

Lecture 16

DIRECTIONAL CONTROL VALVE [CONTINUED]

1.7.1 2/2-Way DCV (Normally Closed)

Figure 1.7 shows a two-way two-position (normally closed) of spool type. A spool valve consists of a cylindrical spool that slides back and forth inside the valve body to connect or block flow between the ports. The larger diameter portion of the spool, the spool land, blocks flow by covering the port. This particular valve has two ports labeled P and A. P is connected to the pump line and A is connected to the outlet to the system. Figure 1.7(a) shows the valve in its normal state and its corresponding symbol. The valve is held in this position by the force of the spring. In this position, the flow from the inlet port P is blocked from going to the outlet port A. Figure 1.7(b) shows the valve in its actuated state and its corresponding symbol. The valve is shifted into this position by applying a force to overcome the resistance of the spring. In this position, the flow is allowed to go to the outlet port.

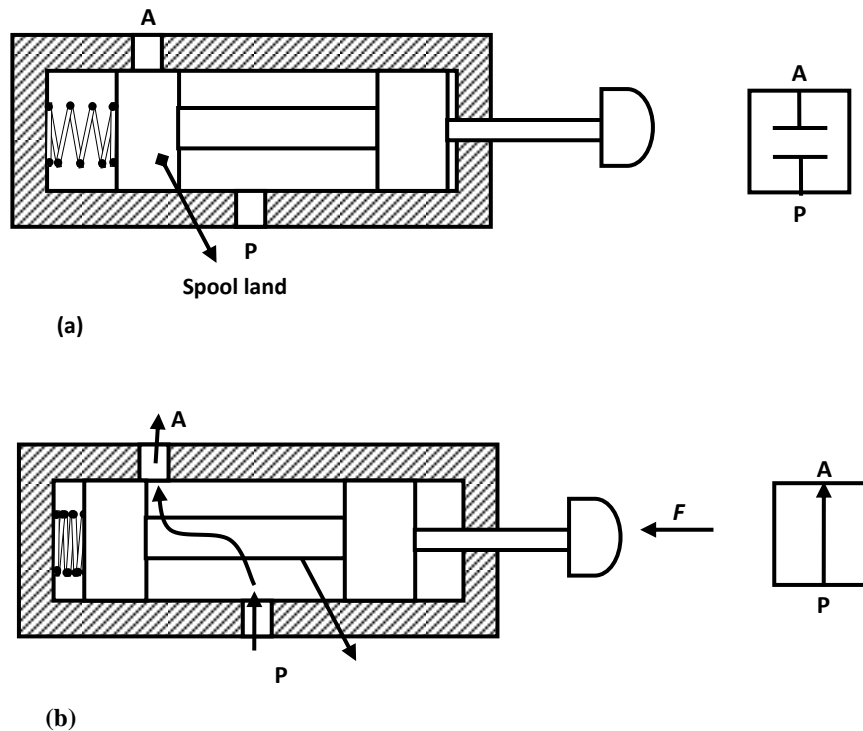


Figure 1.7 Two-way-two-position normally closed DCV. (a) Ports A and P are not connected when force is not applied (valve unactuated). (b) Ports A and P are connected when force is applied (valve actuated).

1.7.2 2/2-Way DCV (Normally Opened)

Figure 1.8 shows a two-way two-position normally open DCV. The spring holds the valve in a position in which ports P and A are connected as shown in Fig 1.8(a). When the valve is actuated, the flow is blocked from going to A as shown in Fig 1.8(b). The complete graphic symbol for the given DCV is shown in Fig 1.8(c).

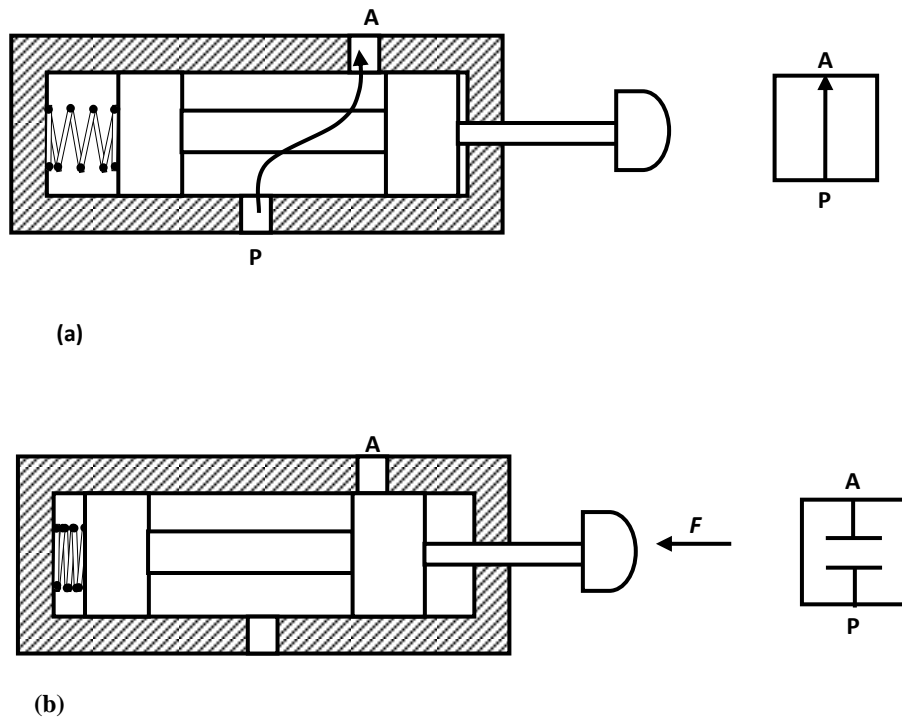


Figure 1.8 2/2 DCV normally opened. (a) Ports A and P are connected when force is not applied (valve unactuated). (b) Ports A and P are not connected when force is applied (valve actuated)

1.7.3 Application of 2/2 DCV

A pair of two-way valves is used to fill and drain a vessel. In Fig.1.9(a), valve 1 is shifted to the open position, while valve 2 remains closed. This fills the vessel. In Fig.1.9(b), valve 2 is shifted to open position and valve 1 remains closed. This drains the vessel.

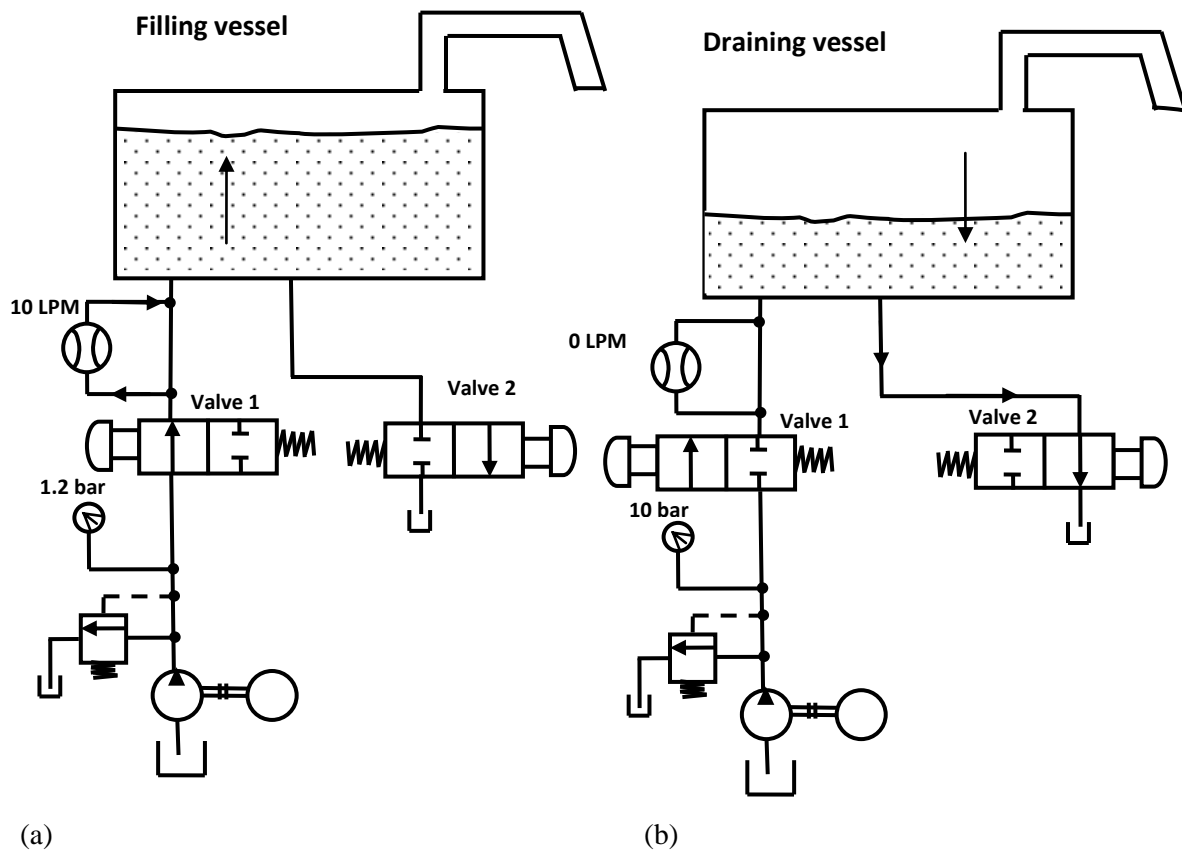


Figure 1.9 Application of 2/2

1.8 Three-Way Direction Control

1.8.1 3/2-Way DCV (Normally Closed)

Three-way valves either block or allow flow from an inlet to an outlet. They also allow the outlet to flow back to the tank when the pump is blocked, while a two-way valve does not. A three-way valve has three ports, namely, a pressure inlet (P), an outlet to the system (A) and a return to the tank (T). Figure 1.10 shows the operation of a 3/2-way valve normally closed. In its normal position, the valve is held in position by a spring as shown in Fig. 1.10(a). In the normal position, the pressure port P is blocked and outlet A is connected to the tank. In the actuated position shown in Fig. 1.10(b), the pressure port is connected to the tank and the tank port is blocked.

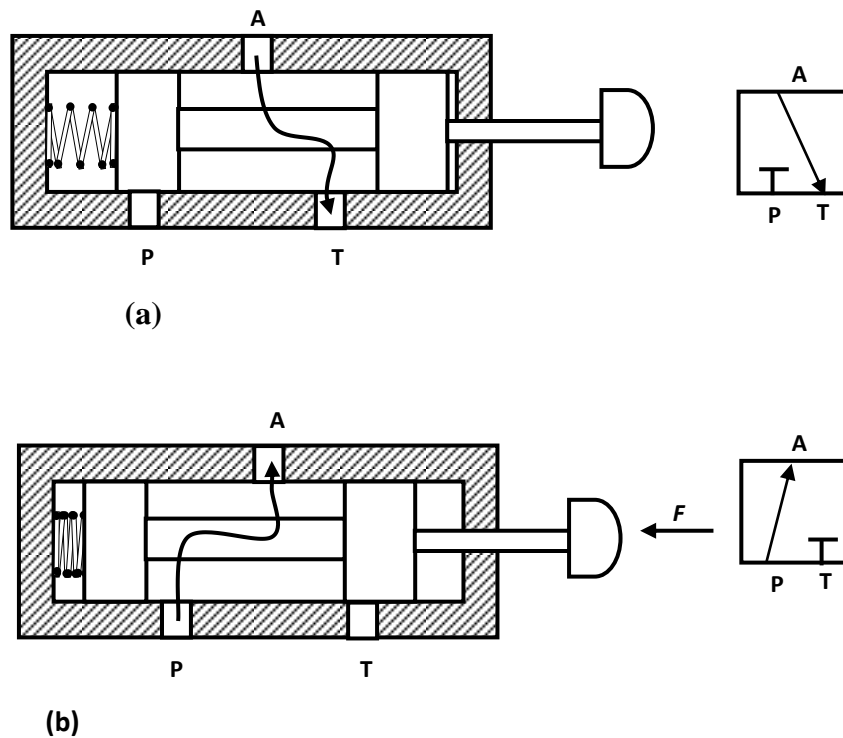
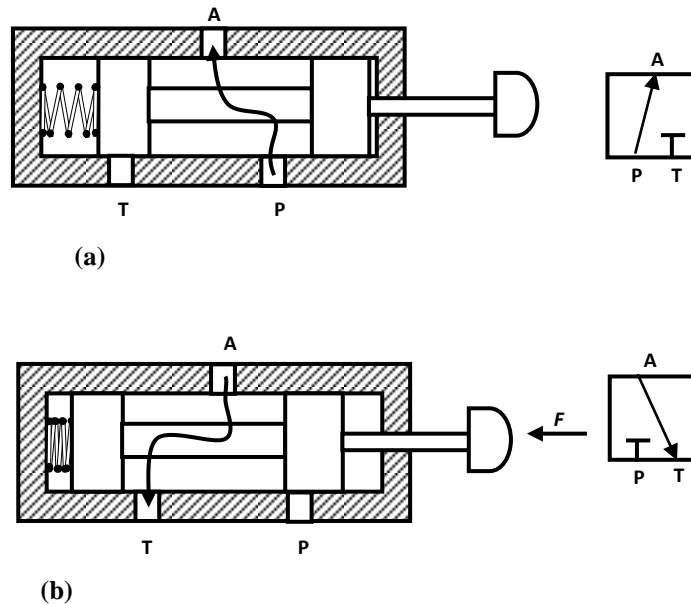


Figure 1.10 3/2-way DCV (normally closed). (a) Ports A and T are connected when force is not applied (valve unactuated). (b) Ports A and P are connected when force is applied (valve actuated).

1.8.23/2-Way DCV (Normally Opened)

Figure 1.11 shows a three-way two-position DCV (normally open) with push button actuation and spring return. In the normal position, shown in Fig. 1.11(a), the valve sends pressure to the outlet and blocks the tank port in the normal position. In the actuated position, the pressure port is blocked and the outlet is vented to the tank.



(a) **Figure 1.11** 3/2-way DCV (normally opened). (a) Ports A and P are connected when force is not applied (valve unactuated). (b) Ports A and T are connected when force is applied (valve actuated).

1.8.3 Applications of 3/2 DCV and 3/3 DCV

3/2 DCV and 3/2 DCV find application in the following ways: **Application of 3/2 DCV for controlling a single-acting cylinder:** A 3/2 DCV is used to control a single-acting cylinder. Figure 1.12(a) shows the valve in its normal position in which the pressure port is blocked and the outlet is returned to the tank. This allows the force of the to act on the piston and retract the cylinder. The cylinder remains in the retracted position as long as the valve is in this position. In Fig.1.12(b), the valve position is shifted by the actuation of the push button. This connects the pressure port P with outlet A and the tank port is blocked. This applies pump flow and pressure to the piston and the cylinder extends against the light force of the spring.

- 1. Application of 3/3 DCV in filling and draining the vessel:** A three-way, three-position DCV may be used to fill and drain a vessel. In this application, the closed neutral is required to hold the vessel at some constant fluid level(Fig. 1.13).
- 2. Application of 3/3 DCV in controlling a gravity return single-acting cylinder:** A gravity return-type single-acting cylinder is controlled by a three-way DCV. A third position called neutral may be desired for its application. This position shown as the center position in the symbol blocks all these ports. This position holds the cylinder in a mid-stroke position. Many cylinder applications require this feature. Figure 1.14 introduces another type of actuation manual lever and detent. A detent is a mechanism that holds the valve in any position into which it is shifted. The detented valve has no normal position because it remains indefinitely in the last position indicated. When the valve is in the closed neutral position or the retract position, the pump flow goes over the pressure relief valve because the pressure port is blocked.
- 3. Application of 3/2-way valve for controlling a double-acting cylinder:** Double-acting cylinders can be controlled with two 3/2-way valves so arranged that when one valve pressurizes one end of the cylinder, the other valve exhausts the other end and vice versa(Fig. 1.15).

Figure 1.12 Application of 3/2 valve—control of single-acting cylinder:(a) return; (b) extend.

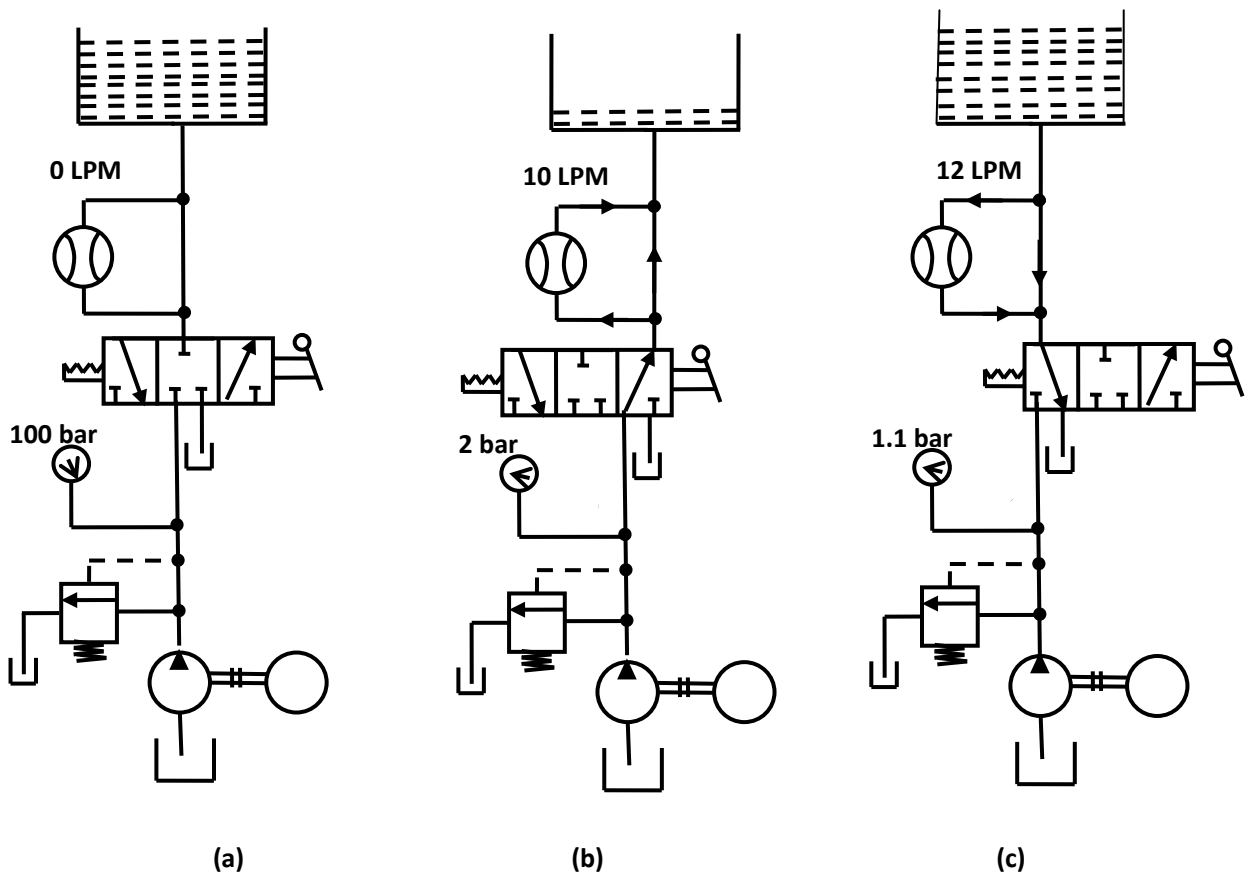


Figure 1.13 Application of 3/2 valve—filling and draining a vessel: (a) hold; (b) fill; (b) drain.

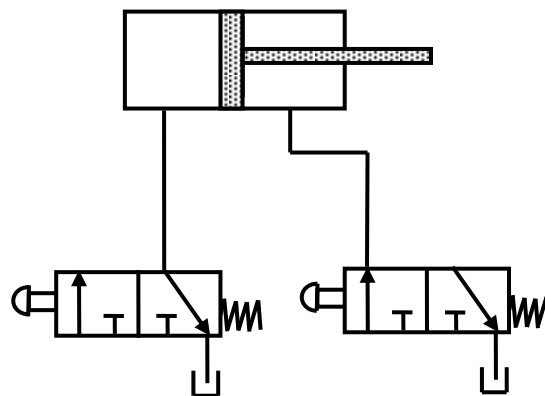


Figure 1.14 Application of 3/2 valve –controlling a double-acting cylinder.

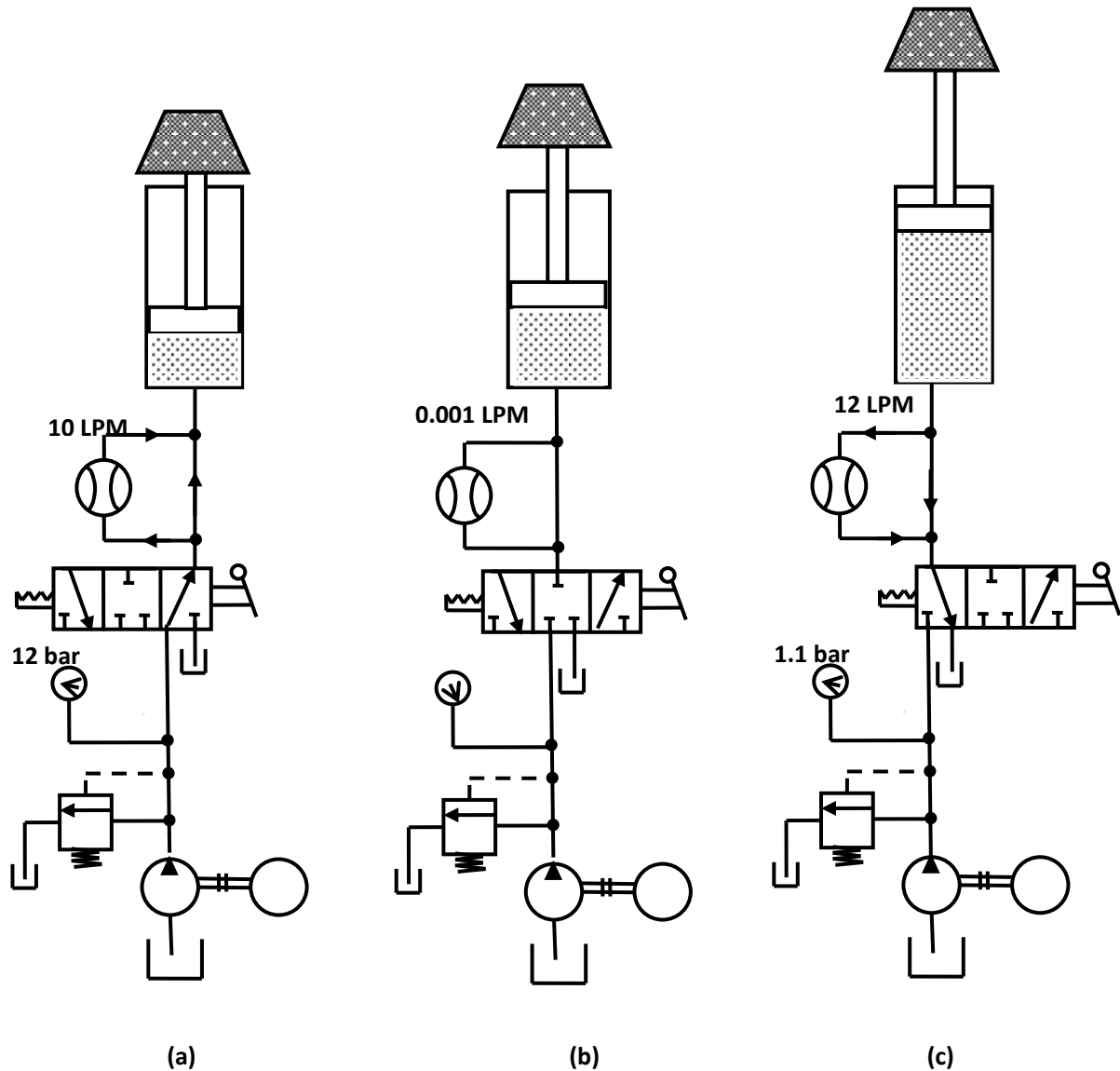


Figure 1.15 Application of 3/3 valve –controlling a single-acting cylinder.

1.9 Four-Way Direction Control Valves

Four-way DCVs are capable of controlling double-acting cylinders and bidirectional motors. Figure 1.16 shows the operation of a typical 4/2 DCV. A four-way has four ports labeled P,T,A and B. P is the pressure inlet and T is the return to the tank; A and B are outlets to the system. In the normal position, pump flow is sent to outlet B. Outlet A is connected to the tank. In the actuated position, the pump flow is sent to port A and port B connected to tank T. In four-way DCVs, two flows of the fluids are controlled at the same time, while two-way and three-way DCVs control only one flow at a time. Figure 1.16 (c) shows the complete graphic symbol for a four-way two-piston DCV.

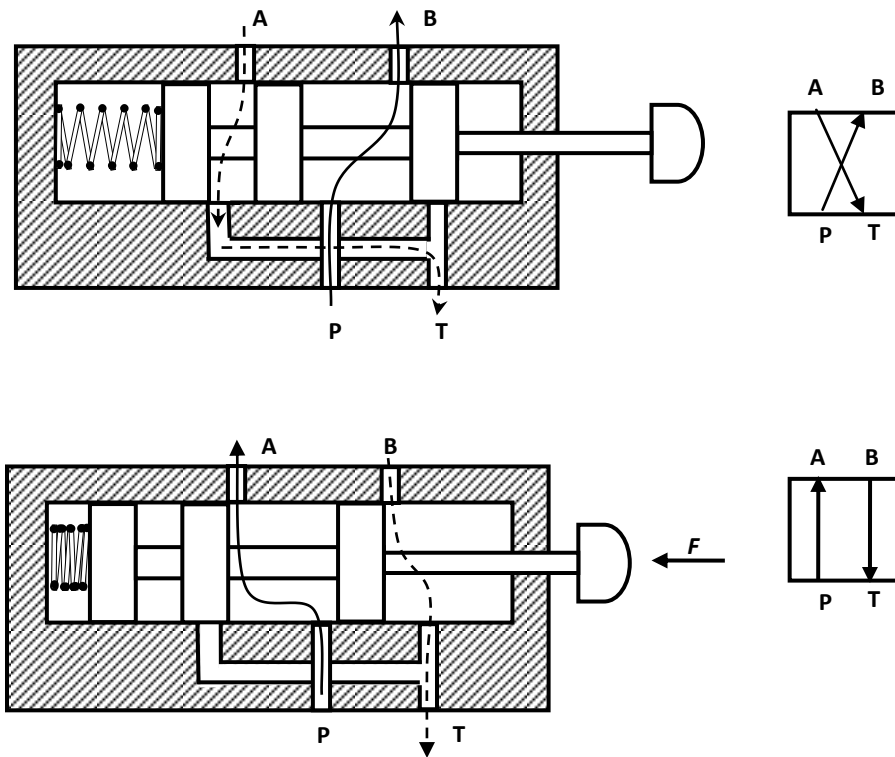


Figure 1.16Four-way DCV.

1.9.1 Applications of 4/2 DCV and 4/3 DCV

4/2 DCV and 4/3 DCV find applications in the following ways:

- 1. Application of 4/2-way valve to control a double-acting cylinder:** A four-way DCV is used to control a double-acting cylinder. When the valve is in the normal position, the pump line is connected to the end of the cylinder and the blind end is connected to the tank as shown in Fig.1.17(a). The cylinder retracts when the cylinder is in this position. When the cylinder is fully retracted, the pump flow goes over to the pressure relief valve and back to the tank. In Fig.1.17(b), the pump line is connected to the blind end of the cylinder and the rod end is connected to the tank. This causes the cylinder to extend. When the cylinder is fully extended, the pump flow again goes over the pressure relief valve to the tank.

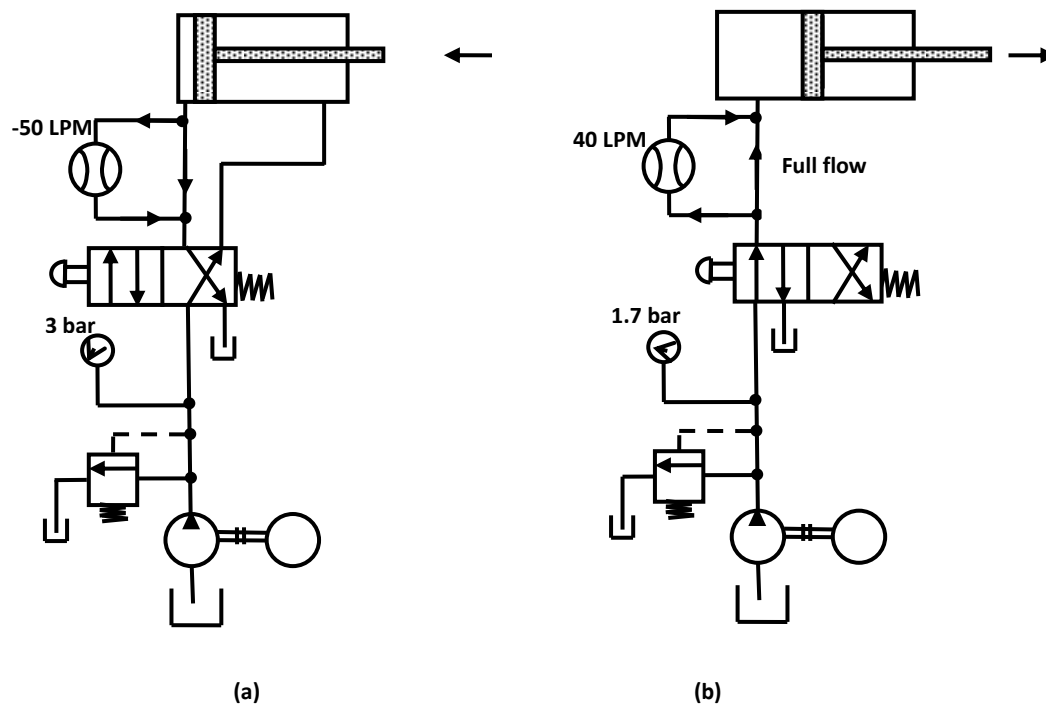


Figure 1.17 Application of a 4/2-way valve – control of single-acting cylinder: (a) return; (b) extend.

2. **Application of 4/2 DCV for controlling bi-directional motors:** A four-way DCV is also used to control bi-directional hydraulic motors. Figure 1.18 shows the schematic for this application. Unlike the cylinder, the motor rotates continuously and does not force the fluid over the pressure relief valve.

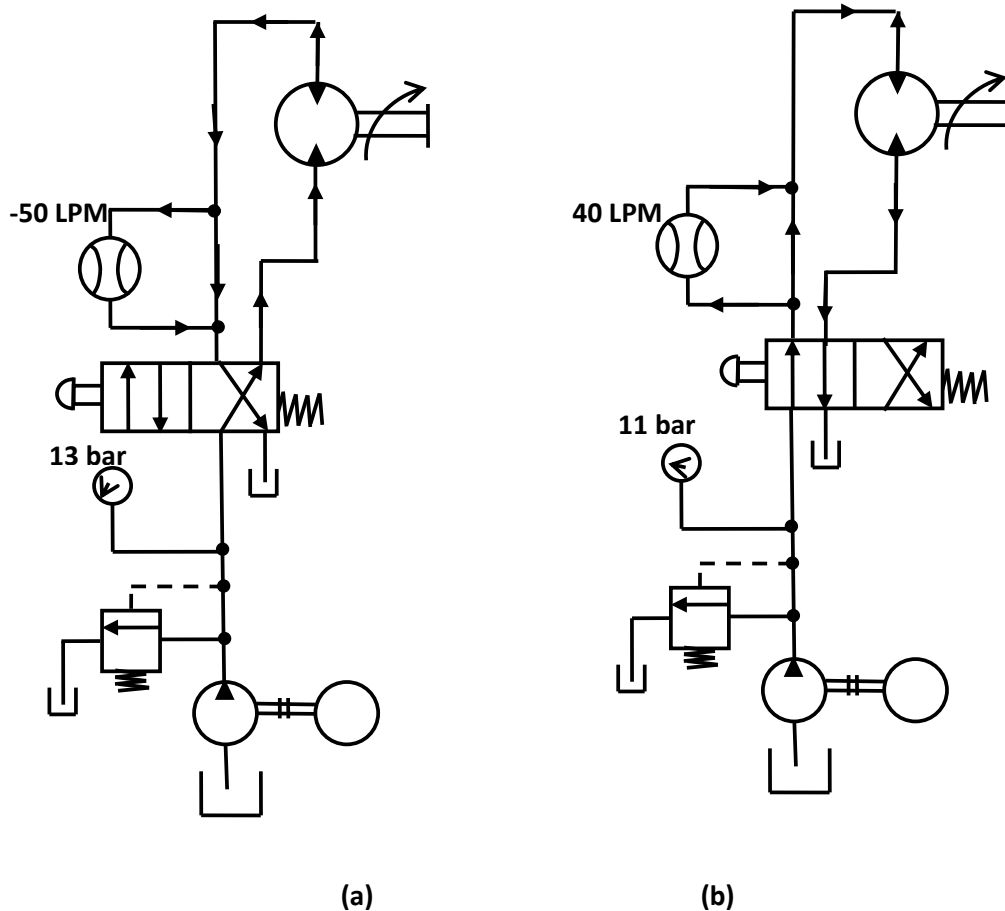


Figure 1.18 Application of 4/2-way valve – control of a bi-directional motor.

The four-way, two-position DCVs used in the previous two applications are sometimes impractical because they continually send pump flow and pressure to the actuator in one direction or the other. Many cylinder and motor applications require a third DCV position or neutral in which the actuator is subjected to pump pressure. Four-way three-position circuits are therefore used in many hydraulic circuits. Many types of neutrals are available; the most common of them are as follows:

- Closed neutral.
- Tandem neutral.
- Float neutral.
- Open neutral.
- Regenerative neutral.

3. Application of 4/3 DCV (closed neutral) for controlling a double-acting cylinder: Figure 1.19 shows it in a simple cylinder circuit. The valve shown here is spring centered, which means that it always returns to the neutral position automatically when not actuated. For closed neutral, the pump line is blocked so that the flow must pass over the pressure relief valve the pressure is at the system maximum. This is a wasteful thing because it generates power in the form of pressure and flow, but does not use it. The wasted energy in the system goes as heat. This is undesirable because the hydraulic fluid becomes thinner (less viscous) as it heats up. When the fluid becomes

too thin, it does not lubricate effectively. This is the result of increased wear. The outlet lines to the cylinder are blocked, so the cylinder is held firmly in position. This is because the lines are full of hydraulic fluid that is incompressible. This type of neutral could also be used to control a motor. Just like cylinder, the motor is held fixed in position when the valve is in the neutral.

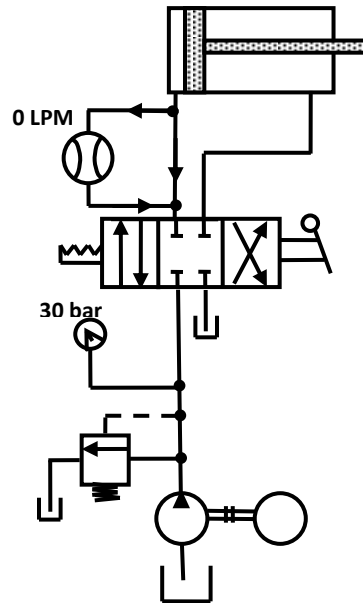


Figure 1.19 Application of 4/3-way valve – closed neutral.

4. **Application of 4/3 DCV (tandem neutral) for controlling a double-acting cylinder:** Figure 1.20 shows it in a simple cylinder circuit. The pump flow is allowed to flow back to the tank through the DCV when it is in the neutral. This is a very desirable situation because only pressure in the pump line is due to the flow resistance of the lines and DCV. This keeps the pressure low when the valve is in the neutral. In this situation, the system is said to be unloaded because the power consumption is reduced. This wastes much less energy than does a closed central neutral that forces the fluid over the pressure relief valve at a high pressure. The cylinder is held in position with a tandem neutral because the outlet port is blocked.

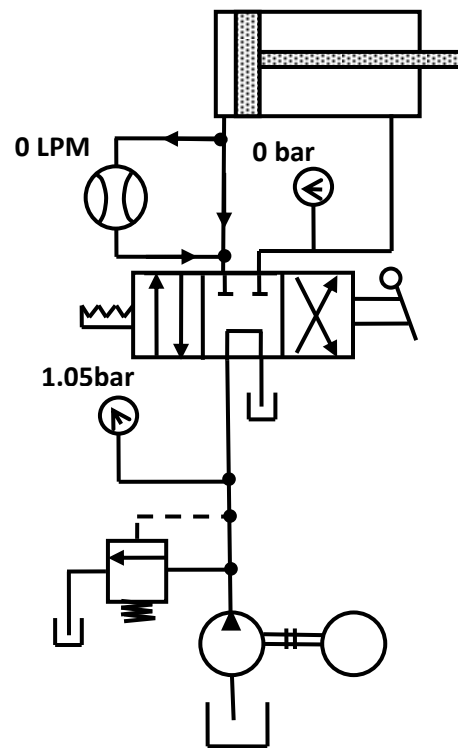


Figure 1.20 Application of 4/3-way valve – tandem neutral.

5. **Application of 4/3 DCV (float neutral) for controlling a bidirectional motor:** Figure 1.21 shows a four-way with a float neutral controlling a bidirectional motor. The pressure port is blocked so that the pump flow is forced over the pressure relief valve. Because both the outlets are connected to the tank, the motor floats or spins freely when the DCV is in the neutral. This type is used in motor circuits because it allows the motor to spin to a stop when the valve is shifted to the neutral. This is often preferable to shifting to a closed position because motors often build up a great deal of momentum. Shifting the valve closed in this situation causes a large pressure hike in the outlet line because the motor tends to keep spinning and tries to push the fluid into its outlet. This is known as shifting shock. Float neutrals are often desirable for cylinder circuits in some applications.

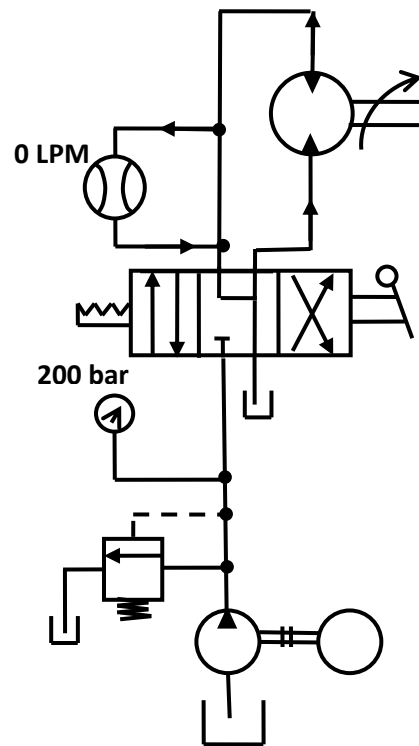


Figure 1.21 Application of 4/3-way valve – floating neutral.

- 6. Application of 4/3 DCV (open neutral) for controlling a double-acting cylinder:** Figure 1.22 shows the four-way with an open neutral controlling a cylinder. Flow always follows the path of least resistance, so the pump flow goes back to the tank. Because the outlets are also connected to the tank, the cylinder floats when this valve is in neutral. This is desirable in a circuit in which some external force must position the cylinder when in the neutral.

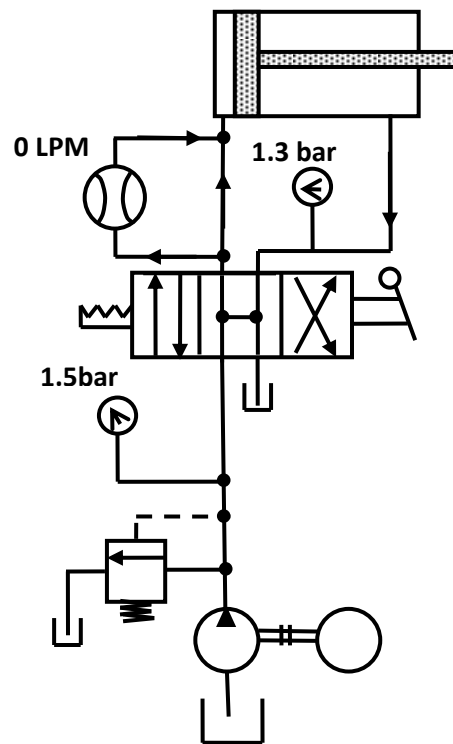


Figure 1.22 Application of 4/3-way valve – open neutral.

Application of 4/3 DCV (regenerative neutral) for controlling a double-acting cylinder: A regenerative neutral is considerably different in its function than other types. A regenerative term is used to describe a system in which the waste is fed back into the system to supplement the input power. In this neutral, the pressure port is connected to both outlets and the tank port is blocked. Figure 1.23 shows a four-way with a negative neutral controlling a cylinder. When this valve is shifted to the neutral, the pump pressure is applied to both sides of the piston. Because the piston area in the rod side of the cylinder is smaller than that on the blind side, there is a net force applied to extend the piston rod. As the piston extends, it forces the outlet flow from the rod side back into the valve, where it combines with the pump flow and goes to the blind end of the cylinder. This causes the considerable increase in cylinder speed. This is the purpose of the regenerative neutral that instead of sending the return flow back to the tank, it sends it into the inlet side of the cylinder, thereby increasing its speed.

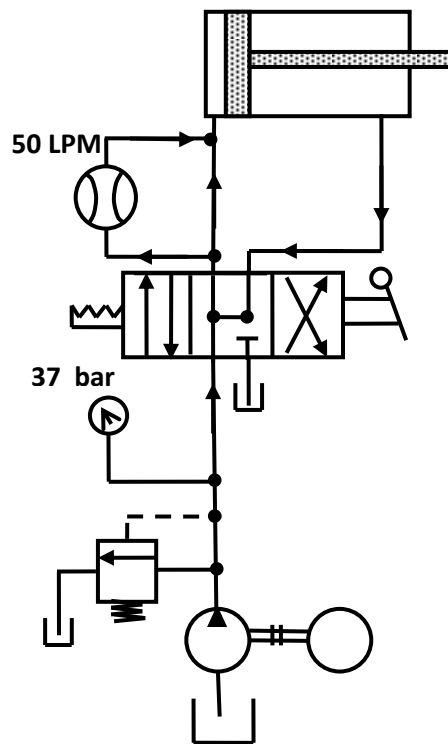


Figure 1.23 Application of 4/3-way valve – regenerative neutral.

1.10 Solenoid-Actuated Valve

A spool-type DCV can be actuated using a solenoid as shown in Figure. 1.24. When the electric coil (solenoid) is energized, it creates a magnetic force that pulls the armature into the coil. This causes the armature to push on the push pin to move the spool of the valve.

Like mechanical or pilot actuators, solenoids work against a push pin, which in turn actuates a spool. There are two types of solenoid designs used to dissipate the heat developed in electric current flowing in the coil. The first type dissipates the heat into surrounding air and is referred to as an “air gap solenoid.” In the second type “wet pin solenoid,” the push pin contains an internal passage way that allows the tank port oil to communicate between the housing of the valve and the housing of the solenoid. Wet pin solenoids do a better job in dissipating heat because the cool oil represents a good heat sink to absorb heat from the solenoid. As the oil circulates, the heat is carried into the hydraulic system where it can be easily dealt with.

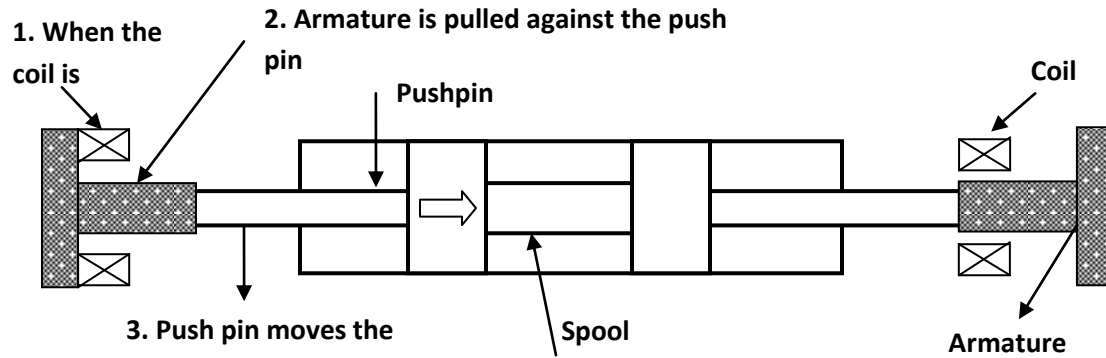


Figure 1.24Solenoid valve.

In the case of direct current (DC) solenoids, the current develops a magnetic field of fixed polarity. The DC solenoids are practically safe from burning out if the correct voltage is applied. The solenoid force depends not only on the solenoid design and current but also on the core position. The available commercial solenoids produce a force of 60–70 N. For a greater force, the number of turns of coil or current should be increased.

Alternating current (AC) solenoids function in the same manner as DC solenoids but their magnetic fields are influenced by the alternating current. The magnetic force is high when AC current is at its positive or negative peak. As the current changes from positive to negative, it must pass through neutral points where there is no current or no force. Due to this, load can push the core slightly out of equilibrium. This is commonly referred to as buzz. To eliminate buzz, shading coils are used. A shading coil creates its own magnetic field but the current produced lags behind the coil current and thus helps to prevent buzz. A comparison between AC and DC solenoids is given in Table 1.3.

Table 1.3Comparison between AC and DC solenoids

Parameter	DC Solenoid	AC Solenoid
Switching time	50–60 ms	20 ms
Service life expectations	20–50 million cycles	10–20 million cycles
Max. switching frequency	Up to 4 cycles/s	Up to 2 cycles/s
Continuous operation	Unlimited	15–20 min for dry solenoids. 60–80 min for wet solenoids
Relative cost	1	1.2
Occurrence rate	10	2

1.11Pilot-Operated Direction Control Valves

Pilot-operated DCVs are used in a hydraulic system operating at a high pressure. Due to the high pressure of the system, the force required to actuate the DCV is high. In such systems, operation at a high pressure uses a small DCV that is actuated by either a solenoid or manually. This pilot DCV in turn uses the pressure of the system to actuate the main DCV as shown in Figure. 1.25.

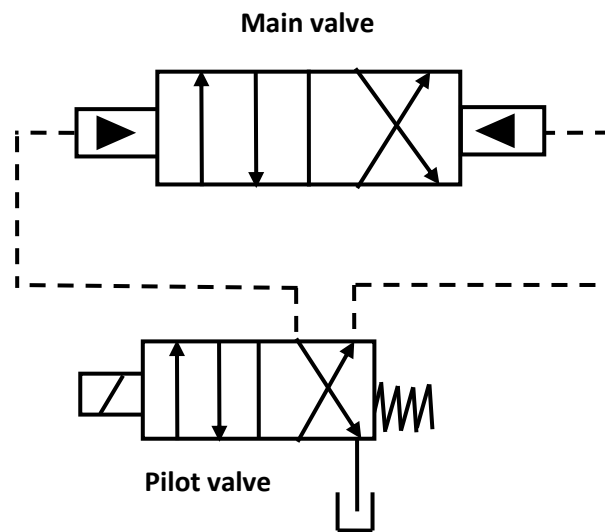


Figure 1.25 Pilot-operated DCVs.