Chapter 9

Hydraulic Valves, Switches, Lines, and Hoses

After studying this chapter, you will be able to:
- Explain how metering valves operate.
- Explain the purpose and construction of the proportioning valve.
- Discuss the reason load-sensing proportioning valves are used.
- Explain the purpose and construction of the residual pressure valve.
- Discuss the operation of a pressure differential valve and switch.
- Explain the purpose and construction of the low brake fluid switch.
- Explain the purpose and construction of the brake light switch.
- Identify the reasons for using steel hydraulic lines.
- Identify types of brake line flares.
- Discuss why flexible hoses are used to connect some brake parts.
- Identify various types of brake fittings and explain their function.

Important Terms

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This chapter covers the valves and electrical switches used to control and monitor the brake hydraulic system. It also covers the steel and flexible hydraulic lines used to connect the brake hydraulic devices, as well as fittings and flares necessary for proper brake system operation. This chapter also discusses the low fluid level and brake light switches.

Pressure Control Valves and Switches

All modern brake hydraulic systems contain pressure control valves. These systems also contain brake switches, which operate dashboard-mounted warning lights, or illuminate the rear brake lights. Pressure control valves affect the hydraulic pressure delivered to the wheel units, which can make brake action more efficient. Brake switches are used to illuminate warning lights on the dashboard, alerting the driver to the presence of a brake problem. Some valves and switches work together to sense problems and warn the driver. The following sections explain the construction and operation of these valves and switches.

If the front brakes apply before the rear brakes, vehicle stability is affected. If the front wheels grip before the rear wheels, the back of the vehicle will have more momentum than the front. The back tries to pass the front, which can cause the vehicle to become unstable, possibly resulting in a skid.

Unfortunately, gravity and the design of modern brake systems makes this problem worse. When the brakes are first applied, much of the vehicle’s weight is transferred to the front. Then, if the rear applies, the rear will begin to move forward, making the front wheels grip even harder, and therefore, more stopping power than the rear wheels. In addition, many modern vehicles are designed with front disc and rear drum brakes.

Metering Valve

As you learned in Chapter 5, the front brake pads are very close to the rotor and are not held in a retracted position. When the brakes are first applied, hydraulic pressure moves the front disc pads into contact with the rotor almost immediately. However, the rear brake shoes are held in the retracted position by return springs and must overcome spring pressure to move the shoes into contact with the drum. This means the front pads would apply much more quickly than the rear shoes. A metering valve is used to keep this from happening.

The metering valve, Figure 9-1, is installed in the brake line between the master cylinder and the front brakes. Vehicless with diagonally split braking systems will have two metering valves. The basic metering valve design contains a spring-loaded valve, which remains closed when no pressure is applied. When the brake pedal is applied, master cylinder pressure is sent to the front and rear wheels. The rear wheels receive full pressure immediately. Since fluid flows to the rear brakes immediately, system pressure remains relatively low and the closed metering valve keeps the front brakes from applying.

When the rear brakes have applied, there is no more fluid movement into the rear hydraulic units, and system pressure rises. When the system pressure reaches a certain point, the metering valve opens, Figure 9-2. Full pressure then applies the front brakes. When the brakes are released, fluid can bypass the main metering valve and return to the master cylinder. While most metering valves are mounted in the brake lines or in a combination valve, some metering valves are installed in the master cylinder, Figure 9-3.

After the front brakes are serviced, the front brake lines may contain air. This air may compress during brake
bleeding and keep the metering valve from opening. In this circumstance, it may not be possible to bleed the front brakes. Therefore, many metering valves have an external plunger which can be depressed during the bleeding operation to allow brake fluid to flow into the front wheel units.

**Proportioning Valve**

As mentioned earlier, when the brakes are applied, much of the vehicle's weight is transferred to the front wheels. If the brakes are applied hard during an emergency stop, so much vehicle weight is transferred to the front wheels that the rear wheels can easily lose traction and lock up. Rear wheel lockup can cause wear on the rear tires and can cause the vehicle to spin out of control, especially on wet or icy roads. The danger of lockup is worse on vehicles with rear drum brakes than on vehicles with rear discs. However, rear wheel lockup is a problem on many vehicles with four-wheel disc brakes, especially those with front-wheel drive.

To prevent rear wheel lockup, a proportioning valve, Figure 9-4, is installed in the rear brake line. Inside the proportioning valve assembly, a calibrated spring holds the valve away from the opening to the rear brakes. Diagonally split braking systems may have two proportioning valves. In some cases, the proportioning valves are installed at the master cylinder outlets, Figure 9-5.

During normal braking, the system pressure cannot overcome spring tension, and passes through the opening to the rear brakes. When the brake pressure rises past a certain point, such as during a panic stop, it will overcome spring tension and push the valve against the opening. This seals the rear brake system from further increases in pressure. Since the amount of pressure entering the rear brakes is limited, the brake friction elements cannot be applied any harder. Note that rear brake pressure is not decreased, it is merely kept from going any higher. When the brake pedal is released, the fluid pressure drops, and the spring opens the passage to the rear brakes. Fluid pressure can then return to the master cylinder.

**Load-sensing Proportioning Valve**

A variation of the proportioning valve is the load-sensing proportioning valve or height-sensing proportioning valve. This type of valve can vary the maximum pressure to the rear brakes according to the load placed on the vehicle. The load-sensing proportioning valve can be thought of as a standard proportioning valve with a mechanism that controls rear brake pressure. Load-sensing proportioning valves are used on pickup trucks, vans, and other vehicles designed to regularly carry heavy loads. The valve is usually installed at the rear wheels, mounted on the vehicle frame as shown in Figure 9-6. A link or lever from the valve is connected from the rear axle assembly.

**Note:** Do not confuse this valve with a height sensor for a ride control suspension system, they are not the same.

In operation, the link moves an adjusting mechanism inside the proportioning valve assembly. See Figure 9-7. Loading the vehicle causes the body to compress the springs, which reduces the distance between the axle and frame. The reduced distance between the axle and frame causes the link to move the adjustment mechanism. This increases spring tension on the proportioning valve, which allows more pressure to enter the rear brakes before the valve closes. Therefore, the rear brakes take more of the braking effort when the vehicle is loaded.

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**Figure 9-3.** A special metering valve installed in the master cylinder body. (ATE)

**Figure 9-4.** A dual proportioning valve setup. Note that with this valve, a separate line is sent to each individual rear brake assembly. (Bendix)

**Figure 9-5.** Proportioning valves which are connected to the master cylinder fluid outlet ports. (DaimlerChrysler)

**Figure 9-6.** Overall view of one particular regulated (load-sensing) proportioning valve, and its operating linkage. (GMC)
When the vehicle is lightly loaded, the rear will rise. This increases the distance between the axle and body, causing the link to extend and lower the pressure sent to the rear wheels. A delay mechanism is built into the proportioning valve to keep quick axle movements (such as those caused by bumps) from affecting the valve.

Residual Pressure Valve

On any vehicle with drum brakes, a small amount of pressure must be maintained in the system to keep the wheel cylinder cup lips from collapsing, usually about 7 psi (47 kPa). All vehicles with drum brakes have a residual pressure valve to maintain this pressure. Figure 9-8 shows a residual pressure valve installed in the end of the master cylinder bore.

Most modern vehicles with drum brakes have a residual pressure valve installed in the outlet to the rear wheels, Figure 9-9. Older vehicles have residual pressure valves installed in each outlet. While this leaves a slight residual pressure on the entire brake system, it is not enough to cause brake drag or accidental brake apply. Some manufacturers feel the small amount of residual pressure makes initial brake application slightly quicker.

The residual pressure valve consists of two check valves. The apply check valve allows fluid flow to the rest of the brake system whenever master cylinder pressure is greater than system residual pressure, Figure 9-10. The return check valve allows fluid flow back to the master cylinder when the brakes are released and system pressure becomes higher than master cylinder pressure, Figure 9-11. However, the return check valve contains a spring which opposes returning fluid pressure. This spring is designed to close the valve when the system pressure goes below a certain point.

When the brakes are applied, the apply check valve unseats and fluid flows to the wheel units. When the brakes are released, the apply check valve closes, and fluid returns to the master cylinder through the return check valve. When the system pressure becomes lower than spring pressure, the spring closes the valve. This traps a small amount of pressure in the brake hydraulic system.

Pressure Differential Valve

The pressure differential valve is a warning device used in all split brake systems. Remember that a split braking system contains two separate brake hydraulic systems or sides. The pressure differential valve is installed so that each side of the hydraulic system presses on one side of the valve, Figure 9-12. Attached to the valve is an electrical switch. This switch receives electrical power whenever the ignition is on. The switch's electrical circuit goes through a dashboard-mounted brake warning light. To complete the circuit, the switch must be grounded by the pressure differential valve.

When the hydraulic system is operating normally, pressure on both sides of the valve will be equal. With the pressure on both sides equal, the valve is centered and the switch is open. When one side of the hydraulic system fails, pressure on the brake pedal will result in normal pressure on one side, and much lower pressure on the other side of the system. The difference in pressure pushes the valve to move toward the side with less pressure, Figure 9-13. When the valve moves, it moves the switch plunger, causing the switch contacts to close. This grounds the switch, allowing current flow to turn on the dashboard warning light.

Combination Valve

For manufacturing ease and quicker service, two or more hydraulic valves are often combined into one assembly. This multiple valve assembly is called a combination valve. A combination valve may contain up to three different hydraulic valves. Common two-unit combination valves usually contain a pressure differential valve and either a metering valve or proportioning valve, Figure 9-14. A few two-unit combination valves contain the metering and proportioning valves. Three-unit combination valves are composed of a metering valve, proportioning valve, and pressure differential valve, Figure 9-15.
Valve. Note that this valve incorporates a warning switch, proportioning and metering valve in one unit. Study the construction. (Raybestos)

Pedal mounting bracket. 2–Switch retainer. 3–Stoplight switch. 4–Stoplight switch mounting bracket. 5–Switch actuator lever. 6–Brake pedal. 7–Plunger. 8–Normal brake pedal travel. (General Motors)

**Figure 9-15.** A cross-sectional view of a two unit combination valve. The left half is a metering valve, and the right half is a pressure differential valve. Study the construction. (DaimlerChrysler)

**Low Brake Fluid Switch**

Master cylinders in many vehicles are equipped with a low brake fluid switch. This switch is usually installed in the reservoir cap. **Figure 9-16,** or in the side of the reservoir. The switch consists of a float and a set of contacts. The switch contacts have electrical power when the ignition is on. The contacts are attached to the float, and close when the float falls below a certain point. The switch electrical circuit is powered through a dash-board-mounted fluid level warning light. When the fluid level becomes too low, the float falls in the reservoir, causing the contacts to close. Closing the contacts grounds the circuit and illuminates the dashboard warning light.

**Figure 9-16.** Cutaway views of float level sensors that are a part of the reservoir cap. A—Switch contacts are open, circuit is off. B—Switch contacts are closed. Warning light will come on if the sensor is functioning correctly. This will alert the driver to a low fluid level in the reservoir. (Honda)

**Figure 9-17.** This master cylinder has a brake fluid level switch located in the side of the reservoir.

**Hill Holder**

Drivers often have difficulty coordinating the clutch, brake and accelerator pedals to start moving on a steep hill. To make starting easier, some vehicles have a hill holder that uses the brake hydraulic system. The main part of the hill holder is a pressure hold valve. The valve is installed in the brake line between the master cylinder and the left front and right rear wheel brakes. The valve has an internal ball that can be moved by both gravity and a mechanical connection from the clutch pedal. Under the right conditions, the ball will seal off the wheel brakes from the master cylinder.

When the vehicle is driven on a road with no grade or a downhill grade, the ball remains away from its seat and the valve has no effect on braking. Since the clutch pedal is in the raised position at this time, the mechanical connection also keeps the ball from seating. When the driver steps on an uphill grade and depresses both the clutch and brake pedals, the ball rolls into contact with its seat. Since the clutch pedal is depressed, the mechanical connection is moved away from the ball, allowing it to seat. This closes the valve, trapping hydraulic pressure in the right rear and left front wheel brakes. The driver can release the brake pedal with no risk of the vehicle rolling backward.

As long as the clutch pedal is depressed, the ball remains seated. Without the need to depress the brake pedal, the driver can engage the clutch while pressing the accelerator pedal for a smooth takeoff. As the clutch is engaged, the mechanical linkage moves the ball away from its seat, releasing the hydraulic pressure in the wheel brakes.

**Brake Light Switch**

To operate the brake lights, a brake light switch or stoplight switch is installed on the brake pedal linkage. One end of the brake pedal switch is mounted to the vehicle body under the dashboard. The other end is installed on the brake pedal linkage. The two most common types of brake switches are the plunger type, **Figure 9-18,** or the pin actuated type.

Some vehicles use a sliding contact brake light switch, **Figure 9-19.** This switch can be easily recognized since it is a switch of another types of brake switches. The sliding contact brake light switch also contains the brake switches for the cruise control and anti-lock brake systems when they are used.

**Brake Lines and Hoses**

For the hydraulic pressure developed in the master cylinder to reach the wheel brakes, they must be connected by some sort of hydraulic tubing. This tubing consists of rigid steel lines and flexible rubber hoses.

**Steel Brake Lines**

Whenever possible, the hydraulic system uses rigid steel brake lines, sometimes called tubing, to transmit hydraulic pressure. Steel lines are resistant to corrosion, high pressure and vibrations, and can stand up to high brake system pressures, and are relatively inexpensive. For added safety, the steel used in the lines is double-wall (double thickness) welded steel made from copper-coated steel sheet. Common steel line sizes range from 1/8-3/8” (3.25-9.5 mm).

Steel lines are often coated with tin, zinc, lead, or Teflon™ to reduce damage from corrosion. The lines are clamped to the vehicle unibody or frame at close intervals to reduce damage from vibration and road debris. The clamps often contain rubber bushings to reduce the possibility of normal vehicle vibration rubbing a hole in the line. **Figure 9-20** shows typical steel line construction.
Another type of line is the **armored line**. Armored lines are standard steel tubes around which steel wire is coiled, Figure 9-21. The steel spring protects the line from impact damage. Armored lines are usually used under the vehicle.

### Line Installation

Factory steel lines are pre-bent to the shape needed to snug fit the frame and other parts of the vehicle. The bends are relatively gentle to reduce the possibility of kinks. Figure 9-22 shows the routing of brake lines on a typical vehicle. Aftermarket steel lines are available in pre-cut lengths, but must be bent and flared to be installed on the vehicle. These procedures are covered in Chapter 10.

#### Tubing Flares

To make a solid connection to the hydraulic units, the ends of all steel lines have tubing flares. A tubing flare is an expanded, or flared section at the end of the line. The flare fits firmly against a seat, forming a leak-proof connection.

To connect to other hydraulic units, many steel brake lines use **double-lap flares** at all connecting points. The double-lap flare will withstand vibration and high pressures. Notice in Figure 9-23A the flare angle is 45° while the angle of the seat is 44°. This is called an interference angle. When the nut is tightened into the fitting, the interference angle causes the seat and the flare to wedge together. This wedging effect provides an effective seal against leakage.

Another type of flare used for brake line connections is the **ISO flare**. ISO stands for International Standards Organization, a group that sets standards for international trade and manufacturing. Similar to the double-lap flare, the ISO flare provides a secure crack-resistant joint. An ISO flare is shown in Figure 9-23B. Note that both flares use a threaded nut, called a flare-nut, to hold the flare against its seat.

#### Flexible Hoses

Since the wheel brake units are independently suspended (they can move in relation to the frame and body), hydraulic connections between the wheels and body cannot be rigid. Flexible hoses, Figure 9-24, are used at the wheels to allow for movement. As the wheels rise, fall, and turn, the flexible hose will transmit high pressure without breaking. Most flexible hose lines are made from natural rubber and synthetic fabric. There are usually two-ply layers of rubber and two-ply of braided fabric material for added pressure resistance. The hose is usually covered by a synthetic rubber sheath to reduce damage from atmospheric pollutants. See Figure 9-25. Some flexible brake hoses use braided steel mesh between the rubber layers for added strength. Braided mesh may also be used over the outside of the hose to protect it from road debris.

Hose fittings are threaded to accept the flared tubing of steel brake lines. The flexible hoses are firmly mounted at each end, and all movement occurs in the hose itself.

#### Brake Fittings

Brake fittings are the threaded connectors that form the junctions or connections in the brake hydraulic system. Brake fittings are usually made of steel, but may also be made of brass. Fittings can be as simple as the flare nut at the end of a brake line, or as complex as a distribution block that splits a single hydraulic line into numerous separate lines. Brake fittings such as distribution blocks and tees are frequently solidly mounted on the frame or axle. Some common brake fittings are shown in Figure 9-26.
A banjo fitting is a specialized type of brake fitting used to connect a brake hose to a component at a right angle. Figure 9-27. These fittings are frequently used to connect brake hoses to brake calipers. They consist of a connector with a bore through it, a bolt with a fluid passage drilled in it, and two copper crush washers. A copper washer is placed on each side of the connector and the bolt is installed through the bore and tightened into the component. Fluid can travel from the hose into the connector, through the hollow bolt, and into the brake component. The copper crush washers prevent the connector from leaking.

**Figure 9-26.** An assortment of typical tubing and hose fittings and connectors. A—Distribution block for four fittings. B—Male elbow. C—Female branch tee. D—Adapter for reducing size. E—inverted union to connect both pipes. F—Distribution block for three fittings. G—Female elbow. H—Crimped on hose fitting. (Weatherhead)

**Figure 9-27.** Exploded view of a disc brake assembly that uses a banjo fitting (named because it resembles a banjo), and sealing washers for brake hose attachment to a caliper. (Infiniti)

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**Summary**

The modern brake hydraulic system contains various valves which control hydraulic pressure to parts of the brake system. One valve is the metering valve, used to prevent application of the front brakes until the rear brakes are partially applied. Another valve is the proportioning valve which controls pressure to the rear wheels during hard braking. A variation of the proportioning valve controls pressure according to the weight placed on the vehicle. The pressure differential valve warns the driver if one side of the hydraulic system loses pressure. All of these valves may be combined into one unit called a combination valve. Combination valves can contain two or three valves.

Electrical brake switches are also used in various ways. In addition to the switch attached to the pressure differential valve, switches also control a dashboard light that warns the driver when the fluid level in the master cylinder reservoir is low. Another switch is installed on the brake pedal linkage to illuminate the brake lights when the brake pedal is depressed.

Hydraulic pressure from the master cylinder reaches the wheel brakes by way of rigid steel lines or flexible rubber hoses. Steel line hydraulic units that do not move in relation to each other, while hoses connect the moveable wheel assemblies with the frame or body lines. Brake fittings are threaded connectors which connect brake lines and hoses. Fittings can be standard or metric pipe threads. Double-lap or ISO flares are used to ensure a solid connection between steel lines and fittings with no leaks. The two types of flares are the double-lap and the ISO flare. One of these two types must be used in brake system flares.

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**Review Questions—Chapter 9**

Please do not write in this text. Write your answers on a separate sheet of paper.

1. A ______ responds to changes in vehicle load.
2. ______ may contain 2-3 valves and an electrical switch.
3. The low brake fluid switch is installed on the master cylinder ______.
4. How does the low brake fluid switch respond to a low fluid level?
5. The rear brake light switch is installed on the _____ linkage.
6. Rigid brake lines are made of ______.
7. Brake lines are usually coated with another metal or Teflon to reduce ______.
8. Define a tubing flare.
9. What are the two types of brake tubing flares?
10. Flexible hoses are firmly mounted at ______.

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**ASE Certification-Type Questions**

1. Technician A says that the metering valve keeps the rear wheels from locking up. Technician B says that the proportioning valve keeps the front wheels from applying too quickly. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A & B.
   (D) Neither A nor B.
2. When is the metering valve closed?
   (A) When no pressure is applied to it.
   (B) When heavy pressure is applied to it.
   (C) When the driver releases the brake pedal.
   (D) When the front disc pads are applied.
3. The load-sensing proportioning works because a load placed in the vehicle trunk ______.
   (A) compresses the frame bushings
   (B) compresses the shock absorbers
   (C) compresses the rear springs
   (D) None of the above.
4. Technician A says that during light braking, the proportioning valve is open. Technician B says that during light braking, the residual pressure valve is closed. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A & B.
   (D) Neither A nor B.
5. A properly functioning residual pressure valve keeps the ______ seals from collapsing.
   (A) caliper
   (B) wheel cylinder
   (C) master cylinder
   (D) Both A & B.
6. Under which of the following conditions will the pressure differential valve illuminate the dashboard light?
   (A) The engine is first started.
   (B) The metering valve sticks closed.
   (C) A severe leak develops in a rear wheel line.
   (D) A front hose swells shut.
7. Which of the following switches will not illuminate a dashboard light?
(A) Pressure differential switch.
(B) Brake fluid level switch.
(C) Brake light switch.
(D) None of the above.

8. All of the following statements about brake lines and hoses are true, EXCEPT:
(A) brake lines are double-walled and single flared.
(B) steel lines are often coated to reduce corrosion damage.
(C) brake hoses are combinations of rubber and fabric.
(D) brake hose ends are solidly mounted.

9. Brake fittings are threaded connectors sometimes made of______.
(A) copper
(B) aluminum
(C) phenolic plastic
(D) None of the above.

10. A banjo fitting is a special type of______.
(A) double-lap flare
(B) ISO flare
(C) tubing nut
(D) brake fitting

Exploded view of a combination valve. The top valve is the pressure differential switch. The bottom valves are proportioning valves. This valve is used on a diagonal split brake system.