Lecture 19

PRESSURE-CONTROL VALVES [CONTINUED]

1.5 Counterbalance Valve

Schematic diagram of counterbalance valve is shown in Fig. 1.14. These normally closed valves are primarily used to maintain a back pressure on a vertical cylinder to prevent it from falling due to gravity. They are used to prevent a load from accelerating uncontrollably. This situation can occur in vertical cylinders in which the load is a weight. This can damage the load or even the cylinder itself when the load is stopped quickly at the end of the travel.

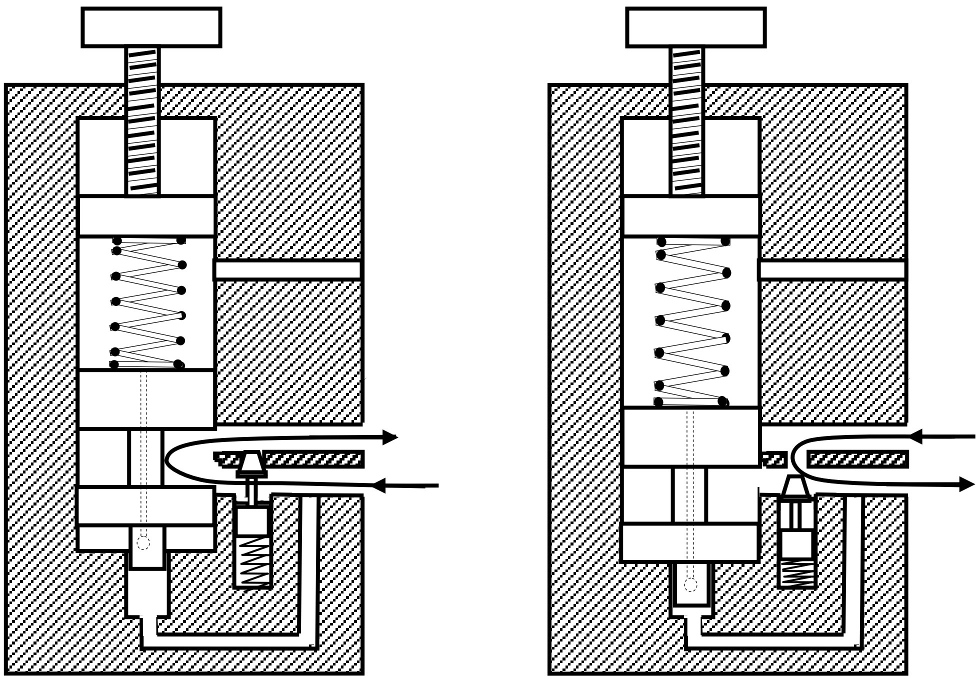


Figure 1.14 Counterbalance valve.

valve's primary port is connected to the cylinder's rod end and the secondary port to the directional control valve. The pressure setting is slightly higher than that required to keep the load from free-falling. When the pressurized fluid flows to the cylinder's cap end, the cylinder extends, increasing pressure in the rod end and shifting the main spool in the counterbalance valve. This creates a path that permits the fluid to flow through the secondary port via the directional control valve and to the reservoir. As the load is raised, the integral check valve opens to allow the cylinder to retract freely.

If it is necessary to relieve back pressure at the cylinder and increase the force at the bottom of the stroke, the counterbalance valve can be operated remotely. Counterbalance valves are usually drained internally. When the cylinder extends, the valve must open and its secondary port should be connected to the reservoir. When the cylinder retracts, it matters little that load pressure is felt in the drain passage because the check valve bypasses the valve's spool. Graphic symbol of a pressure-reducing valve is shown in Fig. 1.15.

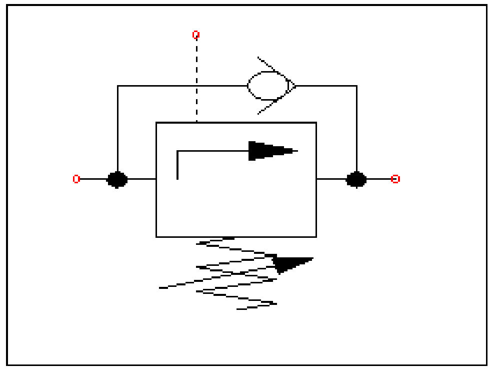


Figure1.15 Symbolic representation of a counterbalance valve.

1.5.1Application of a Counterbalance Valve

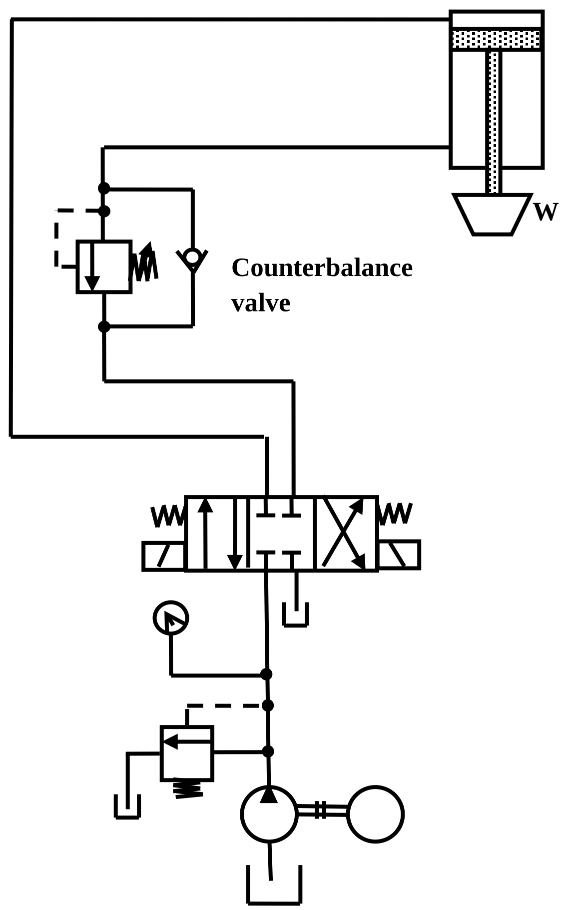


Figure 1.16 Application of a counterbalance valve.

Counterbalance valves are commonly used to counterbalance a weight or external force or counteract a weight such as a platen or a press and keep it from freefalling.Figure1.16 illustrates the use of a counterbalance or back-pressure valve to keep a vertically mounted cylinder in the upward position while the pump idles, that is, when the DCV is in its center position. During the downward movement of the cylinder, the counterbalance valve is set to open at slightly above the pressure required to hold the piston up (a check valve does not permit flow in this direction). The control signal for the counterbalance valve can be obtained from the blank end or rod end of the cylinder.

If derived from the rod end, the pressure setting of the counterbalance valve equals the ratio of the load to the annulus area of the piston. If derived from the blank end, the pressure setting equals the ratio of load to the area of piston. This pressure is less and hence usually it has to be derived from the blank end. This permits the cylinder to be forced downward when pressure is applied on the top. The check valve is used to lift the cylinder up as the counterbalance valve is closed in this direction. The directional control valve unloads the pump.

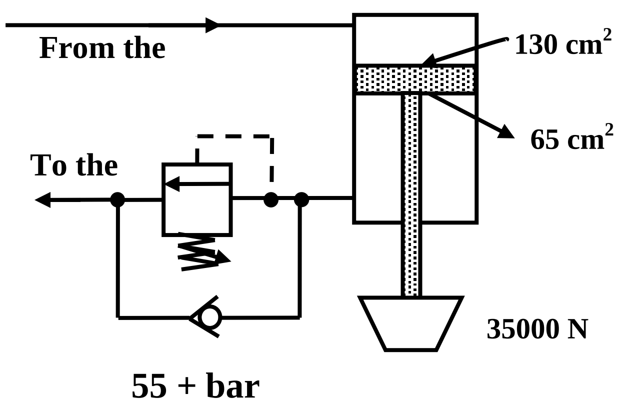
1.6 Source of Pilot Pressure in Counterbalance Valves

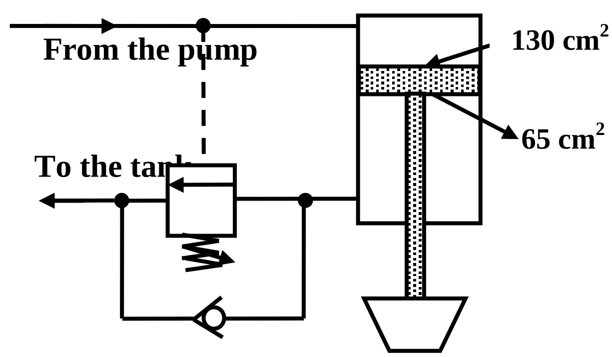
When a counterbalance valve is used in large vertical presses, it may be important to analyze the source of pilot operating pressure. Figure 1.17 shows a comparison between direct pilot and remote pilot operation.

Through the application of Pascal's law, we have

$$p = \frac{\text{Force}}{\text{Area}} = \frac{35000}{65 \times 10^{-4}} \cong 55\,\text{bar}$$

If the pilot pressure is taken directly, then the counterbalance valve operates at about 55 bar or slightly higher because of inertia and friction. In the other case, where the remote pilot pressure is taken from the pressure line at the top of the cylinder, a choice of operating pressure can be made for the valve. A counterbalance valve is normally a closed valve and remains closed until acted upon by the remote pilot pressure source. Therefore, a much lower spring force can be selected to allow the valve to operate at a lesser pilot pressure. It should also be noted that the press load cannot move downward unless flow from the pump is directed into the top of the cylinder, which isa normal function of the machine.





(a) (b)

Figure 1.17(a) Direct pilot and (b) remote pilot.

1.7 Pressure Sequence Valve

A sequence valve is a pressure-control valve that is used to force two actuators to operate in sequence. They are similar to pressure-relief valves. Schematic diagram of sequence valve is shown in Fig. 1.18. Instead of sending flow back to the tank, a sequence valve allows flow to a branch circuit, when a preset pressure is reached. The check valve allows the sequence valve to be bypassed in the reverse direction. The component enclosure line indicates that the check valve is an integral part of the component. The sequence valve has an external drain line; therefore, a line must be connected from the sequence valve's drain port to the tank. The symbol for a sequence valve is shown in Fig. 1.19.

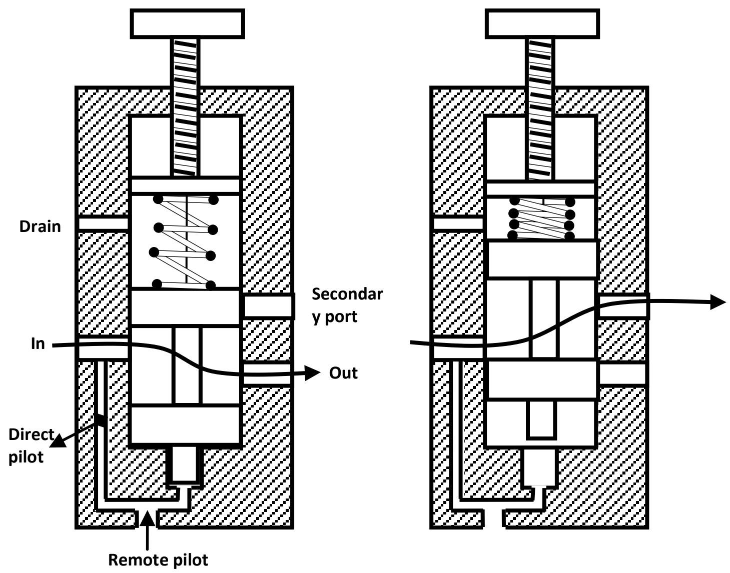


Figure 1.18 Sequence valve.

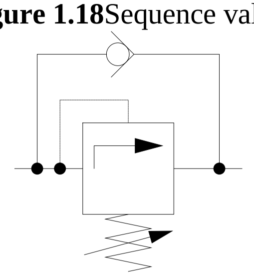


Figure 1.19 Sequence valve with a check valve.

1.7.1 Application of a Sequence Valve

The hydraulic circuit shown in Fig. 1.20 is an example of an application of a sequence valve in which a clamp cylinder extends first to hold a workpiece and then a second cylinder extends to bend the workpiece in the desired shape.

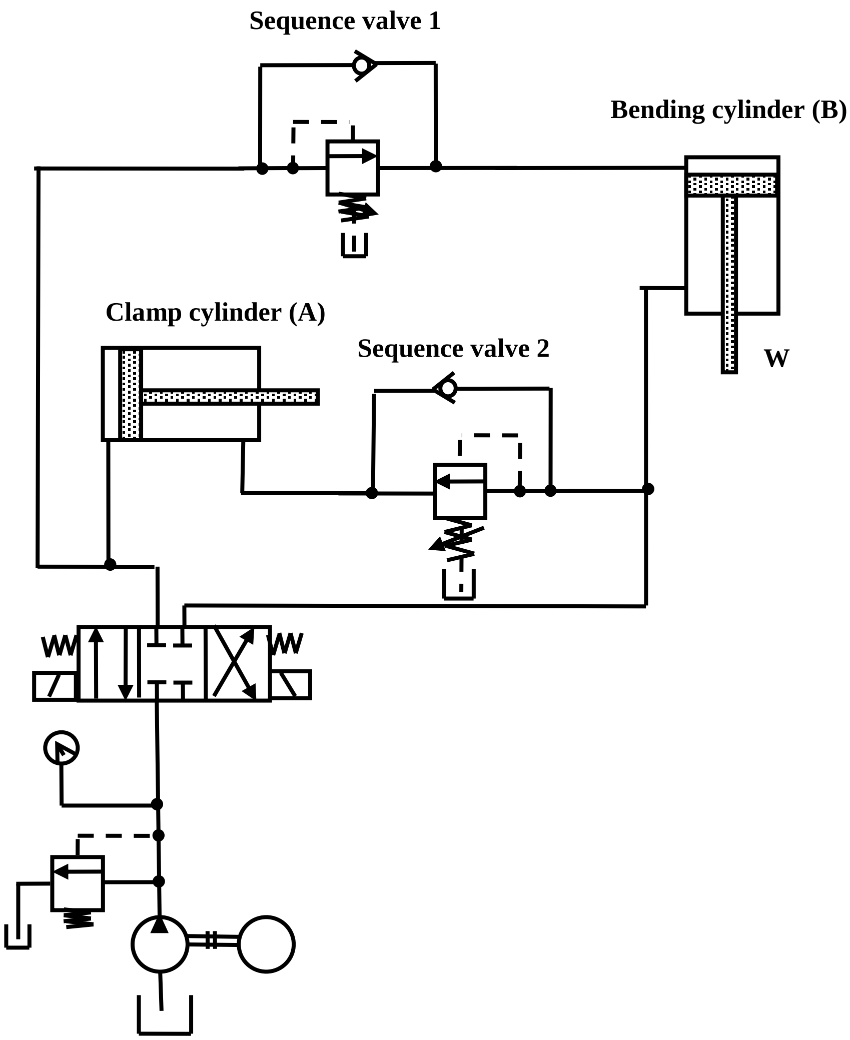


Figure 1.20 Application of a sequence valve.

In this circuit, two cylinders are connected in parallel. Without the sequence valve, these cylinders would extend together as they are both unloaded. In order for this circuit to function properly, the clamp cylinder must extend completely before the bending cylinder begins to extend. The sequence valve accomplishes this by not allowing flow into the bending cylinder branch of circuit until the clamp cylinder has reached the end of its stroke. When the clamp cylinder extends completely, the pressure rises and opens the sequence valve,thus allowing the bending cylinder to extend. The sequence valve must be set high enough so that it opens only after the complete extension of the clamp cylinder.

During the retraction of cylinders, the check valve allows the sequence valve to be bypassed. The sequence valve has no effect on the circuit in this situation. Both cylinders retract together because both are unloaded and split the pump flow.

1.8 Cartridge Valves

Cartridge valves consist of a valve shell that can be mounted in a standard recess in a valve block or manifold. The machine manufacturer does not have to worry about tolerances of moving spools and poppets because these are taken care by the hydraulic valve manufacturer. This is very advantageous for batch production and modularized packages or integrated circuits. Cartridge valves eliminate expensive and potentially leaking pipework and connectors.Cartridge valves can be used as follows:

1. Leak-proof direction control valve.
2. Check valve to obtain unidirectional flow.
3. Throttle valve to control and limit the rate of flow.

The valve shell or body has two main ports (A and B) that are connected or separated by a poppet or a spool. The poppet-type cartridge valve is basically a check valve that can be pilot operated in a number of ways, whereas the spool-type cartridge valve is used as a variable restrictor that is either normally open or closed by the action of the control or vice versa. The actions of the two types of cartridge valvesare completely different.

1.8.1 Poppet-Type Cartridge Valves

In some designs, a poppet fits into cavity and is held in position by a cover or a top plate that contains all pilot connections. Others are designed to fit the standard cavities used by some conventional cartridge valves. Logic elements that have a balanced poppet or spools can be modulated and are largely used as pressure controls. Those with unbalanced poppets are primarily used for switching functions such as directional controls or where the poppet movement can be limited as flow controls.

The principal advantages of poppet-type valves are as follows:

1. A very high flow rate for a relatively small physical size.
2. A positive seal can be obtained.
3. May be extremely rapid acting but can also be easily adopted for soft switching.
4. The shape of the poppet or spool together with its seat can be varied to give different operating characteristics to the valve assembly.

The major disadvantage is that unbalanced poppets, being responsive to pressure changes on all ports, may malfunction owing to pressure surges. Particular care has to be taken in the circuit design to ensure the safe operation. The opening and closing movements of the poppet in a cartridge valve are pressure-dependent and a function of the forces in these areas:

$$A_{\mathrm{A}} = \text{Effective area of the poppet at port A}$$

$$A_{\mathrm{B}} = \text{Effective area of the poppet at port B}$$

$$A_{\mathrm{X}} = \text{Effective area of the poppet at port X}$$

Then

$$A_{\mathrm{X}} = A_{\mathrm{A}} + A_{\mathrm{B}}$$

In a balanced poppet-type shown diagrammatically and symbolically in Fig.1.21, $A_{\mathrm{B}} = 0$ and the areas A_{X} and A_{A} are equal.Pilot X controls the function of the valve. If X is connected to port B, the valve operates as a check valve allowing flow from A to B by opening the poppet but preventing flow from B to A by closing the poppet. If port X is connected to the external pressure, the valve can be used to control closing or opening pressure.

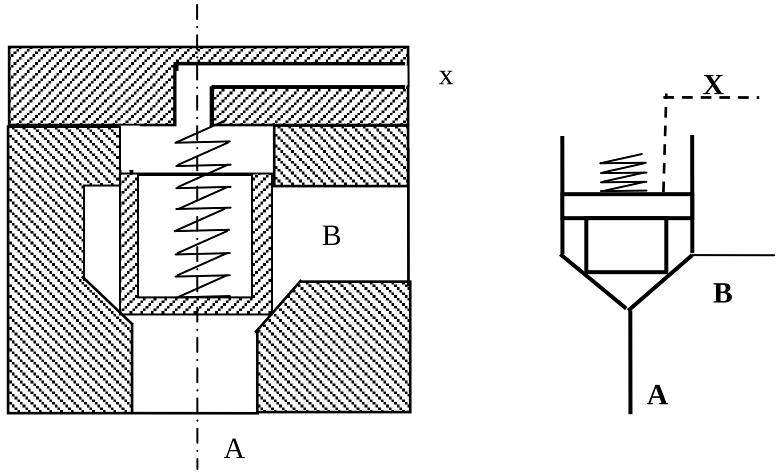


Figure 1.21 Balanced poppet cartridge valve area ratio, $A_{\mathrm{A}} = A_{\mathrm{X}}$.

In an unbalanced poppet-type valve shown diagrammatically and symbolically in Fig.1.22, it is possible to obtain a different area ratio, typically

$$A_{\mathrm{X}} : A_{\mathrm{A}} = 1:1.1, \text{ where } A_{\mathrm{B}} = 0.1 A_{\mathrm{A}}$$

$$A_{\mathrm{X}} : A_{\mathrm{A}} = 1:1.05, \text{ where } A_{\mathrm{B}} = 0.05 A_{\mathrm{A}}$$

$$A_{\mathrm{X}} : A_{\mathrm{A}} = 1:2, \text{ where } A_{\mathrm{B}} = A_{\mathrm{A}}$$

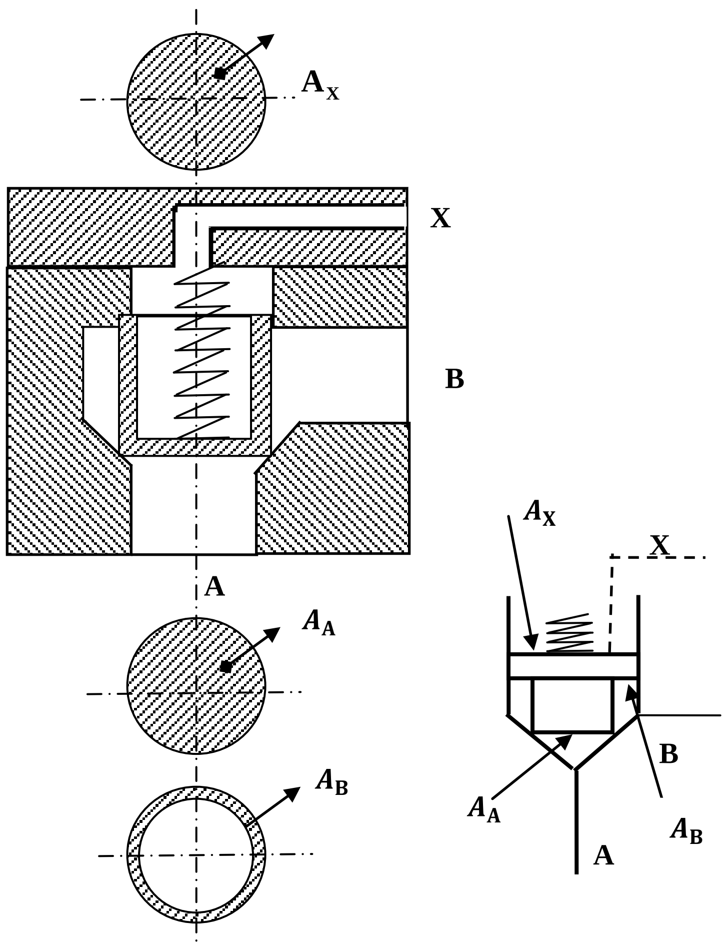


Figure 1.22 Unbalanced poppet cartridge valve area ratio, $A_X = A_A + A_B$.

With the pilot X vented, pressure at port A or B has to overcome the bias spring force only for flow in either direction. However, it can be held closed by a pressure on the pilot port that is dependent on the poppet area ratios.

Figure 1.23 shows how a large double-acting cylinder can be controlled using cartridge valves. A small double-solenoid-operated directioncontrol valve feeds pilot pressure signals to four cartridge valves that are coupled in pairs to each end of the double-acting cylinder. One cartridge valve from each pair is permanently connected to the tank drain line and the other to the pump pressure line. In the position drawn, all the four valves are held closed by the pilot pressure signals and the cylinder position is locked. When solenoid A is energized, pilot pressure is maintained on valves 1 and 3 which remain closed. But valves 2 and 4 are released and open under the influence of fluid pressure in the main system. The fluid under pressure, therefore, flows from the pump through the cartridge valve to the piston side of the cylinder and the cylinder extends. The fluid from the rod end of the cylinder flows through valve 4 back to the tank. When solenoid B is energized, cartridge valves 2 and 4 are closed under pilot pressure and valves 1 and 2 are released, causing the cylinder to retract.

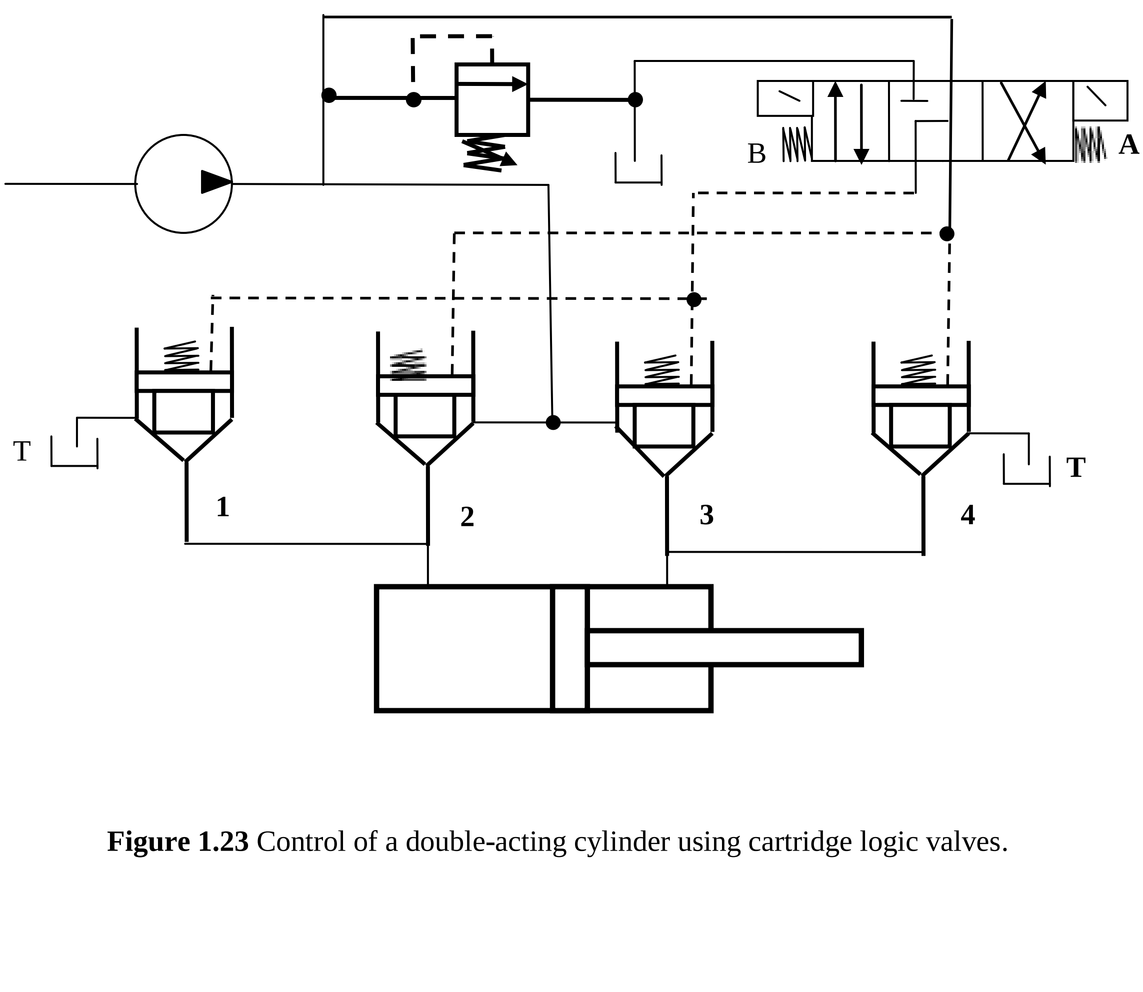


Figure 1.23 Control of a double-acting cylinder using cartridge logic valves.

Objective-Type Questions
Fill in the Blanks

1. A relief valve is similar to a ______ in an electrical system.
2. A pilot-operated pressure relief valve consists of a small ______ and a main relief valve.
3. ______ is used to maintain reduced pressures in specified locations of hydraulic systems.
4. ______ is used to maintain a back pressure on a vertical cylinder to prevent it from falling due to gravity.
5. A pilot-operated unloading relief valve is the same as a pilot-operated relief valve with the addition of an ______ spool.

State True or False

1. Pressure-relief valves limit the maximum pressure in a hydraulic circuit by providing an alternate path for fluid flow when the pressure reaches a preset level.
2. A pilot-operated pressure-relief valve cannot be operated using a remote.
3. A common application of an unloading valve is in high–low pump circuits and punching press.
4. Sequence valves are similar to pressure-relief valves.
5. An unloading valve requires electric signals.

Review Questions

1. Explain the function of pressure-control valves in hydraulic power systems.
2. Discuss in detail the static characteristics of a direct-operated relief valve, and explain how to reduce the over-ride pressure.
3. Draw schematically a pilot-operated relief valve and explain its function.
4. Discuss the application of a pilot-operated relief valve.
5. Discuss the principle of pressure reduction in fluid power systems.
6. Discuss briefly the operation of a pilot-operated pressure reducer.
7. Explain the function of a direct-operated sequence valve.
8. What are the differences between relief and sequence valves?
9. Discuss the application of a sequence valve used in hydraulic systems.
10. Name two applications of a counterbalance valve.
11. What is the function of a sequence valve?
12. What is the function of an unloading valve?
13. How is the unloading valve different from a pressure relief valve?
14. What is the function of a pressure relief valve in fluid power systems?
15. What is the advantage of using an unloading circuit when feed and speed of a machine need to be varied?

Answers
Fill in the Blanks

1.Fuse
2.Pilot relief valve
3.Pressure-reducing valve
4.Counterbalance
5. Unloading

State True or False

1.True
2.False
3.True
4.True
5.False