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Module 3 – Hydraulic Systems

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Objectives:

After completing this section, the student will be able to:

- Describe how to prevent brake system contamination during service
- Fabricate brake pipe
- Install brake pipe and hoses
- Overhaul a master cylinder
- Manually bleed brakes
- Pressure bleed brakes
- Bleed systems with a combination valve
- Fabricate both ISO and double flare fittings

Hydraulic System

The hydraulic system includes:

- Hydraulic master cylinder
- Fluid reservoir
- Brake pipes and hoses
- Calipers and wheel cylinders
- Balance control systems

Master Cylinder

The master cylinder pressurizes and distributes brake fluid to the wheel circuits (Figure 3-1). In the braking system:

- A reservoir stores brake fluid for use by the system
- The brake pedal linkage presses against the master cylinder pistons
- The pistons pressurize the brake fluid
- Internal master cylinder passages ensure the brakes apply and release properly
- Metering and proportioning valves control brake pressure distribution
- Brake pipes and hoses distribute the pressurized fluid to the wheel circuits

Figure 3-1, Master Cylinder
Dual Master Cylinder

The dual master cylinder contains two separate pressure chambers in a single bore (Figure 3-2). Single chamber master cylinders are generally no longer in use.

The master cylinder has two holes between each chamber and the brake fluid reservoir. The holes:

• Provide a supply of fluid during braking
• Allow for normal expansion and contraction of the brake fluid due to temperature change

Each master cylinder chamber supplies pressurized brake fluid to separate wheel brake circuits. The dual system ensures partial braking is available if a failure occurs in one of the circuits. Modern brake systems utilize two split designs:

• Front-to-rear split (normally utilized on rear wheel drive vehicles)
• Diagonal split (normally utilized on front wheel drive vehicles)

Figure 3-2, Dual Master Cylinder (Cross-Section)
Pistons

The master cylinder contains two pistons, each connected to a hydraulic channel (Figure 3-3).

• Primary piston (rear piston, operated by the pedal linkage)
• Secondary piston (front piston, operated by the primary piston)

The pistons pressurize the brake fluid in the hydraulic channels to each wheel brake.

Bypass Hole

The bypass hole is another passage between the reservoir and the master cylinder chambers. The bypass hole is open to the low pressure side of the pistons.

The bypass hole:

• Allows the master cylinder pistons to return to the at-rest position rapidly

During brake release:

• Strong springs retract the pistons faster than the brake fluid can return through the hydraulic channels. The rapid piston movement could create a vacuum in the master cylinder high pressure and low pressure chambers, delaying brake release
• The bypass holes allow brake fluid from the reservoir to fill the low pressure chambers
• The brake fluid from the low pressure chambers passes through holes in the pistons and bypasses the piston lip seals (Figure 3-4)

This action prevents a vacuum in the high pressure chamber which could delay release of the brakes. This could also happen if the seals are installed backwards.

Figure 3-3, Bypass Hole and Compensating Port

Figure 3-4, Bypass Operation
Quick Take-Up Valve

The quick take-up valve is utilized with low-drag disc brake calipers. Low-drag calipers retract the caliper piston slightly after brake release. This reduces brake drag. The quick take-up valve supplies the calipers with a large volume of fluid:

- At low pressure
- With initial brake application

This results in the immediate engagement of all the brakes with relatively little brake pedal travel.

The quick take-up valve is installed in specially designed master cylinders with a large low pressure chamber for the primary piston. On initial brake application:

- The quick take-up valve seals the compensating port passage between the low pressure chamber and the brake reservoir (Figure 3-5)
- The movement of the primary piston forces brake fluid to bypass the primary seals. The fluid is directed to the brake calipers. The high volume also forces the secondary piston forward, taking up the brake clearances in the secondary circuit

![Figure 3-5, Applying at Initial Low Pressure](image_url)
On brake release, the quick take-up valve allows the bypass hole and compensating port to operate normally (Figure 3-7)

A stuck open check valve inside the quick take-up valve could cause extended brake pedal travel
Master Cylinder Overhaul

Disassembly Procedure

Note: Do not hone the master cylinder bore when the brake master cylinder is overhauled. It is recommended that the cylinder be replaced rather than CLEANED UP by honing the bore. The master cylinder has a hard, highly polished BEARINGIZED surface, which is produced by diamond boring followed by ball or roller burnishing under heavy pressure. Honing will destroy this hard smooth surface and cause rapid wear of the rubber cups.

1. Remove the cover (Figure 3-8).
2. Remove the diaphragm.
3. Drain the brake fluid from the reservoir.
4. Remove the reservoir and two grommets from the master cylinder body.
5. Clamp the master cylinder mounting flange in a vise.
6. Remove the snap ring.
7. Remove the primary piston assembly from the master cylinder body (Figure 3-9).

Figure 3-8, Master Cylinder

Figure 3-9, Remove Primary Piston
8. Remove the secondary piston from the master cylinder body (Figure 3-10). Plug the rear port, and apply a small amount of air pressure to the front port.

9. Remove the seals.

10. Remove the spring retainer and the spring from the master cylinder body.

11. Clean all the parts using the following procedure:
   - Clean the metal parts in denatured alcohol
   - Clean the rubber parts in clean brake fluid.

12. Check the diaphragm for cuts, cracks, or swelling.

13. Inspect the cylinder bore for scoring or corrosion.
   - Replace the master cylinder if corrosion is present
   - Do not attempt to hone the cylinder bore.

14. Inspect piston seal and surfaces for damage. Replace pistons as necessary.

15. Check the reservoir for cracks.

Note: Use approved solvents only when cleaning or flushing the master cylinder and related components. The use of these liquids as cleaning solvent will damage the rubber parts in the system if they have any trace of mineral oil or other contaminants.

Caution

If air pressure is used to remove the secondary piston, place the open end of the cylinder bore approximately 25 mm (1 in.) from a padded workbench or other surface to catch the piston when it comes out of the bore. Apply low air pressure very carefully to ease the piston out of the bore. Never point the open end of the bore at anyone when applying air pressure. The piston may come out with considerable force and cause personal injury. Use only dry, non-lubricated air when removing components.
Assembly Procedure

1. Lubricate the grommets, seals and the cylinder bore with clean brake fluid (Figure 3-11).

2. Use new seals when assembling the master cylinder.
3. Install the spring.
4. Install the spring retainer.
5. Install the primary seals on the secondary piston (Figure 3-12).

6. Install the secondary seal on the secondary piston.
7. Install the secondary piston in the master cylinder body.
8. Install the primary piston assembly in the master cylinder body.
9. Install the snap ring.
10. Compress the primary piston in order to install the snap ring.
11. Install two new grommets to the master cylinder. Install the reservoir on the master cylinder body. Install the diaphragm in the cover.
12. Install the reservoir on the master cylinder body.
13. Install the diaphragm in the cover.
14. Install the cover on the reservoir.
Master Cylinder Bench Bleeding

Bench bleed the master cylinder before installation on the vehicle. Bench bleeding removes air from the master cylinder. Bench bleeding reduces the time required to bleed the brake hydraulic system after installation.

1. Plug the outlet ports. Mount the master cylinder in a vise with the front end slightly down.

2. Fill the master cylinder reservoir with clean brake fluid.

3. Stroke the primary piston about 25 mm (1 in.) several times using a smooth round-end tool. The primary piston will not travel the full 25 mm (1 in.) stroke as air bleeds from the master cylinder.

4. Reposition the master cylinder in the vise with the front end tilted slightly up.

5. Stroke the primary piston about 25 mm (1 in.) several times again.

6. Reposition the master cylinder in the vise. The master cylinder should be level.

7. Loosen the plugs in the outlet ports one at a time. Then push the piston into the bore in order to force the air from the cylinder.

8. Tighten the plug(s) before allowing the piston to return to its original position. This prevents air from being drawn back into the cylinder.

9. Fill the master cylinder reservoir with clean brake fluid.

10. Follow normal bleeding procedures after installing the master cylinder.

Important: Do not clamp the bore in a vice. Use the mounting flange ears when clamping the master cylinder in a vice.
**Brake Fluid Reservoir**

The brake fluid reservoir houses brake fluid for the master cylinder and includes separate chambers for the primary and secondary pistons (Figure 3-13).

For many years, reservoirs were cast as part of the master cylinder. Newer composite plastic reservoirs are press fit onto the master cylinder.

In many applications, brake fluid level sensors are integral with the composite reservoir or part of the reservoir cap.

During visual inspection, be sure to take note of the condition of the diaphragm.

If fluid level is low, there may be a system leak or worn out brake pads. For additional information, refer to the Brake Pad Wear Compensation section of this booklet.

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**Caution**

A swollen diaphragm may indicate contaminated brake fluid. Replace all rubber parts in the system, including hoses and flush the entire hydraulic system.

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*Figure 3-13, Brake Fluid Reservoirs*
Brake Fluid

Contamination During Service

Corrosion and particles in the brake hydraulic system quickly destroy the sealing effectiveness of pressure cylinders (master cylinder, wheel cylinder, caliper). Careful work habits during hydraulic service will help prevent contamination of the hydraulic system. Brake fluid can damage painted surfaces. Remember to use care when handling fluids.

- Use only clean DOT 3 brake fluid when assembling hydraulic components.
- Never use petroleum-based cleaners for hydraulic components. Use only approved brake cleaning products such as denatured alcohol.
- Do not dry components with lubricated shop air.
- Service hydraulic components on a clean work bench, away from grinders, Sanders and other particle-generating equipment.
- Store brake fluid in a sealed container. Brake fluid absorbs moisture. Moisture and water can damage hydraulic components.

Caution

Contamination of the brake hydraulic fluid with petroleum-based products can result in system failure.

Brake Pipes

All GM vehicles utilize one of two methods of brake line connection flaring (Figure 3-14):

- ISO (International Standards Organization)
- Double flare

Figure 3-14, Brake Pipe Flares
Caution
Always use double walled, steel brake pipe when servicing brake pipes. Any other pipe is not recommended and may cause brake system failure. Carefully route and retain replacement brake pipes. Always use the correct fasteners and the original location for replacement brake pipes. Failure to correctly route and retain brake pipes may cause damage to the brake pipes and cause brake system failure.

Important: Installing brake lines requires proper routing and torque specifications. If a flare nut is over tightened, the fitting could collapse causing a fluid restriction (Figure 3-15). Over-flaring could result in fitting distortion.

Fabricating and Installing Brake Pipes
All GM vehicles utilize one of two methods of line flaring:

- ISO
- Double flare

ISO Flare
ISO flaring brake pipes requires:

- J 29803-A ISO Flaring Kit
- Hack saw
- Deburring tool
- Vise
- Wrench
1. Obtain the recommended pipe and fittings of correct size. Use the outside diameter of the pipe to specify size.

2. Cut the pipe square and to length with a hack saw. Correct length is determined by measuring the old pipe using a string and adding 0.125 in. (3.2 mm) for each flare.

3. Install fittings on the pipe before starting the flare.

4. Tubing to be flared must have a square cut end and cleanly deburred inside and outside.

5. Chamfer the inside and outside diameter of the pipe with the deburring tool.

6. Remove all traces of lubricant from the brake pipe and flaring tool.

**Important:** Flush the inside and outside of the brake line with a non-volatile solvent. Remove all contaminants from the cutting and deburring process.

7. Clamp the flaring tool body in a vise.

8. Select the correct size collet and forming mandrel for the pipe size used.

9. Insert the correct forming mandrel into the tool body (refer to Figure 3-16). Hold the forming mandrel in place with your finger and thread in the forcing screw until it makes contact and begins to move the forming mandrel. Turn the forcing screw back one complete turn after contact is made.

![Figure 3-16, Forming Mandrel and Forcing Screw for ISO Flare](image-url)
10. Slide the clamping nut over the brake pipe and insert the prepared brake pipe into the correct collet (Figure 3-17). Leave approximately 0.75 in. (19 mm) of tubing extending out the collet. Insert the assembly into the tool body. The brake pipe end must contact the face of the forming mandrel.

11. Tighten the clamping nut into the tool body.

**Important:** If the clamping nut is not securely tightened, the pipe may push out and the flare will not correctly form.

12. Wrench tighten the forcing screw until noticeable resistance is felt.

**Note:** Do not over-tighten the forcing screw or the flare may become oversized.

13. Back the clamping nut out of the tool body and disassemble the clamping nut and collet assembly.

14. Measure the flare diameter (Figure 3-18). It should fall between 0.272 in. to 0.286 in. (6.92 mm and 7.28 mm).

15. Bend the pipe assembly to match the old pipe. Clearance of 0.75 in. (19 mm) is required for all moving or vibrating parts.
Double Flare

Double flaring brake pipe requires (Figure 3-19):

- J 23530 Brake Line Flaring Tool
- Pipe Cutter
- Deburring Tool

Figure 3-19, Double Flare

1. Obtain the recommended pipe and fittings of correct size. Use the outside diameter of the pipe to specify size.

2. Cut the pipe to length with a pipe cutter. Correct length is determined by measuring the old pipe using a string and adding 0.125 in. (3.2 mm) for each flare.

3. Install fittings on the pipe before starting the flare.

4. Tubing to be flared must have a square cut end and cleanly deburred inside and outside.

5. Raise the flaring cone to its highest position above the tubing clamp blocks. Swing the flaring one away as shown.

6. Open the lever handle then slide the hexagonal tube lights toward the tool's handle. Rotate the two hexagonal blocks to the desired size.

7. Insert the tube into the opening between the two hexagon clamp blocks. Position the tube so that its end is level with the top of the gauge (Figure 3-20). Clamp the tube in position by closing the small lever handle.

Figure 3-20, Position Tubing
8. Insert the proper gauge pin into the tube and swing strap into position. Tighten compression screw until gauge bottoms on tool (Figure 3-21).

![Figure 3-21, First Flare](image)

9. Unscrew the compression screw swing strap to one side and remove gauge.

10. Swing strap back into position, then tighten compression screw to complete the double-lap flare (Figure 3-22).

11. Unscrew compression screw and open lever handle.

12. Inspect flared ends for splits, cracks, pits or out of round that could cause leaks.

**Important:** Installing brake lines requires proper routing and torque specifications. If a flare nut is overtightened, the fitting could collapse causing a fluid restriction (Figure 3-23). Over-flaring could result in fitting distortion.

![Figure 3-22, Second Flare](image)

![Figure 3-23, Fitting Distorted by Overtightening](image)
Brake Pipe Bending

When repairing a brake pipe, a tube may have a multiple number of bends and turns. In order to be able to duplicate the existing brake pipe, bending the new brake pipe is usually necessary.

**Important**: Do not kink the pipe as it is being formed or bent.

The preferred method of forming/bending is using a tubing bender of the appropriate size and a piece of stiff wire.

1. Form the stiff wire in the shape of the line to be fabricated on the vehicle, as the existing line may be bent upon removal.
2. Using the tubing bender, bend the tubing in the shape of the stiff wire (Figure 3-24).

**Note**: Slight bending of the tubing by hand to enhance the fit is acceptable.

3. Move the backplate handle and connecting bar assembly around the forming head until the connecting bar stops on the holding bar. The handles should form a 90 degree angle.
4. Place the straight tubing between the appropriate sized grooves on the forming head and the holding bar.

*Figure 3-24, Brake Pipe Tube Bender*
5. Rotate the backplate and handle until contact is made with the tubing and the calibration marks align at zero (tube bending will start at the "0" calibration point).

6. Move the backplate around the forming head until the desired angle is attained as indicated by the alignment of the calibration marks.

7. When all the bends are in place, flare the ends of the line (install the flare nuts first).

Note: In some cases, for a very tight radius, the flare must be done on one end of the tubing first, then the flare nut installed and finally, the bending process begins.

8. Install the new brake line, tighten the fittings, bleed the system and check for leaks.
Brake Hoses

Brake hoses distribute brake fluid to the wheel brakes (Figure 3-25). The flexible hoses allow movement of the suspension, as well as allow the front wheels to turn as the driver steers the vehicle.

When performing brake service:

- Inspect the hoses for damage, kinks or ballooning
- Inspect hoses for proper routing
- Never hang a brake caliper from the rubber hose

A defective or damaged hose could balloon, acting like an accumulator, causing the vehicle to pull during braking or a low pedal concern.

A blocked, restricted, or kinked brake hose could also cause the vehicle to pull during braking.

- A left front hose that is blocked, restricted, or kinked could cause a pull to the right during braking
- A right front hose that is blocked, restricted, or kinked could cause a pull to the left during braking

When replacing rubber hoses, be sure to also replace the copper sealing washers to the calipers.

Figure 3-25, Brake Hoses and Failure Modes
Bleeding Procedures

When the hydraulic system is open to the atmosphere for repairs or due to a leak, bleed the system to remove the air. Unlike liquid, air is compressible which could cause a spongy pedal and inefficient brake application.

See the appropriate service information for wheel circuit bleeding procedures.

This section lists two ways to bleed air from the hydraulic system:

- Manual bleeding
- Pressure bleeding

Manual Brake Bleeding

Manual bleeding requires two people:

- One to operate the brake pedal
- One to bleed the hydraulic system

Note: Brake fluid can damage painted surfaces. Prevent brake fluid from contacting painting surfaces.

1. With the engine OFF, pump the brake several times to remove the power assist reserve.
2. Fill the master cylinder reservoir with brake fluid and keep it at least one-half full of fluid during the bleeding operation.
3. If the master cylinder has air in the bore, then it must be bled before any wheel cylinder or caliper.
4. With the proper box-end wrench over the wheel cylinder or caliper bleeder screw, attach a transparent hose to the bleeder connection. Submerge the end of the hose in clean brake fluid in a transparent container.
5. Press the brake pedal slowly and hold. Open the bleeder screw to purge the air from the system.
6. Close the valve, release the brake pedal, and wait 15 seconds.
7. Repeat steps 5 and 6 until all the air has been bled from the system.

Properly torque the bleeder screw, refill master cylinder to level, and replace top. Dispose of the used brake fluid safely.

Important: Check service information before bleeding the hydraulic system.
Master Cylinder Bleeding

After the master cylinder service and master cylinder bench bleeding, it is necessary to bleed the master cylinder again after it is installed on the vehicle.

1. Remove the brake line from the port at the front of the master cylinder.
2. Fill the reservoir until brake fluid runs out of the open port.
3. Reconnect the brake pipe to the master cylinder and tighten.
4. Press the brake pedal one time slowly and hold. Loosen the front brake pipe to purge the air from the cylinder. Wait 15 seconds, then repeat until all the air is purged from the cylinder.
5. Repeat for the rear connections.

Pressure Brake Bleeding

The following procedure refers to the Kent-Moore diaphragm brake bleeder, J 29532, or its equivalent (Figure 3-26).

1. Install the correct bleeding adapter to the master cylinder.
2. Ensure that the pressure bleeder tank is at least one-third full of clean DOT 3 brake fluid. Charge the pressure bleeder air tank to 140-175 kPa (20-25 psi).
3. Attach the hose to the master cylinder bleeder adapter and open the pressure tank fluid valve. Inspect for any leaks.
4. With the proper box-end wrench over the bleeder valve, attach a bleeder tube to the valve. The discharge end of the tube must be submerged in brake fluid in a clean transparent container.
5. Open the bleeder valve at least a three-quarter turn and allow the fluid to flow until bubbles stop flowing from the bleeder tube.

6. Close the bleeder valve. Be sure that it is properly sealed.

7. Repeat steps 5, 6 and 7 until all air has been bled from the system.
   Torque the bleeder screw to specification.

8. Close the pressure tank fluid valve; disconnect the bleeding equipment and adapters.

9. Refill the master cylinder reservoir and replace the top.

Dispose of the used brake fluid safely.

**Bleeding Brake Systems with a Combination Valve**

The hydraulic pressure generated by manual bleeding is sufficient to open the metering valve in the combination valve and allow fluid to flow to the front calipers. This is not true when pressure bleeding. Therefore, it will be necessary to hold the valve stem open manually when pressure bleeding.

To hold the metering valve open, push the valve stem in. Do not use more than 25 pounds pressure to push the stem in. Otherwise the valve may be damaged. Tool number J 39177 (Figure 3-27) may be used to hold the valve stem open, since it is specifically designed for this purpose. Do not use a screw clamp, wedges or blocks that may put excessive pressure on the valve stem.

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*Figure 3-27, Holding Metering Valve Stem*