

# 19MEE09

# FLUID POWER CONTROL SYSTEMS

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# UNIT 3 FLUID POWER ELEMENTS

Construction of Control Components: Direction Control valve - 3/2 way valve - 4/2 way valve - Shuttle valve- check valve -pressure control valve - pressure reducing valve, sequence valve, Flow control valve -Fixed and adjustable, electrical control solenoid valves, Relays. Ladder diagram Accumulators and Intensifiers: Types of accumulators - Accumulators circuits, sizing of accumulators, intensifier - Applications of Intensifier - Intensifier circuit. (9)

# DIRECTION CONTROL VALVE

A Direction Control Valve (DCV) is a key component in hydraulic and pneumatic systems, used to control the direction of fluid flow. It determines the movement of actuators (such as cylinders or motors) by directing the fluid to different paths.

## Functions of DCVs

- Controls the **start, stop, and direction** of fluid flow
- Provides **isolation and interlocking** of different circuits
- Allows **speed and force** control in hydraulic/pneumatic systems

# TYPES OF DIRECTION CONTROL VALVES

## 1. Based on Number of Positions:

1. **2/2 DCV** – Two ports, two positions (e.g., simple on/off valve)
2. **3/2 DCV** – Three ports, two positions (e.g., used for single-acting cylinders)
3. **4/2 DCV** – Four ports, two positions
4. **4/3 DCV** – Four ports, three positions (used for bidirectional control with a neutral position)

## 2. Based on Actuation Method:

1. **Manually Operated** (lever, push-button, foot pedal)
2. **Mechanically Operated** (cams, rollers)
3. **Solenoid Operated** (electrically controlled)
4. **Pneumatically or Hydraulically Operated**

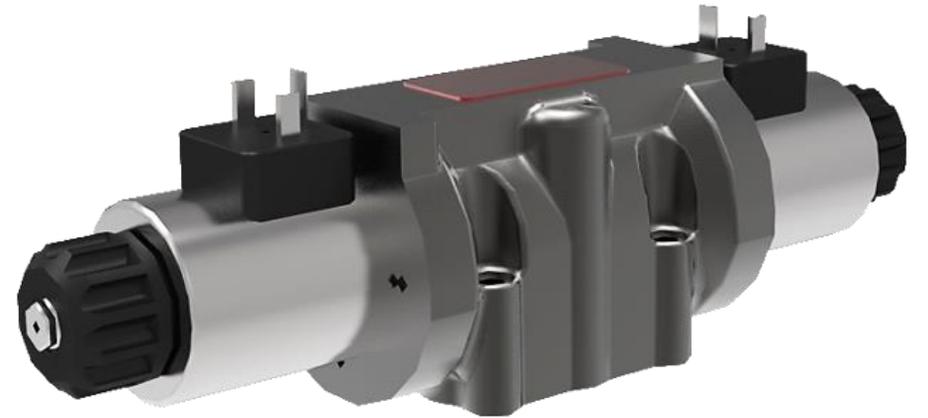
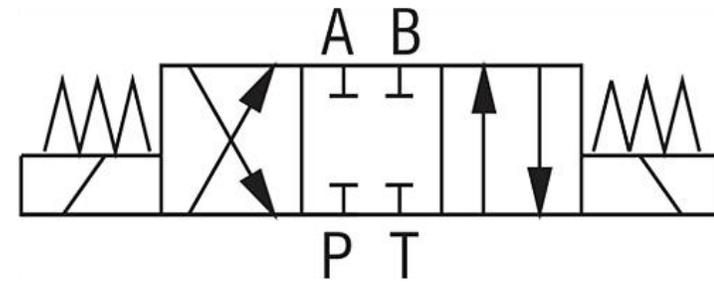
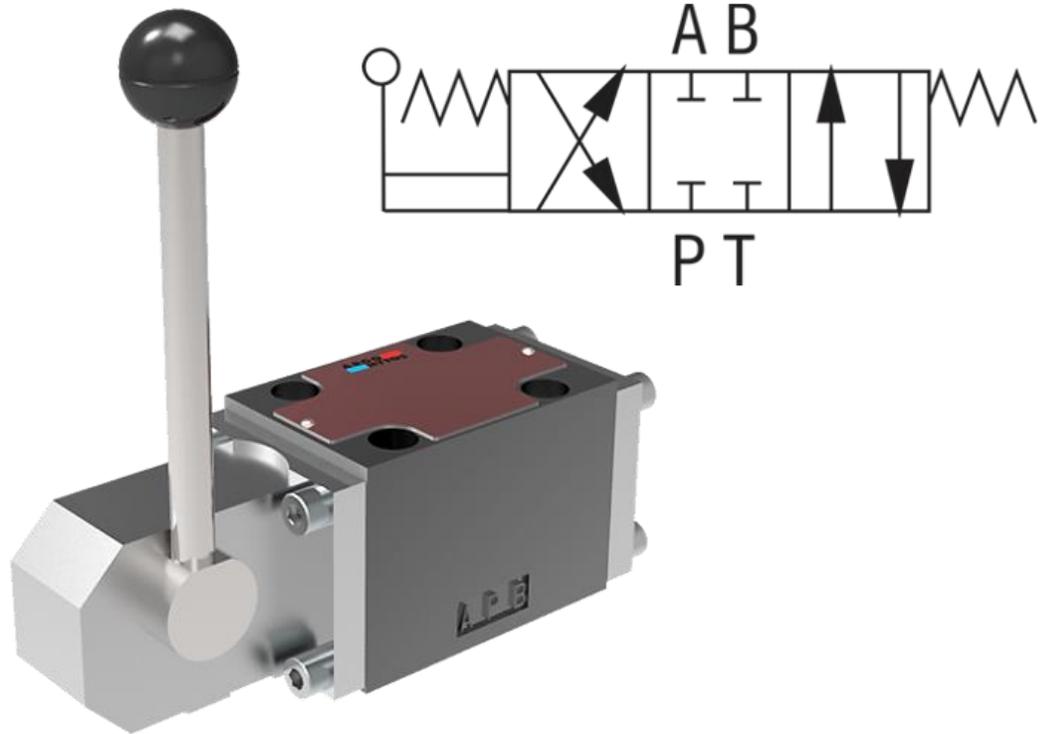
## 3. Based on Construction:

1. **Spool Valve** (most common, used for smooth operation)
2. **Poppet Valve** (quick response, used in high-speed applications)

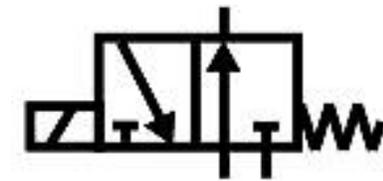
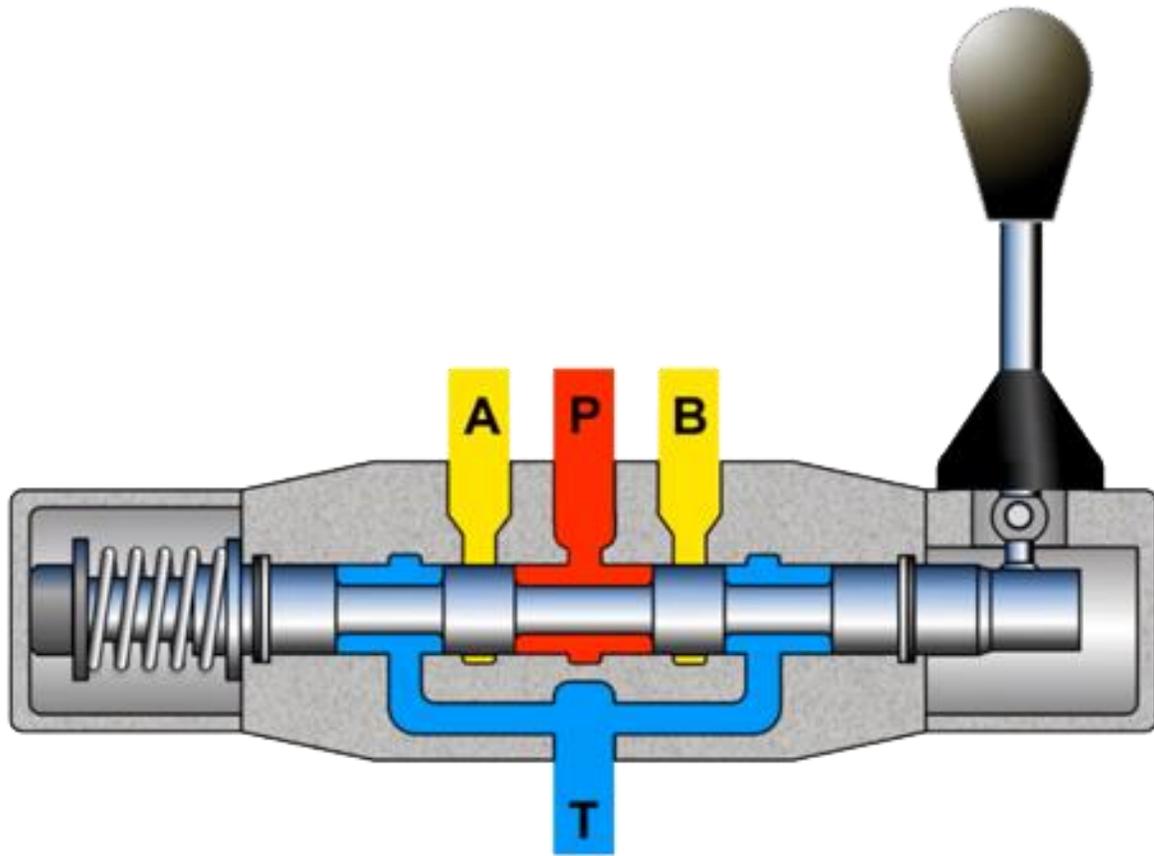
# DIRECTION CONTROL VALVE



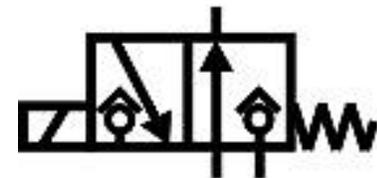
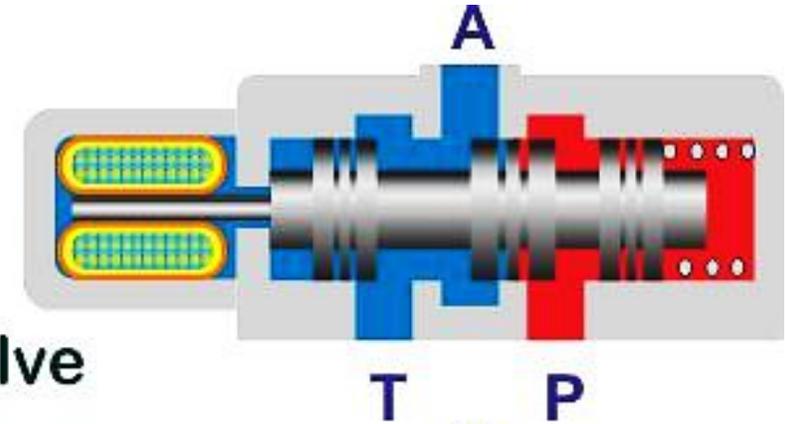
# DIRECTION CONTROL VALVE



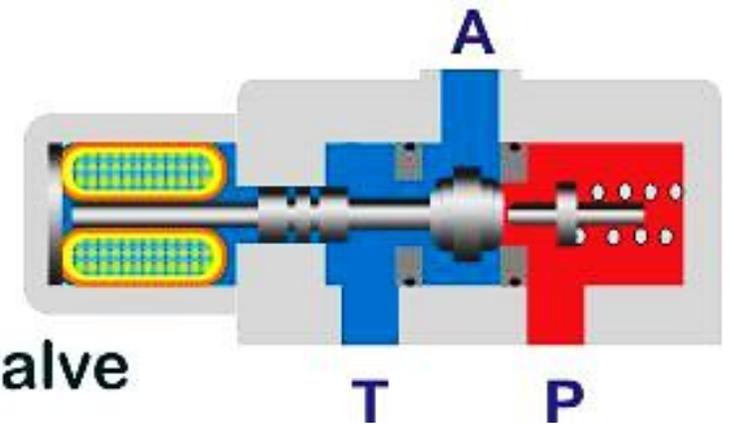
# DIRECTION CONTROL VALVE



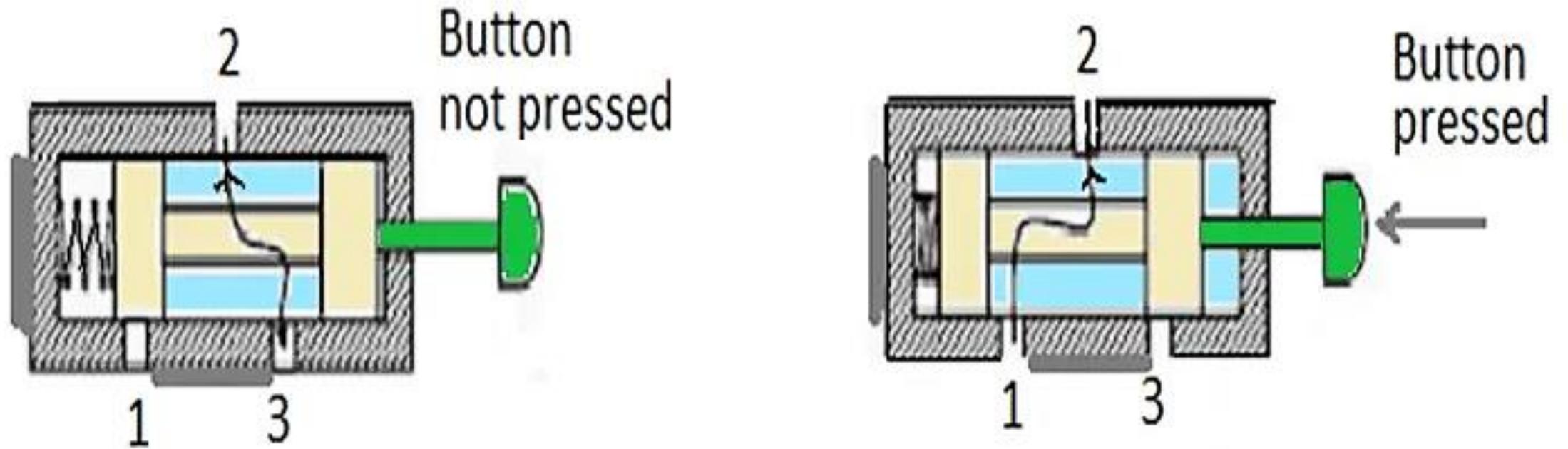
Spool valve



Poppet valve

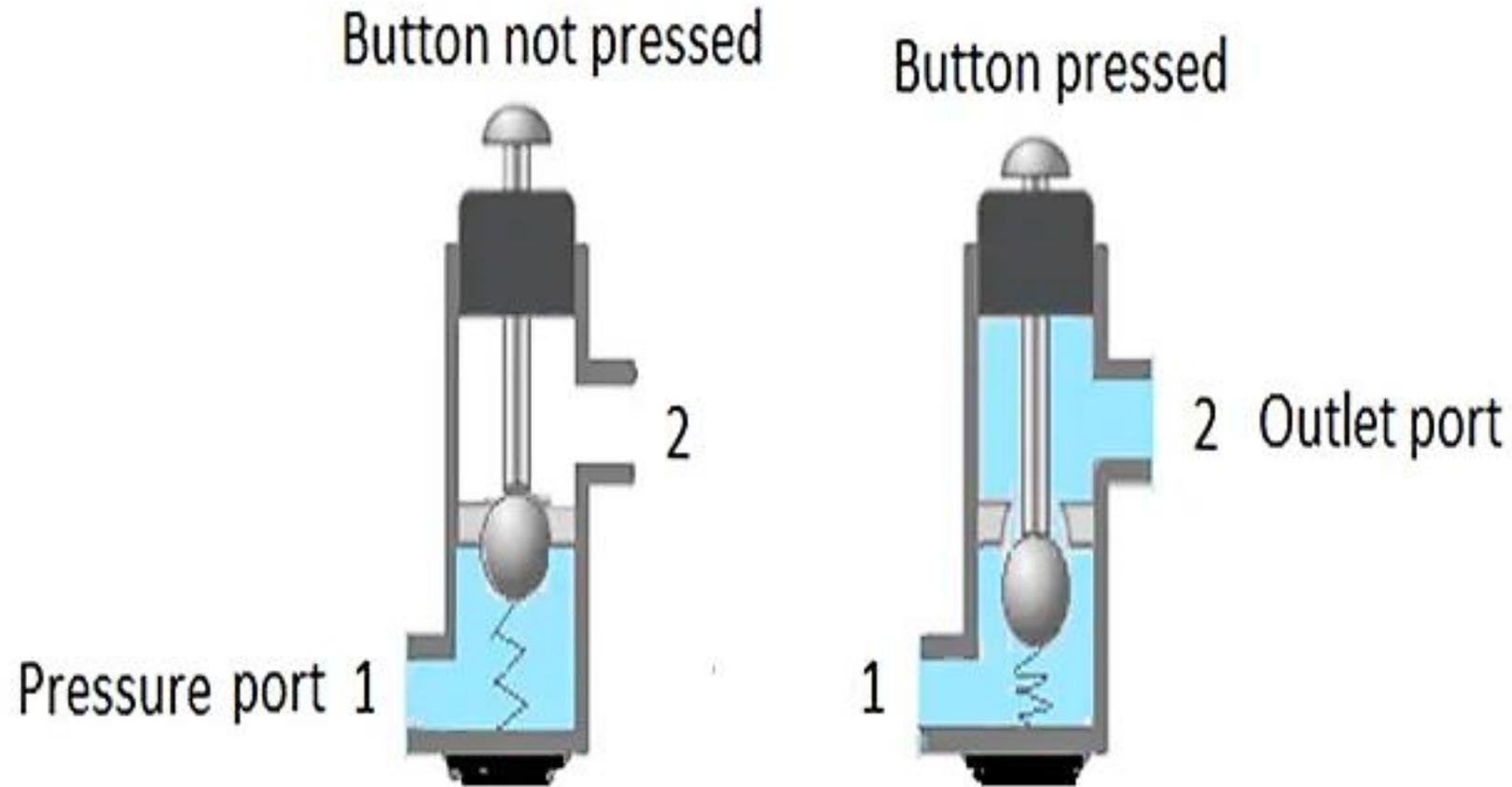


# DIRECTION CONTROL VALVE



**Spool Movement**

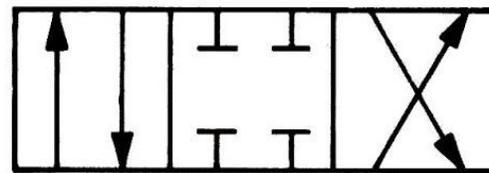
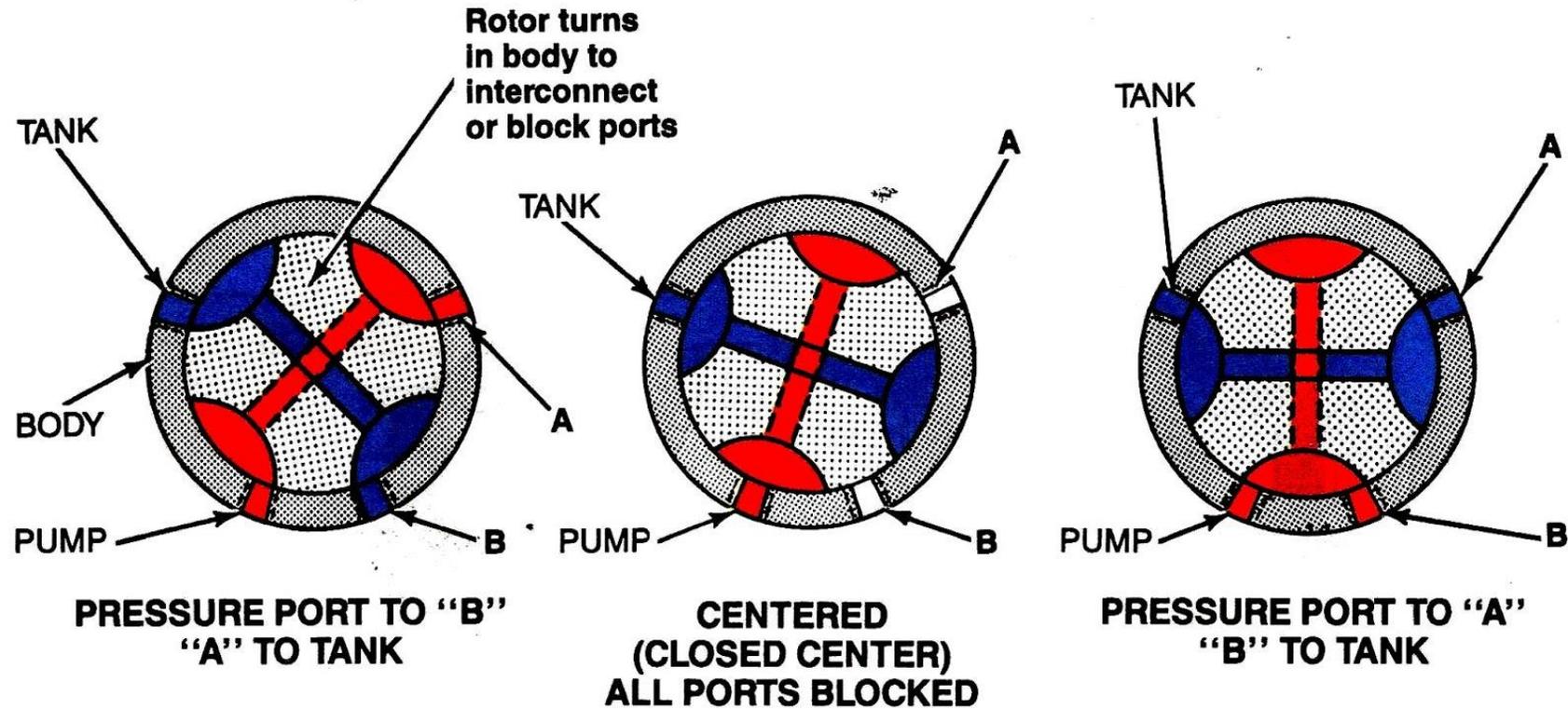
# DIRECTION CONTROL VALVE



**Poppet Movement**

# DIRECTION CONTROL VALVE

## ROTARY SPOOL MOVEMENT



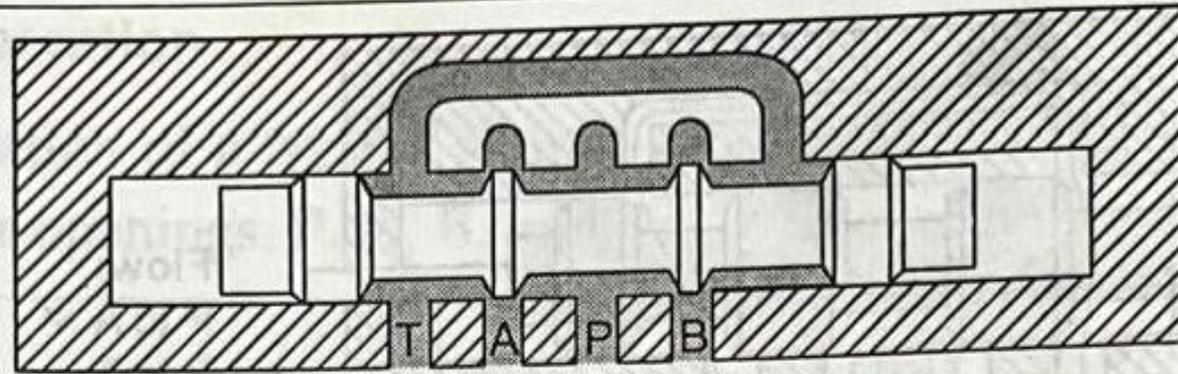
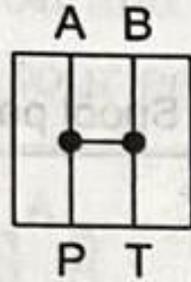
GRAPHICAL SYMBOL

# DCV

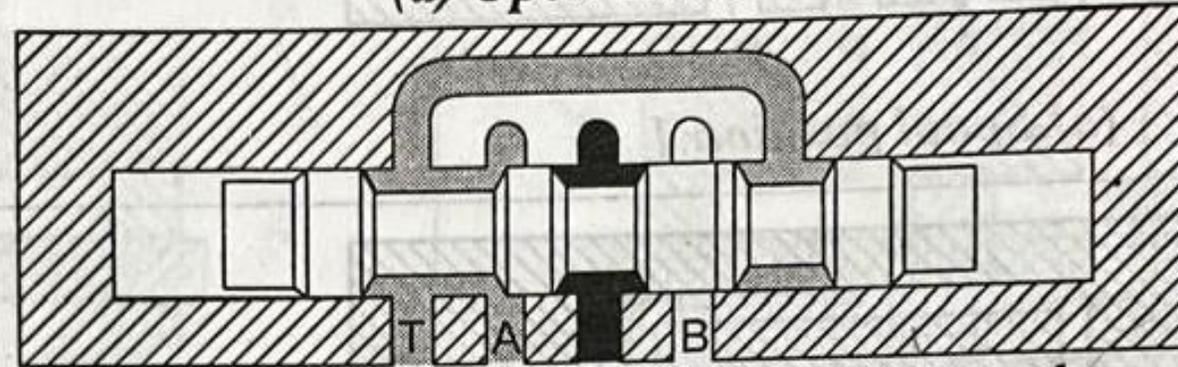
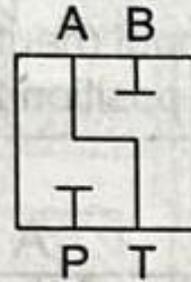
Table 3.3. Graphic symbols used for directional control valves

Description	Symbol	Diagram
2/2 - way valve	S20	
3/2 - way valve	S21	
4/2 - way valve	S22	
4/3 - way valve	S23	

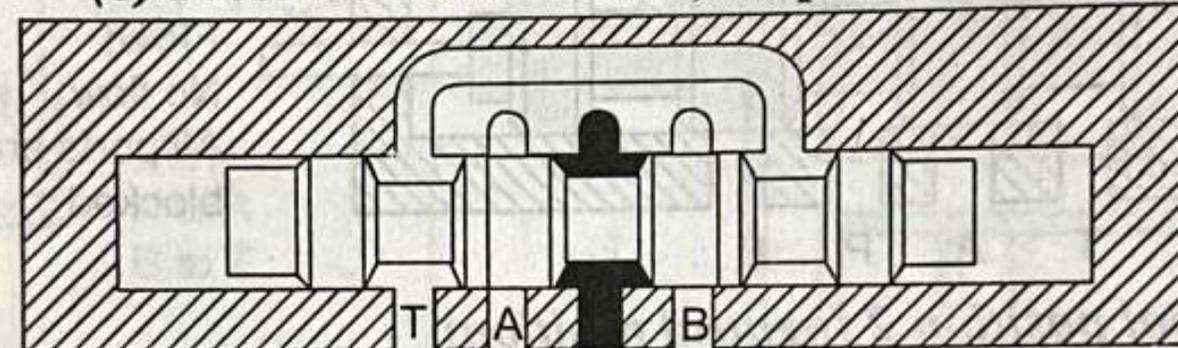
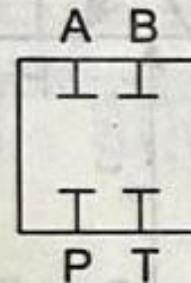
# DCV



*(a) Open center*

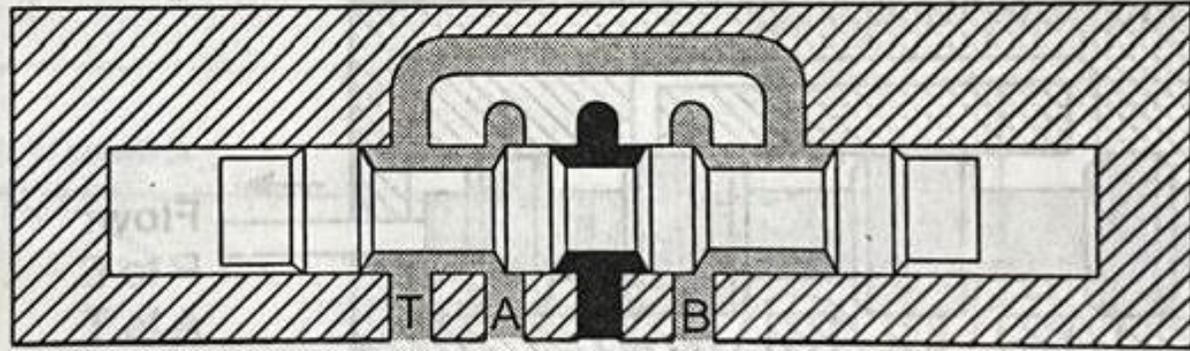
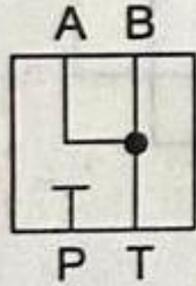


*(b) Pressure and B closed; A open to tank*

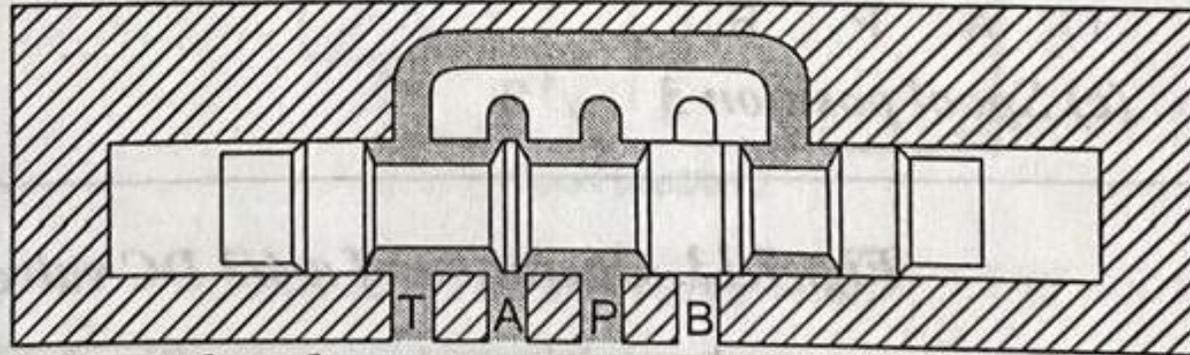
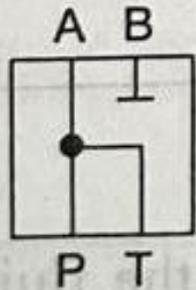


*(c) Closed center – All ports closed*

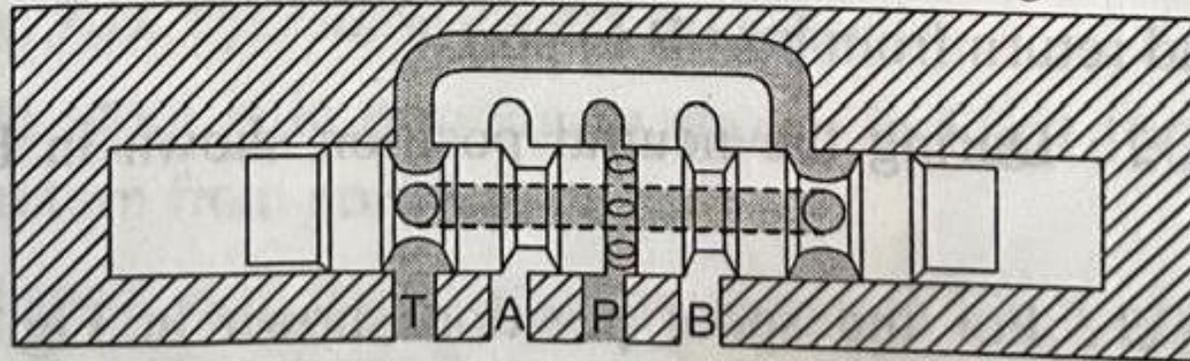
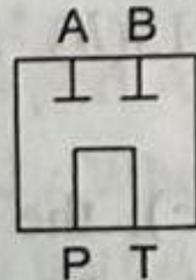
# DCV



*(d) Pressure closed; A & B open to tank*



*(e) B closed; pressure open to tank through A*



*(f) Tandem centre*

# PRESSURE CONTROL VALVE (PCV)

A Pressure Control Valve (PCV) is a type of valve used to regulate or limit fluid pressure (liquid or gas) within a system. It helps maintain safe and efficient operation by preventing excessive pressure buildup, which can lead to system failure or damage.

## Types of Pressure Control Valves

- 1. Pressure Relief Valve (PRV)** – Opens when pressure exceeds a set limit to release excess fluid and prevent overpressure.
- 2. Pressure Reducing Valve (PRV)** – Reduces incoming pressure to a desired lower level for downstream equipment.
- 3. Back Pressure Regulator** – Maintains a set pressure upstream by allowing excess fluid to bypass or return to a tank.
- 4. Sequence Valve** – Ensures that a secondary operation occurs only after reaching a certain pressure level.
- 5. Unloading Valve** – Diverts fluid back to a reservoir under low-pressure conditions to improve efficiency.

# PRESSURE CONTROL VALVE (PCV)

## Working Principle

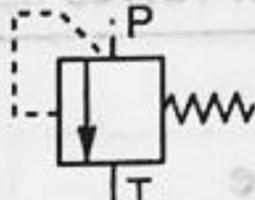
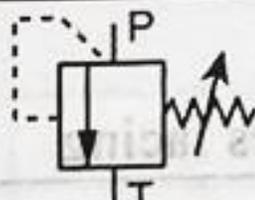
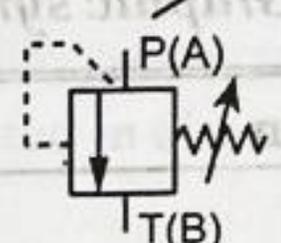
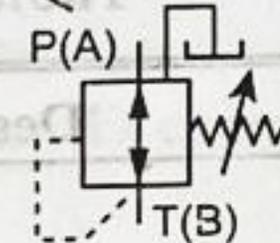
- **Spring-loaded mechanism:** A spring opposes the fluid pressure, opening or closing the valve at a preset limit.
- **Pilot-operated control:** Uses an external pilot valve for more accurate pressure regulation.
- **Proportional or electronic control:** Uses sensors and actuators for precise pressure adjustment.

## Applications

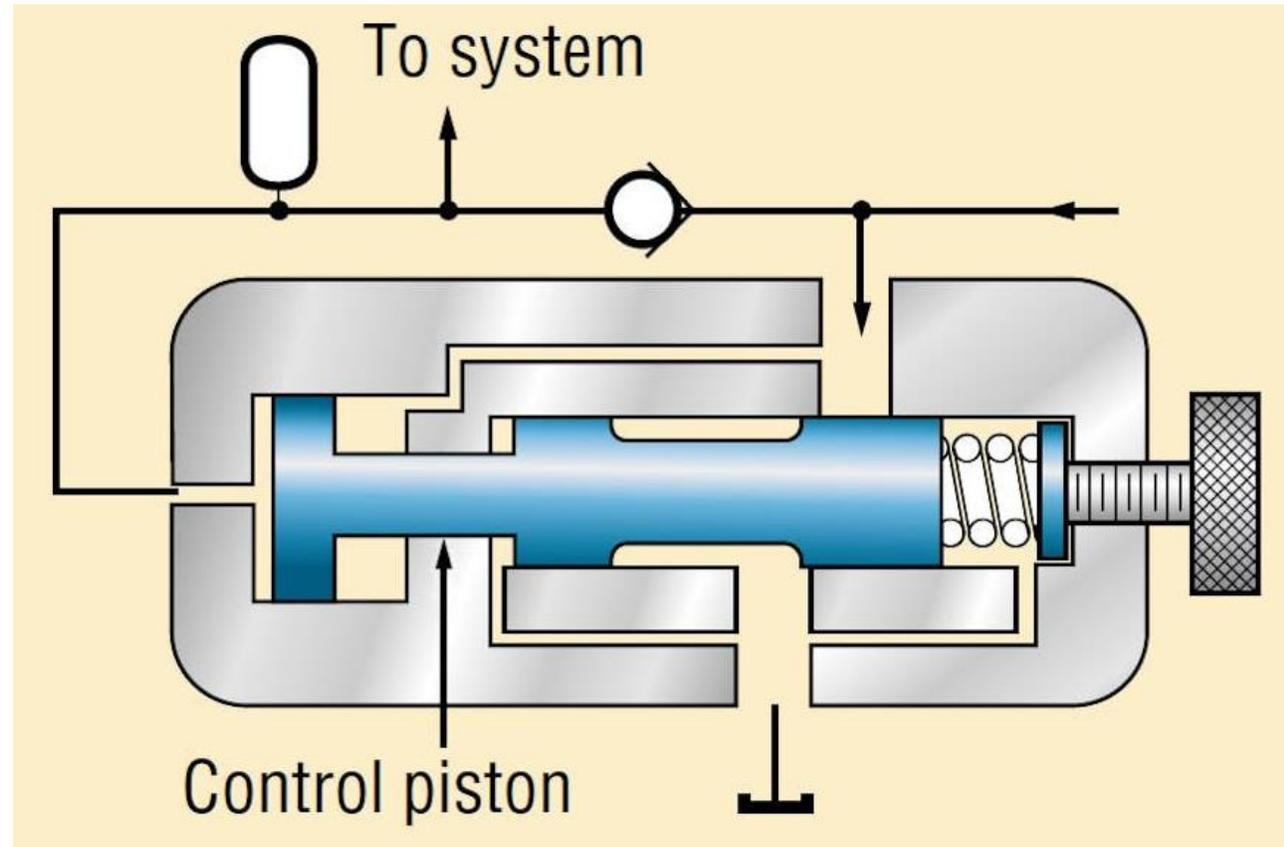
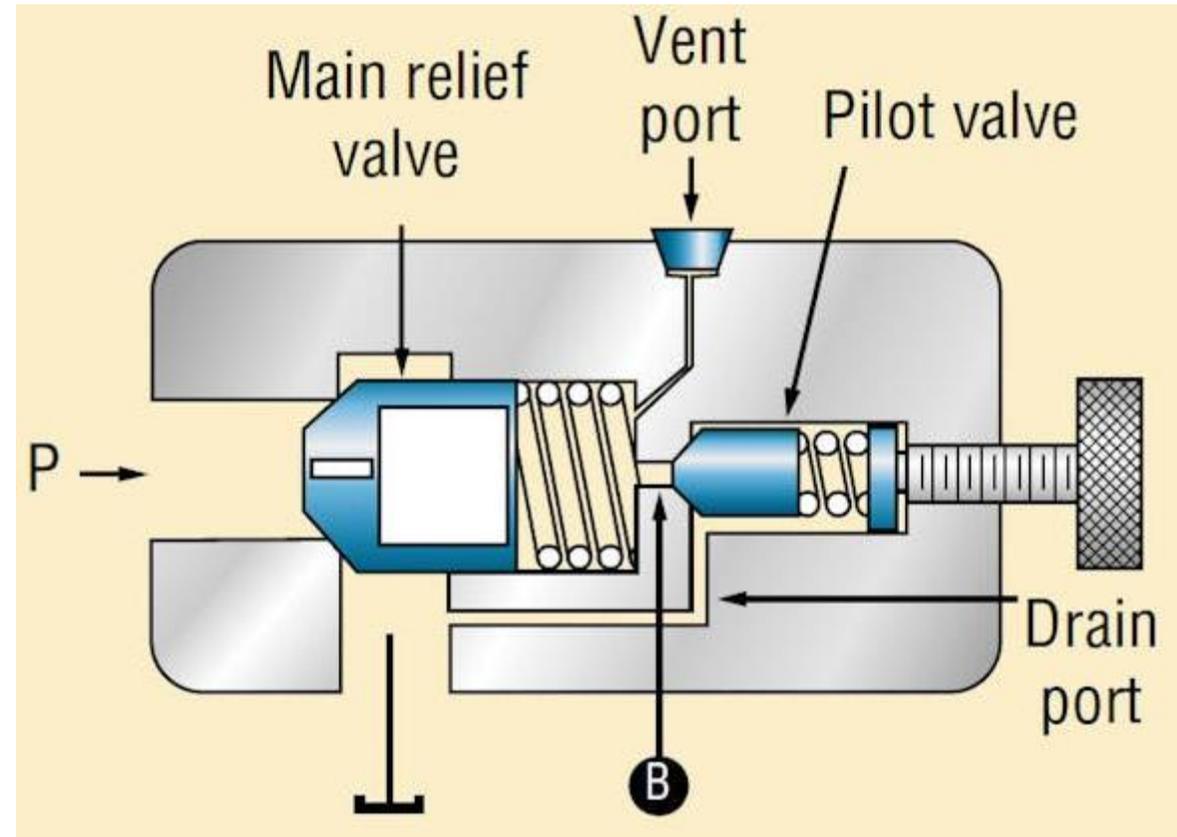
- Steam and gas turbines (pressure regulation in pipelines)
- Hydraulic and pneumatic systems
- Oil and gas processing
- Water supply networks
- HVAC systems

# PRESSURE CONTROL VALVE

Table 3.4. Graphic symbols used for pressure valves

Description	Symbol	Diagram
Set pressure relief valve	S24	
Adjustable pressure relief valve	S25	
3-way pressure regulator	S26	<p style="text-align: center;">Pressure valves</p> <div style="display: flex; justify-content: space-around;"> <div data-bbox="1375 1013 1656 1256">  <p style="text-align: center;">Pressure relief valve</p> </div> <div data-bbox="1834 1013 2114 1256">  <p style="text-align: center;">3-way pressure regulator</p> </div> </div>

# PRESSURE CONTROL VALVE



# FLOW CONTROL VALVE (FCV)

A Flow Control Valve is a device used to **regulate the flow rate** of a fluid (liquid or gas) in a system. These valves are essential in various industries, including oil and gas, power generation, water treatment, HVAC, and aerospace.

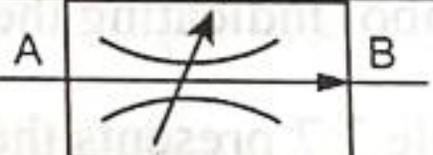
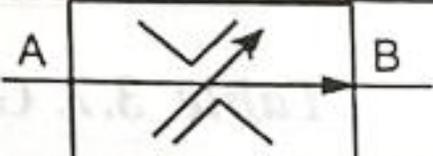
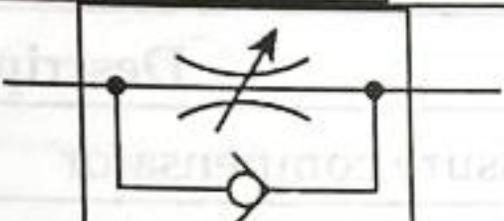
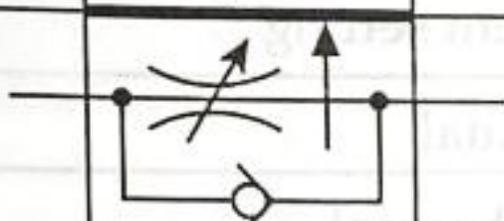
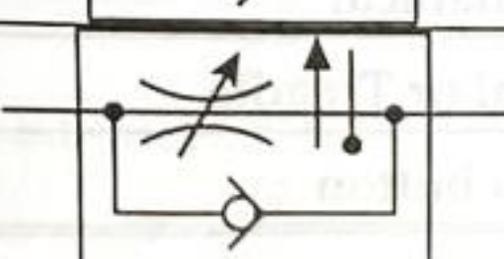
## Types of Flow Control Valves

- 1. Throttle Valves** – Adjust flow by varying the orifice size (e.g., needle valves, globe valves).
- 2. Pressure-Compensated Flow Control Valves** – Maintain a consistent flow rate despite pressure variations.
- 3. Proportional Flow Control Valves** – Electronically controlled for precise flow regulation.
- 4. Ball Valves & Butterfly Valves** – Used for on/off flow control with some throttling capability.

## Applications

- **Hydraulic & Pneumatic Systems** – Regulate fluid flow to actuators.
- **Gas Turbines & Power Plants** – Control fuel and cooling fluid flow.
- **Industrial Processing** – Ensure accurate material flow in manufacturing.
- **Water & Wastewater Treatment** – Maintain flow rates in pipelines.

# FLOW CONTROL VALVE (FCV)

Description	Symbol	Diagram
Adjustable flow control valve with throttle	S27	
Adjustable flow control valve with orifice	S28	
Adjustable with bypass	S29	
Adjustable and pressure compensated with bypass	S30	
Adjustable temperature and pressure compensated	S31	

# FLOW CONTROL VALVE (FCV) - THROTTLE VALVES

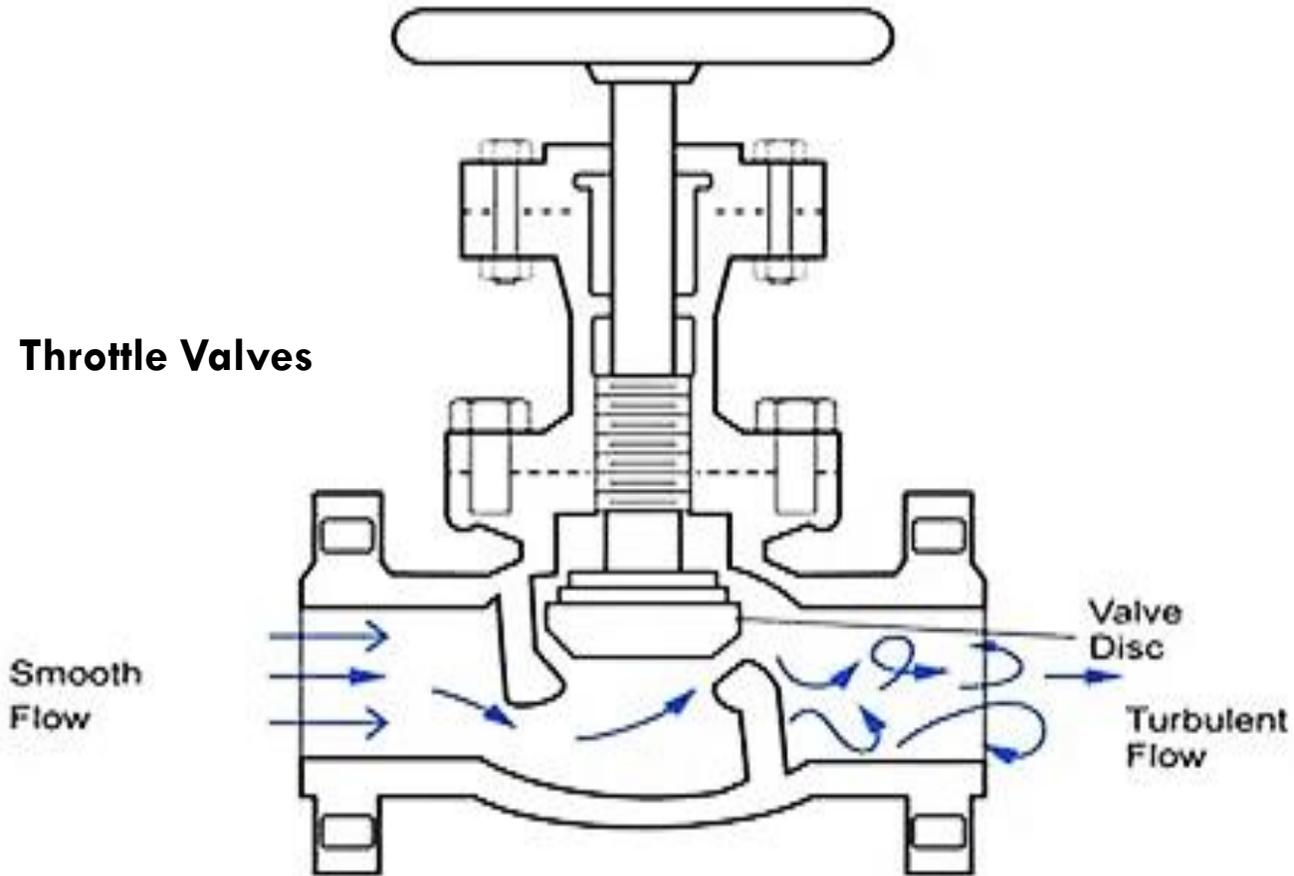
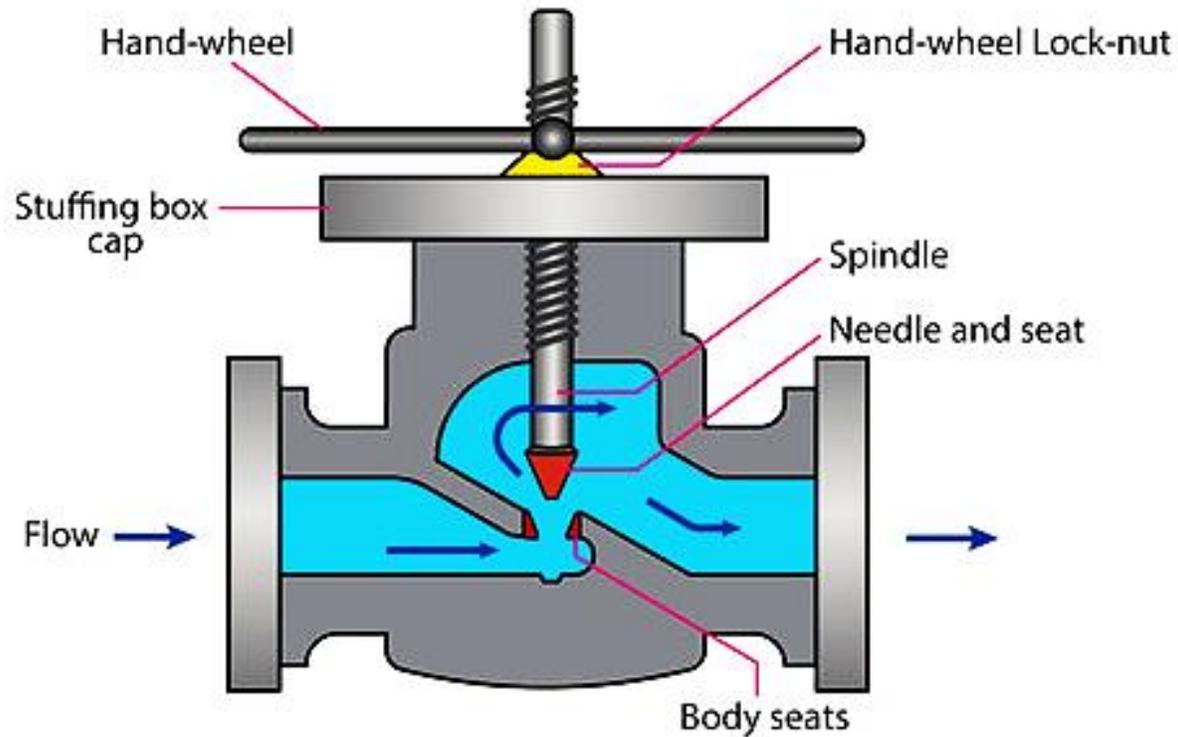


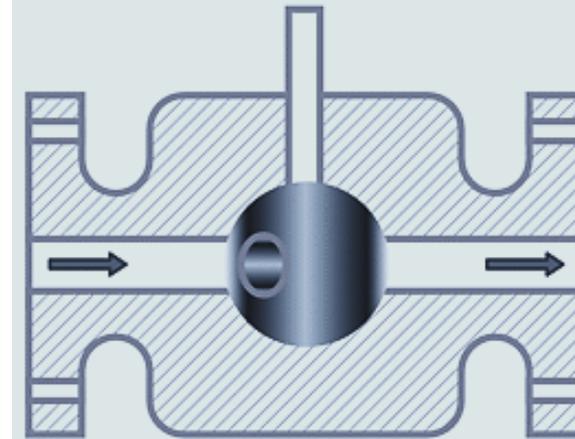
Figure: Throttling Process by a Valve

# FLOW CONTROL VALVE (FCV) - THROTTLE VALVES

## NEEDLE VALVE

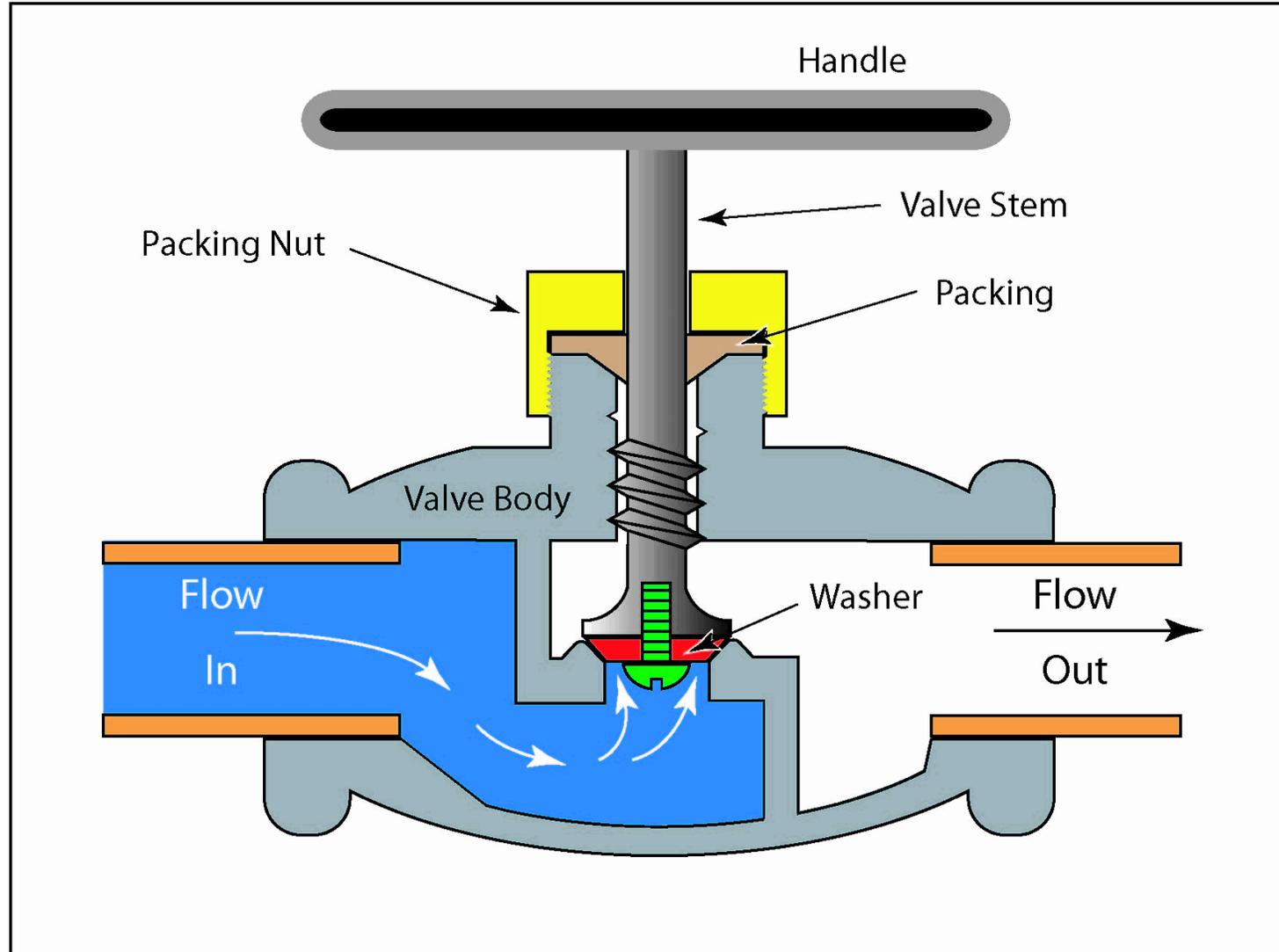


## BALL VALVES

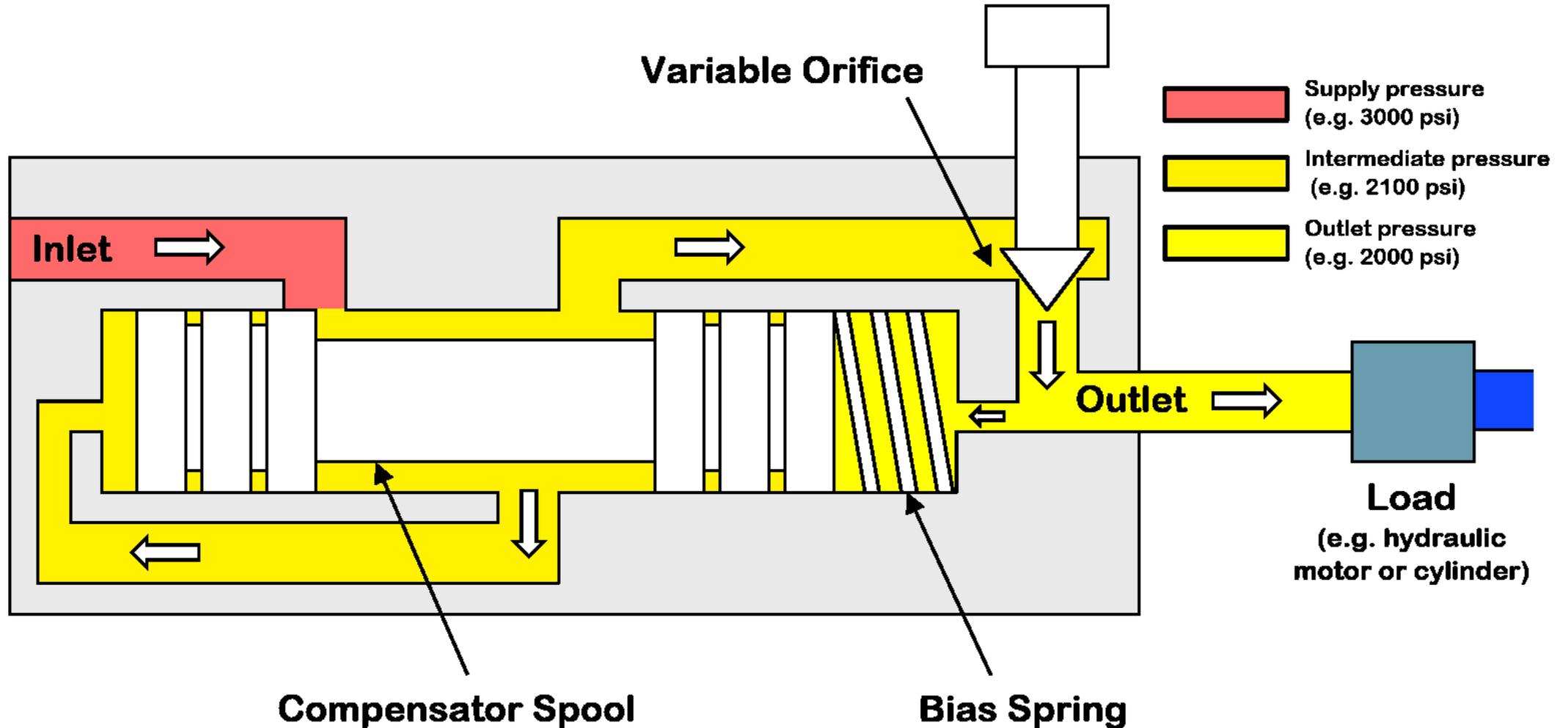


- Offer rapid actuation using a 90-degree rotation
- Causes minimal pressure drop or flow throttling
- Not suited for extended throttling

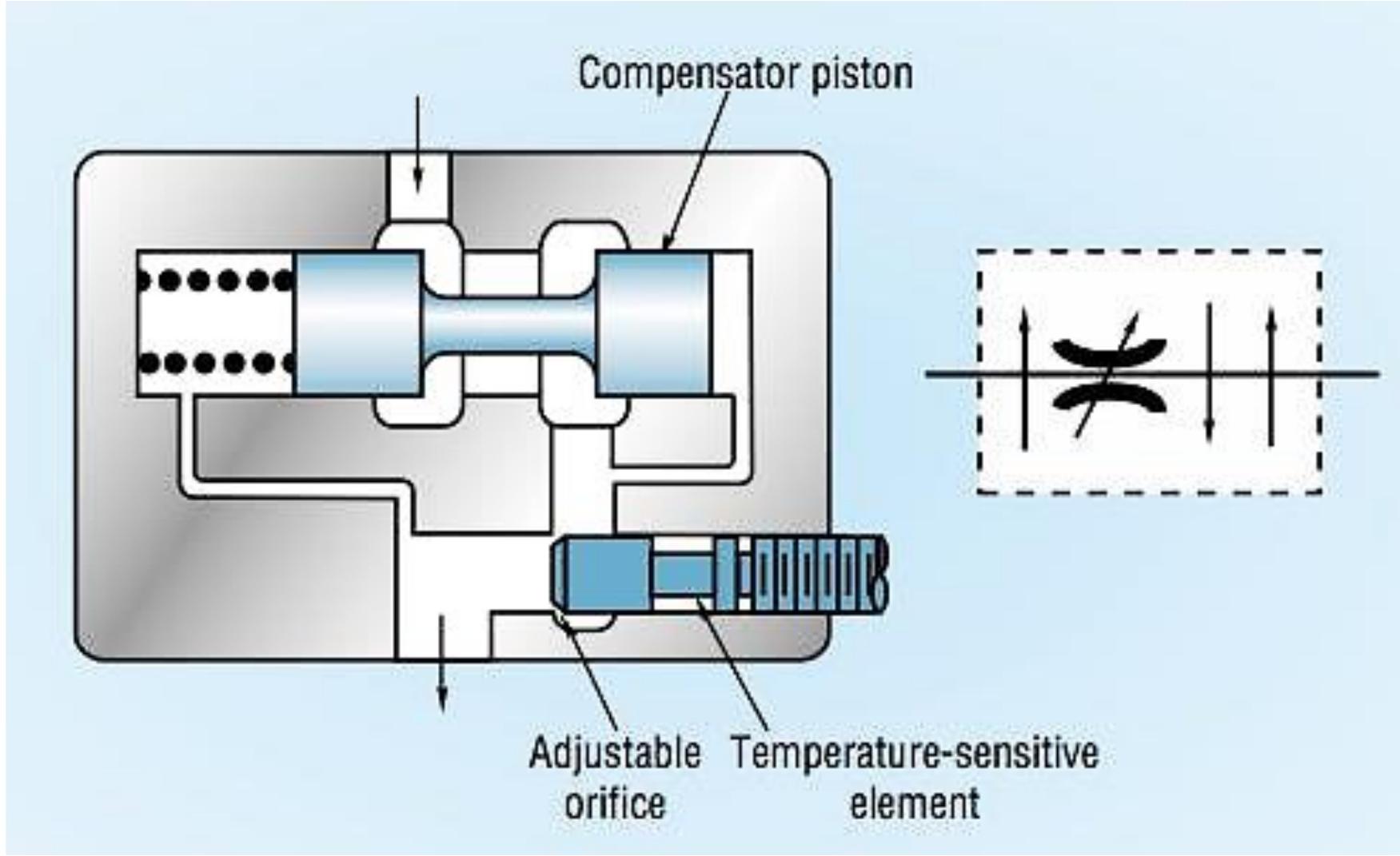
# FLOW CONTROL VALVE (FCV) - GLOBE VALVES



# FLOW CONTROL VALVE (FCV) PRESSURE COMPENSATED



# FLOW CONTROL VALVE (FCV) PRESSURE & TEMPERATURE COMPENSATED



# SEQUENCING VALVE

A **Sequencing Valve** is a type of pressure-operated valve used in hydraulic systems to ensure that one actuator (cylinder or motor) completes its movement before another starts. It helps in controlling the order of operations in a multi-actuator system.

## Working Principle

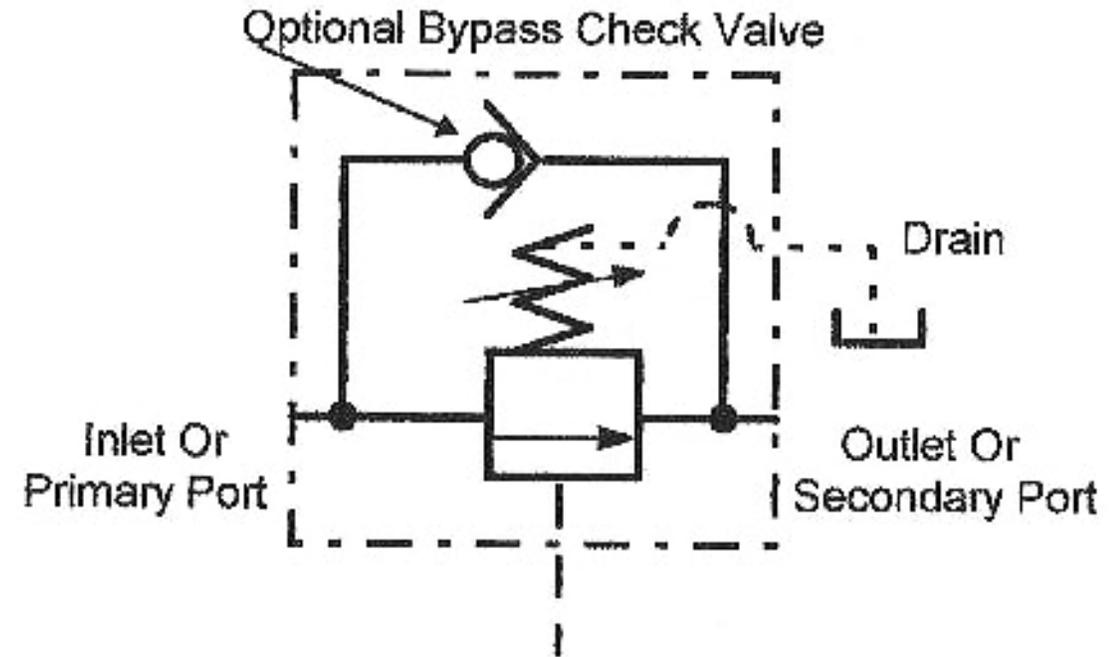
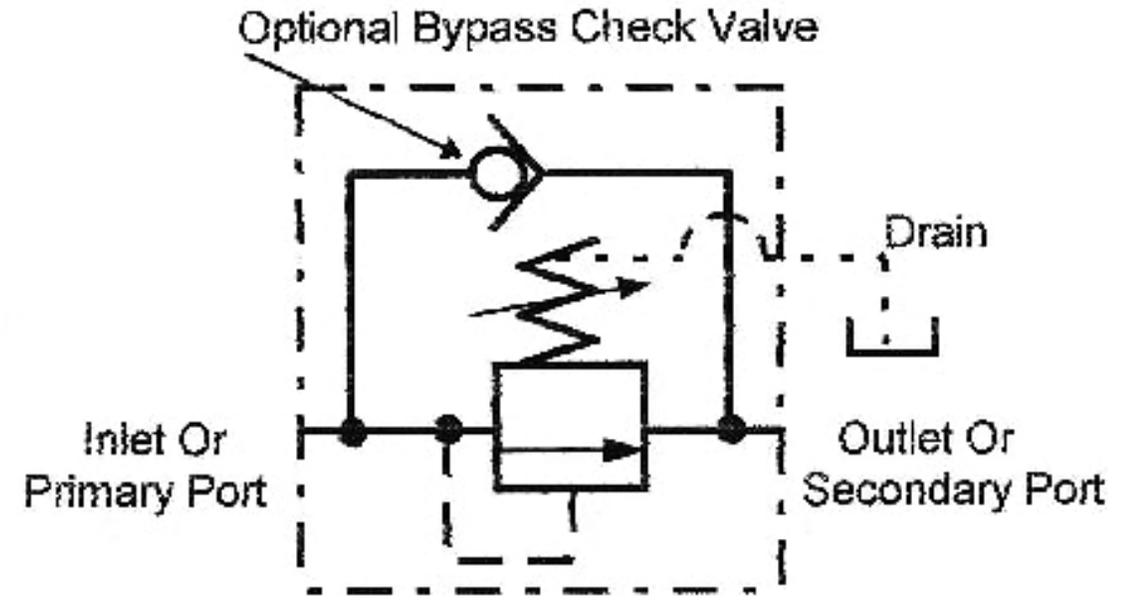
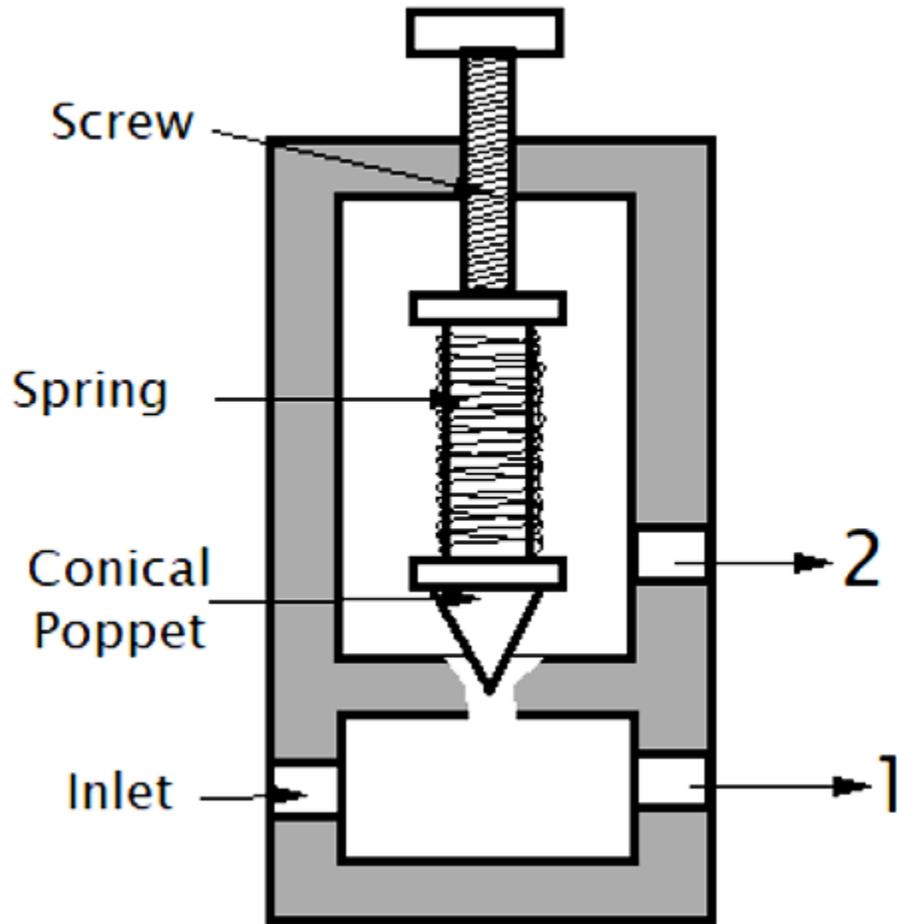
- The valve remains closed until the first actuator reaches a set pressure.
- Once the set pressure is achieved, the valve opens and allows fluid to flow to the next actuator.
- This ensures a controlled sequence of operations without the need for electrical control.

## Types of Sequencing Valves

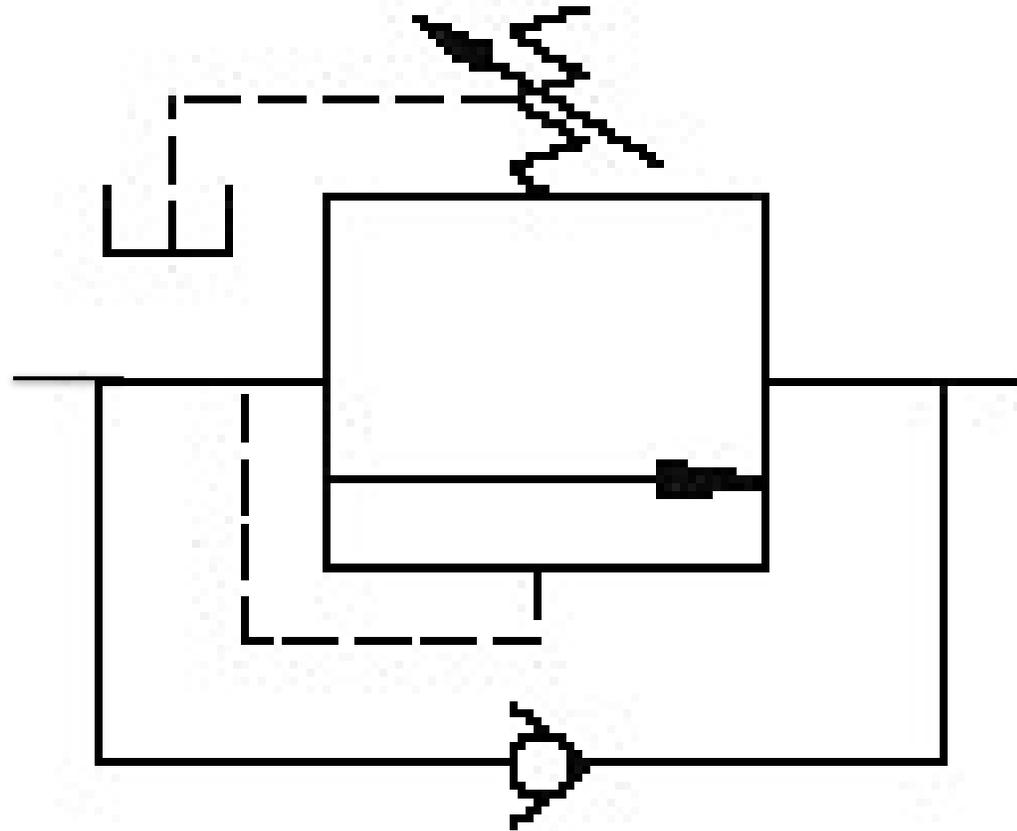
**1.Externally Drained Sequencing Valve**

**2.Internally Drained Sequencing Valve**

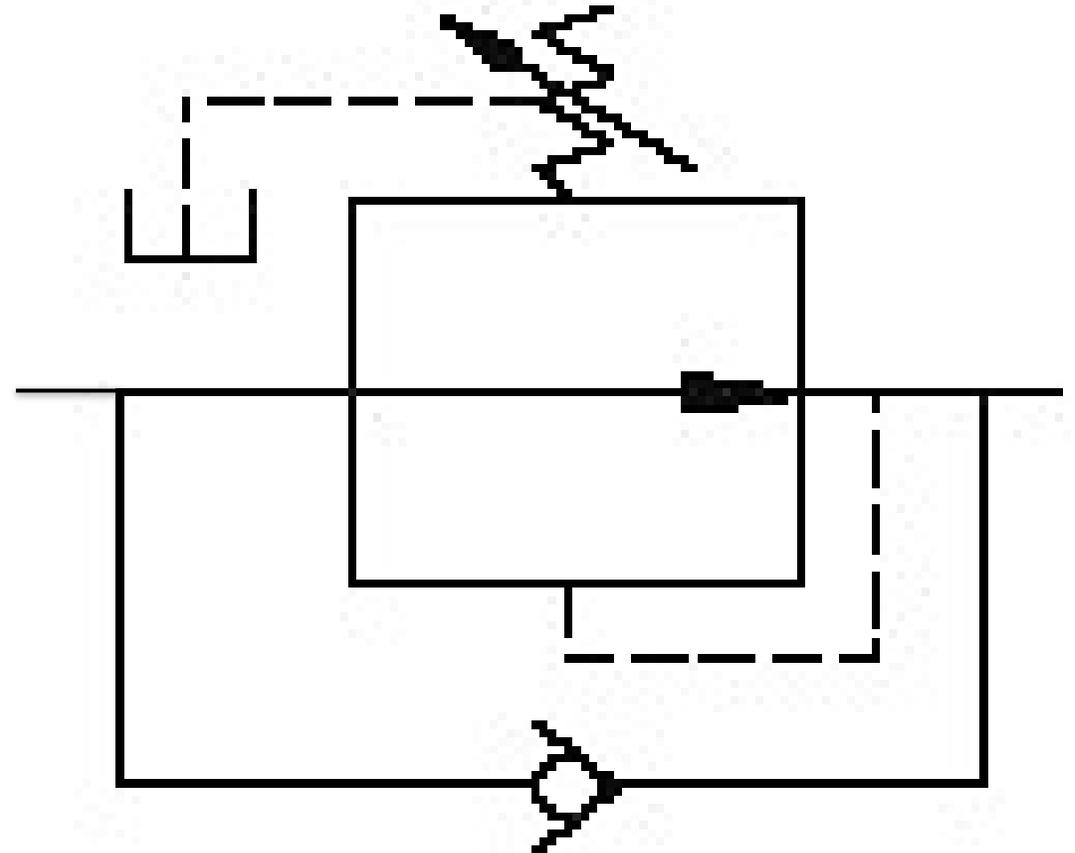
# SEQUENCING VALVE



# SEQUENCING VALVE



Sequencing Valve



Reducing Valve

# ACCUMULATORS

A hydraulic accumulator is a device used to store pressurized hydraulic fluid and release it when needed. It helps in energy storage, shock absorption, pulsation dampening, and maintaining system pressure in hydraulic systems.

## Types of Hydraulic Accumulators

### 1. Bladder Accumulator

1. Uses a rubber bladder inside a pressure vessel.
2. Pre-charged with gas (usually nitrogen).
3. Provides rapid response and good energy storage.

### 2. Piston Accumulator

1. A piston separates hydraulic fluid and gas.
2. Handles high pressure and large volumes.
3. Common in heavy machinery and industrial systems.

# ACCUMULATORS

## 1. Diaphragm Accumulator

1. A flexible diaphragm separates gas and hydraulic fluid.
2. Compact design with moderate energy storage.
3. Used in small hydraulic systems.

## 2. Spring Accumulator

1. Uses a mechanical spring instead of gas.
2. Provides constant force but has lower energy storage.
3. Suitable for applications where gas is not ideal.

# ACCUMULATORS

## Functions of Hydraulic Accumulators

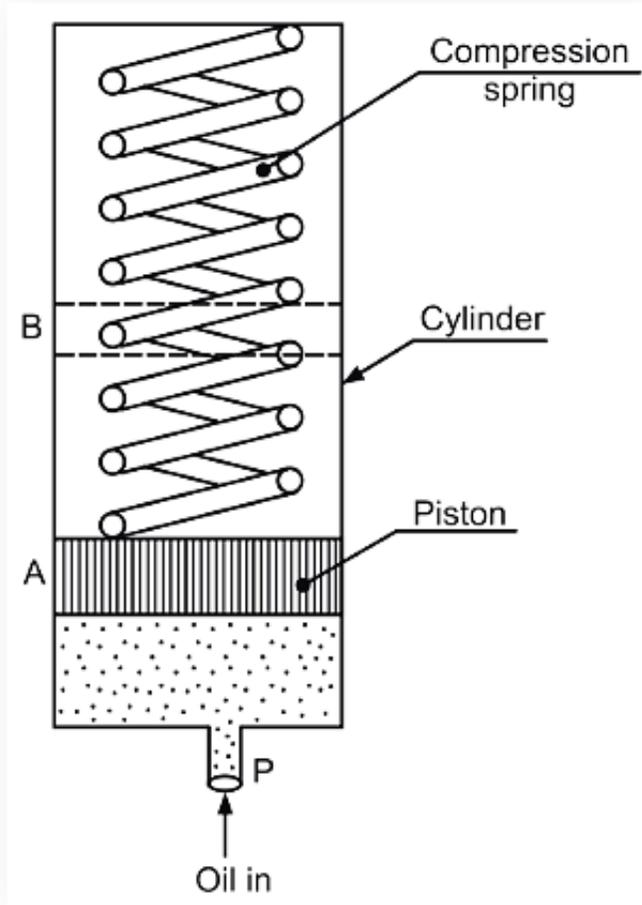
- **Energy Storage** – Stores excess hydraulic energy and releases it when needed.
- **Shock Absorption** – Dampens pressure spikes and hydraulic shocks.
- **Pulsation Dampening** – Smoothens flow in systems with reciprocating pumps.
- **Leakage Compensation** – Maintains system pressure when there are small leaks.
- **Emergency Power Supply** – Provides backup hydraulic power in case of pump failure.

# ACCUMULATORS

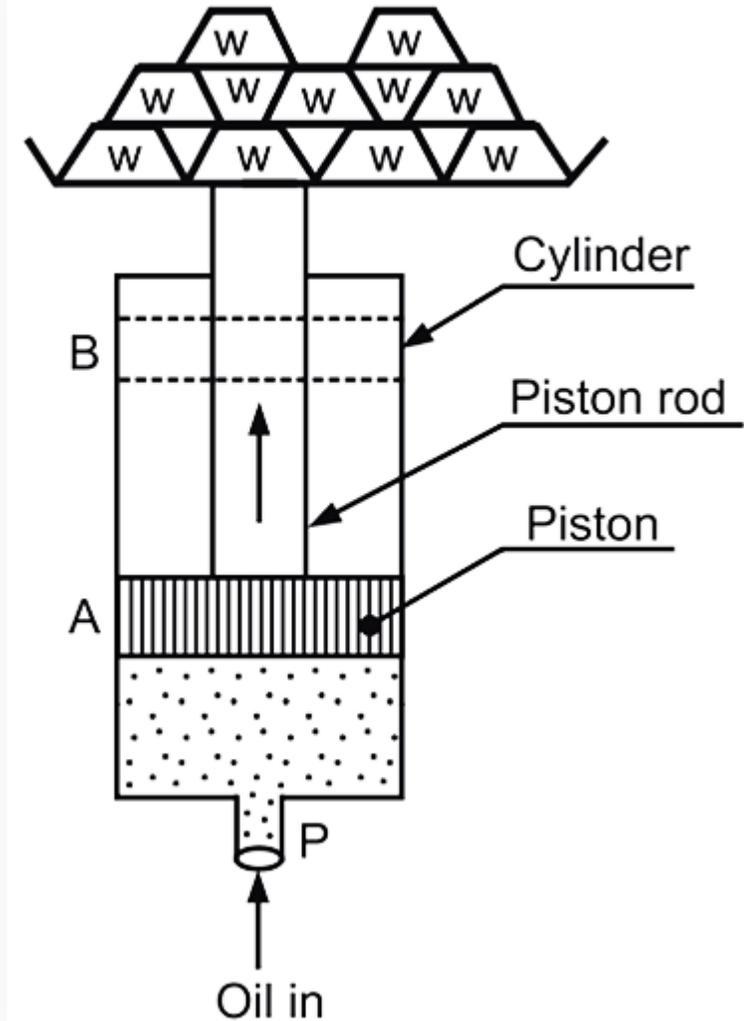
Description	Symbol	Diagram
Accumulator	S62	
Spring loaded accumulator	S63	
Gas charged accumulator	S64	
Weighted accumulator	S65	

# ACCUMULATORS

Spring Loaded Accumulator



Dead Weight Accumulator



# SIZING OF ACCUMULATORS

## 8.12.1. Analysis of Weight-Loaded Type Accumulators

Fig.8.12 shows a simple weight-loaded type accumulator.

**Capacity of accumulator:** The maximum amount of energy that the accumulator can store is known as the capacity of the accumulator.

**Derivation :**

Let  $A = \text{Area of the sliding ram} = \frac{\pi}{4} D^2,$

$D = \text{Diameter of the ram,}$

$L = \text{Stroke or lift of the ram,}$

$P = \text{Intensity of pressure of hydraulic fluid supplied by the pump, and}$

$W = \text{Total weight of the ram including the weight of the dead-load on the ram.}$

We know that,  $W = P \times A$

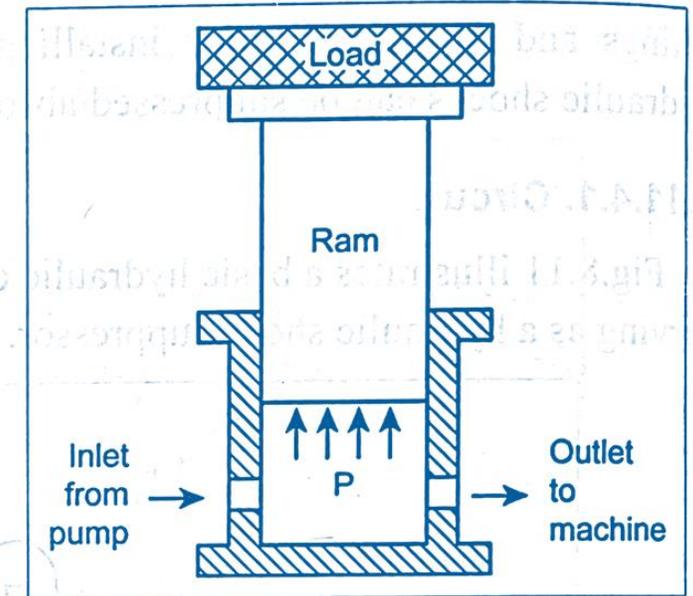
Work done in lifting the ram  $= W \times \text{Lift of ram}$

$= W \times L = P \times A \times L$  [∵  $W = P \times A$ ]

But,  $\left\{ \begin{array}{l} \text{Work done in} \\ \text{lifting the ram} \end{array} \right\} = \left\{ \begin{array}{l} \text{Energy stored in} \\ \text{the accumulator} \end{array} \right\} = \left\{ \begin{array}{l} \text{Capacity of the} \\ \text{accumulator} \end{array} \right\}$

∴  $\text{Capacity of the accumulator} = P \times A \times L$  ... (8.1)

$= P \times \text{Volume of accumulator}$  ... (8.2)



**Fig. 8.12. Weight-loaded type accumulator**

# SIZING OF ACCUMULATORS

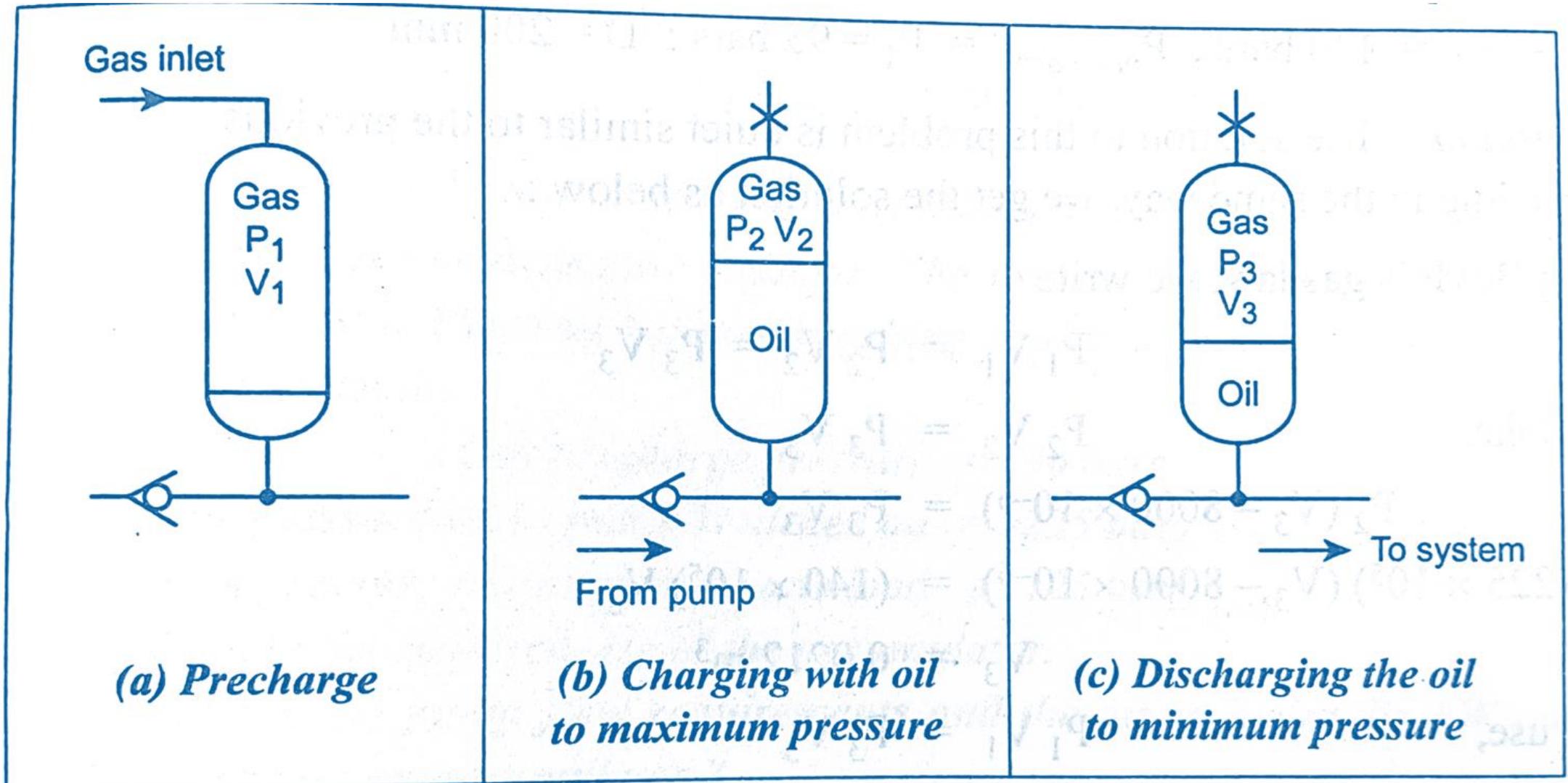
## 8.12.2. Analysis of Gas-Loaded Accumulators

- ✓ As we have discussed in Section 8.5, gas-loaded accumulators are governed by the Boyle's gas law. That means, the compression and expansion of the gas in gas-loaded accumulators are governed by the Boyle's law of gas.
- ✓ The rate of discharge determines whether the process is isothermal or adiabatic. If the rate of discharge is quick, the expansion process can be assumed to be adiabatic ( $P_1 V_1^\gamma = P_2 V_2^\gamma$ ). Isothermal ( $P_1 V_1 = P_2 V_2$ ) relations can be used for compression if the process is slow.
- ✓ The precharge pressure should be selected so that use is made of all liquid in the accumulator.
- ✓ 
$$\left\{ \begin{array}{l} \text{Size or total volume} \\ \text{of the accumulator} \end{array} \right\} = \left\{ \begin{array}{l} \text{Volume of the compressed} \\ \text{gas supplied} \end{array} \right\} + \left\{ \begin{array}{l} \text{Volume of the liquid} \\ \text{required by the system} \end{array} \right\}$$

The compressed gas volume is a function of the charge and discharge time. The required liquid volume can be determined from the performance of the accumulator.

The following solved numerical problems explain how the sizing of the gas-loaded accumulator can be determined in hydraulic circuits.

# SIZING OF ACCUMULATORS



# SIZING OF ACCUMULATORS

$V_a$  - Total volume of fluid in the pipe line

$t_1$  - Initial temperature of the system ( $^{\circ}\text{C}$ )

$t_2$  - Final temperature of the system ( $^{\circ}\text{C}$ )

$\alpha$  - Coefficient of linear expansion of pipe material per ( $^{\circ}\text{C}$ )

$\beta$  - Coefficient of cubical expansion of the fluid per ( $^{\circ}\text{C}$ )

$P_1$  - Gas precharge pressure of accumulator

$P_2$  - System pressure at temperature ( $t_1$ ) - minimum system pressure

$P_3$  - System pressure at temperature ( $t_2$ ) - maximum system pressure

## (ii) Shock Suppressor

The size of accumulator required

$$V = \left( \frac{W}{2g} U^2 \right) \left( \frac{n-1}{P_1} \right) \left[ \frac{1}{\left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1} \right]$$

$P_1$  - System pressure at normal flow rate, also the accumulator precharge pressure

$P_2$  - Maximum allowable shock pressure

$W$  - Total weight of fluid in the pipe line

$g$  - Acceleration due to gravity

$U$  - Flow velocity.

## (iii) Thermal expansion compensator

The size of the accumulator required

$$V_1 = \frac{V_a (t_2 - t_1) (\beta - 3\alpha) \left( \frac{P_2}{P_1} \right)^{\frac{1}{n}}}{1 - \left( \frac{P_2}{P_3} \right)^{\frac{1}{n}}}$$

# SIZING OF ACCUMULATORS

**Example 8.4** The accumulator of Fig.8.14 is to supply  $8000 \text{ cm}^3$  of oil with a maximum pressure of 225 bars and a minimum pressure of 140 bars. If the nitrogen precharge pressure is 95 bars, find the size of the accumulator. The hydraulic cylinder piston diameter is 200 mm.

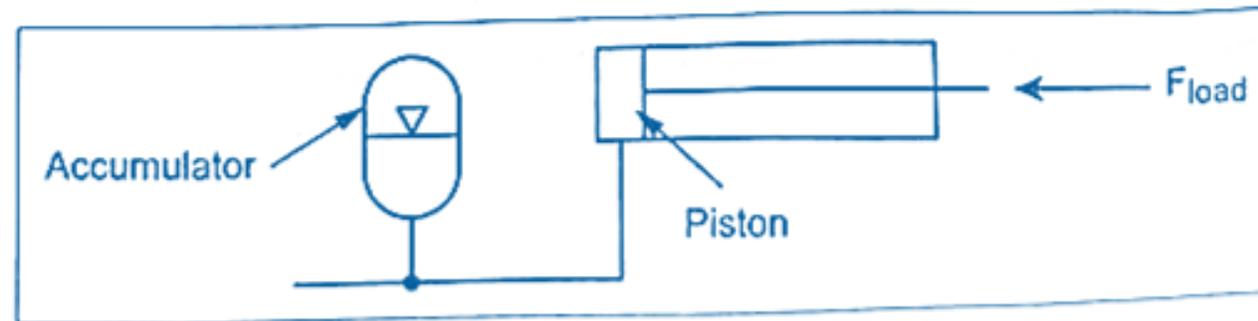


Fig. 8.14.

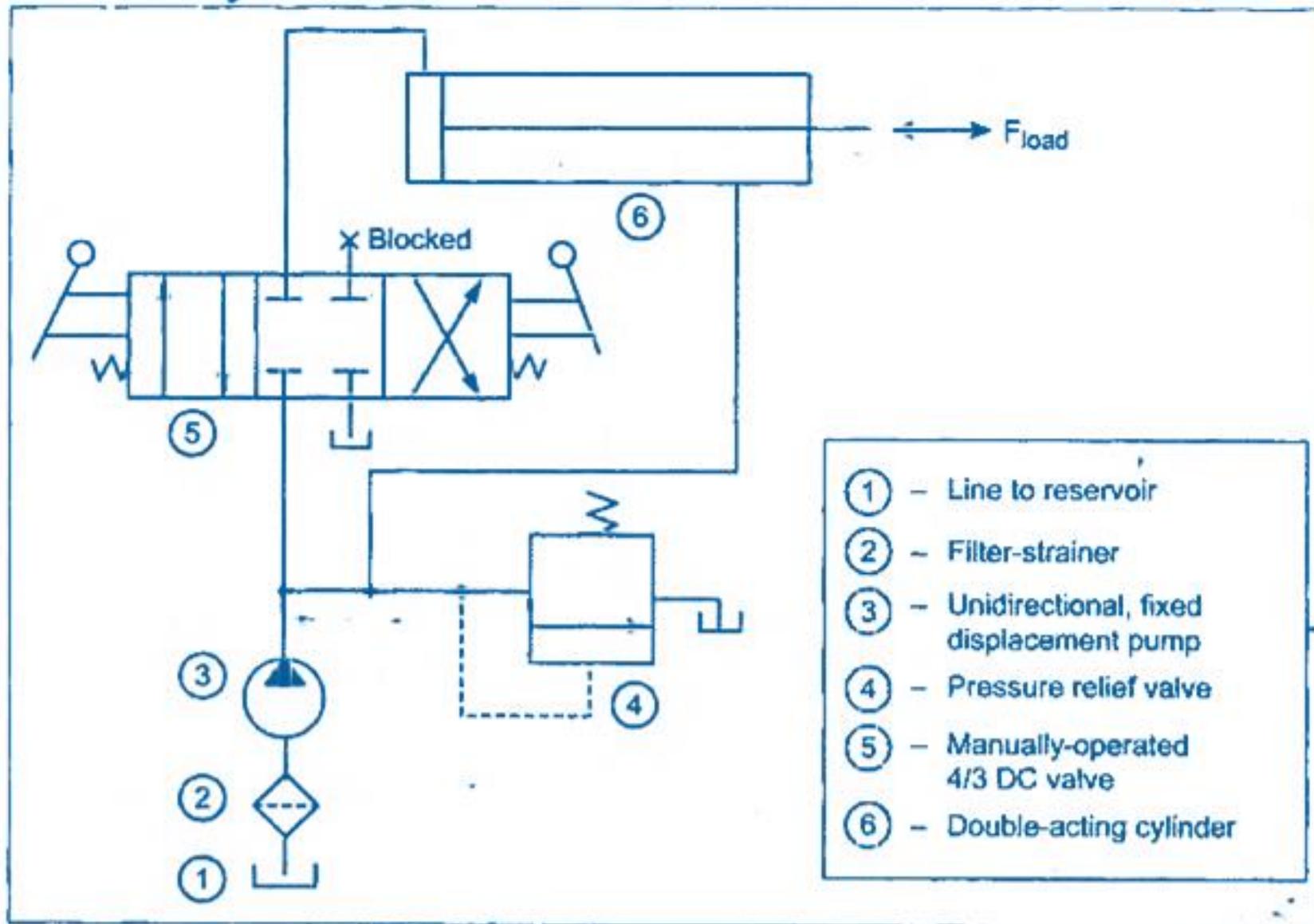
# UNIT 4 BASIC HYDRAULIC CIRCUITS

Design of Hydraulic circuits - speed control, sequencing circuits, regenerative circuits, unloading circuits. Design and application of hydraulic circuits of machine tool, press, Mobile hydraulic and other industrial applications. (8)

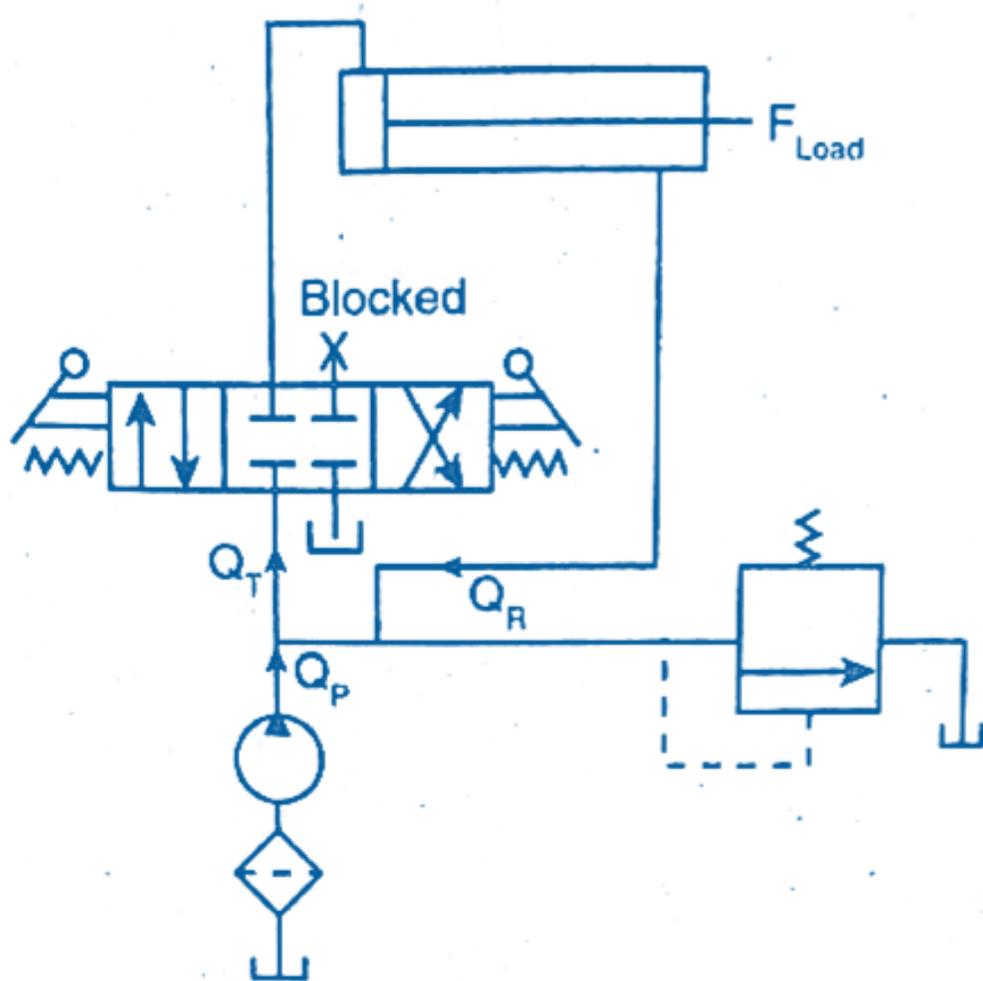
# REGENERATIVE HYDRAULIC CIRCUITS

- A circuit is said to be operating on the regenerative principle when the fluid returning from another end of the cylinder is forced into the head end of the cylinder.
- Regenerative circuits provide faster cylinder extension speeds by taking the oil from the rod end and diverting it to the head end of the cylinder.

# REGENERATIVE HYDRAULIC CIRCUITS



# REGENERATIVE HYDRAULIC CIRCUITS



**Extending speed** The equation for the extending speed can be obtained as follows. The total flow rate ( $Q_T$ ) entering the blank end of the cylinder equals the pump flow rate ( $Q_P$ ) plus the regenerative flow rate ( $Q_R$ ) coming from the rod end of the cylinder.

$$Q_T = Q_P + Q_R$$

Solving for the pump flow,

$$Q_P = Q_T - Q_R$$

$$\text{But } Q_T = A_p \times V_{\text{EXT}}$$

$$Q_R = (A_p - A_R) \times V_{\text{EXT}}$$

where  $A_R$  = Rod area,  $A_p$  = Piston area,  $V_{\text{EXT}}$  = Extending speed

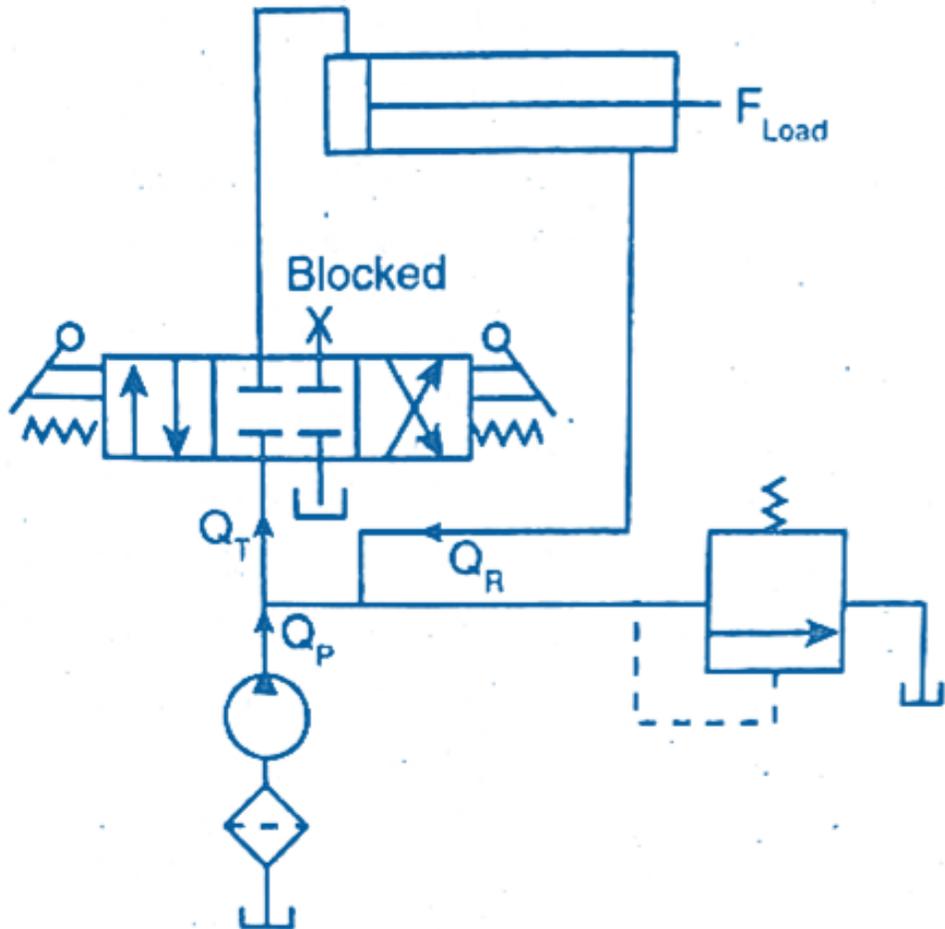
$$Q_P = (A_p \times V_{\text{EXT}}) - [(A_p - A_R) \times V_{\text{EXT}}]$$

$$= A_R \times V_{\text{EXT}}$$

$$V_{\text{EXT}} = Q_P / A_R$$

So the extending speed is equal to the pump flow rate divided by the area of the rod. Thus a small rod area provides a large extending speed.

# REGENERATIVE HYDRAULIC CIRCUITS



## Speed Ratio

$$\text{Retracting speed } V_{\text{RET}} = \frac{Q_P}{(A_P - A_R)}$$

$$\frac{V_{\text{EXT}}}{V_{\text{RET}}} = \frac{Q_P / A_R}{Q_P / (A_P - A_R)} = \frac{A_P - A_R}{A_R}$$

Upon further simplification

$$\frac{V_{\text{EXT}}}{V_{\text{RET}}} = \frac{A_P}{A_R} - 1$$

In general, the greater the ratio of piston area to rod area, the greater is the ratio of extending speed to retracting speed. When the piston area equals two times the rod area, the extension and retraction speeds are equal.

**Load carrying capacity** In accordance with Pascal's law, the same system pressure is acting on both sides of the piston during the extension stroke.

$$\begin{aligned} F_{\text{load}} &= (A_P \times P) - [(A_P - A_R) \times P] \\ &= A_R \times P \end{aligned}$$

# UNLOADING HYDRAULIC CIRCUITS

An **unloading circuit** diverts excess fluid flow back to the reservoir at low pressure when the system demand is low. It helps in reducing power consumption and heat generation in hydraulic systems.

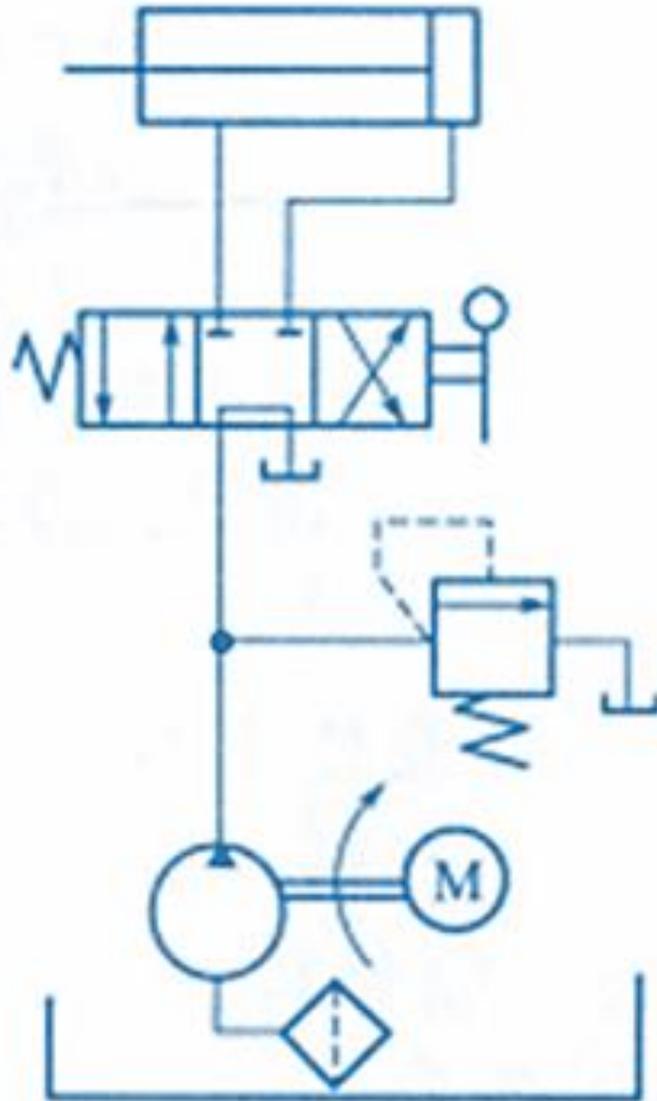
## Working Principle:

- A **pressure-operated unloading valve** is used to bypass fluid from the pump when the desired system pressure is reached.
- When the actuator completes its operation, the excess flow is redirected to the tank at minimal pressure, reducing energy losses.

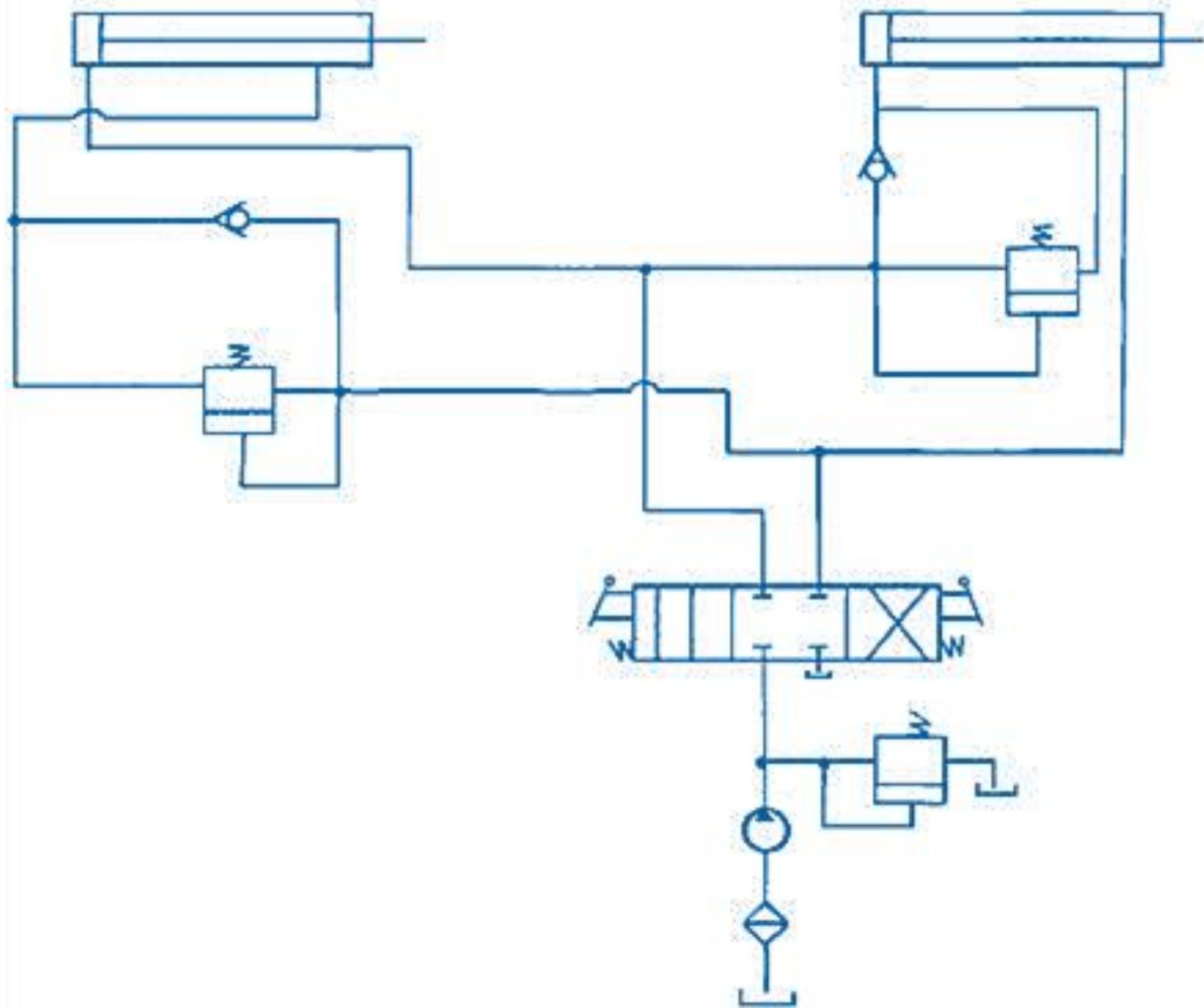
## Applications:

- Used in **accumulator charging circuits** to maintain pressure efficiently.
- Applied in **high-low pump circuits**, where a high-flow, low-pressure pump is unloaded while a high-pressure pump continues operation.

# UNLOADING HYDRAULIC CIRCUITS



# QUIZ



# SEQUENCING HYDRAULIC CIRCUITS

Sequencing in hydraulic circuits ensures that actuators (such as cylinders or motors) operate in a predefined order to achieve efficient and controlled machine operation. Sequence valves are commonly used to regulate the activation of multiple actuators based on pressure or flow conditions.

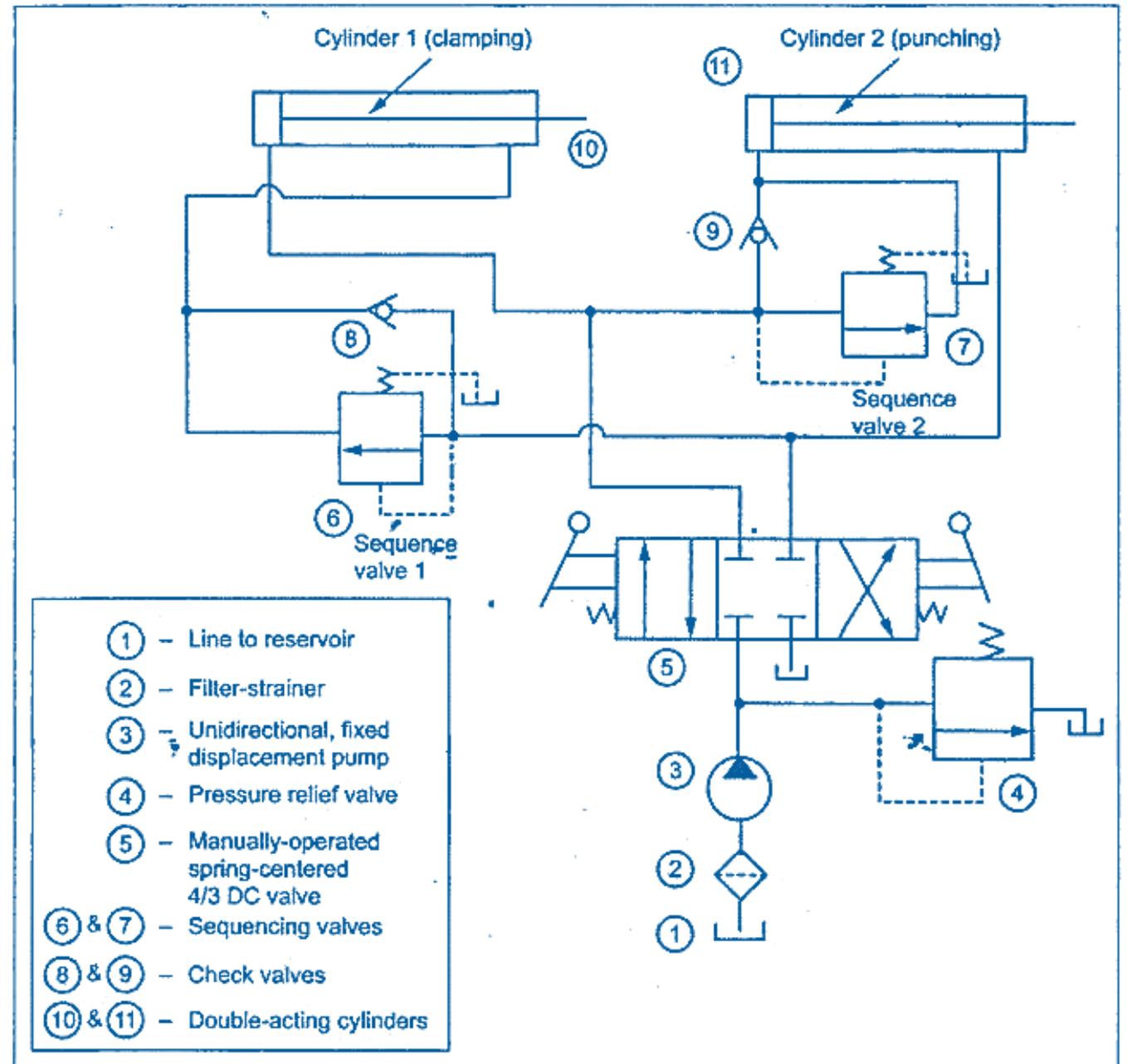
## **Working Principle of a Sequencing Circuit:**

- 1.Primary Actuator Activation** – Hydraulic fluid is directed to the first actuator (e.g., a cylinder) until it reaches a certain pressure.
- 2.Sequence Valve Activation** – Once the preset pressure is achieved, the sequence valve opens, allowing flow to the next actuator.
- 3.Secondary Actuator Operation** – The second actuator performs its function after the first has completed its movement.
- 4.Return and Reset** – The system resets based on directional valve position, ready for the next cycle.

## **Applications of Sequencing Hydraulic Circuits:**

- **Pressing and Clamping Operations** – Ensuring clamping occurs before pressing.
- **Manufacturing and Automation** – Controlling multiple hydraulic arms in a defined sequence.
- **Injection Molding Machines** – Coordinating mold closing, injection, and ejection stages.
- **Lifting and Positioning Systems** – Activating multiple hydraulic cylinders in a controlled order.

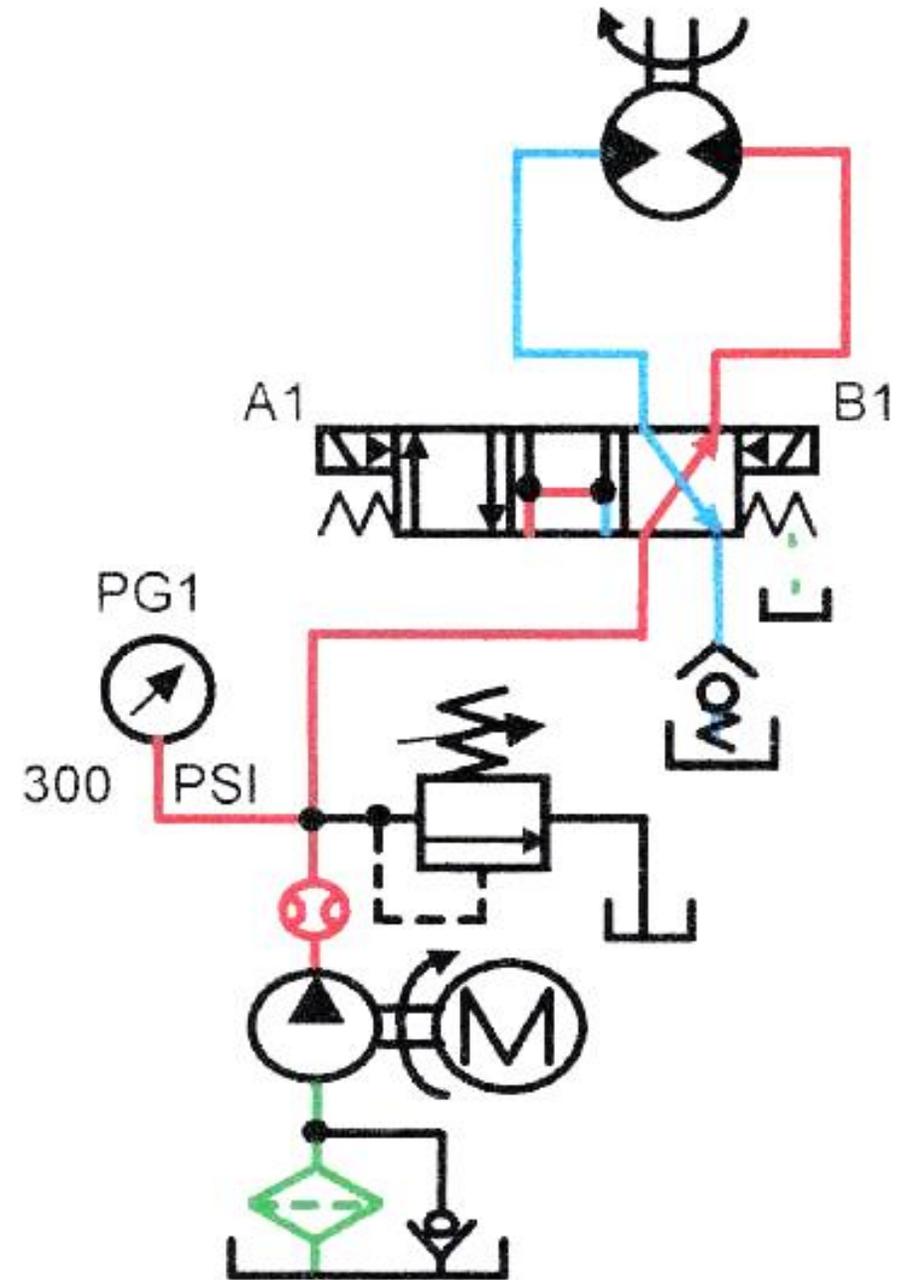
# SEQUENCING HYDRAULIC CIRCUITS



*Fig. 8.10. Hydraulic cylinder sequence circuit (for clamping and punching operations)*

# HYDRAULIC MOTOR CIRCUIT

Bi-directional hydraulic motor running clockwise

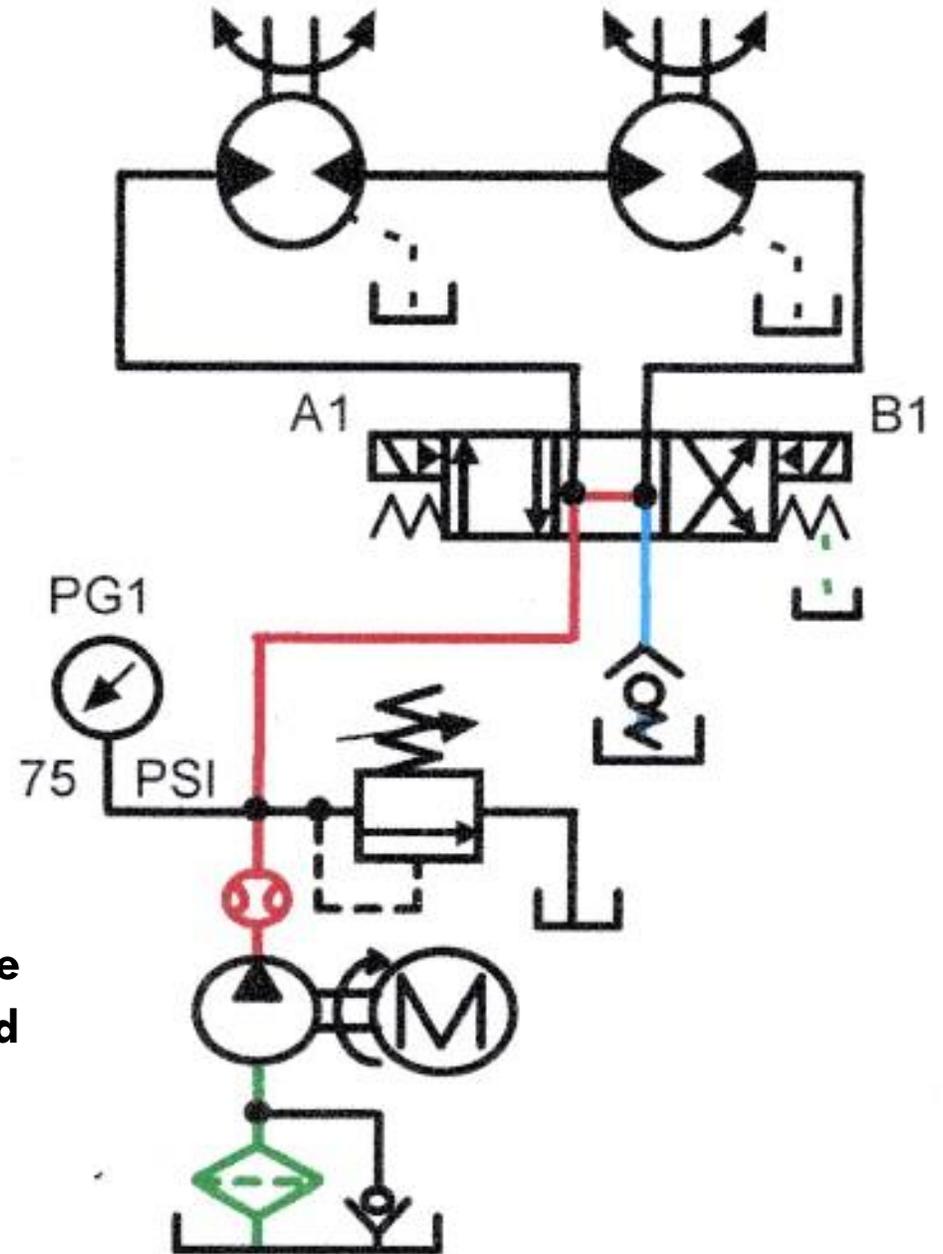




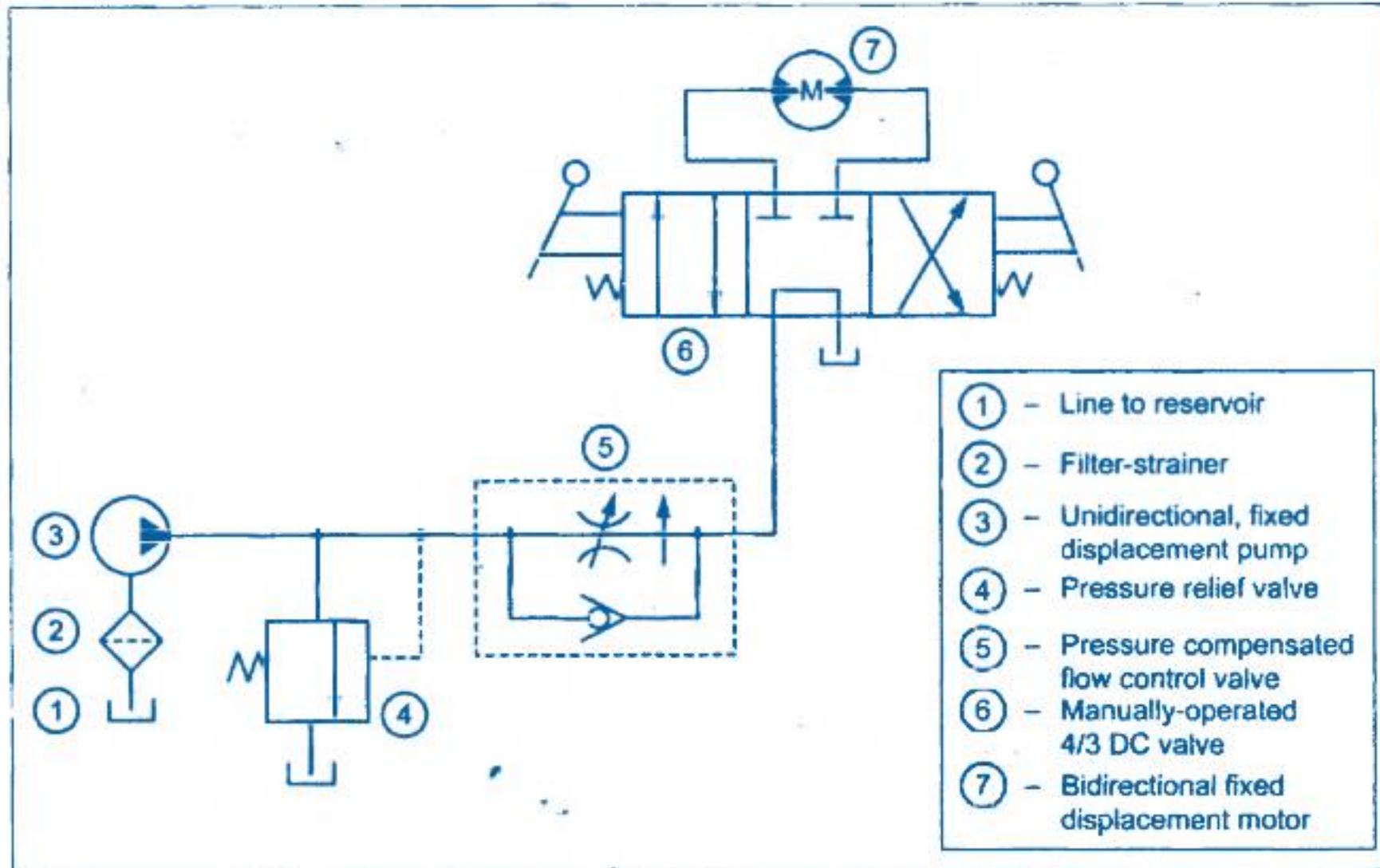
# HYDRAULIC MOTOR CIRCUIT

## Series hydraulic motor circuit with bi-directional rotation

The outlet of the first motor is piped to the inlet of the second. This series circuit gives nearly perfect speed synchronization but reduces each motor's power.

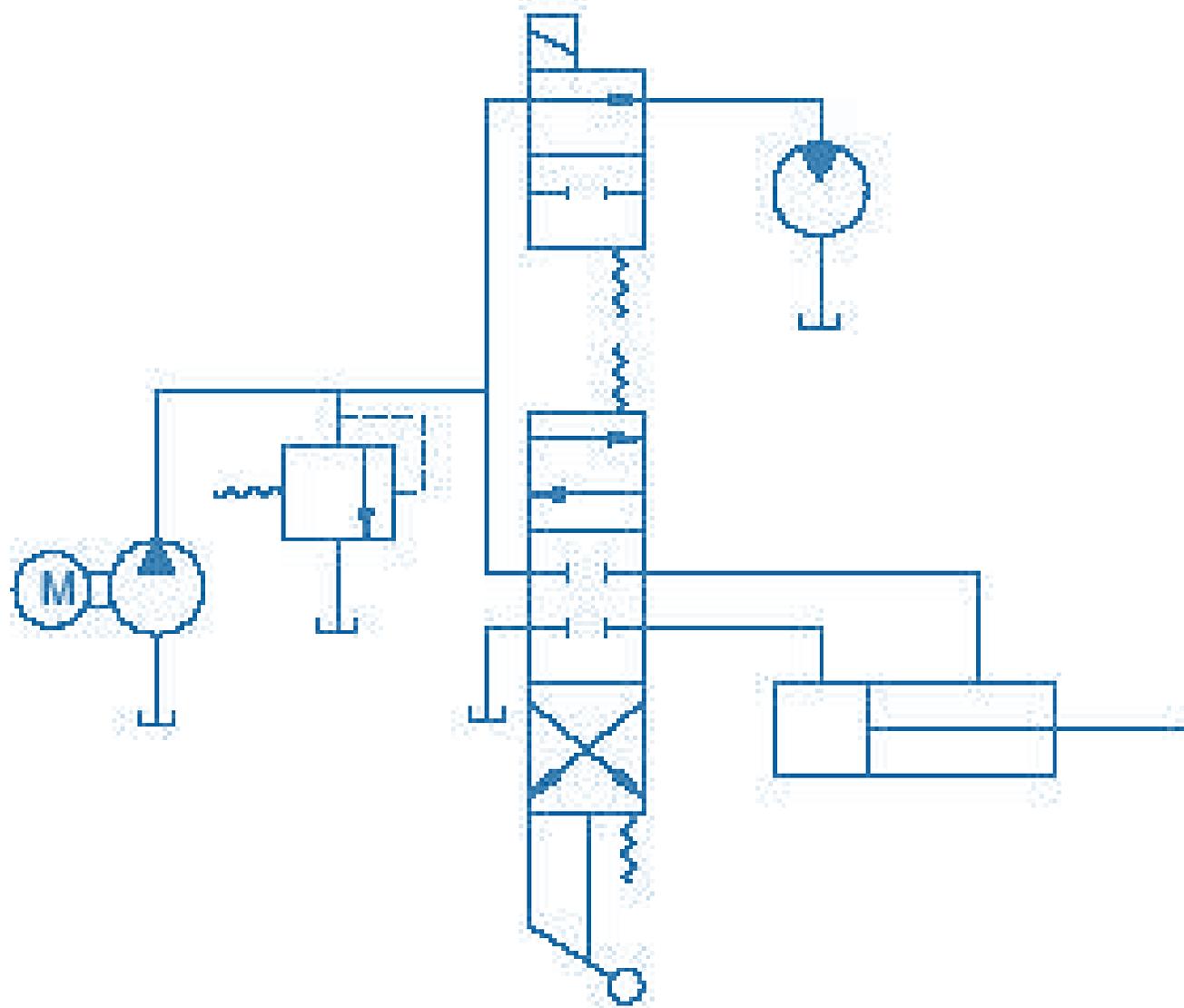


# HYDRAULIC MOTOR CIRCUIT



*Fig. 8.21. Speed control of hydraulic motor using flow control valve*

# QUIZ



# UNIT 5 PNEUMATIC SYSTEMS AND COMPONENTS

Pneumatic Components: Properties of air - Compressors - Filter, Regulator, Lubricator Unit - Pneumatic system, pneumatic components - pressure - flow - direction controls valves, Air control valves, Quick exhaust valves, pneumatic actuators. (3)

# UNIT 6 PNEUMATIC CIRCUITS DESIGN

Design of pneumatic circuits for automation, selection and specification of circuit components, sequencing circuits, cascade, and karnaugh - Veitch map method - Regenerative, speed control, synchronizing circuits. (8)

# UNIT 7 ELECTRO PNEUMATICS AND PLC CIRCUITS

Use of electrical timers, switches, solenoid, relays, proximity sensors etc. electro pneumatic sequencing Ladder diagram – PLC-elements, functions and selection - PLC programming - Ladder and different programming methods - Sequencing circuits. (6)