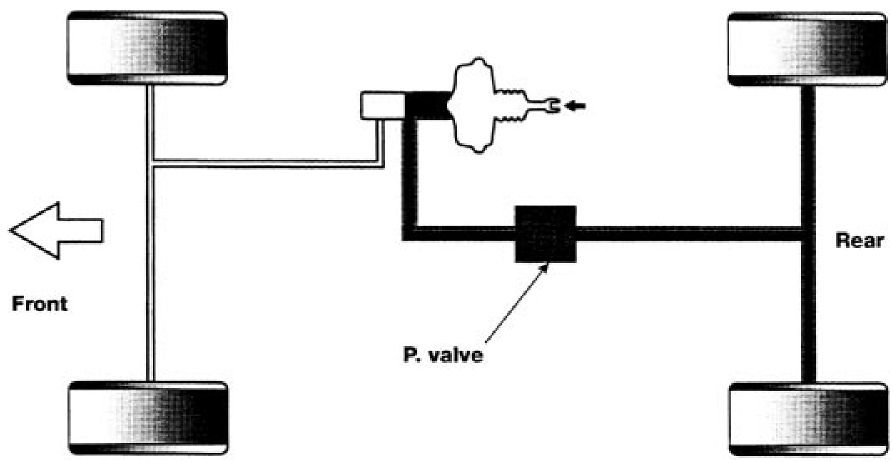
Assuming that the front and rear wheels exert an identical braking force in the above condition, the rear tires, which are subject to a smaller load, tend to lockup early. This will cause the rear tires to lose traction or skid.

When the tires skid, the friction between the tires and the road becomes extremely small, and the tires will fail to remain in sufficient contact with the road. Unless the vehicle is moving straight ahead, it will "fishtail", which can be very dangerous.

The braking force of the rear tires must be reduced below that of front tires in order to prevent early lock-up. This is achieved by the proportioning valve (P. valve). It is designed to automatically reduce the hydraulic pressure for the rear wheel cylinders in proportion to hydraulic pressure from the master cylinder.

Proportioning Valve Location

The braking force of the rear tires must be reduced below that of front tires in order to prevent early lock-up.

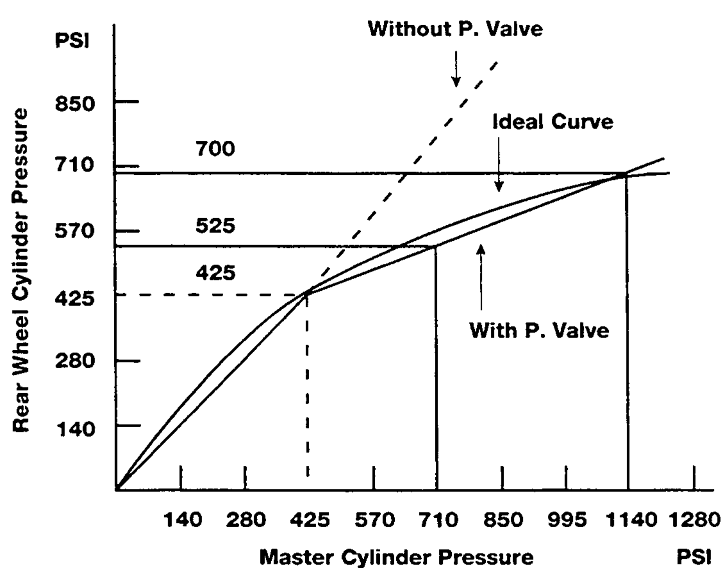


Hydraulic Pressure Curve

The graph below shows an ideal hydraulic pressure curve for the front and rear wheels (actual values vary from one vehicle model to another). The proportioning valve is designed to bring actual pressure curves as close to the ideal as technically possible.

Hydraulic Pressure Curve

The P-valve is designed to bring actual pressure curves as close to the ideal as technically possible.

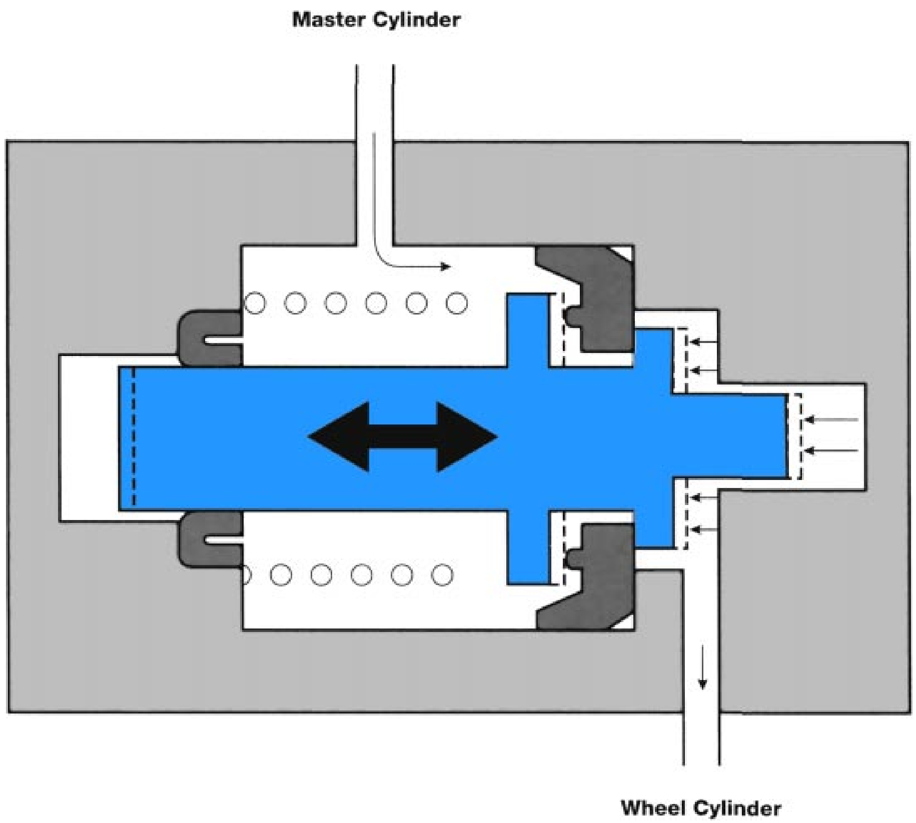


Proportioning Valve Operation

The spring in the Proportioning valve holds the valve in the open position. During normal braking the brake fluid flows through the valve without any proportioning action. However, when heavier braking occurs, pressure on the wheel cylinder side of the proportioning valve pushes the valve against spring tension and closes the valve. This in effect reduces pressure to the rear brakes. As pressure increases on the master cylinder side, it lifts the valve, increasing pressure to the wheel cylinder side of the valve. As pressure increases on the wheel cylinder side of the valve, it seats again. This occurs in rapid succession as long as pressure from the master cylinder increases.

Proportioning Valve

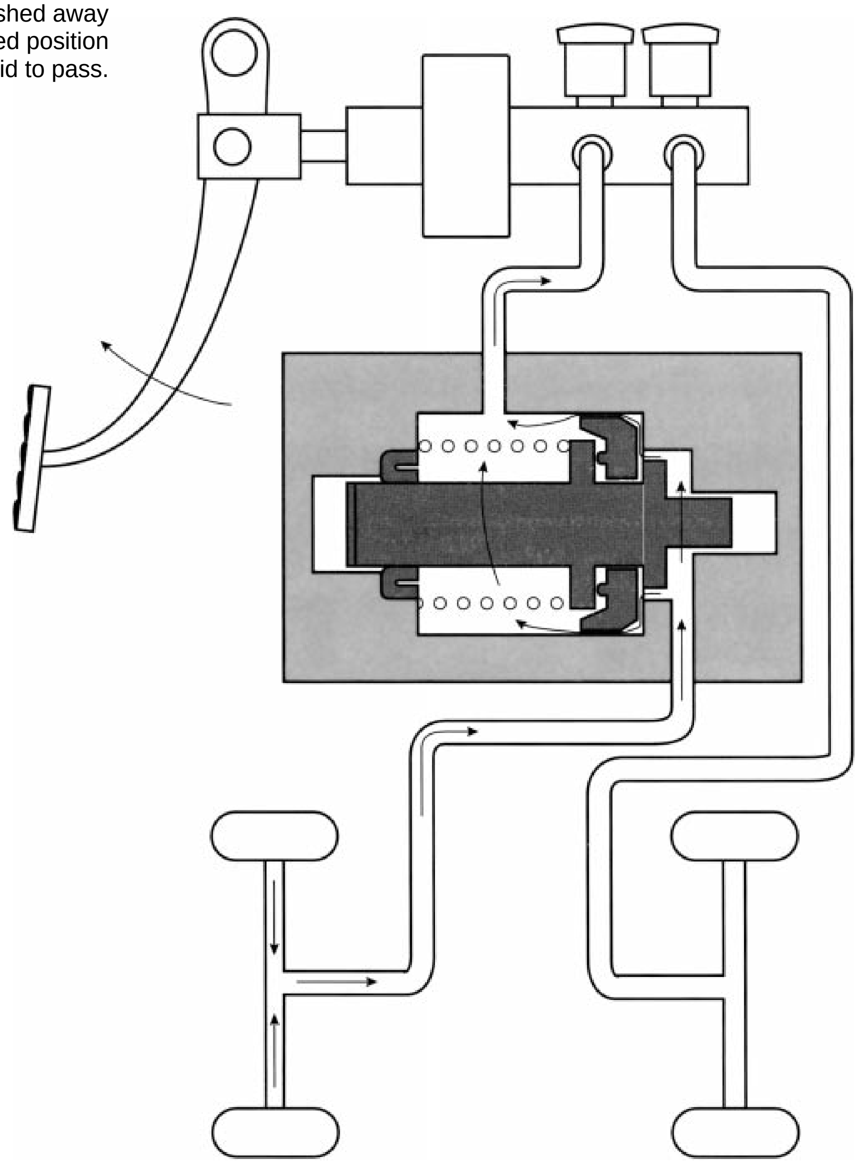
Pressure on the rear cylinder side pushes the valve against spring tension and closes the valve.



In order to release the pressure between the proportioning valve and the rear wheel cylinders, the valve seat floats as shown in the illustration. When the pressure from the master cylinder is released, the pressure difference on the valve seat causes it to be pushed away from its seated position on the valve body. This allows fluid to pass the valve seat and the brakes to release.

Proportioning Valve Brake Released

When the pressure from the master cylinder is released, the valve seat pushed away from its seated position allows fluid to pass.



Proportioning and Bypass Valve Operation

The proportioning function of this valve is the same as that described on the previous pages however, a **Bypass Valve** is incorporated into the valve body. It ensures maximum braking pressure to the rear brakes when there is a loss of brake pressure in the front brake circuit.

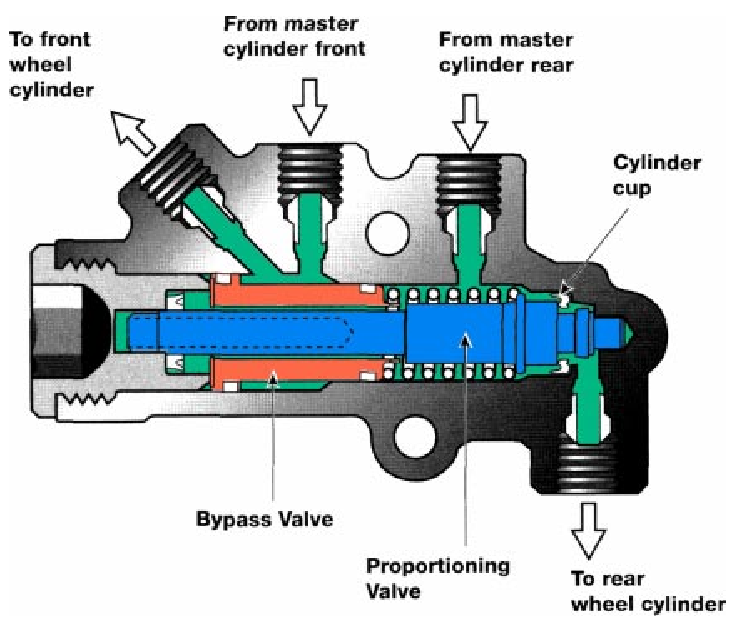
The hydraulic circuit from the master cylinder to the front brakes flows through part of the proportioning valve housing where the Bypass Valve

monitors front brake pressure. The spring pushes the bypass valve to the left and pushes the proportioning valve to the right, providing the proper spring tension for proportioning valve operation.

Rear brake hydraulic pressure pushes the bypass valve to the right while front brake pressure pushes the valve to the left. The overall hydraulic effect on the valve is neutral and the spring holds it to the left.

Bypass Valve Operation

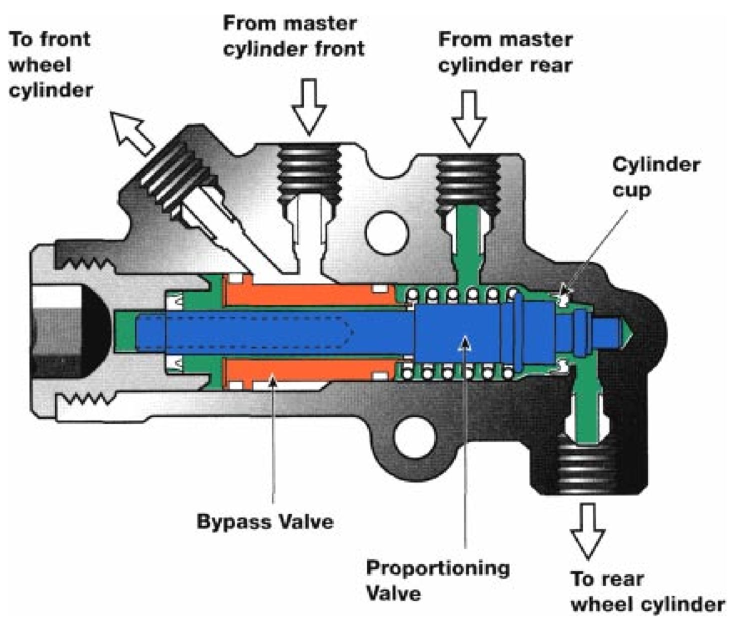
Spring loaded to the left, the bypass valve establishes the spring position for normal proportioning operation.



Should the hydraulic circuit to the front brakes fail, rear brake pressure will move the bypass valve to the right, forcing the proportioning valve to the right, which allows unregulated pressure to apply the rear brakes.

Bypass Valve Operation

The bypass valve moves right when front brake pressure drops, increasing spring tension of the proportioning valve thereby ensuring maximum pressure.

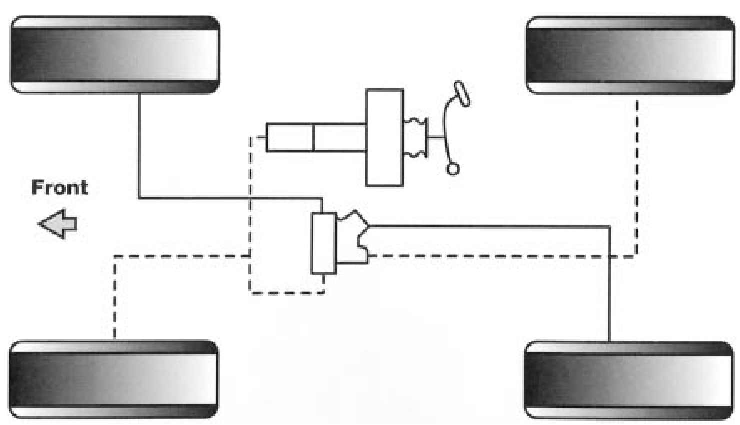


Double Proportioning Valve

The diagonal split brake system incorporated on all FWD vehicles uses a double proportioning valve in which two valves are arranged parallel to one another in the same valve housing. One valve controls pressure to the right rear brakes and the other valve controls pressure to the left rear brakes.

Proportioning Valve on Diagonal Split Brake System

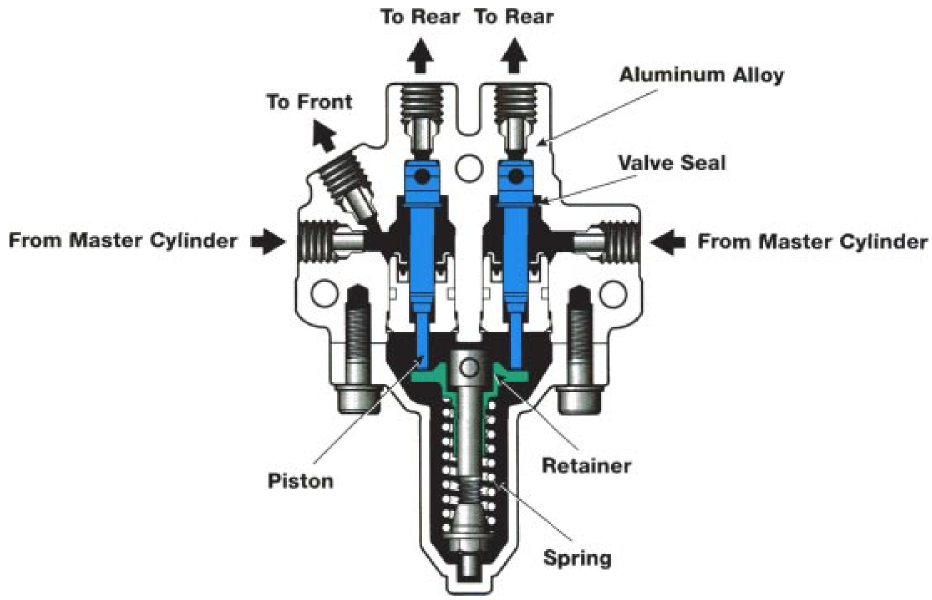
All FWD vehicles use a double proportioning valve to control one front brake and one rear brake on the opposite side.



The movement of both valves is controlled by the tension of one spring. With a single spring, a balanced pressure is applied to each valve through the retainer.

Double Proportioning Valve

Both valves are controlled by the tension of one spring.

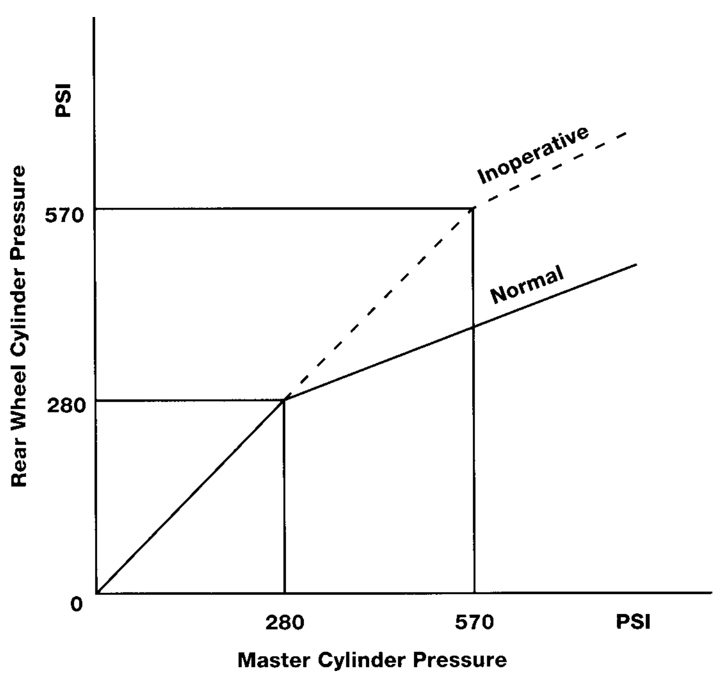


Pressure Loss in One Circuit

The real advantage to one spring is seen when one hydraulic circuit loses pressure. In this case only one valve counteracts the spring tension which requires additional hydraulic pressure to compress it. This results in higher pressure to the rear brake, providing a greater degree of vehicle control.

Rear Wheel Cylinder Pressure

When one circuit fails, pressure to the rear cylinder increases higher in proportion to master cylinder pressure because only one piston compresses the spring.



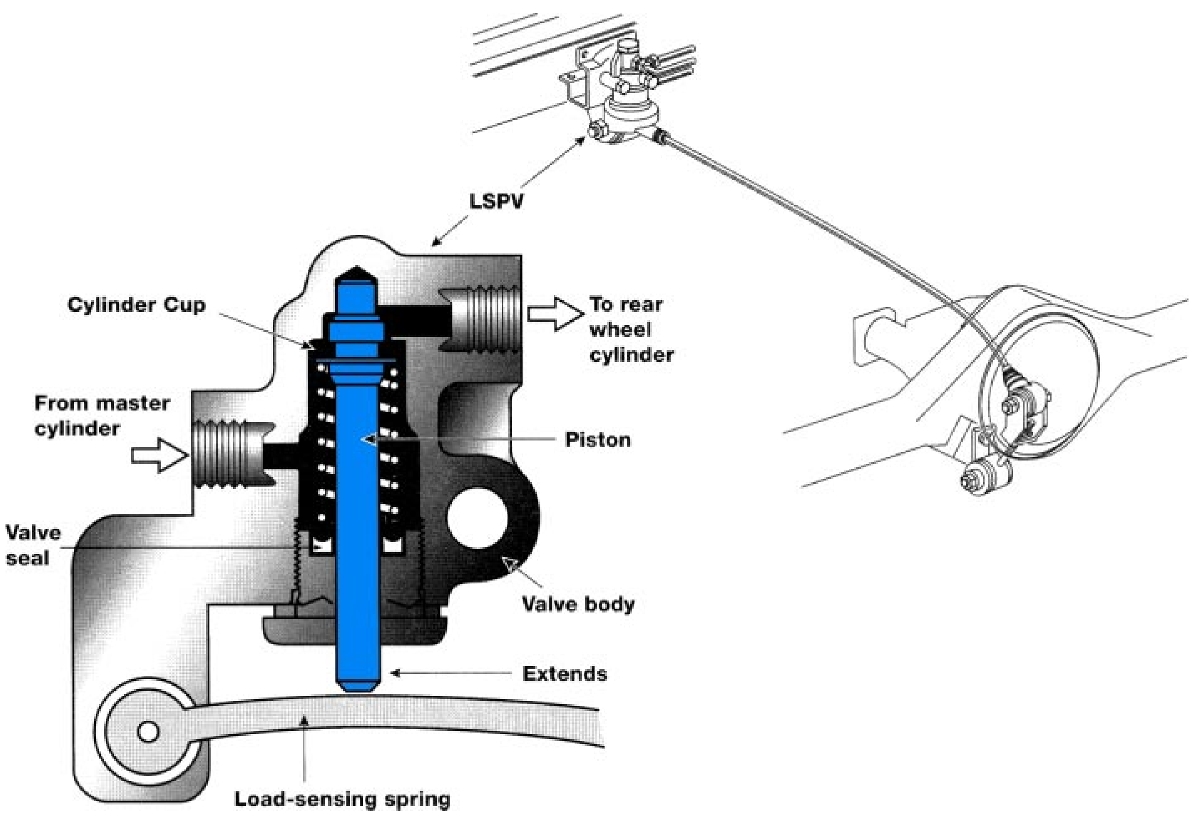
Load Sensing Proportioning Valve

The LSPV is used on Toyota models such as Truck, Van and Station Wagons which may be used to carry a variety of loads. The heavier the load, the greater the portion of braking is required of the rear brakes. The LSPV allows higher pressure to the rear brakes to accomplish this.

The LSPV is attached to the body or frame above the left rear control arm or axle housing. Load sensing is accomplished by suspending the sensing spring between the vehicle body and the rear axle housing. The load sensing spring movement caused by vehicle height changes due to load, is transmitted to the proportioning valve.

Load Sensing Proportioning Valve

Load sensing is accomplished by suspending the sensing spring between the vehicle body and the rear axle housing.

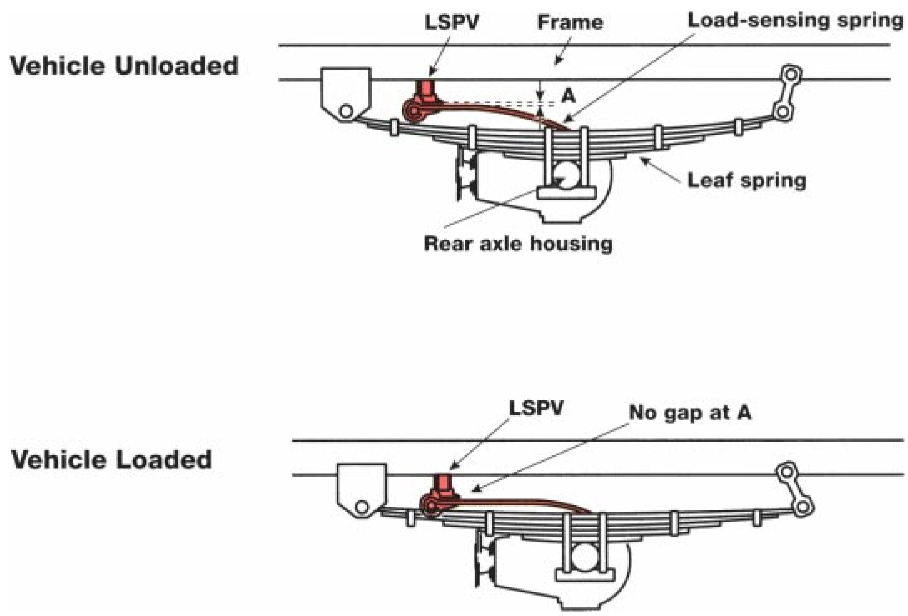


LSPV Operation

As a vehicle is loaded, the leaf springs are compressed as the vehicle body lowers. The load sensing spring provides a variable force pushing the proportioning piston up as the vehicle is loaded. As the piston is lifted, a higher brake hydraulic pressure is required to force the piston down resulting in higher pressure at the rear wheels.

LSPV Lever Balance

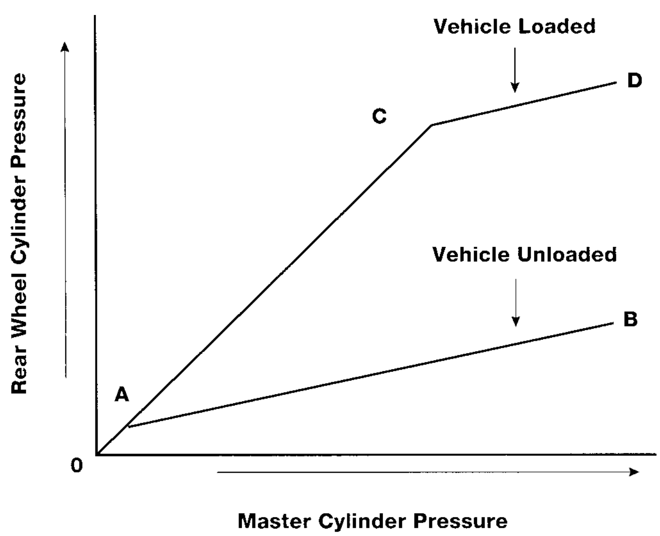
The load sensing spring provides additional pressure to the proportioning valve based on vehicle load.



Rear wheel cylinder pressure is adjusted according to increases or decreases in vehicle load. The pressure change for one rear wheel is shown below.

LSPV Rear Wheel Cylinder Pressure

Pressure to the rear brakes is regulated at a higher pressure when the vehicle is loaded.



Unloaded Vehicle

When unloaded, *a* vehicle body rises to normal vehicle height and no force from the load sensing spring is applied to the piston. The rear wheel cylinder is regulated at a lower pressure as shown by the line O - A - B in the chart on the previous page.

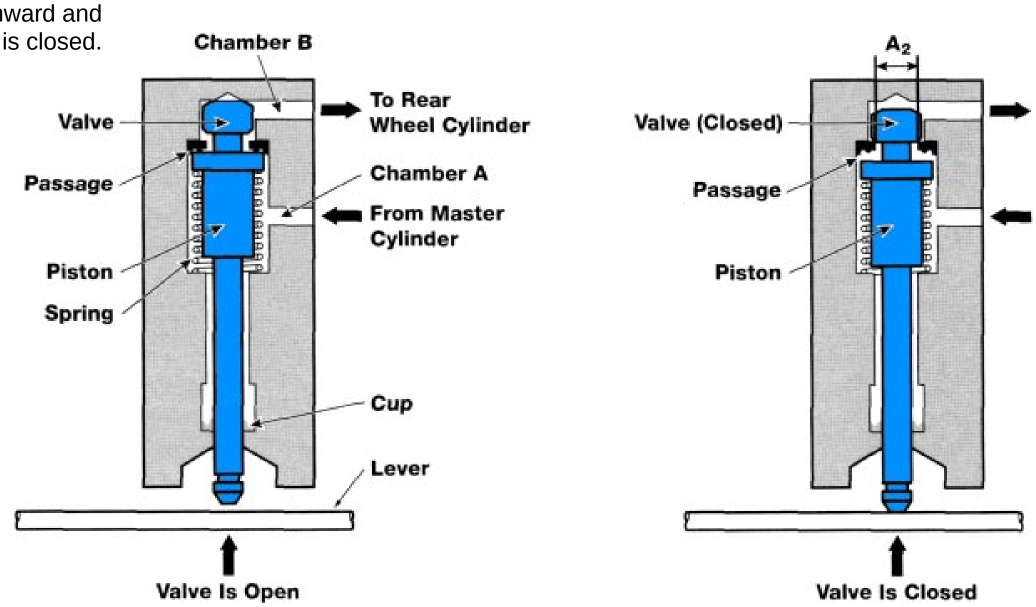
When the fluid pressure from the master cylinder is low the piston is pushed upward by the force of the piston spring. Fluid pressure is transmitted from chamber A through the passage into chamber B and to the rear wheel cylinder.

When the master cylinder pressure rises and pressure on the valve top (A2) becomes greater than piston spring tension, the piston is pushed downward and the valve is closed. Hydraulic pressure to the rear cylinders at this time will be as indicated by the point of deflection “A” in the graph. The upward force of the piston spring is equal to the downward force of hydraulic pressure when the valve is in the closed position.

As the master cylinder fluid pressure increases with further brake application, the piston is pushed upward again and the valve opens. Pressure to the rear wheel cylinders increases when the valve opens, but the piston is pushed down before wheel cylinder pressure becomes equal to master cylinder pressure, and the valve closes.

Proportioning Valve in Unloaded Position

The proportioning valve is normally open. When the master cylinder pressure rises and pressure on the valve top (A2) becomes greater than piston spring tension, the piston is pushed downward and the valve is closed.



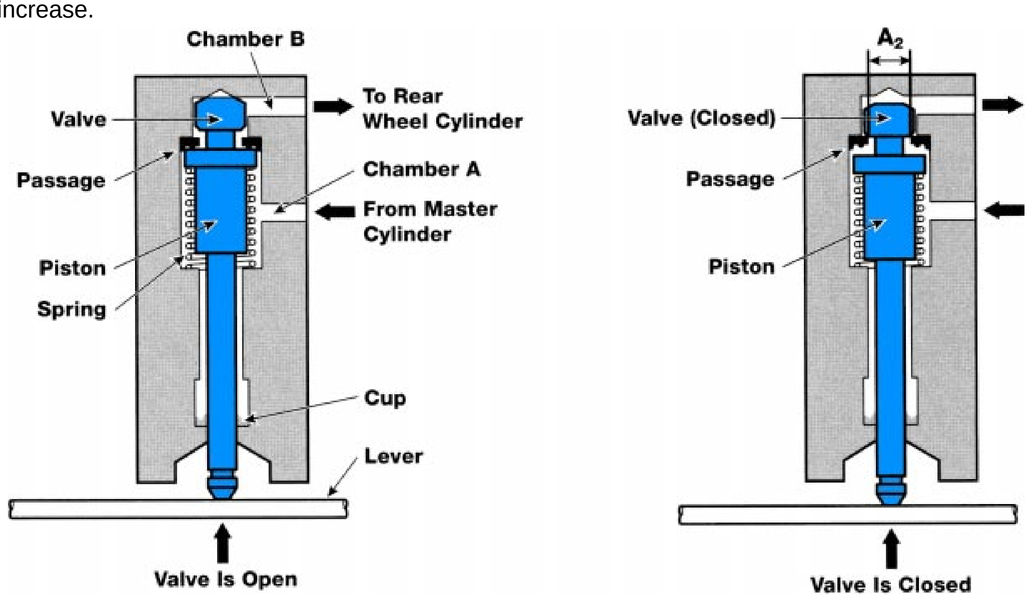
Loaded Vehicle

As the load in the vehicle is increased, the vehicle body moves down, and the LSPV piston is pushed up by the lever causing the rear wheel cylinder to be regulated at a higher pressure as shown in the graph (O - C - D).

When the fluid pressure from the master cylinder is low, the hydraulic pressure going to the rear wheel cylinder is not controlled. As master cylinder pressure rises and becomes greater than the combined spring tension, the piston is pushed downward and the valve is closed regulating pressure to the rear brake cylinder.

Proportioning Valve in the Loaded Position

The LSPV piston is pushed up by the lever causing the rear wheel cylinder pressure to increase.



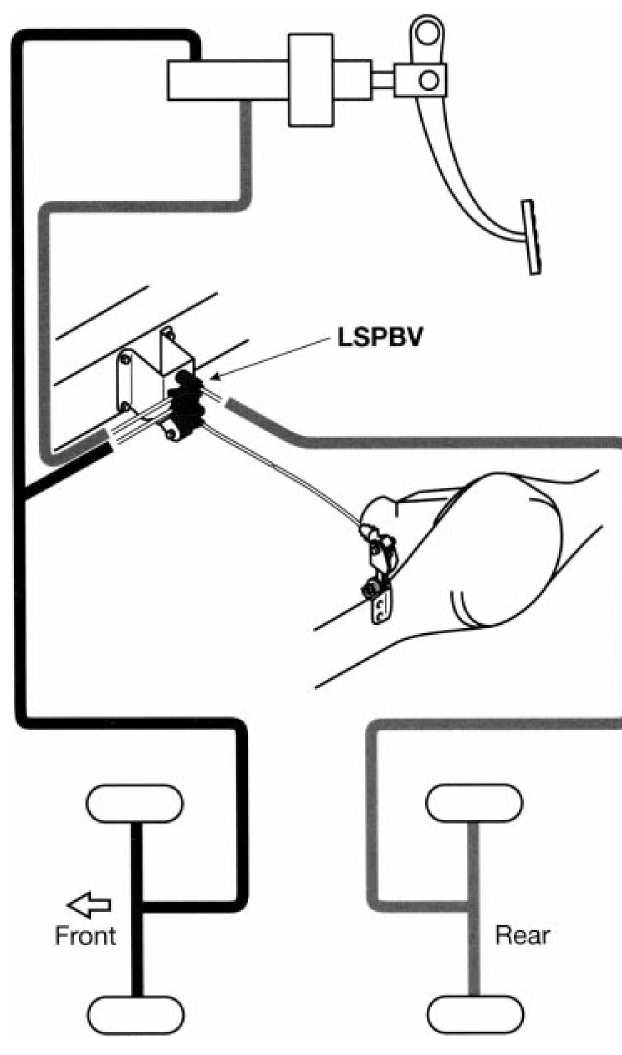
Load Sensing Proportioning and Bypass Valve

The LSPBV is used on Previa's, Trucks, Tacoma's, T-100's, Cab and Chassis 2WD and 4WD models. The LSPBV is a LSPV to which a bypass circuit has been added. The operation of the bypass valve is similar to the Proportioning and Bypass Valve.

When the front brake circuit is operating normally, the LSPBV varies the pressure transmitted from the master cylinder to the rear wheels based on vehicle load, in the same way as the LSPV. However, if the front brake circuit fails, hydraulic pressure is transmitted directly to the rear wheel cylinders, bypassing the proportioning part of the valve so that enough braking force can be applied.

The hydraulic sensing circuit which links the front brake hydraulic circuit to the LSPBV, is part of the front hydraulic circuit. When bleeding the front brake system, be sure to bleed air from the LSPBV as well, or the pedal may feel spongy with diminished brake performance.

Load Sensing Proportioning and Bypass Valve



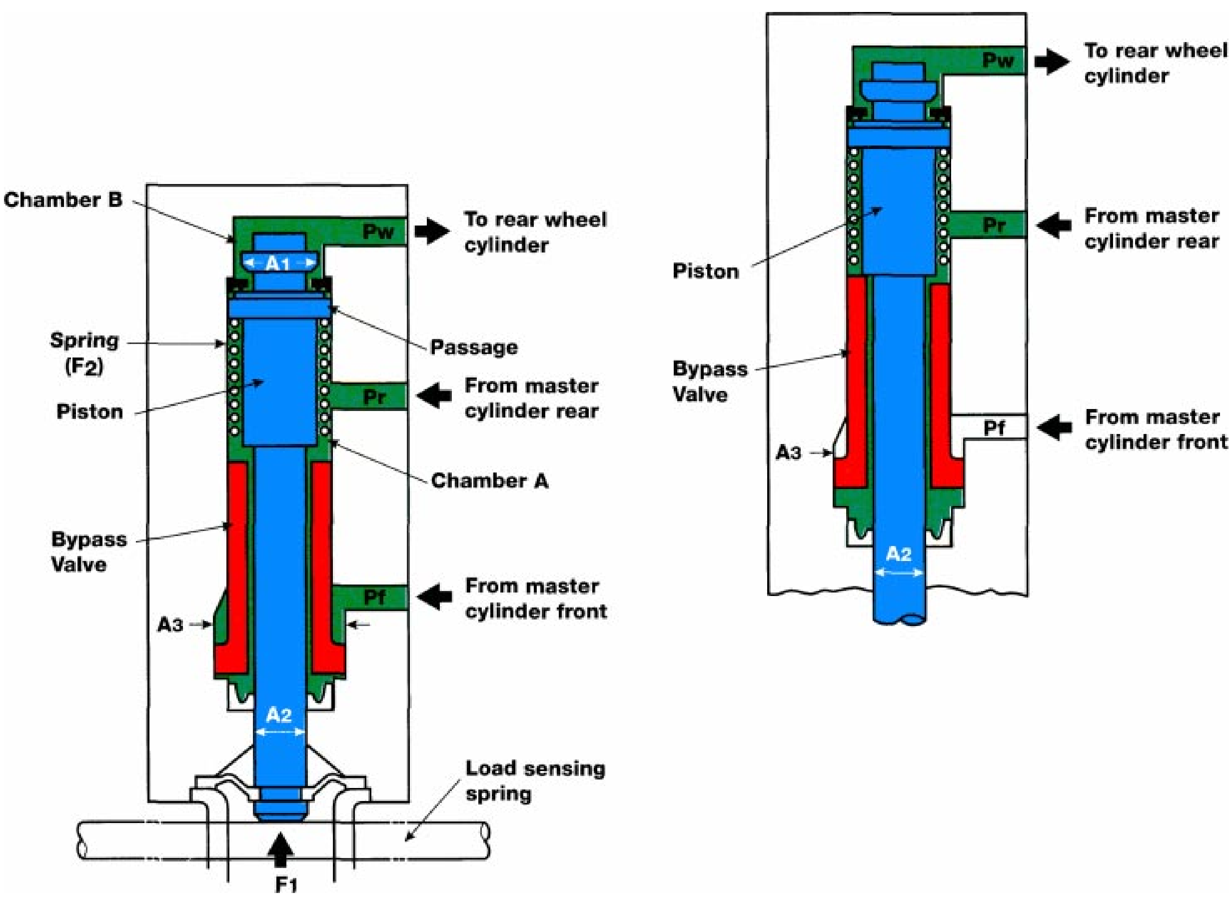
Bypass Valve Operation

When the front brake circuit is operating normally, pressure from the master cylinder front and master cylinder rear are equal. The bypass piston is pushed and held down by the spring.

If pressure from the front brakes falls to zero, a difference will exist between the hydraulic pressure pushing the bypass valve up and the pressure pushing the valve down. This causes the bypass valve to be pushed upward, pushing the piston upward, and opening the passage at the top of the valve. The hydraulic pressure from the master cylinder is not controlled. Full pressure from the master cylinder is transmitted to the rear wheel cylinder.

Fail-safe Operation

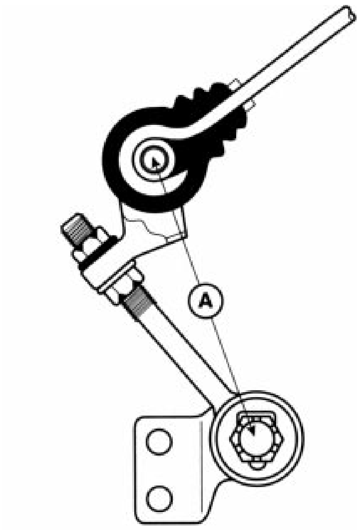
When pressure from the front brakes (Pf) is lost, Piston No. 2 rises compressing the spring and opening the valve.



LSPV Adjustment

Adjustment of the LSPV is accomplished by changing the length of (A) in the illustrations below. The distance has an initial length which can be found in the Repair Manual.

Adjustment Length



If distance (A) is too short, the hydraulic pressure breaking point will decrease. Hydraulic pressure to the rear wheel cylinders will be lower than normal, reducing braking performance.

When distance (A) is too long, the hydraulic pressure breaking point will rise. Hydraulic pressure to the rear wheel cylinder will be higher than normal, increasing the braking force of the rear wheels.

To adjust the valve properly and ensure efficient braking, the LSPV gauge (SST 09709-29017-01) must be used to measure the front and rear brake pressure.

Pressure Gauge SST

To adjust the valve properly and ensure efficient braking, the LSPV gauge (SST 09709-29017-01) must be used to measure the front and rear brake pressure.

The gauges are provided in the SST Kit. Install one gauge at the front wheel cylinder. The other gauge is installed at the rear wheel cylinder. Having opened the system, the air must be bled from the system before accurate system pressures can be read. Bleed screws are located on the hose end of the gauge.

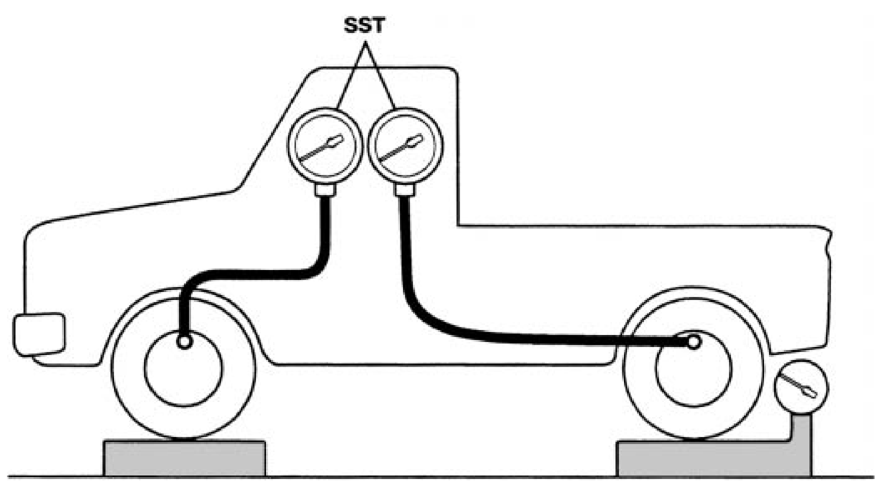
Follow the procedure outlined in the Repair Manual to determine the following:

1. Rear axle load (based on vehicle model).
2. Front brake pressure specifications.
3. Rear brake pressure specifications.

The weight of the vehicle measured at the rear axle must be determined and additional weight added to meet the Repair Manual specification. This will establish the proper relationship of the proportioning valve and the rear axle housing.

Hydraulic Pressure Measurement

Hydraulic pressure at the front brake should be compared with the pressure of the rear brake in two stages.



Next, the hydraulic pressure at the front brake should be compared with the pressure of the rear brake in two or three stages as specified in the Repair Manual.

- First, the front pressure is brought to a specified pressure (example: 1,138 psi) and the rear pressure should be within a specific pressure range (example: 583 psi to 768 psi).
- Second, without releasing the brake pedal, the front pressure is increased (example: 1,422 psi) and the rear brake pressure should increase (example: between 688 psi to 873 psi).

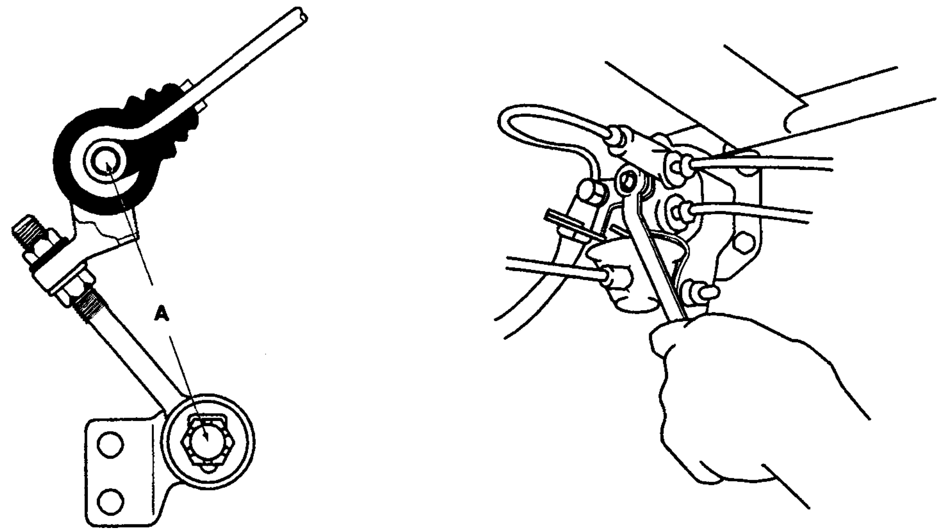
NOTE Rear pressure readings should be taken within two seconds of obtaining the specified front pressure.

If the rear pressures do not fall within the stated specification, adjust distance (A):

- Lengthening (A) if the pressure is low.
- Shortening (A) if the pressure is high.

LSPV Adjustment

If the rear pressures do not fall within the stated specification, adjust distance A.



If adjustment of the springs does not bring the rear pressure into specification, adjust the valve body:

- If pressure is low, lower the valve body.
- If the pressure is high, raise the valve body.

WORKSHEET 8-1 (ON-CAR)
LSPV Adjustment

Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

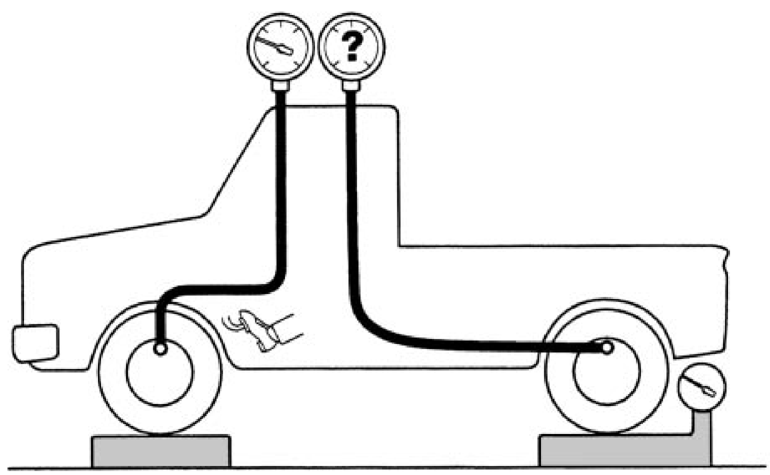
In this Worksheet you will practice the procedure for measuring and adjusting the LSPV.

Tools and Equipment:

- LSPV Pressure Gauge SST. (09709-29017-01)
- Weight Scale Printout.
- Hand Tool Set.
- Tape Measure or Ruler.
- Brake Fluid.
- Repair Manual.

Preparation:

- Raise the vehicle on a lift and install the LSPV gauges.
- Bleed air from the brake lines.
- Place weight scales under the wheels and lower the vehicle onto the scales.



Measurement:

1. Record the specified weight from Repair Manual, subtract the rear vehicle weight to find amount of additional weight required. Additional weight should be placed above the rear axle.

Specified Weight	
Rear Axle Weight	
Added Weight	

Measurement (cont'd):

2. Raise front brake pressure and check rear brake pressure.

Model	Front Pressure Spec.	Rear Axle Spec.	Rear Axle Measured

3. How does this compare to the specified pressure? ____

LSPV Adjustment:

1. Record the initial length of the No.2 shackle. ____

2. Rotate the adjusting nut two (2) complete turns and record the change in rear pressure. ________________

3. Recheck the pressures, has the pressure at the rear brakes increased or decreased? _________________

   If so, by how much? ____________________

Summary:

1. Why is the weighting of the rear of the vehicle important?

   ____

   ____

2. What effect would mis-adjustment have on the brake system?

   ____

   ____

3. Refer to the Repair Manual for Previa and Camry and record the pressure change for each rotation of the No.2 shackle adjusting nut.

   ____

   ____

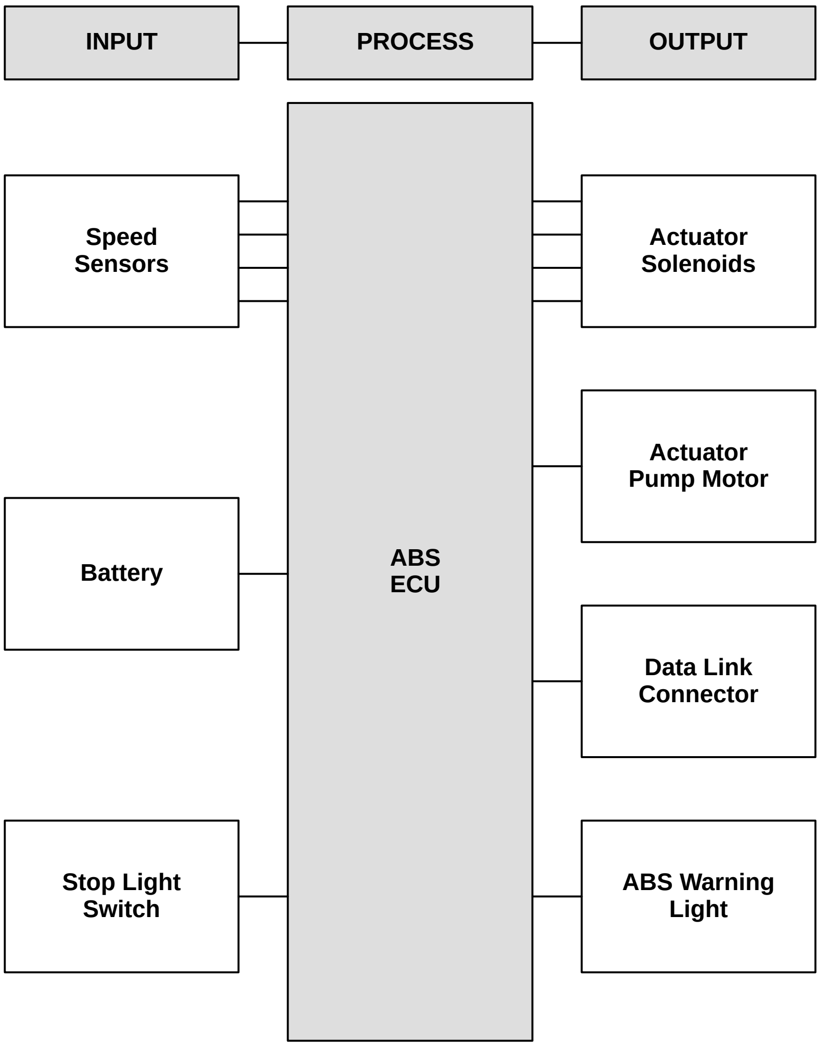
4. To increase the pressure at the rear wheels, would the No.2 shackle be shortened or lengthened?

   ____

   ____

Section 9

ANTI-LOCK BRAKES



Lesson Objectives

1. Identify and describe the function of components in the ABS system.
2. Relate the basic operation strategy of the ABS system.
3. Explain the control of the solenoid and pump relays.
4. Describe the signal generation of a speed sensor.
5. Describe the operation of the two-position solenoid actuator for controlling wheel lock-up.

Fundamental ABS Systems

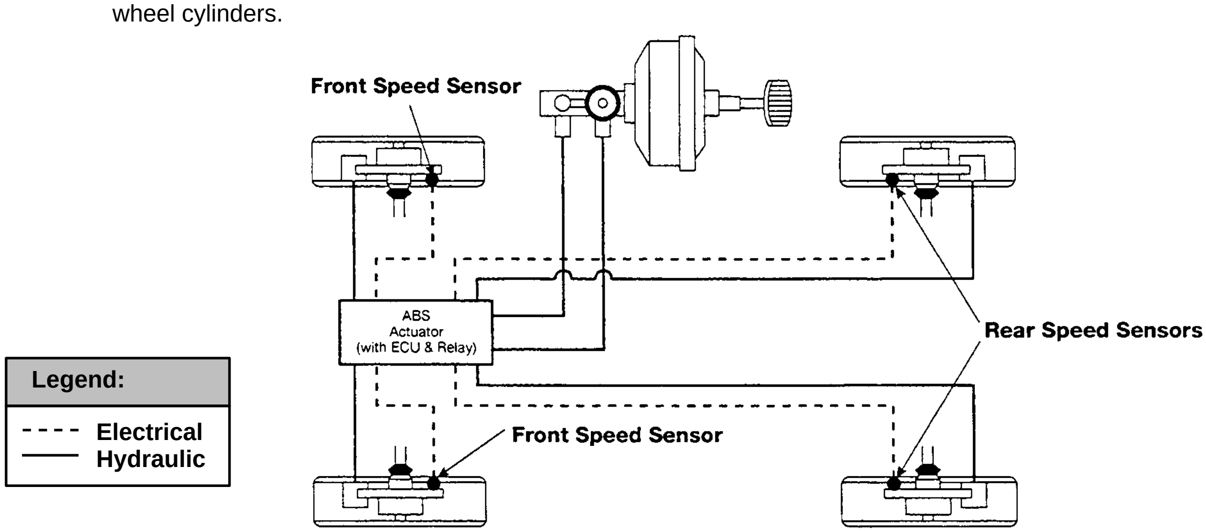
Toyota Antilock Brake Systems (ABS) are integrated with the conventional braking system. They use a computer controlled actuator unit, between the brake master cylinder and the wheel cylinders to control brake system hydraulic pressure.

Antilock Brake Systems address two conditions related to brake application; wheel lockup and vehicle directional control. The brakes slow the rotation of the wheels, but it is actually the friction between the tire and road surface that stops the vehicle. Without ABS when brakes are applied with enough force to lock the wheels, the vehicle slides uncontrollably because there is no traction between the tires and the road surface. While the wheels are skidding, steering control is lost as well.

An antilock brake system provides a high level of safety to the driver by preventing the wheels from locking, which maintains directional stability. A professional driver may be capable of maintaining control during braking by pumping the brake pedal which allows a locked wheel to turn momentarily. Whereas a professional driver may be capable of modulating the brakes approximately once per second, ABS is capable of modulating the brake pressure at a given wheel up to fifteen times per second. An ABS system does something else that no driver can do, it controls each front brake separately and the rear brakes as a pair whenever one of the wheels starts to lock. ABS helps stop a car in the shortest possible distance without wheel lockup while maintaining directional control on most types of road surface or conditions. If a Toyota ABS system malfunctions, normal braking will not be affected.

ABS System Diagram

ABS is combined with the conventional braking system and located between the master cylinder and the wheel cylinders.



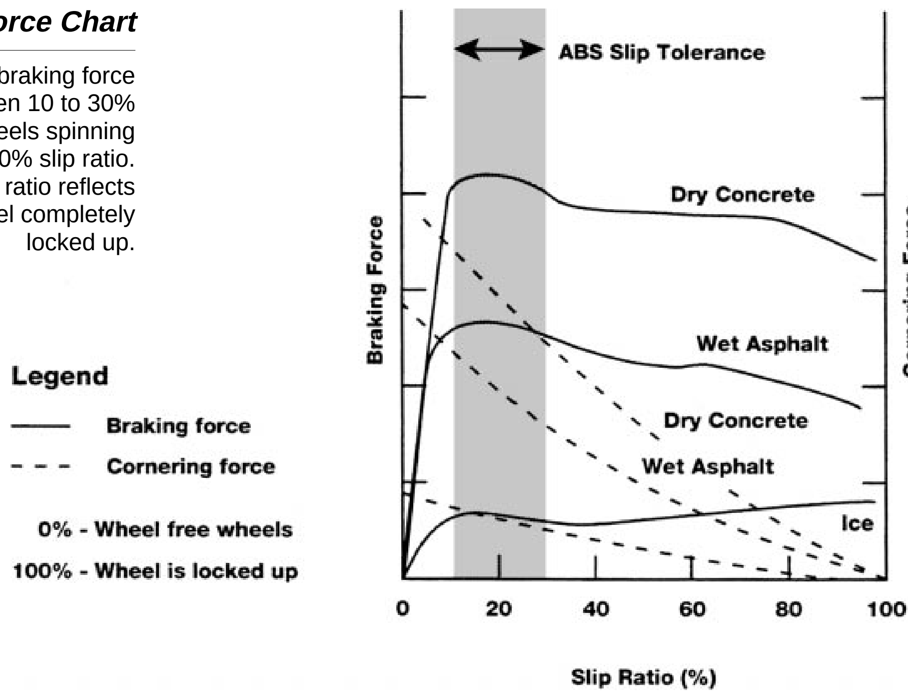
Tire Traction and ABS

The chart below shows the slip tolerance band (shaded area) in which the most efficient braking occurs. From a slip ratio of zero (0), at which the wheel speed and the vehicle speed are equal, to a slip ratio of 10, braking is mild to moderate and good traction between the tire and the road surface is maintained. Between slip ratios of 10 to 30 the most efficient braking occurs. This is where the tires are at a point where they may begin to lose traction with the road surface. This is also the band in which ABS operation occurs. Beyond a slip ratio of 30%, braking efficiency is reduced, stopping distance is increased and directional control is lost.

The amount of braking force on the left vertical line will vary based on the driver's pressure on the brake pedal and on the road surface; less braking force may be applied on wet asphalt than on dry concrete before lockup occurs, therefore the stopping distance is increased.

Braking Force Chart

Maximum braking force occurs between 10 to 30% slip ratio. Wheels spinning freely is 0% slip ratio. 100% slip ratio reflects a wheel completely locked up.



Basic Operation

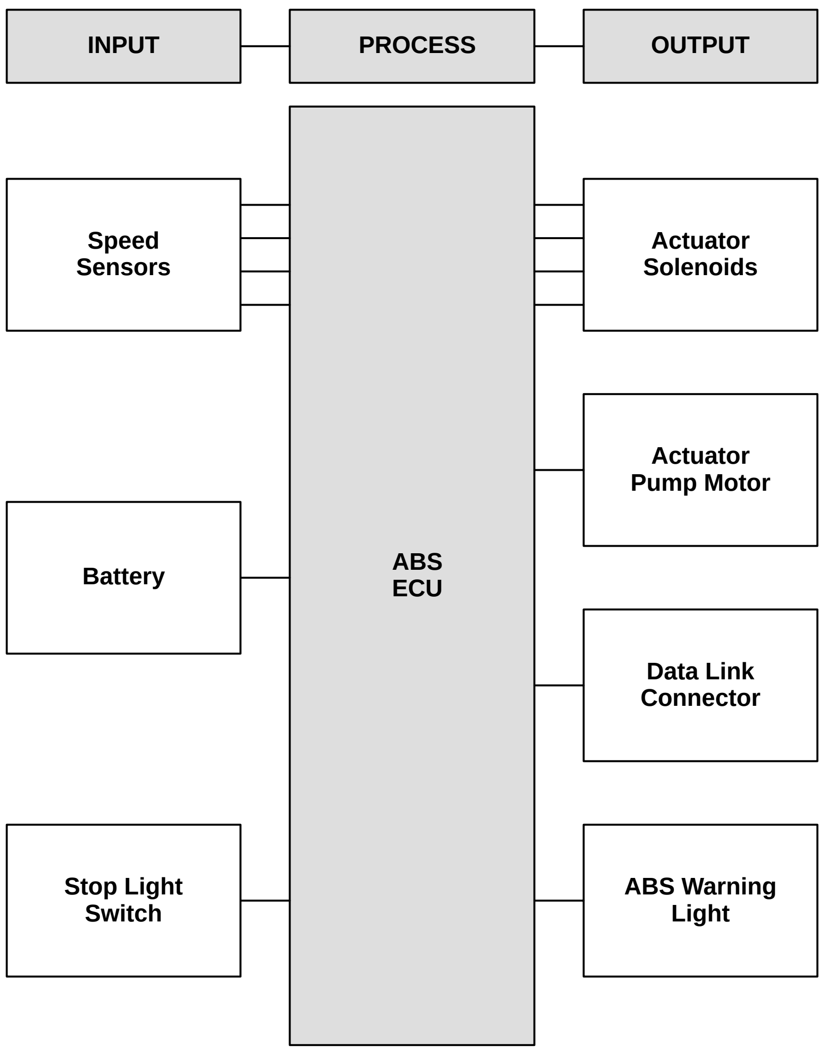
Four Wheel ABS Systems use a speed sensor at each front wheel and either a single speed sensor for both rear wheels or individual speed sensors at each rear wheel. The speed sensors are monitored by a dedicated ECU. The system controls the front brakes individually and rear brakes as a pair.

In a panic braking situation, the wheel speed sensors detect any sudden changes in wheel speed. The ABS ECU calculates the rotational speed of the wheels and the change in their speed, then calculates the vehicle speed. The ECU then judges the slip ratio of each wheel and instructs the actuator to provide the optimum braking pressure to each wheel. For example, the pressure to the brakes will be less on slippery pavement to reduce brake lockup. As a result, braking distance may increase but directional control will be maintained. It is also important to understand that ABS is not active during all stops.

The hydraulic brake actuator operates on signals from the ABS ECU to **hold, reduce or increase** the brake fluid pressure as necessary, to maintain the optimum slip ratio of 10 to 30% and avoid wheel lockup.

Typical ABS Control System

The ECU monitors the four wheel sensors, processes the data and controls the actuator solenoids and pump motor through the ABS Relay.



Types of Toyota ABS

There are four types of ABS systems used in current Toyota models distinguished by the actuator. The four actuator types include:

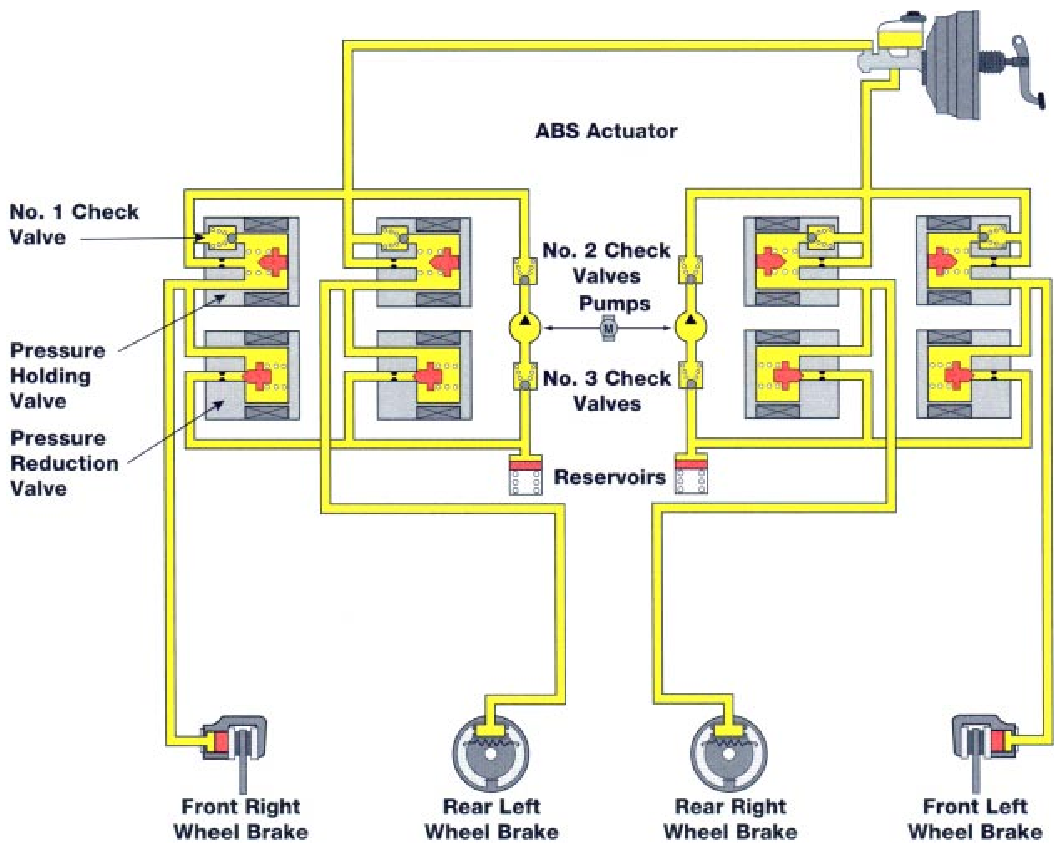
- 2-position solenoid valves.
- 3-position solenoid valves with mechanical valve (Bosch).
- 3-position solenoid valves (Nippondenso).
- 2-position solenoid controlling power steering hydraulic pressure which controls brake hydraulic pressure.

2-Position Solenoid

2-position solenoid actuators come in configurations of six or eight solenoids. The eight solenoid configuration uses two solenoids per brake assembly. The six solenoid configuration uses two solenoids to control the rear brake assemblies while the front brake assemblies are controlled independently by two solenoids each.

***2-Position Solenoid* Types**

Controls pressure to four brake assemblies in three stages: pressure holding, increase and reduction.

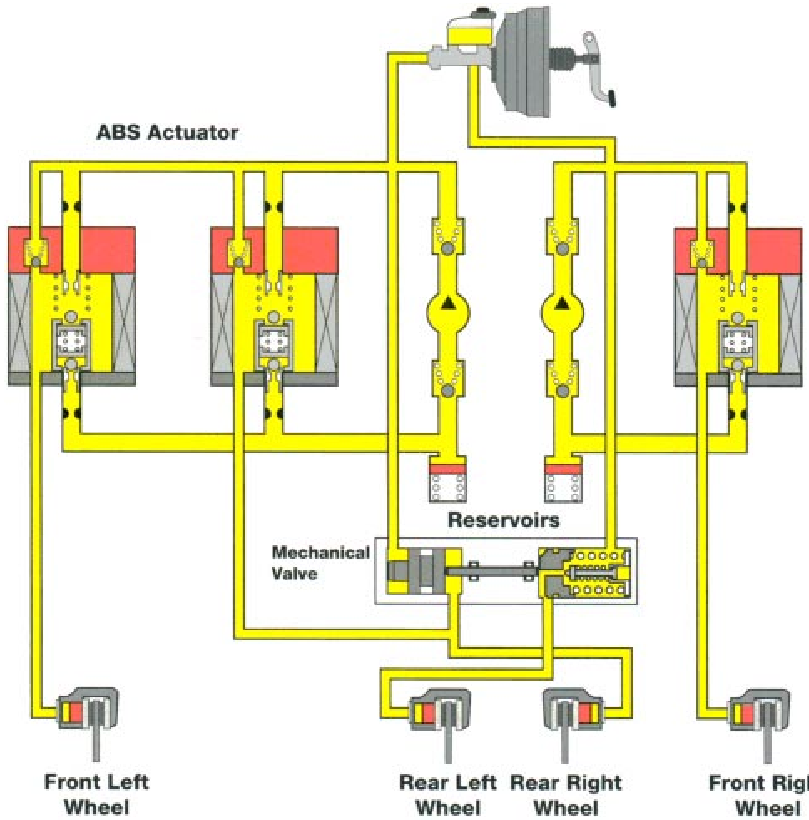


3-Position Solenoid and Mechanical Valve

This actuator uses three, 3-position solenoid valves. Two solenoids control the front wheels independently while the third solenoid controls the right rear and the mechanical valve translates controls to the left rear.

3-Position Solenoid With Mechanical Valve

The third solenoid controls the right rear and the mechanical valve translates controls to the left rear.

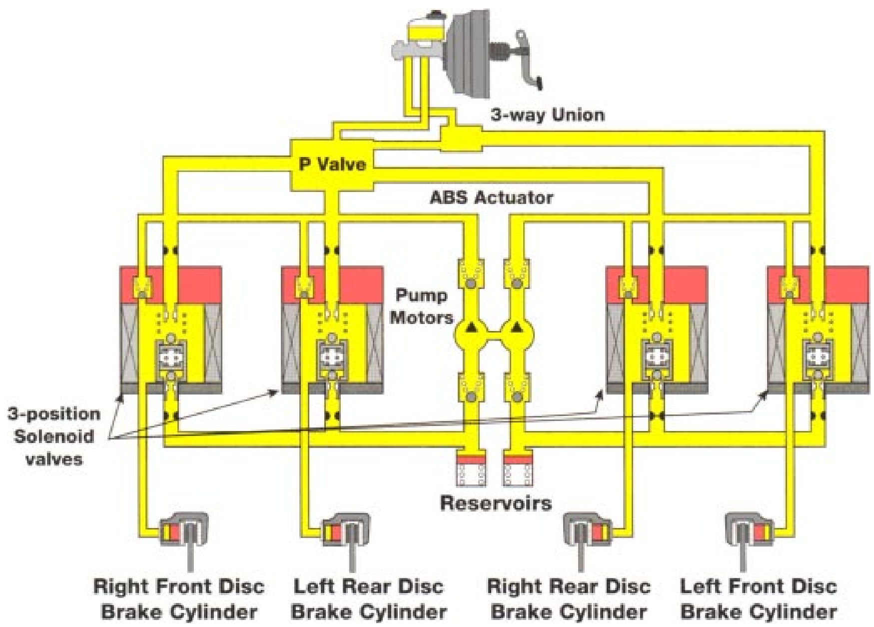


3-Position Solenoids

The 3-position solenoid valve actuator comes in three solenoid or four solenoid configurations. The four-solenoid system controls hydraulic pressure to all four wheels. In the 3-solenoid system, each front wheel is controlled independently while the rear wheels are controlled in tandem.

3-Position Solenoids

Controls pressure to four brake assemblies in three stages: pressure holding, pressure increase and pressure reduction.

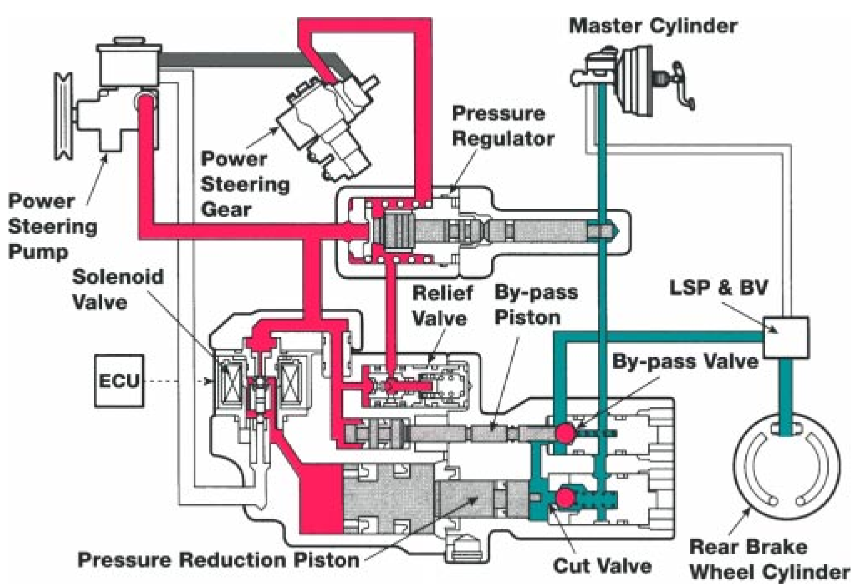


Power Steering Control

The last actuator type uses power steering pressure to regulate brake pressure using a single 2-position solenoid, a cut valve and bypass valve. Brake system pressure is controlled for the rear brakes only.

Power Steering Hydraulic Pressure Controls Brake Hydraulic Pressure

A single 2-position solenoid regulates power steering pressure which controls brake hydraulic pressure to the two rear wheels only.



System Components

Each ABS type shares common components which provide information to the ECU. This section will examine each of these components and then describe each of the actuator types and their operation.

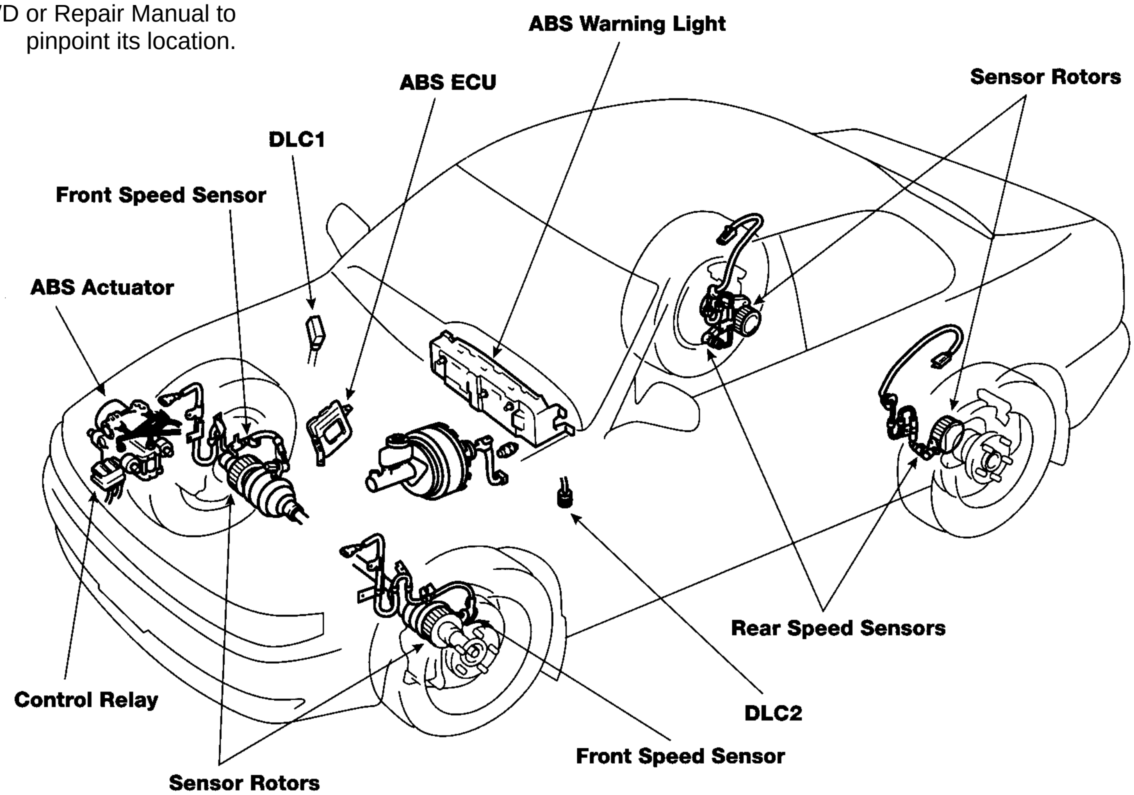
The components identified below are typical of most Toyota ABS systems.

- **Speed Sensors** monitor wheel speed.
- **G-Sensor** monitors rate of deceleration or lateral acceleration.
- **ABS Actuators** control brake system pressure.
- **Control Relay** controls the Actuator Pump Motor and Solenoids.
- **ABS ECU** monitors sensor inputs and controls the Actuator.
- **ABS Warning Lamp** alerts the driver to system conditions.

The location of components may vary by model and year, therefore, for accurate location of components, consult your EWD or Repair Manual.

Typical Component Layout

Component location is typical for most models: speed sensors at each wheel, actuator in engine compartment. The ECU however may require an EWD or Repair Manual to pinpoint its location.

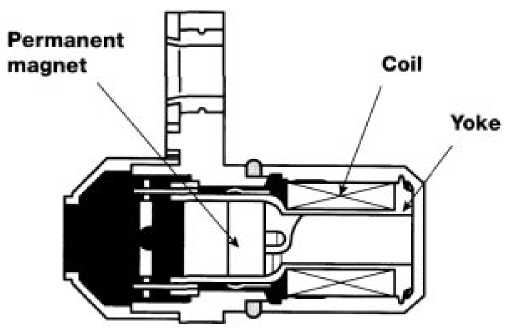


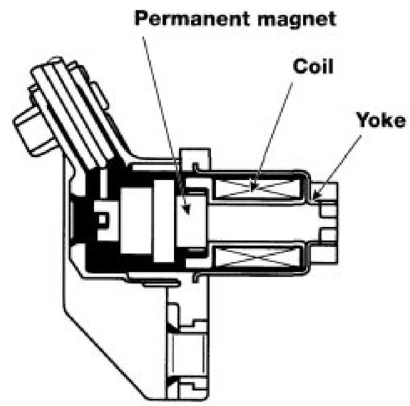
Wheel Speed Sensor

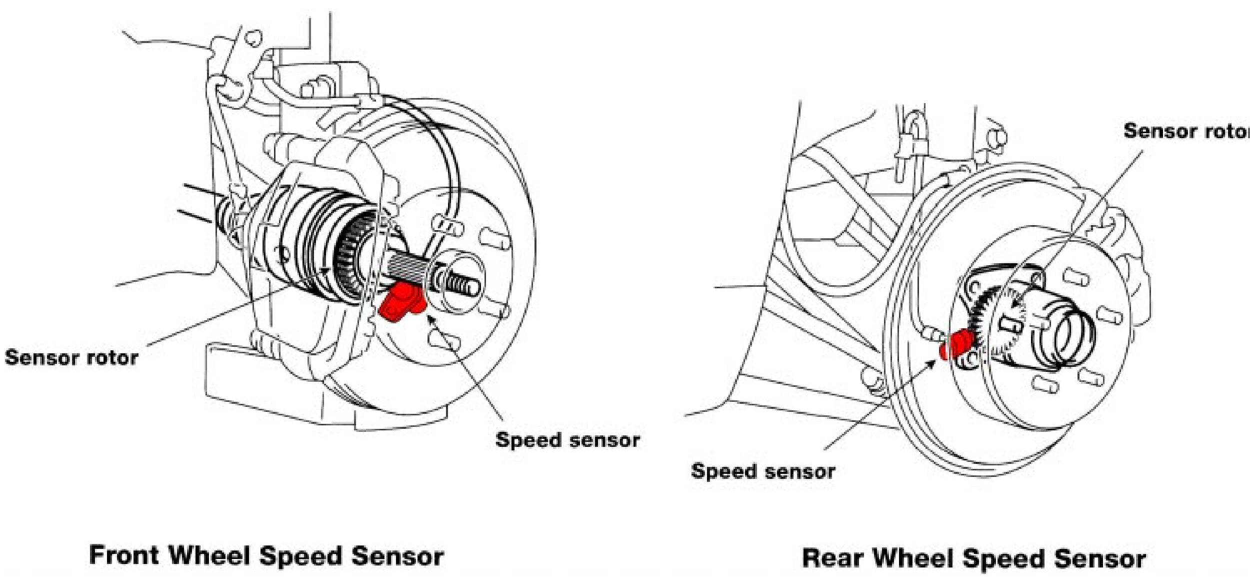
A wheel speed sensor is mounted at each wheel and sends a wheel rotation signal to the ABS ECU. The front and rear wheel speed sensors consist of a permanent magnet attached to a soft iron core (yoke) and a wire wound coil. The front wheel speed sensors are mounted to the steering knuckle, and the rear speed sensors are mounted to the rear axle carrier. Serrated rotors are mounted to the drive axle shaft or brake rotor, and rotate as a unit.

Wheel Speed Sensors

Speed sensors monitor individual wheel speed.







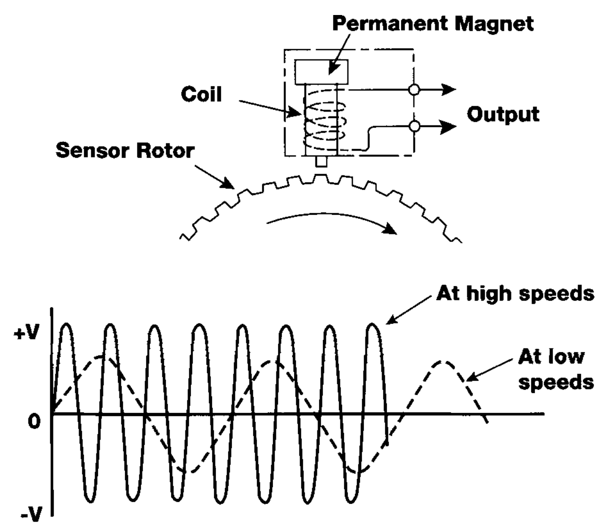
Early Supras including the 1993 model year and Cressidas equipped with ABS, used a single rear speed sensor mounted on the transmission extension housing to monitor rear wheel speed.

Operation

Speed sensor operation is similar to the magnetic pick-up in a distributor. When the teeth of the Sensor Rotor pass the iron core, the magnetic lines of force cut through the coil windings causing a voltage to be induced into the coil. As the tooth approaches the iron core, the magnetic field contracts causing a positive voltage to be induced in the coil. When the tooth is centered on the iron core the magnetic field does not move and zero volts are induced in the coil. As the tooth moves away from the iron core the magnetic field expands, resulting in a negative voltage. As the rotation of the sensor rotor increases, the voltage and the frequency of this signal increase, indicating to the ECU a higher wheel speed.

Speed Sensor Operation

Voltage is induced into the coil when the magnetic field changes each time the sensor rotor teeth pass the iron core.



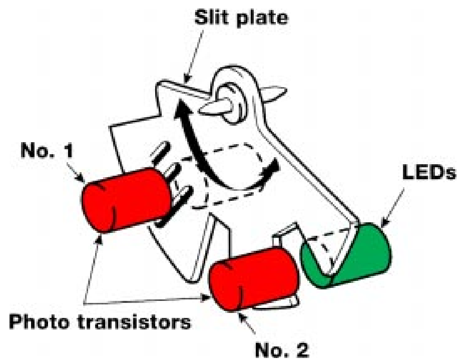
Deceleration Sensor

The deceleration sensor is used on some systems to provide input to the ABS ECU about the vehicle's rate of deceleration to improve braking performance. In a typical ABS system, the ECU compares individual speed sensors to determine the speed of the vehicle and rate of wheel deceleration. The deceleration sensor is used on all full-time 4WD vehicles equipped with ABS to determine deceleration, as the front and rear axles are connected through the transfer case and present unique braking characteristics. Models equipped with only rear-wheel ABS have a single speed sensor and no means of determining the actual vehicle speed or rate of deceleration.

The deceleration sensor is composed of two pairs of LEDs (light emitting diodes) and phototransistors, a slit plate, and a signal conversion circuit. The deceleration sensor senses the vehicle's rate of deceleration and sends signals to the ABS ECU. The ECU compares the rate of deceleration and vehicle speed to determine the precise road surface conditions and takes appropriate control measures.

Deceleration Sensor Components

The slit plate swings between the LED's and Phototransistors.

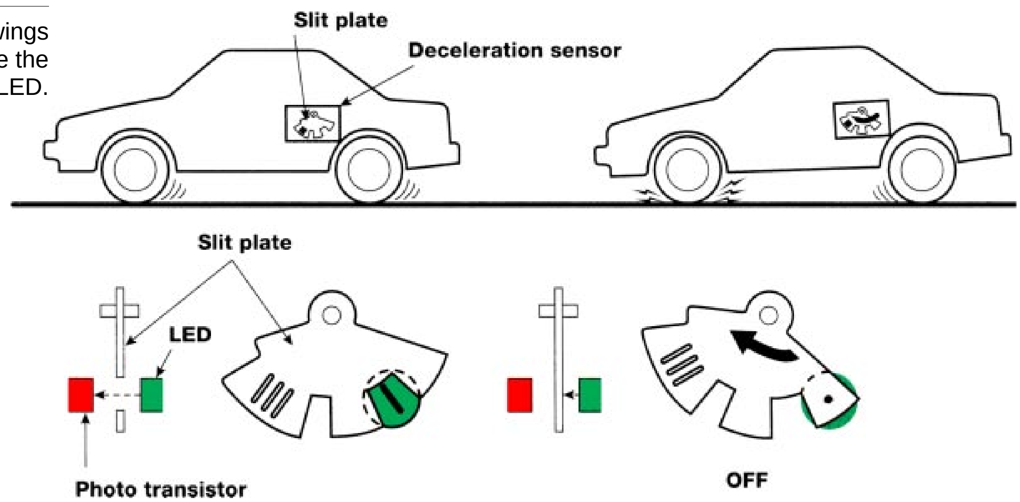


Operation

Both LED's are located on one side of the slit plate and both photo transistors are located on the opposite side. The LED's are ON when the ignition switch is in the ON position. When the vehicle's rate of deceleration changes, the slit plate swings in the vehicle's rear-to-front direction. The slits in the slit plate act to expose the light from the LEDs to the phototransistors. This movement of the slit plate switches the phototransistors ON and OFF.

Deceleration Sensor Operation

As the slit plate swings forward the slits expose the phototransistor to the LED.



Lateral Acceleration Sensor

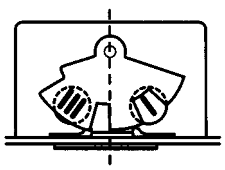
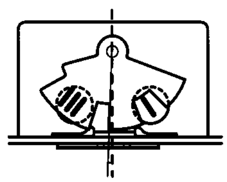
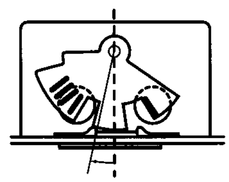
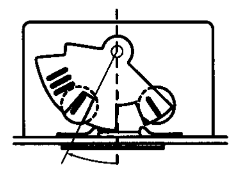
The lateral acceleration sensor has similar construction to the deceleration sensor described above. Rather than having the slit plate swing rear-to-front, the sensor is mounted in such a way that the slit plate swings from side to side. This sensor is found only on the 1993 1/2 and later model Supra to detect lateral forces while braking.

Deceleration Rate

The combinations formed by these phototransistors switching ON and OFF distinguish the rate of deceleration into four levels, which are sent as signals to the ABS ECU. The chart below indicates the rate of deceleration based on input from the two phototransistors. For example: when the No. 1 and No. 2 photo transistors are both blocked and turned OFF, the deceleration rate is medium.

Deceleration Rate Level

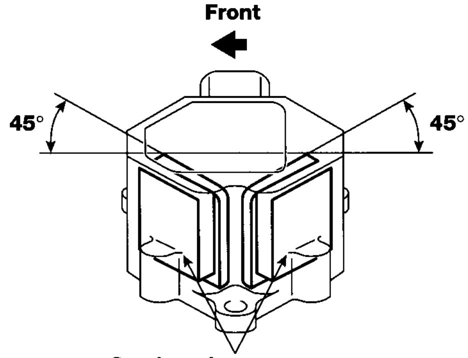
Deceleration Rate Level

Rate of deceleration	Low-1	Low-2	Medium	High
No. 1 Photo Transistor	ON	OFF	OFF	ON
No. 2 Photo Transistor	ON	ON	OFF	OFF
Position of Slit Plate	 No. 1 Photo Transistor (ON) No. 1 Photo Transistor (ON)	 (OFF) (ON)	 (OFF) (OFF)	 (ON) (OFF)

Semiconductor Deceleration Sensor

A new style deceleration sensor was introduced in the 1996 4WD RAV4 only. The sensor consisted of two semiconductor sensors. They are mounted at 90° to one another and installed so that each has an angle of 45° to the centerline of the vehicle. Each semiconductor sensor is provided with a mass which exerts pressure based on the deceleration force applied to the vehicle. The sensor converts the force into electronic signals, and outputs the signals to the ABS ECU.

Semiconductor Deceleration Sensor



Actuator

The actuator controls hydraulic brake pressure to each disc brake caliper or wheel cylinder based on input from the system sensors, thereby controlling wheel speed. These solenoids provide three operating modes during ABS operation:

- **Pressure Holding.**
- **Pressure Reduction.**
- **Pressure Increase.**

2-Position Solenoid Type

The two position solenoid actuator was first used on the 1993 Corolla and subsequently on all Toyota models by 1997 except Land Cruiser. Consult the ABS Comparison Chart on page 225 of this publication for the specific model application.

The actuator consists of six or eight 2-position solenoid valves, a pump and reservoir. Each hydraulic circuit is controlled by a single set of solenoids:

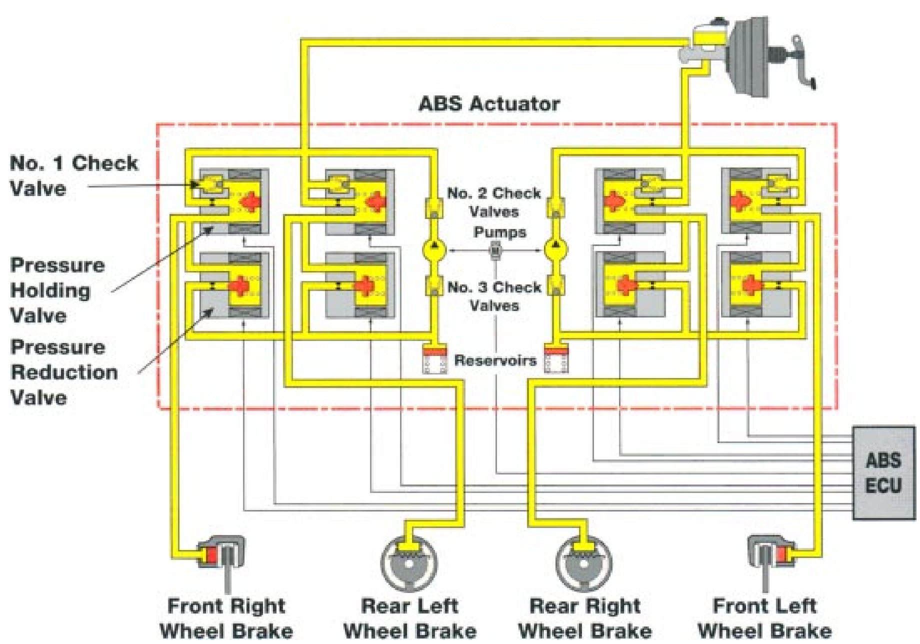
- pressure holding solenoid.
- pressure reduction solenoid.

Aside from the 2-position solenoid valves, the basic construction and operation of this system is the same as the 3-position solenoid system:

- four speed sensors provide input to the ECU which controls the operation of the solenoids and prevent wheel lock-up.
- the two front wheels are controlled independently and the two rear wheels are controlled simultaneously for three channel control.
- Supra has four channel control where the two rear wheels are controlled independently just like the front wheels.

2-Position Solenoid Hydraulic Circuit

The actuator consists of six or eight 2-position solenoids. Two solenoids are used to control each wheel hydraulic circuit.

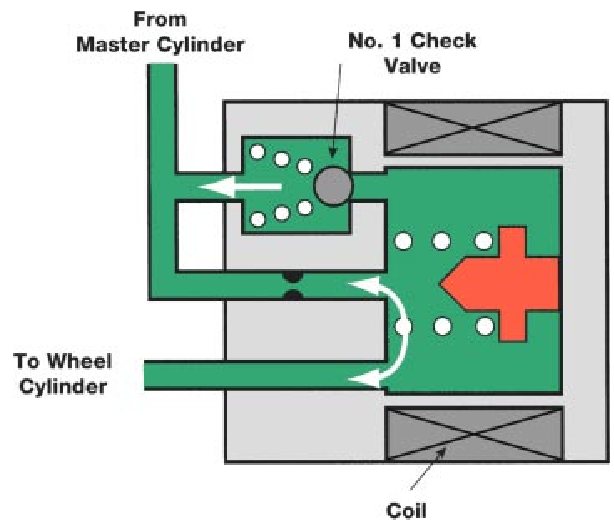


Pressure Holding Valve

The pressure holding valve controls (opens and closes) the circuit between the brake master cylinder and the wheel cylinder. The valve is spring loaded to the open position (normally open). When current flows in the coil the valve closes. A spring loaded check valve provides an additional release passage when pressure from the master cylinder drops.

Pressure Holding Valve

Controls the circuit between the brake master cylinder and the wheel cylinder.

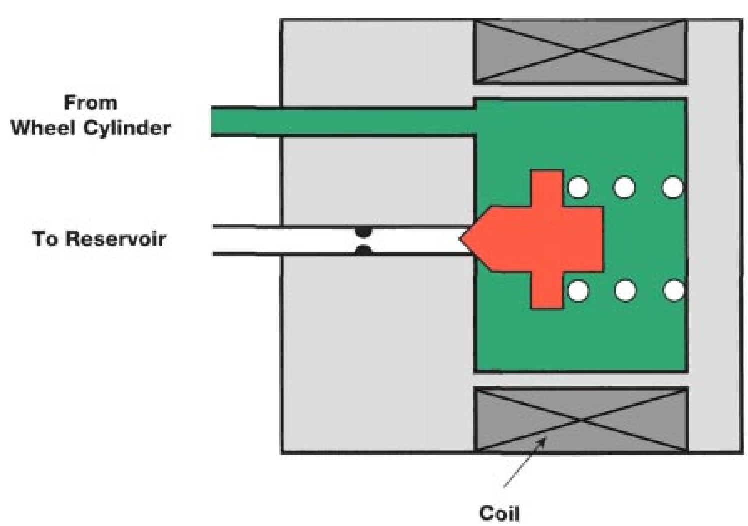


Pressure Reduction Valve

The pressure reduction valve controls (opens and closes) the circuit between the wheel cylinder and the actuator reservoir. The valve is spring loaded in the closed position (normally closed). When current flows through the coil, the valve compresses the spring and opens the valve.

Pressure Reduction Valve

Controls the circuit between the wheel cylinder and the actuator reservoir.



Operation During Normal Braking (ABS Not Activated)

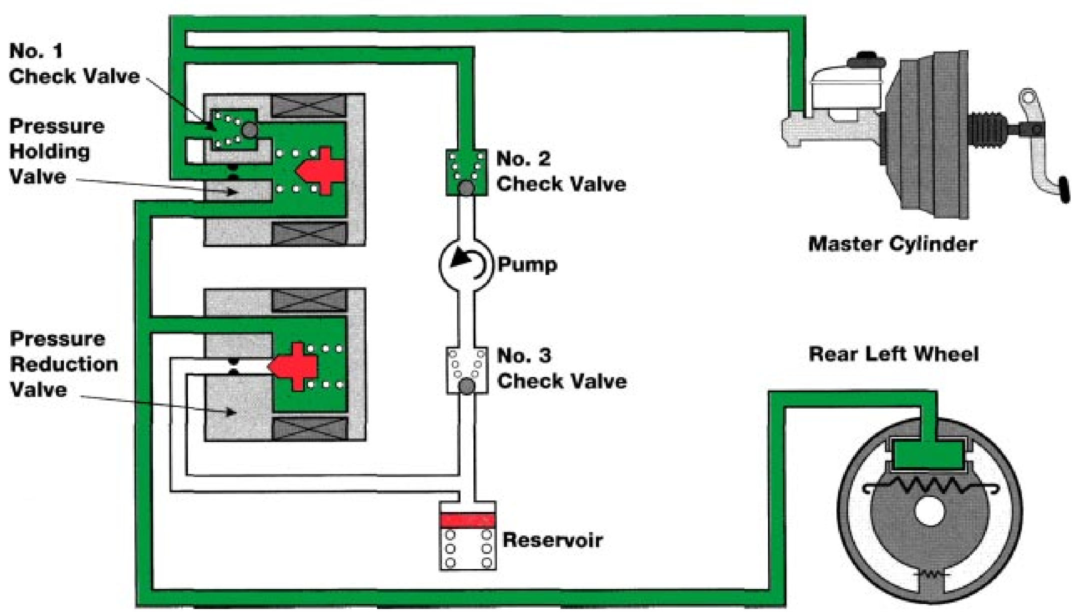
During normal braking the solenoids are not energized so the pressure holding valve remains open and the pressure reduction valve remains closed.

When the brake pedal is depressed, the master cylinder fluid passes through the pressure holding valve to the wheel cylinder. The pressure reduction valve prevents fluid pressure from going to the reservoir. As a result normal braking occurs.

Normal Braking Mode

During normal braking the solenoids are not energized so the pressure holding valve remains open and the pressure reduction valve remains closed.

Part Name / ABS Conditions		Pressure Holding Valve	Pressure Reduction Valve	Pump Motor
Not Activated	During Normal Braking	OFF (Open)	OFF (Closed)	OFF



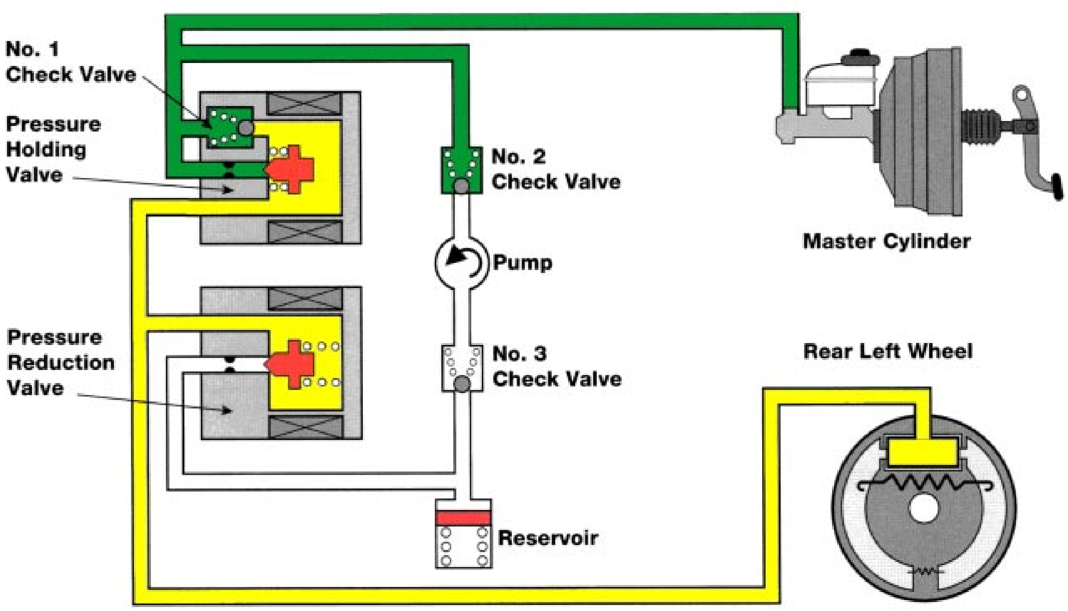
Pressure Holding Mode

When any wheel begins to lock, the ABS ECU initially goes to hold mode to prevent any additional increase in pressure. The ECU turns OFF the Pressure Reduction Valve and turns the Pressure Holding Valve ON. The pressure reduction valve closes, preventing hydraulic fluid from going to the reservoir. The pressure holding valve remains closed so no additional fluid pressure can reach the wheel cylinder.

Pressure Holding Mode

The pressure reduction valve closes, preventing hydraulic fluid from going to the reservoir.

Part Name / ABS Conditions		Pressure Holding Valve	Pressure Reduction Valve	Pump Motor
Activated	Holding Mode	ON (Closed)	OFF (Closed)	ON



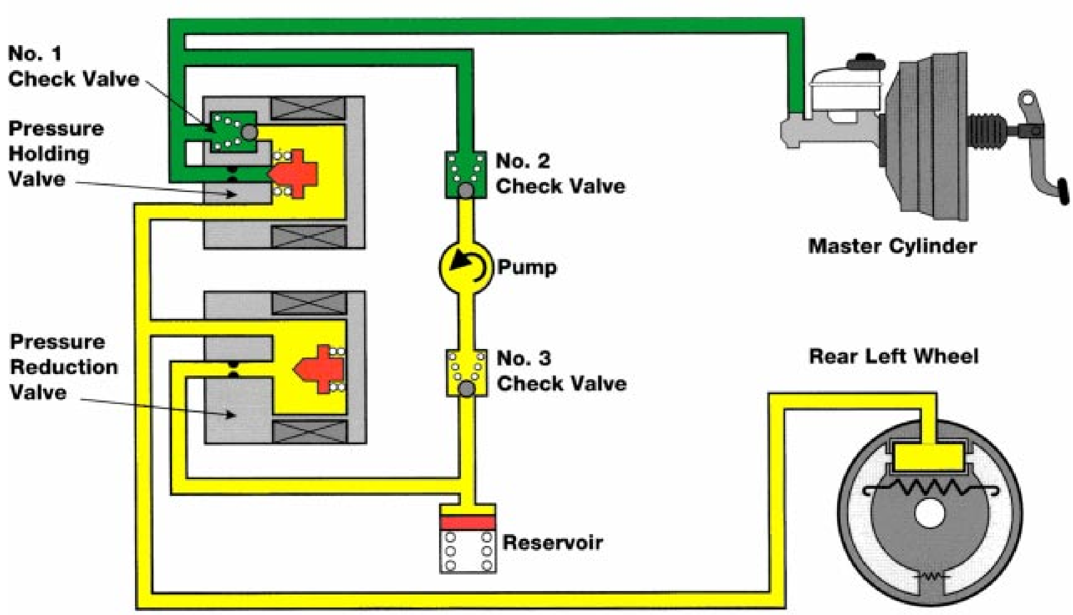
Pressure Reduction Mode

After the initial hold mode operation, the ABS ECU energizes both the holding valve and the reduction valve. The pressure holding valve closes and blocks pressure from the master cylinder. The open reduction valve allows hydraulic pressure from the wheel cylinder circuit into the reservoir, reducing brake pressure. The pump is also energized to direct hydraulic fluid back to the master cylinder. This causes brake pedal feedback and alerts the driver to ABS operation.

Pressure Reduction Mode

When the slip ratio of any wheel exceeds 30%, the ABS ECU energizes both the holding valve and the reduction valve.

Part Name / ABS Conditions		Pressure Holding Valve	Pressure Reduction Valve	Pump Motor
Activated	Pressure Reduction Mode	ON (Closed)	ON (Open)	ON



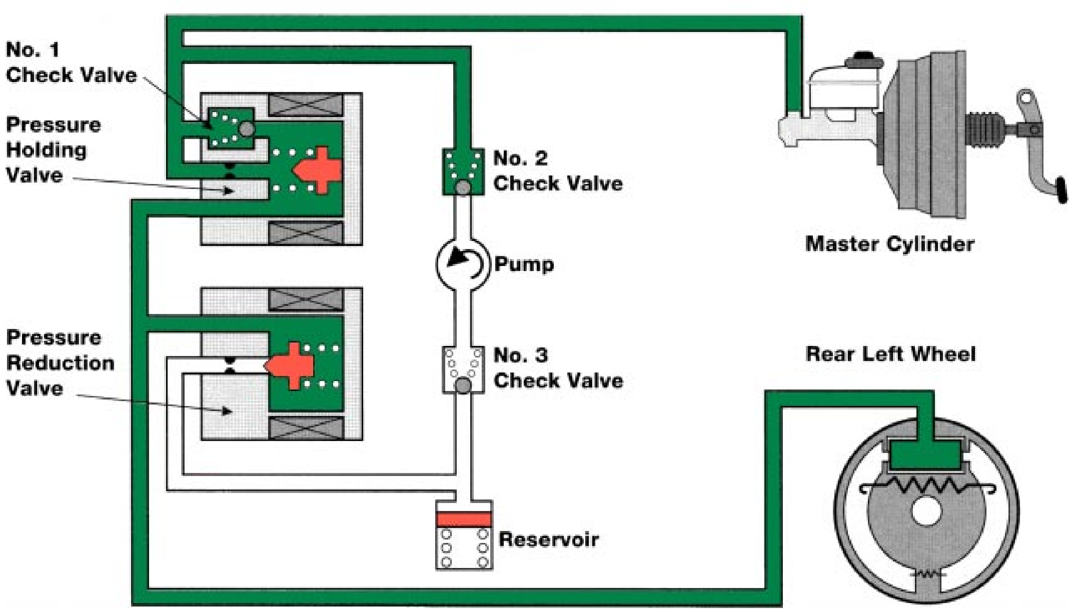
Pressure Increase Mode

As pressure inside the wheel cylinder is reduced and the speed sensor sends a signal indicating that the speed is above the target level, the ECU turns OFF both the Pressure Reduction Valve and the Pressure Holding Valve. The pressure reduction valve closes, preventing hydraulic fluid from going to the reservoir. The pressure holding valve opens so additional pressure enters the wheel cylinder if the driver maintains pedal pressure. The operation is the same as Normal Mode except the pump is on.

Pressure Increase Mode

The ECU turns OFF both the Pressure Reduction Valve and the Pressure Holding Valve.

Part Name / ABS Conditions		Pressure Holding Valve	Pressure Reduction Valve	Pump Motor
Activated	Pressure Increase Mode	OFF (Open)	OFF (Closed)	ON

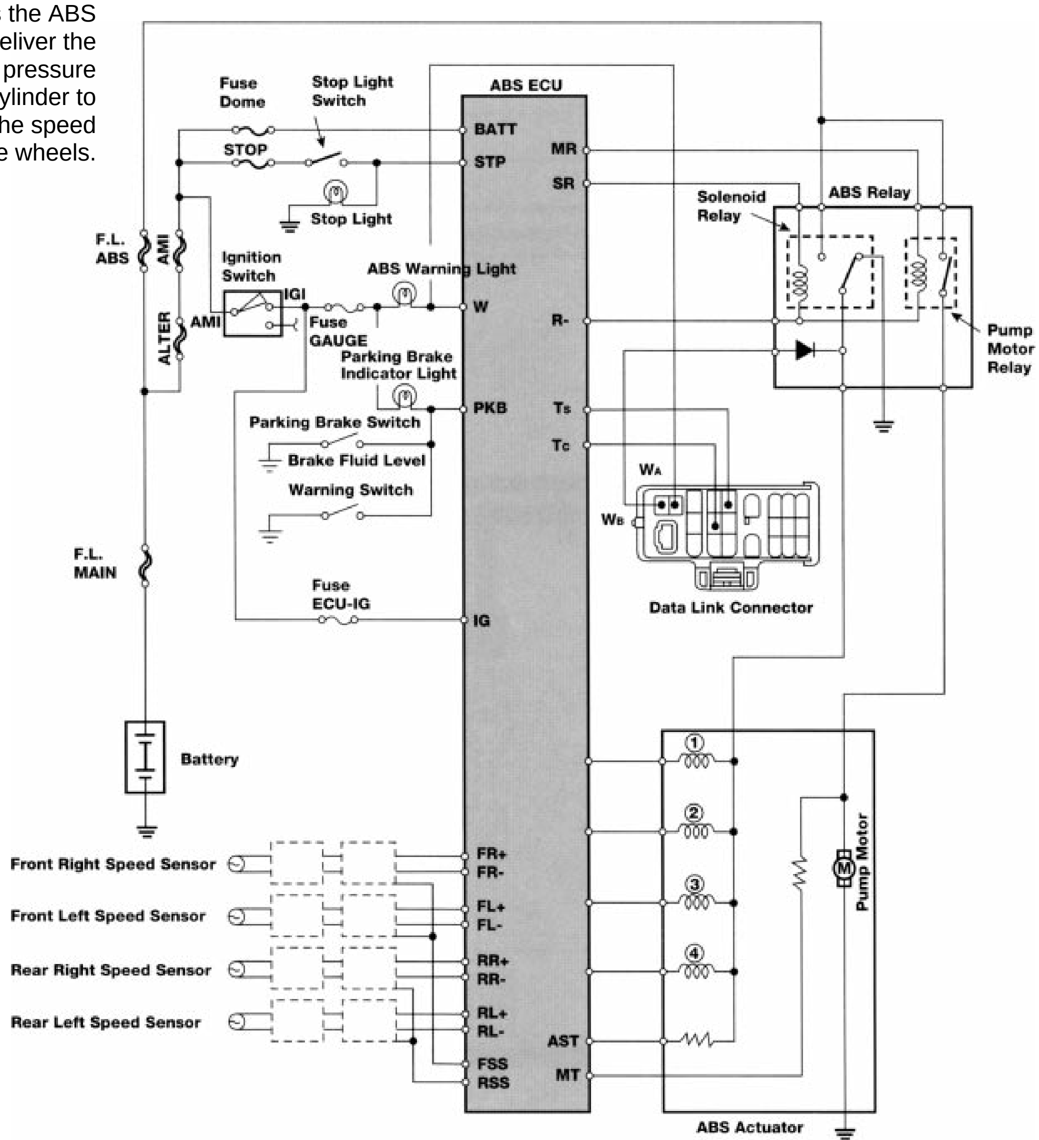


ABS ECU The ABS ECU senses the rotational speed of the wheels as well as the vehicle speed based on signals from the wheel speed sensors. During braking, the deceleration rate will vary depending on pedal pressure, the vehicle speed during braking, and the road surface conditions. For example, the deceleration rate is much greater on dry asphalt, compared to a wet or icy surface.

The ECU judges the slip condition between the wheels and the road surface by monitoring the change in the wheel's rotational speed during braking. The ECU controls the ABS actuator to deliver the optimum hydraulic pressure to the brake cylinder to precisely control the speed of the wheels, maintaining maximum brake force with a 10 to 30% slip ratio.

ABS Wiring Diagram

The ECU controls the ABS actuator to deliver the optimum hydraulic pressure to the disc brake cylinder to precisely control the speed of the wheels.



Solenoid Relay Control

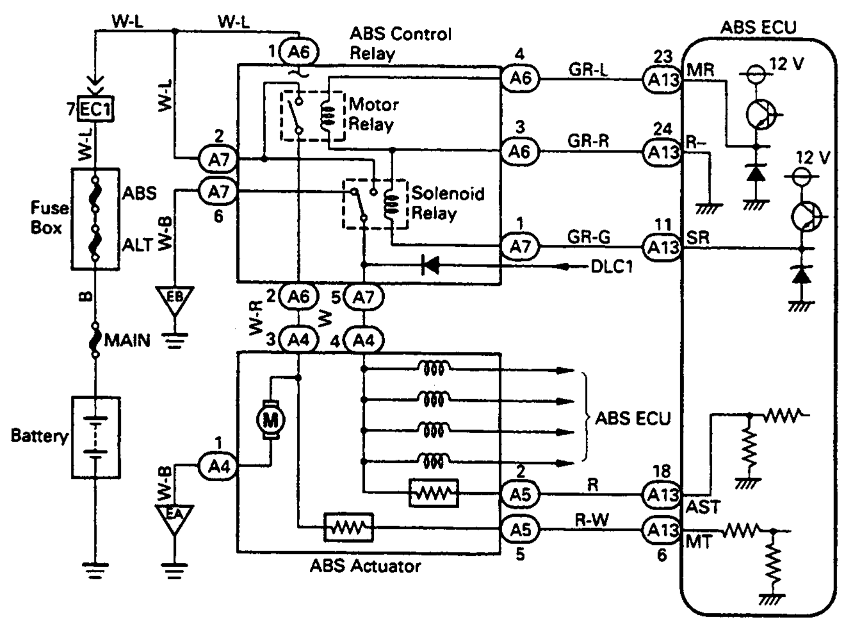
The Solenoid Relay supplies power to the solenoids. The ECU turns the Solenoid Relay ON when the following conditions are met:

- Ignition switch ON.
- The Initial-Check Function is completed properly.

The ECU turns the solenoid relay OFF if any of the above conditions are not met.

ABS Control Relay

The motor relay switches voltage to the pump motor. The solenoid relay switches voltage to the actuator solenoids.



Pump Motor Relay Control

The Pump Motor Relay supplies power to the ABS pump motor located in the Actuator. The ECU turns the relay ON when the following conditions are met:

- During ABS operation or during the Initial Check.
- When the Solenoid Relay is ON .

The ECU turns the pump motor relay OFF when any of the above conditions are not met.

Wheel Speed Control

The ECU continuously receives wheel speed signals from the speed sensors and deceleration sensor. By calculating the speed and deceleration of each wheel, the ECU estimates the vehicle speed. When the brake pedal is depressed, the hydraulic pressure in each disc brake cylinder begins to increase and the wheel speed begins to decrease. If any of the wheels are near a lock-up condition the ECU goes into pressure hold mode to stop the increase of hydraulic pressure in the disc brake cylinder of that wheel.

SECTION A

The ECU sets the solenoid valves to the pressure reduction mode based on wheel speed, thus reducing the hydraulic pressure in the disc brake cylinder.

After the pressure drops, the ECU switches the solenoid valves to the Holding Mode then monitors the change in wheel speed.

If the ECU judges that the hydraulic pressure needs to be reduced further, it will return to reduction mode.

SECTION B

When the hydraulic pressure inside the disc brake cylinder decreases (section A), the hydraulic pressure applied to the wheel falls. This allows the wheel that was locking up to speed up. However, if the hydraulic pressure is held down, the braking force acting on the wheel will become too low. To prevent this, the ECU sets the solenoid valves to the pressure increase mode and holding mode alternately as the wheel which was locking up, recovers speed.

SECTION C

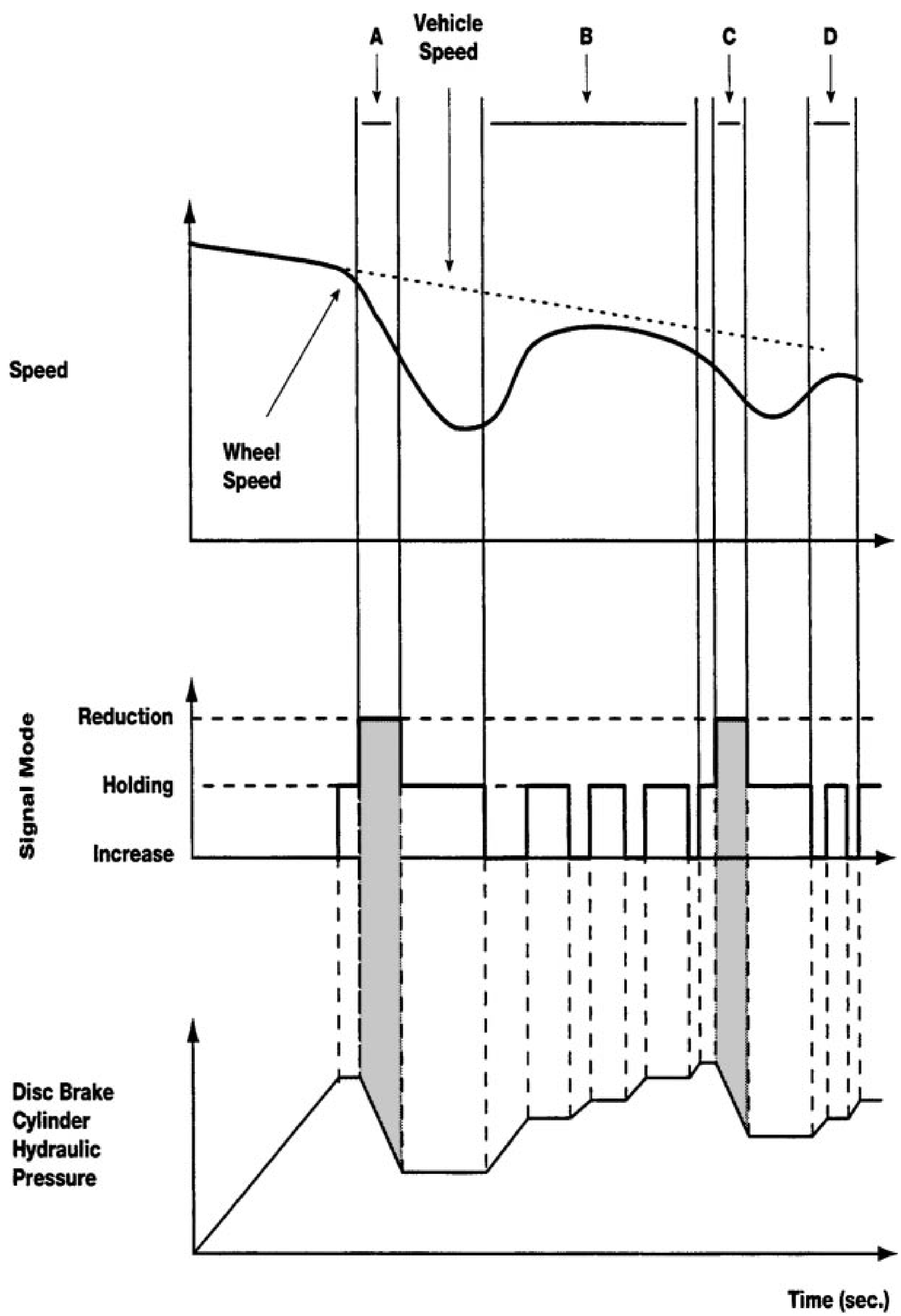
As the hydraulic pressure is gradually increased in the brake cylinder by the ECU actuator (section B), the wheel tends to lock up again. In response, the ECU again switches the solenoid valves to the pressure reduction mode to reduce the hydraulic pressure inside the disc brake cylinder.

SECTION D

Since the hydraulic pressure in the brake cylinder is decreased again (section C), the ECU starts to increase the pressure again as in section B.

The cycle of Hold, Reduce and Increase is repeated many times until the wheels are no longer outside the 30% slip ratio.

Wheel Speed Control Chart



Notes

ABS DIAGNOSIS

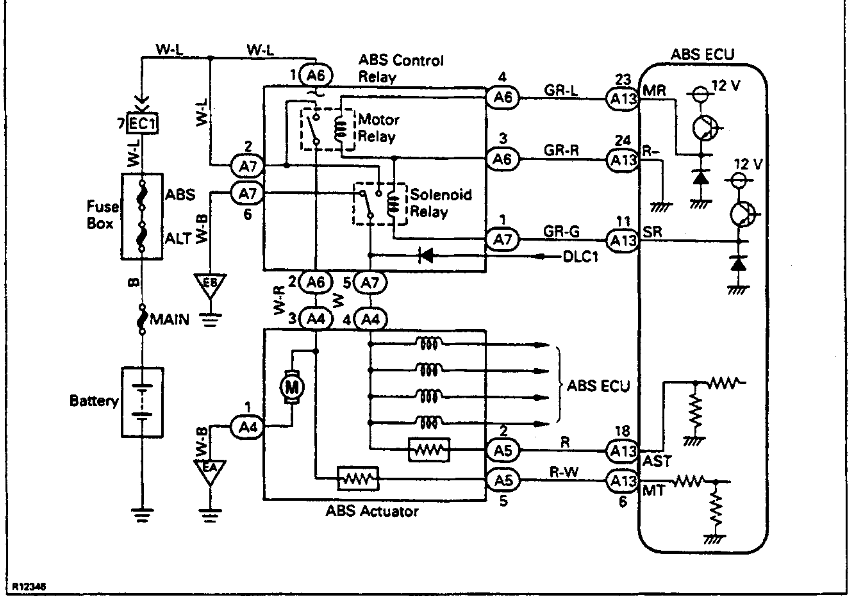
CIRCUIT DESCRIPTION

This relay supplies power to each ABS solenoid. After the ignition switch is turned ON, if the initial check is OK, the relay goes on.

DTC No.	Diagnostic Trouble Code Detecting Condition	Trouble Area
11	Conditions (1) and (2) continue for 0.2 sec. or more: (1) ABS control (solenoid) relay terminal (SR) voltage: Battery positive voltage (2) ABS control (solenoid) relay monitor terminal (AST) voltage: 0 V	• ABS control (solenoid) relay • Open or short in ABS control (solenoid) relay circuit • ECU
12	Conditions (1) and (2) continue for 0.2sec. or more: (1) ABS control (solenoid) relay terminal (SR) voltage: 0 V (2) ABS control (solenoid) relay monitor terminal (AST) voltage: Battery positive voltage	• ABS control (solenoid) relay • B+ short in ABS control (solenoid) relay circuit • ECU

Fail safe function: If trouble occurs in the control (solenoid) relay circuit, the ECU cuts off current to the ABS control (solenoid) relay and prohibits ABS control.

WIRING DIAGRAM



Lesson Objectives

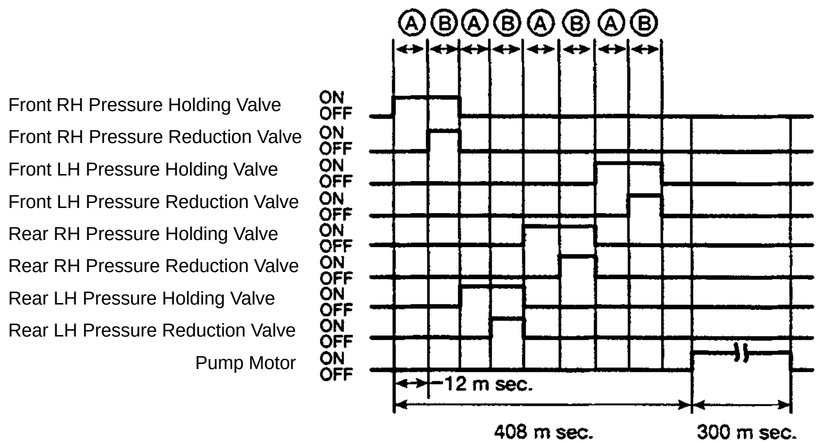
1. Using the actuator tester and the appropriate Repair Manual and/or TSB, select the proper SSTs to use in diagnosing an ABS system.
2. Using the On-Board Diagnosis (OBD) system and a Repair Manual, perform a dynamic diagnosis of speed sensors and deceleration sensor.
3. Using a Repair Manual perform the self-diagnosis to access trouble codes to determine malfunctions within the ABS and/or TRAC systems.

Diagnosis and Troubleshooting

The ABS ECU has a self-diagnostic system which monitors the input and output circuits. The ABS ECU operates the solenoid valves and the pump motor in sequence in order to check each respective electrical system. This function operates only once each time the ignition switch is turned ON. On some earlier models it operates when the vehicle is traveling at a speed greater than 4 mph with the stop light (brake light) switch OFF. During this check the operation of the actuator can be heard, however this is normal and does not indicate a malfunction.

Initial Check Function

The check function may vary depending on the number of solenoids.

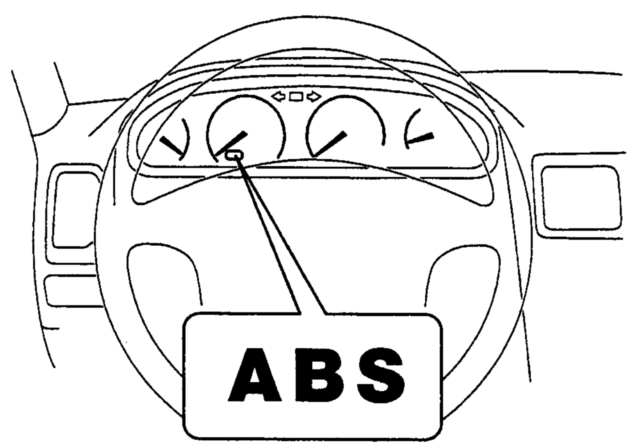


Diagnostic Function

When a problem is detected in any of the signal systems, the ECU turns on the ABS warning light in the combination meter to alert the driver that a malfunction has occurred. The code is stored in memory for access at a later time. Diagnostic trouble codes can be read from the Warning light. The ABS ECU will also store the diagnostic trouble codes for any ABS malfunction.

ABS Warning Light

The light warns the driver of an ABS malfunction.



Trouble Code Check

To access the diagnostic trouble codes stored in the ECU, locate the Data Link Connector (DLC1) or (DLC2). Consult the Repair Manual or the ABS Reference Card to determine whether the ABS Check Connector is physically disconnected or the short pin for Wa and Wb is removed.

To access diagnostic codes:

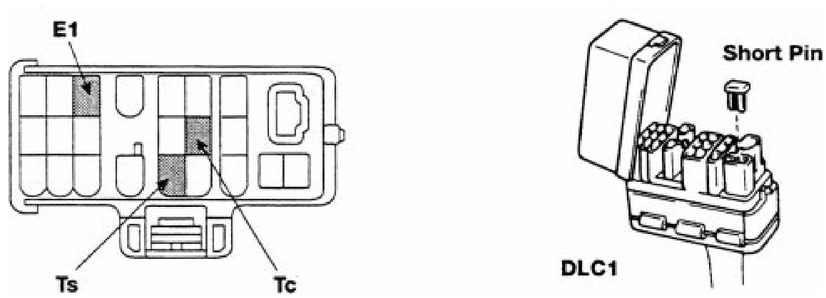
- Disconnect the check connector or remove the short pin in DLC1.
- Jumper terminals Tc and E1 of the Data Link Connector (DLC1 or DLC2).
- Turn the ignition switch ON and read the trouble code from the ABS warning light on the Combination Meter.

NOTE

Camry and Avalon w/Bosch ABS, no Short Pin. Jumper Tc and El.

Trouble Code Check

To access diagnostic codes, remove the short pin, jumper Tc and E1 in DLC1 and turn the ignition switch ON.



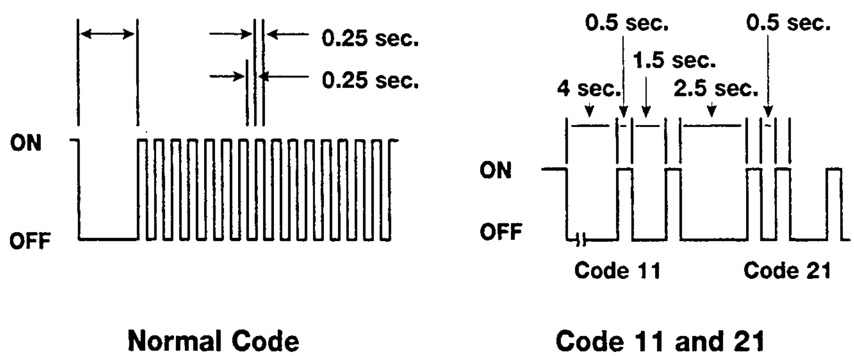
Diagnostic Codes

If the computer has not detected a malfunction, the lamp will blink two times per second after a two second pause. When a malfunction has been detected there will be a 4 second pause, then the first digit will begin. The number of times the lamp blinks before a one and a half second pause is the first digit of the code. Next, the number of blinks before the second pause is the second digit of the code. In the example below, the first code is Code 11 and the second code is 21.

If there is more than one trouble code, the code with the smallest number will appear first, followed by a pause for 2.5 seconds, then the next code

Diagnostic Codes

A normal code (steady flashing trouble light) is output when there is no fault found. If more than one fault is detected, each code is displayed.

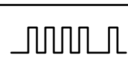
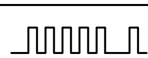
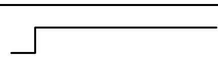


will appear in the same manner as described earlier. Finally, the entire procedure will be repeated after a four second pause.

The chart below identifies each code and reveals the circuit or component which requires further diagnosis. The total number of diagnostic codes may vary between vehicles so it is important to refer to the Repair Manual for the specific vehicle you are diagnosing.

Trouble Code Chart

The code identifies the component or circuit which requires further diagnosis.

Code	ABS Warning Light Blinking Pattern	Diagnosis
11	ON OFF  BE3831	Open circuit in ABS control (solenoid) relay circuit
12	ON OFF  BE3831	Short circuit in ABS control (solenoid) relay circuit
13	ON OFF  BE3831	Open circuit in ABS control (motor) relay circuit
14	ON OFF  BE3831	Short circuit in ABS control (motor) relay circuit
21	ON OFF  BE3832	Open or short circuit in 3-position solenoid circuit for right front wheel
22	ON OFF  BE3832	Open or short circuit in 3-position solenoid circuit for left front wheel
23	ON OFF  BE3832	Open or short circuit in 3-position solenoid circuit for right rear wheel
24	ON OFF  BE3832	Open or short circuit in 3-position solenoid circuit for left rear wheel
31	ON OFF  BE3833	Right front wheel speed sensor signal malfunction
32	ON OFF  BE3833	Left front wheel speed sensor signal malfunction
33	ON OFF  BE3833	Right rear wheel speed sensor signal malfunction
34	ON OFF  BE3832	Left rear wheel speed sensor signal malfunction
35	ON OFF  BE3833	Open circuit in left front or right rear speed sensor circuit
36	ON OFF  BE3833	Open circuit in right front or left rear speed sensor circuit
37	ON OFF  BE3833	Faulty rear speed sensor rotor
41	ON OFF  BE3834	Low battery positive voltage or abnormally high battery positive voltage
51	ON OFF  BE3836	Pump motor is locked Open in pump motor ground
Always on	ON OFF 	Malfunction in ECU

Circuit Inspection

The Repair Manual takes the diagnosis several steps further in providing a circuit inspection and inspection procedure for each diagnostic code. It provides a circuit description as well as the parameters under which the code was set for each stored code. A wiring diagram schematic of the electrical circuit is also provided for ready reference.

Circuit Description and Wiring Diagram

A circuit description includes the parameters for setting the code.

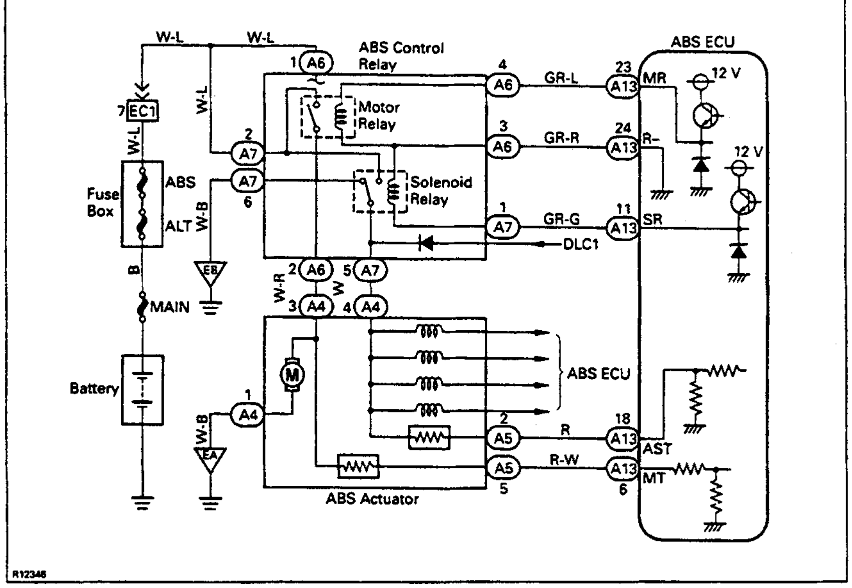
CIRCUIT DESCRIPTION

This relay supplies power to each ABS solenoid. After the ignition switch is turned ON, if the initial check is OK, the relay goes on.

DTC No.	Diagnostic Trouble Code Detecting Condition	Trouble Area
11	Conditions (1) and (2) continue for 0.2 sec. or more: (1) ABS control (solenoid) relay terminal (SR) voltage: Battery positive voltage (2) ABS control (solenoid) relay monitor terminal (AST) voltage: 0 V	• ABS control (solenoid) relay • Open or short in ABS control (solenoid) relay circuit • ECU
12	Conditions (1) and (2) continue for 0.2sec. or more: (1) ABS control (solenoid) relay terminal (SR) voltage: 0 V (2) ABS control (solenoid) relay monitor terminal (AST) voltage: Battery positive voltage	• ABS control (solenoid) relay • B+ short in ABS control (solenoid) relay circuit • ECU

Fail safe function: If trouble occurs in the control (solenoid) relay circuit, the ECU cuts off current to the ABS control (solenoid) relay and prohibits ABS control.

WIRING DIAGRAM

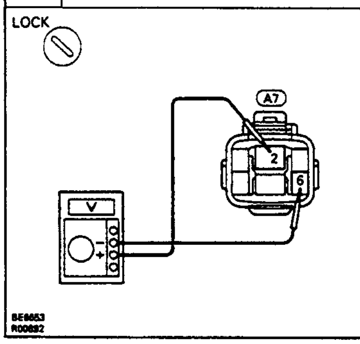


An inspection procedure follows the circuit inspection with components, connectors, pin locations and measurement values to diagnose the circuit. Each step is outlined in sequence, leading to a repair.

Inspection Procedure

The inspection procedure includes components, connectors and pin locations as well as measurement values to diagnose the circuit.

1 **Check voltage between terminals (A7) 2 and (A7) 6 of ABS control relay connector.**



P Disconnect the ABS control relay connector.

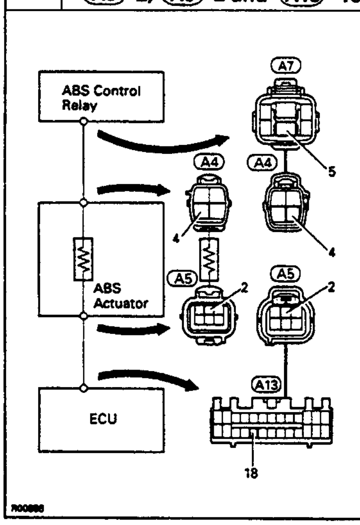
C Measure voltage between terminals (A7) 2 and (A7) 6 of ABS control relay harness side connector.

OK **Voltage: 10 – 14 V**

OK ↓

NG 〉 **Check and repair harness or connector.**

2 **Check continuity between terminals (A7) 5 and (A4) 4, (A4) 4 and (A5) 2, (A5) 2 and (A13) 18.**



P Disconnect the 2 connectors from ABS actuator.

C Check continuity between terminals (A7) 5 and (A4) 4, (A4) 4 and (A5) 2, (A5) 2 and (A13) 18.

OK **Continuity**

HINT: There is a resistance of 4 ~ 6 Ω between terminals (A4) 4 and (A5) 2.

OK ↓

NG 〉 **Repair or replace harness or ABS actuator.**

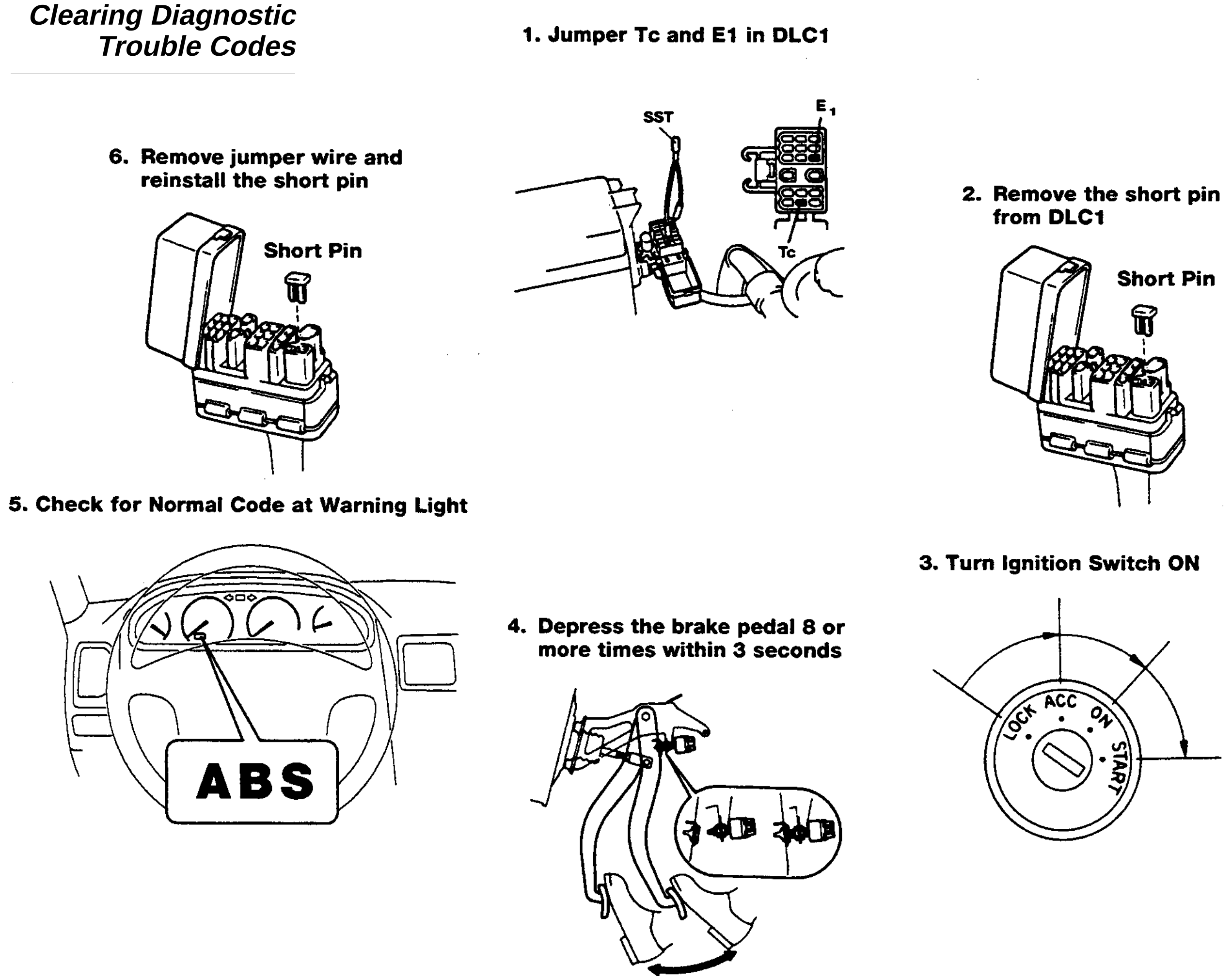
Diagnostic Trouble Code Clearance

Following diagnosis and repair, clear the trouble codes stored in the ECU. The procedure will vary depending on the model and year. Either refer to the ABS Reference Card or Repair Manual for specifics. The essential difference is in disconnecting the actuator check connector on earlier models as compared to the removal of the short pin connector in the DLC1 or DLC2 connector. A typical procedure is outlined below:

- Jumper terminals Tc and E1 of the DLC2 or DLC1 and remove the short pin from DLC1.
- Turn ignition switch ON.
- Depress the brake pedal 8 or more times within 3 seconds.
- Check that the warning light shows the normal code.
- Remove the jumper wire and reinstall the short pin.

To ensure that the brake light switch opens and closes each time, allow the brake pedal to return to the full up position each time when clearing codes. If the code does not clear, the ignition switch must be cycled OFF then ON before depressing the brake pedal 8 times in 3 seconds.

Clearing Diagnostic Trouble Codes



Speed Sensor Signal Check

Eight additional diagnostic codes (71 through 78) are available to trouble-shoot the speed sensors and rotors. They determine whether the signal to the ECU is a low output voltage or an abnormal change in output voltage. When using the signal check, make sure that the vehicle is driven straight ahead.

The ECU is placed in signal check mode differently based on model and year, so again it is important to have the appropriate repair manual available. In some early models, the parking brake in conjunction with the service brake were used to enter this mode.

In most cases, connect terminals Tc and E1 at DLC1 prior to driving the vehicle. To read the code:

- Connect terminals Ts and E1 (Tc and E1 remain connected).
- In earlier models the actuator check connector was disconnected.

Diagnostic Trouble Codes for Speed Sensor Check Function

Consult the Repair Manual for specific instructions to place the ECU into the diagnostic mode and to read the codes.

Code No.	Diagnosis	Trouble Area
71	Low output voltage of right front speed sensor	• Right front speed sensor • Sensor installation
72	Low output voltage of left front speed sensor	• Left front speed sensor • Sensor installation
73	Low output voltage of right rear speed sensor	• Right rear speed sensor • Sensor installation
74	Low output voltage of left rear speed sensor	• Left rear speed sensor • Sensor installation
75	Abnormal change in output voltage of right front speed sensor	• Right front speed sensor rotor
76	Abnormal change in output voltage of left front speed sensor	• Left front speed sensor rotor
77	Abnormal change in output voltage of right rear speed sensor	• Right rear speed sensor rotor
78	Abnormal change in output voltage of left rear speed sensor	• Left rear speed sensor rotor

Deceleration Sensor Check

The deceleration sensor can be checked both statically and dynamically. Jumpering E1 and Ts at DLC1 and observing the ABS light are the essential steps.

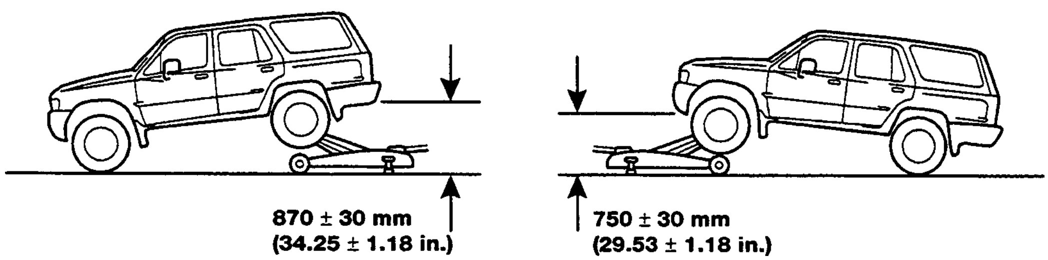
Static Testing

With Ts and E1 jumpered and the engine running, raise the rear of the vehicle slowly to the specified height as described in the Repair Manual, then observe the ABS light. The light should blink 4 times per second. If the light remains ON, inspect the sensor installation. If its properly installed, replace the deceleration sensor.

Lower the vehicle slowly and then raise the front slowly to the specified height and observe the light as in the procedure described above.

Static Testing

Raising the front and rear separately to a specific height and note the condition of the ABS light.



Dynamic Testing

For most vehicles except 1996 RAV4, jumper terminals Ts and E1 in DLC1, drive the vehicle straight forward at about 12 mph:

- Lightly depress the brake pedal and the light should remain flashing 4 times per second.
- Bring the speed up to 12 mph or more and depress the brake pedal moderately hard and the light should come on while braking.
- Bring the speed up to 12 mph or more and depress the brake pedal strongly and again the light should come on while braking. If the light does not operate as specified, inspect the sensor installation. If the installation is OK, replace the deceleration sensor.

RAV4 Static Test

The RAV4 deceleration sensor is tested after removal from the vehicle.

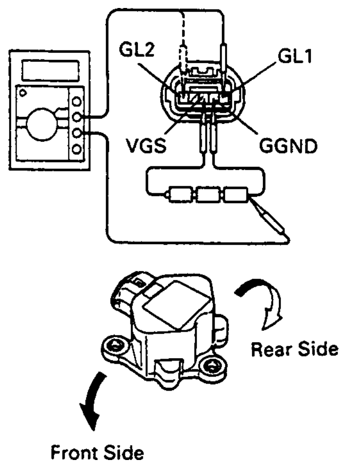
- assemble three 1.5 volt dry cell batteries in series.
- connect the positive side of the battery to terminal VGS and the negative side to the GGND.
- check the output of GL1 and GL2 terminals with a voltmeter comparing your readings with the chart below.

CAUTION

Do not turn the sensor upside down when removed from the vehicle. If dropped, it should be replaced.

RAV4 Deceleration Sensor Test

Applies to 1996 RAV4 only.



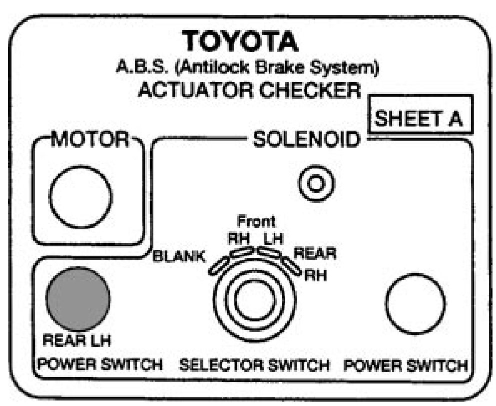
Symbols	Condition	Standard Value
GL1	Horizontal	about 2.3 V
GL1	Lean forward	0 - about 2.3 V
GL1	Lean rearward	about 2.3 V - 4.5 V
GL2	Horizontal	about 2.3 V
GL2	Lean forward	about 2.3 V - 4.5 V
GL2	Lean rearward	0 - about 2.3 V

ABS Actuator Checker

The actuator operation can be checked using a Special Service Tool called an ABS Actuator Checker and related subharness and overlay sheet where needed. This special service tool can check the operation of the solenoid valves and the pump motor. The actuator is disconnected from the vehicle harness, taking the ECU out of the loop and operated independently by the special service tool.

ABS Actuator Checker

This special service tool can check the operation of the solenoid valves, the by-pass valve and the pump motor.



The ABS actuator checker statically checks the operation of the actuator which includes: the pump, solenoids, and relays. If a normal code is displayed, but symptoms still occur, refer to the Problem Symptoms Chart in the Repair Manual. The chart indicates when the checker is to be used.

When to Use Actuator Checker

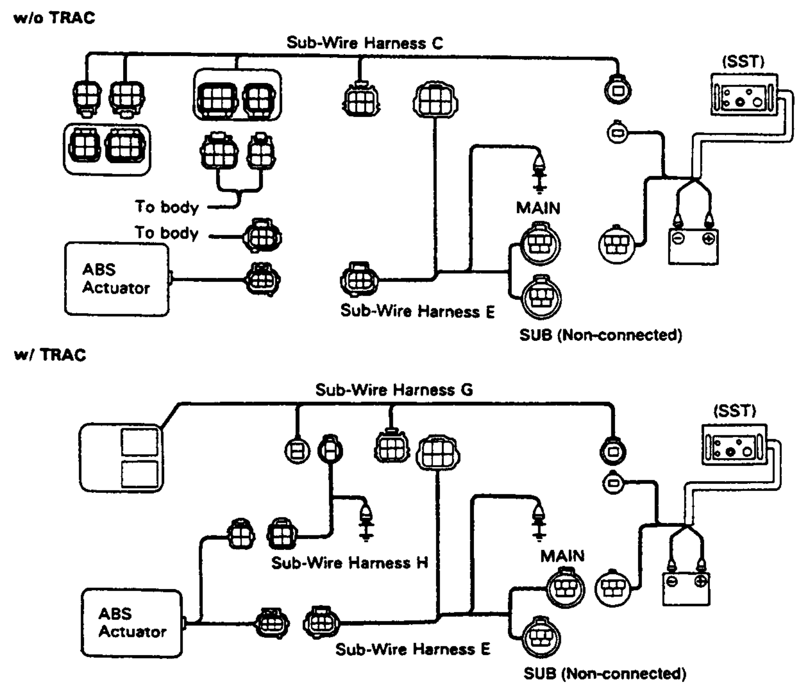
If a normal code is displayed but symptoms still occur, the Repair Manual chart identifies circuits to check and use of the Actuator Checker.

Symptoms	Inspection Circuit	See page
ABS does not operate.	Only when 1. ~ 4. are all normal and the problem is still occurring, replace the ABS ECU. 1. Check the DTC, reconfirming that the normal code is output. 2. IG power source circuit. 3. Speed sensor circuit. 4. Check the ABS actuator with a checker. If abnormal, check the hydraulic circuit for leakage (see page BR-79).	BR-50 BR-70 BR-66 BR-37
ABS does not operate efficiently.	Only when 1. ~ 4. are all normal and the problem is still occurring, replace the ABS ECU. 1. Check the DTC, reconfirming that the normal code is output. 2. Speed sensor circuit. 3. Stop light switch circuit. 4. Check the ABS actuator with a checker. If abnormal, check the hydraulic circuit for leakage (see page BR-79).	BR-50 BR-66 BR-72 BR-37
ABS warning light abnormal.	1. ABS warning light circuit. 2. ABS ECU.	BR-74
DTC check cannot be done.	Only when 1. and 2. are all normal and the problem is still occurring, replace the ABS ECU. 1. ABS warning light circuit. 2. Tc terminal circuit.	BR-74 BR-76
Speed sensor signal check cannot be done.	1. Ts terminal circuit. 2. ABS ECU.	BR-78

Refer to the Repair Manual for adapter harnesses required and the illustration depicting proper connections. The illustration below shows the connections for Supra models with or without TRAC.

ABS Actuator Checker Installation

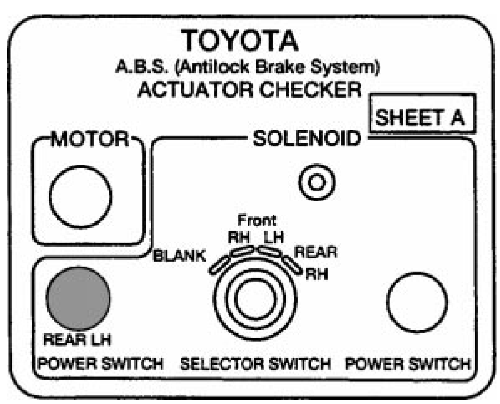
Follow the references in the Repair Manual for the proper harnesses and connector configuration. This Supra example shows different adapter harnesses based on it being equipped with Traction Control.



Pay particular attention to the operating procedure as you perform the diagnosis. Note that the illustrations of the checker buttons are darkened to emphasize which ones are pressed for a given step. When the procedure indicates that the pedal goes UP or DOWN it means that the pedal will move a short distance in that direction.

Actuator Checker Overlay

The illustrations of the Actuator Checker buttons in the Repair Manual are darkened to emphasize which ones are pressed for a given step.



The Actuator cannot be disassembled for service. If a malfunction develops with the solenoid valves or pump motor, the entire ABS Actuator assembly must be replaced.

Bleeding the ABS hydraulic system does not differ from the bleeding procedure of a conventional brake system except for rear wheel ABS. As fluid is bled, it flows through the solenoids to the wheels. The part of the actuator hydraulic circuit going from the solenoids through the No. 1 check valve is sealed to prevent air entry when the ABS is not activated.

If a malfunction occurs in the electrical system to the ECU, current to the actuator from the ECU is turned off. As a result, the brake system operates the same as if the antilock brake system is not operating and normal braking function is assured.

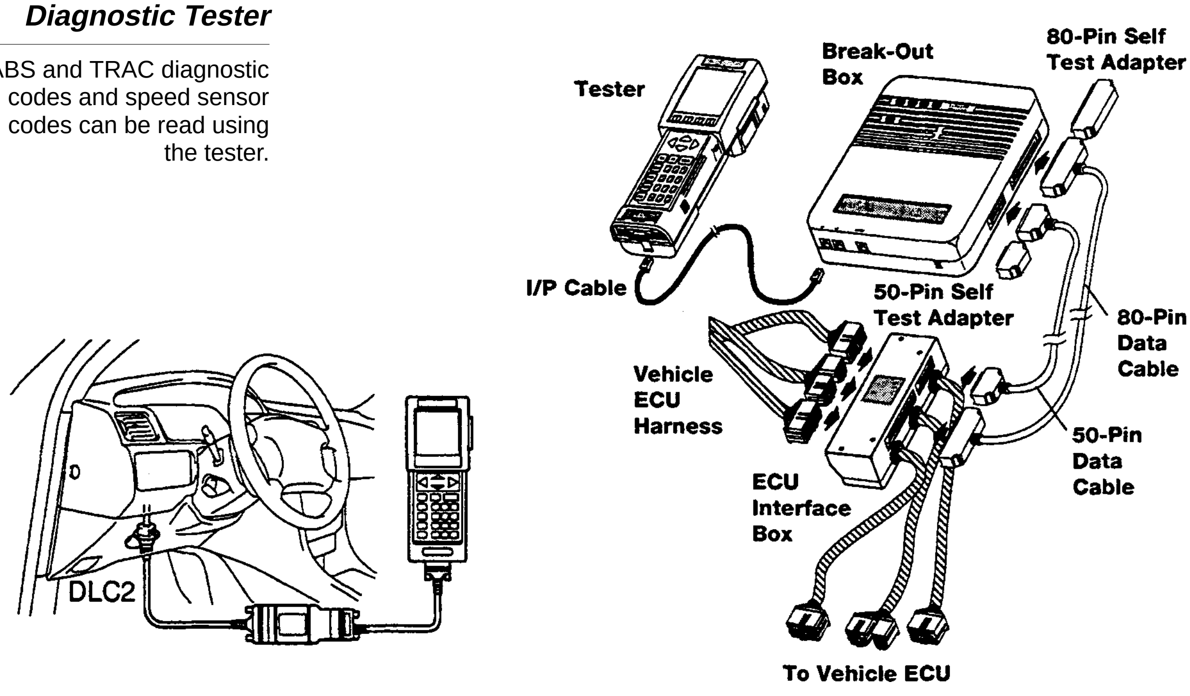
Toyota Diagnostic Tester

Toyota models equipped with a DLC2 connector located under the instrument panel have the capability to read diagnostic codes using the Diagnostic Tester. In addition, ECU pin voltage values on all ABS ECU's can be read on the Tester screen using the Vehicle Break-out Box feature. The Diagnostic Tester has a number of components and harnesses which vary, based on the vehicle and ECU being tested. An Operators Manual is provided with the Tester which describes the test functions and tool set-up. The Vehicle Break-out Box is connected between the vehicle harness and the ECU connectors.

Remember that while diagnosing any electrical system, disconnecting and reconnecting electrical connectors may eliminate a system fault.

Diagnostic Tester

ABS and TRAC diagnostic codes and speed sensor codes can be read using the tester.



WORKSHEET 10-1 (ON-CAR)
ABS Actuator Checker

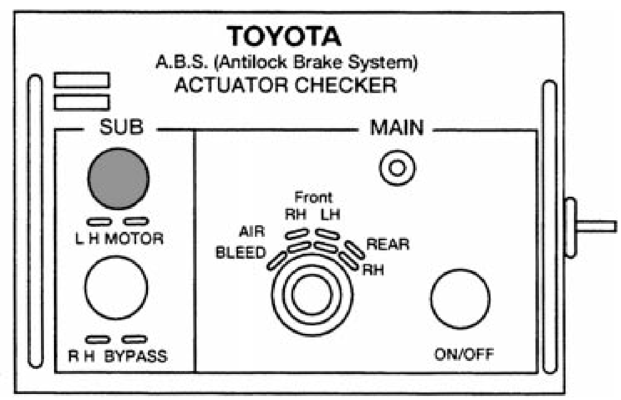
Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this Worksheet you will practice the use of the ABS Actuator Checker (Not to be used with TMM Camry/Avalon).

Tools and Equipment:

- ABS Actuator Checker (09990-00150).
- Vehicle Specific Harness Adapters.
- Vehicle Repair Manual.
- DVOM.
- Jumper Wire or SST 09843-18020.



Preparation:

- Disconnect the actuator/control relay electrical connectors.
- Connect the actuator checker to the actuator, control relay and body side harness. Place the cover sheet on to the checker if needed. Refer to the appropriate Repair Manual for the proper adapter harnesses.

Required Adapter Harnesses

Required Checker Cover sheet

Actuator Testing:

1. Inspect battery voltage.

Measured Battery Voltage	**Battery Voltage Specification**	**Pass/Fail**

2. Connect the sub-wire harness battery connectors to the battery.
3. Start the engine and run at idle.
4. Turn the selector switch to “FRONT RH” position.
5. Push and hold the MOTOR switch for a few seconds.
6. Depress and hold the brake pedal and push the POWER Switch (do not depress switch for more than 10 seconds).

   a. What happened to the brake pedal?

   ____

7. Release the switch and notice the brake pedal action.

   a. What happened to the brake pedal?

   ____

   b. What component(s) were checked?

   ____

8. While pressing the brake pedal, press the MOTOR Switch for a few seconds.

   a. What happened to the position of the brake pedal?

   ____

   b. What component(s) were checked?

   ____

9. Depress and hold the brake pedal for 15 seconds. While holding the brake pedal press the MOTOR Switch.

   a. Does the brake pedal pulsate?

   ____

10. Turn the main selector switch to the other three wheel positions and repeat the actuator tests above.
11. Disconnect and remove ABS Checker and harnesses.
12. Clear diagnostic codes (if any) from memory.

WORKSHEET 10-2 (ON-CAR)
Speed Sensor Signal Check

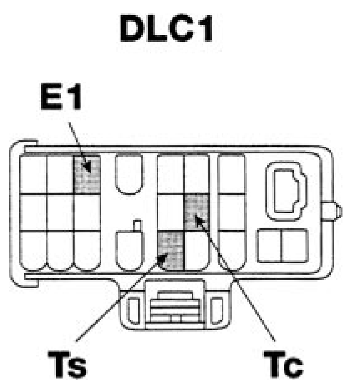
Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this Worksheet you will practice the procedure for checking the speed sensor signal.

Tools and Equipment:

- Jumper wire (SST 09843-18020) or equivalent jumper.
- Vehicle Repair Manual.



Procedure:

1. Turn the ignition switch OFF.
2. Jumper terminals Ts and E1 at DLC1.
3. Start engine.
4. Check the ABS warning light and record your observation.

   ____

   a. If the warning light does not blink, what should be checked first?

   ____

5. Drive the vehicle faster than 28 mph for several seconds.
6. Stop the vehicle and jumper terminals Tc and E1 of DLC1.
7. Record the codes as output by the ABS Warning Light.

   ____

8. Disconnect terminals Ts and E1 and Tc and E1 at DLC1 and turn ignition switch OFF.

Summary:

1. Answer the following questions for Speed Sensor Code 72.

   a. Which sensor is at fault?

   ____

   b. What is the cause of the fault?

   ____

2. Answer the following questions for Speed Sensor Code 78.

   a. Which sensor is at fault?

   ____

   b. What could cause this fault?

   ____

WORKSHEET 10-3 (ON-CAR)
Toyota Diagnostic Tester

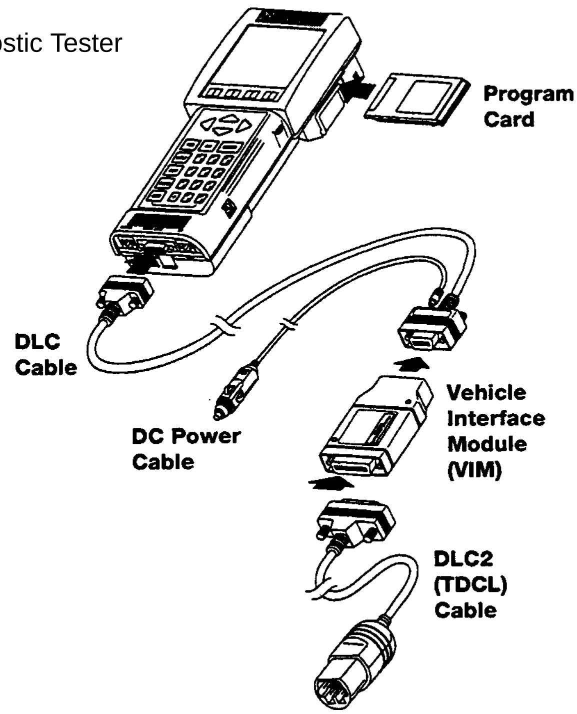
Vehicle	Year/Prod. Date	Engine	Transmission

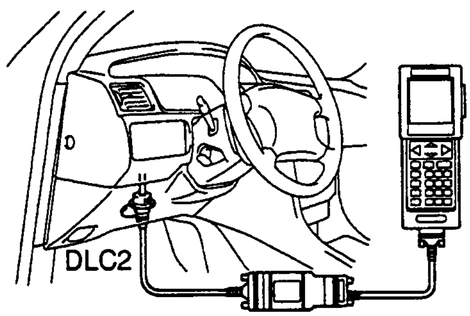
Worksheet Objectives

In this Worksheet you will practice the use of the Toyota Diagnostic Tester to access ABS diagnostic codes.

Tools and Equipment

- Vehicle Repair Manual.
- Diagnostic Tester (TOY220036).





Procedure:

1. Attach the DLC2 Cable, Vehicle Interface Module (VIM) and the DLC Cable to the Tester.
2. Attach the DC Power Cable to the DLC Cable and plug into the auxiliary power source.
3. Connect the DLC2 Cable to the vehicle.
4. Power up the unit and select ENTER.
5. At the Main Menu select OBD and press ENTER.
6. Follow the screen prompts for the vehicle you are working on.
7. At the OBD MENU select CODES (ALL).
8. Record the codes and components/circuits that appear on the tester screen.

 ____

 ____

9. Clear the diagnostic codes.
   a. Jumper TC and E1 and remove the short pin in DLC1.
   b. Turn ignition switch ON.
   c. Depress the brake pedal 8 or more times within 3 seconds.
   d. Is the Normal Code given at the warning light?
   e. Remove jumper wire and install short pin.

Notes

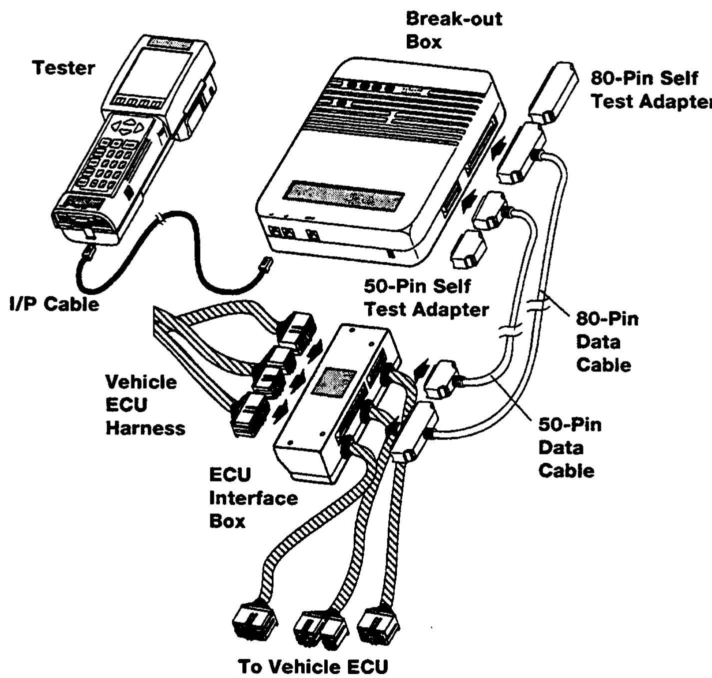
WORKSHEET 10-4 (ON-CAR)
Toyota Diagnostic Tester and Vehicle Break-out Box

Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this Worksheet you will practice the use of the Toyota Diagnostic Tester and Break-out Box to:

- access ABS ECU terminal signals
- access speed sensor oscilloscope patterns



Tools and Equipment

- Vehicle Repair Manual.
- Diagnostic Tester (TOY220036).
- Program Card.
- V-BOB Interface Card.
- V-BOB.
- Misc. V-BOB Harnesses.

Procedure:

1. Insert the Program Card in the Tester.
2. Connect the I/P Cable to the I/P connector on the bottom of the tester and the I/P connector on the Breakout Box.
3. Connect both the Tester and Break-out Box to a power source.
4. Power up the unit and select ENTER.
5. At the Main Menu select Breakout Box and press ENTER.
6. Follow the screen prompts for the vehicle you are working on.
7. At the Vehicle Confirmation Screen verify the information is correct for the vehicle and select YES.
8. When the vehicle and system have been selected, the Tester displays which ECU Interface Box, harness, and connectors are required to attach the V-BOB.
9. With the ignition switch OFF, disconnect the ECU harness connector.
10. Connect the vehicle harness to the ECU interface Box.
11. Connect the 50-pin and 80-pin Data Cables to the Break-out Box and ECU Interface Box.
12. Select DATA LIST from the Break-out Box Menu.
13. Turn ON the ignition switch and record the values for the items listed below:

    IG1_________ MT_________ MR_________ SR_________ AST_________

14. Refer to the Repair Manual or EWD and identify the circuit of each of the terminals above.

IG1 ______________________________

MT ______________________________

MR ______________________________

SR ______________________________

AST ______________________________

Oscilloscope Function:

1. From the Break-out Box Menu select oscilloscope and press ENTER.
2. Select FR+ (for front-wheel-drive) or RR (for rear-wheel-drive) and press ENTER.
3. Drive the vehicle at 15 mph and note the oscilloscope pattern height and frequency.
   a. Pause screen
   b. Print Screen or copy the oscilloscope pattern in the space below (SEND)
4. Drive the vehicle at 30 mph and note the oscilloscope pattern.
   a. Pause screen
   b. Print Screen or copy the oscilloscope pattern in the space below

3b. **4b.**

5. What is the difference between the oscilloscope patterns in 3 and 4 above?

____

____

6. Describe the A\C wave form for a speed sensor with a missing tooth.

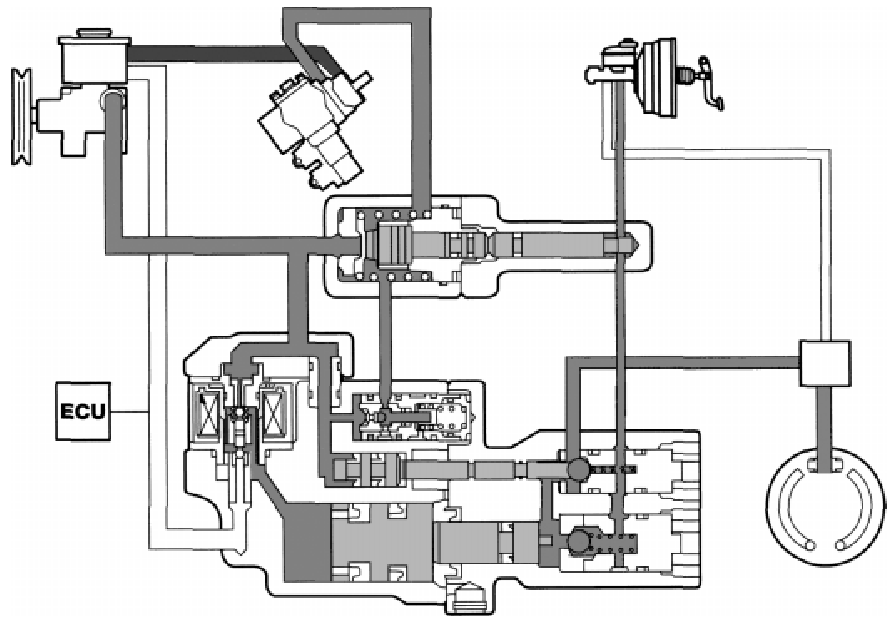
____

____

____

Section 11

OTHER ABS ACTUATORS



Lesson Objectives

1. Describe how the solenoid controlled power steering fluid controls brake pressure in the rear wheel ABS system.
2. Describe the function of the mechanical valve in the 3-position solenoid and mechanical valve actuator.
3. Describe the three control positions of the 3-position solenoid in maintaining ABS operation.

Other Actuator Designs

Toyota uses several types of ABS actuators, each differs in how the modulation of pressure is accomplished. The function of sensors and ECU control already discussed in Section 8, do not differ.

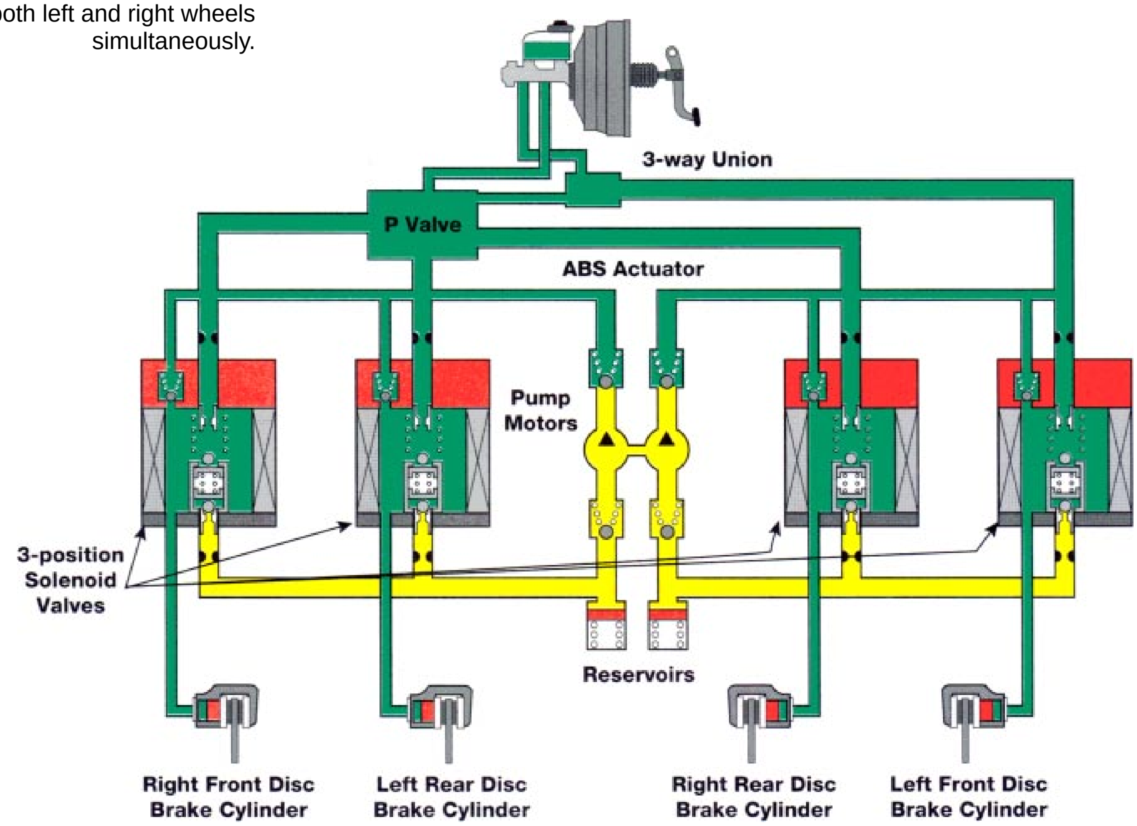
3-Position Solenoid Type

The 3-position solenoid valve uses a 3-position valve, electrical coil and check valve. As current flows through the solenoid windings, it creates a magnetic field around the 3-position valve causing it to move toward the center of the coil compressing the return spring. Current from the ABS ECU is switched in three steps; 0 amps, 2 amps and 5 amps in order to control the strength of the magnetic force in the coil.

There are four 3-position solenoid valves in the ABS actuator described here; those for the front wheels control the left and right wheels independently, while those for the rear wheels control both the left and right wheels simultaneously. The system is therefore known as a three-channel system.

3-Position Solenoid Actuator

The 3-position solenoid valves for the front wheels control the left and right wheels independently, those for the rear wheels control both left and right wheels simultaneously.



Operation During Normal Braking (ABS Not Activated)

During normal braking ABS is not activated and the 3-position valve is pushed down by a return spring. The solenoid inlet, port “A”, remains open while the outlet to the reservoir, port “B” remains closed.

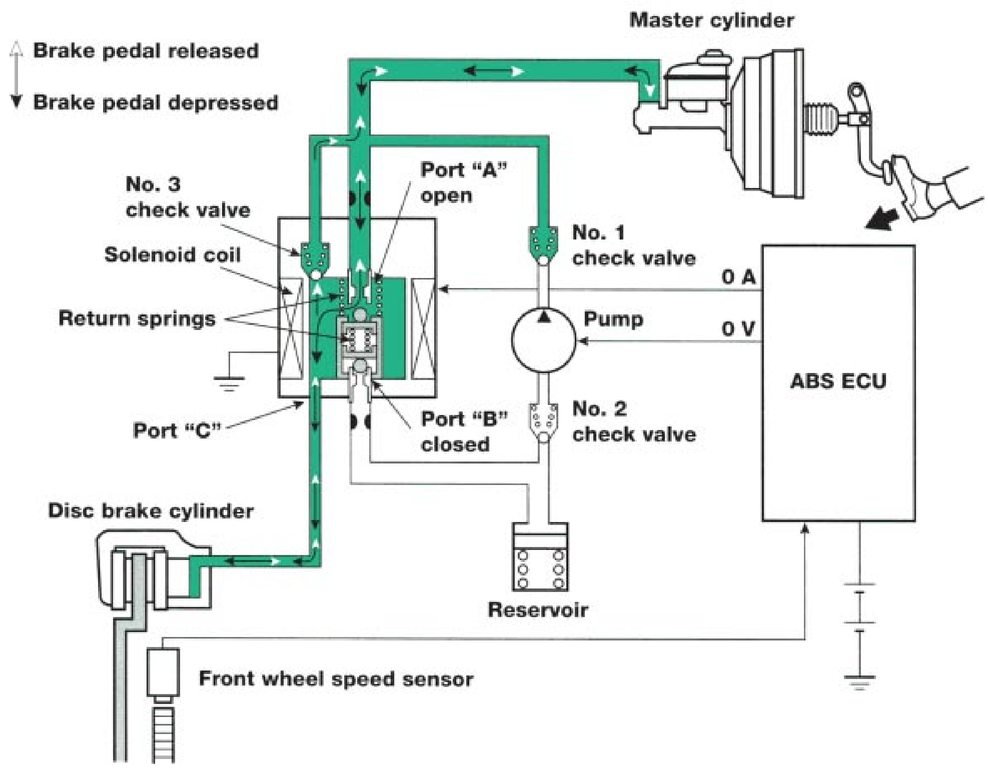
When the brake pedal is depressed, brake fluid passes from port “A” to port “C”, to the disc brake cylinder. Brake fluid is prevented from flowing into the pump by the No. 1 Check Valve located in the pump circuit.

When the brake pedal is released, the brake fluid returns from the disc brake cylinder to the brake master cylinder through port “C” to port “A” and the No. 3 Check Valve in the 3-position solenoid valve.

Normal Braking

With zero amps applied to the solenoid, port A is open, pressure is applied to the brake cylinder.

Part Name	Operation
3-Position Solenoid Valve	Port “A” Open
	Port “B” Closed
Pump Motor	Stopped



“Holding” Mode

When the ECU determines that a wheel is about to lockup, it switches to the holding mode to stop the increase in hydraulic pressure. As the pressure inside the disc brake cylinder is reduced or increased, and the speed sensor indicates that the speed is at the target level, the ECU supplies a 2 ampere signal to the solenoid coil to hold the pressure in the disc brake cylinder at that level.

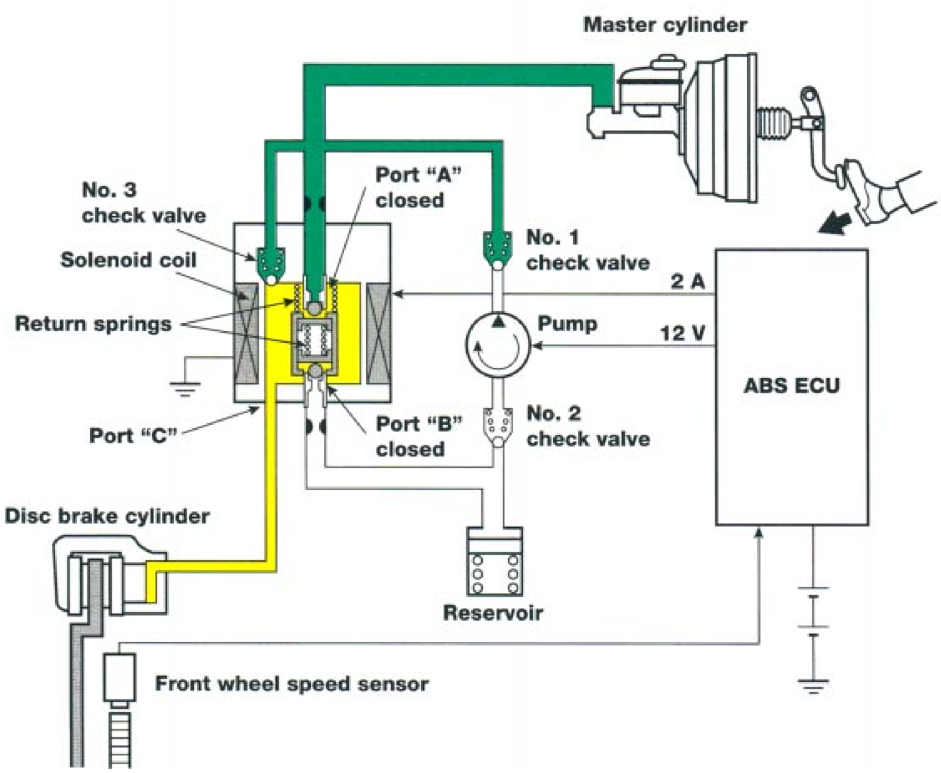
When the current supplied to the solenoid coil is reduced from 5 amperes (in the pressure reduction mode) to 2 amperes (in holding mode), the magnetic force generated in the solenoid coil also decreases. The 3-position solenoid valve then moves down to the middle position by the force of the return spring, closing port “B”.

With the ECU holding Port A closed, and pedal pressure closing check valves #1 & #3, brake caliper pressure holds steady, and cannot be increased.

“Holding” Mode

Two amps applied to the solenoid, Port A and Port B are closed, pressure remains constant.

Part Name	Operation
3-Position Solenoid Valve	Port “A” Closed
	Port “B” Closed
Pump Motor	On



"Pressure Reduction" Mode

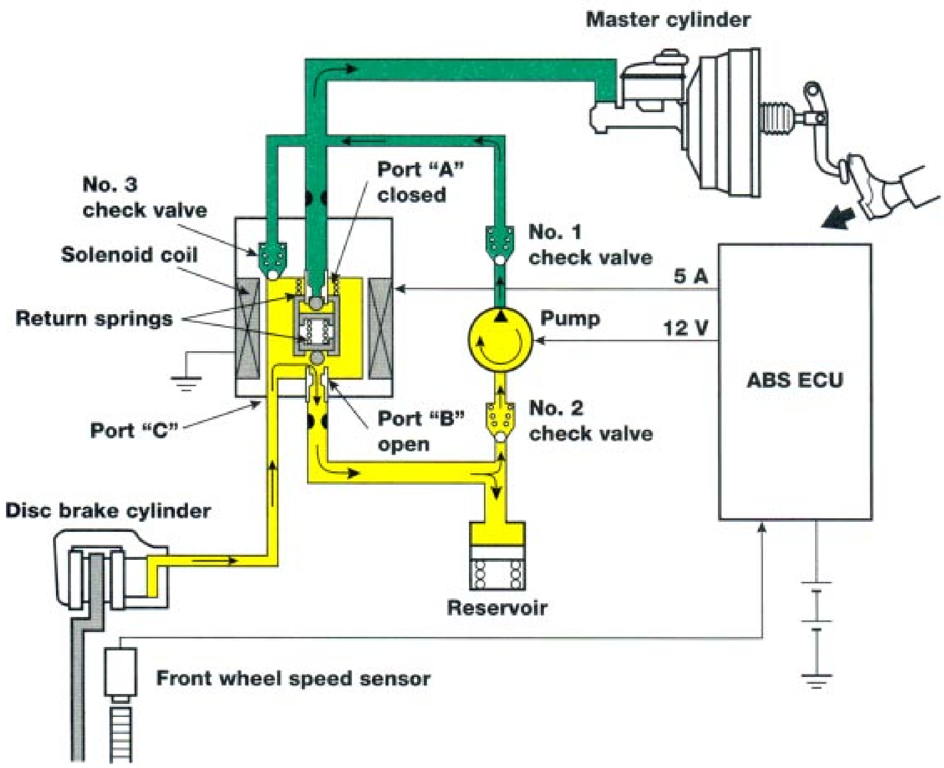
When the wheels are about to lock, the ECU supplies a 5 ampere signal to the solenoid to close port "A" and open port "B" in the 3-position solenoid. As a result, brake fluid from the disc brake cylinder passes through port "C" to port "B" in the 3-position solenoid and flows to the reservoir. At the same time, a computer signal causes the pump to operate. Fluid stored in the reservoir is pumped to the master cylinder.

The forced return of pressure from the brake caliper circuit to the master cylinder forces the pedal up slightly. This causes the driver to feel the ABS system operation.

"Pressure Reduction" Mode

Five amps applied to solenoid, port A dosed, port B open, allowing pressure from wheel cylinder to flow to the reservoir.

Part Name	Operation
3-Position Solenoid Valve	Port "A" Closed
	Port "B" Open
Pump Motor	On



"Pressure Increase" Mode

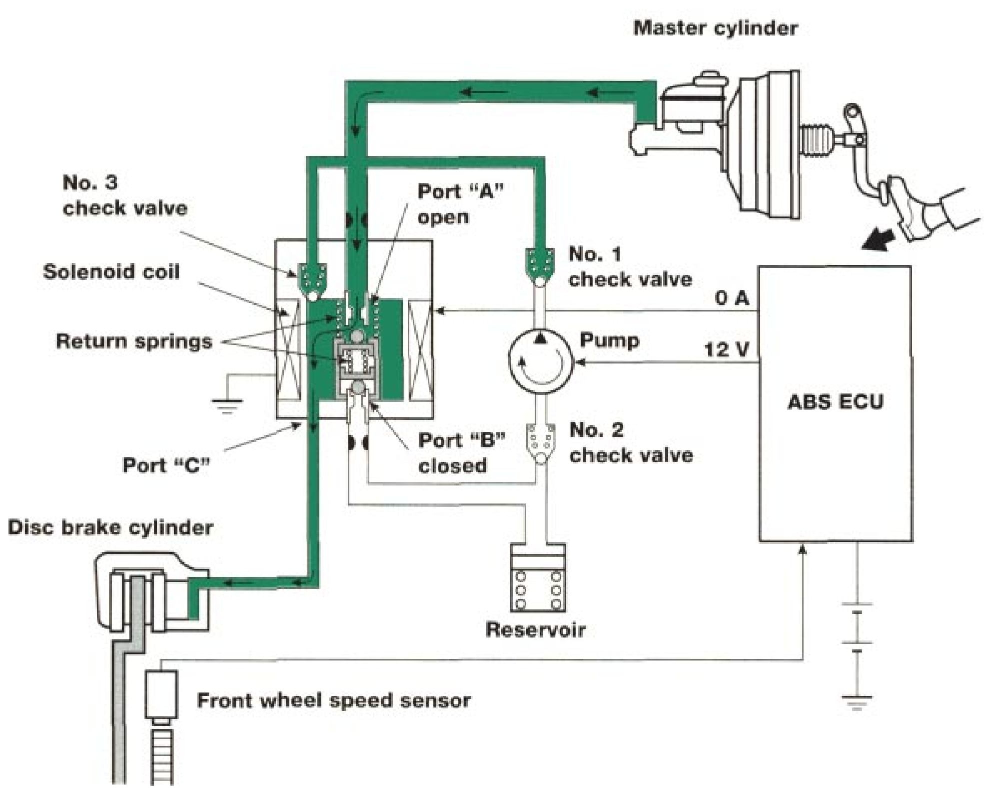
When the pressure in the disc brake cylinder needs to be increased to apply more braking force, the ECU stops sending current to the solenoid coil. This opens port "A" of the 3-position valve and closes port "B". This allows the fluid in the master cylinder to pass from port "C" in the three-position solenoid valve to the disc brake cylinder. The hydraulic pressure increase rate is controlled by the repetition of the pressure increase and holding modes.

Brake caliper pressure will increase as long as the driver continues to apply pedal pressure.

"Pressure Increase" Mode

Zero amps applied to solenoid, Port A open allowing pressure application at wheel cylinder.

Part Name	Operation
3-Position Solenoid Valve	Port "A" Open
	Port "B" Closed
Pump Motor	On

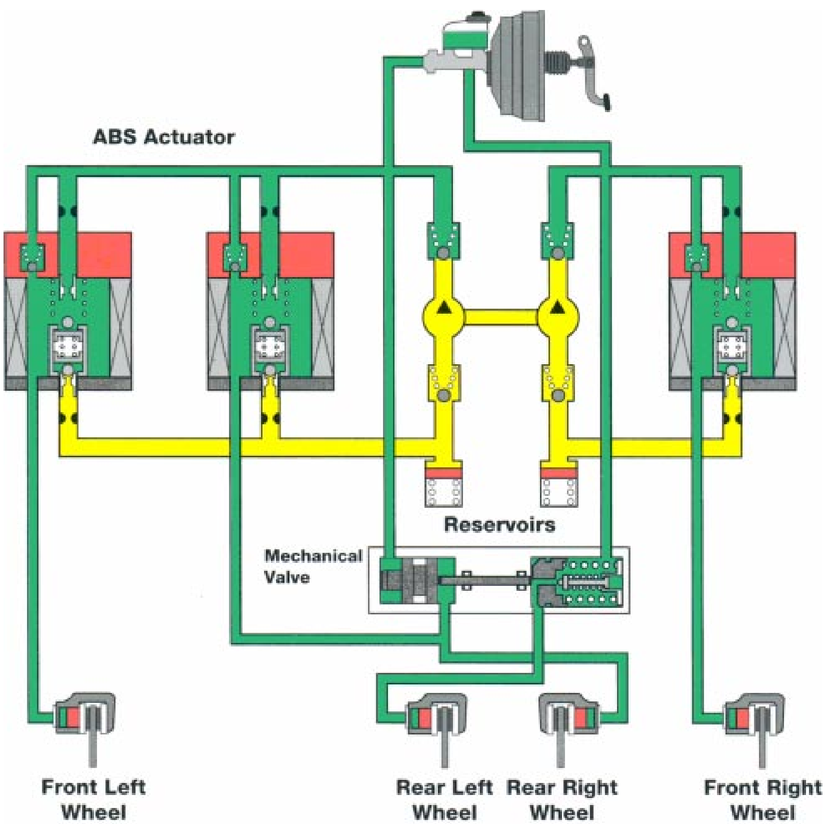


3-Position Solenoid and Mechanical Valve

This actuator is fundamentally the same as the 3-position solenoid type just discussed. It consists of three, 3-position solenoid valves, a mechanical valve, pump and reservoir. The solenoid that controls pressure to the right rear wheels also uses a mechanical valve that controls pressure to the left rear wheel. This actuator was first introduced on the 1994 Camry produced by Toyota Motor Manufacturing (TMM) in Georgetown, Kentucky and later in the Avalon.

3-Position Solenoid and Mechanical Valve Actuator

The solenoid which controls pressure to the rear wheels also uses a mechanical valve which controls pressure to the left rear wheel.



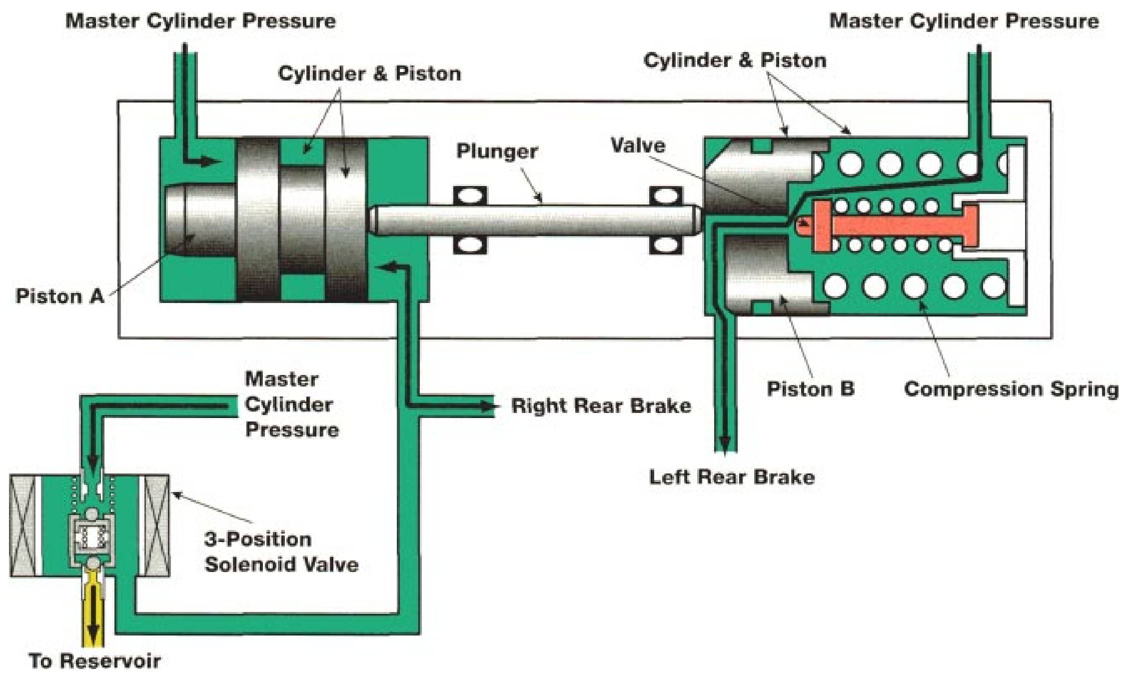
Mechanical Valve Construction

The mechanical valve consists of two sets of cylinders and pistons and a plunger to link their movement. Piston A monitors the pressure from the master cylinder on its left side and monitors pressure to the right rear brake circuit from the 3-position solenoid valve on its right side. Piston A moves based on differences in pressure since piston surface areas are equal.

Any movement of piston A is traced by piston B through the plunger. In addition a spring loaded valve opens and closes the master cylinder passage to the left rear brake. Piston B is spring loaded to the left which leaves the valve unseated and the fluid path open.

Mechanical Valve

This valve controls pressure to the left rear brake eliminating the need for another solenoid.



Pressure Increase Mode

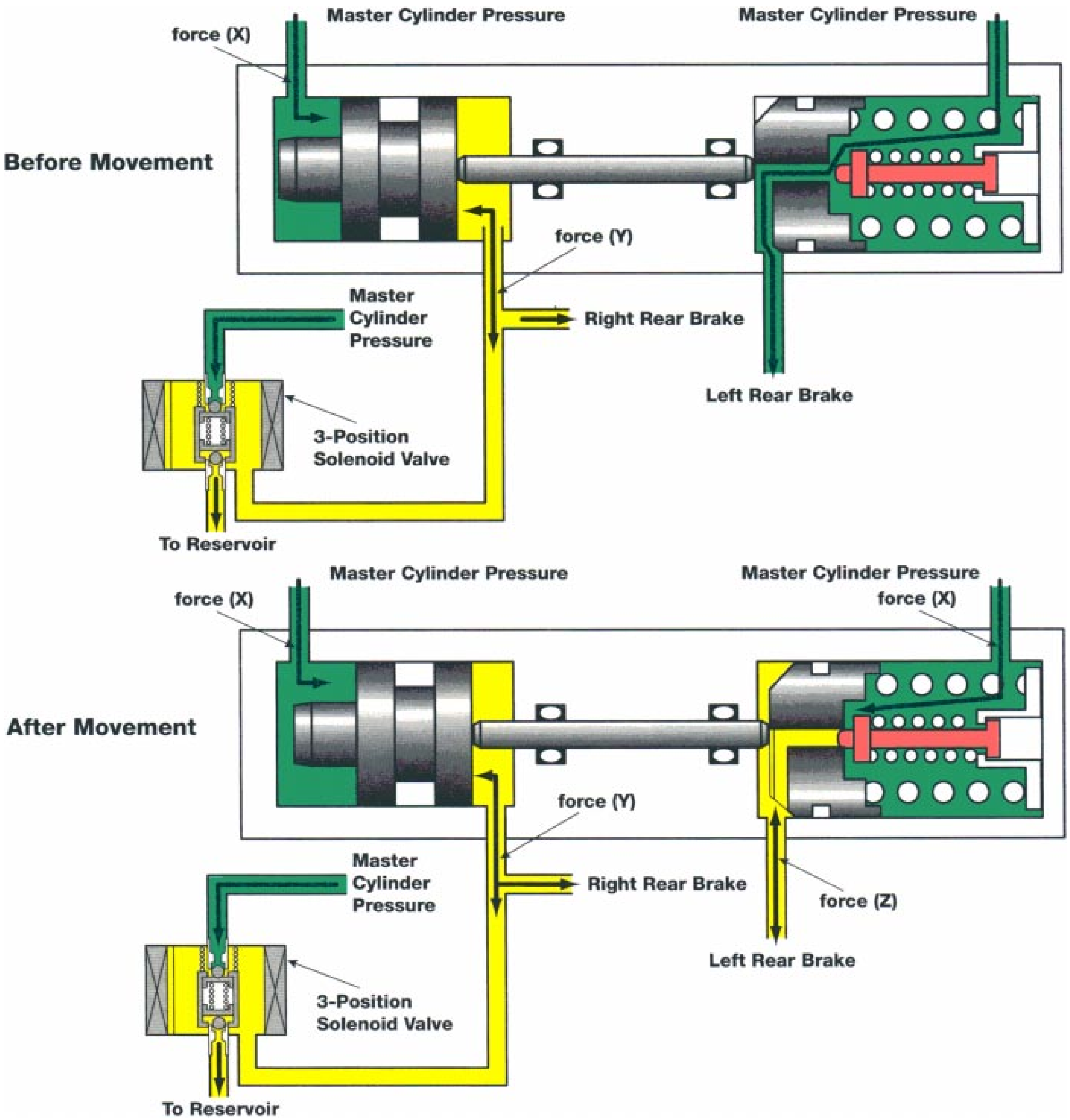
The pressure increase mode is also the normal braking position for brake operation without ABS, as shown in the illustration above. Pressure from the master cylinder is equal to the pressure coming through the 3-position solenoid to the right rear brake cylinder. Piston A does not move and is held to the left by the spring acting on piston B. Pressure increase comes from the master cylinder through the brake pedal pressure.

Pressure Hold Mode

When the 3-position solenoid goes into the hold position, it blocks hydraulic fluid and pressure in the circuit between the solenoid, the right rear brake cylinder and the right side of piston A. With pressure in the right rear brake held, pressure from the master cylinder increases, causing piston A to move right. The piston forces the plunger to move piston B to the right, blocking fluid from the left rear brake cylinder. This action mirrors the pressure hold on the right rear cylinder.

Pressure Hold Mode

The Mechanical Valve causes pressure at the left rear brake to mirror the pressure to the right rear brake.

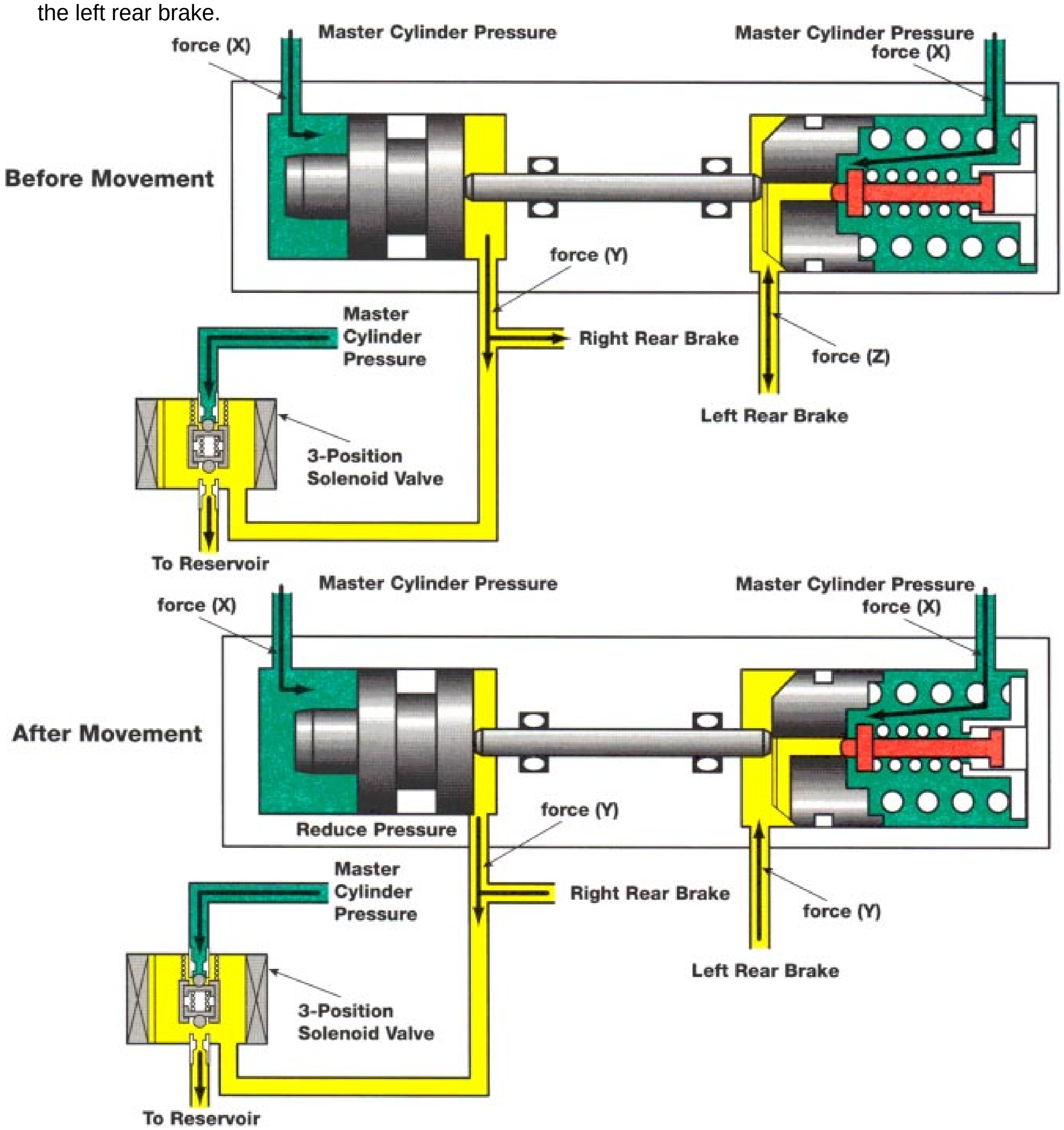


Pressure Reduction Mode

The 3-position solenoid goes into the reduction position venting hydraulic fluid and pressure in the circuit between the solenoid, the right rear brake cylinder and the right side of piston A. Pressure from the master cylinder increases causing piston A to move right forcing the plunger to move piston B to the right compressing the spring. The movement of piston B increases the area volume in the left rear brake cylinder hydraulic circuit. This action mirrors the pressure reduction in the right rear cylinder.

Pressure Reduction Mode

Pressure reduction is accomplished by the movement of piston B creating an increase in volume to the circuit to the left rear brake.



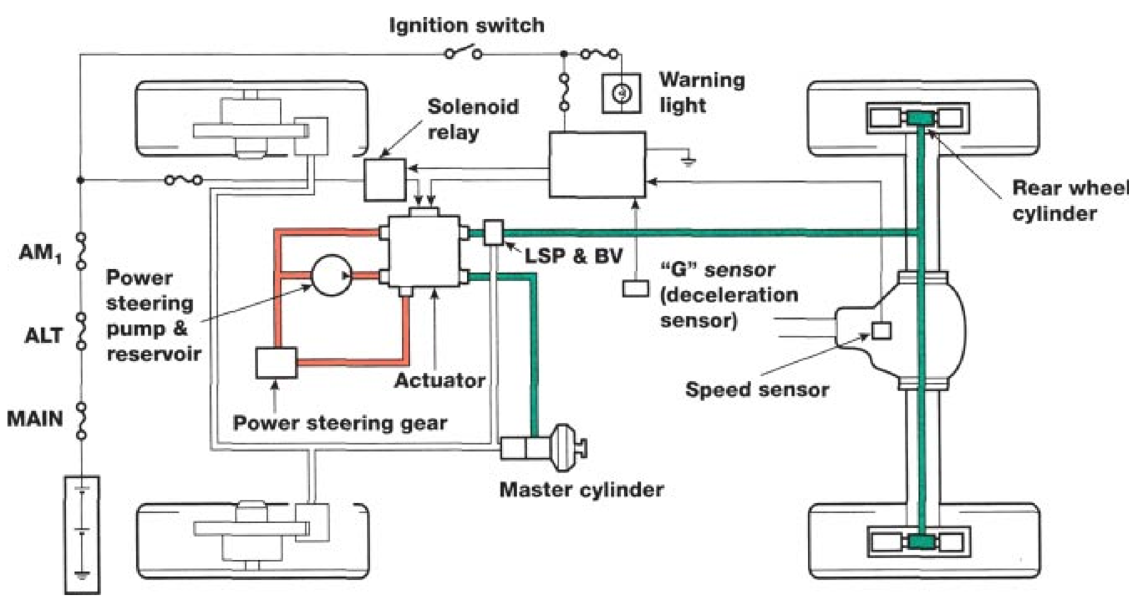
Power Steering Pressure Controls Brake Pressure

This system was an option on ’90 - ’94 Trucks, 4Runners and T100’s. It represents the greatest departure from the systems we have studied to this point. The following summary highlights the unique features of this system:

- Controls the rear wheels only.
- Single 2-position solenoid in the actuator.
- Uses a deceleration sensor and a single speed sensor.
- Power steering pressure is used to control brake pressure.

Rear Wheel ABS Diagram

The ECU uses input from the single speed sensor and deceleration sensor to control rear wheel brake pressure.



A single 2-position solenoid controls the hydraulic pressure from the power steering to control brake pressure. This system uses only one speed sensor, mounted on top of the ring gear on the differential case. For this reason, a deceleration (“G”) sensor is necessary for the ECU to sense the deceleration rate to help determine the slip rate of the rear wheels.

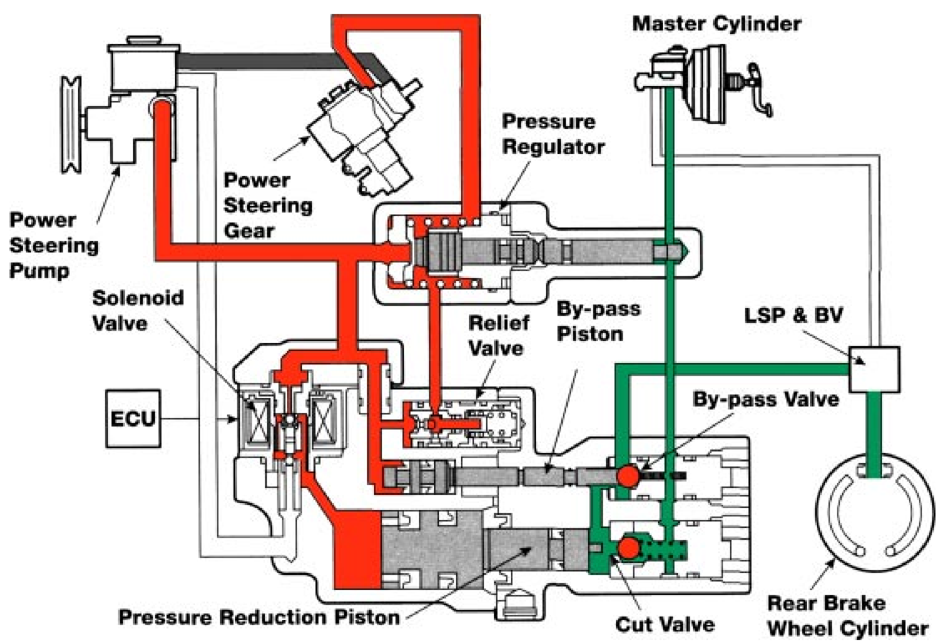
The actuator modulates power steering fluid pressure to control brake hydraulic pressure when the rear wheels slip while the brakes are applied. Modulation is accomplished by the ECU controlled two-position solenoid based on input from the deceleration sensor and speed sensor.

The actuator is made up of several components each having a specific function:

- **Solenoid valve** is controlled by the ABS ECU and modulates the power steering pressure on the pressure reduction piston.
- **Pressure regulator valve** regulates the power steering pressure in relation to brake pressure. Brake pressure acting on the right side of the valve compressing the spring would raise power steering pressure. (Located in the Actuator)
- **Relief valve** relieves the power steering pressure if it gets too high in the actuator.
- **By-pass piston** opens and closes the by-pass valve according to power steering pressure. It constantly monitors power steering pressure to keep the by-pass valve closed. If the power steering pressure is lost, the by-pass valve opens to allow brake pressure to by-pass actuator control.
- **Pressure reduction piston** opens and closes the cut and by-pass valve to direct the brake fluid. Changes the brake pressure to the rear wheels by increasing or decreasing the volume in its bore.
- **Cut valve and By-pass valve** controls the path of brake fluid depending on mode of operation.

Actuator Hydraulic Circuit

The actuator modulates power steering fluid pressure to control brake hydraulic pressure when the rear wheels slip.



Control of the brake fluid pressure acting on the rear brake cylinders is carried out in three modes:

- pressure holding.
- pressure reduction.
- pressure increase.

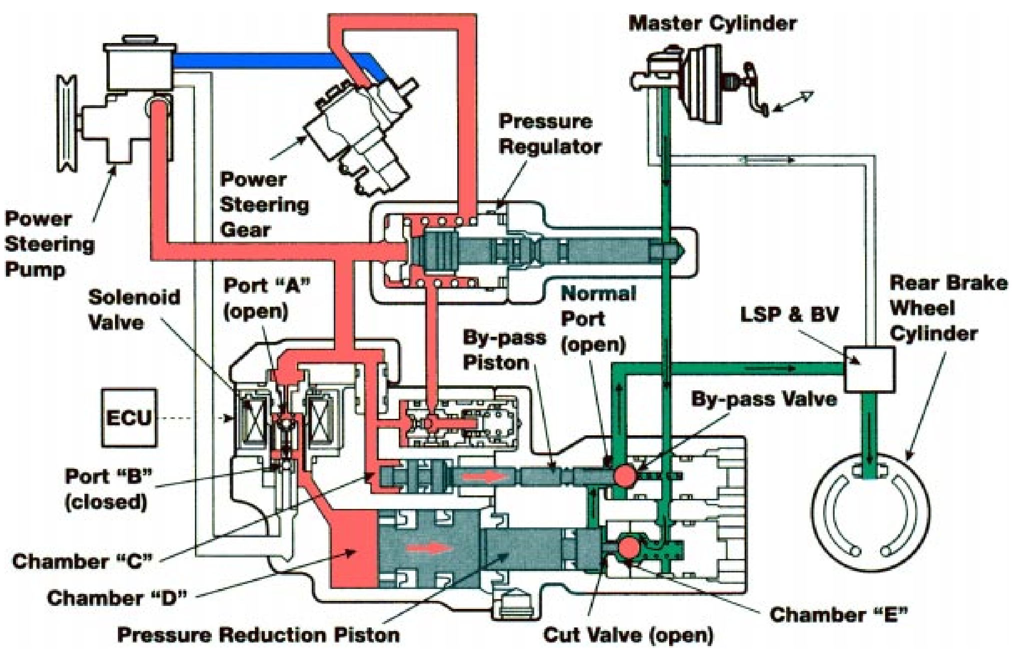
Operation During Normal Braking

The rear-wheel anti-lock brake system is not activated during normal braking. In this mode the power steering fluid pressure acts on chambers “C” and “D” pushing both the by-pass valve and cut valve toward the right. This causes the cut valve to open and the normal port on the left side of the by-pass valve to open.

When the brake pedal is depressed, the master cylinder fluid pressure rises. The brake fluid passes from the cut valve to the normal port in the by-pass valve, and is sent to the rear brake wheel cylinders.

Normal Braking

Power steering fluid pressure acts on chambers “C” and “D” pushing both the by-pass valve and cut valve toward the right.



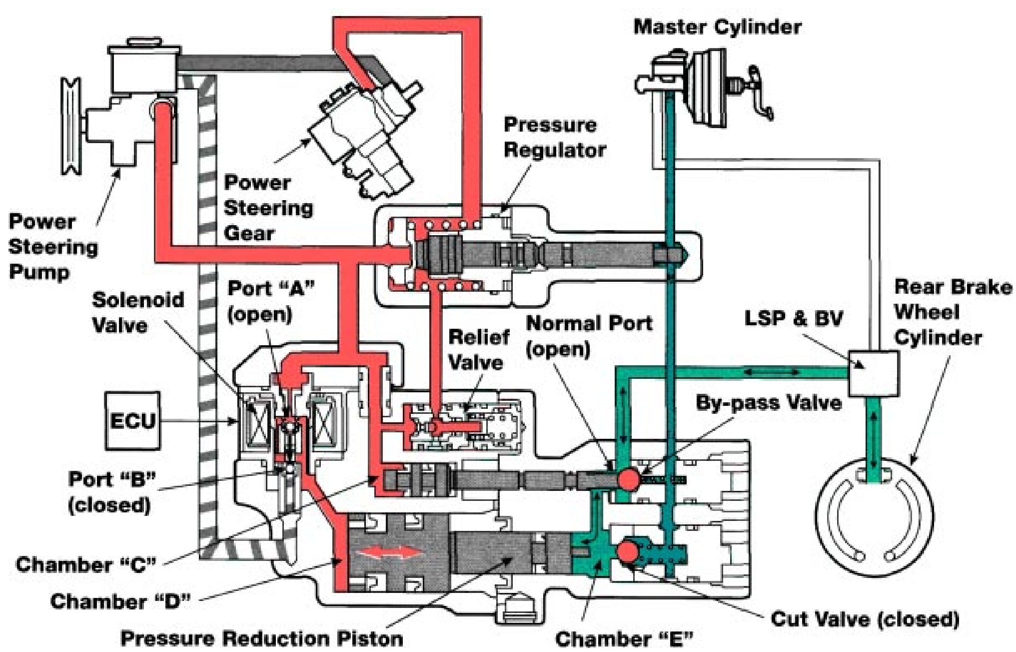
Holding Mode

This system does not have a specific holding mode: instead, rear brake cylinder pressure hold mode is maintained by the ECU quickly pulsing the solenoid valve ON and OFF between pressure increase and pressure reduction modes. The ECU maintains the pressure to the rear wheel cylinders within a narrow range as it continues to monitor wheel speed.

Holding Mode

The holding mode is maintained by the ECU quickly pulsing the solenoid valve ON and OFF between pressure increase and reduction to maintain the brake pressure to the rear brakes.

Part Name	Operation	
	Pressure Increase	Pressure Reduction
Solenoid Valve	Port "A" Open	Port "A" Close
	Port "B" Close	Port "B" Open
Cut Valve	Close	←
By-pass Valve	Normal Port Open	←



Pressure Reduction Mode

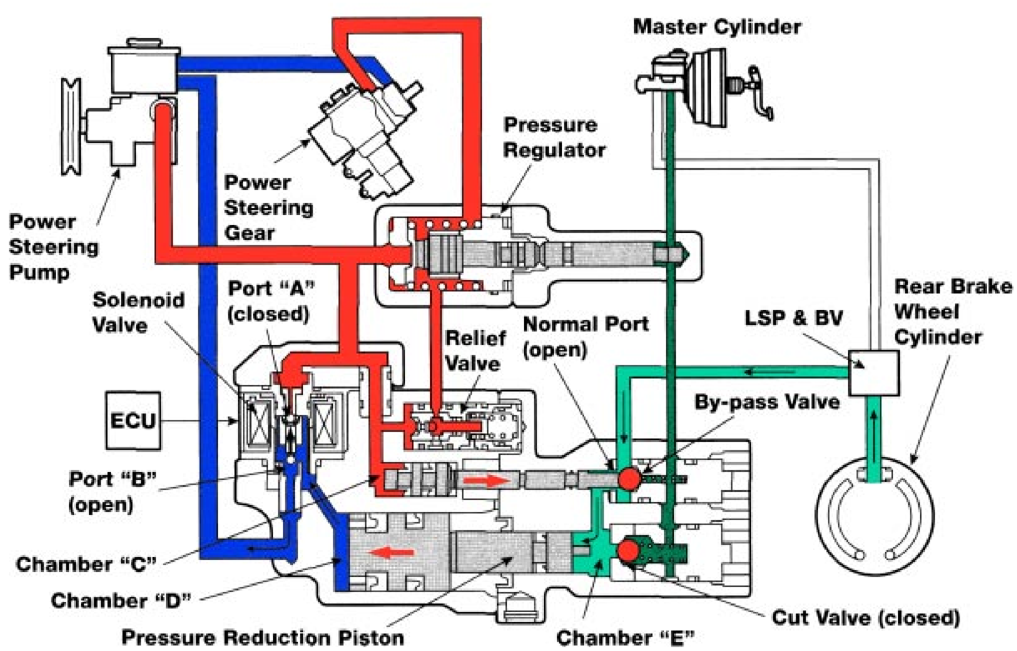
When the rear wheel begins to lock-up, the ECU energizes the solenoid coil, generating a magnetic force. The plunger moves upward and port "A" closes while port "B" opens. As a result, the power steering fluid acting on chamber "D" returns to the power steering reservoir. This causes the pressure reduction piston to move to the left, first closing the cut valve, then causing the brake fluid pressure, acting on the rear brake wheel cylinders, to accumulate in chamber "E".

As a result, the pressure level inside the rear brake wheel cylinders decreases to prevent wheel locking.

Pressure Reduction Mode

The solenoid plunger moves upward and port "A" closes while port "B" opens. As a result, the power steering fluid acting on chamber "D" returns to the reservoir.

Part Name	Operation
Solenoid Valve	Port "A" Close
	Port "B" Open
Cut Valve	Close
By-pass Valve	Normal Port Open



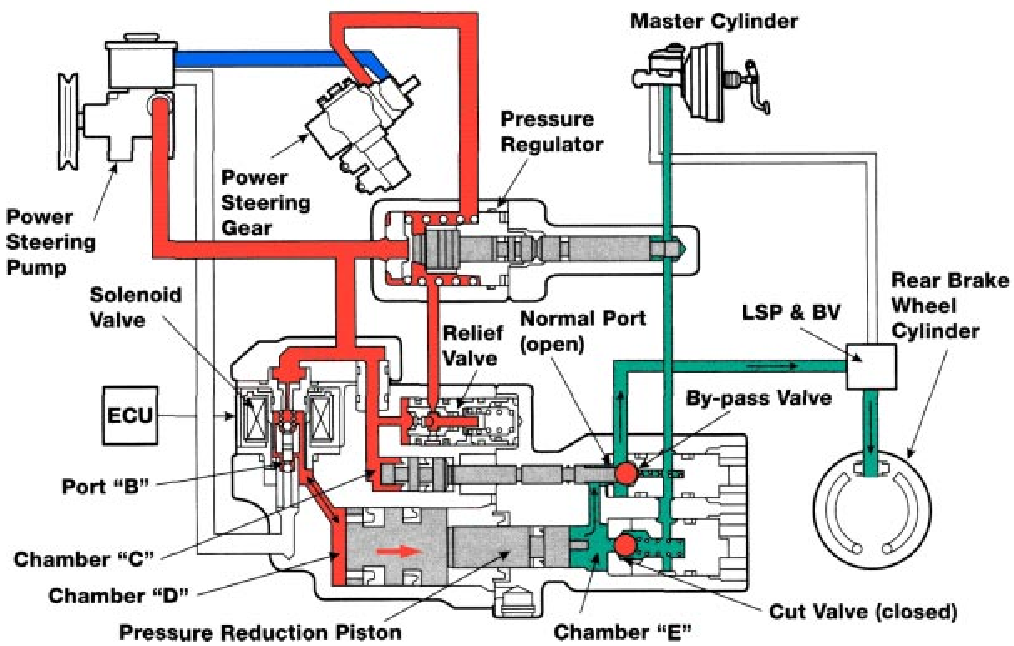
Pressure Increase Mode

When the fluid pressure in the rear brake wheel cylinders needs to be increased to apply more braking force, the ECU changes the ratio in which the solenoid valve is turned on and off. In the pressure increase mode, the brake fluid pressure in the rear wheel brake cylinders is increased while the solenoid valve is switched on and off repeatedly. By extending the amount of time the solenoid is switched off in the on/off cycle, the amount of time port “A” is open and port “B” is closed is extended and this causes the pressure in chamber “E” to rise gradually. The cut valve remains closed during the operation. The pressure reduction piston is moved gradually to the right and increases the brake fluid pressure acting on the rear brake wheel cylinders.

Pressure Increase Mode

By extending the amount of time the solenoid is switched off in the on/off cycle, the amount of time port “A” is open and port “B” is closed is extended and this causes the pressure in chamber “E” to rise gradually.

Part Name	Operation	
	Pressure Increase	Pressure Reduction
Solenoid Valve	Port “A” Open	Port “A” Close
	Port “B” Close	Port “B” Open
Cut Valve	Close	←
By-pass Valve	Normal Port Open	←



Fail-safe Mode

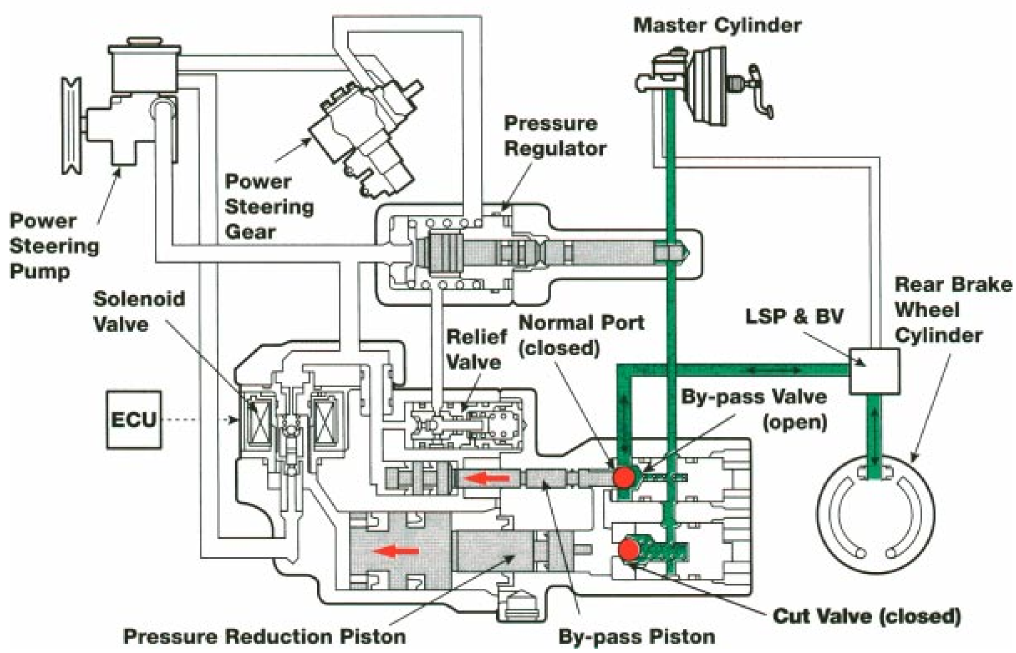
In the event power steering fluid pressure is insufficient, the By-pass Piston and Pressure Reduction Piston move to the left by brake hydraulic pressure. This causes the Cut Valve and the Normal Port of the Bypass Valve to close. With the Normal Port closed, the By-pass Port is open allowing the master cylinder to apply pressure to the wheel cylinder.

In the event of a malfunction in the signal system to the ABS ECU, the solenoid relay is shut OFF. The spring loaded Solenoid Valve allows power steering pressure to move the Pressure Reduction piston and By-pass Piston to the right opening the Cut Valve. The brake system operates as a normal brake system without ABS.

Fail-safe Mode

Allows brake fluid to by-pass the actuator control in the event of power steering pressure loss.

Part Name	Operation
Cut Valve	Close
By-pass Valve	By-pass Port Open



Bleeding the Rear Wheel Antilock Brake System

Rear wheel ABS requires a special bleeding procedure when a component of the steering system or the actuator is replaced. A typical procedure is outlined here however, check the appropriate Repair Manual as procedures may vary:

- Bleed the power steering system using the conventional method.
- Bleed the brake system with the engine running.
- Bleed the brake system with the engine OFF.
- Bleed the power steering system using the brake actuator checker.

The conventional method of bleeding the power steering system requires that the reservoir be full.

- Run the engine at 1000 rpm or less.
- Turn the steering wheel from lock to lock three or four times.
- The fluid in the reservoir should not be foamy or cloudy indicating presence of air.

After the brakes are bled connect the ABS actuator checker.

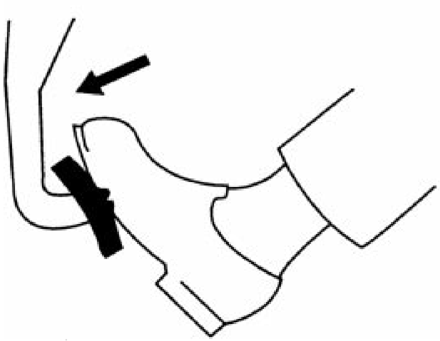
- Run the engine at idle.
- Turn the selector switch on the actuator checker to “AIR BLEED”.
- Strongly depress the brake pedal and hold it.
- Push the ON/OFF switch five times for three seconds each time while holding the brake pedal down.

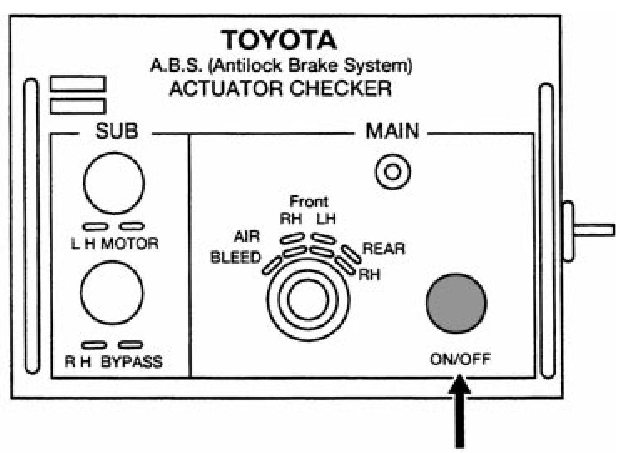
CAUTION

Do not press the ON/OFF switch before depressing the brake pedal and do not release the brake pedal while the ON/OFF switch is ON or damage to the master cylinder piston cups may occur.

Rear Wheel ABS Bleeding

Bleeding the ABS requires bleeding both the power steering system as well as the brake system.

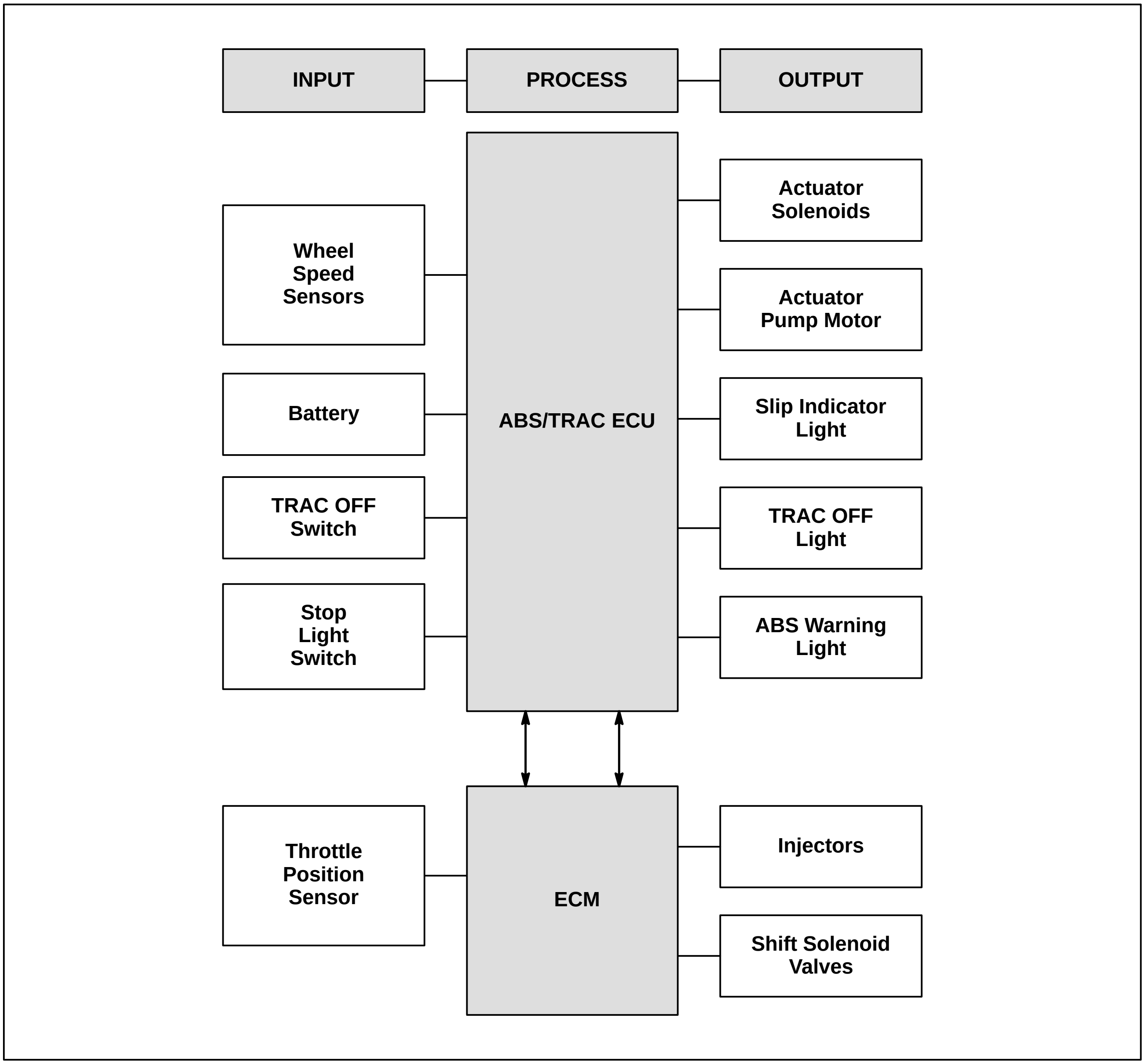




Notes

Section 12

TRACTION CONTROL SYSTEM (TRAC)



Lesson Objectives

1. Identify the main components of the TRAC systems.
2. Describe the function of components in the TRAC system.
3. Describe the engine torque control system used on the Camry and Avalon.
4. Describe the fail-safe function of the Camry and Avalon actuator.
5. Describe the primary differences between Camry /Avalon and the Supra TRAC systems.

Traction Control System

Traction Control was first introduced on the 1994 Turbo Supra and expanded to include the six cylinder Camry and Avalon models in 1997.

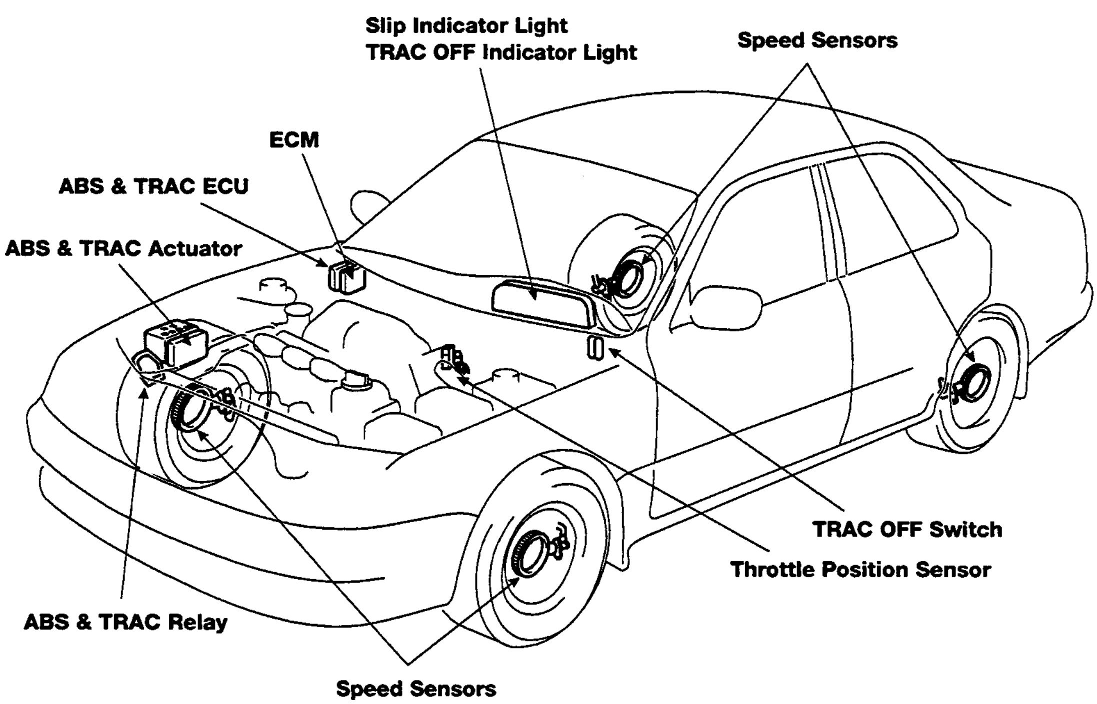
The purpose of the Traction Control System is to prevent wheel spin from occurring due to acceleration. The maximum torque that can be transmitted to the wheels is determined by the coefficient of friction generated between the road and the tires. If torque exceeds that level, the wheels are likely to spin. Conditions for TRAC operation may include: loose gravel, slippery road surfaces, acceleration while cornering and hard acceleration.

Once activated, the TRAC System reduces engine torque and drive wheel speed as necessary to bring the vehicle under control which improves vehicle stability when starting, accelerating or turning on slippery roads.

Although the Supra and Camry/Avalon TRAC system both control engine torque and drive wheel braking, how that is accomplished varies and therefore the two systems are covered separately in this section.

Camry TRAC Component Locations

The TRAC Systems share some ABS components to control traction control functions.

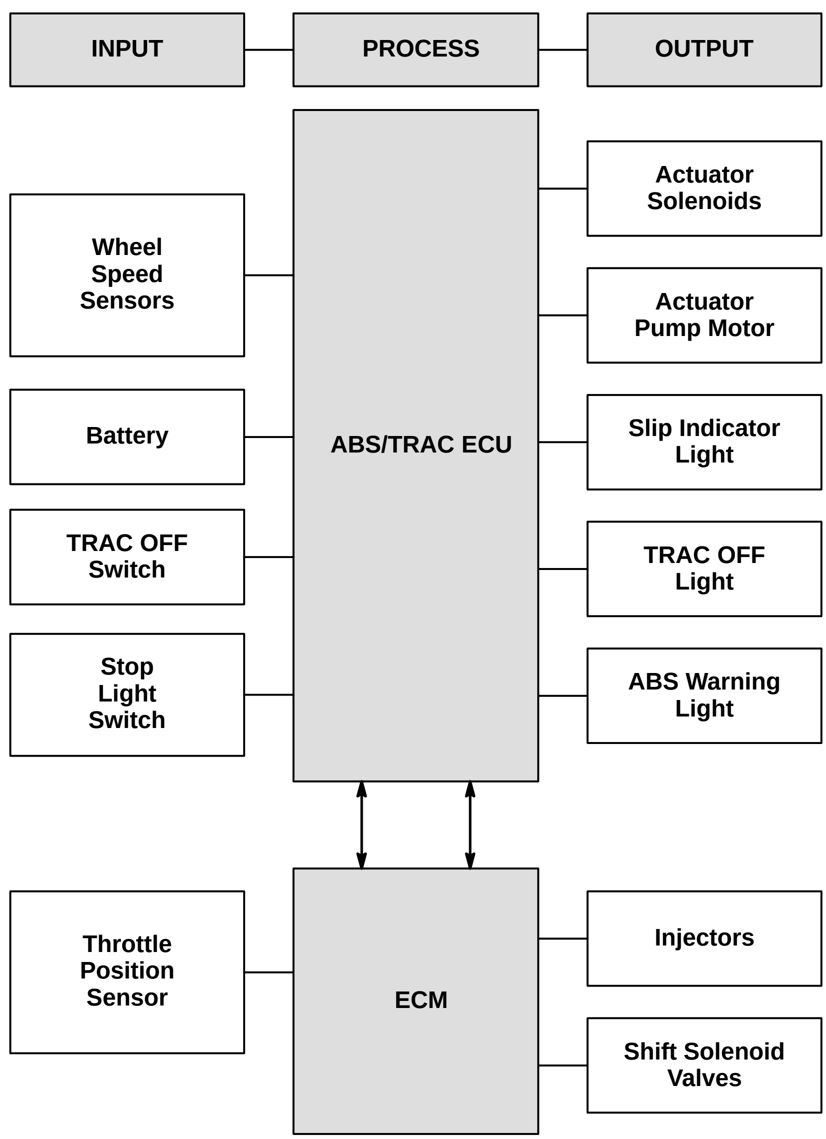


Camry/Avalon TRAC

The ABS/TRAC ECU and ECM work together to provide traction control. The ABS/TRAC/ECU monitor signals from the four speed sensors to determine the speed of each wheel and vehicle speed. When slippage is determined:

- The ABS/TRAC ECU activates the actuator solenoids and pump motor which applies hydraulic pressure to the brakes at the drive wheels.
- The ECM monitors the throttle position sensor and denies fuel injection on up to five cylinders to limit engine torque.
- The ECM prohibits shifting of the automatic transaxle.
- The slip indicator light is turned ON to notify the driver of TRAC operation and a signal is sent to the ECM.

Typical ABS/TRAC Control System



Wheel Speed Control

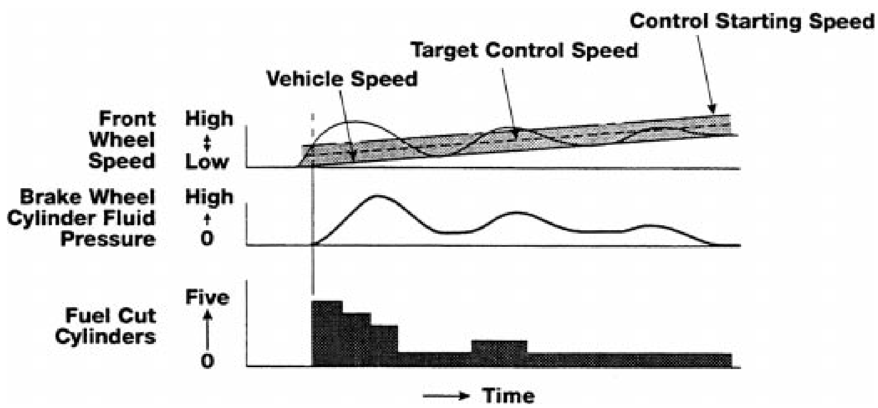
Wheel speed control is accomplished by two means:

- Brake application through the TRAC & ABS actuator.
- Reduce engine torque by temporarily disabling from one to five injectors.

Fuel injector control is performed through the ECM. In the example below, speed of the front wheel exceeds the Control Starting Speed. The ECM initially shuts off five injectors and turns some injectors back ON as wheel speed decreases. As wheel speed approaches Target Control Speed, an additional injector is shut off temporarily to prevent over-shooting the Control Starting Speed.

Wheel Speed Control

Brake pressure and control of injectors reduce wheel speed when slippage occurs.



Operation of Components

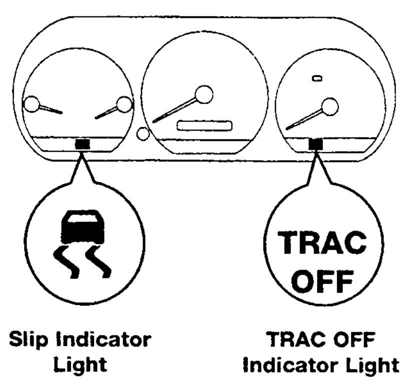
The TRAC OFF switch located on the instrument panel allows the driver to activate or deactivate the TRAC system. The system defaults to ON when the ignition switch is cycled.

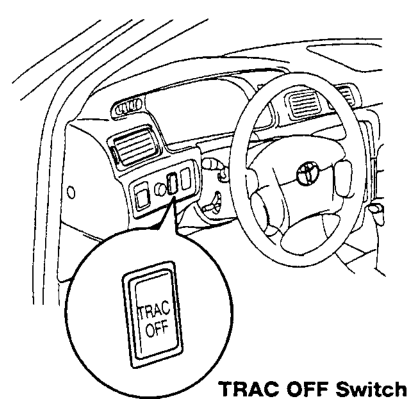
The TRAC OFF Indicator Light goes on when the TRAC system is turned OFF. Additionally, it blinks when a malfunction has occurred in the engine or the TRAC system.

The Slip Indicator Light blinks when the TRAC system is operating to inform the driver.

TRAC OFF Switch and Indicator Lights

The TRAC OFF switch allows the driver to control the TRAC system operation.





ABS & TRAC Actuator

The ABS & TRAC actuator is contained in one housing and has twelve 2-position solenoid valves which control hydraulic pressure to the brake calipers. In addition there are two pumps controlled by one motor, two reservoirs and two regulator valves.

Of the twelve solenoid valves there are:

- Two Master Cut Solenoid Valves.
- Two Reservoir Cut Solenoid Valves.
- Four Pressure Holding Valves.
- Four Pressure Reduction Valves.

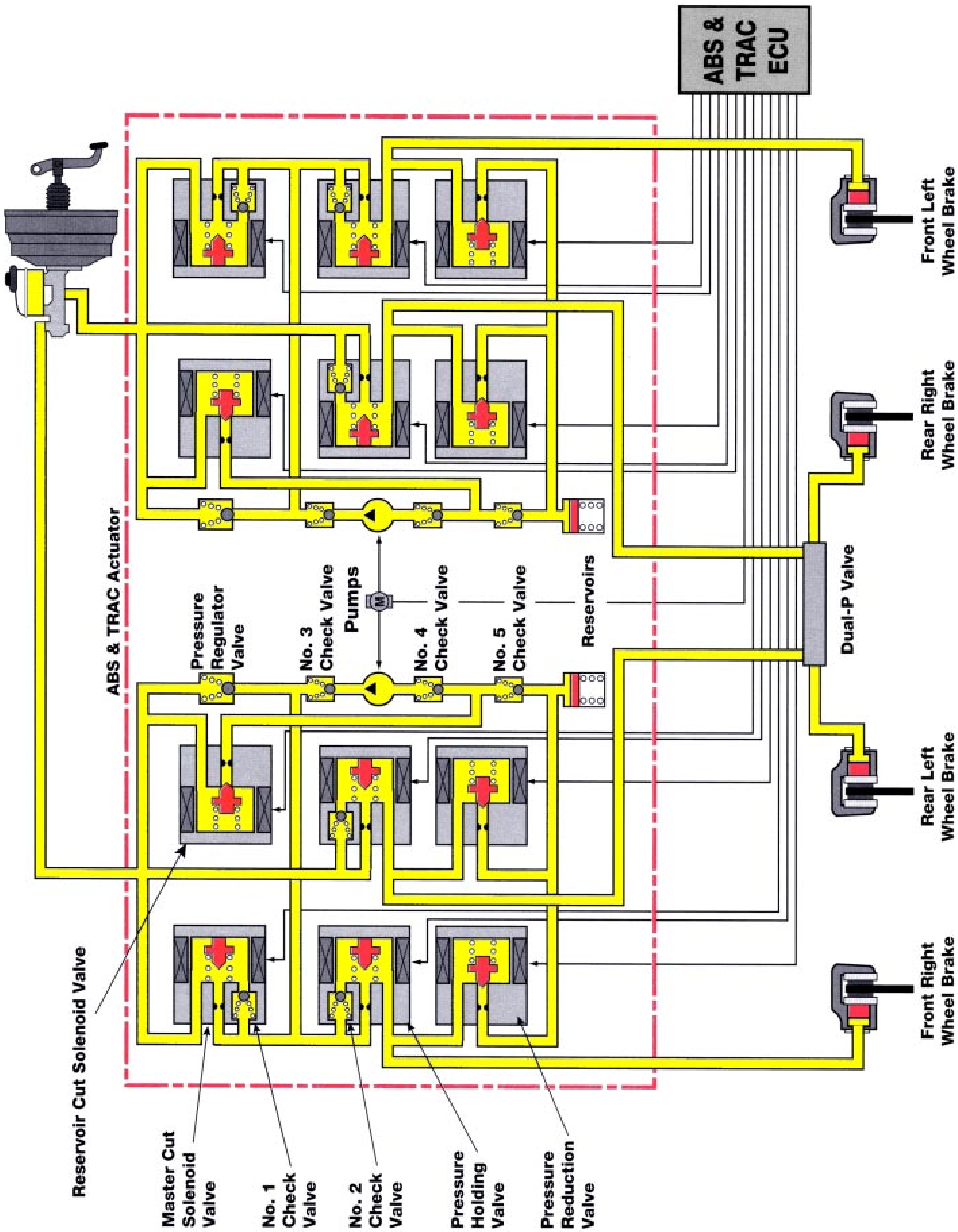
The **Master Cut Solenoid Valve** opens and closes the hydraulic circuit between the master cylinder and the ABS pressure holding valve 2-position solenoid and on to the front brake caliper. Its normal position is spring loaded in the **open** position. Its construction and operation are the same as the pressure holding valve.

The **Reservoir Cut Solenoid Valve** opens and closes the hydraulic circuit from the master cylinder to the actuator pump. Its normal position is spring loaded in the **closed** position. Its construction and operation are the same as the pressure reduction valve.

The **Pressure Regulator Valve** regulates brake fluid pressure generated by the actuator pump.

When the TRAC system is activated the Master Cut Solenoid Valve and Reservoir Cut Solenoid Valve control the brake system to the drive wheels while the Pressure Holding Valve and Pressure Reduction Valves of the ABS system modulate the pressure in three phases: Pressure Increase, Pressure Holding and Pressure Reduction.

ABS & TRAC Actuator

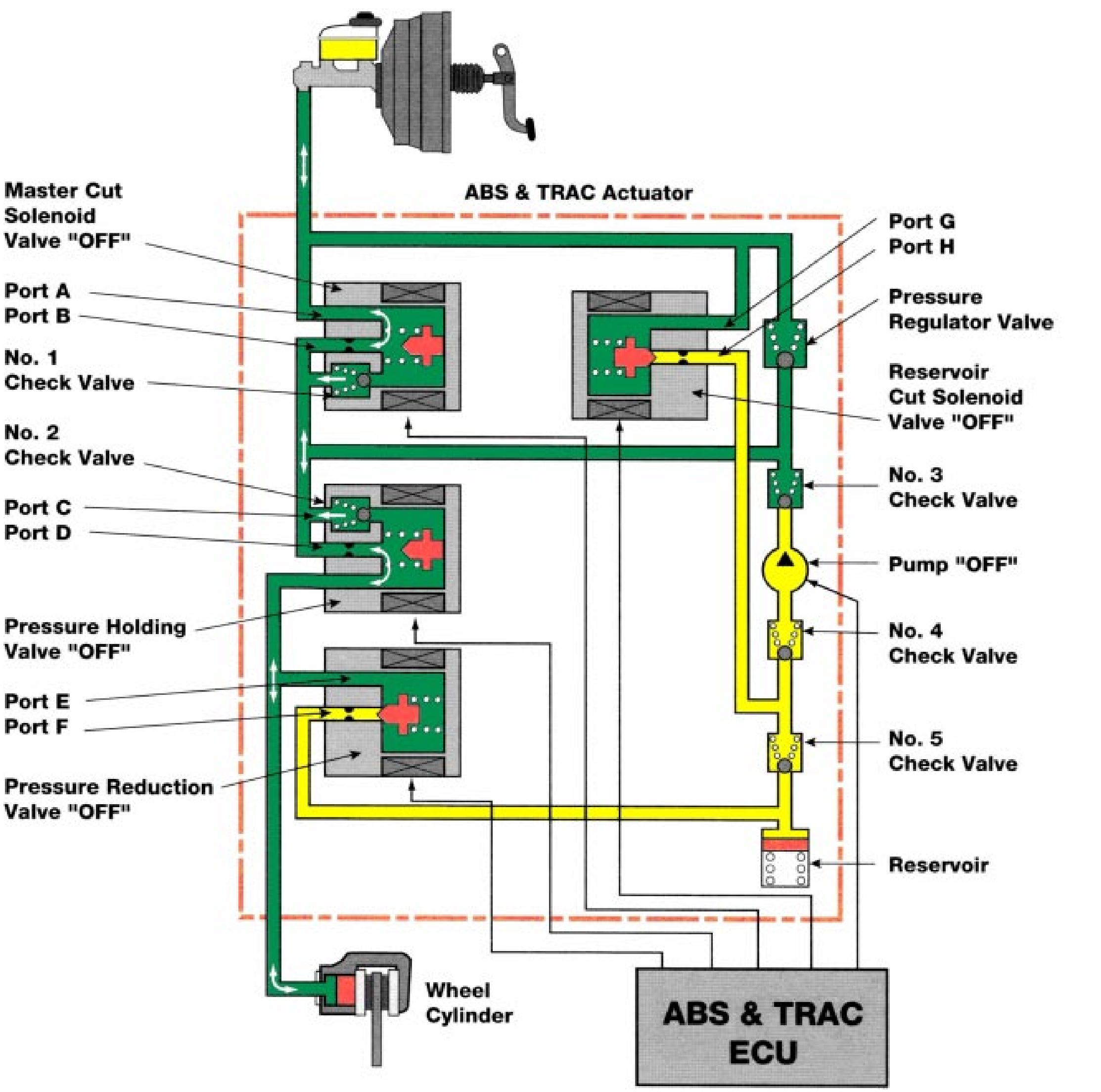


Normal Operation Mode

During normal operation when the TRAC system is not activated all actuator valves are OFF. The Master Cut Solenoid Valve is open allowing fluid from the master cylinder to flow through the Pressure Holding Valve to the wheel cylinder. In this mode the brakes function just like a system without ABS or TRAC.

Normal Operation Mode

Part Name	Signal from ABS & TRAC ECU	Operation	
Master Cut Solenoid Valve	OFF	Port Ⓑ	Open
Reservoir Cut Solenoid Valve	OFF	Port Ⓗ	Closed
Pressure Holding Valve	OFF	Port Ⓒ	Open
Pressure Reduction Valve	OFF	Port Ⓕ	Closed
Pump	OFF	Stop	



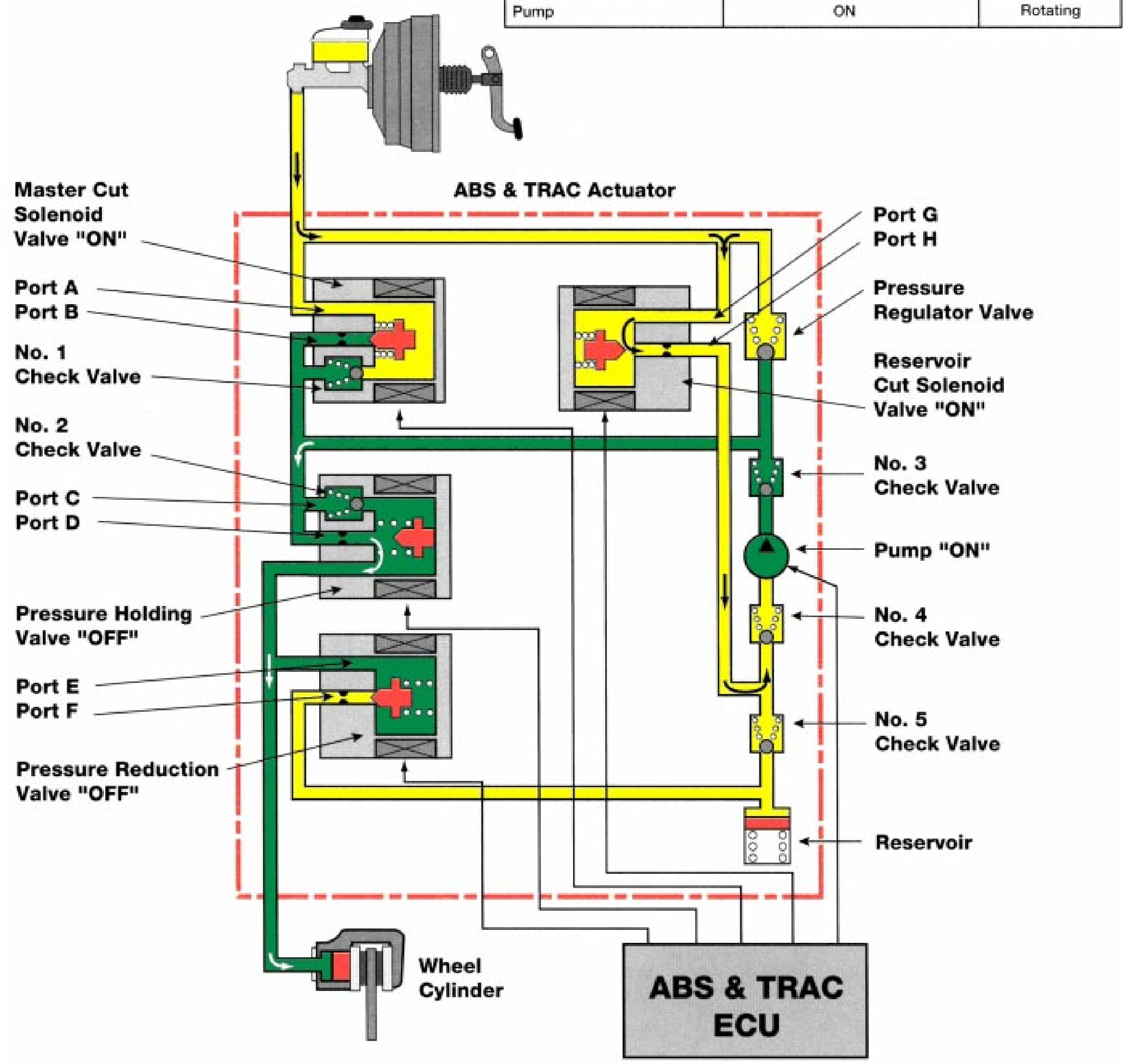
Pressure Increase Mode

During sudden acceleration or driving on a slippery surface, if the drive wheels start to slip the ABS & TRAC ECU causes the actuator to go into pressure increase mode.

- The Master Cut Solenoid is ON blocking the brake circuit to the master cylinder.
- The Reservoir Cut Solenoid Valve is ON opening the master cylinder to the pump.
- The pump is turned ON generating pressure and sending it through the Pressure Holding Valve and on to the wheel cylinder.

Pressure Increase Mode

Part Name	Signal from ABS & TRAC ECU	Operation	
Master Cut Solenoid Valve	ON	Port Ⓑ	Closed
Resorvoir Cut Solenoid Valve	ON	Port Ⓗ	Open
Pressure Holding Valve	OFF	Port Ⓒ	Open
Pressure Reduction Valve	OFF	Port Ⓕ	Closed
Pump	ON	Rotating	



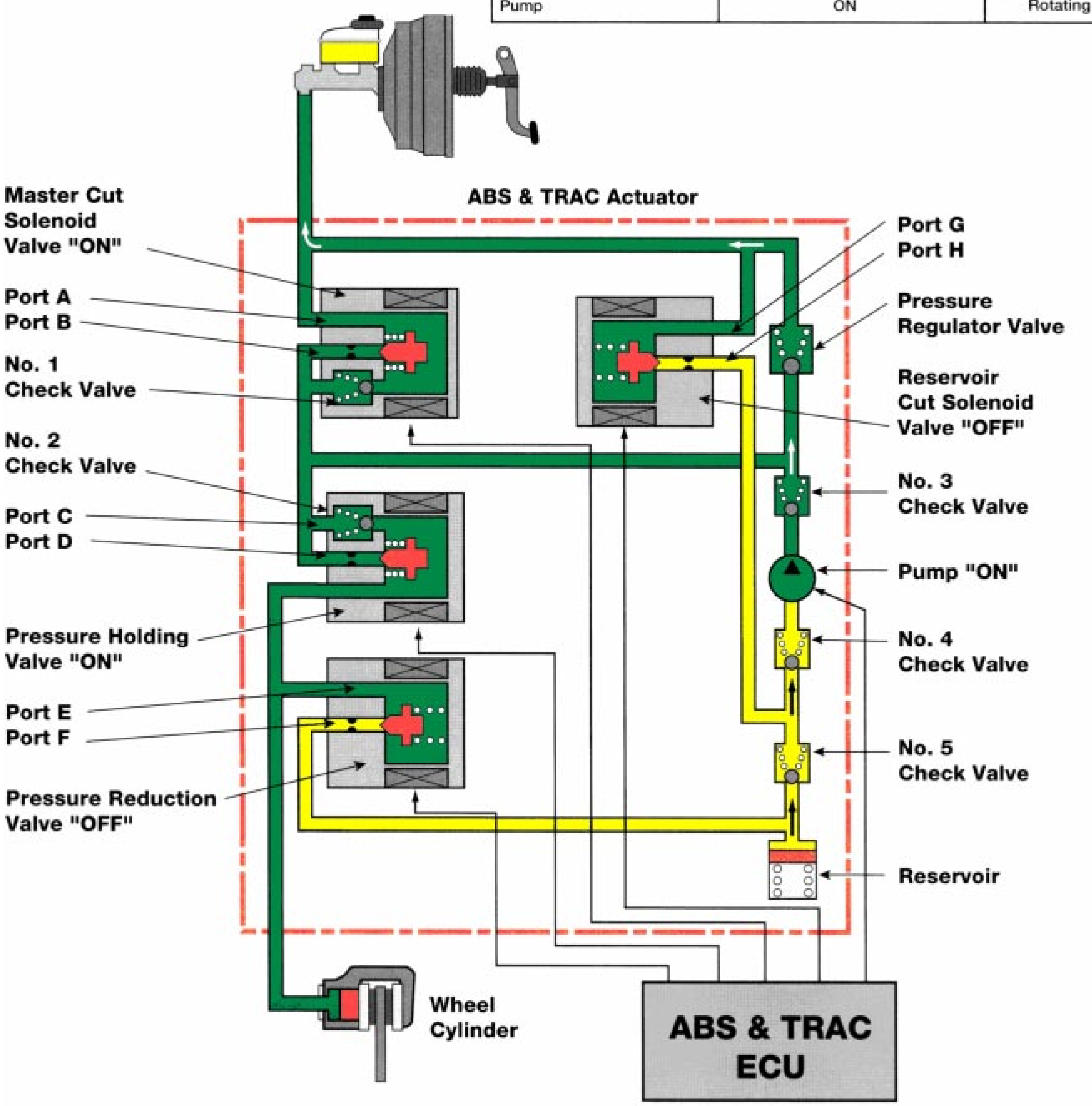
Pressure Holding Mode

When fluid pressure in the wheel cylinder circuit is optimized by an increase or decrease in pressure, the ABS & TRAC ECU controls the system as follows:

- The Pressure Holding Valve is turned ON blocking pressure from the pump.
- The Reservoir Cut Solenoid Valve is turned OFF, blocking additional fluid from the master cylinder
- The pump continues to rotate.

Pressure Holding Mode

Part Name	Signal from ABS & TRAC ECU	Operation	
Master Cut Solenoid Valve	ON	Port Ⓑ	Closed
Reservoir Cut Solenoid Valve	OFF	Port Ⓗ	Closed
Pressure Holding Valve	ON	Port Ⓒ	Closed
Pressure Reduction Valve	OFF	Port Ⓕ	Closed
Pump	ON	Rotating	



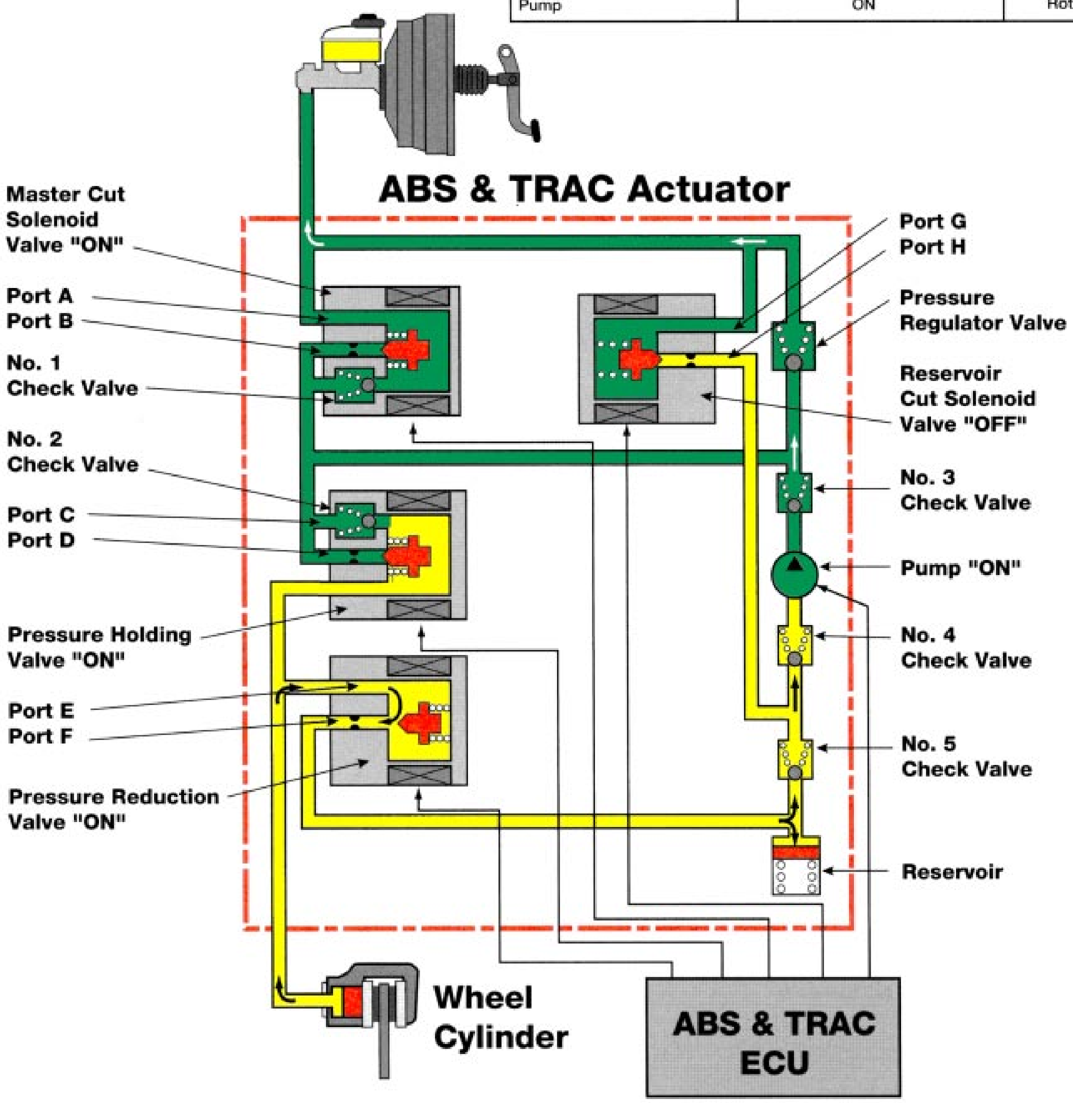
Pressure Reduction Mode

When fluid pressure in the wheel cylinder needs to be reduced:

- Reservoir Cut Solenoid Valve is OFF and spring loaded in the closed position blocking fluid from the Master Cylinder to the Pump.
- Master Cut Solenoid is ON, blocking the master cylinder from the wheel cylinder.
- Pressure Reduction Valve is turned ON, allowing fluid pressure to flow to the reservoir and pump, and allowing the wheel to turn.

Pressure Reduction Mode

Part Name	Signal from ABS & TRAC ECU	Operation	
Master Cut Solenoid Valve	ON	Port Ⓑ	Closed
Resorvoir Cut Solenoid Valve	OFF	Port Ⓗ	Closed
Pressure Holding Valve	ON	Port Ⓒ	Closed
Pressure Reduction Valve	ON	Port Ⓕ	Open
Pump	ON	Rotating	



Supra TRAC

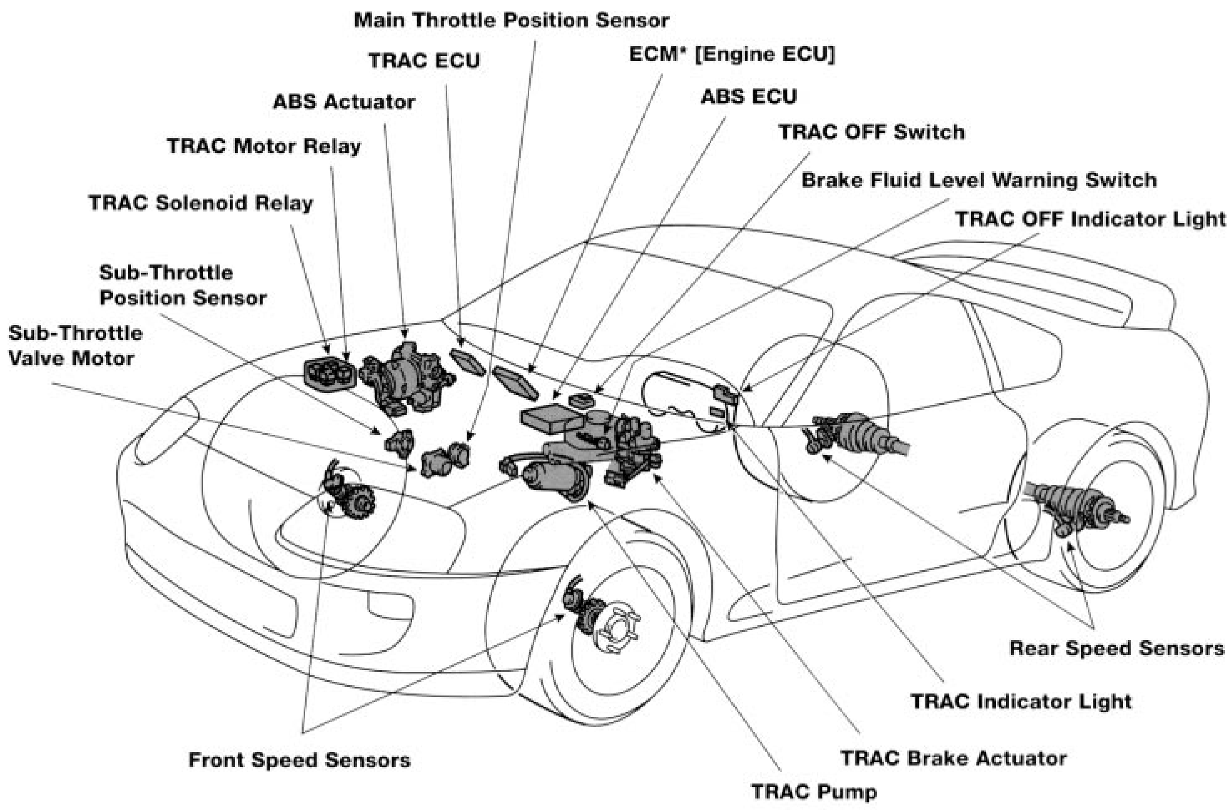
The operation of the TRAC system on the Supra is similar to the Camry and Avalon however there are distinct differences between the two systems:

- Most notable is the separate TRAC actuator and ABS actuator in 1993.5 through 1995.
- Engine torque is controlled via a sub-throttle actuator which controls the sub-throttle ahead of the valve in the throttle body.
- Beginning with 1996 production, brake actuation is no longer utilized for Supra traction control.

Once activated, the TRAC System reduces engine torque and rear wheel speed as necessary to bring the vehicle under control. The ABS ECU, TRAC ECU and ECM all work together to provide traction control. ABS speed sensors are monitored by the TRAC ECU which in turn controls a sub-throttle plate and applies the rear brakes. The ECM also retards engine timing while the ABS modulates pressure at the rear brakes.

Supra TRAC Component Locations

The TRAC System shares some ABS components to control braking functions.



*ECM (Engine Control Module)

Operation Of Components

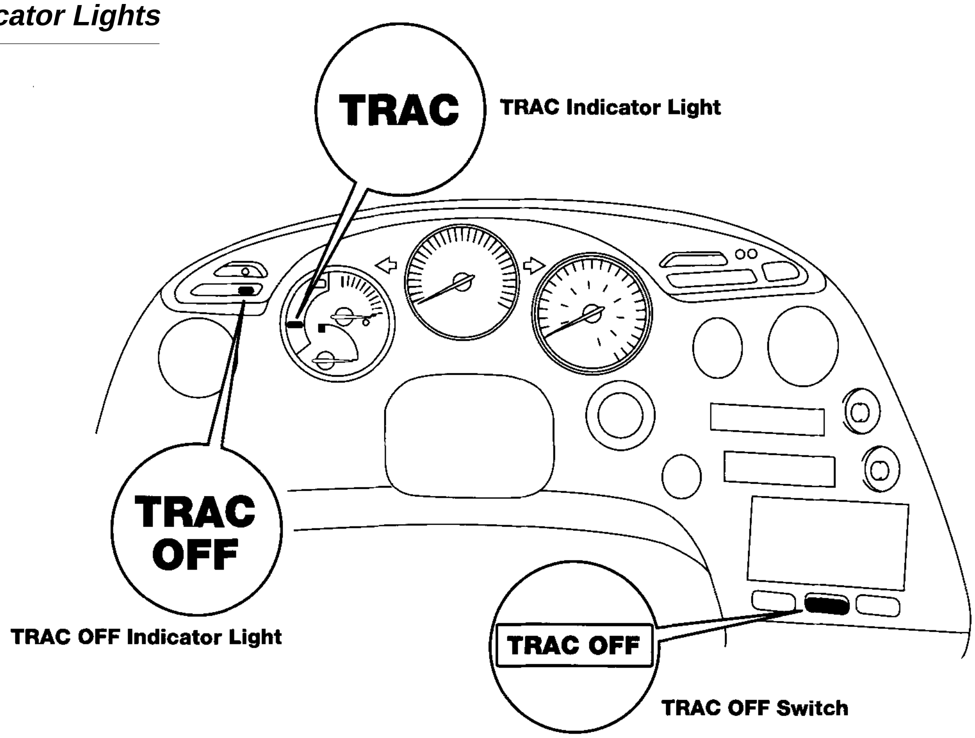
The TRAC OFF switch is located on the instrument panel above the center console. It allows the driver to activate or deactivate the TRAC system when the switch is depressed. The system defaults to ON when the ignition switch is cycled.

The TRAC OFF indicator light goes on when any one of the following occur:

- the TRAC system is deactivated by the TRAC OFF switch.
- a TRAC related problem is detected with the engine.
- an ABS related problem is detected. The TRAC indicator light indicates when:
- the system is operating.
- a malfunction occurs in the system (it remains illuminated to warn the driver).
- the TRAC ECU is set to the diagnostic mode (the light blinks the trouble code).

A change in January of 1996 included a SNOW feature which modifies the engine torque control when selected. This feature ensures reduced engine torque in anticipation of a lower coefficient of friction between the tire and the road surface. The driver selects this feature by pressing the SNOW button. Like the TRAC OFF switch, cycling the ignition switch defaults the system to normal operation.

TRAC OFF Switch and Indicator Lights

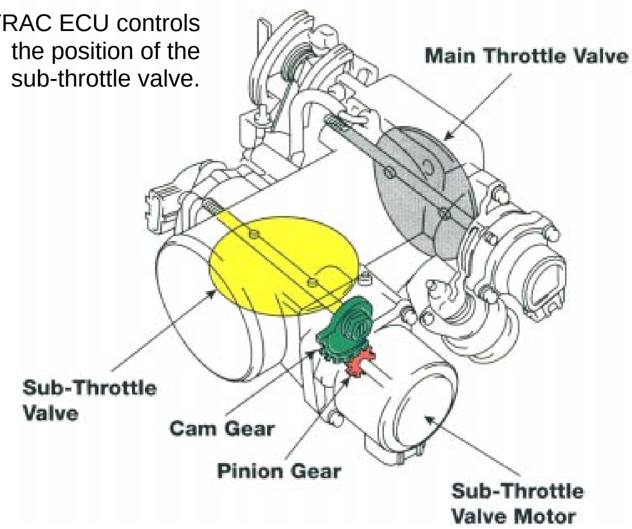


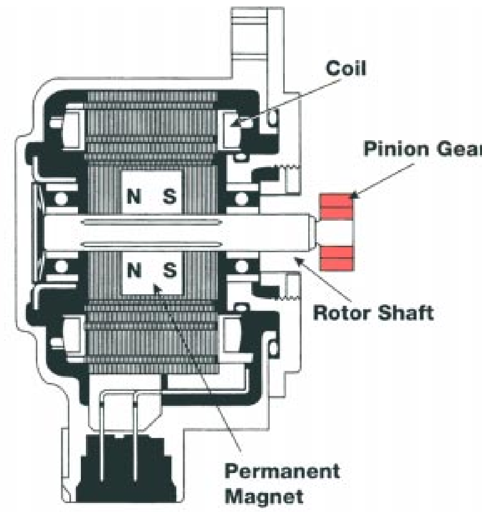
Sub-Throttle Valve Motor

The Sub-Throttle Actuator uses a step motor located between the main throttle valve and air cleaner. It is fitted on the throttle body and controls the position of the sub-throttle valve based on commands made by the TRAC ECU thus controlling the engine output. By controlling the sub-throttle plate, engine management controls engine torque reducing wheel spin.

Sub-Throttle Valve Motor

The TRAC ECU controls the position of the sub-throttle valve.



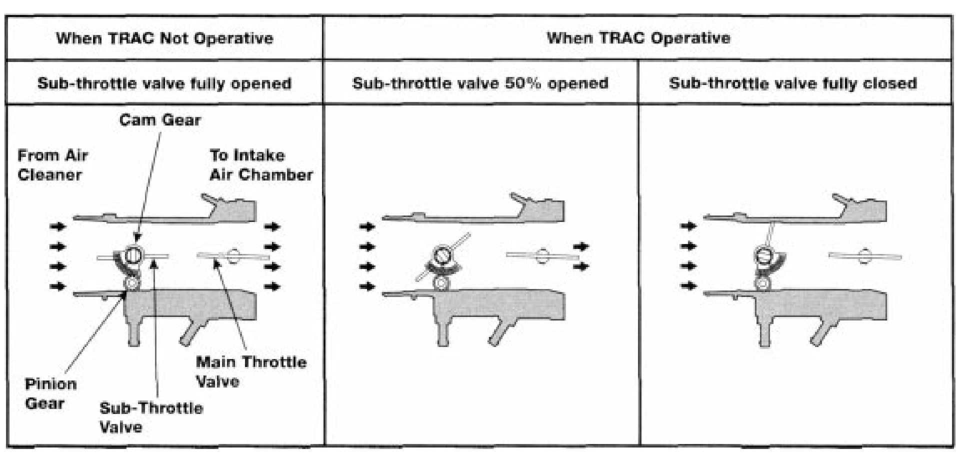


Sub-Throttle Valve Motor

The sub-throttle valve motor consists of a permanent magnet, a coil, a rotor shaft and pinion gear. It is a step motor that is rotated by a signal from the ABS & TRAC ECU. The pinion gear rotates a cam gear, fitted on the sub-throttle valve shaft end, controlling the sub-throttle valve opening angle.

Sub-Throttle Actuator Operation

The position of the sub-throttle valve controls the incoming volume of air to control engine torque.

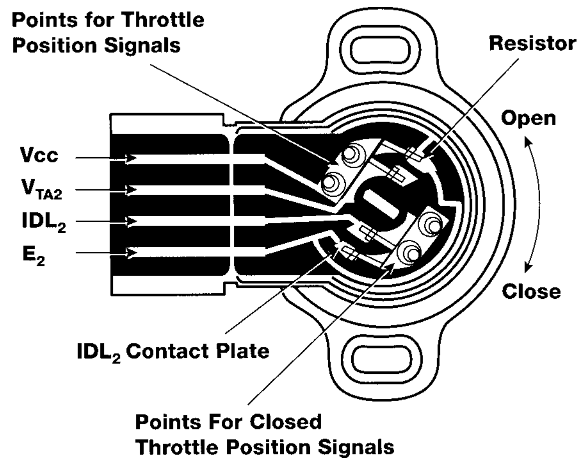


Sub-Throttle Position Sensor

This sensor is fitted to the sub-throttle valve shaft. It converts the sub-throttle valve opening angle to a voltage signal and sends this signal to the TRAC ECU via the ECM (Engine ECU). The sensor is built and operates in the same way as the main Throttle Position Sensor.

Sub-Throttle Position Sensor

Converts the sub-throttle valve opening angle to a voltage signal and sends this signal to the ECM and TRAC ECU.

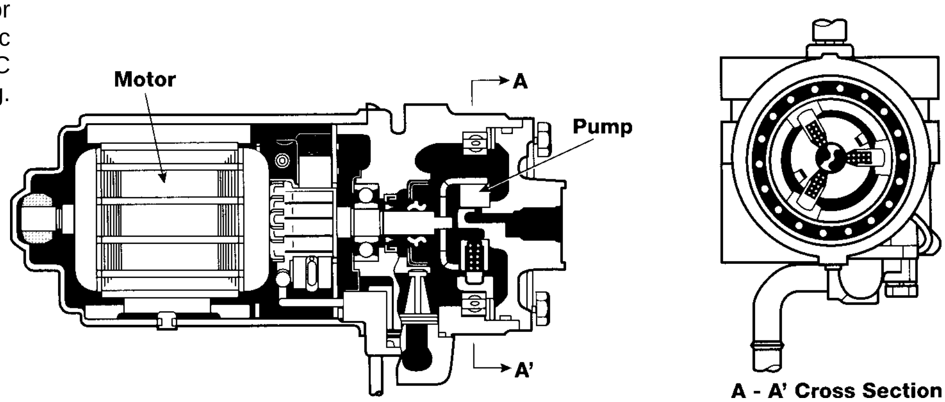


TRAC Pump

The function of the TRAC Pump is to generate brake fluid pressure necessary for applying the rear disc brakes when the TRAC system is operating. It draws brake fluid from the master cylinder reservoir, pressurizes and directs it to the TRAC brake actuator. It is a motor-driven, three chamber radial pump.

TRAC Pump

Generates brake fluid pressure necessary for applying the rear disc brakes when the TRAC system is operating.



TRAC Brake Actuator

The **TRAC Brake Actuator** consists of two cut solenoid valves and three spring loaded valves which regulate the brake fluid pressure in the right and left rear wheels. The rear wheels are controlled independently through the ABS actuator based on signals from the ABS ECU.

The **Master Cylinder Cut Solenoid Valve** opens and closes the hydraulic circuit from the master cylinder or TRAC pump to the ABS actuator. When the TRAC system is operating, it supplies the brake fluid pressure from the TRAC pump to the disc brake cylinders via the ABS actuator. It also prevents the fluid from flowing out of the ABS actuator pump to the master cylinder.

The **Reservoir Cut Solenoid Valve** is located between the return side of the ABS 3-position solenoid and the master cylinder. It returns the fluid from the disc brake cylinders back to the master cylinder reservoir.

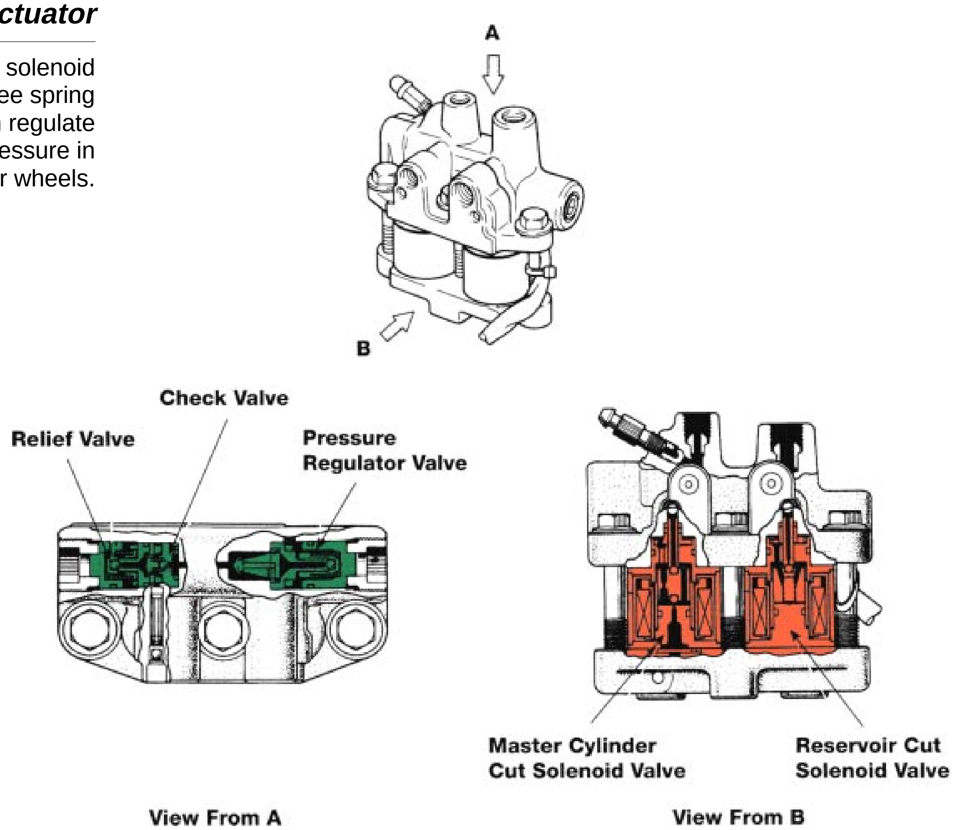
The **Pressure Regulator Valve** controls the brake fluid pressure generated by the TRAC pump.

The **Relief Valve** relieves the systems highest pressure should a malfunction occur.

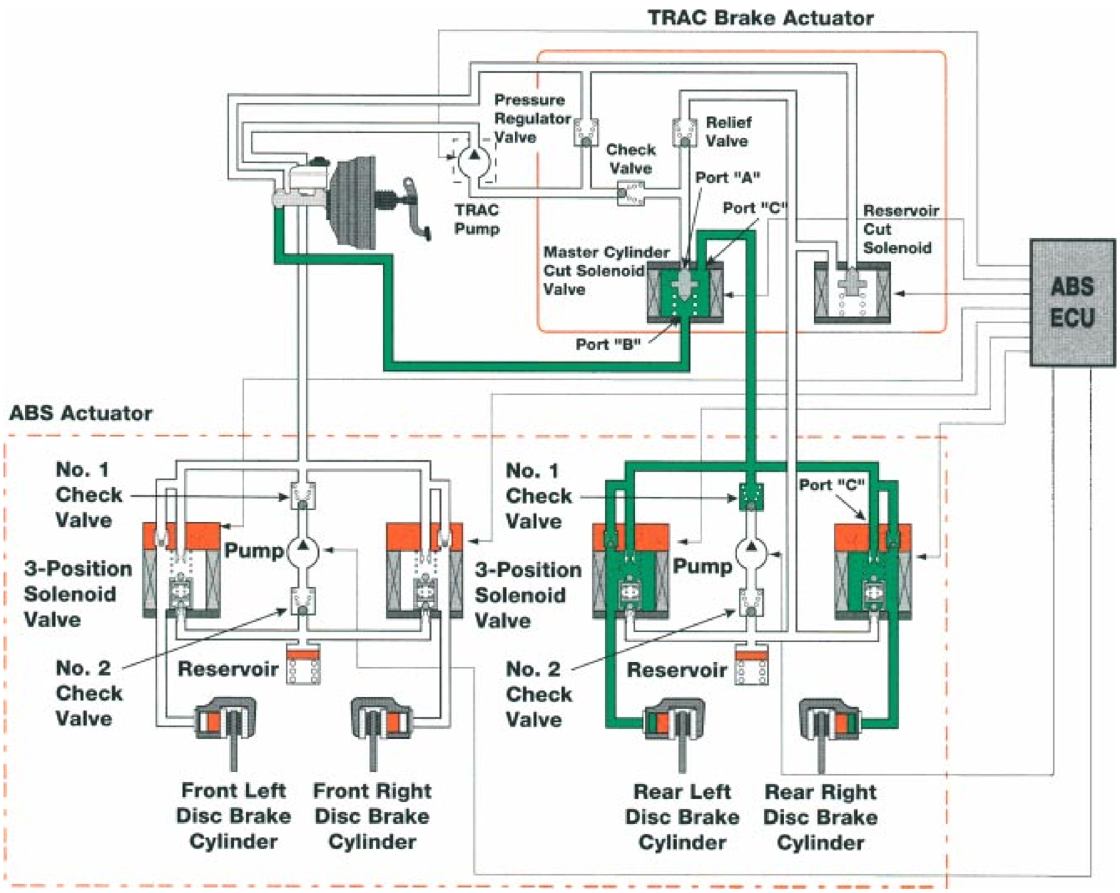
The **Check Valve** prevents fluid from flowing out of the disc brake cylinder to the TRAC pump.

TRAC Brake Actuator

Consists of two cut solenoid valves and three spring loaded valves which regulate the brake fluid pressure in the right and left rear wheels.



TRAC System Hydraulic Circuit



TRAC Operation

Dialing normal operation (TRAC not activated) all solenoid valves of the TRAC brake actuator remain inactive when the brakes are applied. As the brake pedal is depressed, brake fluid pressure generated by the master cylinder is applied to the disc brake cylinders, via the master cylinder cut solenoid valve, and the 3-position solenoid valves in the ABS actuator. When the brake pedal is released, fluid pressure returns from the disc brake cylinders to the master cylinder.

During vehicle acceleration (TRAC operative) when a rear wheel slips the TRAC system controls the engine output and braking of the rear wheels to help prevent wheel slippage.

The brake fluid pressure applied to the right and left rear wheels is controlled separately according to 3 control modes:

- Pressure Increase.
- Pressure Holding.
- Pressure Reduction.

Pressure Increase Mode

When a rear wheel starts to slip, just as the accelerator pedal is being depressed:

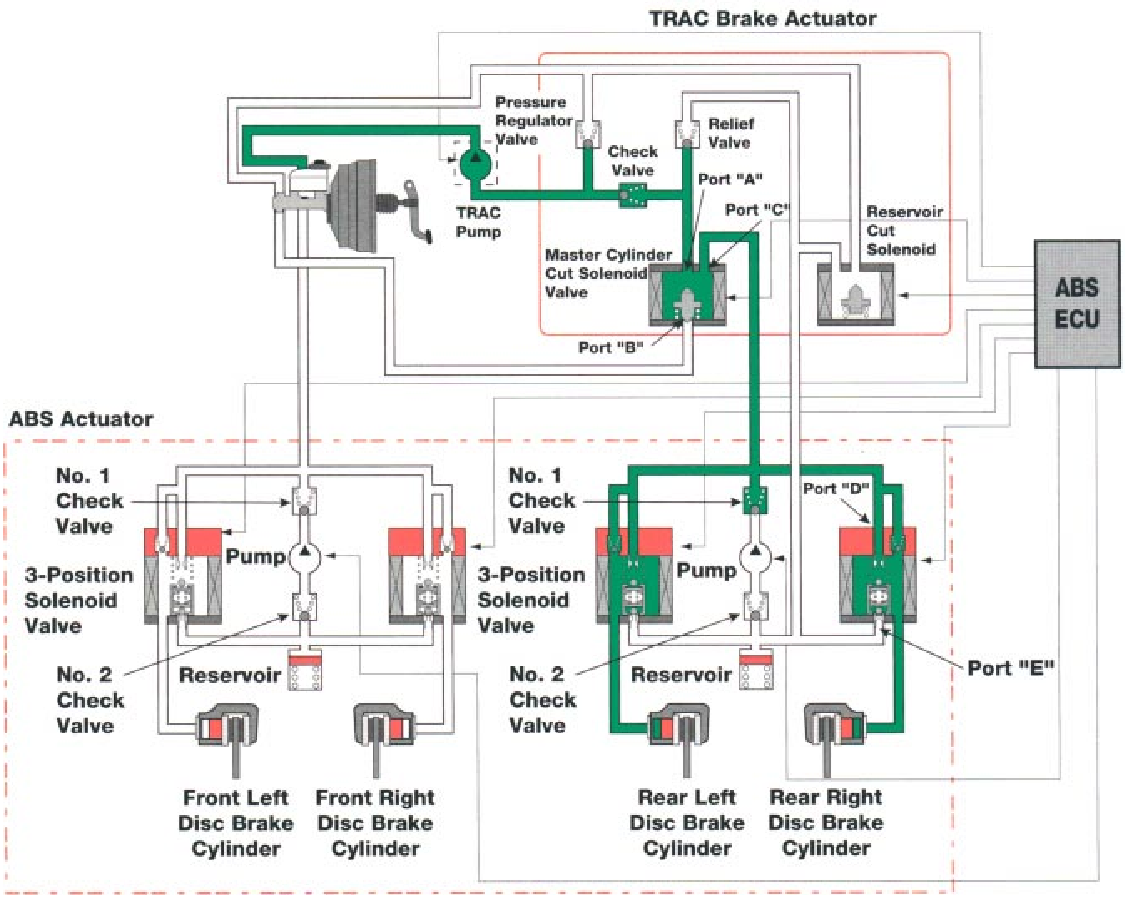
- All the solenoid valves in the TRAC Brake Actuator are activated by signals received from the ABS ECU.
- The 3-Position Solenoid Valves in the ABS actuator are engaged in the pressure increase mode.
- The Master Cylinder Cut Solenoid Valve is activated (ports “A” and “C” open), and brake fluid pressure generated by the TRAC pump is applied to the disc brake cylinders via the Master Cylinder Cut Solenoid Valve and the 3-Position Solenoid Valves in the ABS actuator.
- The Reservoir Cut Solenoid Valve is also activated (open) allowing fluid to flow back to the master cylinder reservoir.
- The TRAC pump discharge pressure is maintained constant by the Pressure Regulator Valve.

Pressure Increase Mode

Brake fluid pressure generated by the TRAC pump is applied to the disc brake cylinders via the master cylinder cut solenoid valve and the 3-position solenoid valves in the ABS actuator.

▶ Condition of Each Component ◀

Components			Operation
TRAC Pump			ON
TRAC Brake Actuator	Master Cylinder Cut Solenoid Valve	Port "A"	Open
		Port "B"	Close
	Reservoir Cut Solenoid Valve		Open
ABS Actuator	3-Position Solenoid Valve	Port "D"	Open
		Port "E"	Close



Pressure Holding Mode

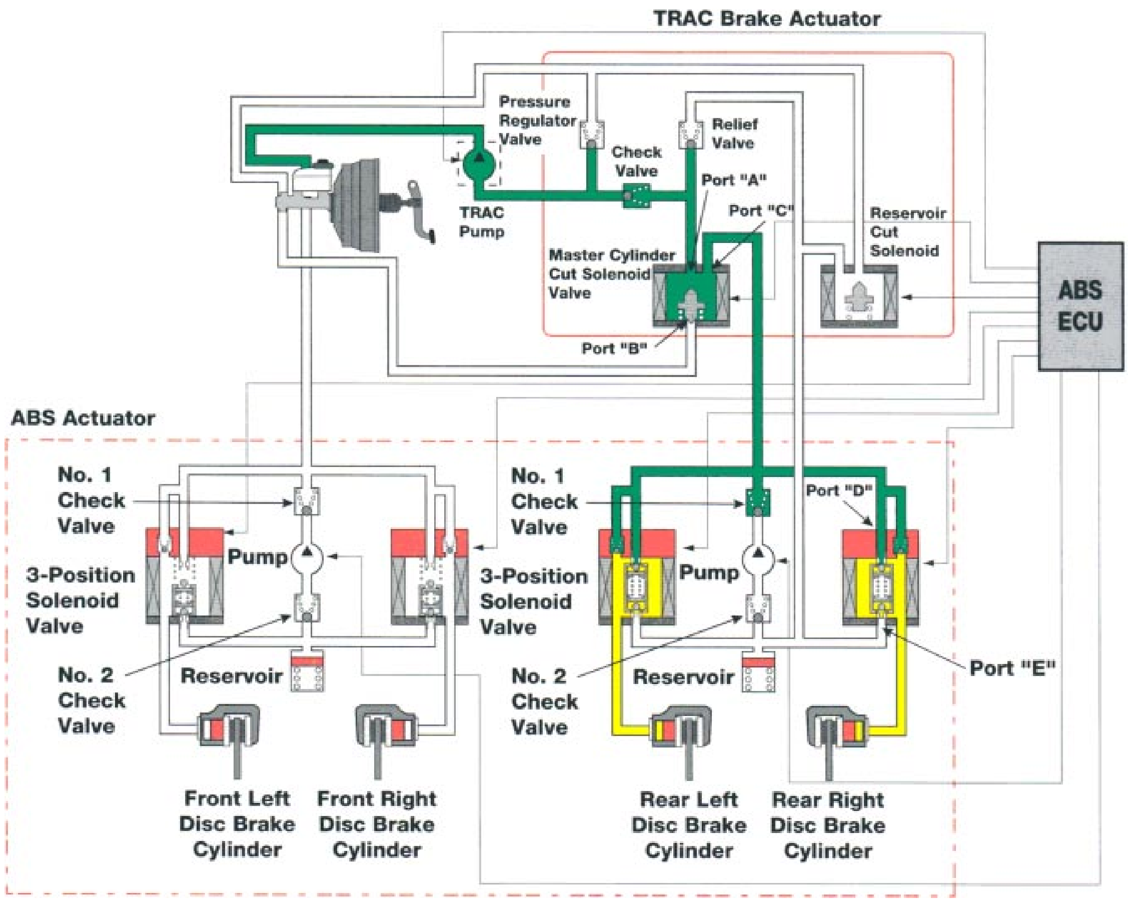
When the brake fluid pressure for the rear brake cylinders is increased or decreased as required, the system switches to the holding mode. This mode change is performed by engaging the 3-position solenoid valve in the ABS actuator to the holding mode. This results in blocking the TRAC pump pressure from flowing to the disc brake cylinder through port D.

Pressure Holding Mode

This mode change is performed by engaging the 3-position solenoid valve in the ABS actuator to the holding mode closing port D.

▶ Condition of Each Component ◀

Components			Operation
TRAC Pump			ON
TRAC Brake Actuator	Master Cylinder Cut Solenoid Valve	Port "A"	Open
		Port "B"	Close
	Reservoir Cut Solenoid Valve		Open
ABS Actuator	3-Position Solenoid Valve	Port "D"	Close
		Port "E"	Close



Pressure Reduction Mode

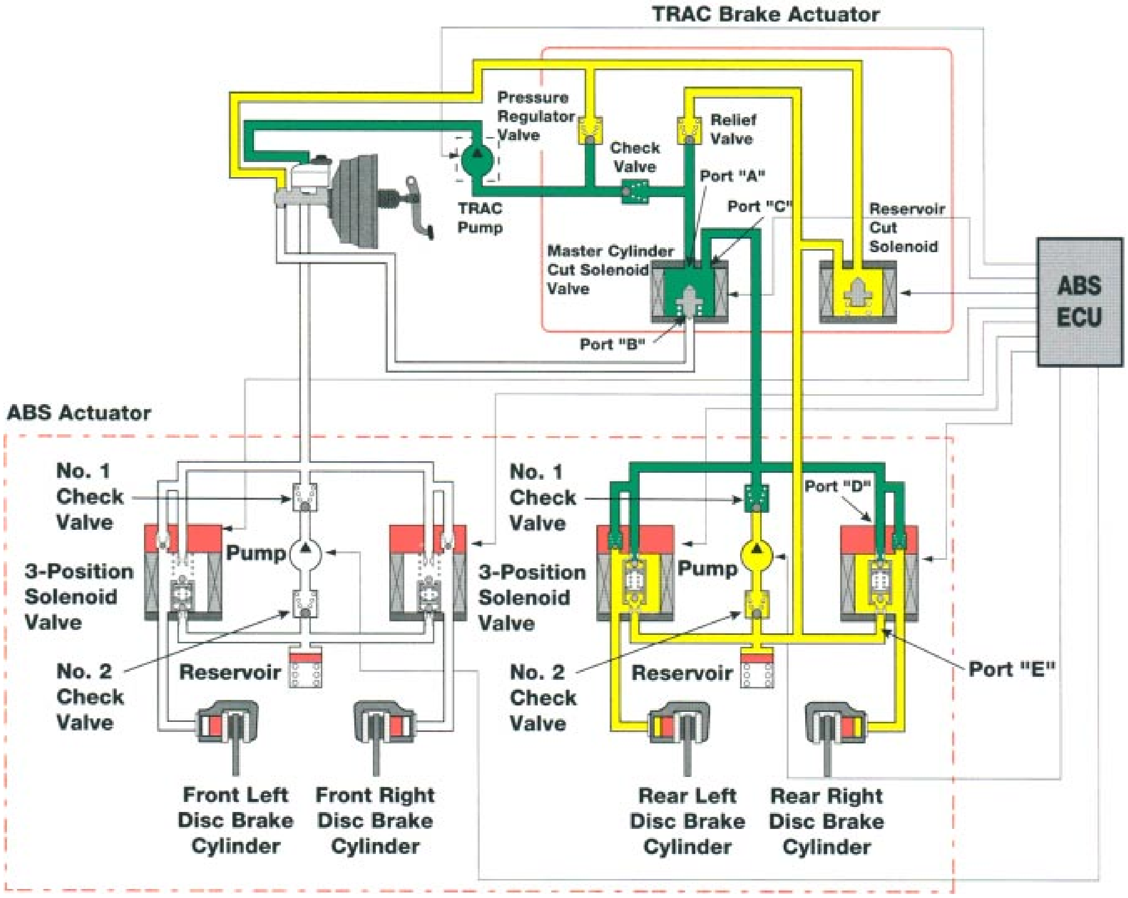
When decreasing pressure applied to the rear brake cylinders, the ABS ECU engages the 3-position solenoid valve in the ABS actuator to the pressure reduction mode. Fluid pressure applied to the brake cylinder returns to the master cylinder reservoir from the 3-position solenoid valve and reservoir in the ABS actuator to the Reservoir Cut Solenoid Valve, thus alleviating the brake fluid pressure.

Pressure Reduction Mode

The ABS ECU engages the 3-position solenoid valve in the ABS actuator in the pressure reduction mode.

▶ Condition of Each Component ◀

Components			Operation
TRAC Pump			ON
TRAC Brake Actuator	Master Cylinder Cut Solenoid Valve	Port “A”	Open
		Port “B”	Close
	Reservoir Cut Solenoid Valve		Open
ABS Actuator	3-Position Solenoid Valve	Port “D”	Close
		Port “E”	Open



Wheel Speed Control

The TRAC ECU constantly receives signals from the 4 speed sensors and calculates the speed of each wheel. At the same time, it estimates the vehicle speed based on the speed of the 2 front wheels and sets a target control speed.

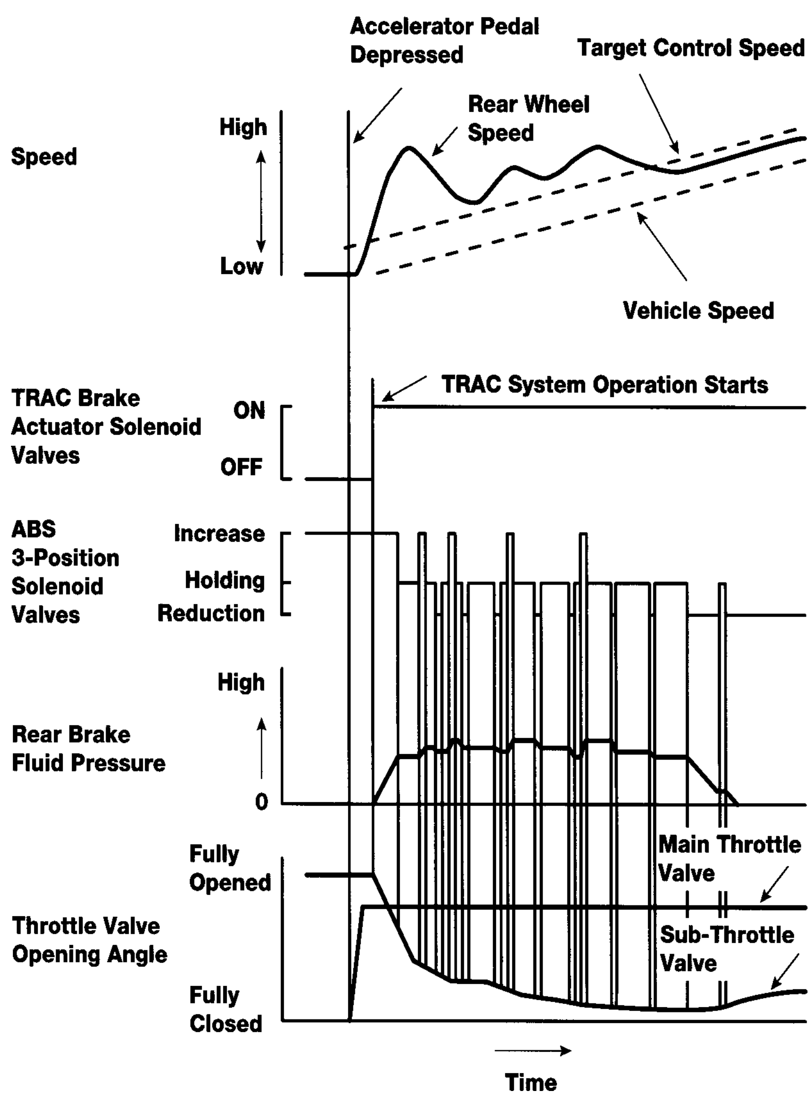
When the accelerator pedal is depressed on a slippery road, the rear wheels (driving wheels) begin to slip and the rear wheel speed exceeds the target control speed. The TRAC ECU then sends a close signal to the sub-throttle valve motor.

At the same time, ABS ECU sends a signal to the TRAC brake actuator and causes it to supply brake fluid pressure to rear disc brake cylinders, changing the rear disc brakes in the TRAC mode.

The 3-position solenoid valves of the ABS actuator are modulated to control rear brake fluid pressure to prevent wheel slippage.

TRAC Wheel Speed Control

When the rear wheels begin to slip, the TRAC ECU sends a sub-throttle valve close signal. The ABS ECU sends a signal to the TRAC brake actuator to supply brake fluid pressure to the rear disc brake.



Initial Check Function

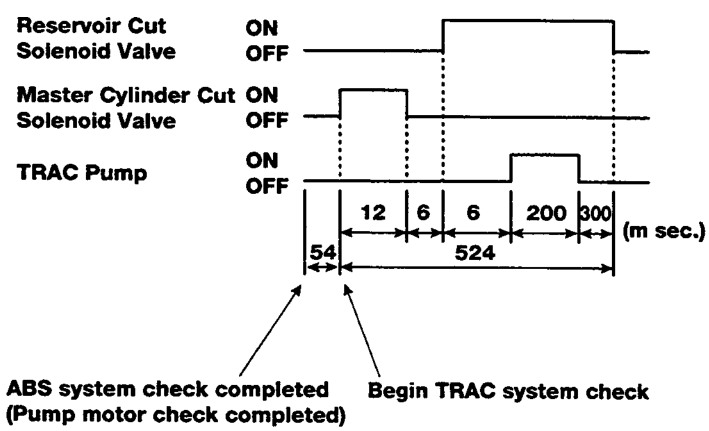
After completing the Initial Check of the ABS system, the ABS ECU cycles the solenoid valves of the TRAC actuator and operates the TRAC pump.

When the shift lever is in park or neutral range with the main throttle valve fully closed and the ignition key is turned from ACC to the ON position, the TRAC ECU drives the sub-throttle valve motor to fully close the sub-throttle valve.

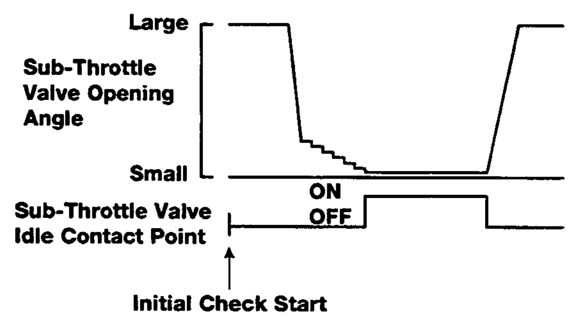
This Initial Check occurs once per key cycle.

TRAC Actuator and Pump Check

The ABS ECU checks the TRAC actuator and the TRAC pump. The TRAC ECU drives the sub-throttle valve motor to fully close the sub-throttle valve.



TRAC Actuator and TRAC Pump



Sub-Throttle Valve Motor

Self-Diagnosis

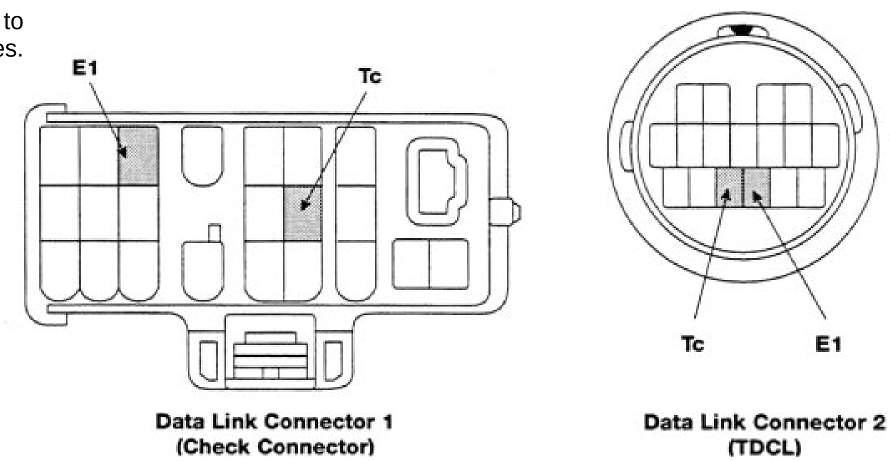
If a malfunction occurs in any of the signal systems, the TRAC indicator light in the Combination Meter will light and alert the driver that a malfunction has occurred. The TRAC ECU will also store codes for each of the malfunctions.

Diagnostic trouble codes are accessed when the following conditions are met:

- Ignition switch is turned on.
- Tc and E1 terminals in the Data Link Connector 1 or 2 [Check Connector or TDCL] are jumpered.

Data Link Connectors

Jumper connectors E1 and TC to access diagnostic codes.

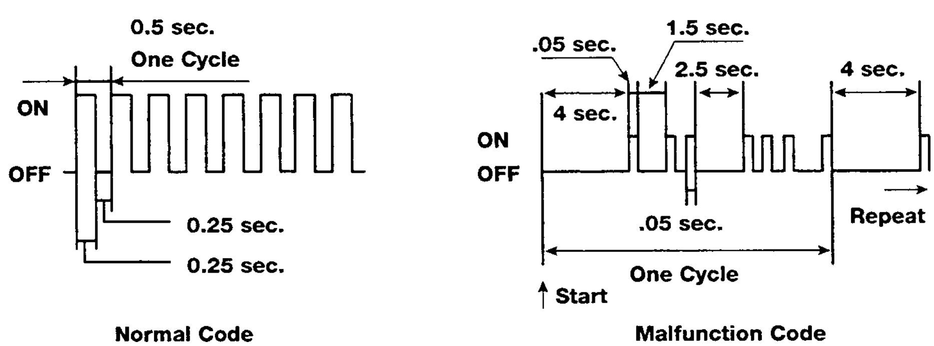


Diagnostic Trouble Codes

Diagnostic trouble code(s) are indicated in the same fashion as ABS codes. The light blinking pattern code for 12 and 31 are shown in the example below. If two or more malfunctions are indicated at the same time, the lowest numbered diagnostic trouble code will be displayed first. There is a 2.5 second pause between codes and a longer 4 second pause before the codes are repeated.

Diagnostic Trouble Codes

Diagnostic trouble code(s) are indicated in the same fashion as ABS codes.



ABS and TRAC Related Diagnostic Codes

The diagnostic chart on the following page shows the ABS diagnostic codes on the left and a general description of components and related circuits on the right. Following the diagnostic code, the indicator lights identify whether the ABS or TRAC systems monitor the specific component. Additionally, the TRAC OFF light will illuminate if the fault causes the TRAC system to be turned OFF.

For example, code 11 (open circuit in the solenoid relay circuit) will cause the ABS indicator light to turn ON. The ABS solenoid is not monitored by the TRAC ECU so it will not illuminate however, it will cause the TRAC system to be switched OFF and therefore the TRAC OFF light will illuminate.

If any of the diagnostic codes 31 through 34 and 41 are detected by both ABS and TRAC systems, the TRAC light will flash.

ABS/TRAC Related Diagnostic Code Chart

This chart identifies diagnostic codes common to ABS and TRAC Systems.

Code No.	Indicator Lights			Code No. at TRAC ECU*2	Diagnosis
	ABS	TRAC	TRAC OFF		
11*1	○		○	43	Open circuit in solenoid relay circuit.
12*1	○	-	○		Short circuit in solenoid relay circuit.
13*1	○	-	○		Open circuit in pump motor relay circuit.
14*1	○	-	○		Short circuit in pump motor relay circuit.
15	○	○	○		Open circuit in TRAC solenoid relay circuit.
16	○	○	-		Short circuit in TRAC solenoid relay circuit.
17	-	○	○		Open circuit in TRAC motor relay circuit.
18	-	○	○		Short circuit in TRAC motor relay circuit.
21*1	○	-	○		Open or short circuit in 3-position solenoid of front right wheel.
22*1	○	-	○		Open or short circuit in 3-position solenoid of front left wheel.
23*1	○	-	○		Open or short circuit in 3-position solenoid of rear right wheel.
24*1	○	-	○		Open or short circuit in 3-position solenoid of rear left wheel.
25	○	○	○		Open or short circuit in master cylinder cut solenoid valve circuit of TRAC brake actuator.
27	○	○	○		Open or short circuit in reservoir cut solenoid valve circuit of TRAC brake actuator.
31*1	○	○*3	○	31, 43	Front right wheel speed sensor signal malfunction.
32*1	○	○*3	○	32, 43	Front left wheel speed sensor signal malfunction.
33*1	○	○*3	○	33, 43	Rear right wheel speed sensor signal malfunction.
34*1	○	○*3	○	34, 43	Rear left wheel speed sensor signal malfunction.
35*1	○	-	○	43	Open circuit in front left and rear right speed sensors.
36*1	○	-	○		Open circuit in front right and rear left speed sensors.
41*1	○	○*3	○	41, 43	Low battery voltage (9.5 V or lower) or abnormally high battery voltage (17 V or higher).
44*1	○	-	○	-	Lateral acceleration sensor signal malfunction.
51*1	○	-	○	43	Pump motor locked or open circuit.
55	-	○	○		Fluid level of brake master cylinder reservoir dropped causing master cylinder reservoir level warning switch to go on.
58	-	○	○		Open circuit in TRAC motor.
61	-	○	○		Open or short circuit in circuit which inputs TRAC system operation to ABS ECU.
62*4	-	○	○		Malfunction in ABS ECU (Involving vehicle speed signal input inside ABS ECU).
Always ON*1	○	○	○		Malfunction in ABS ECU.

○ Diagnostic trouble code indicated
- Not applicable
*1 Both the code number and description of diagnosis are identical to those of the ABS ECU without the TRAC system (2JZ-GE engine model).
*2 To find out which of the indicator lights the TRAC ECU uses to output the codes shown in the chart, refer to the chart for the diagnostic items of TRAC ECU shown on page 194.
*3 The indicator light flashes only if the same diagnosis is also detected by the TRAC ECU.
*4 The ABS ECU deletes the stored code No.62 when it detects the malfunctions numbered from No.31 to No.36 (wheel speed sensor signal malfunction).

TRAC Related Diagnostic Codes

The diagnostic codes in the chart below are specifically TRAC related. The speed sensor codes are similar to ABS codes. If both indicator lights are ON however, begin your diagnosis in the Repair Manual ABS section first. In addition, codes 44 through 48 which identify the main throttle position sensor and the sub-throttle position sensor, begin your diagnosis in the engine control system to determine whether the ECM has the same diagnostic codes stored first before pursuing diagnosis of the TRAC system.

TRAC Related Diagnostic Code Chart

The diagnostic codes in the chart are specifically TRAC related.

Code No.	Indicator Lights			Code No. at TRAC ECU*1	Diagnosis
	ABS	TRAC	TRAC OFF		
24	-	○	-	-	Open or short circuit in step motor circuit of sub-throttle actuator
25	-	○	-	-	Step motor does not move to a position decided by TRAC ECU.
26	-	○	-	-	Leak at sub-throttle position sensor or stuck sub-throttle valve.
31	○*2	○	○*2	31	Front right wheel speed sensor signal malfunction.
32	○*2	○	○*2	32	Front left wheel speed sensor signal malfunction.
33	○*2	○	○*2	33	Rear right wheel speed sensor signal malfunction.
34	○*2	○	○*2	34	Rear left wheel speed sensor signal malfunction.
41	-	○	-	-	Low battery voltage (9.5 V or lower) or abnormally high battery voltage (17 V or higher).
43	○	○	○	-	Malfunction in ABS ECU.
44	-	○	-	-	Engine speed signal (NE) is not input from the ECM* [Engine ECU] during TRAC control.
45	-	○	-	-	Short circuit in 1DL signal circuit of the main throttle position sensor.
46	-	-	-	-	Open or short circuit in VTA1 signal circuit of the main throttle position sensor.
47	-	○	-	-	Open or short circuit in IDL signal circuit of the sub-throttle position sensor.
48	-	○	-	-	Open or short circuit in VTA2 signal circuit of the sub-throttle position sensor.
51	-	-	○	-	Malfunction in engine control system causes malfunction indicator lamp [CHECK ENGINE warning lamp] to go on.
53	-	○	-	-	Malfunction in communication circuit to ECM* [Engine ECU].
61	-	○	-	-	Malfunction in communication circuit to ABS ECU.
Always ON	-	○	○	-	Malfunction in TRAC ECU.

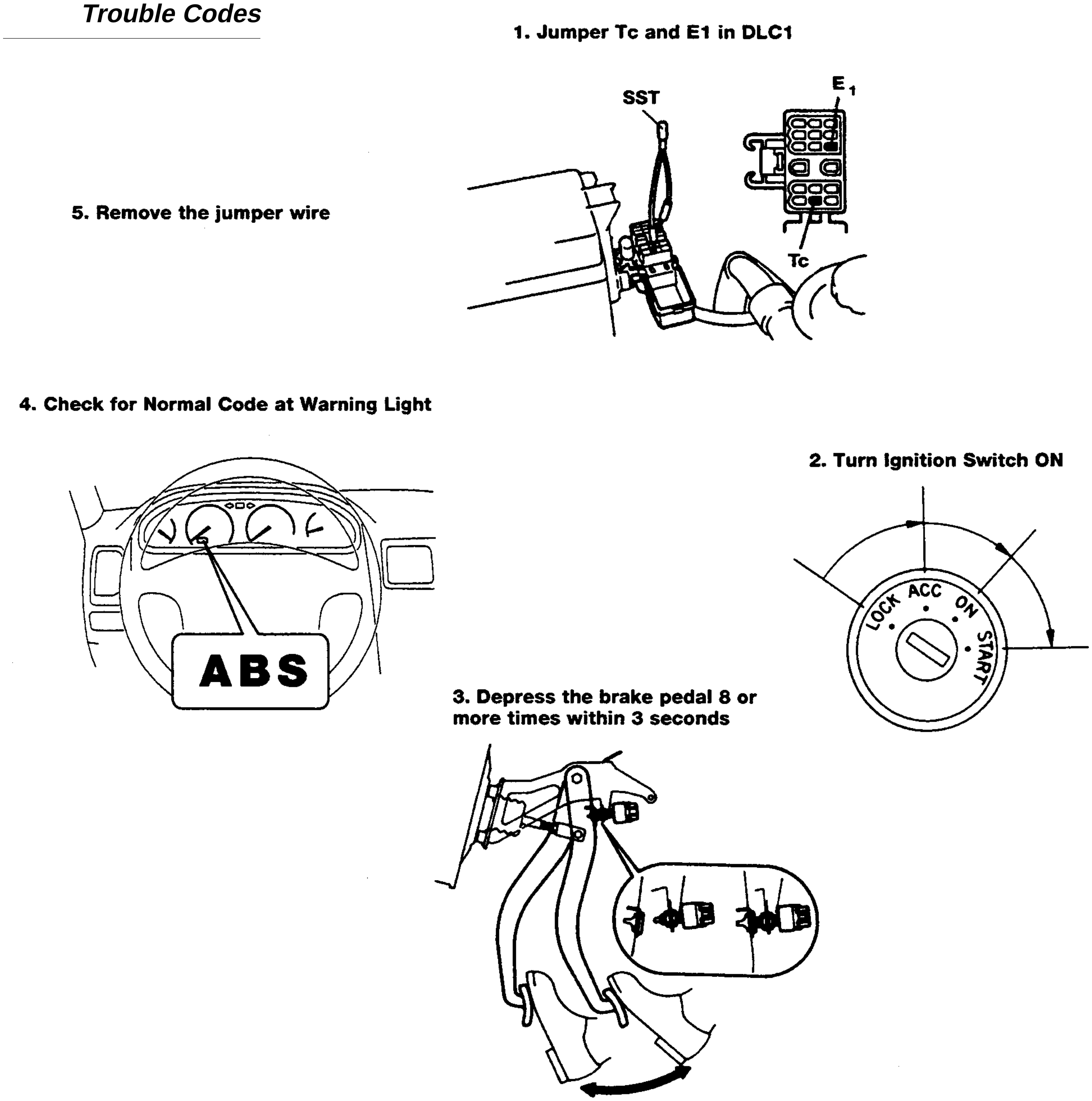
○ Diagnostic trouble code indicated
\- Not applicate
*1 To find out which of the indicator lights the ABS ECU uses to output the codes shown in the chart, refer to the chart for the diagnosis of ABS ECU shown on page 193.
*2 The indicator light flashes only if the same diagnosis is also detected by the ABS ECU.
*3 ECM (Engine Control Module)

Clearing Diagnostic Codes

Diagnostic trouble codes in the TRAC ECU can be cleared after repairs are completed with the following steps:

1. Jumper terminals Tc and E1 in the DLC1 or DLC2 [Check Connector or TDCL].
2. Turn ignition switch ON.
3. Depressing the brake pedal 8 or more times within 3 seconds.
4. Check that the warning light shows the normal code.
5. Remove the jumper wire.

Clearing Diagnostic Trouble Codes



Fail-Safe

When a malfunction occurs while the TRAC system is inoperative, the TRAC ECU immediately turns OFF the TRAC motor relay and TRAC solenoid relay, and stops TRAC system operation.

When the TRAC system is operative, the TRAC ECU continues control, stops the control, or fully opens the sub-throttle valve depending on the type of malfunction.

After the TRAC system becomes inoperative, the engine and brake system operates in the same way as models without the TRAC system.

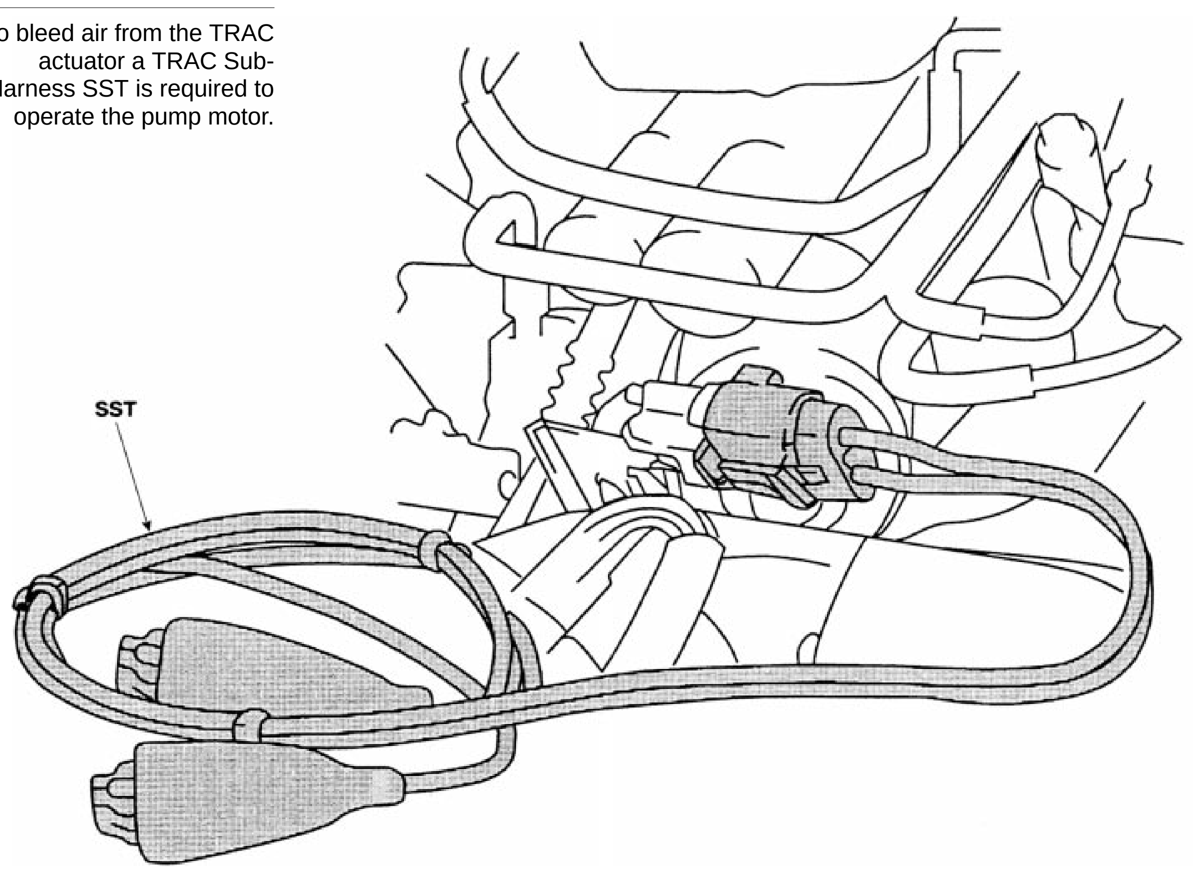
Bleeding Procedure

In order to bleed air from the TRAC actuator a new TRAC Sub-Harness SST (09990-00330) is required to operate the pump motor. The harness is connected to the TRAC pump connector and the other end is connected to the battery to power the pump motor.

1. Disconnect the connector from the TRAC pump.
2. Connect the harness to the pump connector.
3. Connect a vinyl tube to the bleeder plug of the TRAC actuator and loosen the bleeder.
4. Start the engine.
5. Connect the harness leads to the battery terminals.
   - Allow the pump to run for 60 seconds.
   - Close the bleeder plug.
   - Allow the pump to run for 30 additional seconds.
6. Check fluid level.
7. Reconnect the TRAC pump to the vehicle harness.

TRAC Bleeding Harness

To bleed air from the TRAC actuator a TRAC Sub-Harness SST is required to operate the pump motor.



WORKSHEET 12-1 (ON-CAR)
TRAC and ABS Diagnostic System

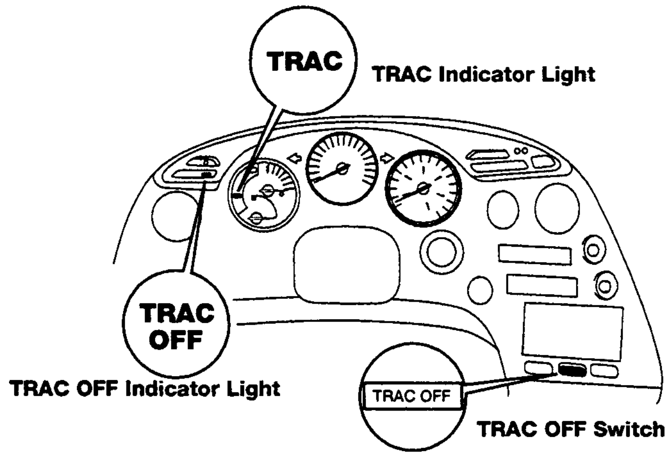
Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this Worksheet you will practice the use of the ABS and TRAC warning lights.

Tools and Equipment:

- Repair Manual.
- Jumper Wire SST.



Procedure:

1. Disconnect the sub-throttle actuator connector (S4) and the TRAC actuator connector (T3).

2. Start the engine and note the condition of the ABS warning and TRAC indicator lights in the following chart.

ABS Warning Light	TRAC Indicator Light	TRAC OFF Light	Master Warning Light

3. Next, output diagnostic codes by turning the ignition switch ON, pulling short pin from DLC1, and connecting terminals Tc to E1 at DLC1 or DLC2.

4. Record the codes in the chart below and indicate which light outputs each code.

5. Refer to the Repair Manual and record the malfunction condition indicated by each code.

ABS Warning Light	TRAC Indicator Light	ABS Code No.	TRAC Code No.	Malfunction Condition

6. Which TRAC conditions (codes) were output by the ABS Diagnostic system?

7. Why do you think a TRAC related problem would output an ABS code?

8. Erase codes by connecting terminals Tc to E1 at DLC1 or DLC2, turn ignition switch ON, and press the brake pedal at least 8 times in 3 seconds.

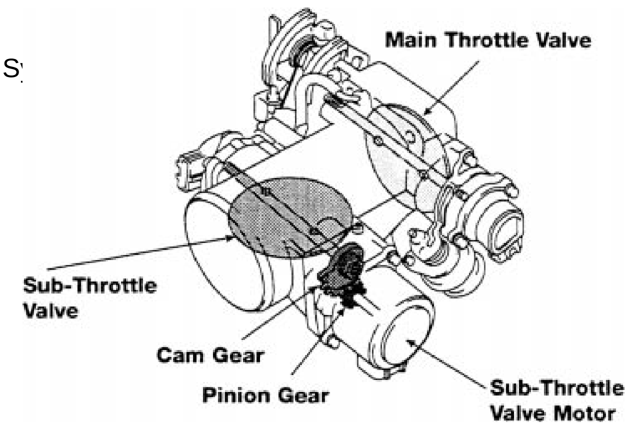
9. Reinstall short pin to DLC1.

WORKSHEET 12-2 (ON-CAR)
Traction Control System Operation

Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this Worksheet you will verify the operation of the TRAC Sy



Tools and Equipment:

- Vehicle Lift or Floor Jack.
- Jack Stands.

Preparation:

- Mount the vehicle on a lift and raise the wheels six inches from the floor.
- For safety considerations make sure no one is standing to the front or rear of the vehicle.
- Make sure that the lift does not interfere with the rotating wheels.
- Make sure that the TRAC OFF switch is in the enabled position.

Procedure:

1. Start engine and place the transmission in Drive Range.
2. From idle, quickly depress the throttle and hold momentarily.

   a. What immediately happened to engine RPM?

   ____

   b. What was the maximum engine RPM achieved?

   ____

3. From idle, depress the throttle and hold momentarily a second time. What immediately happened to the drive wheel speed?

   ____

4. How were both of these TRAC functions accomplished?

   ____

   ____

5. During TRAC operation what happened to the TRAC Indicator?

   ____

WORKSHEET 12-3 (ON-CAR)
TRAC Control System Bleeding

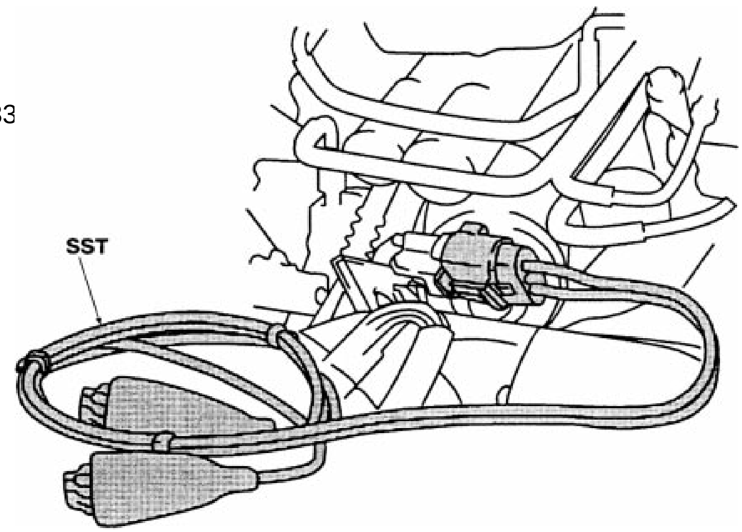
Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this Worksheet you will practice the use of the ABS and TRAC warning lights.

Tools and Equipment:

- Repair Manual.
- TRAC Sub-Harness SST (09990-0033



Procedure:

1. Disconnect the TRAC pump connector and attach the TRAC sub-harness to the pump.
2. Connect a vinyl tube to the bleeder plug of the TRAC actuator, then loosen the bleeder plug.
3. Start the engine.
4. Connect the sub-harness leads directly to the battery terminals to operate the TRAC pump.
5. Close the bleeder screw after 60 seconds.
6. Allow the pump to run for 30 seconds after tightening the bleeder screw.
7. Listen for pump operation.

Notes

Appendix A

GLOSSARY OF TERMS

A

Ampere - The unit for measuring the rate of electrical current flow in a circuit.

Anti-squeal Shims - A single or multiple metal plates located between the brake pad and caliper to reduce brake squeal.

Arcing - A grinding process that machines drum brake lining to the proper curvature for a given drum size

Asbestos - The generic name of a group of minerals used in brake friction materials and made up of individual fibers. Poses a serious health hazard if inhaled or ingested.

Atmospheric Pressure - The pressure on the earth's surface caused by the weight of **air in the atmosphere. At sea level -** 14.7 psi.

Automatic Adjusters - Brake adjusters that use shoe movement or parking brake application, to continually reset the lining to drum clearance.

B

Backing Plate - A pressed steel plate attached to the vehicle suspension. The wheel cylinder and shoes are mounted to the backing plate. Braking torque is transferred from the brake shoes through the backing plate to the suspension.

Brake Dust - The dust created when brake friction materials wear during brake application.

Brake Fade - The partial or total loss of braking power occurring when excessive heat is absorbed by brake components reducing friction.

Brake Lines - The network of steel tubing and rubber hoses used to transmit brake hydraulic pressure from the master cylinder to the wheel cylinders.

C

Caliper - Mounted to the steering knuckle or suspension and houses the piston or pistons. Converts the action of hydraulic pressure on the piston to mechanical force used to apply brake pads against the rotor.

Coefficient of Friction - A numerical value expressing the amount of friction between two objects. Obtained by dividing force by the weight of an object.

Compensating Port - The opening between the fluid reservoir and pressure side of the master cylinder piston.

Cup Seal - Circular rubber seals with a depressed center surrounded by a raised sealing lip. Seals in one direction only allowing fluid to bypass it in the opposite direction.

D

Disc Brake - Brake system which uses brake pads rubbing against the sides of a brake rotor to generate friction to stop a vehicle.

Drum - Rotating part of the drum brake assembly which turns with the wheel. Brake shoes are forced to contact the drum creating friction necessary to stop the vehicle.

Dual Servo Brake - A drum brake that has servo action in forward and reverse directions.

E

Energy - The capacity or ability to do work.

Equalizer - A bracket or cable guide in parking brake linkage used to ensure both brakes receive equal application force.

F

Friction - The resistance to motion between two surfaces in contact.

Friction Modifiers - Additives used to alter the friction coefficient of a brake lining material.

G

Gas Fade - Brake fade caused by hot gases and dust particles that reduce friction in a brake system under hard prolonged braking.

Glazed Lining - An overheated brake lining with a smooth shiny appearance.
Hygroscopic - An affinity or attraction for water.

I

Inertia - The property of a body at rest to remain at rest, and a body in motion to remain in motion in a straight line unless acted upon by an outside force.

Intermediate Lever - A parking brake linkage component used to increase parking brake application force.

K

Kinetic Energy - The energy of mass in motion.

L

Lateral Runout - Side to side movement of the friction surfaces of a brake rotor.

Leading-Trailing Brake - A non-servo brake with one shoe energized and one de-energized. The brake assembly works as well in forward or reverse. (see self energizing action)

Lining Fade - Brake fade caused a drop in the lining coefficient of friction as a result of excessive heat under hard prolonged braking.

Lockheed Master Cylinder - A master cylinder design having a compensating port and inlet port.

M

Master Cylinder - Converts mechanical pressure from the brake pedal into hydraulic pressure for the wheel cylinders.

Mechanical Fade - Brake fade caused by heat expansion of the brake drum away from the brake shoes.

P

Parallelism - A measurement of the two rotor surfaces that are an equal distance apart at every point around the circumference.

Pad Wear Indicator - Attaches to the brake pad and projects beyond the metal backing to contact the rotor when the lining has worn. The squealing sound warns the driver of worn pads.

Pedal Height - The distance from the melt sheet of the floor and the top of the brake pedal with the pedal retracted. Adjusted with the push rod.

Pedal Freeplay - The travel of the brake pedal from the retracted position to the point that resistance in the brake pedal is felt as the pushrod contacts the booster or master cylinder.

Pedal Reserve Distance - The distance from the melt sheet of the floor and the top of the brake pedal with the pedal depressed.

Portless Master Cylinder - A master cylinder design which does not use a compensating port. A single passage is open from the reservoir to the cylinder controlled by a mechanical valve.

Proportioning Valve - A valve in the brake hydraulic system that reduces pressure to the rear brakes to achieve better brake balance.

R

Radial Runout - A change in dimension from the center of a round object to its outer edge (radius).

Residual Pressure - A constant pressure held in the brake hydraulic circuit when the brakes are not applied.

Rotor Phase Matching - Repositioning the rotor on the spindle hub to obtain the least amount of rotor-run-out.

S

Self Energizing Action - A characteristic of drum brakes in which the rotation of the drum increases the application force of a brake shoe by wedging it tighter against the drum surface.

Servo Brake - A drum brake that uses the stopping power of one shoe to help increase the application force of the other shoe.

Slip Ratio - The difference between the vehicle's body speed and the speed of the wheels measured as a percentage.

T

Tandem Booster - A vacuum power booster that uses two diaphragms to increase brake application force.

Tandem Master Cylinder - A master cylinder design having two pistons providing pressure to separate hydraulic circuits.

Thickness Variation - Differences in parallelism measurements made on the circumference of a rotor. If great enough will cause feedback through the brake pedal.

Tire Slip - The difference between vehicle speed and the speed of the tire tread moving along the pavement.

Torque - The turning or twisting force applied at the end of a rotation shaft.

Traction - The amount of grip between the tire tread and the road surface

A.B.S. COMPARISON CHART

ITEM / MODEL	Celica 2WD (88,89) Camry 2WD (881/2-91)	Supra (87,88)	Supra (89-92)	Cressida (88-91)	Camry 4WD (88-91) Celica 4WD (88, 89)	Celica 2WD, 4WD (90-93)	Celica (95-96)	Camry (92-96) Except 94, 96 TMM	RAV4 (96) Corolla, Tercel, Paseo (93-96)	MR2 (91-95)	Previa 2WD, 4WD (91-96)	Land Cruiser (93-96)	Avalon (95, 96) TMM Camry (94-96)	4 Runner (94-96) T100 (95, 96) Tacoma (95, 96)	Truck (90-95) T100 (93-94) 4 Runner (90-93) Rear Wheel A.B.S.	Supra (94-96)
POWER SOURCE	Motor	Motor	Motor	Motor	Motor	Motor	Motor	Motor	Motor	Motor	Motor	Motor	Motor	Motor	Power Steering Pump	Motor
SOLENOID VALVES BY-PASS VALVE	3 Position (4) No	(3) Yes	(3) No	(3) No	(4) No	(4) No	(8) No	(4) No	2 Position(8) No	(3) No	(3) No	(3) No	(3) Mechanical valve	2 Position (6) No	Solenoid valve (1) Mechanical By-pass	(4) No
RESERVOIR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	P/S press, regulator	Yes
DAMPER	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	Brake press, regulator	No
ACTUATOR LOCATION	Engine Compartment	←	←	←	← Celica (Rear seat)	←	←	←	←	Front luggage	Front hood	Engine Compartment	←	←	←	←
CONTROL RELAY	Camry/ In actuator (2) Celica/Behind left suspension tower (1)	←	←	←	←	2WD Near actuator (2) 4 WD in actuator (2)	←	←	← (2) Engine Compartment[4]	←	←	←	In actuator (1)	(1) Right inner fender Near actuator[5]	Solenoid relay (1) Right inner fender	In actuator Near actuator[6]
FRONT SPEED SENSORS	2	2	2	2	2	2	2	2	2	2	2	2	2	2	None	2
(ROTOR)	(Front axle hub) 96 teeth	← ←	← ←	← 48 teeth	← 96 teeth	(Front drive shaft) 48 teeth				(Front axle hub) 48 teeth	(Front axle hub or drive shaft) 48 teeth	← 48 teeth	Front drive shaft ←	Front axle hub ←	— —	(Front axle hub) 96 teeth 48 teeth[6]
REAR SPEED SENSORS	2	1	1	1	2	2	2	2	2	2	2	2	2	2	1	2
(ROTOR)	(Rear axle hub) 48 teeth	(W58: Reverse gear) 39 teeth (R154, A340E: Trans output shaft) 32 teeth		← ←	(Rear drive shaft) 48 teeth	2WD (Rear drive shaft) 4WD (Rear axle hub) 48 teeth	(Rear axle hub) 48 teeth	(Rear axle hub) 48 teeth		(Rear drive shaft) 48 teeth	←	←	(Rear axle (hub) 48 teeth	(Rear axle shaft) ←	(Rear differential ring gear) —	(Rear axle hub) 48 teeth
"G" SENSORS	No	No	No	No	Yes	2WD = No 4WD = Yes	No	No	2WD = No 4WD = Yes	No	2WD = No 4WD = Yes	Yes	No	2WD = No 4WD = Yes	Yes	Yes
COMPUTER	3 Channel control	←	←	←	←	←	←	←	←	←	←	←	3 Channel	3 Channel	1 Channel	←
DIAG Read diag. Codes	A.B.S. Check Connector	←	←	← TDCL (Tc)	←	← Tc terminal	Eng. check conn. (DLC1) Tc, Pull jumper Wa/Wb				← Tc terminal 94-Pull jumper	Pull jumper Wa/Wb Tc terminal	DLC2 or DLC1 Tc terminal Pull jumper	DLC1 Tc terminal	← Tc terminal	DLC1 or DLC2 Tc terminal pull jumper
DIAG Sensor(s) Check mode	Speed sensor	No	No	Speed TDCL (Tc)	Speed & G[1] Ts conn.	Speed & G[1] Ts, Tc term.	Speed Ts, Tc term.	Speed sensor & G[1] Ts, Tc term.		Speed sensor Ts, Tc term.	Speed & G[1] Ts, Tc term.	Speed & G[1] Ts. Tc term.	Speed DLC1 Ts, Tc term.	Speed & G[1] Ts, Tc term.	Speed & G Ts, Tc term.	Speed sensor Ts, Tc term.

SSTs	Celica 2WD (88,89) Camry 2WD (881/2-91)	Supra (87,88)	Supra (89-92)	Cressida (88-91)	Camry 4WD (88-91) Celica 4WD (88, 89)	Celica 2WD, 4WD (90-93)	Celica (95-96)	Camry (92-96) Except 94, 96 TMM	RAV4 (96) Corolla, Tercel, Paseo (93-96)	MR2 91-92	MR2 93-95	Previa 91-93	Previa 94-95	Land Cruiser (93-96)	Avalon (95, 96) TMM Camry (94-96)	4 Runner (94-96) T100 (95, 96) Tacoma (95, 96)	Truck (90-95) T100 (93-94) 4 Runner (90-93) Rear Wheel A.B.S.	Supra (94-96)
TOY220036								←							←			W/O Trac ← 09990-00150-01 09990-00200 09990-00210 W/Trac 09990-00150-01 09990-00210 09990-00250 09990-00280 09990-00300
09990-00150-01	←	←	←	←	←	←	←	←	←	←	←	←	←	←	—	←	←	
09990-00163	←	—	—	—	←	←	←	←	←	—	←	—	—	—	—	←[3]	09990-00205	
09990-00165[2]	←	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
09990-00200	—	—	—	—	—	←	←	←	←	—	—	—	←	←	—	←	—	
09990-00210	←	—	—	—	—	—	—	←	—	—	—	—	←	←	—	←	—	
09990-00250	—	—	—	—	—	—	←	—	—	—	←	—	—	—	—	09990-00205	—	
09990-00300	—	—	—	—	—	—	←	—	←	—	←	—	—	—	—	←[3]	—	
09990-00360	—	—	—	—	—	—	←	—	—	—	←	—	—	—	—	09990-00370	—	

[1] 4WD only
[2] Celica only
[3] 4Runner only
[4] RAV4 only
[5] Tacoma and 96 4Runner
[6] 96 Model only

DIAGNOSTIC CODES

AVALON	TERCEL/ PASEO/ MR2	COROLLA	CAMRY	CELICA	SUPRA (MA70)	SUPRA (JZA80)	CRESSIDA	PREVIA	TRUCK	4RUNNER/ T100/ TACOMA	LAND CRUISER/ RAV4	CODE	DIAGNOSIS	POSSIBLE TROUBLE AREAS
•	•	•	•	•	•	•	•	•	•	•	•	11	Open or short in solenoid relay circuit	– Solenoid relay circuit wire harness and connectors
	•	•	•	•	•	•	•	•	•	•	•	12	Open or short in solenoid relay circuit	– Control relay
•	•	•	•	•	•	•	•	•		•	•	13	Open circuit in pump motor relay circuit	– Control relay
	•	•	•	•	•	•	•	•		•	•	14	Short circuit in pump motor relay circuit	– Pump motor relay circuit wire harness and connectors
						•[9]						15	Open or short in TRAC solenoid relay circuit	– TRAC solenoid relay circuit
						•[9]						16	B+ short in TRAC solenoid relay circuit	– TRAC solenoid relay circuit
						•[9]						17	Open or short in TRAC motor relay circuit	– TRAC solenoid relay circuit
						•[9]						18	B+ short in TRAC motor relay circuit	– TRAC solenoid relay circuit
•	•	•	•	•	•	•	•	•		•	•	21	Open or short circuit in 3 position solenoid of right front wheel	– Actuator, SFR circuit
•	•	•	•	•	•	•	•	•		•	•	22	Open or short circuit in 3 position solenoid of left front wheel	– Actuator SFL circuit
•	•	•	•	•	•[3]	•	•[3]	•		•	•	23	Open or short circuit in 3 position solenoid of right rear wheel	– Actuator, SRR circuit
		•	•	•	•[4]	•					•[12]	24	Open or short circuit in 3 position solenoid of left rear wheel	– Actuator, SRL circuit
						•[9]			•			25	Short circuit in solenoid valve circuit	– Solenoid
						•[9]						27	Open or short in TRAC actuator solenoid circuit (SRC circuit)	– TRAC actuator (SRC) circuit
•	•	•	•	•	•	•	•	•		•	•	31	Right front wheel speed sensor signal malfunction	– Circuit wire harness and connectors
•	•	•	•	•	•	•	•	•		•	•	32	Left front wheel speed sensor signal malfunction	– Speed sensor circuit
•	•	•	•	•	•	•	•	•	•	•	•	33	Right rear wheel (or rear) speed sensor signal malfunction	– Speed sensor circuit
•	•	•	•	•	•	•		•		•	•	34	Left rear wheel speed sensor signal malfunction	– Sensor rotor & sensor circuit
•	•[8]	•	•	•[8]		•	•	•		•[10]	•	35	Open circuit in left front (or right rear) wheel speed sensor	– Speed sensor wire harness and connectors
•	•[8]	•	•	•[8]		•		•		•[10]	•[13]	36	Open circuit in right front (or left rear) wheel speed sensor	– Speed sensor circuit
•		•	•[1]	•[8]			•[5]			•	•[1]	37	Wrong left and right rear rotors (FRONT hubs on Cressida)	– Sensor rotors
•			•[7]									38	Open circuit in right rear speed sensor circuit	– Speed sensor, rotor
•			•[7]									39	Open circuit in left rear speed sensor circuit	– Speed sensor wire harness and connectors
•	•	•	•[6]	•	•	•	•	•	•	•	•	41	Low battery voltage (9.5V or lower)	– Battery
			•		•		•		•			42	Abnormally high battery voltage (16.2V or higher)	– Voltage regulator
			•[2]					•[2]	•	•[2]	•[2]	43	Malfunction in deceleration sensor	– Deceleration sensor - Sensor installation
			•[2]			•		•[2]	•	•[2]	•[2]	44	Open or short circuit in deceleration sensor	– Sensor wire harness/connectors
											•[12]	45	Malfunction in deceleration sensor	– Deceleration sensor
										•[11]	•[13]	48	Open or short in center/rear differential lock circuit	– Center/rear differential lock circuit
•	•	•	•	•	•	•	•	•		•	•	51	Actuator pump motor locked or open in pump motor circuit	– Pump motor or relay - Circuit wire harness/connectors
						•						53	ECM communication circuit malfunction	– EFI+, EFI–, TRC+, TRC– circuit
						•[9]						55	Brake fluid reservoir level low	– Brake level warning switch circuit
						•[9]						58	Open circuit in TRAC pump motor circuit	– TRAC pump motor circuit
						•[9]						61	ABS & TRAC ECU communication circuit malfunction	– ABSO, BRC, BRP circuit
•			•[8]			•[9]						62	Malfunction in computer	– Malfunction in ECU
	•	•	•	•	•	•	•		•	•	•	ON	Malfunction in computer	– Computer

[1]Except All-Trac [2]All-Trac only [3]Rear wheel solenoid [4]By-pass solenoid (87, 88) [5]Wrong both front hubs (Cressida only) [6]93 Camry 9.5V or lower of 16.2V or higher [7]94 Celica and Camry [8]Except 96 Model [9]w/TRAC [10]4Runner only [11]Tacoma only [12]RAV4 only [13]Except RAV4

SPEED SENSOR CODES

TERCEL/ PASEO/ COROLLA/ MR2/ CAMRY/ CELICA/ SUPRA/ AVALON	4RUNNER (PRE-1994)/ TRUCK/ T100 (1993-1994)	CRESSIDA	RAV4/ LAND CRUISER/ PREVIA/ T100 (1995-96)/ TACOMA (1995-96)	CODE	DIAGNOSIS	TROUBLE AREA
•		•	•	71	Low voltage, right front speed sensor signal	Speed sensor of installation
•		•	•	72	Low voltage, left front speed sensor signal	
•	•	•[1]	•	73	Low voltage, right rear speed sensor signal	
•			•	74	Low voltage, left rear speed sensor signal	
•		•	•	75	Abnormal change, right front speed sensor signal	
•		•	•	76	Abnormal change, left front speed sensor signal	Sensor rotor
•	•	•[1]	•	77	Abnormal change of right rear speed sensor signal	
•			•	78	Abnormal change of left rear speed sensor signal	
	•		•[2]	79	Deceleration sensor is faulty	Deceleration sensor

[1]One rear speed sensor (transmission mount) [2]4WD only

Appendix C

HANDLING ASBESTOS

In 1986 the Occupational Safety and Health Administration (OSHA) established workplace standards for repair facilities that perform brake and clutch repair to reduce the level of asbestos in the workplace. The following is a summary of the workplace standard. You should obtain specific compliance advice from your company's attorney or OSHA specialist. Additionally there may be state or local regulations that may be applicable. Encourage your employee to establish an information and training program for all employees.

Controlling asbestos residue in the workplace is of importance to everyone. Using compressed air to remove the brake dust from brake assemblies may endanger the health of everyone in the workplace and should never be done.

When touching a hot exhaust manifold, one knows immediately that continued contact will result in tissue damage and sustained levels of pain. The immediate response is to pull away from the source of heat; not so with substances such as asbestos. Damage caused by asbestos may have a latency period of 15 to 30 years before symptoms occur and can be diagnosed. Asbestos does not melt, burn, breakdown, dilute or digest, it remains indestructible inside the body. Controlling asbestos residue is the only rational course of action.

Special vacuum cleaner equipment recommended by OSHA, utilize High Efficiency Particulate Air (HEPA) filters that are very efficient in removing asbestos fibers. Most asbestos fibers in brake dust are smaller than four tenths of a micron in size. Therefore, a special vacuum and filter system is required to prevent these fibers from getting airborne. A regular shop vacuum is insufficient for containing these small fibers and should never be used for this purpose as it will further broadcast the asbestos throughout the shop. Asbestos can spread 75 feet from the point of origin if a shop vacuum is used.

Some of the systems recommended by OSHA encase the brake assembly and allow the technician to blow the brake dust loose with a regulated internal air nozzle, while the system vacuum cleaner draws the dust into its filter. Once the brake dust has been removed, the brake assembly can be worked on. Also vacuum the dust from the brake drum using the OSHA recommended vacuum, before servicing it.

There are other OSHA approved systems consisting of a low velocity solvent which moistens the brake dust until it is stuck together and collected in a tray or basin. Using a brake cleaner propellant or water to wash down the brake dust should not be done as it will also cause some of the dust to become airborne. Later, when the cleaner or water evaporates, the dust again may become airborne.

In all cases avoid breathing asbestos when performing clutch and brake services. Make every effort to effectively collect the dust in these operations with OSHA approved methods. If you wear a respirator, make sure that it is OSHA approved for working with asbestos and that is fits properly around the corner of the face. Even if you use a respirator for your protection, you must also use an approved collection system to protect others in the workplace.