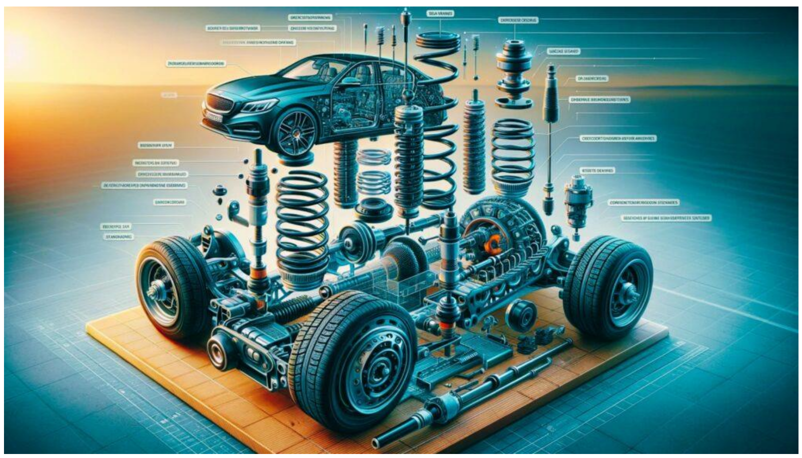
Automotive Mechanics

Level V

Based on December, 2024 Curriculum Version II



Module Title: - Developing and Applying Vehicle's Hydraulic System Modifications

Module code: EIS AUM5 M02 1224

Nominal duration: 60 Hour

Prepared by: Ministry of Labor and Skill

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Addis Ababa, Ethiopia

Table of Contents

Acknowledgment

Ministry of Labor and Skills wish to extend thanks and appreciation to the many representatives of TVT instructors and respective industry experts who donated their time and expertise to the development of this Training Materials (TM).

Acronym

AWD	All wheel drive
CAN	Computer area network
CV	Continues Variable
FWD	Front wheel drive
Lap-Test	Learning activity performance
MP	Multi-purpose
SST	Special service tools
SUV	Sport utility vehicle
TTLM	Teaching, Training and Learning Materials
U-joint	Universal joint

Introduction to module

In the modern automotive industry, the performance, efficiency, and reliability of vehicles are greatly influenced by the quality and functionality of their hydraulic systems. Hydraulic systems are integral to many key components of a vehicle, from braking and steering to suspension and lifting systems. As vehicle technology continues to evolve, the need for effective modifications to hydraulic systems has become increasingly important. These modifications are necessary to optimize vehicle performance, enhance safety, and adapt to new operational demands.

This training module, "Developing and Applying Vehicle's Hydraulic System Modifications," is designed to provide a comprehensive understanding of how hydraulic systems work, the potential for modifications, and the best practices for applying those modifications in real-world automotive applications. This module will guide learners through the principles of hydraulic system, the components involved, and how to assess the need for and execute modifications that meet specific requirements.

The primary objective of this training module is to equip automotive professionals and technicians with the knowledge and skills required to develop, modify, and apply hydraulic system changes effectively. The module focuses on practical aspects, such as modifying hydraulic circuits for improved performance, troubleshooting common issues, and enhancing vehicle functionality with advanced hydraulic technologies.

This module covers the units:

- Basic Principles of Hydraulic Systems:
- Key components of a hydraulic system:
- The role of hydraulic systems in vehicle subsystems such as steering, suspension, and braking.
- Evaluating the Need for Hydraulic System Modifications:
- Designing Hydraulic System Modifications:
- Application of Hydraulic Modifications in Vehicle Systems:

- Testing and Troubleshooting Modified Hydraulic Systems:
- Safety Considerations and Best Practices:

Learning Objective of the Module

By the end of this training module, participants will be able to:

- Describe the core principles of hydraulic systems, including pressure, flow, force, and energy conversion.
- Identify the key components of a hydraulic system, such as pumps, valves, actuators, reservoirs, and hydraulic fluids.
- Explain the role of hydraulic systems in various vehicle subsystems (e.g., steering, braking, suspension, lifting).
- Recognize the performance limitations or operational demands that necessitate modifications to the hydraulic system.
- Analyze scenarios where hydraulic modifications can improve efficiency, performance, safety, or reliability in vehicles.
- Assess the impact of hydraulic system modifications on vehicle dynamics and overall functionality.
- Develop strategies for designing modifications to optimize hydraulic circuit performance.
- Modify hydraulic components such as pumps, actuators, and valves to meet specific vehicle requirements.
- Use design tools (e.g., CAD software) to create and simulate hydraulic system modifications before implementation.
- Apply modifications to hydraulic systems in specific vehicle subsystems such as braking, steering, suspension, and lifting.
- Integrate hydraulic modifications seamlessly with other vehicle systems, ensuring compatibility and performance.
- Understand the challenges involved in integrating modified hydraulic systems with modern vehicle control and monitoring systems.
- Conduct testing to evaluate the effectiveness and performance of modified hydraulic systems.

- Diagnose and troubleshoot common issues that may arise after modifying a hydraulic system, such as leaks, pressure inconsistencies, or component failures.
- Perform routine maintenance tasks to ensure the longevity and reliability of modified hydraulic systems.
- Identify and adhere to safety protocols and industry standards when working with high-pressure hydraulic systems.
- Implement best practices to minimize risks and ensure the safe operation of modified hydraulic systems.
- Understand relevant regulatory requirements and ensure that modifications comply with safety and environmental standards.
- Apply modifications to improve the efficiency, energy consumption, and performance of hydraulic systems in vehicles.
- Identify opportunities for reducing the environmental impact of hydraulic systems, such as through the use of more efficient components or eco-friendly hydraulic fluids.
- Optimize hydraulic systems for specific applications, such as off-road vehicles, performance cars, and commercial trucks

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the “LAP test” giver at the end of each unit and
5. Read the identified reference book for Examples and exercise

1. Unit one: Overview of Hydraulics and the Application in Automotive Systems

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Introduction to Hydraulics
- Types of Hydraulic System
- Major components of Simple hydraulic circuits
- Symbols and Schematics of Hydraulic System
- Overview of Hydraulics Application in Automotive System

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Fundamental concepts applicable to hydraulics
- Hydraulic Levers
- Hydraulic Flow
- Hydraulic Reservoirs/Tanks
- Hydraulic Pumps
- Hydraulic Valves
- Hydraulic Actuators
- Conductors and Connectors
- Hydraulic fluids
- Hydraulic brakes and clutch System
- Hydraulic Power steering systems
- Hydraulic Coupling and Torque converters
- Automatic transmissions
- Engine Systems (Fuel, Cooling and Lubrication)
- Shock absorbers and hydraulic suspension
- Air conditioning System
- Hydraulic Implements

1.1 Overview of Automotive Hydraulics Systems

1.1.1 Introduction to Hydraulics

Mechanics is the oldest physical science that deals with both stationary and moving bodies under the influence of forces. The branch of mechanics that deals with bodies at rest called statics, while the branch that deals with bodies in motion called dynamics. The subcategory of fluid mechanics defined as the science that deals with the behavior of fluids at rest (fluid statics) or in motion (fluid dynamics), and the interaction of fluids with solids or other fluids at the boundaries. Fluid mechanics is also referred to as fluid dynamics by considering fluids at rest as a special case of motion with zero velocity.

Fluid mechanics itself also divided into several categories. The study of the motion of fluids that are practically incompressible (such as liquids, especially water, and gases at low speeds) usually referred to as hydrodynamics. A subcategory of hydrodynamics is hydraulics, which deals with liquid flows in pipes and open channels. Gas dynamics deals with the flow of fluids that undergo significant density changes, such as the flow of gases through nozzles at high speeds. The category aerodynamics deals with the flow of gases (especially air) over bodies such as aircraft, rockets, and automobiles at high or low speeds.

Heavy vehicles and equipment found at commercial transportation, construction sites, open pit mines, and quarries these days is capable of hauling hundreds of tons at a time. Most of them used hydraulic fluid under pressure to convert diesel engine power to fluid power, and then convert it back to mechanical power at the wheels or tracks. The term hydraulics used to describe fluid power circuits that use liquids, usually specially formulated oils in confined circuits to transmit force or motion. A heavy equipment technician is required to have a good knowledge of hydraulics to understand steering and brake systems, hydraulic auxiliary equipment, engine operation, fuel systems, and many types of transmissions.

Although we do not often differentiate between them, hydraulics can be divided into two branches, which we know as hydrostatics and hydrodynamics. Hydrostatics is the science of transmitting force by pushing on a confined liquid. In a hydrostatic system, transfer of energy takes place because a confined liquid is subject to pressure.

- Hydrostatic principal is defined as ‘‘high-pressure fluid moving at a slow rate of speed.’’ A good example of a hydrostatic circuit is that used to actuate a boom cylinder.

  Hydrostatics: low fluid movement with high system pressures.

- Hydrodynamics is the science of moving liquids to transmit energy. Hydrodynamic principal defined as ‘‘low-pressure fluid moving at a high rate of speed. ’The best example on mobile equipment chassis is the torque converter used to impart drive to a power-shift transmission.

  Hydrodynamics: high fluid velocity with lower system pressures.

Hydraulic systems have many desirable features and many advantages that make it the most economical means of power transmission. However, one disadvantage is the original high cost of the various components

- Efficiency:-Minimum energy loss or all the energy transmitted through a hydraulic system received at the output end, where the work performed.
- Control Sensitivity:-The confined liquid of a hydraulic system operates like a bar of steel in transmitting force
- Flexibility of Installation: - Hydraulic lines can be run almost anywhere. Unlike mechanical systems that must follow straight paths, the lines of a hydraulic system can be led around obstructions.
- Low Space Requirements:-The functional parts of a hydraulic system are small in comparison to those of other systems; therefore, the total space requirement is comparatively low.
- Low Weight:-The hydraulic system weighs remarkably little in comparison to the amount of work it does.
- Self-Lubricating-The majority of the parts of a hydraulic system operate in a bath of oil. Thus, hydraulic systems are practically self-lubricating.
- Low Maintenance Requirements:-records consistently show that adjustments and emergency repairs to the parts of hydraulic systems are seldom necessary.

1.1.2 Hydraulic Levers or Pascal’s law

Pressure in an enclosed fluid can be considered uniform throughout a practical system. This equality of pressure is known as Pascal’s law, and is illustrated in (Figure 1-1) below where a small force F_1 is applied to a piston of small area at A_1.

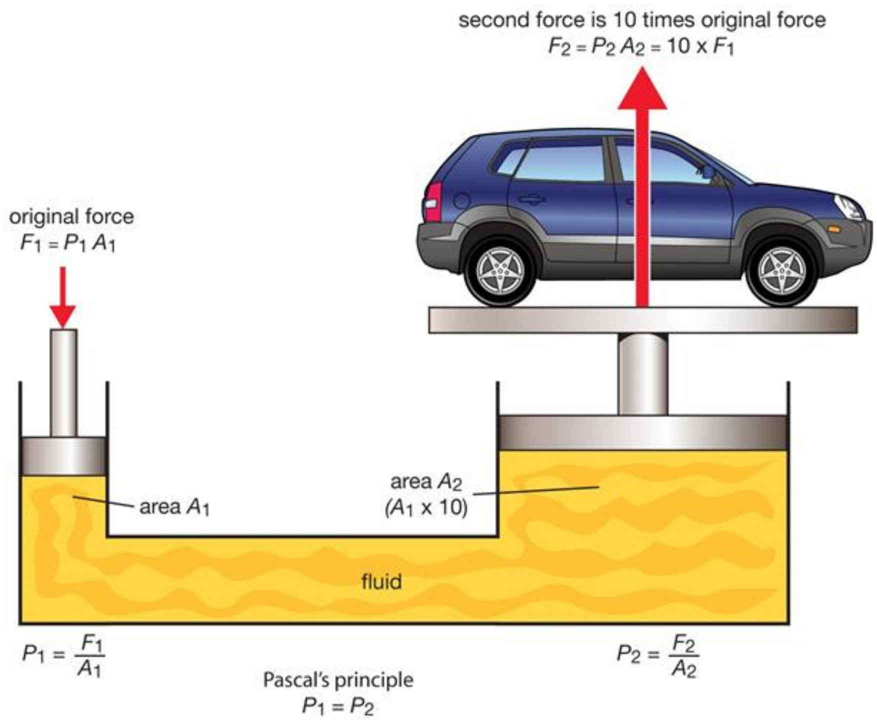


Figure 1-1: Typical application of Pascal's principle

This produces a uniform pressure at every point within the fluid, which acts with equal force per unit area on the walls of the system. Liquid properties enable large objects (rudder, planes, etc) to be moved smoothly. According to Pascal's principle Magnitude of force transferred is indirectly proportional to the surface area (F α A) , hence proportionality coefficient (pressure is constant).

$$P = \frac{F}{A} \qquad 1.1$$

Where, P = Pressure, F = Force and A = Area

1.1.3 Pressure

Pressure is force applied to a specific area. When a confined fluid is subject to pressure, the force applied to the area of confinement will be uniform throughout (Pascal's law). When a liquid confined in a vessel is pushed on, the pressure that results acts evenly on all of the walls of the vessel. This characteristic makes it possible to transmit force or ‘‘push’’ through pipes. In hydraulics, we use liquids rather than gases as hydraulic fluids, because liquids are not easily compressed. Because of this incompressibility, we can relay action almost instantaneously, so long as the circuit is full of liquid and contains no air.

Pressure measurement

The actual pressure at a given position is the absolute pressure, and it is measured relative to absolute vacuum (i.e., absolute zero pressure). However, most pressure measuring devices calibrated to read zero in the atmosphere, and so they indicate the difference between the absolute pressure and the local atmospheric pressure. This difference is the gage pressure.

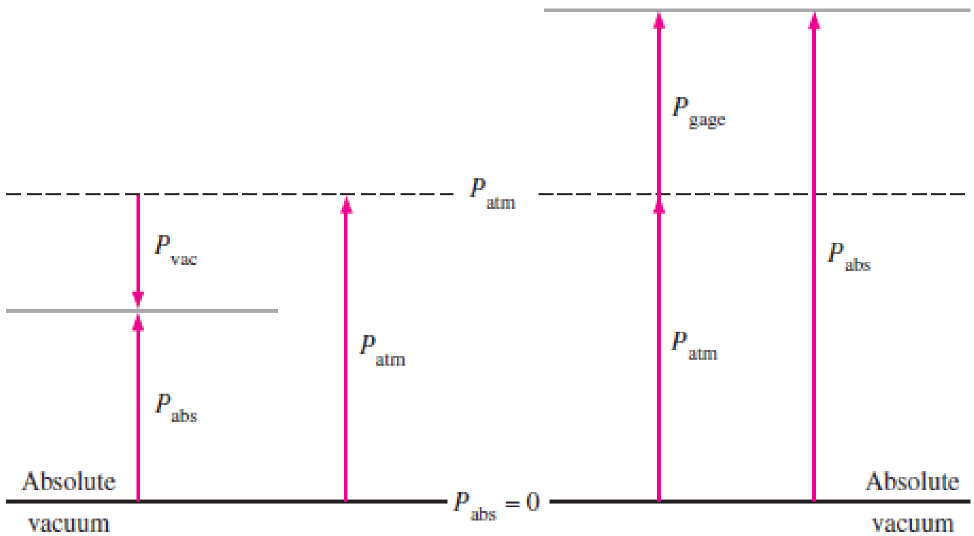


Figure 1-2: Relationship among absolute (P_{abs}), atmospheric (P_{atm}) and gauge pressures (P_{gage})

Pressures below atmospheric pressure are vacuum pressures and measured by vacuum gages that indicate the difference between the atmospheric pressure and the absolute pressure. Absolute, gage, and vacuum pressures are all positive quantities and related to each other by equations given below.

$$P_{gage} = P_{abs} - P_{atm}$$

$$P_{gage} = P_{abs} - P_{atm} \quad 1.2$$

Force is push or pull effort. The weight of one object placed upon another exerts force on it proportional to its weight. The formula for force (F) is calculated by multiplying pressure (P) by the area (A) it acts on.

$$F = P \times A \qquad 1.3$$

Pressure is usually expressed in pounds per square inch or kilopascals. Additionally, there are a number of different pressure scales whereas all based on atmospheric pressure. One unit of atmosphere is the equivalent of atmospheric pressure and it can be expressed in all these ways:

- 1atm = 1 bar (European) =14.7psia = 29.92'' Hg (inches of mercury) = 101.3kPa (metric)

However, each of the above values is not precisely equivalent to the others:

- 1atm = 1.0192 bar
- 1bar = 29.53'' Hg = 14.503psia
- 1'' Hg = 13.6'' H_2O @ 60° F

1.1.4 Hydraulic Levers

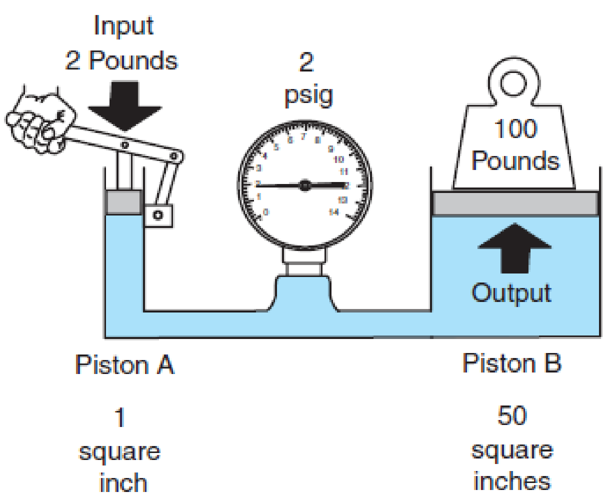


Figure 1-3: Hydraulic Lever

Hydraulic levers can be used to demonstrate Pascal's Law. Pressure equals force divided by the sectional area it acts on. Similarly, force equals pressure multiplied by area. Therefore, if we want to calculate the force exerted by a cylindrical ram we would use the following formula:

- Force exerted = hydraulic pressure (psi) × cylindrical area (diameter^2 × 0.7854)

If we build a simple hydraulic circuit such as that shown in (Figure 1-3), we have the building blocks of a hydraulic jack.

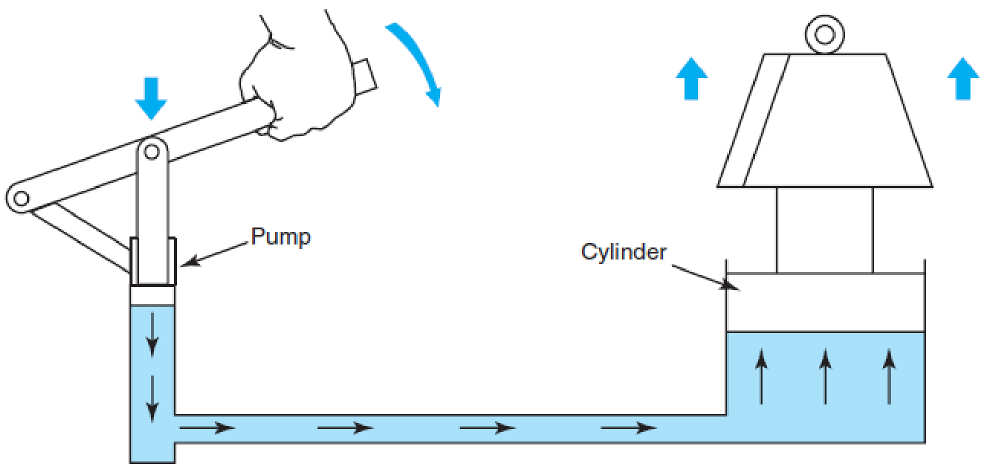


Figure 1-4 Simple hydraulic lever: Pressure multiplies force. (Reproduced with permission from Deere & Company)

A variation on the hydraulic jack principle can be seen in the type of hydraulic circuit shown in (Figure 1-4), the basis of a hydraulic ram. This consists of a pair of unequally sized cylinders connected by a pipe. In the figure, one of the cylinders has a sectional area of 1 sq. in. and the other 50 sq.in. Therefore, the following would be true:

Applying a force of 2lb on the piston in the smaller cylinder produces a circuit pressure (potential) of 2psi because the force is applied to a sectional area of 1sq. in and it would lift a weight of 100lb supported on a piston in the larger cylinder with sectional area of 50 sq.in. Accordingly, if a force of 10lb was to be applied to the smaller piston, the resulting circuit pressure would be 10 psi and the circuit would have the potential to raise a weight of 500 lb.
This principle is applied every time we use a hydraulic jack. A hydraulic jack is a simple hydraulic lever as is a cab lift ram or dump ram. However, when 2lb of force is applied to the

smaller cylinder to raise a 100lb weight 1in. in the larger cylinder, the piston in the smaller piston must move through 50in. as shown in (Figure 1-5). This movement is accomplished using multiple strokes and a check valve in typical hydraulic circuits.

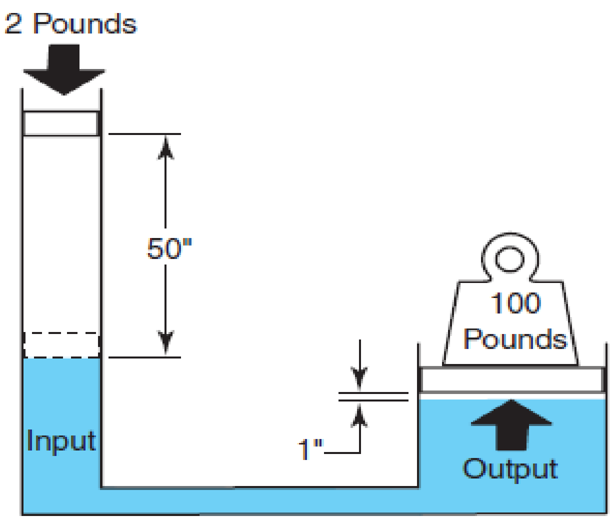


Figure 1-5: Force multiplication of hydraulic system

1.1.5 Flow

Flow is the term we use to describe the movement of a hydraulic medium through a circuit. Flow occurs when there is a difference in pressure between two points. In a hydraulic circuit, a device such as a pump creates flow. A pump exerts push effort on a fluid.

Flow can be measured in two ways: velocity and flow rate. The velocity of a fluid in a confined circuit is the speed at which the fluid moves through it. It is measured in feet per second (fps). Flow rate is the volume of fluid that passes a point in a hydraulic circuit in a given time. It is measured in gallons per minute (gpm).

Flow rate determines the speed at which a load moves. Fluid velocity and flow rate have to be considered when sizing the hydraulic hoses and lines that connect hydraulic circuit components.

- If a small-diameter pipe opens into a larger-diameter one, then we can conclude:
- A constant flow rate will result in lower velocity when the diameter increases.
- A constant flow rate will result in higher velocity when the diameter decreases.

- The velocity of oil in a hydraulic line is inversely proportional to its cross-sectional area.

We should also add that lower fluid velocities are generally desirable to reduce friction and turbulence in the fluid. The same will work for hydraulic cylinders. Given an equal flow rate, a small cylinder will move faster than a larger cylinder.

If the objective is to increase the speed, at which a load moves, then:

- Decrease the size (sectional area) of the cylinder.
- Increase the flow to the cylinder (gpm).

The opposite would also be true, so if the objective were to slow the speed at which a load moves, then:

- Increase the size (sectional area) of the cylinder.
- Decrease the flow to the cylinder (gpm).

Therefore, the speed of a cylinder is proportional to the flow it is subject to and inversely proportional to the piston area.

1.1.6 Work and energy

Work occurs when effort or force produces an observable result. In a hydraulic circuit, this means moving a load. To produce work in a hydraulic circuit, we must have flow. Work is measured in units of force multiplied by distance, for example, in pound-feet.

$$W = F \times S \qquad 1.4$$

Where W = Work, F = Force and S = Distance

Energy simply means the capacity to perform work. In a hydraulic circuit, the objective is to transfer energy. We transfer energy from one form to another and from one point to another. The idea is to accomplish this as efficiently as possible and not waste too much by transforming it to heat. In a typical hydraulic circuit, mechanical energy is required to drive a hydraulic pump to create flow and kinetic energy potential in the fluid. Fluid under pressure is the potential energy of a hydraulic circuit. This energy can then be reconverted to mechanical energy to move a load-that is, kinetic energy or the energy of motion. The prime source of the energy used in a hydraulic system may be the heat value of the fuel used in an engine, or the electrical energy in a battery. The term prime mover is used to describe the machine that creates the mechanical energy required to power a hydraulic pump, though it is also sometimes used to describe the pump itself.

1.1.7 Types of Hydraulic System

Hydraulic systems can be grouped into two main categories:

- Open-center systems
- Closed-center systems

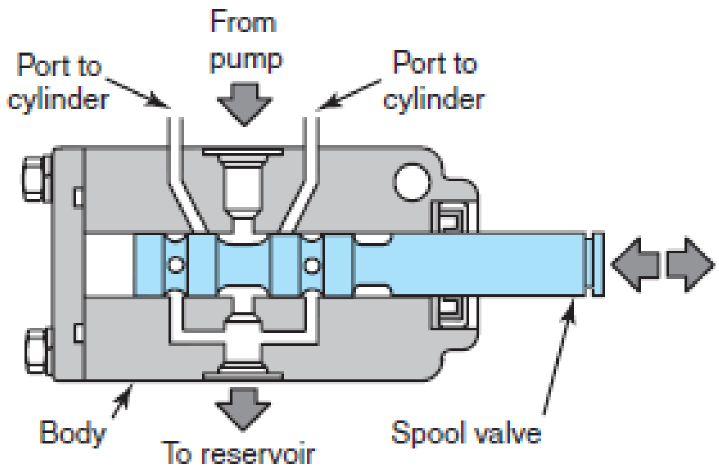


Figure 1-6: Control valve for open system

The primary difference between open-center and closed-center systems has to do with what you do with the hydraulic oil in the circuit after it leaves the pump.

In an open-center system, the pump runs constantly, which means that oil flows through the circuit continuously. A valve is used to manage the circuit and when this valve is in its "open" or neutral position, fluid is allowed to return to the reservoir. An example of an open-center hydraulic system on a truck is power assisted steering. Figure 1-6 shows an example of an open-center spool valve.

In a closed-center system, the pump can be "rested" during operation whenever flow is not required to operate an actuator. This means that the control valve blocks flow from the pump when it is in its "closed" or neutral position. A closed-center system requires the use of either a variable displacement pump or proportioning control valves. Closed-center systems have many uses on agricultural and industrial equipment, but on trucks, they would be used on garbage packers and front bucket forks.

1.2 Hydraulic system components and their purpose

Most of the components in a hydraulic circuit are interrelated in much the same way as components in an electrical circuit.

1.2.1 A hydraulic tank (reservoir)

If you keep on operating the pump to raise the weight, a supply of extra oil is needed.

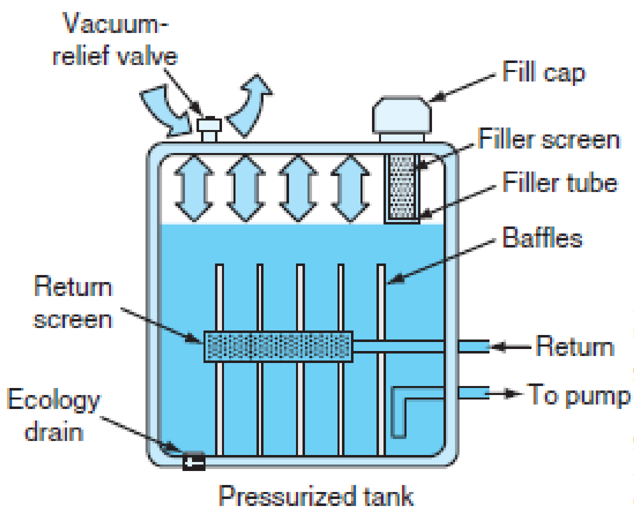


Figure 1-7: Parts of pressurized oil reservoir

- Stores hydraulic oil.
- Helps keep oil clean and free of air.
- Acts as a heat exchanger to help cool the oil.

The reservoir has an air vent, which allows oil to be forced into the pump by gravity and atmospheric pressure when the pump piston is retracted.

- Filler Cap. This is the means of replenishing oil in the hydraulic circuit.
- Oil Level Gauge or Dipstick. To verifying that there is sufficient oil in the reservoir.
- Outlet and Return Lines. To conduct the oil out of and back into the reservoir.
- Baffle(s). The function of a baffle or baffles in a reservoir is to separate the return oil from that being drawn out by the pump.

- Inlet Filter/Screen. The inlet filter is often just a screen or strainer located in series with the system hydraulic pump.
- Inspection Cover. Used to gain access to the internal side of the reservoir for scheduled inspections and clean-out maintenance.
- Hydraulic Filter
- Drain plug

1.2.2 Hydraulic pump

The pump is the heart of the hydraulic system. It creates the flow of fluid which supplies the whole circuit. They operate on a principle called displacement. The fluid is taken in and displaced to another point. Displacement can be done in two ways:

- Non-Positive Displacement
- Positive Displacement

Positive displacement pump

The positive displacement pump, used in hydraulics today, not only creates flow, it also backs it up. Notice the sealed case around the gear. This traps the fluid and holds it while it moves.

As the fluid flows out the other side, it is sealed against back up. This sealing is the "positive" part of displacement. Without it, the fluid could never overcome the resistance of the other parts in the system. When high pressure is needed in a circuit, a positive displacement pump is a must. This is true for all modern hydraulic systems which provide fluid power. Gear, Vane, Piston are the examples of Positive Displacement Pump .

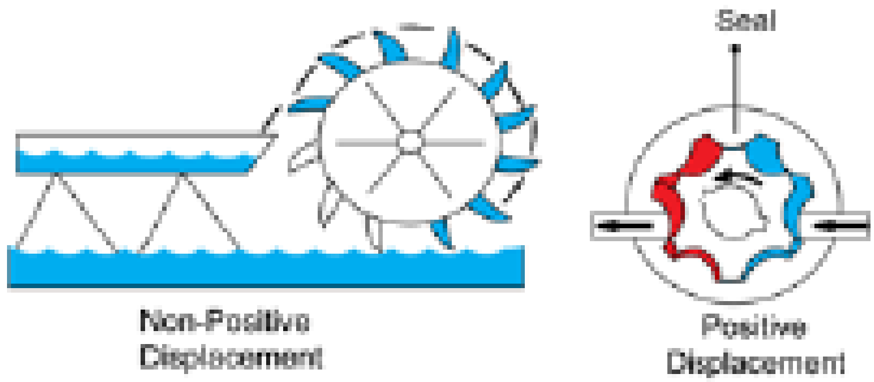


Figure 1-8 Positive and non-positive displacement hydraulic pumps

In low-pressure systems, such as water cooling or crop spraying types, the old non-positive displacement pump still works. Displacement is the volume of oil moved or displaced during each cycle of a pump. In this sense, hydraulic pumps fall into two broad types:

- Fixed Displacement Pumps
- Variable Displacement Pumps

Fixed displacement-Pumps move the same volume of oil with every cycle. This volume is only changed when the speed of the pump is changed. The pressure can affect volume in the system, but this is due to an increase in leakage back to the pump inlet. Usually this occurs when pressure rises. This leakage means that fixed displacement pumps are usually found in lower pressure systems or as aids to another pump in a higher-pressure system.

Variable displacement pumps can vary the volume of oil they move with each cycle-even at the same speed. These pumps have an internal mechanism which varies the output of oil, usually to maintain a constant pressure in the system. When system pressure drops, volume increases and as pressure rises, volume decreases. Remember: A hydraulic pump does not create pressure: it creates flow. Pressure is caused by resistance to flow.

Types of hydraulic pumps

A. Gear pumps

Gear pumps are of the fixed displacement type. They are widely used because they are simple and economical. While not capable of variable displacement, they can produce the volume needed by most systems using fixed displacement. Often they are used as charging pumps for larger system pumps of other types. Servo systems also make use of gear pumps. Basic types of gear pumps are used: External Gear Pumps and Internal Gear Pumps

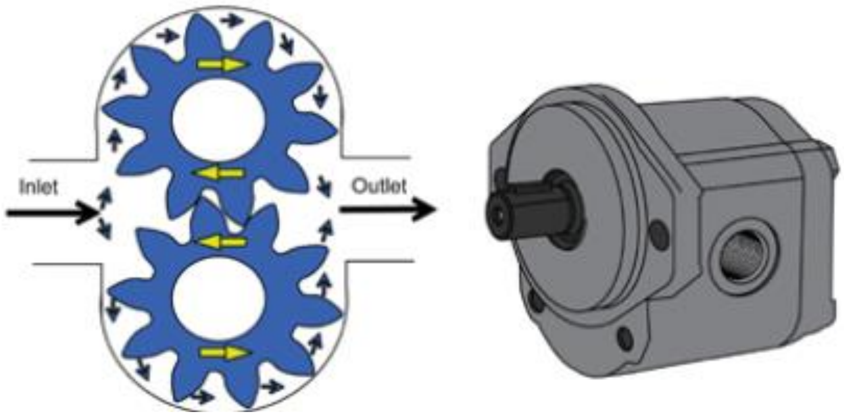


Figure 1-9 External gear pump

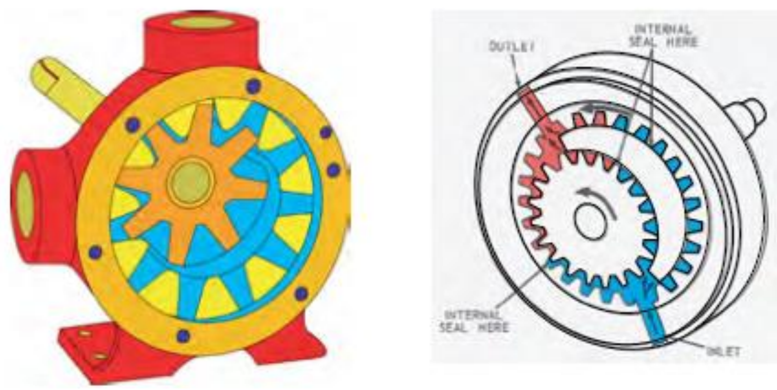


Figure 1-10 Internal gear pump

B. Vane pumps

Vane pumps are fairly versatile pumps and can be designed as single, double, or even triple units.

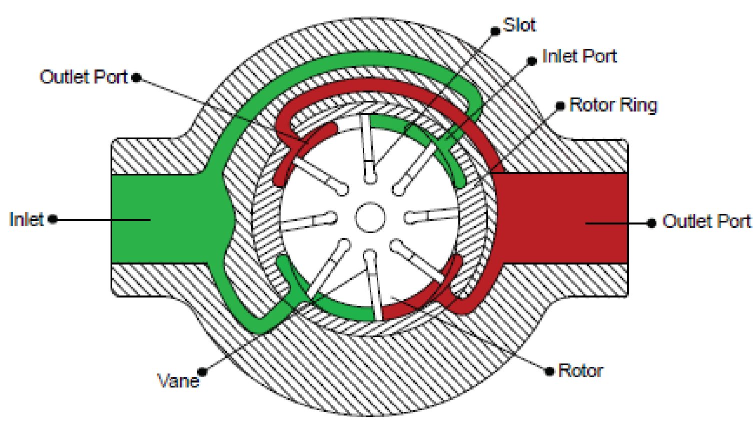


Figure 1-11 Balanced vane pump

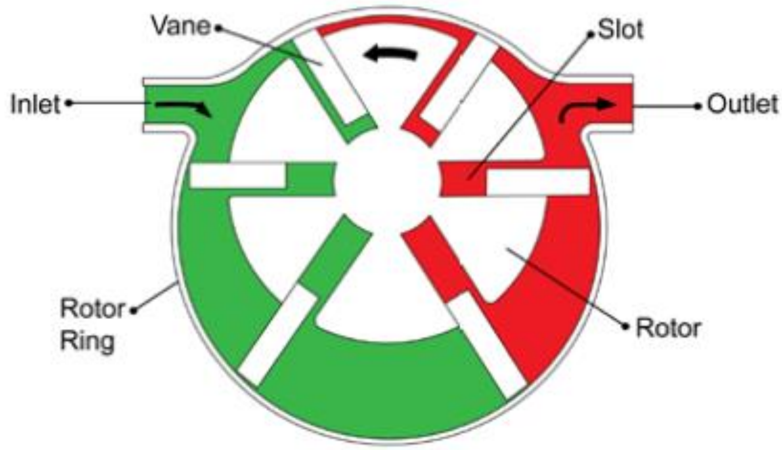


Figure 1-12 Unbalanced vane pump

All vane pumps move oil using a rotating slotted rotor with vanes fitted into the slots. Two types of vane pumps are most often used: Balanced Vane Pumps and Unbalanced Vane Pumps

The balanced vane pump is strictly a fixed displacement type. The unbalanced vane can have a fixed or a variable displacement.

C. Piston pumps

Piston pumps are often favored on modern hydraulic systems which use high speeds and high pressures. However, piston pumps are more complex and more expensive than the other two types. Piston pumps can be designed for either fixed or variable displacement.

- Axial Piston Pumps
- Radial Piston Pumps

In-line Axial Piston Pumps the cylinder block is mounted on a drive shaft and rotates with the shaft. The pistons work in bores in the cylinder block which are parallel to the axis of the block. The heads of the pistons are in contact with a tilted plate called a swashplate. The swashplate does not turn but it can be tilted back and forth. It mounts on a pivot and is controlled either manually or by an automatic “servo” device. When the swashplate is tilted as shown. As the cylinder block rotates, piston bores align with this port and oil is forced into the bores by the small charging pump. This oil pushes the pistons against the swashplate. Then as they revolve, these pistons follow the tilt of the swashplate and force the oil out of their bores into the outlet port. If the angle of the swashplate was fixed, the pump would operate as a fixed displacement type, putting out the same amount of oil with each revolution.

Figure 1-13 In-line swashplate and bend Axial piston pumps

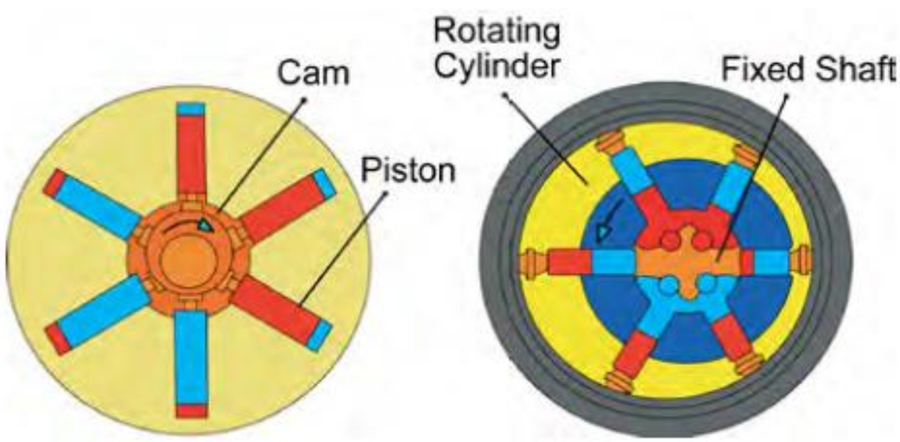


Figure 1-14 Radial piston pumps

Hydrostatic driven wheel loaders used to be equipped with bent axis hydraulic motors. Since more difference in speed and torque is needed, the latest type of wheel loaders are equipped with a axial piston pump, variable displacement, two directions of flow. The hydraulic motors are no longer of fixed displacement type but are variable and some Wheel loader have two of them fixed onto the transfer box (high and low speed).

Radial piston pumps are among the most sophisticated of all pumps. They are capable of high pressures, high volumes, high speeds, and variable displacement. The basic operation is simple, but by using extra valves and other devices, this pump can be adapted to many systems and needs. This pump is closely fitted, so wear can be a problem unless clean oil is used. And the oil must contain properties which lubricate the closely fitted parts.

1.2.3 Hydraulic Valves

Valves are the controls of the hydraulic system. They regulate the pressure, direction, and volume of oil flow in the hydraulic circuit. Valves can be divided into three major types:

- Pressure Control Valves
- Directional Control Valves
- Volume Control Valves

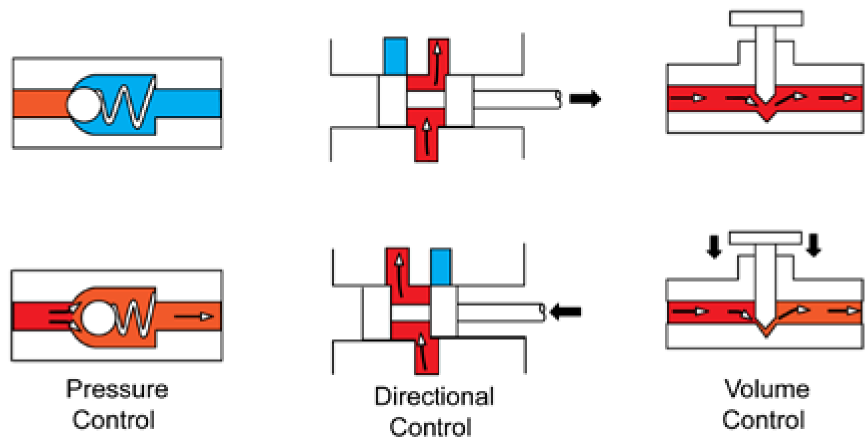


Figure 1-15 Different type hydraulic valves

- Pressure control valves are used to limit or reduce system pressure, unload a pump, or set the pressure at which oil enters a circuit. Pressure control valves include relief valves, pressure reducing valves, pressure sequence valves, and unloading valves.
- Directional control valves control the direction of oil flow within a hydraulic system. They include check valves, spool valves, rotary valves, pilot controlled poppet valves, and electrohydraulic valves.
- Volume control valves regulate the volume of oil flow, usually by throttling or diverting it. They include compensated and non-compensated flow control valves and flow divider valves

A. Relief valves

Each hydraulic system is designed to operate in a certain pressure range. Higher pressures can damage the components or develop too great a force for the work to be done. Relief valves remedy this danger. They are safety valves which release the excess oil when pressures get too high. Types of relief valves are used:

- Direct acting relief valves are simple open-closed valves.
- Pilot operated relief valves have a “trigger” which controls the main relief valve.

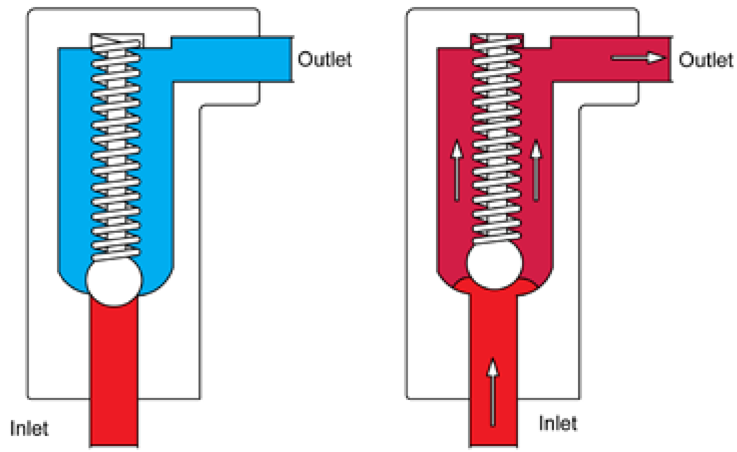


Figure 1-16 Direct acting relief valves

When a relief valve is needed for large volumes with little pressure differential, a pilot operated relief valve is often used. The pilot valve is a “trigger” which controls the main relief valve. It is usually a small, spring loaded relief valve built into the main relief valve. The main relief valve is closed when inlet oil pressure is below the valve setting. In (Figure 1-16) Passage (1) in the main valve (6) keeps it in hydraulic balance, while spring (5) holds it closed. The pilot valve (3) is also closed at this time. Inlet pressure through sensing passage (2) is less than the pilot valve setting.

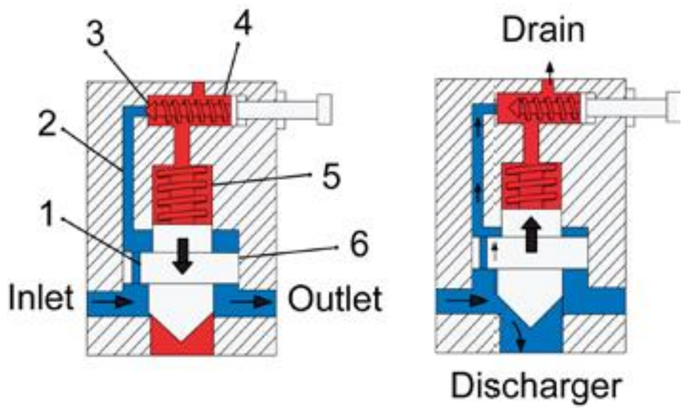


Figure 1-17 Pilot operated relief valves

B. Pressure reducing valves

A pressure-reducing valve is used to keep the pressure in one branch of a circuit below that in the main circuit. When not operating, a pressure-reducing valve is open. When it operates, it tends to close as shown.

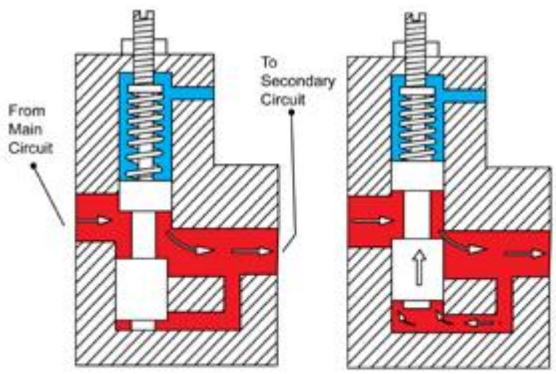


Figure 1-18 Pressure reducing valve

When pressure starts to rise in the secondary circuit, force is exerted on the bottom of the valve spool, partly closing it. Spring tension holds the valve against the oil pressure so that only enough oil gets past the valve to serve the secondary circuit at the desired pressure (The spring tension can be adjusted using the screw shown at the top) The pressure sensing for the valve comes from the outlet side, Or the secondary circuit. This valve operates the reverse of a relief valve, which senses pressure from the inlet and is closed when not operating. A pressure-reducing valve will limit maximum pressures in the secondary circuit, regardless of pressure changes in the main circuit, as long as the system workload does not create backpressure into the reducing valve port. Backpressure would close the valve completely

C. Pressure Sequence Valves

Pressure sequence valves are used to control the sequence of flow to various branches of a circuit. Usually the valves allow flow to a second function only after a first has been fully satisfied. When closed, the valve directs oil freely to the primary circuit. When opened, the valve diverts oil to a secondary circuit. The valve opens when pressure oil to the primary reaches a preset point (adjustable at the valve spring). The valve is then lifted off its seat as shown and oil can flow through the lower port to the secondary.

One use of the sequence valve is to regulate the operating sequence of two separate cylinders. The second cylinder begins its stroke when the first completes its stroke. Here the sequence valve keeps pressure on the first cylinder during the operation of the second. Sequence valves sometimes have check valves which allow a reverse free flow from the secondary to the primary, but sequencing action is provided only when the flow is from primary to secondary.

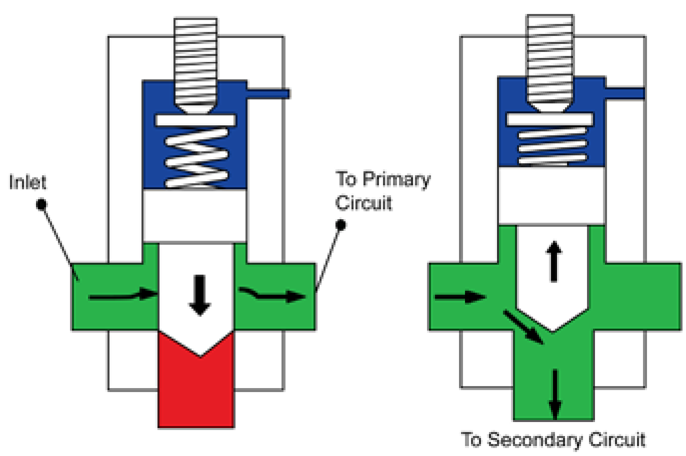


Figure 1-19 Pressure Sequence Valves

D. Unloading valves

The unloading valve directs pump output oil back to reservoir at low pressure after system pressure has been reached. They may be installed in the pump outlet line with a tee connection. In some hydraulic systems pump flow may not be needed during part of the cycle. If pump output has to flow through a relief valve at system pressure, much hydraulic energy is wasted as heat. This is where an unloading valve works best.

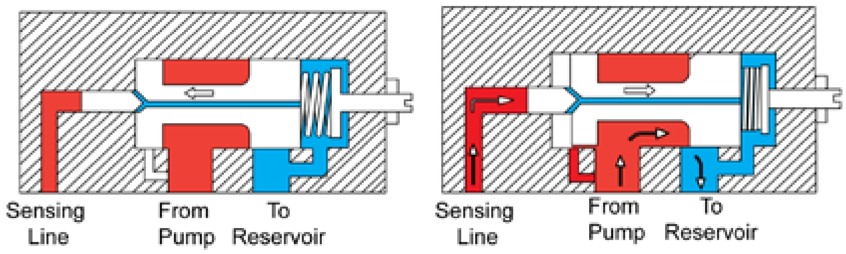


Figure 1-20 Unloading valve

When closed, spring pressure holds the valve on its seat. Sensing pressure at the other end of the valve is less than spring pressure. The reservoir outlet is closed and no unloading occurs. The valve opens when the sensing pressure rises and overcomes the spring thrust. The valve moves back, opening the outlet to the reservoir. Pump output oil is now diverted to the reservoir at low pressure.

E. Unloading Valves for Accumulator Circuits

An unloading valve is often used in an accumulator circuit to unload the pump after the accumulator is charged. The valve is closed while the pump charges the accumulator with oil. As the pressure rises it forces the small sensing piston against the large valve and compresses the spring. When accumulator pressure reaches that determined by the spring setting, the valve opens by passing oil and relieving the pump. At this time the low neutral pressure oil is directed to the large end of the large piston.

When the accumulator discharges and the system pressure drops, the spring moved the valve against the reduced system pressure in the small piston and the neutral pressure against the large end of the valve. This means the valve will close at a slightly lower pressure than it opens. This gives the valve an operating range and prevents chattering.

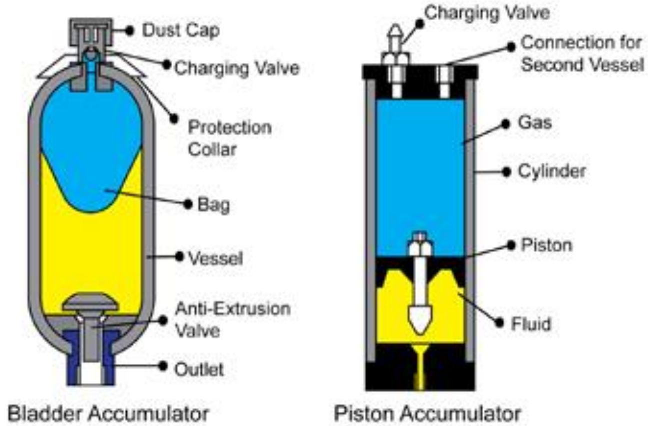


Figure 1-21 Unloading Valves for Accumulator Circuits

1.2.4 Accumulators

Accumulators used in hydraulic circuits perform the following roles:

- Store potential energy.
- Dampen shocks and pressure surges.
- Maintain a consistent pressure.

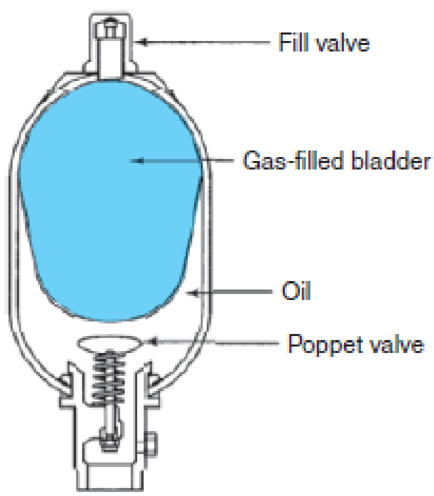


Figure 1-22: Gas filled accumulator

In an actual hydraulic circuit, an accumulator is usually used for a specific function in one of the foregoing roles. An accumulator that stores potential energy is often used to back up a hydraulic pump in the event of pump failure or at system start-up. For instance, in large offhighway dump trucks using hydraulically assisted brakes, in the event of oil supply failure, an accumulator is used to feed several charges of oil into the circuit to effect an emergency stop. Accumulators can also be used to dampen shock loads, control pressure surges, and ensure smooth operation of a hydraulic circuit. Although it uses a self-contained circuit, any vehicle shock absorber is a type of accumulator. In terms of operating principles, accumulators generally fall into one of three categories:

- Gas-loaded
- Weight-loaded
- Spring-loaded

1.2.5 Actuators

Hydraulic actuators convert the fluid power from the pump into mechanical work. In mobile hydraulic systems, actuators can be grouped as hydraulic cylinders and hydraulic motors. A hydraulic cylinder is a linear actuator. A hydraulic motor is a rotary actuator. Three types of hydraulic cylinders are used:

- Piston
- Vane
- Telescopic

A. Piston-Type Cylinders

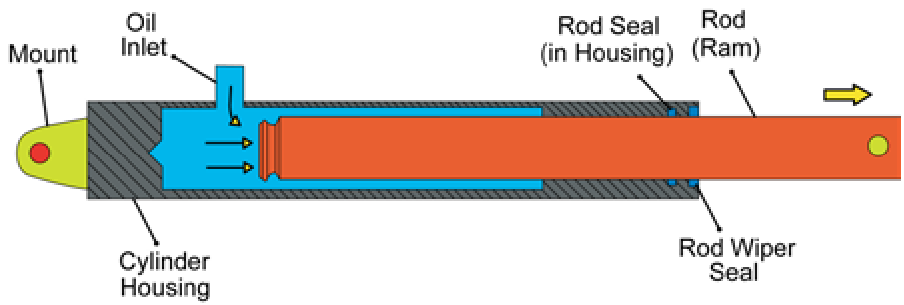


Figure 1-23 single acting cylinder

In hydraulics, both single acting and double-acting cylinders are used. In both types, a piston is moved linearly within the cylinder bore when it is subjected to pressurized oil. A single acting cylinder is hydraulically actuated in one direction only.

A double-acting cylinder is hydraulically actuated in both directions. In application, a dump box ram requires only a single-acting cylinder while the boom on an excavator requires a double acting cylinder.

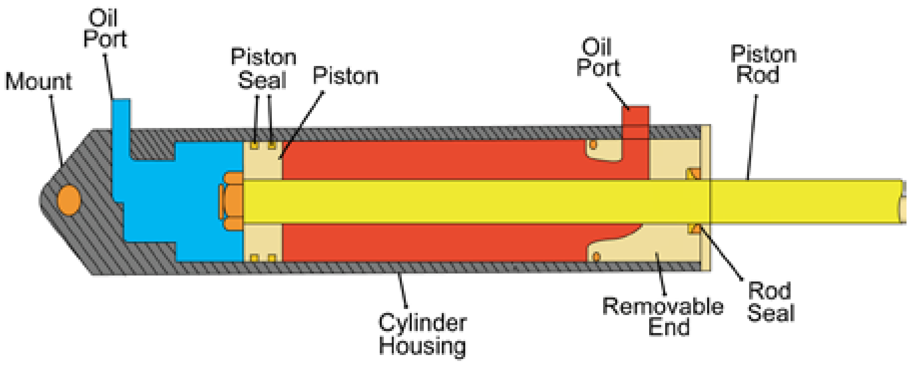


Figure 1-24 Double acting cylinder

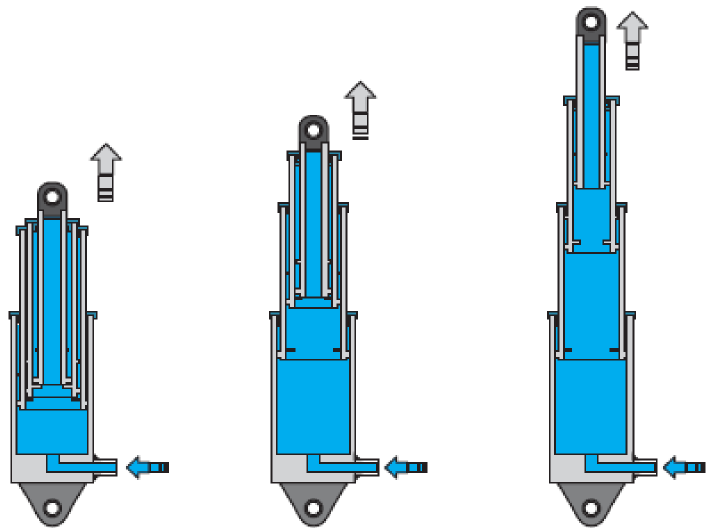


Figure 1-25 single acting telescopic cylinder

B. Hydraulic Motors

The function of hydraulic motors is opposite that of hydraulic pumps: Pump: draws in oil and displaces it, converting mechanical energy into fluid force. Motor: oil under pressure is forced in and spilled out, converting hydraulic energy into mechanical energy. A pump drives its fluid, while a motor is driven by fluid. Figure 1-25 shows this principle.

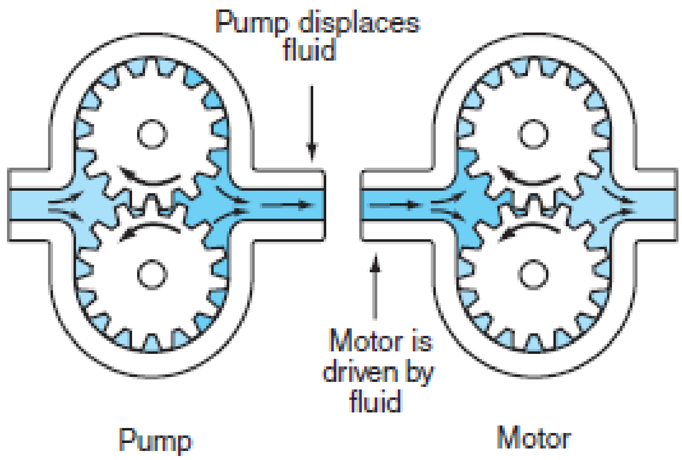


Figure 1-26 Hydraulic pump verses motor

The work output of a motor is in the form of twisting force that we describe as torque. Like pumps, motors can be either fixed displacement or variable displacement. In a fixed-displacement motor, the speed is varied by managing the input flow of oil: this type of motor usually has a fixed torque rating. Variable displacement motors can have both variable speeds and output torque.

There are three categories of hydraulic motors:

- Gear motors
- Vane motors
- Piston motors

All hydraulic motors rotate; they are driven by incoming hydraulic oil under pressure.

1.2.6 Conductors and Connectors

In any hydraulic circuit, the hydraulic medium has to conduct from the various components plumbed into the circuit. In mobile hydraulic equipment, hoses tend to function best as hydraulic conductors because they:

- Allow for movement and flexing
- Absorb vibrations

- Sustain pressure spikes
- Enable easy routing and connection on the chassis

A. Hydraulic Hoses

The selection of hoses in a hydraulic circuit is important because the hoses play a major role in determining how the system performs. The flow requirements of a conductor determine what the internal diameter of a hose should be. For instance, a hose that can withstand the pressure specification but has too small internal diameter will restrict circuit flow, causing overheating and pressure losses. The size of any hydraulic hose is determined by its inside diameter.

B. Couplers (Connectors)

Hydraulic hose couplers (also known as connectors and fittings) are made of steel, stainless steel, brass, or fiber composites. Hose couplers or fittings can either be reusable or permanent. Hose fittings are installed at the hose ends and the mating end consists of either a nipple (male fit) or a socket (female fit).

C. Pipes and Tubes

Pipes used in hydraulic circuits are generally made from cold drawn, seamless, mild steel. The pipe should never be galvanized because the zinc can flake off and plug up hydraulic circuits. Tubing can also be used, and it has the advantage of being able to sustain some flex, hence its use in vehicle brake systems. Tubing should be manufactured from cold drawn steel if used in moderate- to high-pressure circuits. For low-pressure circuits, copper or aluminum tubing may be used.

1.2.7 Hydraulic Fluids

Hydraulic fluid is the medium used to transmit force through a hydraulic circuit. Most hydraulic fluids are refined from petroleum-base stocks and are seldom compatible with vehicle brake fluids. Hydraulic fluids used in hydraulic systems are usually specialty hydraulic oils, but engine and transmission oils can also be used. Always check when adding or replacing hydraulic oil. Synthetic hydraulic oils are commonly used in today's hydraulic circuits because they have wider temperature operating ranges and offer greater longevity. Hydraulic oils must perform the following:

- Act as hydraulic media to transmit force.
- Lubricate the moving components in a hydraulic circuit.
- Resist breakdown over long periods of time.
- Protect circuit components against rust and corrosion.
- Resist foaming.
- Maintain a relatively constant viscosity over a wide temperature range.
- Resist combining with contaminants such as air, water, and particulates.
- Conduct heat

1.3 Symbols, schematic diagrams, graphs, and drawing

1.3.1 Symbols and Schematics

When working with vehicle hydraulic schematics, it is important to be able to interpret standard symbols. Symbols are two-dimensional figures that roughly approximate the components they represent in a hydraulic schematic. The symbols used in hydraulic schematics are standardized by the American National Standards Institute (ANSI) and by the International Standards Organization (ISO). This helps make life easier because most manufacturers today use either ANSI or ISO symbols in their schematics. The graphics used in hydraulic schematics consist of shapes and marks.

The basic shapes used in hydraulic schematics are:

- Circle/semicircle-indicates a pump or motor symbol.
- Square (or envelope)-represents one position or path through a valve. Two squares together indicate a two-position valve.
- Diamond-indicates a component that conditions fluid in the circuit, such as a filter or heat exchanger.
- Rectangle-indicates a hydraulic cylinder or reservoir.

A symbol is drawn by using one of the four basic shapes above and adding the appropriate marks. Typical marks include:

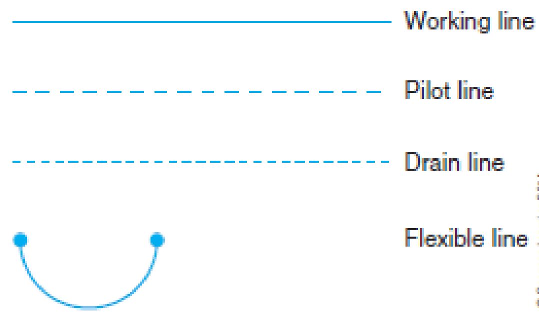


Figure 1-27 Conductor symbols

- Solid lines-indicate the flow route for hydraulic fluid.
- Dashed lines-indicate a pilot line that connects control circuit to a slave circuit.
- Dotted lines-indicate a return or exhaust circuit.
- Center lines-enclose assemblies.
- Arrows-show the direction of fluid flow or rotational direction of pumps and motors. Arrows at 45-degree angle indicate an adjustment point. A vertical arrow in a component indicates pressure.
- Arcs-show points of adjustment in the circuit such as the flow-control valve.

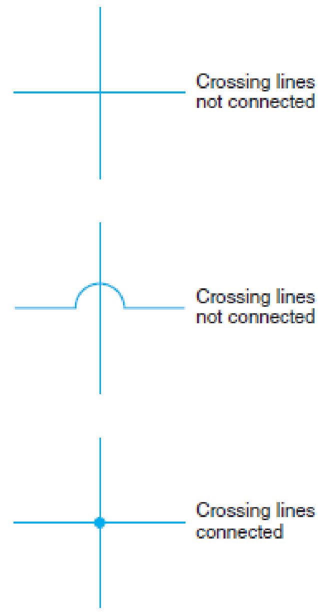


Figure 1-28 Intersecting lines

Lines on a schematic represent conductors. Solid lines indicate inlet, pressure, or return circuits. Broken lines with long dashes usually indicate pilot or control lines, while lines of short dashes indicate leakage oil. An arced line (that is not semicircular) between two dots indicates a flexible hose. Figure 1-26 shows how conductors are typically represented on a hydraulic schematic.

A semicircular loop on one line crossing another indicates that the two lines are not hydraulically connected. However, sometimes crossing (but not hydraulically connected) lines simply cross each other. In the event that a pair of intersecting lines are hydraulically connected, a dot is shown at the intersection point. These three arrangements are shown in Figure 1-27.

A. Reservoir Symbols.

A horizontal rectangle is used in schematics to represent a reservoir. A pressurized reservoir is indicated when the rectangle is drawn fully enclosed as indicated in Figure 1-28. A vented-to atmosphere reservoir is indicated when the rectangle is open at the top as indicated in Figure 1-28.

The way in which lines are shown entering a rectangle symbol is also of significance. Either a line terminating above the rectangle or before its base indicates that return flow is above the fluid, whereas one that is drawn contacting the base of the rectangle indicates a line that terminates below the fluid level.

All these symbols are shown in Figure 1-28. Lines connected to a reservoir are usually drawn from the top, regardless of where the connection is made on the actual component. Every reservoir has at least two hydraulic lines connected to it and can have many more. Because numerous components in a hydraulic circuit may depend on a single reservoir, the reservoir symbol is often repeated rather than creating a scramble of return lines all over the schematic. In most cases, the reservoir symbol is the only one to be repeated on a schematic; you can regard it in the same way a ground symbol is regarded on an electrical schematic.

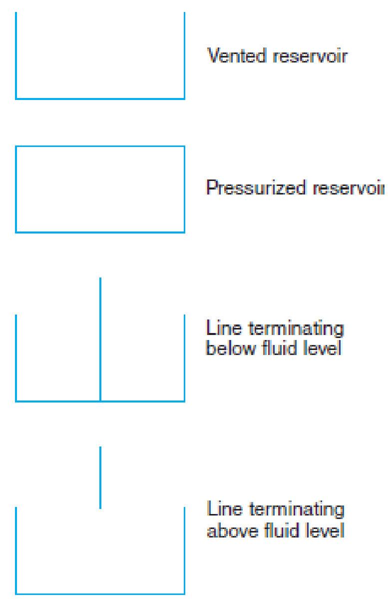


Figure 1-29 Reservoir symbols

B. Pump and Motor Symbols.

Pump and motor symbols are similar in appearance. Both use a circle. A hydraulic pump is indicated when the small triangle at the output line (within the circle) is shown pointing outward (see Figure 1-29).

A hydraulic motor is indicated when the small triangle at the inlet line (within the circle) is shown pointing inward (see right end in Figure 1-29).

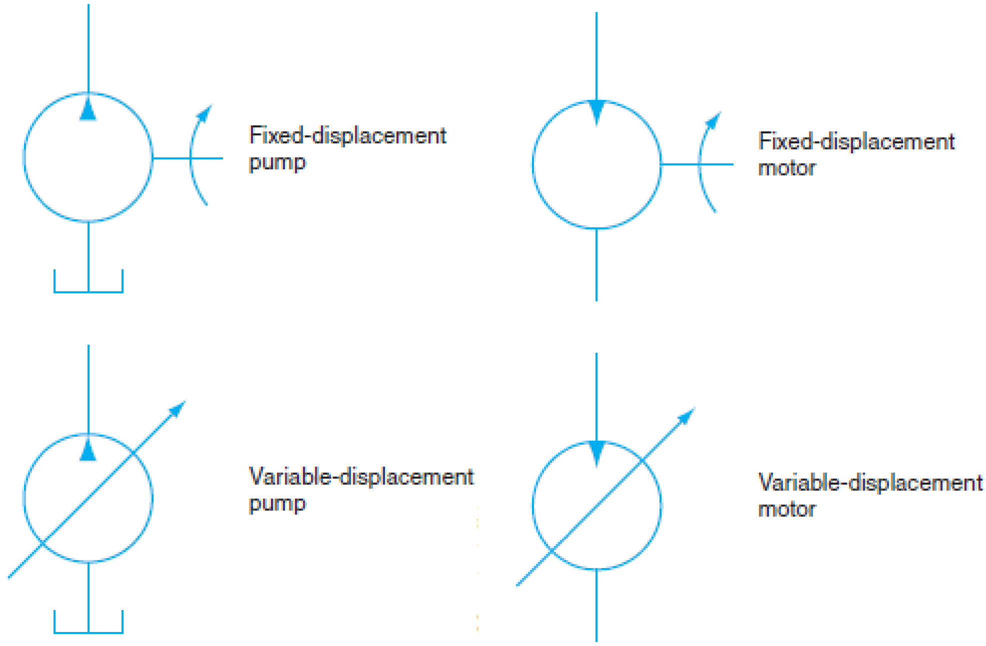


Figure 1-30 Fixed- and variable-displacement hydraulic pump (left) and motor (right)

C. Valve Symbols

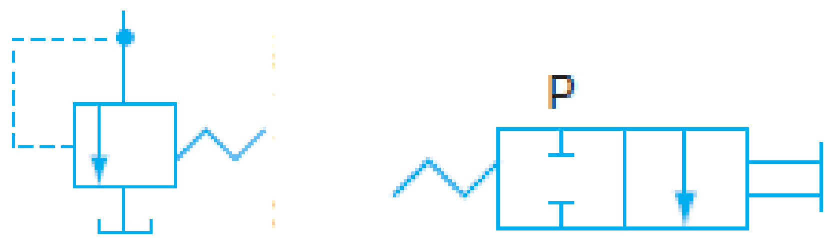


Figure 1-31 Pressure relief valve (left) and Two-position, two-way valve (right) symbol

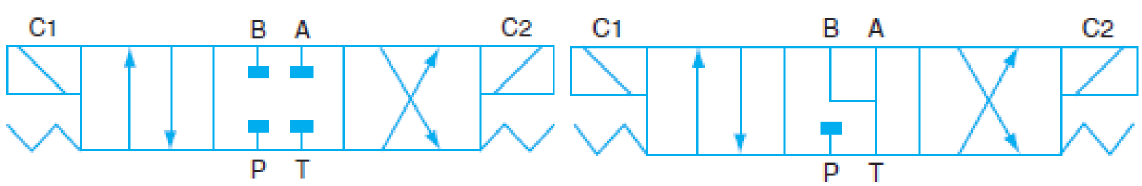


Figure 1-32 Three-position, four-way valve (left) and Alternate three-position, four-way valve (right) symbol

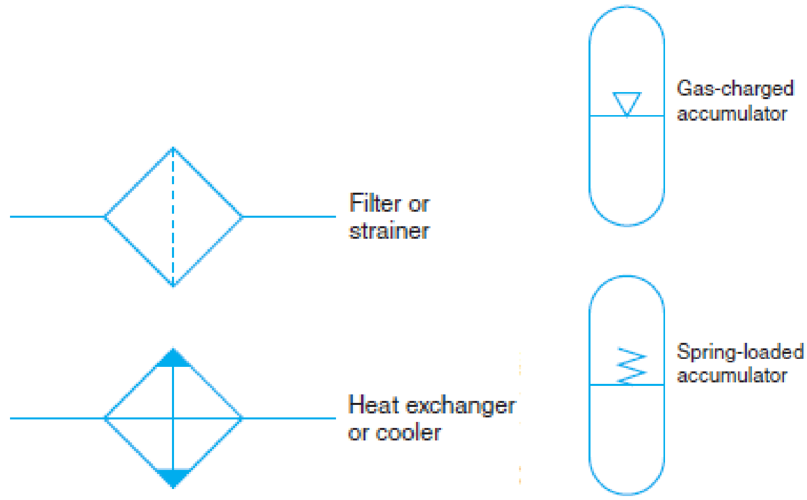


Figure 1-33 Symbols for filters and strainers (left) and accumulator symbols (right)

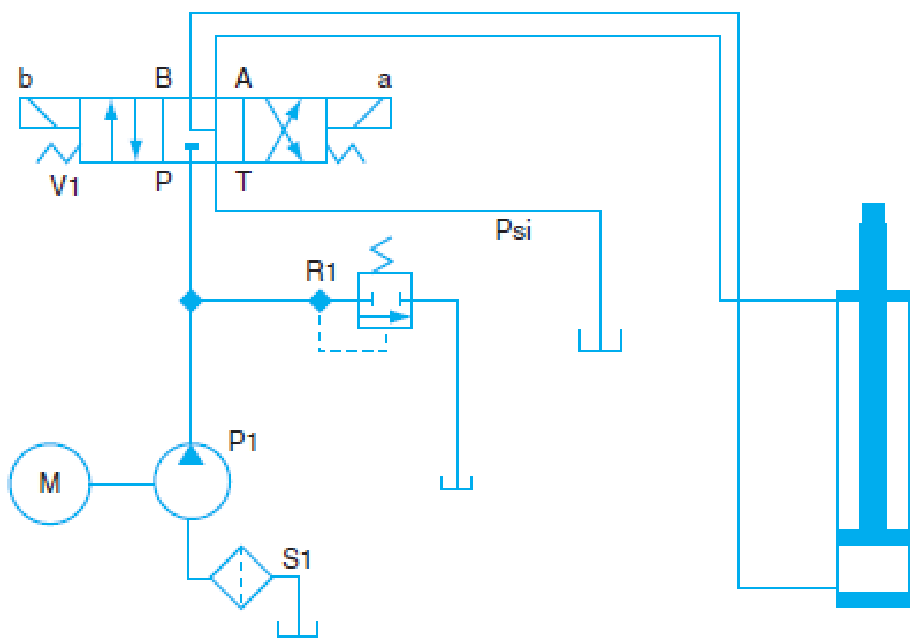
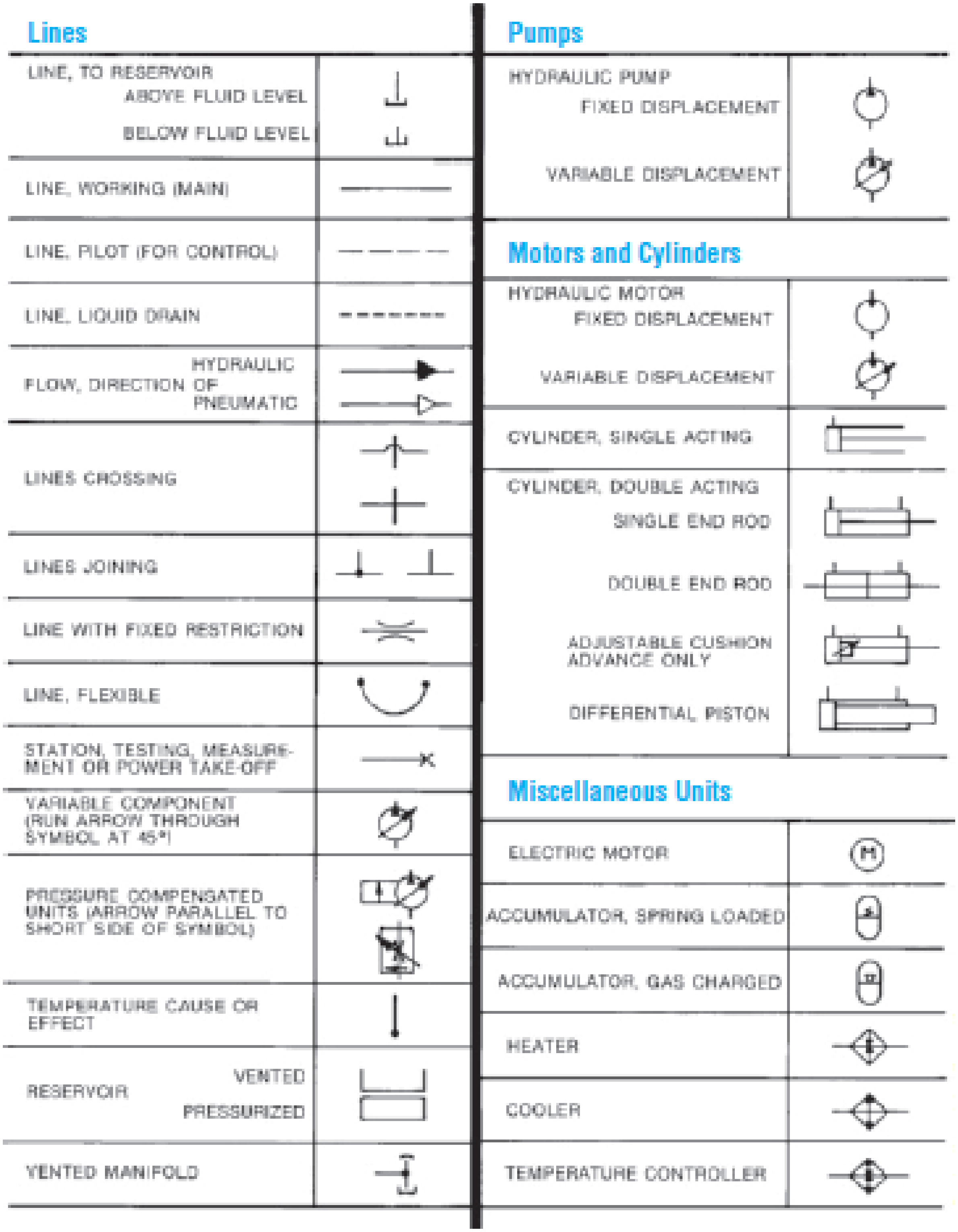


Figure 1-34 Simple hydraulic circuit used to actuate a cylinder


Lines
LINE, TO RESERVOIR
ABOVE FLUID LEVEL
BELOW FLUID LEVEL
LINE, WORKING (MAIN)
LINE, PILOT (FOR CONTROL)
LINE, LIQUID DRAIN
HYDRAULIC
FLOW, DIRECTION OF
PNEUMATIC
LINES CROSSING
LINES JOINING
LINE WITH FIXED RESTRICTION
LINE, FLEXIBLE
STATION, TESTING, MEASUREMENT OR POWER TAKE-OFF
VARIABLE COMPONENT (RUN ARROW THROUGH SYMBOL AT 45°)
PRESSURE COMPENSATED UNITS (ARROW PARALLEL TO SHORT SIDE OF SYMBOL)
TEMPERATURE CAUSE OR EFFECT
RESERVOIR
VENTED
PRESSURIZED
VENTED MANIFOLD
Pumps
HYDRAULIC PUMP
FIXED DISPLACEMENT
VARIABLE DISPLACEMENT
Motors and Cylinders
HYDRAULIC MOTOR
FIXED DISPLACEMENT
VARIABLE DISPLACEMENT
CYLINDER, SINGLE ACTING
CYLINDER, DOUBLE ACTING
SINGLE END ROD
DOUBLE END ROD
ADJUSTABLE CUSHION ADVANCE ONLY
DIFFERENTIAL PISTON
Miscellaneous Units
ELECTRIC MOTOR
ACCUMULATOR, SPRING LOADED
ACCUMULATOR, GAS CHARGED
HEATER
COOLER
TEMPERATURE CONTROLLER

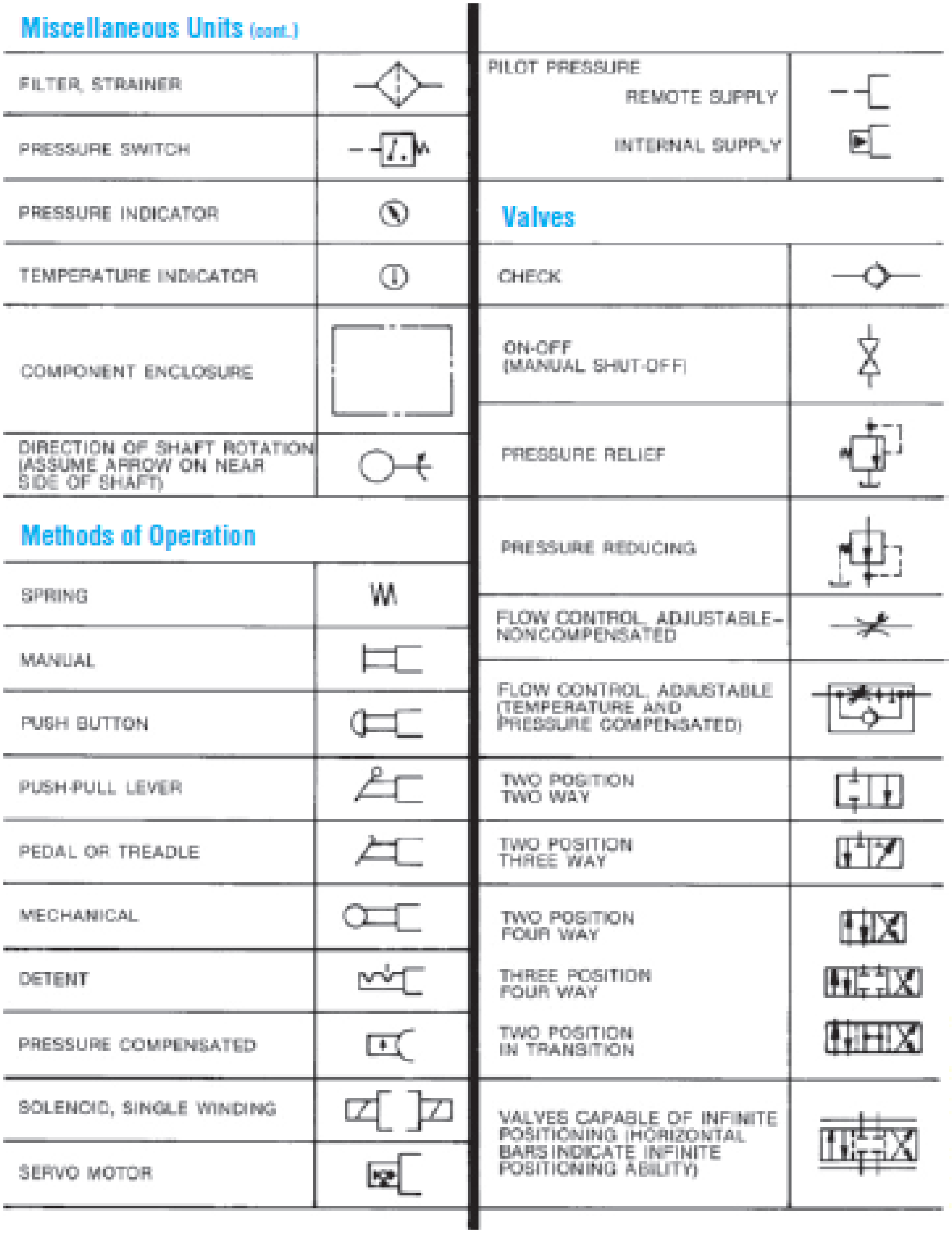


Figure 1-35 ISO/ANSI schematic symbols

1.3.2 Hydraulic circuit diagrams

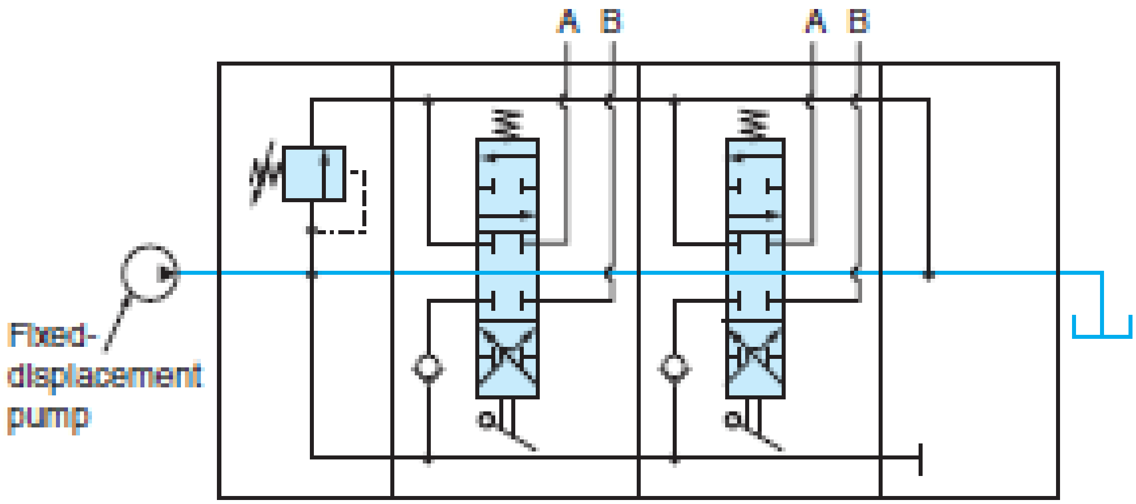


Figure 1-36 Open-center schematic.

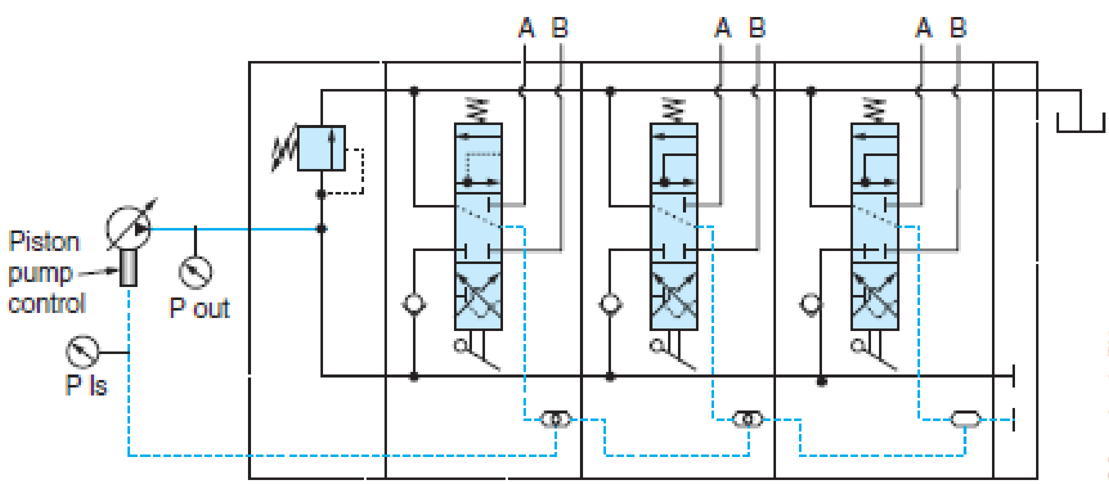


Figure 1-37 Closed-center schematic load sensing

Self-check-

Instruction: Choose the best answer and circle the letter corresponds to best answer

1 What force moves the fluid through the circuit upstream to the hydraulic pump when a vented reservoir is used in a hydraulic system?

A. vacuum
B. atmospheric pressure
C. hydraulic pressure
D. return pressure

2 How much linear force is generated when a hydraulic force of 1000 psi acts on a sectional area of 50 sq. in?

A. 50 pounds
B. 5,000 pounds
C. 50,000 pounds
D. 500,000 pounds

3 Which of the following is a measure of flow rate?

A. psi
B. gpm
C. BHP
D. lb/ft

4 When a hydraulic pump discharges the same slug volume it picks up per cycle, it should be described as:

A. variable-displacement
B. constant cycle
C. positive displacement
D. non-positive cycle

5 Which of the following is not a function of a hydraulic accumulator?

A. dampens pressure surges
B. stores potential energy
C. maintains consistent circuit pressure
D. charges hydraulic actuators

6 Which valve is classified as a pressure-control valve?

A. check valve
B. relief valve
C. priority valve
D. directional control valve

2. Unit Two: Modification of Automotive Hydraulic Systems

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Introduction to System modification
- Requirements of hydraulic system modification
- Typical Modifications Applicable to Automotive Hydraulic System
- Significant modifications requiring certification
- Preliminary analysis of the impacts of modification
- Assessing and interpreting benchmark specifications

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Introduce to System modification
- Mention requirements of hydraulic system modification
- Typical Modifications Applicable to Automotive Hydraulic System
- Significant modifications requiring certification
- Analyse preliminary impacts of modification
- Assess and interpret benchmark specifications

2.1 Introduction to Hydraulic System Modification

Hydraulic systems are integral to many applications, including automotive, industrial, aerospace, and manufacturing, due to their ability to provide high force with relatively simple components. These systems typically rely on the transmission of power through pressurized fluid to perform tasks like lifting, pushing, or braking. However, in some cases, hydraulic systems need to be modified or upgraded to meet new requirements, improve performance, adapt to different applications, or enhance efficiency.

Hydraulic system modification: involves altering or upgrading the existing hydraulic components, layout, or control mechanisms of the system to suit new operational conditions, increase efficiency, or provide better control. Modifications can range from replacing individual components to completely overhauling the system to improve its capacity, responsiveness, and reliability.

2.1.1 Reasons for Hydraulic System Modification

A. Improved Performance:

- Modifications can enhance the system's efficiency, such as improving the speed of response, increasing the load-handling capacity, or reducing energy consumption.
- For example, replacing outdated pumps with higher efficiency ones can reduce power loss and improve overall system efficiency.

B. Adapting to New Applications:

- A hydraulic system designed for one purpose may need to be modified to suit a different application. For example, an automotive hydraulic system in a passenger car might need modifications to accommodate larger payloads in a utility vehicle or to enhance comfort in a luxury vehicle.
- In industrial settings, a hydraulic press may be modified to handle a different material or perform a different function.

C. System Upgrade:

- Over time, technological advancements in hydraulic components such as pumps, valves, and accumulators may make it beneficial to upgrade older systems to keep up with modern standards.

- For example, upgrading from a mechanical to an electronically controlled hydraulic system can provide more precise control and reduce wear on components.

D. Increased Safety:

- In some cases, hydraulic systems may need modifications to meet newer safety standards or mitigate risks like overpressure, overheating, or fluid leaks. Upgrading the safety features such as pressure relief valves or monitoring systems can help prevent accidents.
- Introducing sensors for temperature, pressure, and flow rate can provide real-time data for safety and troubleshooting.

E. Cost Reduction:

- Hydraulic systems can sometimes be modified to reduce operational costs, such as improving energy efficiency by replacing inefficient components or by using alternative hydraulic fluids that are cheaper or environmentally friendly.
- Optimizing the layout or design of the system to reduce the length of piping or number of components can also minimize maintenance costs and improve reliability.

F. Maintenance and Longevity:

- Modifications can enhance the durability and longevity of hydraulic systems by replacing worn-out or outdated parts with more durable, modern components.
- Regular modifications and upgrades can help reduce downtime, minimize repairs, and prolong the lifespan of the system.

2.1.2 Common Types of Hydraulic System Modifications

A. Component Replacement or Upgrades:

- Pumps: Swapping out a pump for a more efficient or higher capacity model.
- Valves: Replacing control valves or pressure-relief valves for more precise control or improved safety.
- Hydraulic Cylinders: Upgrading cylinders for greater force, stroke length, or durability.

- Filters: Upgrading filtration systems to improve fluid cleanliness and prevent component wear.

B. System Configuration Changes:

- Piping and Tubing: Modifying the layout of hydraulic lines to optimize fluid flow and reduce losses or pressure drops.
- Fluid Reservoirs: Expanding or improving the design of the reservoir to increase fluid capacity, improve cooling, or reduce contamination.
- Fluid Cooling Systems: Installing or upgrading cooling systems (like oil coolers) to maintain optimal fluid temperatures for efficiency and longevity.

C. Control System Modifications:

- Automation and Electronics: Adding electronic controls such as sensors, programmable logic controllers (PLCs), or variable speed drives to improve control and adaptability in real-time operations.
- Hydraulic Circuit Modifications: Reconfiguring circuits for better pressure or flow control, or adding accumulators to store energy and smooth out pressure variations.

D. Leak Prevention and Sealing:

- Seals and Gaskets: Replacing old seals to prevent fluid leaks, improve pressure retention, and reduce contamination risks.
- Improved Sealing Materials: Using advanced sealing materials to cope with higher pressures, temperatures, or specific chemical environments.

E. Integration of New Technologies:

- Integrating smart sensors to monitor hydraulic pressure, flow rate, and temperature, providing real-time feedback and enhancing control over the system’s performance.
- Implementing energy recovery systems, such as hydraulic hybrids or regenerative braking systems, to capture and reuse energy in systems like electric or hybrid vehicles.

2.1.3 Requirements of Automotive hydraulic system modification

When modifying an automotive hydraulic system, several key requirements must be met to ensure that the modification is effective, safe, and aligned with the vehicle's performance goals. These requirements include considerations related to system compatibility, safety, efficiency, cost, and regulatory standards. Below are the primary requirements for modifying an automotive hydraulic system:

A. Compatibility with Existing System

- System Integration: Any modifications must be compatible with the existing hydraulic system. This includes ensuring that new components, such as pumps, valves, cylinders, or actuators, are compatible with the system's pressure, flow rate, and fluid type.
- Component Matching: New components must be selected based on their ability to integrate seamlessly with existing components. For example, upgrading a pump might require adjustments in the piping, reservoir size, or valve specifications.
- Hydraulic Fluid Compatibility: If any parts of the system are replaced (e.g., seals, hoses), it's important to ensure that they are compatible with the existing hydraulic fluid in terms of viscosity, chemical properties, and temperature range.

B. System Efficiency and Performance Enhancement

- Improved Power Transmission: The modification should enhance the overall efficiency of the system. This may involve upgrading pumps for better flow or pressure handling, using more efficient valves, or optimizing the hydraulic circuit to reduce losses.
- Optimizing Flow and Pressure: Hydraulic systems in automotive applications often rely on precise flow and pressure control. Modifications must maintain or improve the performance characteristics of these systems, such as ensuring that pressure relief valves are set to appropriate levels and that the system can operate efficiently under varying loads.
- Reduced Energy Consumption: A modification might aim to reduce the energy consumption of the hydraulic system by using more efficient components or

optimizing system configuration. This can include replacing an inefficient pump with a variable displacement model or integrating energy recovery systems.

C. Safety Considerations

- Overpressure Protection: Hydraulic systems need reliable protection against overpressure conditions. Modifications should ensure that pressure relief valves are correctly rated and located to prevent damage to system components.
- Leak Prevention: All hydraulic lines, hoses, and seals must be leak-proof to avoid fluid loss, contamination, and fire hazards. Modifying seals or incorporating better sealing materials might be required.
- Pressure Monitoring and Controls: Adding sensors for real-time pressure monitoring can help prevent dangerous pressure spikes or drops. This can help maintain optimal system performance and ensure safe operation.
- Emergency Fail-Safes: Incorporating fail-safe mechanisms such as emergency pressure relief, pressure shutdown systems, or backup hydraulic pumps can ensure safety if the system fails.

D. Cost-Effectiveness

- Cost-Benefit Analysis: The benefits of the modification should outweigh the costs. For instance, modifying the hydraulic system to improve efficiency or performance should result in long-term savings through reduced fuel consumption, reduced maintenance, or increased vehicle lifespan.
- Affordable Components: While upgrading to more efficient or advanced components may offer better performance, it's important to ensure the modifications don't make the vehicle overly expensive or introduce excessive costs that outweigh the benefits.
- Maintenance Considerations: Modifications should be made with an eye toward ease of maintenance. Complex modifications that require specialized tools or knowledge could result in higher long-term maintenance costs.

E. Compliance with Industry Standards and Regulations

- Environmental Regulations: Modified hydraulic systems must comply with environmental standards, particularly those regarding the use of hydraulic fluids (e.g., non-toxic, biodegradable fluids) and the management of any fluid leaks.
- Safety Standards: Compliance with local and international safety standards (e.g., SAE, ISO) is critical. The modification should meet or exceed the regulatory requirements for the vehicle, including standards for hydraulic pressure, fluid quality, and safety.
- Certification and Testing: Some modifications may require testing or certification, especially if the vehicle is to be used in commercial or industrial settings. This ensures that the modifications meet legal and operational standards.
- Vehicle Manufacturer Specifications: It's important to adhere to the original manufacturer's guidelines, especially if the modification affects a critical component like braking or steering. Some manufacturers may require specific approvals for modifications to the hydraulic system to avoid voiding warranties.

F. Long-Term Reliability and Durability

- Wear Resistance: Any modified hydraulic component must be durable enough to handle the expected loads and operational conditions over the vehicle's lifespan. This includes ensuring that parts are resistant to wear, corrosion, and fatigue, particularly in harsh driving conditions.
- Corrosion Resistance: Materials used in the hydraulic system, such as pipes, cylinders, and pumps, should be resistant to corrosion from hydraulic fluid and external elements (e.g., moisture, road salt). Modifications might include switching to corrosion-resistant materials or adding protective coatings.
- Lifecycle Considerations: Consideration should be given to the full lifecycle of the modified system, including ease of replacement or servicing over time. Components should be chosen based on their expected durability and ease of maintenance.

G. Improved Control and Precision

- Precision Control: For systems requiring precise control (e.g., active suspension or automatic transmission), modifications may involve adding or upgrading electronic control systems that manage hydraulic pressure, flow, and actuation more accurately.

- Automation: Modifications can include upgrading the system to include automation, such as electronically controlled valves or actuators, allowing for better integration with modern vehicle control systems and improving performance in adaptive systems.
- Integration with Vehicle Systems: If modifying an automotive hydraulic system like the power steering or suspension, ensuring the hydraulic system is well integrated with the vehicle's electronic control systems (e.g., CAN bus or ECU) is essential for optimized performance.

H. Space and Weight Considerations

- Compact Design: Many modifications aim to reduce the size of the hydraulic system components to save space in a vehicle, which can be critical for meeting design goals or improving fuel efficiency.
- Weight Reduction: Modifications should ideally reduce the overall weight of the hydraulic system or vehicle without compromising performance. This can be achieved by using lightweight materials or optimizing the design to eliminate unnecessary components.
- Layout Optimization: Redesigning the hydraulic circuit layout to improve fluid flow efficiency and reduce the number of parts or fluid loss points can save space and weight.

I. Fluid Handling and Quality

- Filtration and Fluid Quality: The quality of the hydraulic fluid is critical to system performance. Modifying the system may include upgrading or improving the filtration system to ensure clean fluid, which helps extend component life and prevent system failures.
- Fluid Containment: Any modifications that introduce higher pressures or larger volumes of hydraulic fluid must include adequate containment measures to prevent spills or leaks, especially in automotive applications where fluid leakage can cause serious problems.

Modifying an automotive hydraulic system requires a thorough understanding of the system's current design and performance goals, as well as the vehicle's overall requirements. A successful modification should enhance system performance, safety, and durability while maintaining compatibility, compliance with regulatory standards, and cost-effectiveness. By carefully considering the above requirements, automotive hydraulic system modifications can improve efficiency, driving experience, and vehicle longevity.

2.1.4 Automotive Hydraulics System Applicable for modifications

Automotive hydraulic systems are critical for various functions, including braking, steering, suspension, and power transmission. Many of these systems are subject to modification to improve performance, enhance safety, reduce maintenance, or adapt to new technologies. Below are the main automotive hydraulic systems that are applicable for modification:

A. Modification of Hydraulic Brake System

- Modification Objectives:
  - ➢ Enhanced Stopping Power: Upgrading brake components such as the master cylinder, calipers, or rotors can improve braking force and performance.
  - ➢ Improved Brake Fluid and Cooling: Modifying the brake fluid to a higher performance fluid or adding an enhanced cooling system can prevent brake fade and overheating under extreme conditions.
  - ➢ ABS (Anti-lock Braking System) Integration: Adding or upgrading an ABS system for better control under emergency braking scenarios.
  - ➢ Performance Pads/Rotors: Upgrading to high-performance brake pads and rotors for better heat dissipation and braking power, especially for performance or off-road vehicles.
- Benefits of Modification:
  - ➢ Enhanced braking efficiency.
  - ➢ Reduced brake fade and overheating.
  - ➢ Improved safety and vehicle handling.

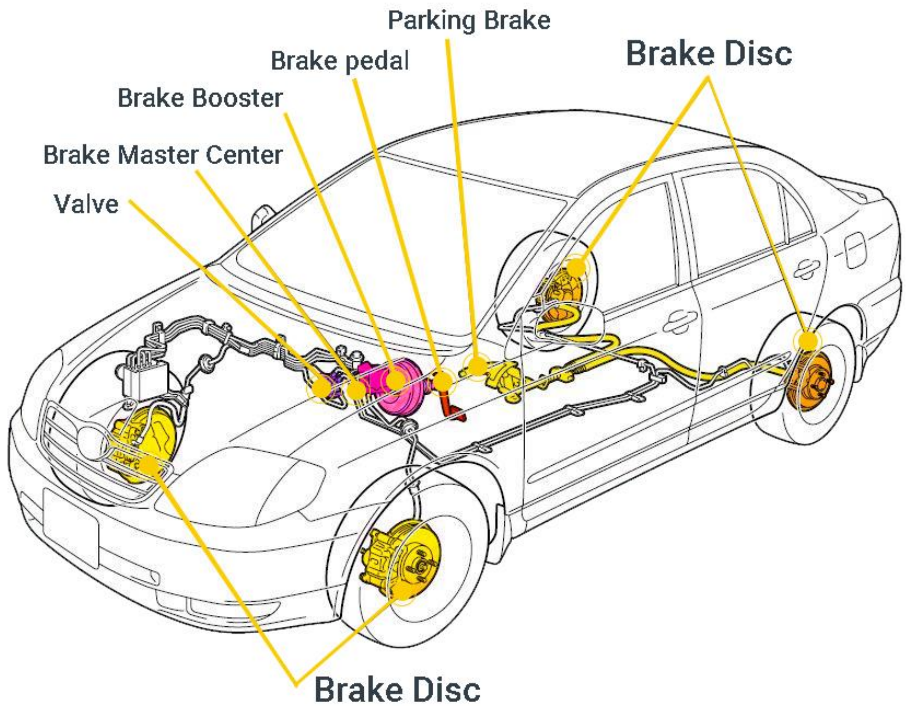


Figure 2-2-1: Hydraulic brake system

B. Power Steering System

- Modification Objectives:
  - ➢ Upgraded Steering Pump: A more efficient hydraulic pump can provide better power steering assistance, especially for vehicles with larger tires or off-road applications.
  - ➢ Variable Assist Steering: Adding or upgrading to a variable assist steering system that adjusts the steering effort based on speed and road conditions, improving handling and comfort.
  - ➢ Fluid Change or Additions: Using advanced hydraulic fluids that offer improved lubrication and heat resistance, which can increase system longevity and performance.
  - ➢ Electric-Hydraulic Steering Systems: In some cases, transitioning from a traditional hydraulic power steering system to an electric-hydraulic hybrid system can provide better fuel efficiency and reduce weight.
- Benefits of Modification:

- Reduced steering effort, especially in larger or more specialized vehicles.
- Enhanced handling and responsiveness.
- Better steering feel and feedback, particularly in performance vehicles.

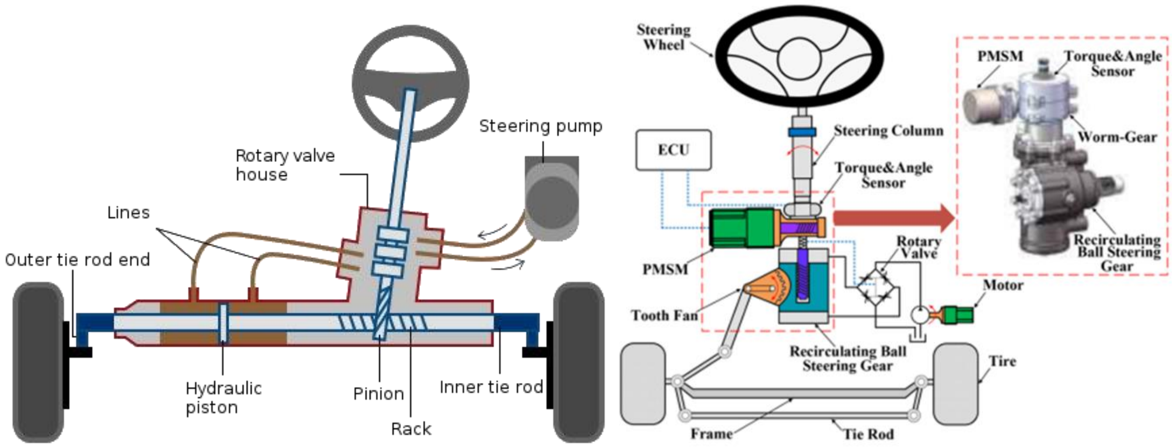


Figure 2-2-2: Hydraulic power steering system

C. Automatic Transmission System

- Modification Objectives:
  - Transmission Fluid Upgrade: Switching to a high-performance transmission fluid can improve the fluid's heat resistance, viscosity, and overall efficiency.
  - High-Flow Pumps: Upgrading to a high-flow hydraulic pump can increase the transmission's ability to handle higher performance or heavier loads.
  - Control Valve Reconfiguration: Modifying the valve body and solenoids can help optimize gear-shifting performance and responsiveness, especially in racing or performance vehicles.
  - Torque Converter Modifications: Installing a performance torque converter to improve power transfer and responsiveness in high-performance or racing vehicles.
- Benefits of Modification:
  - Smoother, faster shifting.
  - Improved transmission performance, especially in performance or heavy-duty vehicles.
  - Increased overall durability of the transmission system.

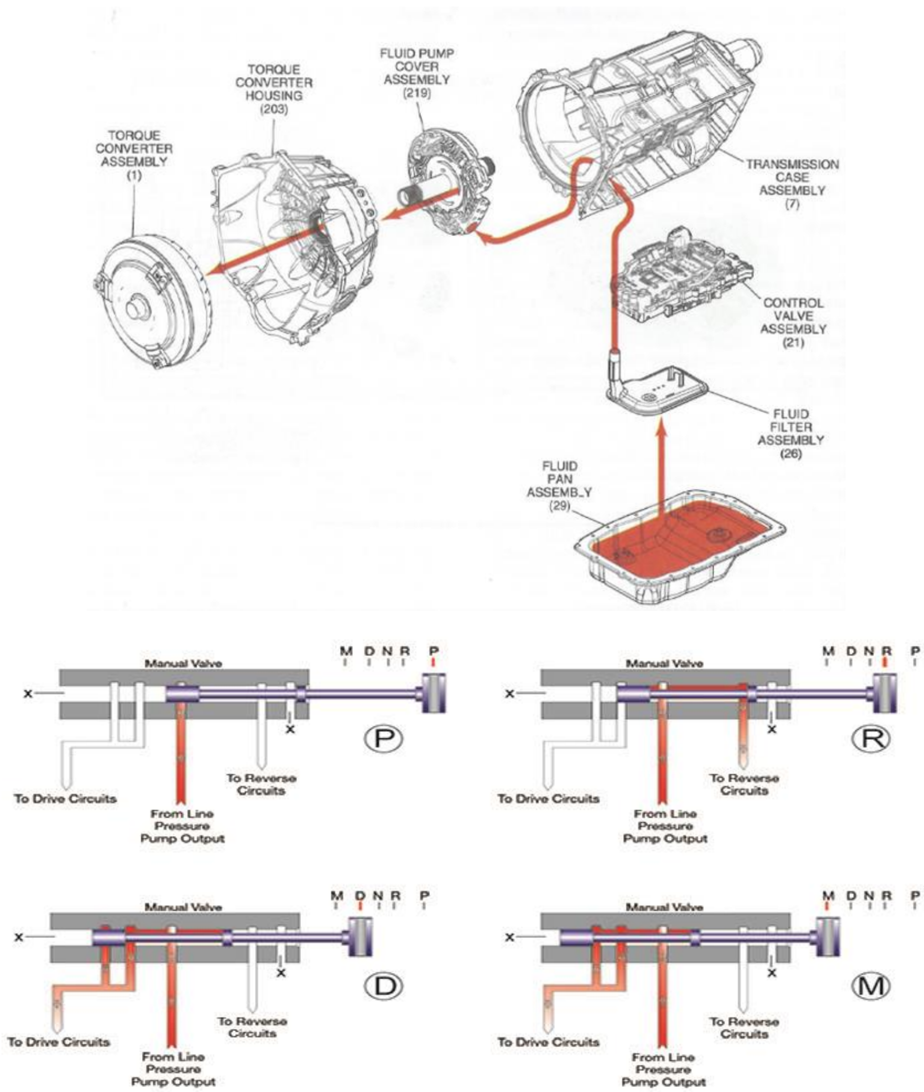


Figure 2-3: Hydraulic control of Automatic transmission

D. Hydraulic Suspension Systems

- Modification Objectives:
  - ➢ Adaptive Suspension: Modifying the suspension system to include adaptive or active suspension components that adjust damping force based on road conditions or driving behavior.
  - ➢ Air-Hydraulic Hybrid Suspension: Upgrading from a traditional coil spring suspension to an air-hydraulic hybrid setup, which allows for dynamic ride height adjustment.

- Upgraded Shocks and Dampers: Swapping out conventional hydraulic shocks for high-performance, adjustable dampers for improved ride quality and handling.
- Strengthened Hydraulic Cylinders: Upgrading the hydraulic cylinders that control the suspension height or damping rate to handle greater loads or off-road conditions.

- Benefits of Modification:
  - Improved ride quality and comfort.
  - Better handling and stability, particularly in high-performance or off-road vehicles.
  - Enhanced vehicle control and adaptability to different road conditions.

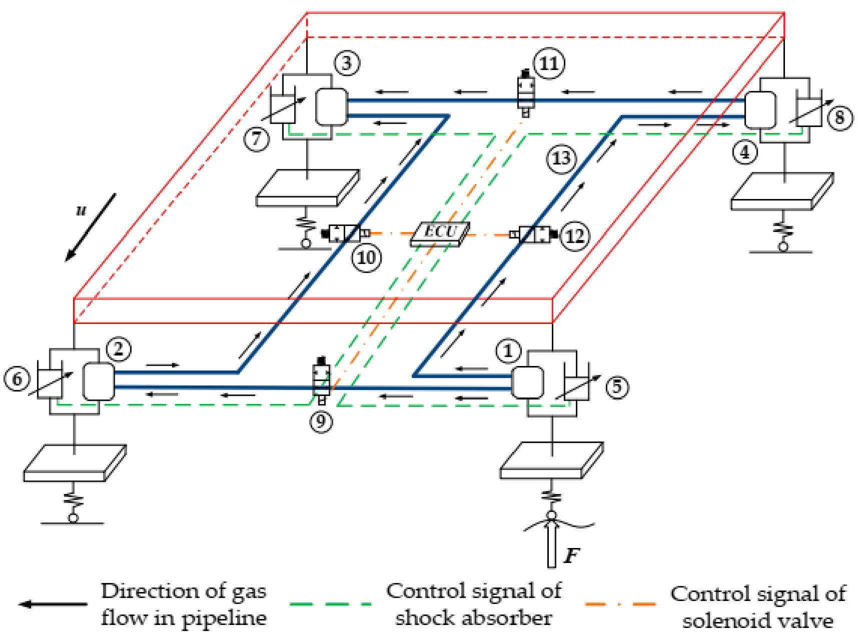


Figure 2-4: Hydraulically interconnected suspension system

E. Hydraulic Clutch System (for Manual Transmission)

- Modification Objectives:
  - Larger Master/Slave Cylinder: Upgrading the clutch master and slave cylinders for higher performance or greater clutch engagement force, particularly in racing or performance vehicles.

- High-Performance Clutch Fluid: Using a higher-quality or more heat-resistant fluid for better performance under high-temperature conditions (such as track driving).
- Increased Pedal Feel and Response: Adjusting the hydraulic system for a more responsive clutch pedal, offering better control over clutch engagement, especially in high-performance vehicles.

- Benefits of Modification:
  - Smoother and more responsive clutch engagement.
  - Enhanced durability under high-performance driving conditions.
  - Reduced clutch pedal effort for easier shifting.

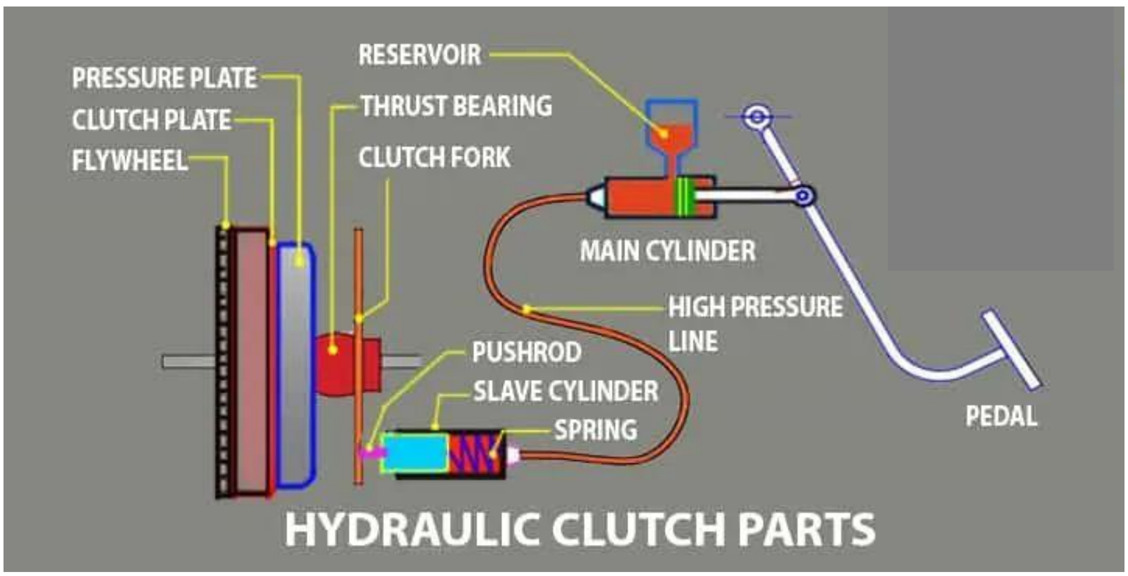


Figure 2-5 Hydraulic clutch system

F. Energy Recovery and Regenerative Hydraulic Systems

- Modification Objectives:
  - Energy Recovery Systems: Installing regenerative braking or energy recovery systems that capture kinetic energy during braking and convert it into hydraulic pressure, which can be reused to assist in acceleration or other vehicle operations.
  - Hybrid Hydraulic Systems: Integrating hydraulic hybrid systems with electric motors to improve overall vehicle efficiency, particularly in hybrid and electric vehicles.

- ➢ Pressure Accumulators: Adding or upgrading hydraulic accumulators to store excess energy for later use, improving overall system efficiency.
- Benefits of Modification:
  - ➢ Reduced energy consumption and improved fuel efficiency.
  - ➢ Reduced environmental impact through energy recovery and efficient fluid use.
  - ➢ Enhanced vehicle performance and driving range, particularly in hybrid and electric vehicles.

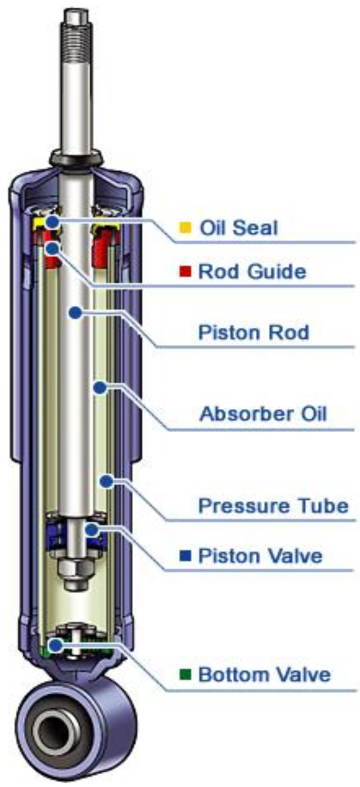


Figure 2-6 Regenerative shock absorber

Automotive hydraulic systems are versatile and crucial to many vehicle functions, from basic braking to advanced suspension and power transmission systems. Modifying these systems can enhance performance, safety, efficiency, and vehicle adaptability. Whether upgrading the power steering for better handling, improving the hydraulic brakes for superior stopping power, or integrating energy recovery systems for better fuel efficiency, modifications can significantly benefit both the vehicle's functionality and the driver's experience. The modifications should always be carefully planned to ensure compatibility, safety, and performance improvements

G. Hydraulic Lift and Cargo Systems

- Function: Hydraulic systems are used in various automotive applications, including cargo handling, lift gates, and service vehicles, to lift and lower heavy loads with ease.
- Components:

3. Hydraulic Cylinders: Lift or lower cargo, lift gates, or ramps.
4. Hydraulic Pump: Powers the cylinders to move heavy components.
5. Fluid Reservoir: Stores hydraulic fluid for system use.

- Operation: Pressurized hydraulic fluid is directed into the cylinders to move heavy components, such as lift gates or cargo beds, up and down as required.

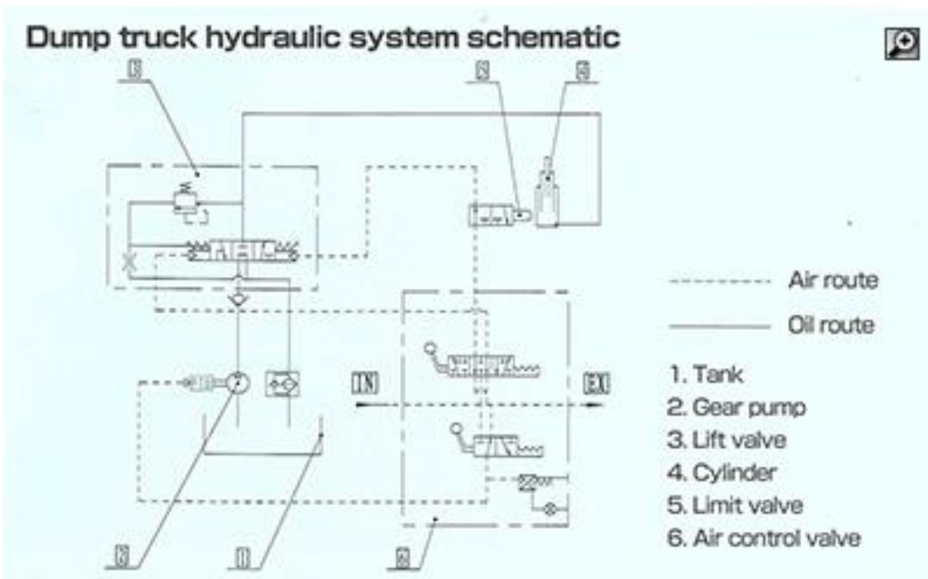


Figure 2-7: Dump truck hydraulic system schematic

Hydraulic systems in automotive applications are fundamental to the operation of various systems, from essential safety features like brakes and steering to performance systems like suspension and transmission. These systems provide precise control, enhanced performance, and ease of operation, playing a vital role in both conventional and advanced vehicle designs. Hydraulic systems offer reliability, power, and efficiency, making them indispensable in modern automotive technology.

5.1 OHS and PPE requirements

To protect yourself from injuries, you must take precautions including Personal Protective Equipment (PPE) and OHS

5.1.1 PPE Requirement

Safety glasses, Protective goggles or face shields can give used where protection more suited to activities encounter; splashing liquid, fume, vapor, dust or powder and working with hydraulic system. Different types of goggles are available which cover the whole eye. Long exposure to high noise levels can result in permanent hearing loss. Hence Ear protection is recommended when:

- Work area is constantly noisy
- Grinding
- Hammering

Skin protection is recommended when: working with chemicals & corrosives and handling heavy materials like wheel bearing service Rubberized Gloves: when working with chemicals, when using the parts washer. Leather gloves: when grinding or welding When lifting heavy engine parts or transmissions.

Your clothing should be well fitted and comfortable but made with strong material.

Wear appropriate clothing while performing tasks

- No sleeveless shirts
- No shorts
- No holes
- No hats

Safety Shoes: protect your feet from injury. There are many designs of safety shoes and boots that also have steel plates built into the toe and shank to protect your feet. Many also have soles that are designed to resist slipping on wet surfaces.

N.B Keep your clothing clean. If you spill gasoline or oil on yourself, change that item of clothing immediately. Oil against your skin for a prolonged period can produce rashes or other allergic reactions. Gasoline can irritate cuts and sores.

Respiratory protection is recommended: When working with chemicals that give. Toxic fumes, extended time around gasoline, when working on brakes or clutches that may contain asbestos. When using power sanding, using the parts washer for extended periods.

5.1.2 OHS Requirement

A. Lifting and Carrying

When doing heavy lifting, always get assistance and lift with your knees, not your back. When lifting any object follow these steps:

B. Clean equipment and tools

- Part cleaning is a necessary step in most repair procedures. Cleaning automotive parts can be divided into three basic categories.
- Chemical cleaning relies primarily on some type of chemical action to remove dirt, grease, scale, paint, or rust.
- Abrasive cleaning relies on physical abrasion to clean the surface. This includes everything from a wire brush to glass bead blasting, airless steel shot blasting, abrasive tumbling, and vibratory cleaning. Chemical in-tank solution sonic cleaning might also be included here because it relies on the scrubbing action of ultrasonic sound waves to loosen surface contaminants.

Clean up procedures

- Clean up every time whenever you leave an area, including sweeping the floor.
- Clean and return all tools to where you got them.
- Use compressed air sparingly; never aim it at another person or use it to clean hair or clothes.
- Shut off and unplug machines when cleaning, repairing, or oiling.
- Never use a rag near moving machinery.
- Use a brush, hook, or a special tool to remove chips, shavings, scraps etc. from the work area. Never use the hands.
- Keep fingers clear of the point of operation of machines by using special tools or devices, such as, push sticks, hooks, pliers, etc.
- Keep the floor around machines clean, dry, and free from trip hazards. Do not allow chips to accumulate.

C. Hazards in the work shop

- Faulty work habits
- Misuse of equipment
- Misuse of hand tools

Select the work place depending on: -

- Environmental condition
  - Free from flammable things
  - Events around the work campus is closer together
  - Climatic condition
  - Working area events

D. Professional Behavior and work area safety

Accidents can be prevented simply by the way you behave. The following list does not include everything you should or should not do; it merely gives some things to think about:

- When working with a hydraulic press, sure the pressure is applied in a safe manner.
- Properly store all parts and tools by putting them away in a place where people will not trip over them.
- Keep your work area clean and uncluttered. Make sure you clean up all spills before continuing to work.
- Any oil, coolant, or grease on the floor can make it slippery. Slips can result in serious injuries.
- Make sure the work areas around machines are large enough to safely operate the machine.
- Keep an up dated list of emergency telephone numbers clearly posted next to the telephone. These numbers should include a doctor, hospital, and fire and police departments.
- The work area should have a first-aid kit for treating minor injuries and eye flushing kits readily available. You should know where these items are kept.
- Keep tools in good condition by using them properly and storing them properly.

- Always keep the place where you work clean. When a job is finished, everything should be replaced neatly in order and wastes should be disposed.
- Do not leave things, even temporarily, in passage ways or entrances and exits where they may obstruct people or cars going in and out.
- Do not leave tools and parts on the floor where you, or any one else, might trip over them. Make a habit of putting them on a workbench
- Clean up any spilled fuel, oil or grease immediately to prevent yourself or others from slipping on the floor.

Operation Sheet:

Title: Modification of Master Cylinder in Vehicle's Hydraulic Brake System

- Background Information:
  - Current Master Cylinder Specifications: Review the existing master cylinder's size, fluid capacity, and specifications. Typically, vehicles use either a single or dual circuit master cylinder. The master cylinder's capacity and size influence pedal feel and braking response.
  - Modification Goals: Increase brake fluid displacement for better braking power. Improve pedal feel (firmer pedal, reduced travel). Enhance the overall efficiency of the hydraulic braking system.
- Modification Scope
  - ➢ Master Cylinder Upgrade:
    - ✓ Larger Bore Size: Replace with a larger bore master cylinder to improve braking power and response.
    - ✓ Enhanced Materials: Upgrade to a more durable or heat-resistant master cylinder for higher performance.
    - ✓ High-Performance Master Cylinder: Install a performance-oriented master cylinder designed for high-performance braking systems (e.g., race cars, trucks).
  - ➢ Fluid Compatibility: Ensure the new master cylinder is compatible with the existing brake fluid or upgrade to a higher-performance brake fluid if required.
- Tools and Equipment Required
  - ➢ Wrenches and Socket Set: To remove and install bolts and fittings.
  - ➢ Torque Wrench: To ensure proper torque settings on the master cylinder and components.
  - ➢ Brake Fluid: Choose the appropriate fluid type (DOT fluid, synthetic fluid) as specified for the new master cylinder.
  - ➢ Brake Bleeder Kit: For removing air from the hydraulic system after modifications.
  - ➢ Brake Fluid Tester: To test the quality of the brake fluid before and after modification.
  - ➢ Sealant/Threadlocker: For ensuring secure sealing of components.

- Fluid Reservoir Cap Wrench: For removing the cap of the brake fluid reservoir if required.

- Pre-Modification Preparation
  - Vehicle Preparation
  - System Check
  - Inspect the current master cylinder, brake lines, and fluid levels. Note any existing issues that might affect the modification process, such as leaks or damage.
  - Record the specifications of the current master cylinder for future reference.
- Modification Procedure
  - Step 1: Remove the Old Master Cylinder: Disconnect Brake Fluid Lines, Disconnect the Push Rod and Unbolt the Master Cylinder
  - Step 2: Install the New Master Cylinder: Prepare New Master Cylinder, Mount the New Master Cylinder, Reconnect Brake Lines, Reconnect the Push Rod and Check Alignment
  - Step 3: Refill Brake Fluid: Refill Fluid Reservoir
  - Step 4: Bleed the Brake System: Start Bleeding Process and Check Fluid Levels
- Post-Modification Testing
  - Step 1: Initial Test of Brake Pedal Feel
  - Step 2: Brake Fluid Leak Test
  - Step 3: Brake Performance Test
  - Step 4: Dynamic Brake Test:
- Troubleshooting Final Inspection and Documentation
  - Spongy Brake Pedal and Brake Fluid Leaks
  - Conduct a thorough inspection to ensure all components are securely installed and functioning correctly. Double-check the fluid level is correct and that there are no leaks.
  - Record the details of the modification, including the specifications of the new master cylinder and any components that were replaced or upgraded.
  - Update the vehicle's service history with details of the modification for future reference.
- Maintenance Recommendations

- Brake Fluid Checks: Periodically check the brake fluid levels and quality. Change the brake fluid as recommended by the manufacturer to maintain optimal braking performance.
- Regular Brake System Inspections: Inspect the brake lines, master cylinder, and related components for wear, leaks, and proper operation.
- Test Brake Performance: Periodically test the braking system to ensure it is performing as expected, especially after long trips or significant use

5.1.3 Unit Three: Develop and validate Hydraulic system modification

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Developing modification concept
- Detailed drawing of modified system
- Identifying and proposing modification methods
- Selecting materials and processes
- Documenting modification

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Develop modification concept
- Show detailed drawing of modified system
- Identify and propos modification methods
- Select materials and processes
- Document modification

3.1 Typical procedures for modifications of Automotive Hydraulics System

Modifying an automotive hydraulic system is a detailed process that requires careful planning, precise implementation, and thorough testing to ensure that the modifications improve performance, safety, and durability. Below is a typical procedure for automotive hydraulic system modifications, which can vary depending on the specific system being modified (braking, steering, suspension, etc.).

3.1.1 Assessment and Planning

Identify the Purpose of the Modification: Determine what you aim to achieve with the modification. Are you aiming to improve performance, safety, or reliability? Define clear objectives such as enhanced braking power, better steering response, or increased lifting capacity. Example: If modifying a braking system, the goal could be to improve heat dissipation and reduce brake fade during high-speed driving.

Evaluate the Existing System: Assess the current hydraulic system to understand its limitations. This includes identifying existing components like cylinders, pumps, hoses, fluid types, and control valves. Example: For a power steering modification, review the steering pump’s flow rate, pressure, and performance.

Compatibility Check: Ensure that the planned modifications are compatible with the vehicle's existing components (e.g., pumps, actuators, master cylinders). This includes ensuring that the new parts can fit within the existing space and that the hydraulic lines and fluid reservoirs are sized appropriately. Set a Budget and Timeline: Determine the cost and time required for the modifications, including parts, labor, and testing.

3.1.2 Design and Component Selection

Choose Components for the Modification: Select the appropriate hydraulic components based on the vehicle type and desired modification. Some examples include:

- Upgraded brake calipers, master cylinders, or rotors for brake system modification.
- A higher-flow hydraulic pump or pressure control valves for power steering or suspension upgrades.

- Performance hydraulic fluid designed to withstand higher temperatures or stresses for racing applications.

Custom Hydraulic System Design: In some cases, especially for custom applications (e.g., off-road vehicles or race cars), a custom hydraulic system may be required. This could involve designing a new hydraulic circuit or selecting specialized components like accumulators or control valves.

Plan for Installation: Decide whether the modifications can be made in stages (e.g., upgrading the pump first, then switching to better fluid) or need to be done in a single installation to ensure system integrity.

3.1.3 Disassembly and Preparation

Drain Hydraulic Fluid: Before starting any modification, it’s essential to drain the existing hydraulic fluid to avoid contamination and ensure a clean start. This is particularly important when replacing or upgrading components like pumps or cylinders. Disconnect and Remove Old Components: Remove any components that are being replaced, such as old brake calipers, steering pumps, or suspension struts. Ensure proper disposal of any old hydraulic components in accordance with environmental regulations.

Clean the System: Clean all hydraulic lines, valves, and reservoirs to prevent contamination. This step is particularly important when adding new components or upgrading to a higher-performance fluid. Inspect and Test Related Components: Inspect related systems that might need adjustment or upgrade, such as brake pads, rotors, or the vehicle’s electrical system (if modifying electric-hydraulic steering).

3.1.4 Installation of New Components

Install New Hydraulic Components: Begin by installing the selected upgraded or modified components. This includes installing new hydraulic pumps, cylinders, valves, hoses, and reservoirs.

- For brake systems, this could involve replacing the master cylinder, installing new brake lines, and adding high-performance brake pads or rotors.
- For steering systems, it may include replacing the power steering pump and adding new hoses or fluid reservoirs.

Ensure Proper Sealing: When installing components like cylinders, hoses, or valves, make sure that seals and O-rings are properly fitted to prevent leaks.

Replace Hydraulic Lines and Hoses: If the modification involves higher pressure or different fluid types, it may be necessary to replace existing hydraulic lines and hoses with ones rated for the new system's demands.

3.1.5 System Reassembly and Fluid Filling

Reassemble the System: Once the components are installed, reassemble any other parts that were removed for installation. This may include reconnecting steering linkages, suspension arms, or brake caliper mounting brackets. Fill Hydraulic Fluid: Add the recommended hydraulic fluid (based on the modified components) to the system. If upgrading fluid, ensure that the fluid is compatible with the new parts and can handle the higher pressures or temperatures associated with the modification. Bleed the System (for Brake or Clutch Modifications): For systems like brakes or clutches, you'll need to bleed the hydraulic lines to remove air from the system. This ensures proper fluid pressure and prevents air bubbles from causing erratic or spongy operation.

- For brake systems, this involves using a vacuum or pressure bleeder to evacuate air from brake lines.
- For clutch systems, this involves cycling the clutch pedal while ensuring fluid flow to remove air from the master/slave cylinders.

3.1.6 Calibration and Tuning (If Applicable)

- Adjust System Pressure and Flow Rates: Some modifications, like those to power steering or suspension systems, may require adjusting system pressure or flow rates. Use pressure gauges and flow meters to verify that the system operates within the desired parameters.
  - ✓ For instance, if upgrading the steering pump, adjust the pressure to ensure the pump provides adequate assistance without over-pressurizing the system.
- Test Pressure Relief Valves: Ensure that any pressure relief valves are set correctly, especially in systems like brakes or suspension where over-pressurization could be dangerous.

- Check for Leaks: Pressurize the system and check for any leaks in hoses, cylinders, and fittings. If any leaks are detected, fix them immediately to ensure system safety.

3.1.7 Testing and Verification final Adjustments and Calibration

Perform System Tests: After installation, perform extensive tests to verify that the hydraulic system operates as intended. This may involve:

- Brake Testing: Perform emergency stop tests to evaluate brake performance and fade resistance. This may involve high-speed braking, hard stops, and repeated use to simulate real-world conditions.
- Steering Testing: Test the power steering system by turning the wheel at various speeds to check for proper assist and responsiveness.
- Suspension Testing: Test the new suspension components by driving over different surfaces to evaluate ride comfort, handling, and system adaptability.

Monitor Fluid Levels: During testing, monitor the hydraulic fluid levels and pressure to ensure there are no leaks and that the system remains within safe operating limits.

Road Test: Conduct a road test, especially for modified braking, suspension, or steering systems, to ensure everything operates smoothly under normal driving conditions.

Fine-Tune Settings: Based on test results, make any necessary adjustments to optimize system performance. This could include recalibrating the brake pedal feel, adjusting suspension damping, or fine-tuning steering assist levels.

Verify Safety and Compliance: Ensure that all modifications meet safety standards and are compliant with local regulations. This is especially important for modifications to braking or steering systems, which are safety-critical.

Update Vehicle Documentation: If the modification affects the vehicle's specifications (e.g., hydraulic fluid type, braking power), update the vehicle documentation to reflect these changes for future maintenance.

3.1.8 Post-Modification Maintenance

- Regular Inspections: After the modifications, ensure that regular inspections are scheduled to check for wear, fluid leaks, and proper operation.

- Fluid Change Schedule: Depending on the type of modification, you may need to implement a different fluid change schedule. For high-performance fluids, ensure they are changed at regular intervals to maintain system performance.
- Monitor System Performance: Regularly monitor the performance of the hydraulic system to ensure that the modifications continue to meet the desired objectives.

3.2 Benchmark specifications for modifying automotive hydraulic system

When modifying automotive hydraulic systems, it's important to follow certain benchmark specifications to ensure that the changes enhance performance, maintain safety, and comply with relevant standards. The specifications vary depending on the type of modification (e.g., brake, steering, suspension, or lifting systems) and the specific requirements of the vehicle. Below are general benchmark specifications for key automotive hydraulic system modifications:

A. Hydraulic Brake System Modifications

Objective: To enhance stopping power, reduce brake fade, and improve pedal feel.

- Master Cylinder Pressure:
  - Benchmark: Typically between 800 to 1200 psi (depending on vehicle class).
  - For high-performance vehicles or racing, the master cylinder pressure may be higher to improve brake response.
- Brake Fluid Type:
  - Standard: DOT 3 or DOT 4 fluid for regular vehicles.
  - High-Performance: DOT 5.1 or Racing Fluid (such as Castrol SRF) with higher boiling points (above 500°F / 260°C) to withstand extreme temperatures.
- Brake Caliper Size:
  - Performance or modified systems often use 6-pot or 8-pot calipers to increase clamping force compared to standard 2-pot or 4-pot calipers.
- Rotor Size and Material:
  - Standard: Typically 280-350 mm in diameter for passenger vehicles.
  - High-performance: 380-410 mm rotors or carbon-carbon composites for race cars.
  - Material: Slotted or vented rotors (for better heat dissipation).

- Brake Pad Coefficient of Friction:
  - Standard: 0.35 to 0.45 for regular use.
  - Performance: 0.45 to 0.65 for high-performance or racing pads, with the ability to withstand higher temperatures and aggressive braking.
- Hydraulic Brake Line Pressure:
  - Standard passenger cars: 1000 to 1500 psi.
  - Race vehicles or performance systems may require lines rated for up to 3000 psi.

B. Power Steering System Modifications

Objective: To enhance steering response, reduce steering effort, and improve overall control.

- Power Steering Pump Pressure:
  - Standard: Typically 800 to 1200 psi.
  - Performance or off-road: Modified systems may increase pressure to 1300 to 1500 psi for improved steering feel and responsiveness.
- Flow Rate:
  - Standard: Typically 1.5 to 2.5 liters per minute (LPM) depending on vehicle size.
  - Performance systems or trucks: Modified pumps may achieve 3.5 to 4.5 LPM for faster steering response.
- Fluid Type:
  - Standard: Use ATF (Automatic Transmission Fluid) or PSF (Power Steering Fluid).
  - Performance: Synthetic PSF or fluids designed for high-temperature conditions are recommended for racing or high-load applications.
- Steering Rack Ratio:
  - Standard: Typically 14:1 to 18:1 for passenger vehicles.
  - Performance: 12:1 or 10:1 for quicker response (commonly used in sports cars and race cars).

C. Suspension System Modifications

Objective: To improve ride comfort, handling, and vehicle adaptability (e.g., off-road or performance tuning).

- Shock Absorber Pressure:

- Standard: Typically 2000 to 3000 psi for conventional shock absorbers.
- Performance: For adjustable or racing dampers, shock absorber pressure can range from 2500 to 4500 psi depending on the application.

- Spring Rate:
  - Standard: Typically 50 to 150 lb/in (pounds per inch) for regular vehicles.
  - Performance or racing: 200 to 500 lb/in or higher, depending on vehicle weight and desired handling characteristics.
- Hydraulic Ride Height Control:
  - Range of adjustment: Typically 30 mm to 100 mm in height adjustment.
  - High-performance systems: May provide greater than 100 mm of adjustment, such as in air suspension systems used in luxury or off-road vehicles.
- Fluid Capacity in Suspension Reservoirs:
  - Standard: 250 to 500 cc per damper.
  - Performance or race suspension: Reservoirs may hold 1L to 2L of fluid per damper to ensure extended cooling and performance during high-stress use.

D. Hydraulic Lifting and Cargo Systems (e.g., Pickup Trucks, Utility Vehicles)

Objective: To enhance lifting power, speed, and reliability.

- Pump Pressure:
  - Standard: Typically 2000 to 3000 psi for lifting systems in light-duty trucks.
  - Heavy-duty trucks: Modified systems may have pressures of 3000 to 4500 psi for lifting heavy loads.

Cylinder Bore Size:

- Standard: Typically 2 to 4 inches for light-duty hydraulic lifts.
- Heavy-duty systems: Modified systems may use larger cylinders with 5 to 6 inches in bore size to handle increased loads.

Lifting Capacity:

- Light-duty systems: Can typically lift 1000 to 5000 lbs.
- Heavy-duty systems: May lift 10,000 to 30,000 lbs or more, especially in commercial and industrial vehicles.

Pump Flow Rate:

- Standard: 1.5 to 3 gallons per minute (GPM) for light-duty systems.
- Heavy-duty: 3 to 5 GPM or more, depending on load capacity and speed of operation.

Hydraulic Fluid Type:

- Standard: ISO 32 or ISO 46 hydraulic fluid for typical vehicle applications.
- Performance: Synthetic hydraulic oils designed for high pressures and temperatures, especially for off-road or heavy-duty applications.

E. Hydraulic Clutch System Modifications

Objective: To improve clutch feel, engagement, and performance in high-performance or racing vehicles.

- Master/Slave Cylinder Pressure:
  - Standard: Typically 600 to 900 psi for passenger vehicle clutch systems.
  - High-performance: Systems may run at 1000 to 1200 psi for improved clutch feel and responsiveness, especially for racing.
- Hydraulic Fluid Type:
  - Standard: Use DOT 3 or DOT 4 brake fluid for most vehicles.
  - Performance: High-performance systems often use high-temperature DOT 5.1 fluid or racing-specific hydraulic fluid designed for low viscosity and high thermal stability.
- Pedal Travel and Engagement Point:
  - Standard: Typically 3 to 4 inches of pedal travel with the engagement point in the middle of the travel.
  - Racing or performance: 2 to 3 inches of pedal travel with the engagement point closer to the top for quicker shifts.

F. Hydraulic System Safety and Reliability Benchmarks

- Pressure Relief Valves: Ensure that systems incorporate pressure relief valves rated at 1.5 to 2 times the system’s maximum operating pressure to prevent over-pressurization.
- Hydraulic Hose and Fitting Specifications:

- Use hoses rated for a minimum of 3000 psi for standard applications and up to 5000 psi or more for high-performance or heavy-duty modifications.
- Use crimped or swaged fittings rated for the corresponding pressures to prevent leaks and failures.

- Accumulators:
    - Accumulators should be designed for system pressure plus 20-30% to allow for system pressure compensation and fluid storage during peak load conditions.
- Fluid Monitoring: Use fluid temperature sensors and pressure gauges to monitor hydraulic system health and ensure that the temperature doesn't exceed safe operating ranges (typically 180°F to 220°F for standard vehicles, higher for high-performance).

G. Testing and Validation Criteria

- Pressure Testing: Ensure the system can withstand 1.5x the normal operating pressure without failure. This ensures durability and safety.
- Leak Testing: Ensure that the system is free from leaks by pressurizing it to operating pressure and checking all joints, seals, and components.
- Thermal Testing: For high-performance applications, ensure that the system can handle high temperatures without degrading the hydraulic fluid or causing performance loss (typically up to 250°F in extreme performance applications).

The benchmark specifications for modifying automotive hydraulic systems vary depending on the modification type (brake, steering, suspension, etc.) and the vehicle's intended use (daily driving, performance, off-road, commercial). Adhering to these specifications ensures the modifications will deliver the desired improvements in performance, safety, and reliability. It is crucial to carefully select compatible components and rigorously test the system after modification to maintain optimal performance and avoid any failure

3.3 Apply and test hydraulic system modifications

To apply and test modifications in automotive hydraulic systems, you'll need to follow a structured approach that involves designing the modifications, implementing them in a controlled environment, and then conducting tests to assess the system's performance. Here's a step-by-step outline to apply and test modifications:

- Understanding the Current System
  - Hydraulic System Components: Familiarize yourself with the key components of the automotive hydraulic system, such as the pump, reservoir, valves, actuators (like brake calipers or steering racks), hoses, and lines.
  - Hydraulic Fluid: Know the type and specifications of hydraulic fluid used, as changes may affect performance.
- Identify the Modification Objectives
  - Performance Improvement: Are you aiming for higher efficiency, increased braking force, or better steering response?
  - Cost-Effective Solutions: You may want to reduce cost while maintaining performance.
  - Safety Enhancements: Modifications could focus on safety features such as preventing brake fade or enhancing emergency brake performance.
  - Environmental Considerations: Modifying fluid for better environmental impact or sustainability.
- Designing the Modification
  - Pump Modifications: Modifying the hydraulic pump to increase or decrease flow, pressure, or efficiency.
  - Valve Modifications: Installing variable flow or pressure valves to better regulate the system.
  - Actuator Modifications: Changes to the actuators (like replacing traditional calipers with more efficient ones) to improve force application.
  - Line and Hose Modifications: Use of higher-diameter lines or specialized hoses for reducing pressure drops or improving fluid flow.
  - Fluid Modification: Changing fluid types to those with different viscosities, or adding additives that improve performance in specific temperatures or pressures.
- System Integration

- ➢ Simulation: Before physically applying the changes, use simulation software to model the hydraulic system. This helps identify any potential issues in the design or integration process.
- ➢ Modification Implementation: Modify the vehicle's hydraulic components based on the design. This may involve:
  - ✓ Replacing or upgrading hydraulic pumps, valves, or actuators.
  - ✓ Changing the type or routing of hydraulic lines.
  - ✓ Installing pressure or temperature sensors for testing purposes.
  - ✓ Adding any new control units if necessary for adjusting the hydraulic fluid flow or pressure dynamically.

- Testing the Modified System
  - ➢ Bench Testing: Before testing on a vehicle, bench test individual components (e.g., the modified pump or valves) to ensure that they perform correctly under controlled conditions. Look for:
    - ✓ Pressure and flow measurements.
    - ✓ Heat generation.
    - ✓ Potential leaks or wear.
  - ➢ Vehicle Integration Testing: After successful bench testing, integrate the components into the vehicle and conduct on-road or controlled environment tests to evaluate overall system performance.
    - ✓ Brake Performance: Test the braking system to assess stopping distance, brake fade, and responsiveness under various conditions.
    - ✓ Steering and Suspension: If modifying steering hydraulics, check for smoothness, responsiveness, and overall driving feel.
    - ✓ Load Testing: If the vehicle is used for heavy-duty purposes, assess the load-bearing capacity and system efficiency when under heavy load.
  - ➢ Dynamic Performance: Conduct driving tests at different speeds, weather conditions, and load scenarios to assess the system's performance.
- Data Collection and Analysis

- Sensors and Monitoring: Use pressure, flow, and temperature sensors installed in the system to collect real-time data during testing. This will help in:
  - ✓ Identifying optimal pressure ranges.
  - ✓ Ensuring fluid temperatures stay within safe limits.
  - ✓ Monitoring system behavior under different loads and conditions.
- Performance Metrics: Measure key performance indicators like:
  - ✓ Response time.
  - ✓ Fluid temperature and pressure fluctuations.
  - ✓ Brake efficiency and force output.
  - ✓ Steering response and feedback.

- Iterative Testing and Optimization
  - Test for Variations: Test the system under different driving conditions (wet roads, off-road, etc.) to see how the modifications hold up.
  - Refinement: Based on the data collected, refine the modifications if necessary. This may include adjusting valve settings, changing the pump output, or fine-tuning the fluid.
- Final Validation and Documentation
  - Compliance: Ensure that the system modifications comply with local safety and environmental standards.
  - Documentation: Provide a detailed report on the modification process, performance tests, and any adjustments made. This helps for future reference, maintenance, and any legal purposes.
  - Tools and Equipment Needed for Testing
    - ✓ Hydraulic test bench (for bench testing components like pumps, valves, and actuators)
    - ✓ Pressure gauges and flow meters
    - ✓ Data acquisition systems (to monitor sensors for pressure, temperature, and fluid flow during tests)
    - ✓ Vehicle dynamometer (to simulate different driving conditions)
    - ✓ Thermal cameras (to check for excessive heating during tests)

- ✓ Brake testing devices (for brake performance under different conditions)

➢ Key Considerations

- ✓ Safety: Always ensure that the hydraulic system is not only performing optimally but also remains safe under high pressure. Overhauling a hydraulic system can involve high risks, including hydraulic failure, leaks, or erratic behavior.
- ✓ Durability: Test the system for long-term wear and fatigue. Hydraulic systems need to handle extensive cycling without degrading quickly.
- ✓ Cost vs. Performance: Strive for modifications that provide the best balance between performance improvements and additional costs or complexity.

By following these steps, you can systematically apply and test modifications to an automotive hydraulic system.

Operation Sheet

Project Title: Modification of Vehicle's Hydraulic Brake System

Direction: Perform the following tasks correctly, regarding modification of Hydraulic Brake System of a Vehicle. Time allotted 3:00hrs for the lap test

- Background Information
  - Existing System: Review of the current hydraulic braking system (e.g., single/double circuit, disc/drum brakes). Key Components: Master cylinder, brake booster, brake fluid, brake lines, calipers, rotors, and pads.
  - Modification Goals: Improve braking performance, including stopping power and pedal feel. Enhance system efficiency and responsiveness. Upgrade components to ensure better durability and heat resistance.
- Modification Scope
  - Master Cylinder: Upgrade to a larger or more efficient master cylinder for better braking power.
  - Brake Calipers: Install performance calipers (e.g., multi-piston calipers) for improved brake force distribution.
  - Brake Fluid: Switch to a higher-quality brake fluid (e.g., DOT 5, synthetic fluid) with a higher boiling point to handle heat better.
  - Brake Hoses and Lines: Replace rubber brake hoses with braided stainless steel hoses to reduce expansion under pressure and improve fluid response.
  - Rotors and Pads: Upgrade to high-performance rotors and pads for better heat dissipation and braking efficiency.
  - Brake Booster: Install or upgrade the brake booster for enhanced pedal feel and reduced effort in braking.
- Tools and Equipment Required
  - Brake Fluid: Select appropriate fluid (e.g., DOT, synthetic) for the modified system.
  - Torque Wrench: For ensuring proper tightening of bolts and components.
  - Brake Bleeder Kit: To remove air from the brake lines after modifications.
  - Brake Cleaner: For cleaning components before reassembly.

- Hydraulic Jack and Jack Stands: For safely lifting and securing the vehicle during modifications.
- Brake Pads and Rotors: High-performance replacement parts (if applicable).
- Brake Line Fittings and Hoses: Braided steel hoses or upgraded brake lines.
- Pressure Bleeder: For efficient brake fluid bleeding after modifications.
- Sealant/Thread locker: For ensuring secure connections where applicable.
- Brake Fluid Tester: To check the quality and boiling point of the fluid.

- Pre-Modification Preparation
  - System Assessment: Inspect the current hydraulic brake system to identify any issues or components that require modification. Check fluid levels, brake pad wear, hose condition, and overall brake performance.
  - Component Selection: Choose components that match the vehicle's specifications and intended use (e.g., performance upgrades for track use or improved reliability for daily driving).
  - Safety Precautions: Ensure the vehicle is secured on a flat surface and lift it safely using a hydraulic jack and jack stands. Use appropriate personal protective equipment (PPE) like gloves and goggles.
  - Drain Existing Brake Fluid: Begin by draining the old brake fluid from the system into a proper disposal container.
  - Documentation: Record the specifications of the existing braking system and the components to be replaced/modified.
- Modification Procedure

Step 1: Disassemble the Brake System

- Lift the Vehicle: Use a hydraulic jack and secure the vehicle with jack stands.
- Remove Wheels: Take off the wheels to access the brake components.
- Remove Old Brake Fluid: Drain the old fluid from the master cylinder and brake lines.

Step 2: Install New Components

- Master Cylinder:
- Brake Calipers and Rotors:

- Brake Hoses and Lines:
- Brake Pads:
- Brake Fluid:

Step 4: Bleeding the Brake System

Step 5: Check for Leaks

Step 6: Test Brake Pedal Feel

- Post-Modification Testing

Test 1: Brake System Functionality

Test 2: Vehicle Road Test: On-Road Testing: Carefully test drive the vehicle at low speeds to check brake response. Gradually increase the speed to test for effective stopping power and system responsiveness. Check for Noise or Vibration: Ensure that there is no unusual noise (e.g., squeaking or grinding) from the brake system, and verify that there is no vibration or pulsation when braking.

Test 3: Brake Temperature: Monitor Brake Temperature: During the test drive, check for any signs of overheating in the brake system. The system should not experience excessive heat build-up, which could lead to brake fade.

Test 4: Brake Pedal Feel: Check Pedal Feel: Ensure the brake pedal is firm and provides the desired stopping force. There should be no sponginess or delayed response.

- Troubleshooting and Adjustments
  - ✓ Low Pedal Feel:
    - Repeat brake bleeding to ensure all air is removed from the lines.
    - Check for any leaks or worn seals that may be affecting hydraulic pressure.
  - ✓ Brake Fade:
    - Ensure the new brake pads and rotors are properly bedded and check the brake fluid's boiling point. If overheating is occurring, consider upgrading to higher-quality pads or fluid with a higher boiling point.
  - ✓ Unusual Noise:
    - Inspect brake pads and rotors for proper alignment. Ensure there is no debris between pads and rotors.
    - Check for any misalignment of calipers or improper mounting.

- ✓ Leaks:
  - Tighten any loose connections and ensure all brake lines and hoses are correctly sealed.

Final Inspection and Documentation

- System Check: Perform a final inspection to ensure all components are securely installed, and there are no leaks or issues with fluid levels.
- Documentation: Record the specifications of the modified braking system, including the new components, fluid type, and any adjustments made. Update the vehicle's service history with details of the modification.

Maintenance and Follow-up

- Routine Maintenance: Periodically check the brake fluid level, hose condition, and pads for wear. Perform brake fluid changes as recommended by the manufacturer.
- Performance Monitoring: Regularly test the braking performance, especially after the first few weeks of use, to ensure the system is performing as expected.
- Brake Pad and Rotor Inspection:
  Inspect the brake pads and rotors periodically for wear and replace them as needed to maintain optimal braking performance.

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