DIRECTIONAL CONTROL VALVES

Introduction

One of the most important considerations in any fluid power system is control. If control components are not properly selected, the entire system does not function as required. In fluid power, controlling elements are called valves.

There are three types of valves:

Directional control valves (DCVs): They determine the path through which a fluid transverses a given circuit. **Pressure control valves:** They protect the system against overpressure, which may occur due to a sudden surge as valves open or close or due to an increase in fluid demand.
Flow control valves: Shock absorbers are hydraulic devices designed to smooth out pressure surges and to dampen hydraulic shock.

In addition, the fluid flow rate must be controlled in various lines of a hydraulic circuit. For example, the control of actuator speeds can be accomplished through use of flow control valves. Non-compensated flow control valves are used where precise speed control is not required because the flow rate varies with pressure drop across a flow control valve. It is important to know the primary function and operation of various types of control components not only for good functioning of a system, but also for discovering innovative methods to improve the fluid power system for a given application.

Directional Control Valves

A valve is a device that receives an external signal (mechanical, fluid pilot signal, electrical or electronics) to release, stop or redirect the fluid that flows through it. The function of a DCV is to control the direction of fluid flow in any hydraulic system. A DCV does this by changing the position of internal movable parts. To be more specific, a DCV is mainly required for the following purposes:

- To start, stop, accelerate, decelerate and change the direction of motion of a hydraulic actuator.
- To permit the free flow from the pump to the reservoir at low pressure when the pump's delivery is not needed into the system.
- To vent the relief valve by either electrical or mechanical control.
- To isolate certain branch of a circuit.

Any valve contains ports that are external openings through which a fluid can enter and exit via connecting pipelines. The number of ports on a DCV is identified using the term "way." Thus, a valve with four ports is a four-way valve A DCV consists of a valve body or valve housing and a valve mechanism usually mounted on a sub-plate. The ports of a sub-plate are threaded to hold the tube fittings which connect the valve to the fluid conductor lines. The valve mechanism directs the fluid to selected output ports or stops the fluid from passing through the valve. DCVs can be classified based on fluid path, design characteristics, control methods and construction.

Classification of DCVs based Fluid Path
Based on fluid path, DCVs can be classified as follows:

- Check valves.
- Shuttle valves.
- Two-way valves.
- Three-way valves.
- Four-way valves.

Classification of DCVs based on Design Characteristics Based on design characteristics, DCVs can be classified as follows:

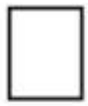
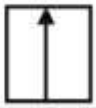
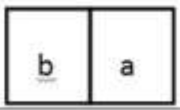
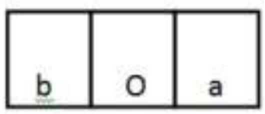
- An internal valve mechanism that directs the flow of fluid. Such a mechanism can either be a poppet, a ball, a sliding spool, a rotary plug or a rotary disk.
- Number of switching positions (usually 2 or 3).
- Number of connecting ports or ways.
- Method of valve actuation that causes the valve mechanism to move into an alternate position.

Classification of DCVs based on the Control Method Based on the control method, DCVs can be classified as follows:

- **Direct controlled DCV:** A valve is actuated directly on the valve spool. This is suitable for small-sized valves.
- **Indirect controlled DCV:** A valve is actuated by a pilot line or using a solenoid or by the combination of electro hydraulic and electro-pneumatic means. The use of solenoid reduces the size of the valve. This is suitable for large-sized valves.

Classification of DCVs based on the Construction of Internal Moving Parts Based on the construction of internal moving parts, DCVs can be classified as follows:

- **Rotary spool type:** In this type, the spool is rotated to change the direction of fluid. It has longitudinal grooves. The rotary spools are usually manually operated.
- **Sliding spool type:** This consists of a specially shaped spool and a means of positioning the spool. The spool is fitted with precision into the body bore through the longitudinal axis of the valve body. The lands of the spool divide this bore into a series of separate chambers. The ports of the valve body lead into these chambers and the position of the spool determines the nature of inter-connection between the ports.

	Each individual switching portion is shown in a square
	Flow path is indicated by means of arrow within a square
	Closed position
	Two-position valve
	Three-position valve

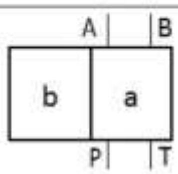
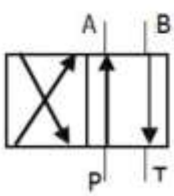
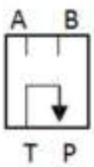
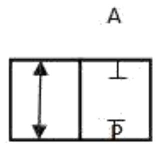
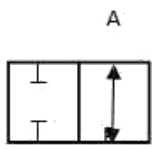
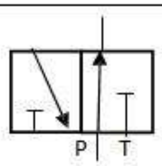
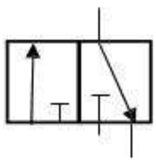
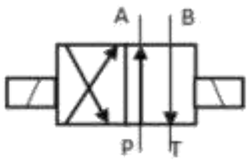
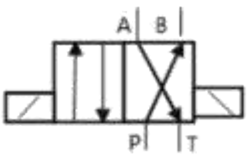
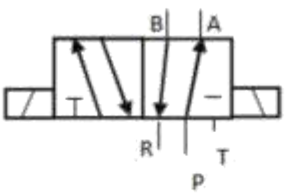
	Ports added to the two-position valve
	Two flow paths
	Two ports are connected, two ports are closed

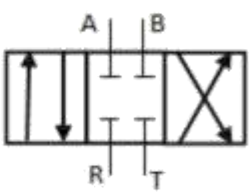
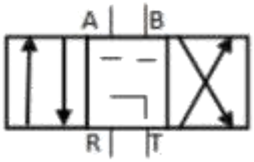
Table 1.2

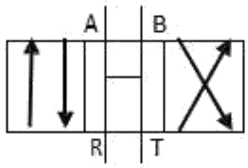
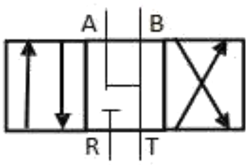
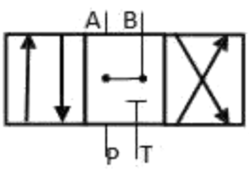
2/2-way valve: 2-ports and 2-position DCV	
	Normally closed position: P is not connected to A. When the valve is not actuated, the way is closed.
	Normally open position: P is connected to A. When the valve is not actuated, the way is open.

3/2 way valve : 3ports and 2 position DCV	
	Normally open position: P is connected to A. When the valve is not actuated, the way is open.
	Normally open position: P is connected to A. When the valve is actuated, the way is closed

4/2-way valve – 4-port and 2-position DCV	
	P is connected to A B is connected to T
	Position 2: P is connected to B A is connected to T

5/2-way valve – 5-port and 2-position DCV	
	Normal position: P is connected to B A is connected to R

4/3-way valve – 4-port and 3-position DCV	
	P, T, A, B
	Mid-position pump reticulating: P to T, A and B closed

	H-Mid-position closed: P to A, B to T
	Mid-position working lines depressurized: P, A to B to T
	P to A to B, T

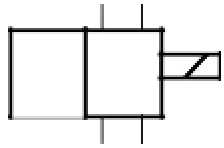
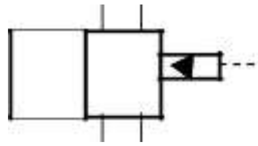
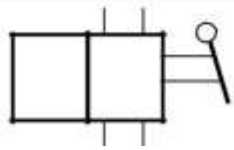
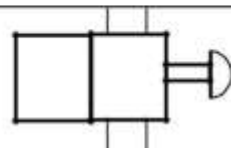
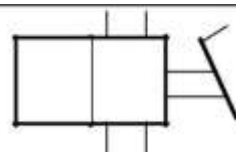
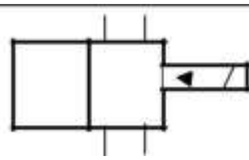
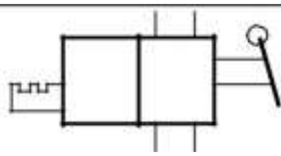
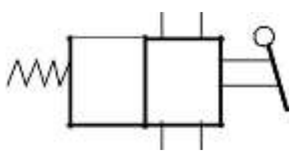
1. Each different switching position is shown by a square.
2. Flow directions are indicated by arrows.
3. Blocked ports are shown by horizontal lines.
4. Ports are shown in an appropriate flow direction with line arrows

The switching position, flow direction, and port for different configurations is represented in Table 1.1. Two-way, three-way, four-way and five-way representation is shown in Table 1.2.

Actuating Devices

Direction control valves may be actuated by a variety of methods. Actuation is the method of moving the valve element from one position to another. There are four basic methods of actuation: Manual, mechanical, solenoid-operated and pilot-operated. Several combinations of actuation are possible using these four basic methods. Graphical symbols of such combinations are given in Table 1.3.

- **Manually operated:** In manually operated DCVs, the spool is shifted manually by moving a handle pushing a button or stepping on a foot pedal. When the handle is not operated, the spool returns to its original position by means of a spring.
- **Mechanically operated:** The spool is shifted by mechanical linkages such as cam and rollers.
- **Solenoid operated:** When an electric coil or a solenoid is energized, it creates a magnetic force that pulls the armature into the coil. This causes the armature to push the spool of the valve.
- **Pilot operated:** A DCV can also be shifted by applying a pilot signal (either hydraulic or pneumatic) against a piston at either end of the valve spool. When pilot pressure is introduced, it pushes the piston to shift the spool.

	Solenoid operated
	Pilot operated
	Manual operated
	Push button
	Foot operated
	Pilot-operated solenoid
	Two-position detent
	Spring return

Check Valve

The simplest DCV is a check valve. A check valve allows flow in one direction, but blocks the flow in the opposite direction. It is a two-way valve because it contains two ports. Figure 1.1 shows the graphical symbol of a check valve along with its no-flow and free-flow directions.

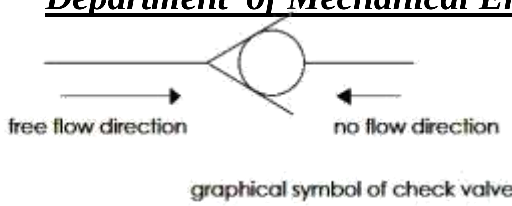


Figure 1.1 Graphical symbol of a check valve.

In Fig. 1.2, a light spring holds the ball against the valve seat. Flow coming into the inlet pushes the ball off the seat against the light force of the spring and continues to the outlet. A very low pressure is required to hold the valve open in this direction. If the flow tries to enter from the opposite direction, the pressure pushes the ball against the seat and the flow cannot pass through.

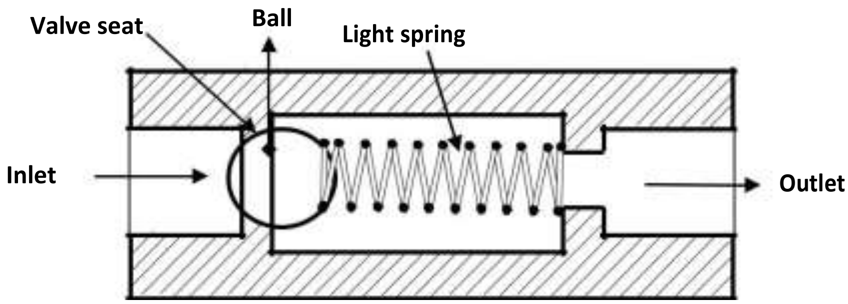


Figure 1.2 Ball-type check valve.

Figure 1.3 provides two schematic drawings showing the operation of a poppet check valve. A poppet is a specially shaped plug element held on a valve seat by a light spring. Fluid flows through the valve in the space between the seat and poppet. In the free flow direction, the fluid pressure overcomes the spring force. If the flow is attempted in the opposite direction, the fluid pressure pushes the poppet in the closed position. Therefore, no flow is permitted

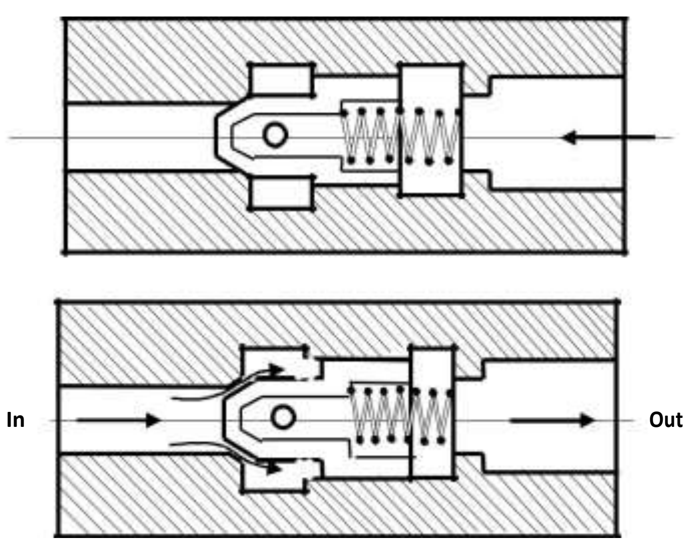


Figure1.3 Poppet check valve: (a) Open and (b) closed position

Advantages of a poppet valve

- Virtually zero leakage in closed position.
- Poppet elements do not stick even when left under pressure for long periods.
- Fast, consistent response time: typically 15 ms.

Disadvantages of a Poppet Valve
A poppet valve has the following disadvantages:

- Axial pressure balance is impossible and considerable force may be needed to open the poppet against the flow at a high pressure. This limits valves that have direct mechanical actuation to low flow duties.
- Generally individual poppets are required for each flow path that significantly increases the complexity of multi-port valves.
- Lapping and super finishing of valves add cost.

1.5 Pilot-Operated check Valve
A pilot-operated valve along with its symbol is shown in Fig. 1.4. This type of check v alve always permits free flow in one direction but permits flow in the normally blocked opposite direction only if the pilot pressure is applied at the pilot pressure point of the valve. The check valve poppet has the pilot piston attached to the threaded poppet stem by a nut.
The light spring holds the poppet seated in a no-flow condition by pushing against the pilot piston. The purpose of the separate drain port is to prevent oil from creating a pressure build-up at the bottom of the piston. The dashed line in the graphical symbol represents the pilot pressure line connected to the pilot pressure port of the valve. Pilot check valves are used for locking hydraulic cylinders in position.

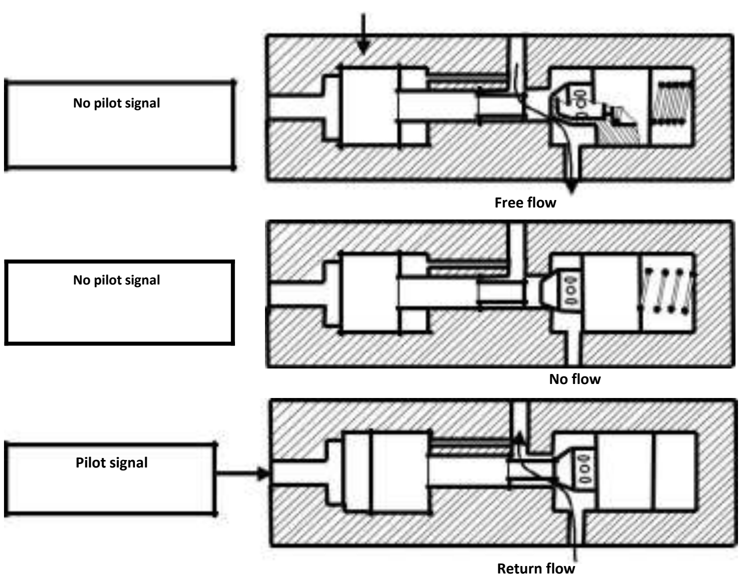


Figure 1.4Pilot-perated check valve

Shuttle Valve

A shuttle valve allows two alternate flow sources to be connected in a one-branch circuit. The valve has two inlets P_1 and P_2 and one outlet A. Outlet A receives flow from an inlet that is at a higher pressure. Figure 1.5 shows the operation of a shuttle valve. If the pressure at P_1 is greater than that at P_2, the ball slides to the right and allows P_1 to send flow to outlet A. If the pressure at P_2 is greater than that at P_1, the ball slides to the left and P_2 supplies flow to outlet A

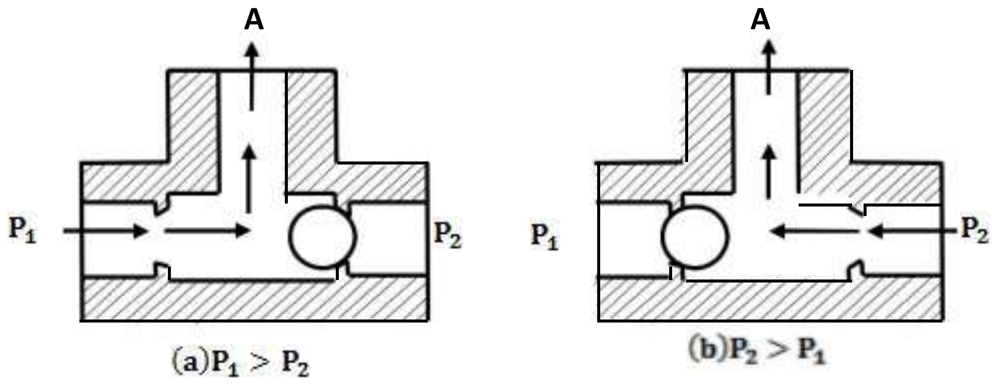


Figure 1.5 Shuttle valve: (a) Flow from left to outlet and (b) flow from right to outlet in Fig. 1.5.

One application for a shuttle valve is to have a primary pump inlet P1 and a secondary pump inlet P2 connected to the system outlet A The secondary pump acts as a backup, supplying flow to the system if the primary pump loses pressure. A shuttle valve is called an "OR" valve because receiving a pressure input signal from either P1 or P2 causes a pressure output signal to be sent to A. Graphical symbol of shuttle valve is shown in Fig. 1.6.

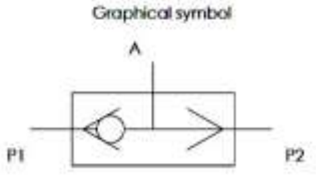


Fig 1.6 symbol of Shuttle valve