Module 4: Hydraulic Systems and Components

- Brake Linings
  - Brake lines carry brake fluid from the master cylinder to the brakes, and for most of their length, they are steel and attached to the body with clips or brackets to prevent damage from vibration. They are basically the same on all brake systems.
  - A flexible section must be included between the body and the suspension to allow for steering and suspension movement, and hoses are made of tough reinforced tubing to contain pressures and to protect them from objects that could be thrown by tires.
  - If a brake line is damaged, it is usually replaced rather than repaired.

- Brake Fluid
  - Brake fluid is a special purpose high-boiling point fluid, and it transmits the hydraulic pressure generated by the master cylinder to the brake units.
  - Brake fluid testing and compliance
    - Properties of different types of brake fluids are tested for many different characteristics such as pH value, viscosity, resistance to oxidation, and stability.
    - Brake fluid is graded against compliance standards set by the United States Department of Transportation (DOT).
  - Brake fluid DOT (WET) specifications
    - DOT 2 is castor oil-based.
    - DOT 3 is composed of various glycol esters and ethers and has a boiling point of 284°F (140°C).
  - DOT 4 is also composed of glycol esters and ethers and has a boiling point of 311°F (155°C).
  - DOT 5 is silicone-based and is NOT recommended for any vehicle equipped with anti-lock brakes (ABS). It provides protection against corrosion, is more suitable for use in wet driving conditions, and it has a boiling point of 356°F (180°C).
  - DOT 5.1 is a high-boiling point fluid that is suitable for ABS-equipped vehicles. It contains polyalkylene glycol ether, but is more expensive than other brake fluids and has a boiling point of 375°F (190.6°C).
  - Even if they have similar base compositions, brake fluids with different DOT ratings must not be mixed.

- Bleeding
  - Bleeding means to remove air from a hydraulic system.
  - When pressure is applied to liquid in a hydraulic system, the liquid does not compress into a smaller volume. Pressure is transmitted without loss. Gases however are compressible.
  - Pressure applied to air changes its volume, and some pressure is lost, which is why if air enters a hydraulic braking system, it can be dangerous.
  - Pressure on the brake pedal will not be transmitted in full through the system to apply the brakes, and the brakes will be spongy.
  - Bleeding the brakes means removing this air, so that only liquid is left in the system.
Master Cylinder
READY FOR REVIEW

- The single-piston master cylinder transforms the applied pedal force into hydraulic pressure that is transmitted simultaneously to all four wheels.
- The master cylinder is connected to the brake pedal via a pushrod.
- There is a single master cylinder for a drum brake system, and its one piston has a primary and a secondary cup.
- The primary and secondary cups are also known as seals because, when force is applied to the brake pedal, the primary cup seals the pressure in the cylinder, and the secondary cup prevents loss of fluid past the end of the piston.
- An outlet port links the cylinder to the brake lines, and an inlet port connects the reservoir with the space around the piston. A compensating port connects the reservoir to the cylinder, ahead of the primary cup.
- With the brakes off, this port connects the brake system with the reservoir, and it compensates for changes in volume of the fluid due to heat or wear.
- The rod from the brake pedal pushes on the piston, and it moves, closing off the compensating port and trapping fluid ahead of the primary cup.
- Any fluid trapped in the cylinder is then forced through a valve called a residual pressure valve into the brake lines, and when the brakes are released, the master cylinder piston returns to its original position.
- When the piston fully returns against its stop, the primary cup uncovers the compensating port, and fluid ahead of the primary cup can now return this way to the reservoir.
- When the pedal is released quickly, the spring makes the piston return quickly, but the fluid cannot return as quickly to the cylinder and a low-pressure area develops ahead of the primary cup, which could draw air into the system.
- To prevent this, small holes are drilled in the piston and fluid from the reservoir can pass through the inlet port and past the edge of the primary cup. This is called recuperation.
- When the fluid in the lines returns to rest, its pressure is held above atmospheric pressure by a valve called the residual line pressure valve. The residual pressure helps stop air from entering at the wheel cylinder and also keeps the fluid from leaking out.

Tandem Master Cylinder
READY FOR REVIEW

- The tandem master cylinder transforms applied brake force into hydraulic pressure, which is transferred to the wheel units through two separate circuits. This provides residual braking in the event of fluid loss.
- With a basic master cylinder in the braking system, any loss of fluid, perhaps because a component fails, could mean the whole braking system fails. To reduce this risk, modern vehicles must have at least two separate hydraulic systems, and that's why the tandem master cylinder was introduced.
- The two systems can be split front-to-rear—the front brakes operate from one circuit and the rear brakes from the other circuit. The two systems can also be split diagonally, such that one front wheel is paired with the rear wheel on the opposite side in one brake circuit and vice versa in the other circuit.
- Like two single-piston cylinders end-to-end, a tandem cylinder has a primary piston and a secondary piston. Each section of the cylinder has inlet and outlet ports and compensating ports, and can be two separate reservoirs or just one divided into separate sections.
- When the brake is applied, the primary piston moves and closes its compensating port. The fluid pressure rises and acts on the secondary piston, which then moves, closing its compensating port.
- Pressure builds up in this circuit. Both pistons then move and displace fluid into their separate circuits and apply the brakes.
- If there is a failure in the secondary circuit, the primary system continues to operate normally, but with increased travel.
- If the primary circuit fails, no pressure is generated to move the secondary piston, and the rod attached to the front of the primary piston will push the secondary piston directly so that it still operates. A switch can warn of loss of pressure in the front or rear circuits, or one fitted to the reservoir can warn of a low fluid level.
- Just like the single-piston master cylinder, a tandem master cylinder can have problems with a low-pressure area developing when the piston returns quickly but the fluid lags. This problem is overcome by using grooves inside of the primary cup that allow fluid to flow from the inlet port into the low-pressure area.
Terms and Definitions

- **Bleeding**: is the process of removing air from the hydraulic brake system.
- **To flare**: is to spread the end of a metal tube so that a connector can be installed.
- **Flushing**: is the process of removing the fluid in a hydraulic brake system in order to remove contaminants in the fluid.
- **Hydraulic**: is pertaining to a system in which force is transmitted by means of a liquid.
- **A kink**: is a bend in tubing in which the inside diameter of the tubing does not remain uniformly curved.
- **Metering**: is the process of controlling the rate of flow of a substance through holes.
- **A reservoir**: is the section of an assembly designed to store a liquid.
- **Split**: means divided, usually into two halves.
  - **Note**: Many brake systems are split as a safety feature, so that if there is a leak in one part of the system, the other half is not affected.
- **A valve**: is the device used to meter or proportion the fluid pressure or flow in a hydraulic system.

Components of a Hydraulic System

- **Rear brake hose**
- **Brake light switch**
- **Brake lines**
- **Rear wheel cylinder**
- **Master cylinder**
- **Combination valve**
- **Front brake hoses**
- **Front brake caliper**

Functions of Hydraulic System Components

- The brake pedal transfers force from the vehicle operator to the brake hydraulic system.
- The master cylinder stores brake fluid and transfers force from the brake pedal to the wheel cylinders.
- Brake hoses and lines route brake fluid between the master cylinder and the wheel cylinders.
- The combination brake valve meters and proportions fluid pressure through the system.
- The wheel cylinder transfers the force of the brake pedal to engage the brakes against the braking surface.
- The brake light switch turns the brake lights on as the operator applies the brake.

Parts of a Brake Pedal

- **Master cylinder**
- **Push rod**
- **Brake pedal**
- **Clevis**
- **Pedal support bracket**

Parts of a Combination Brake Valve

- **Metering valve**
- **Pressure differential valve**
- **Proportioning valve**

Functions of a Combination Brake Valve

- The metering valve ensures that the front and rear brakes are applied at the same time.
- The pressure differential valve monitors for differences in system hydraulic pressure as an indication of brake failure.
- The proportioning valve reduces pressure to the rear wheels during hard braking.
Brake Valve Defects and their Descriptions

<table>
<thead>
<tr>
<th>Defect</th>
<th>Description</th>
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<tbody>
<tr>
<td>An external leak</td>
<td>An external leak is when brake fluid leaks from the valve through cracks in the housing,</td>
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<tr>
<td></td>
<td>loose or defective fittings, or bad seals.</td>
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<tr>
<td>An internal leak</td>
<td>An internal leak is when brake fluid leaks past the pistons and seals so that the valve does</td>
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<tr>
<td></td>
<td>not hold pressure.</td>
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<td>Frozen parts</td>
<td>Frozen parts are parts that do not move as required, due to corrosion, misalignment from</td>
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<td>wear, or deformity from overheating.</td>
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<td>Broken or worn springs</td>
<td>Broken or worn springs are malfunctions that result from springs that do not provide</td>
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<td>adequate pressure or that are broken, misaligned, or deformed.</td>
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<tr>
<td>Contamination of fluid</td>
<td>Contamination of fluid refers to a poor hydraulic response due to air, water, or other</td>
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<td>contaminants in the brake fluid.</td>
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Methods of Bleeding the Hydraulic System

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<thead>
<tr>
<th>Method</th>
<th>Description</th>
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<tbody>
<tr>
<td>Manual bleeding</td>
<td>Manual bleeding is when brake fluid is added to part of the brake system and drained from it</td>
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<td>until there is no longer evidence of air in the form of bubbles in the fluid.</td>
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<td>Bench bleeding</td>
<td>Bench bleeding is the bleeding of a single component of the brake system while it is removed</td>
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<td>from the system.</td>
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<tr>
<td>Pressure bleeding</td>
<td>Pressure bleeding is the use of a device that provides brake fluid under pressure so that the</td>
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<td>system can be bled without operating the system components.</td>
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Parts of a Master Cylinder

<table>
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<tr>
<th>Part</th>
<th>Description</th>
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<tbody>
<tr>
<td>Primary piston</td>
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<tr>
<td>Floating piston</td>
<td></td>
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<tr>
<td>Master cylinder casting</td>
<td></td>
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<tr>
<td>Reservoir seal</td>
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<tr>
<td>Reservoir cover</td>
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</table>

Types of Wheel Cylinders

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
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<tbody>
<tr>
<td>Category 1: Single piston</td>
<td></td>
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<tr>
<td>Category 2: Double piston</td>
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</tbody>
</table>

Types of Brake Lines

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>Steel tubing</td>
<td>• A hollow brake line made of bendable steel that has been coated to reduce rust and corrosion.</td>
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<td>• Lengths can be adjusted as needed with a tubing cutter and flaring tools.</td>
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<tr>
<td>Hoses</td>
<td>• A hollow brake line made of alternating layers of flexible rubber and fabric with threaded</td>
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<td>metal fittings at each end.</td>
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<td>• Must be purchased from the original equipment manufacturer (OEM) at specified lengths, and</td>
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<td>the ends are not replaceable.</td>
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Types of Brake Line Connections

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<thead>
<tr>
<th>Connection</th>
<th>Description</th>
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<tbody>
<tr>
<td>Double flare fitting</td>
<td>Double flare fitting is for steel tubing brake lines.</td>
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<tr>
<td>ISO flare fitting</td>
<td>ISO flare fitting is for steel tubing brake lines.</td>
</tr>
<tr>
<td>Hose-type connections and fittings</td>
<td>Hose-type connections and fittings are for brake lines made of hoses.</td>
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Types of Parking Brakes

- Manual is used for driveline or rear transmission parking brakes operated by a lever and cable.
- Hydraulic uses hydraulic pressure to release a mechanical spring brake or wedge-type spring brake that is hydraulically released.

Switch Operation for Brake Lights

- Hydraulic switch systems
  - Movement of the hydraulic fluid in the master cylinder bore expands a diaphragm in the switch.
  - The diaphragm closes the contacts inside the switch to complete the circuit.
  - With the circuit complete, electricity from the battery flows to the brake lights and illuminates them.
  - When the brakes are released, the pressure on the diaphragm is removed, and the contacts open.

- Mechanical switch systems
  - Movement of the brake pedal depresses a spring-loaded switch in the switch unit.
  - The switch closes the contacts inside the switch assembly to complete the circuit.
  - With the circuit complete, electricity from the battery flows to the brake lights and illuminates them.

Brake Failure Warning Light Switches

- Brake failure warning light switches are used to indicate a brake system failure.
- If the pressure is greater on one side than on the other, the piston between the two fluid passages will cause the piston to shift away from the higher pressure.
- The shifting of the piston pushes a switch that closes a contact in the warning light circuit.
- When the pressure is equalized, the piston may or may not return to its centered position, depending on the design of the valve.

- When the brakes are applied, hydraulic fluid is forced through the system, including the pressure differential valve.
- The fluid is split between two of the halves of the system with fluid flowing on each side of the pressure differential valve.