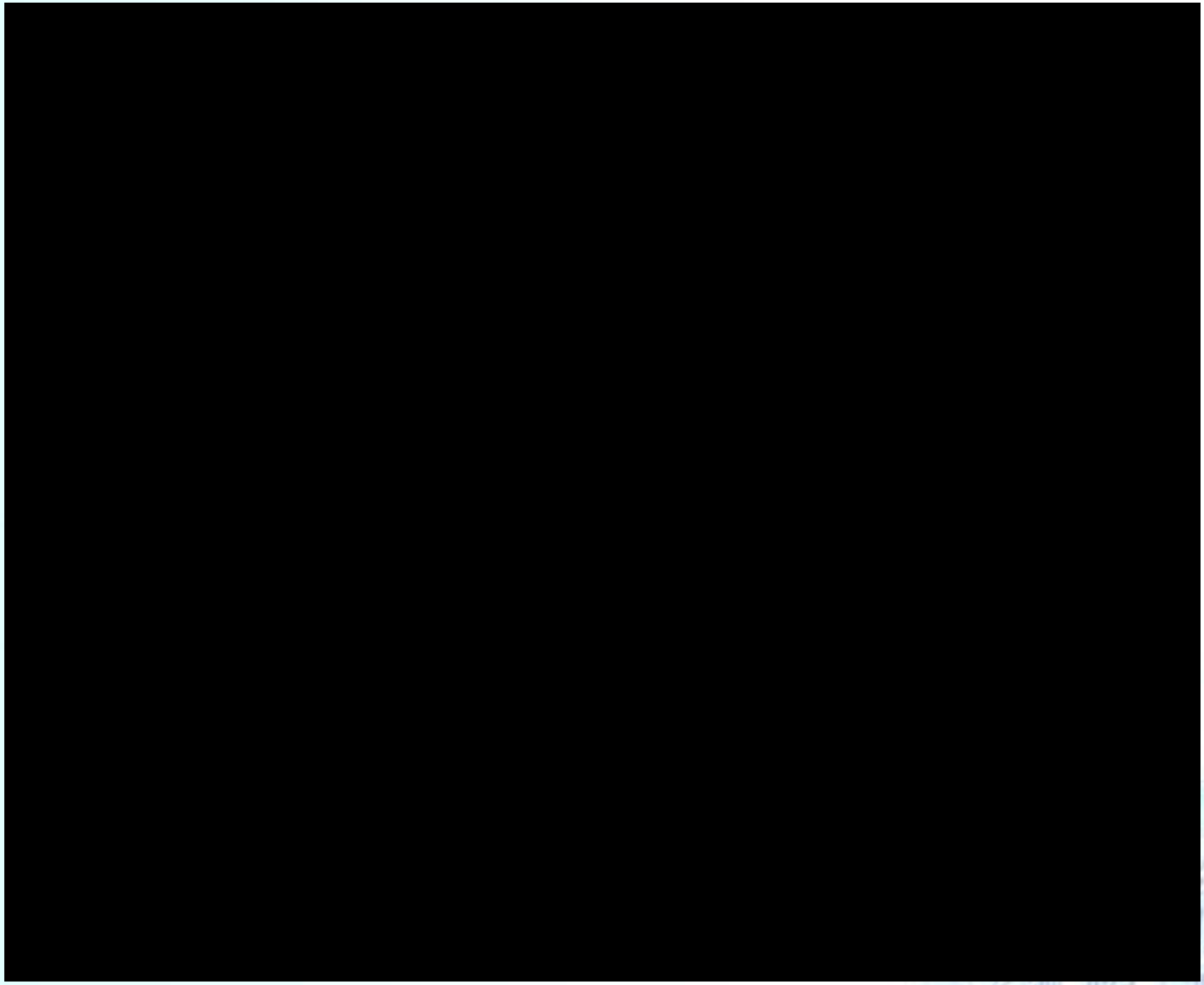
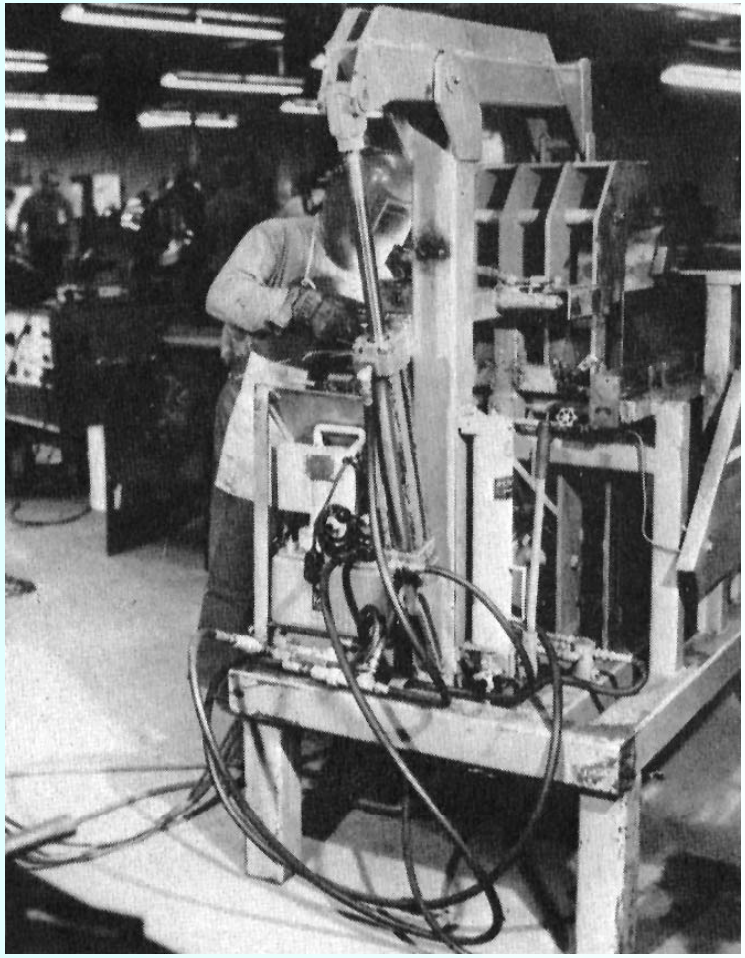
8. Hydraulic Valves

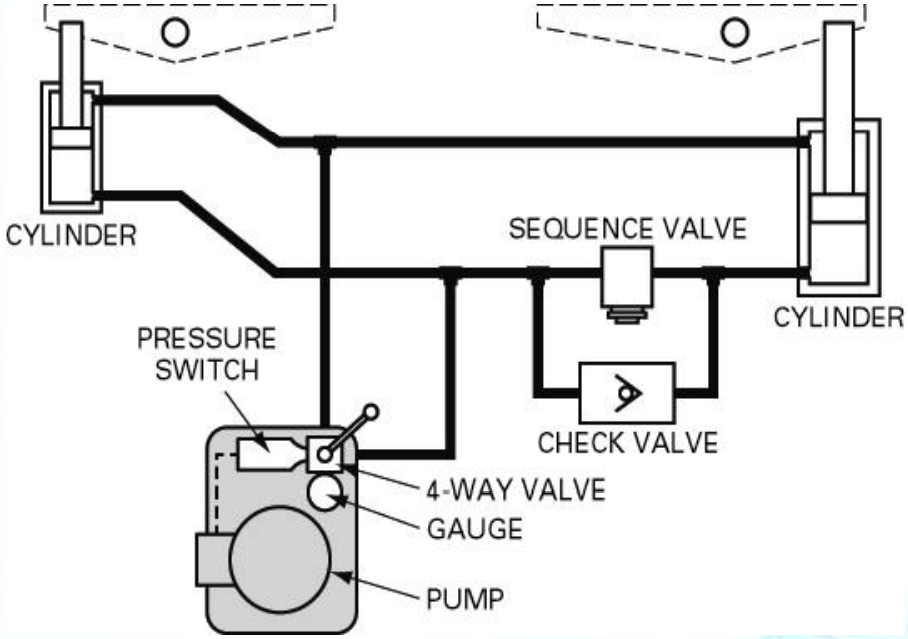
- **Directional control valves**
  - 2-way, 3-way, & 4-way directional control valves
  - Manual, mechanical, fluid pilot, & electric solenoid actuating methods
- **Pressure control valves**
  - Pressure relief valve, pressure-reducing valve, sequence valve, unloading valve
  - Power loss in pressure relief & unloading valves
- **Flow control valves**
  - Analysis of flow control valve
  - Non-compensated & compensated flow control valve
- **Mechanical-hydraulic & electrohydraulic servo valves**
- **Cartridge valves**

유압밸브



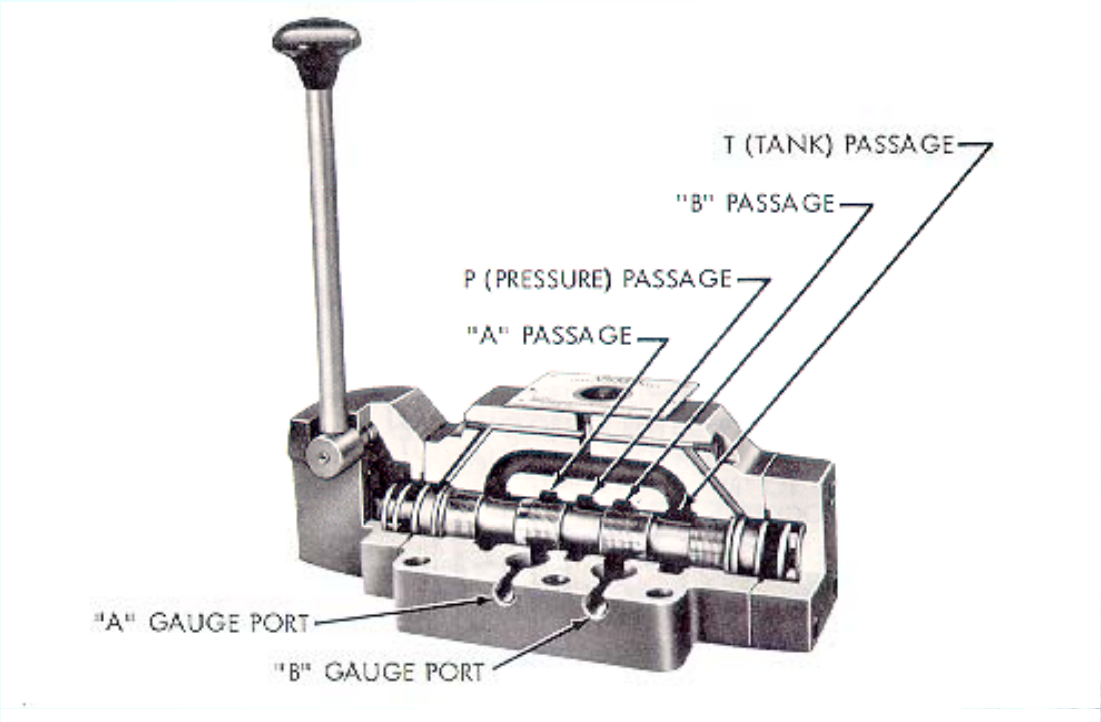
8.1 Welding Machine Application



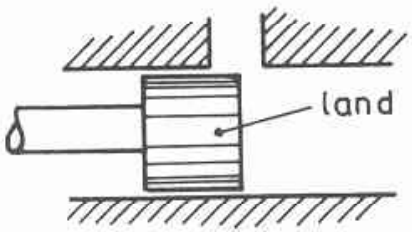


Hydraulic Valves

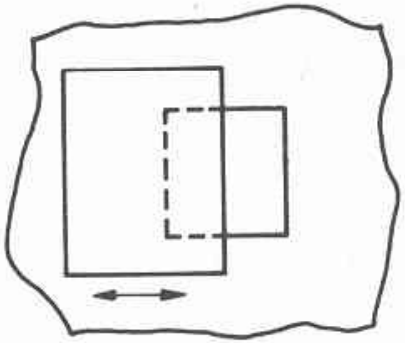
- 밸브의 정의
  - 유체동력원**(fluid power source)**의 흐름 방향, 유량, 압력을 제어하기 위하여 기계적인 운동**(mechanical motion)**을 사용하는 장치



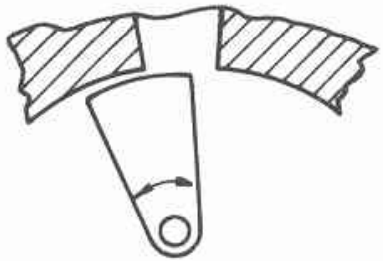
Types of Valves: shearing elements



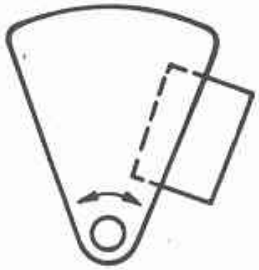
(a) Spool



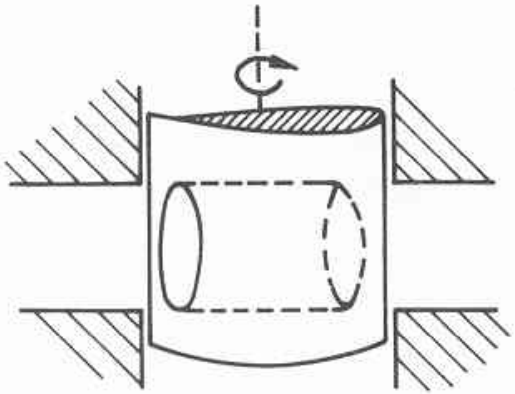
(b) Sliding Plate



(c) Rotary Spool

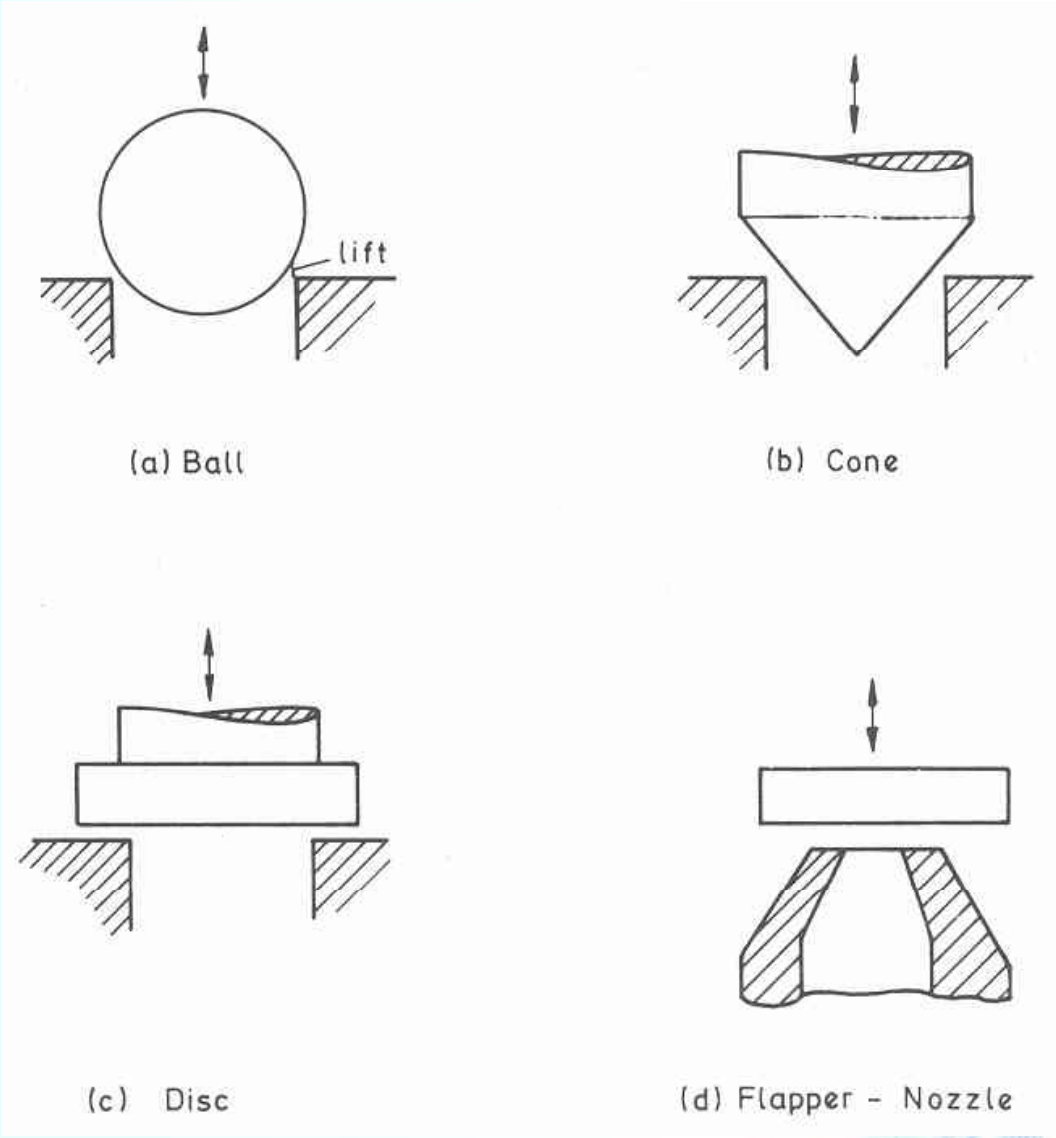


(d) Rotary Plate



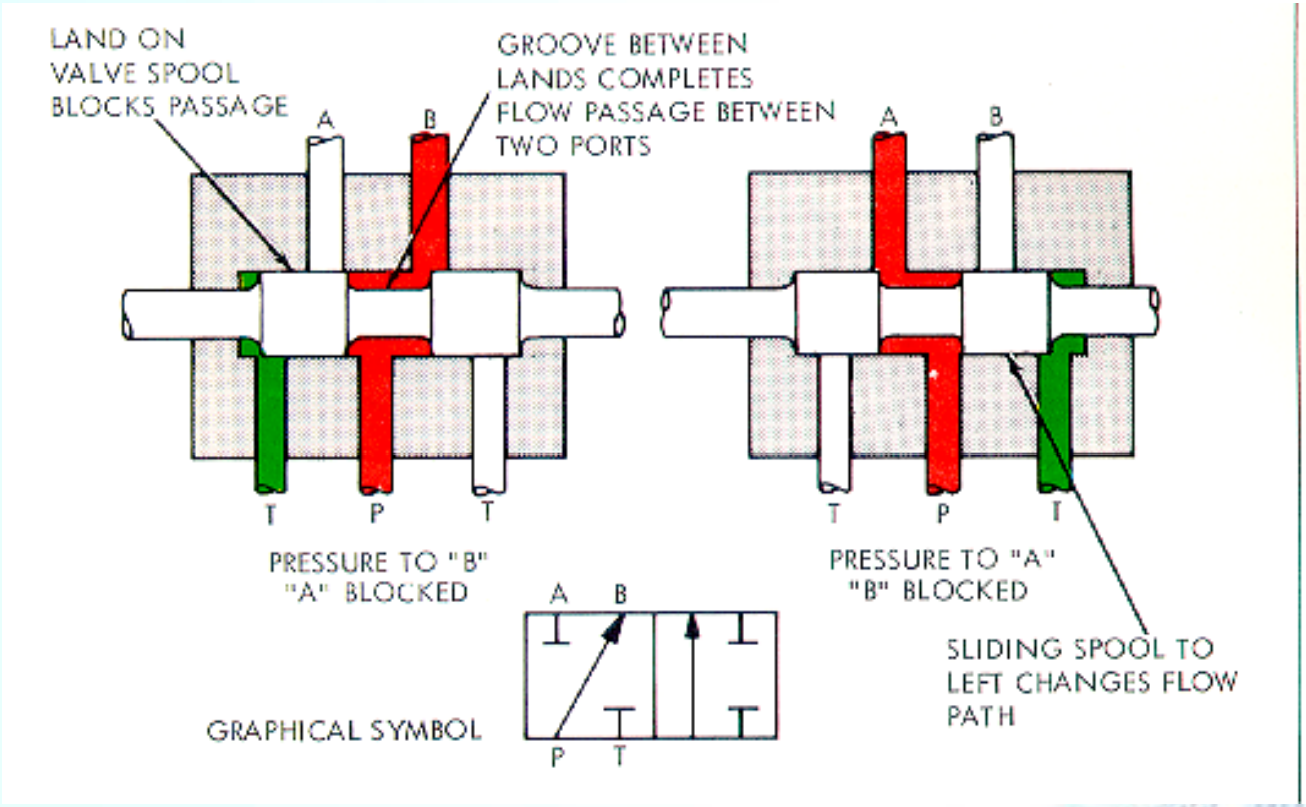
(e) Rotary Plug

Types of Valves: seating elements



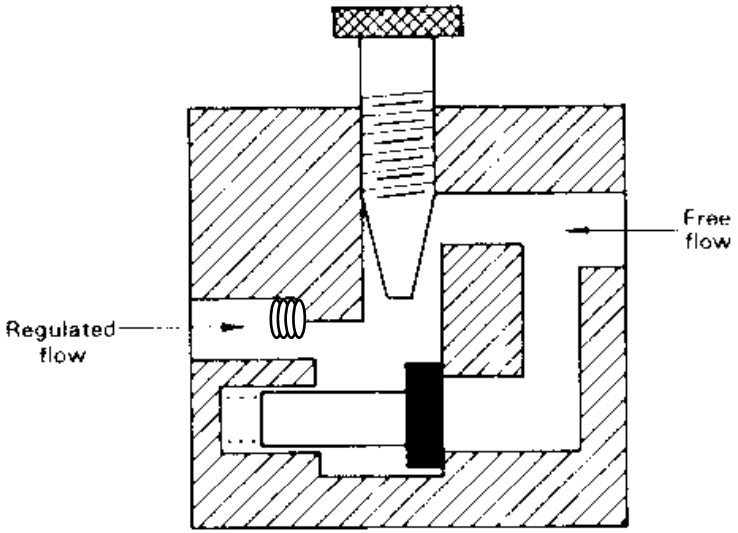
Classification of Valves: Directional Control

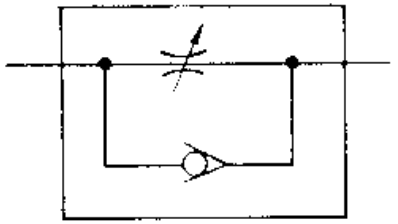
- 방향제어 밸브 **(Directional control valve)**
  - 회로 내에서 작동신호에 따라 유체의 경로 결정



Classification of Valves: Flow Control

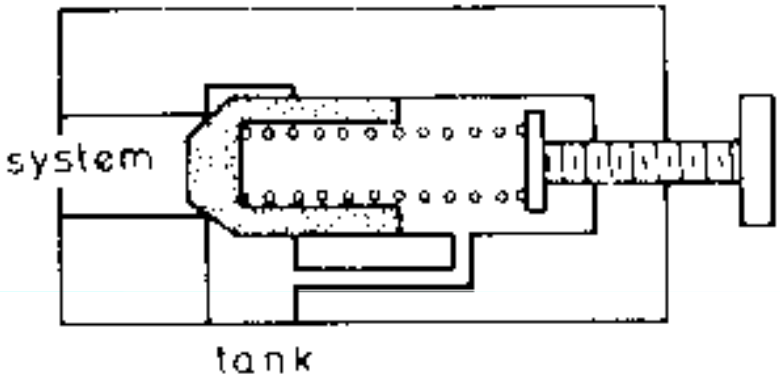
- 유량제어 밸브 **(Flow control valve)**
  - **piston motor**의 속도 조절
  - 대부분 한 방향만 유량조절
    (non-return valve와 조합**)**

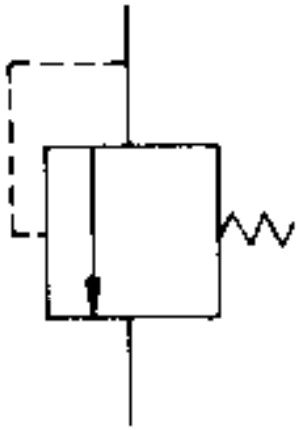




Classification of Valves: Pressure Control

- 압력제어 밸브 **(Pressure control valve)**
  - 압력을 조절 또는 압력에 의해 조작되는 밸브

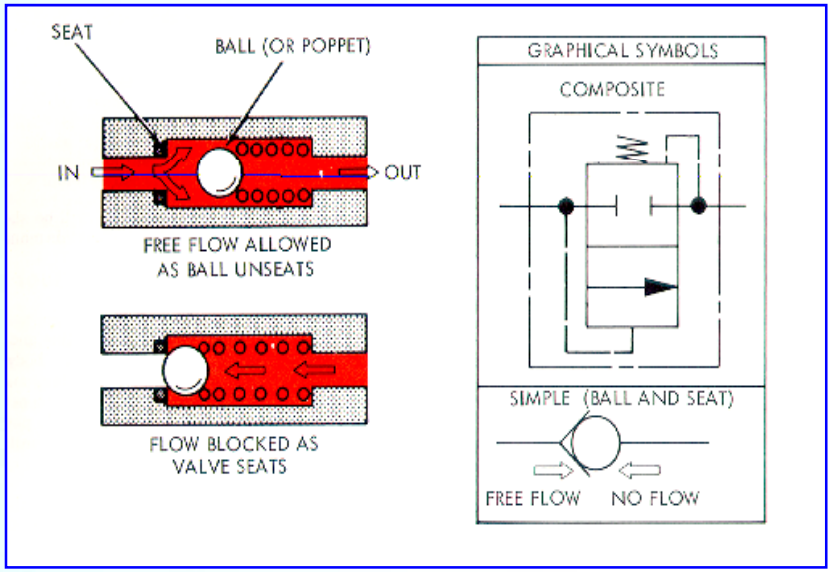


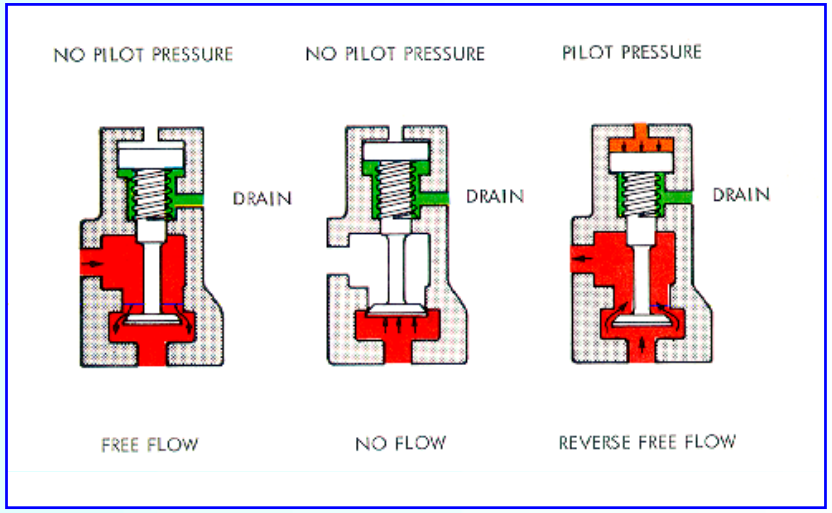


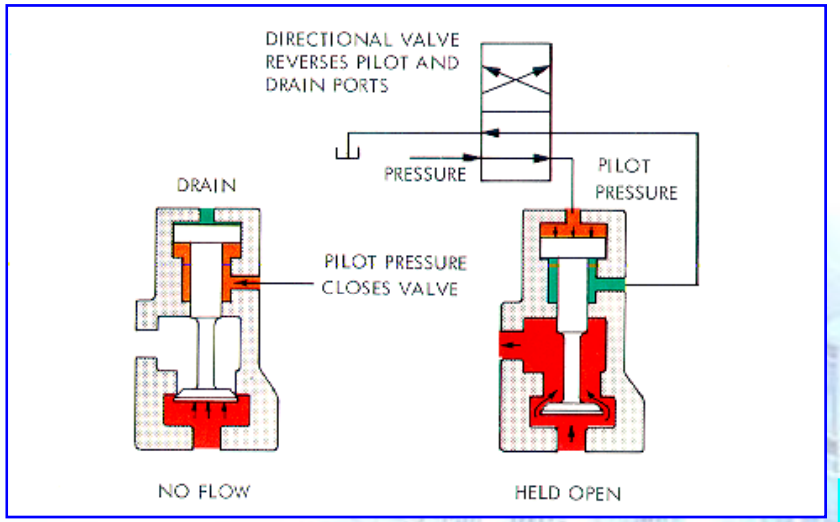
Classification of Valves: Operating Methods

- 수동식(Manual)
  - 레버방식, 페달방식, 누름 버튼 방식
- 기계식(Mechanical)
  - 압봉 방식, 로울러 방식, 스프링 방식
- 파일럿(Pilot) 방식
  - 직접형, 간접형
- 솔레노이드(Solenoid) 방식
  - 단 코일형, 복 코일형
- 서보(Servo) 방식
  - **electric servo-motors, magneto-strictive devices, piezoelectric crystals, proportional solenoid, ac torque motors, moving coil devices**

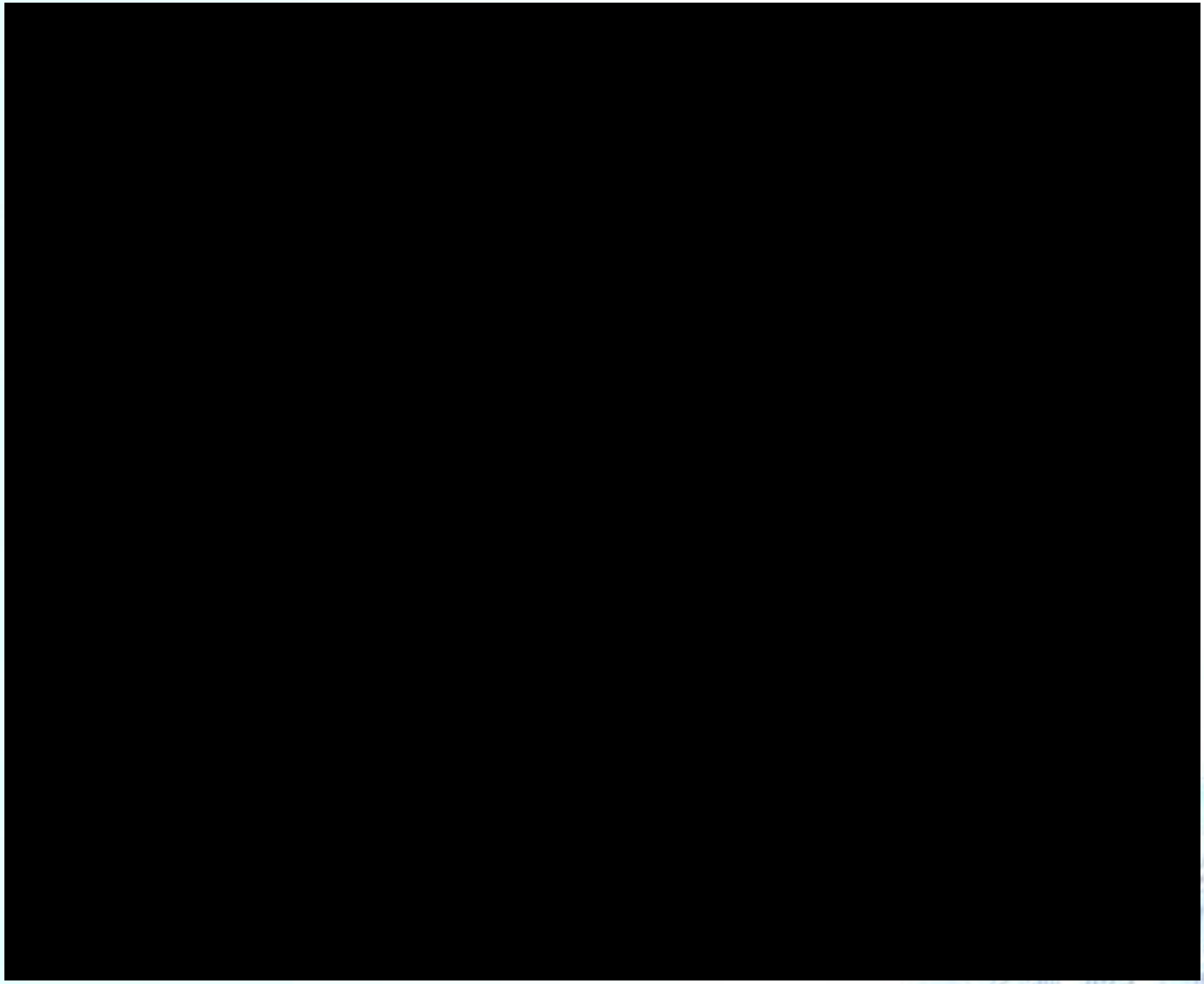
8.2 Directional Control Valve: Check Valve



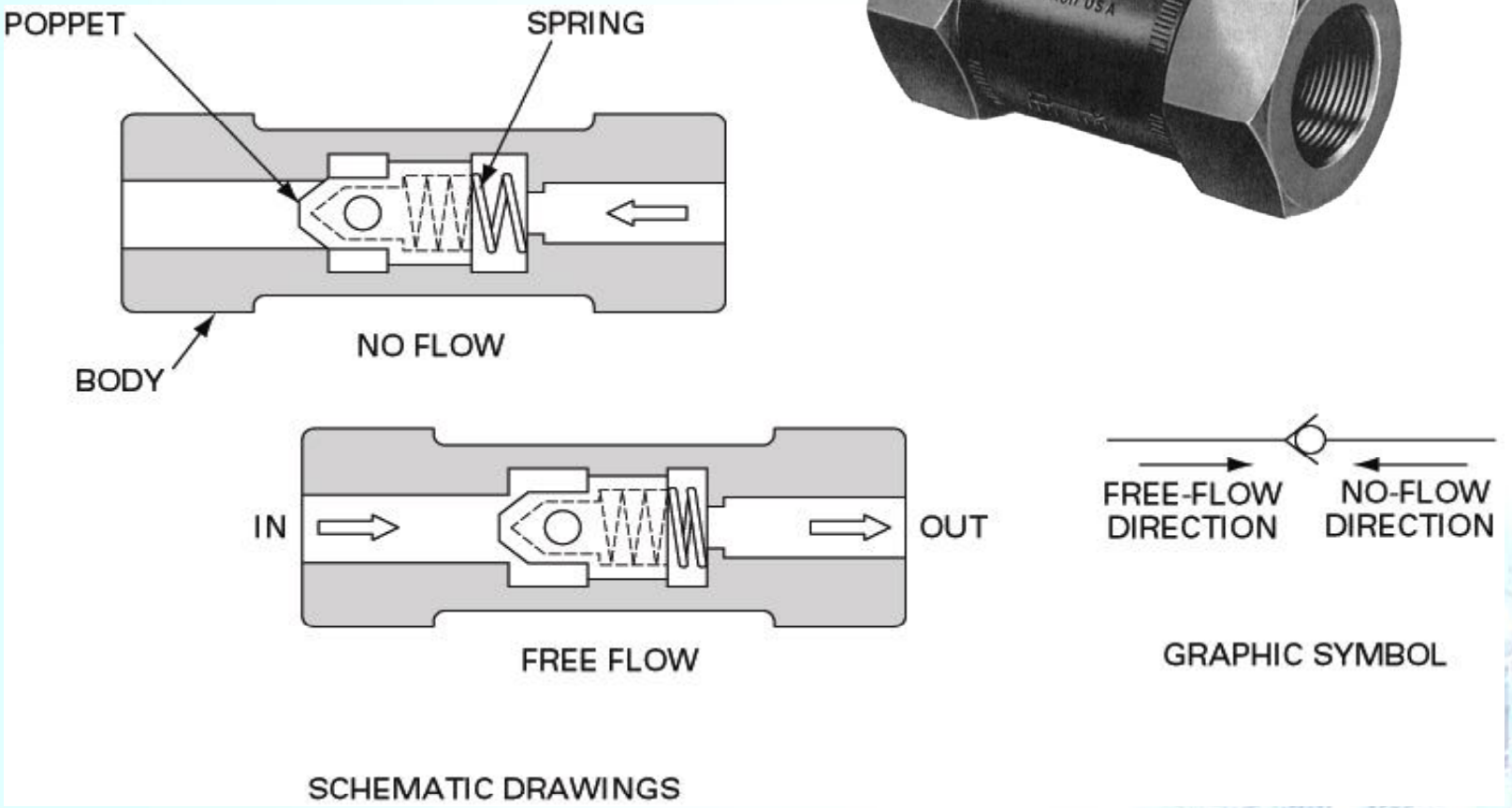




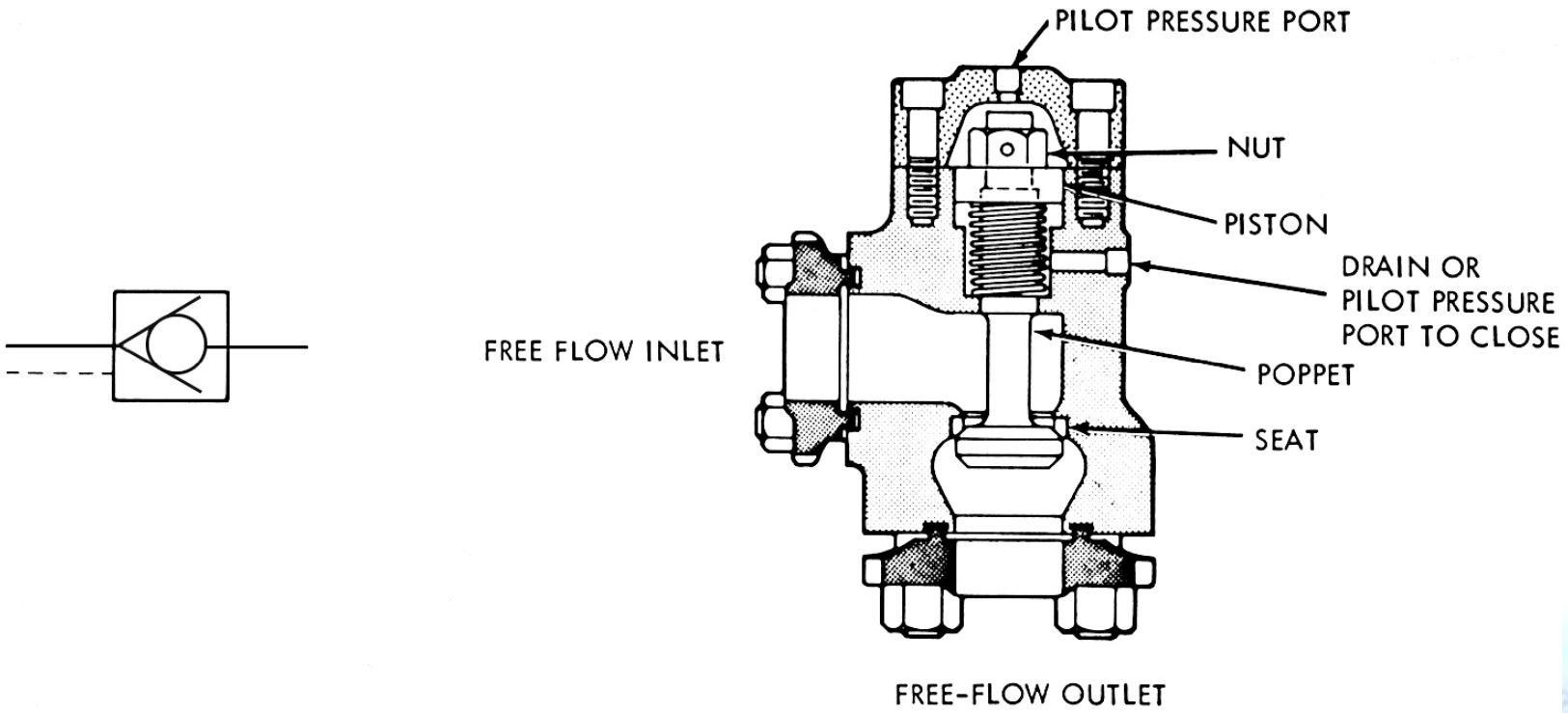
Check Valve



Operation of Check Valve

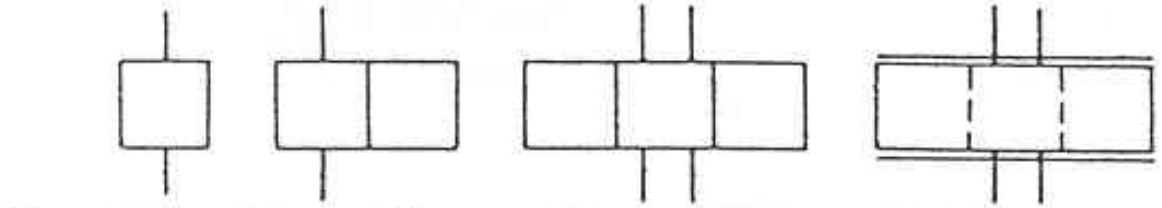


Pilot Operated Check Valve



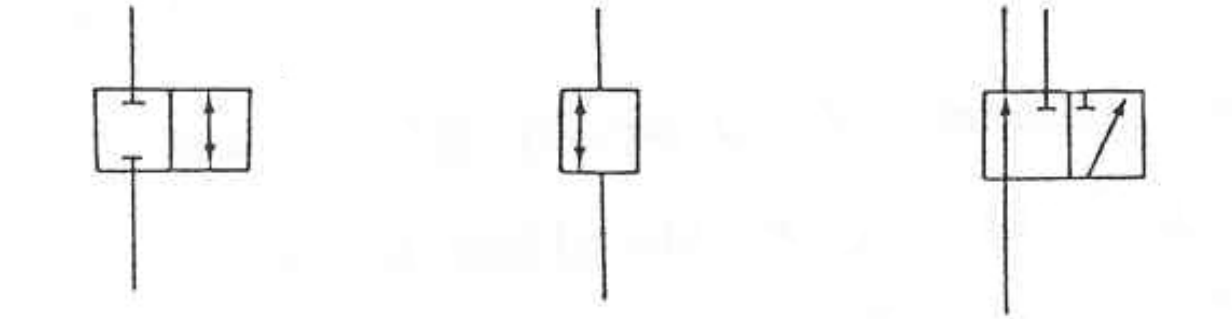
Directional Control Valve

- **Position**



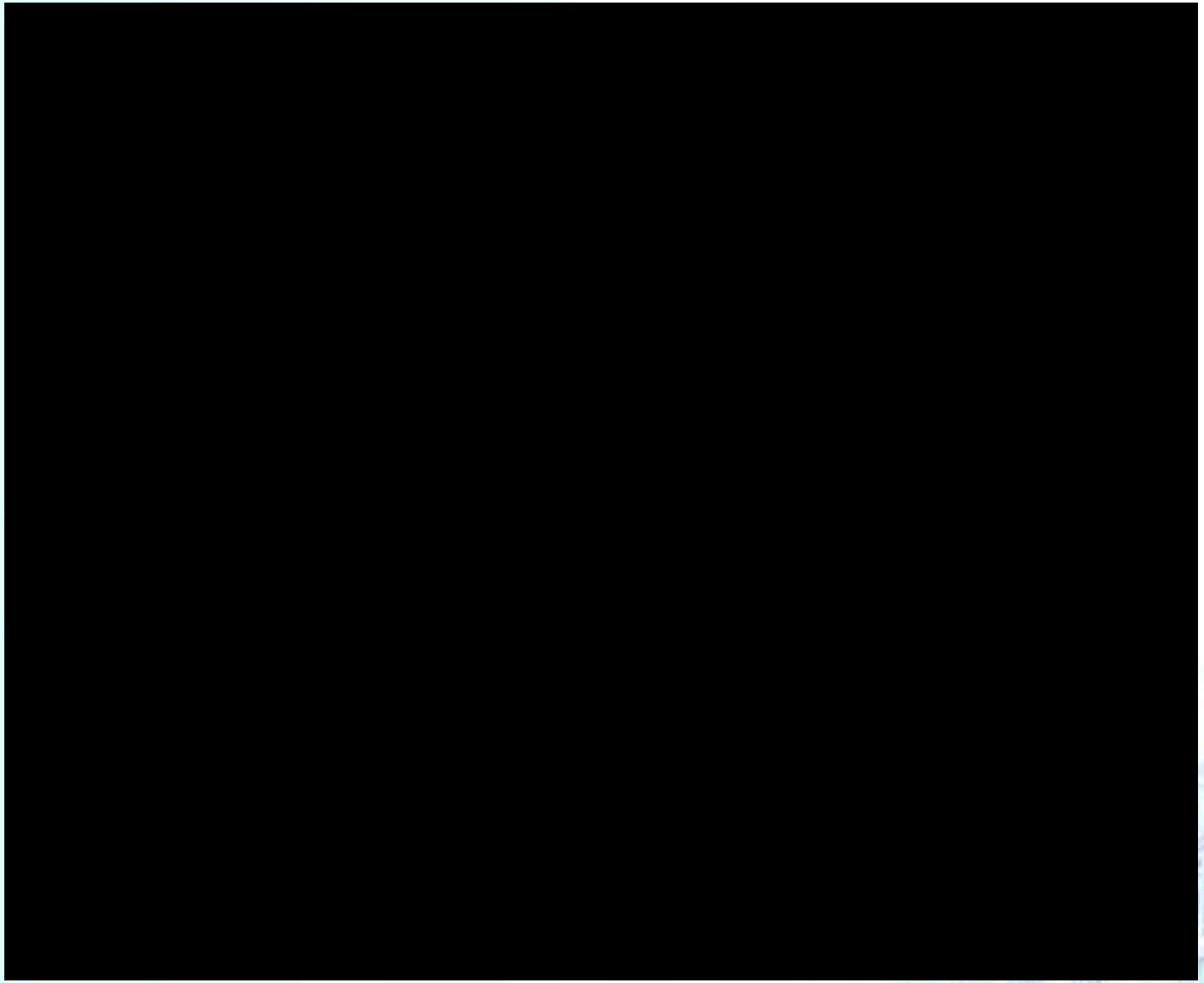
One-position (or infinite position single envelope) | Two-position | Three-position | Infinite-position

- **Way**
- **Port**

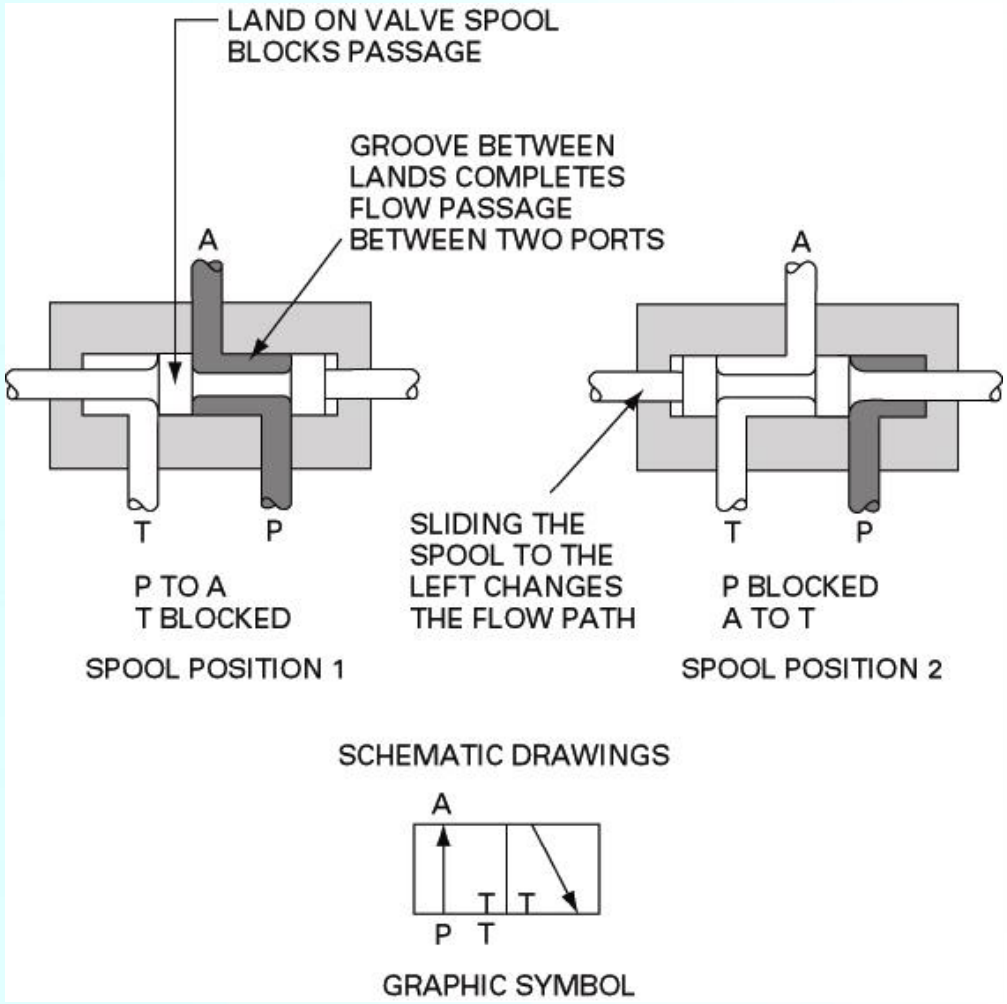


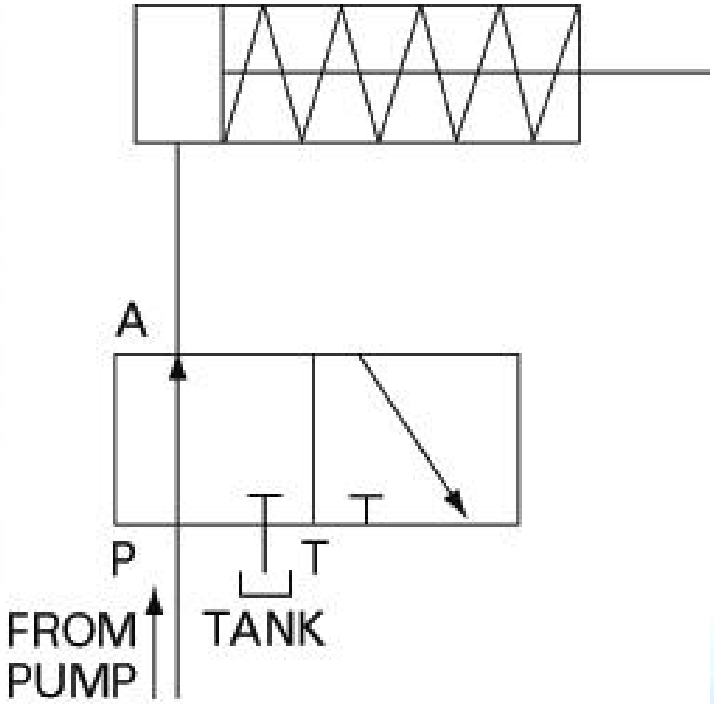
Two-way, two position, two-port, normally closed | Two-way, infinite position, two-port, normally closed | Three-way, two-position, three-port

방향 제어 밸브

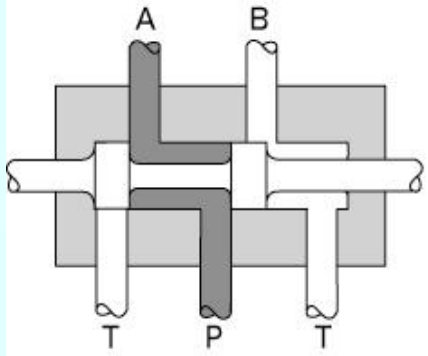


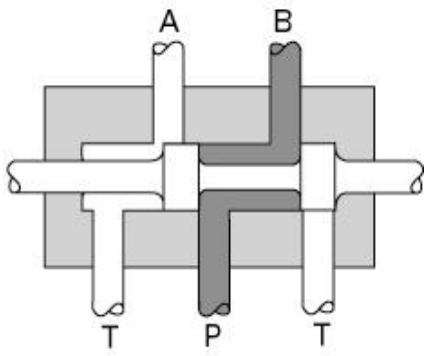
Three-Way Valve



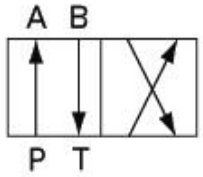


Four-Way Valve

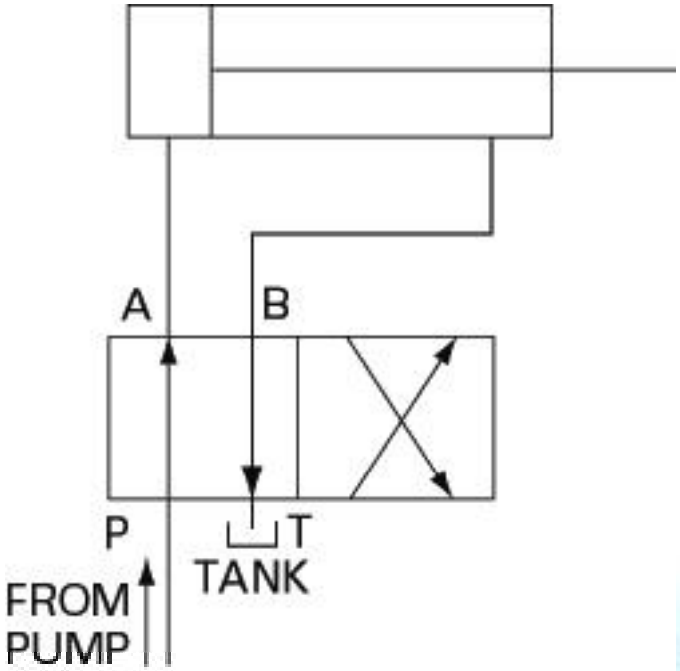




SCHEMATIC DRAWINGS

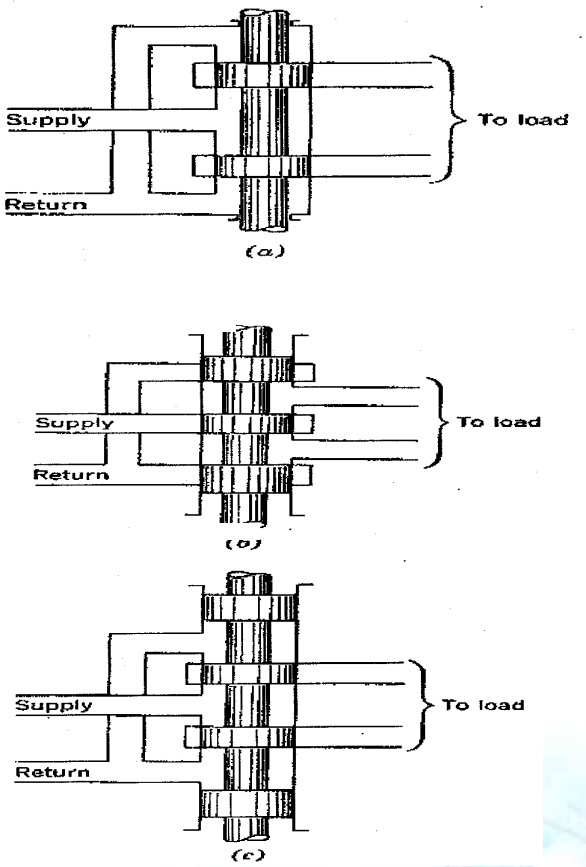


GRAPHIC SYMBOL



Types of Spool Valves: Way, Land

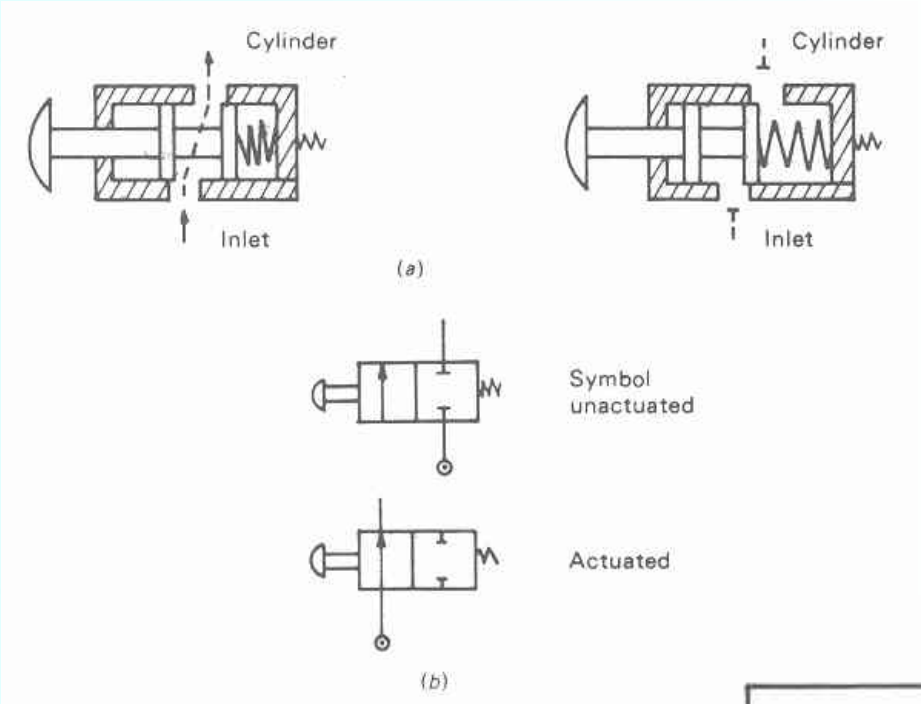
- 유로(Way)의 수
  - 모든 밸브는 three-way 혹은 four-way (supply, return, 최소 한 개 이상의 load line)
  - two-way valve는 유로의 역전(reversal)기능 제공 못함
  - three-way valve는 방향 전환(direction reversal) 위하여 피스톤 단면적을 다르게 함
  - four-way valve는 load로 가는 line이 두 개
- **Land**의 수
  - **land** 수는 **2, 3, 4, 6**개짜리

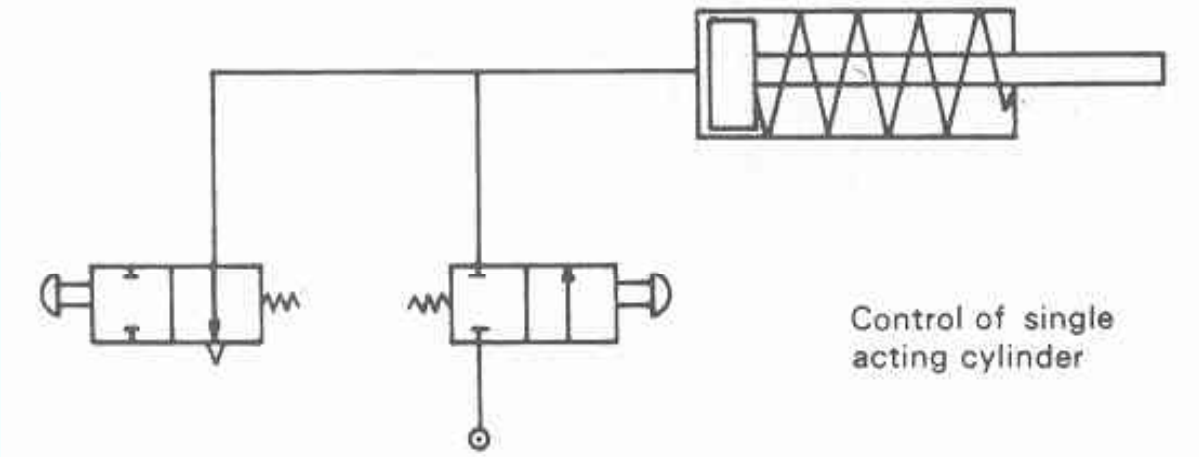


Typical hydraulic spool valves

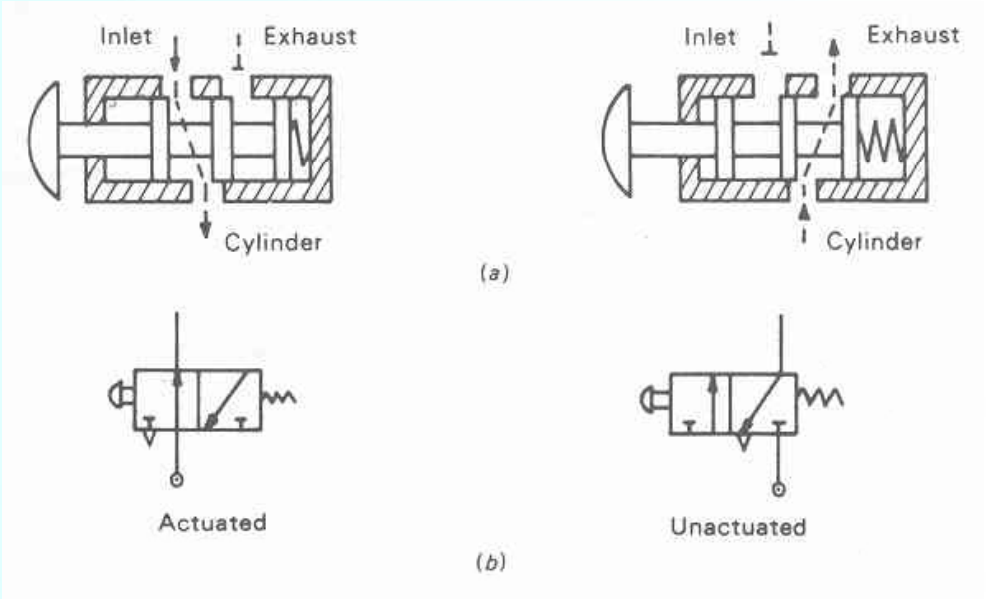
(a) two-land four-way spool valve
(b) three-land four-way spool valve
(c) four-land four-way spool valve

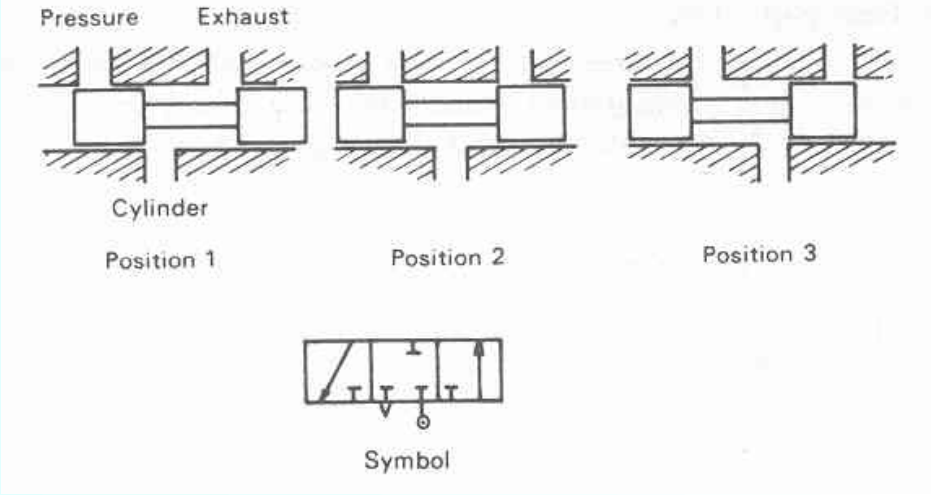
Two Port Valve

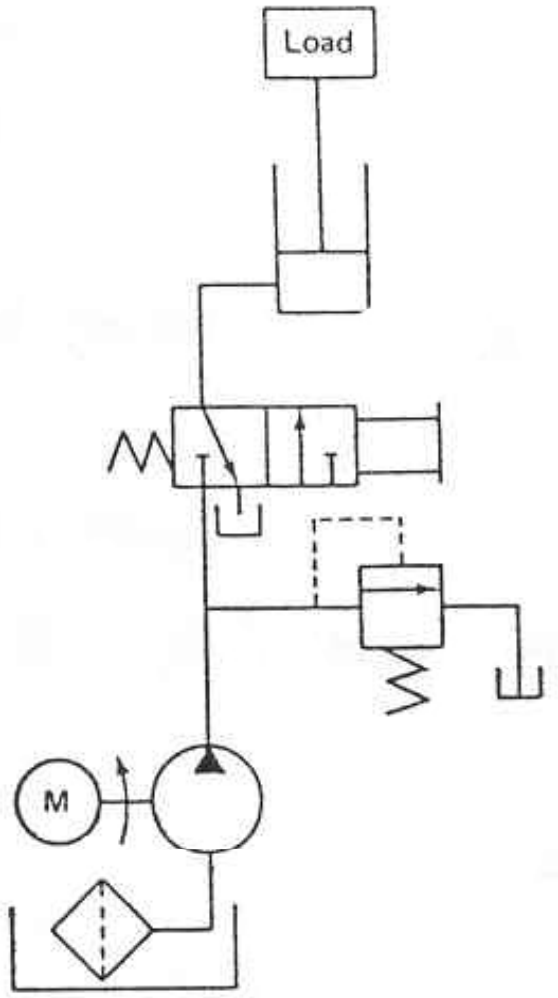




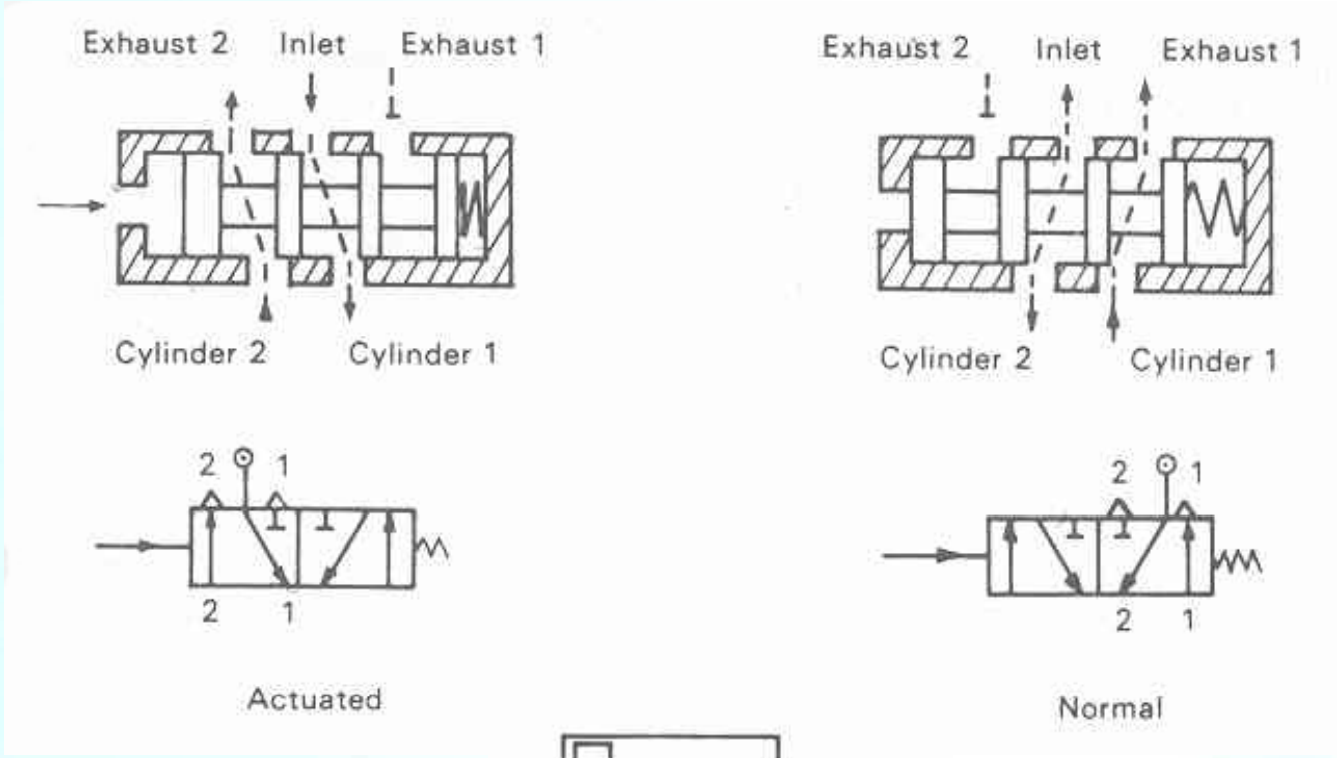
Three Port Valve

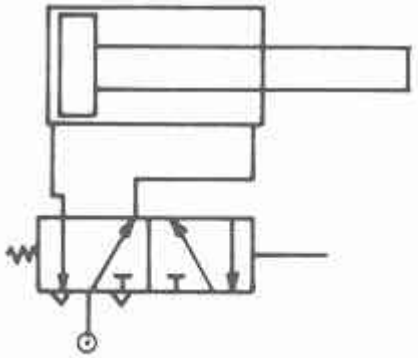






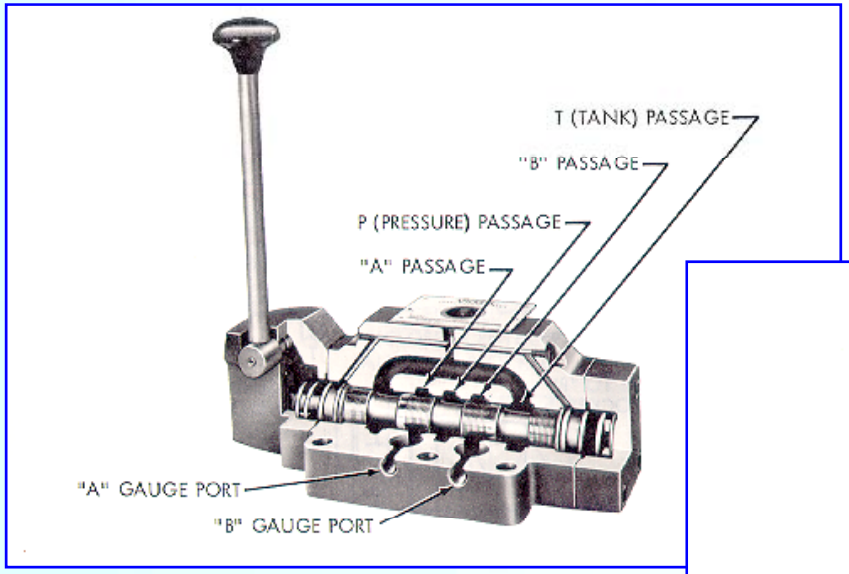
Five Port Valve

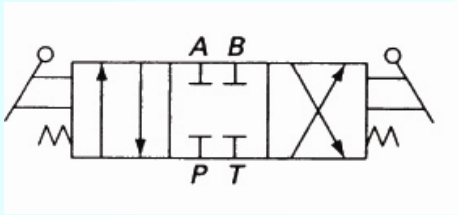




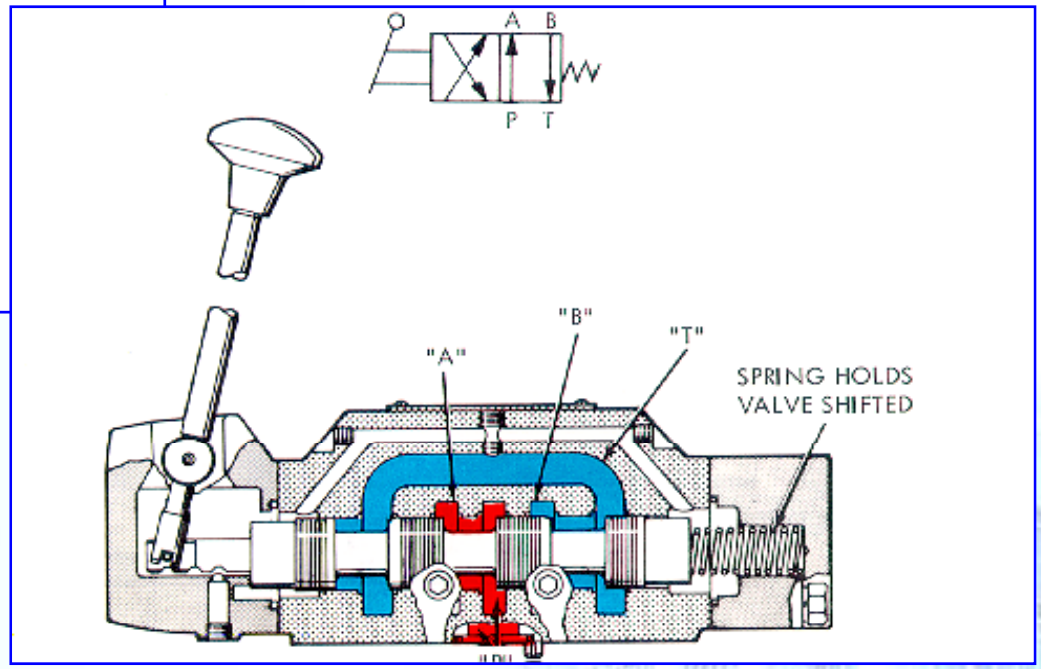
Manually Actuated Valves

❖ **Manually actuated, spring-centered, three-position, four-way valve**



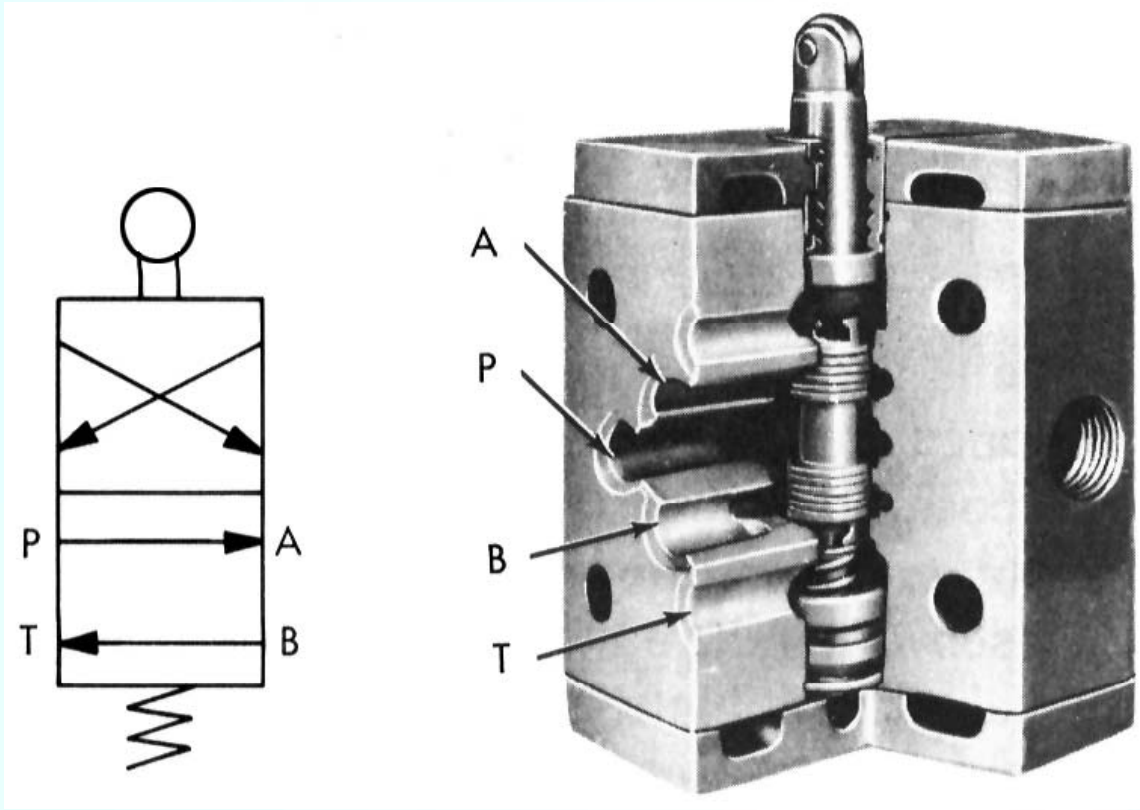


❖ **Manually actuated, spring-offset, two-position, four-way valve**

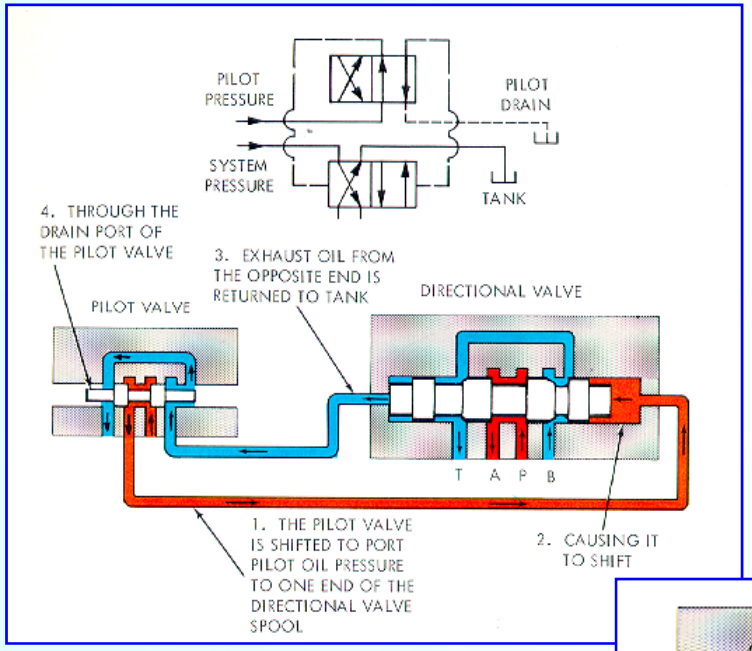


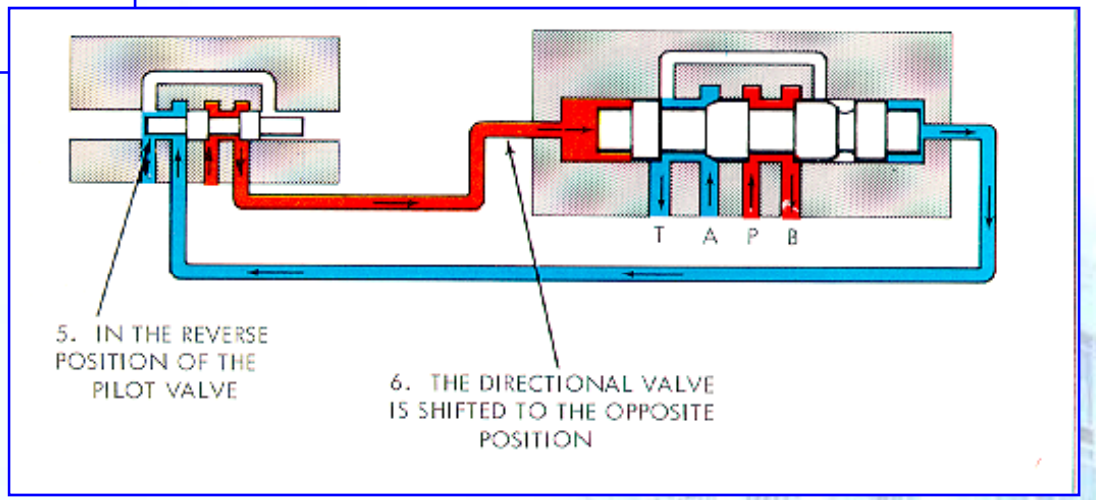
Mechanically-Actuated Four-Way Valve

- **Mechanically actuated spring offset, two-position, four-way valve**



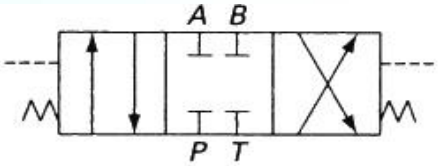
Pilot-Actuated Valves

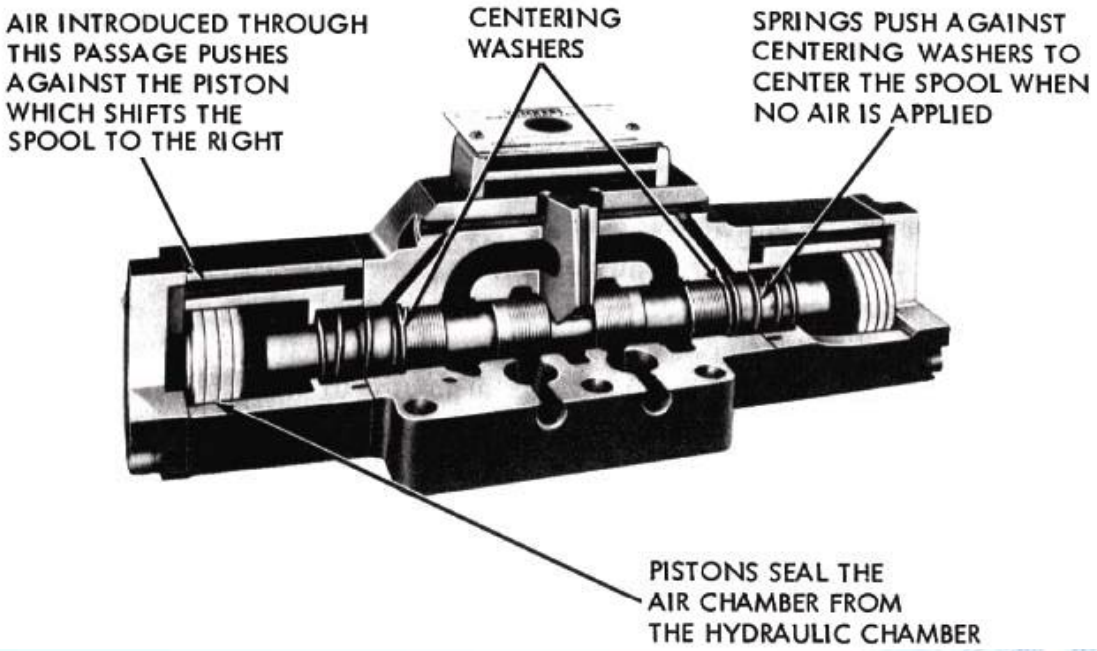




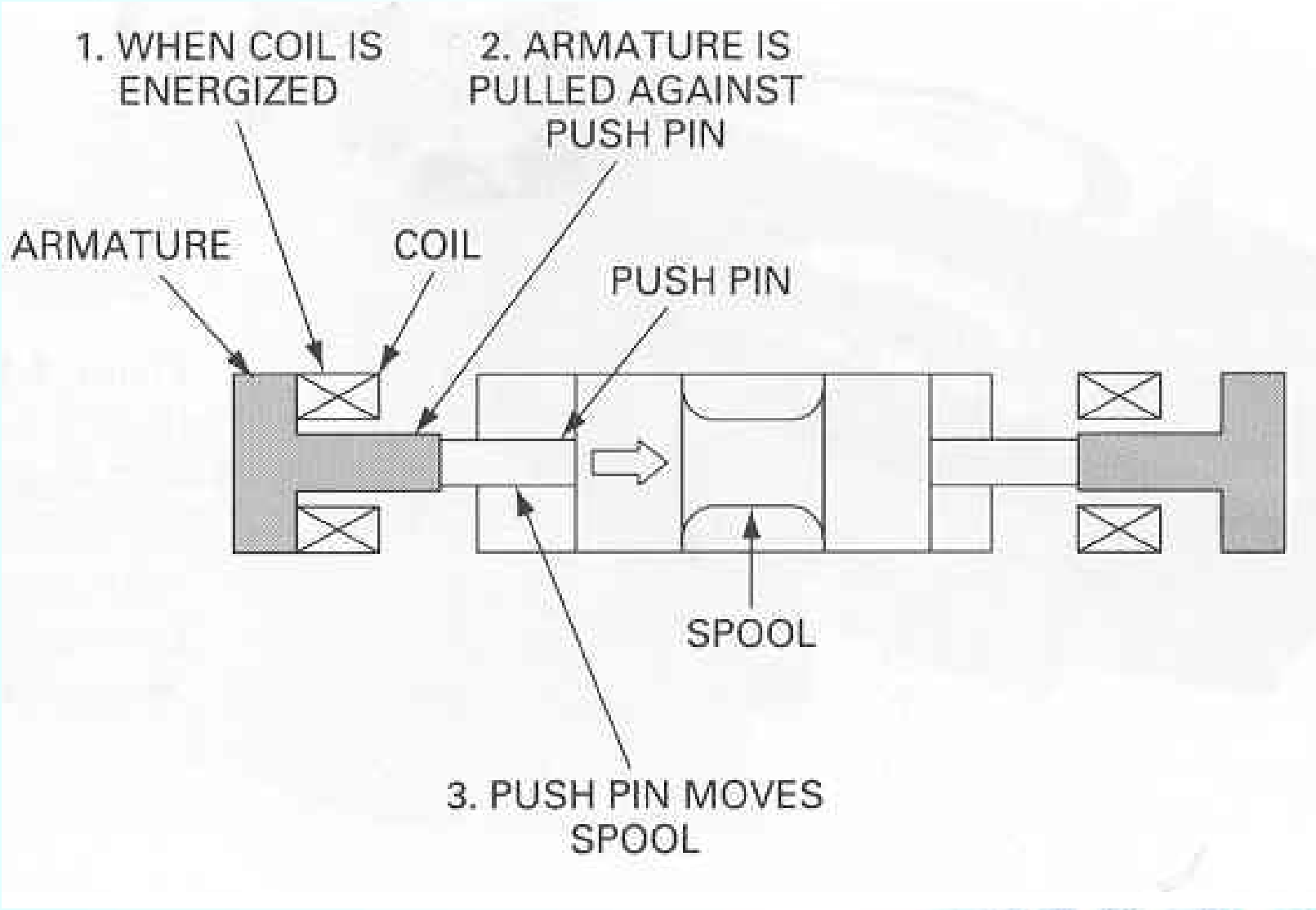
Air Pilot-Actuated Four-Way Valve

- **Air pilot-actuated three-position, spring-centered, four-way valve**

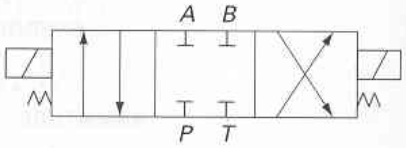




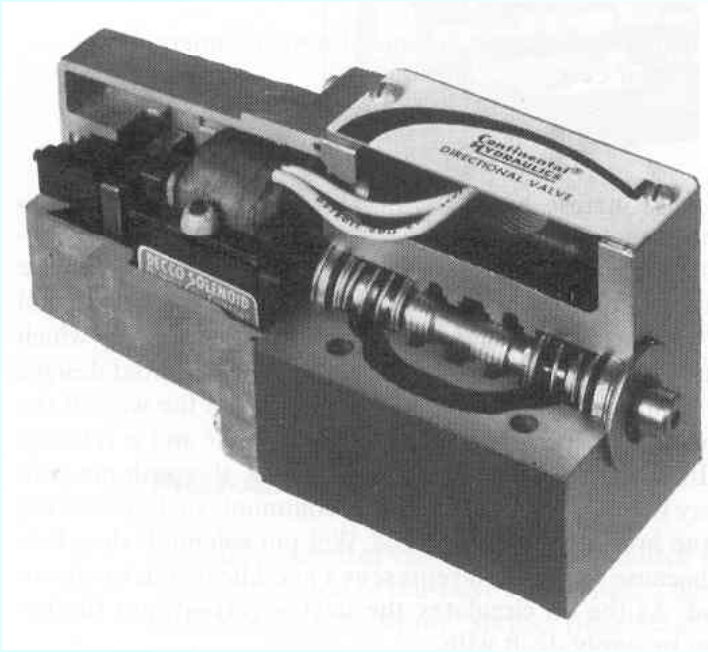
Operation of Solenoid to Shift of Valve

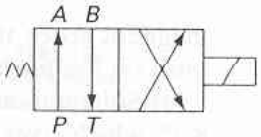


Solenoid-Actuated Valves



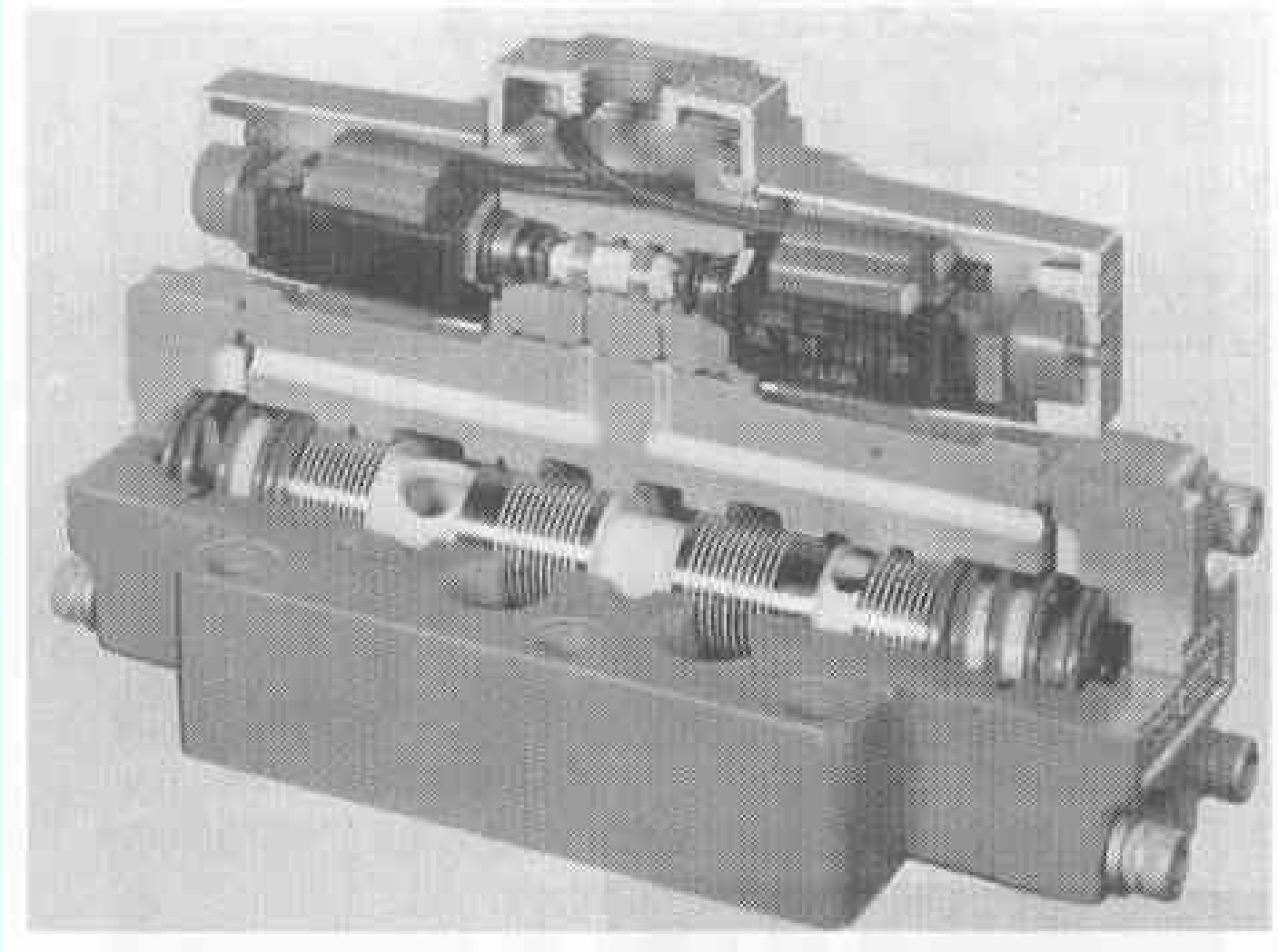
❖ **Solenoid-actuated, three-position, spring-centered, four-way, directional control valve**



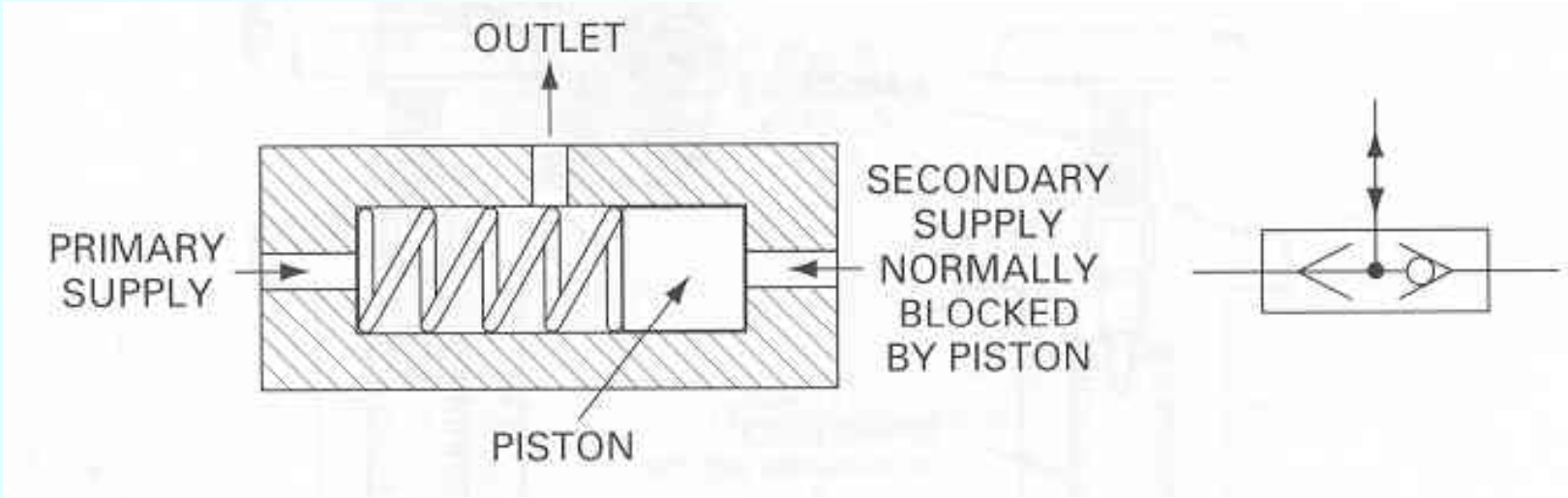


❖ **Single solenoid-actuated, two-position, spring-offset, four-way, directional control valve**

Solenoid-controlled, Pilot-operated Valve

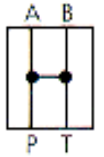


Shuttle Valve

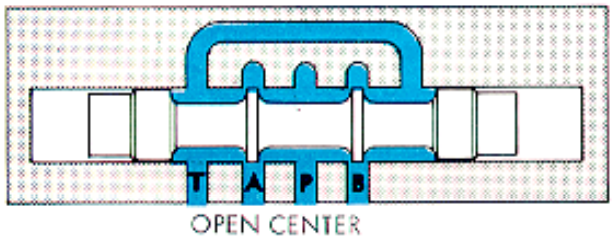


Types of Spool Valves: Center Type 1

- **Center type**
  - open center (under lapped)
    - land의 폭 < valve sleeve의 port size
  - critical center (zero lapped)
    - land의 폭 = valve sleeve의 port size
  - closed center (over lapped)
    - land의 폭 > valve sleeve의 port size

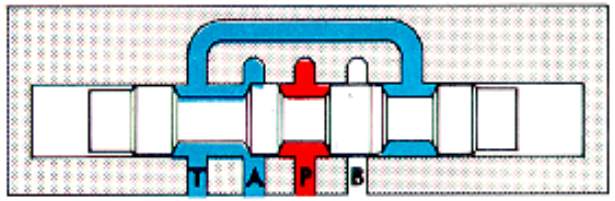


TYPE "0"



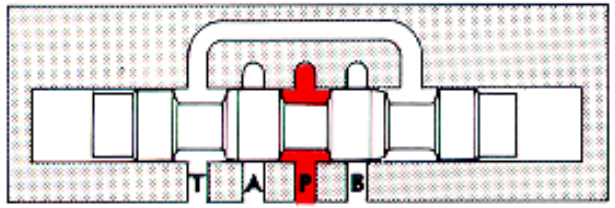
OPEN CENTER

TYPE "3"



PRESSURE AND "B" CLOSED-"A" OPEN TO TANK

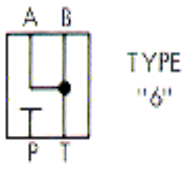
TYPE "2"

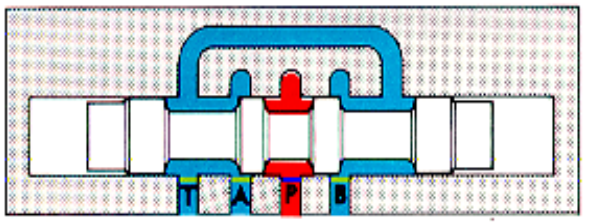


CLOSED CENTER-ALL PORTS CLOSED

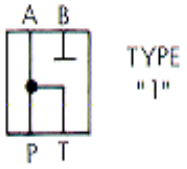
Types of Spool Valves: Center Type 2

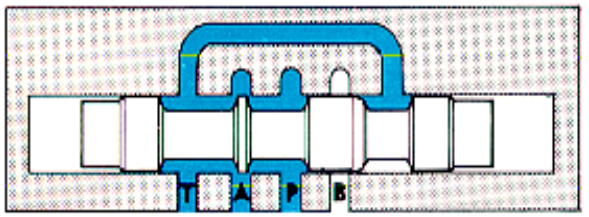
- **Center type**
  - open center (under lappe
  - tandem type



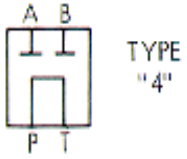


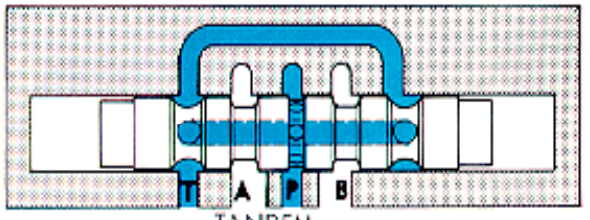
PRESSURE CLOSED-"A" & "B" OPEN TO TANK





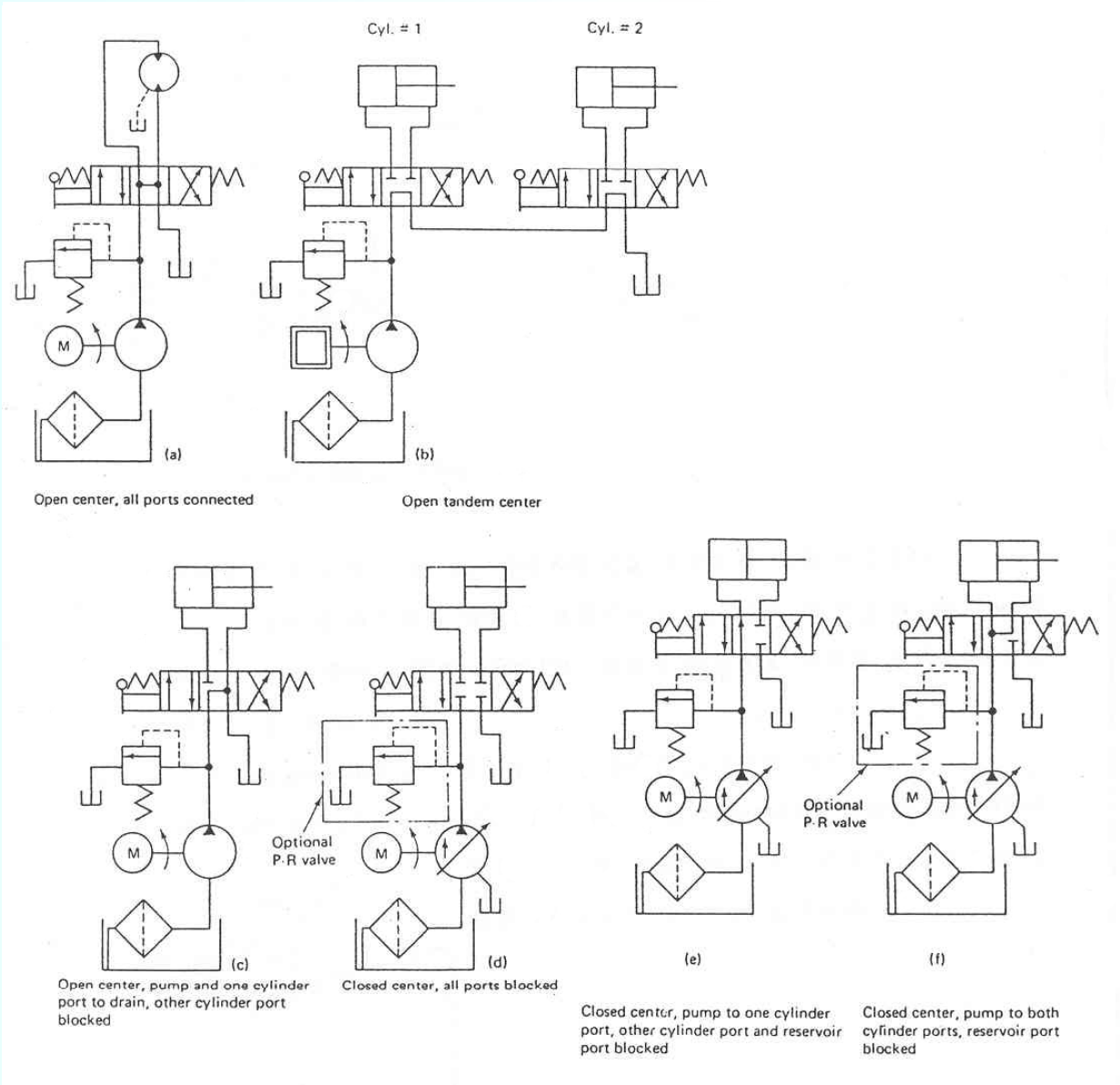
"B" CLOSED-PRESSURE OPEN TO TANK THRU "A"





TANDEM

Open and Closed Center Valve Circuit



Center Type에 따른 Flow Gain

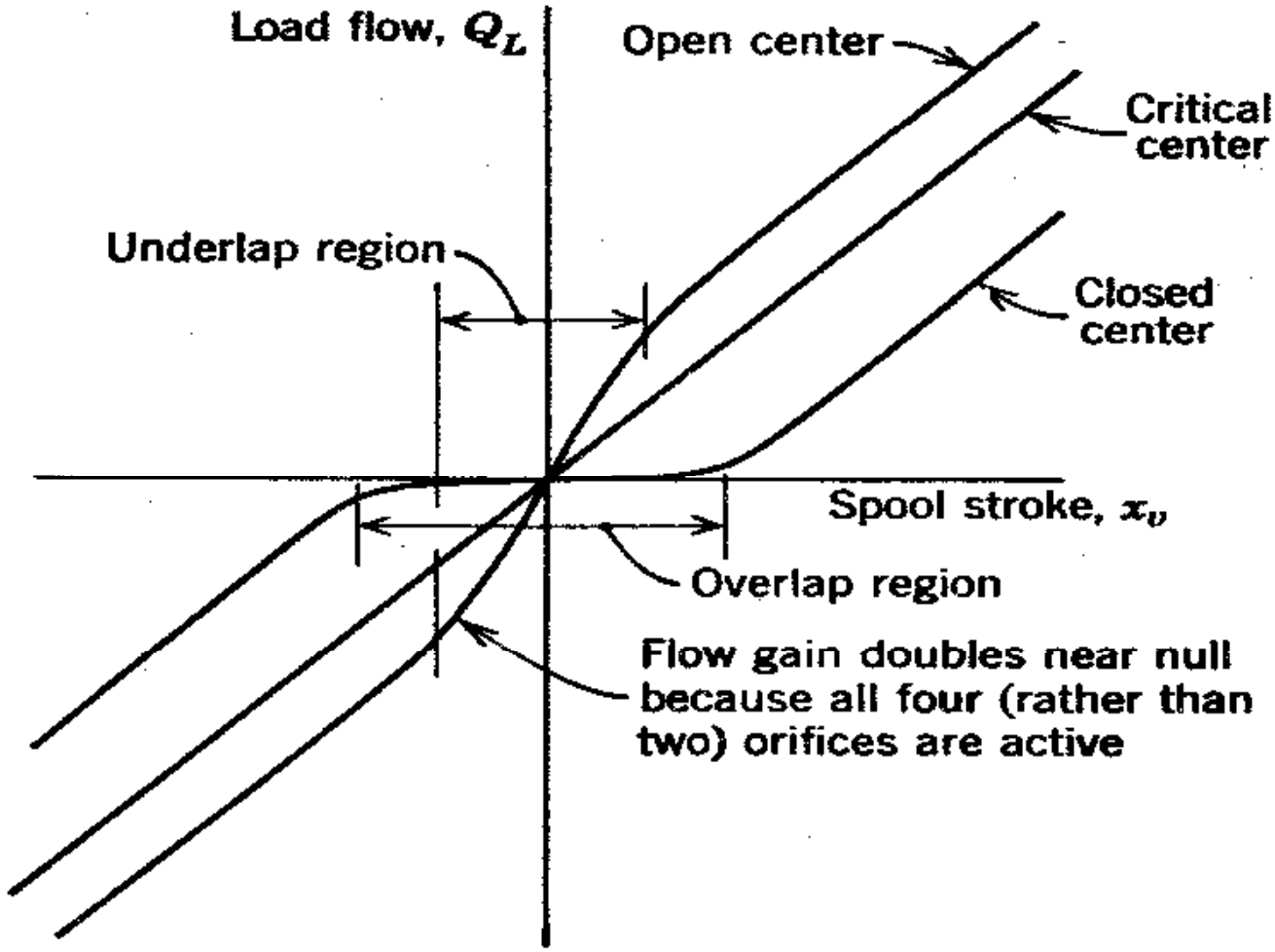


Figure 5-2 Flow gain of different center types.

Spool Valve의 Center Type에 따른 특성

- **Open center valve**는 적절한 유체 온도 유지를 위하여 유체의 지속적인 순환이 요구되거나, **Constant flow system**에 사용

- 대부분의 **Four-way valve**는 **Linear flow gain**특성을 얻기 위하여 **Critical center** 형태로 제조됨

- **Closed center valve**는 **Flow gain**에서 **Deadband** 특성을 보임. **Deadband**는 **Steady-state error**와 **Backlash**의 원인이 될 수 있음

Pressure-Flow Curve

- **Critical center four-way spool valve**

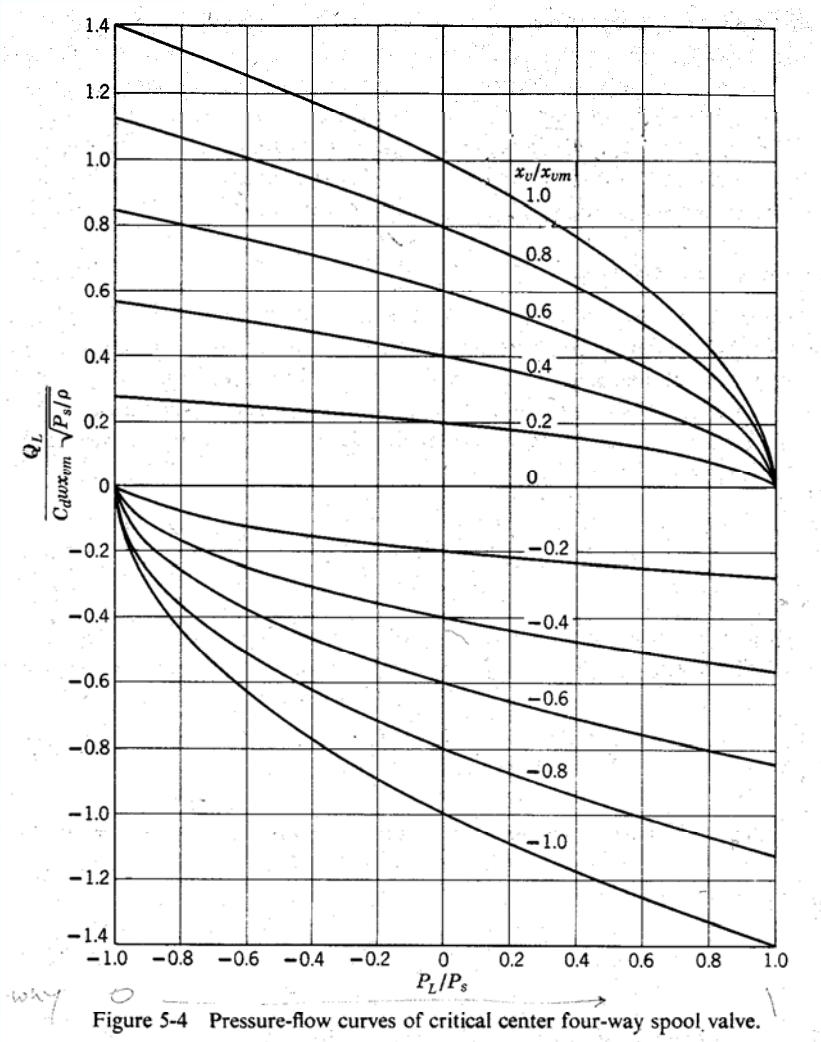
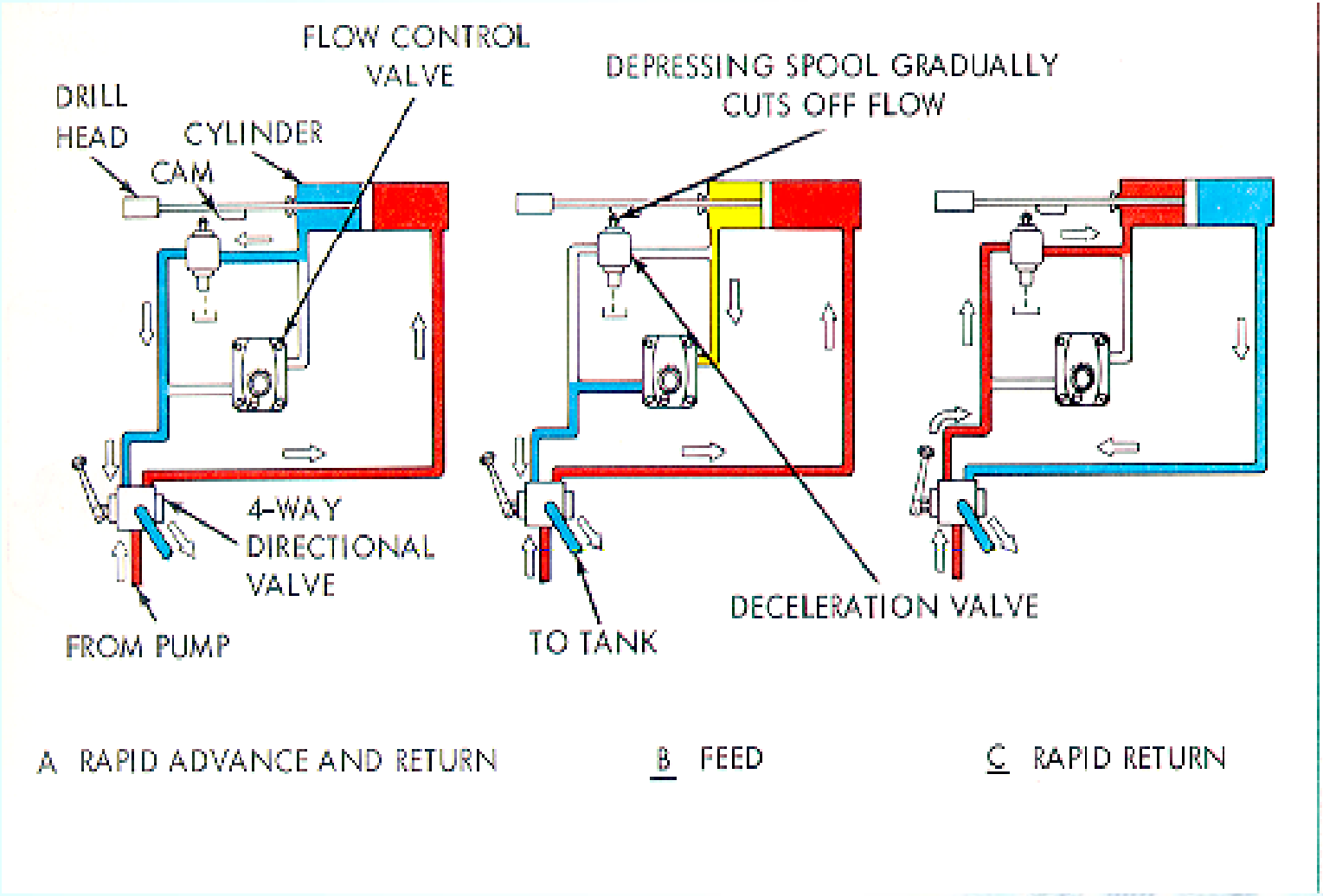
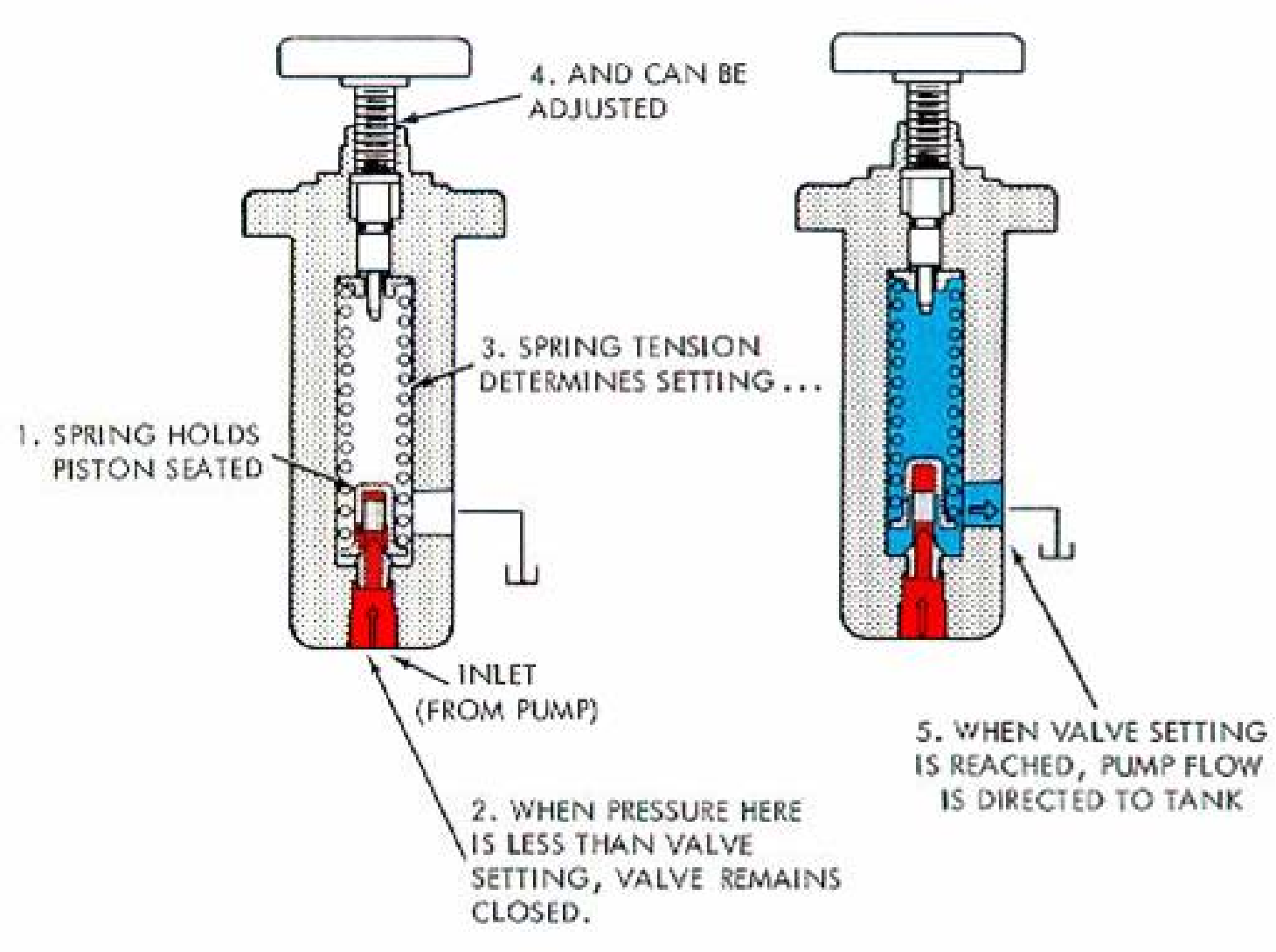


Figure 5-4 Pressure-flow curves of critical center four-way spool valve.

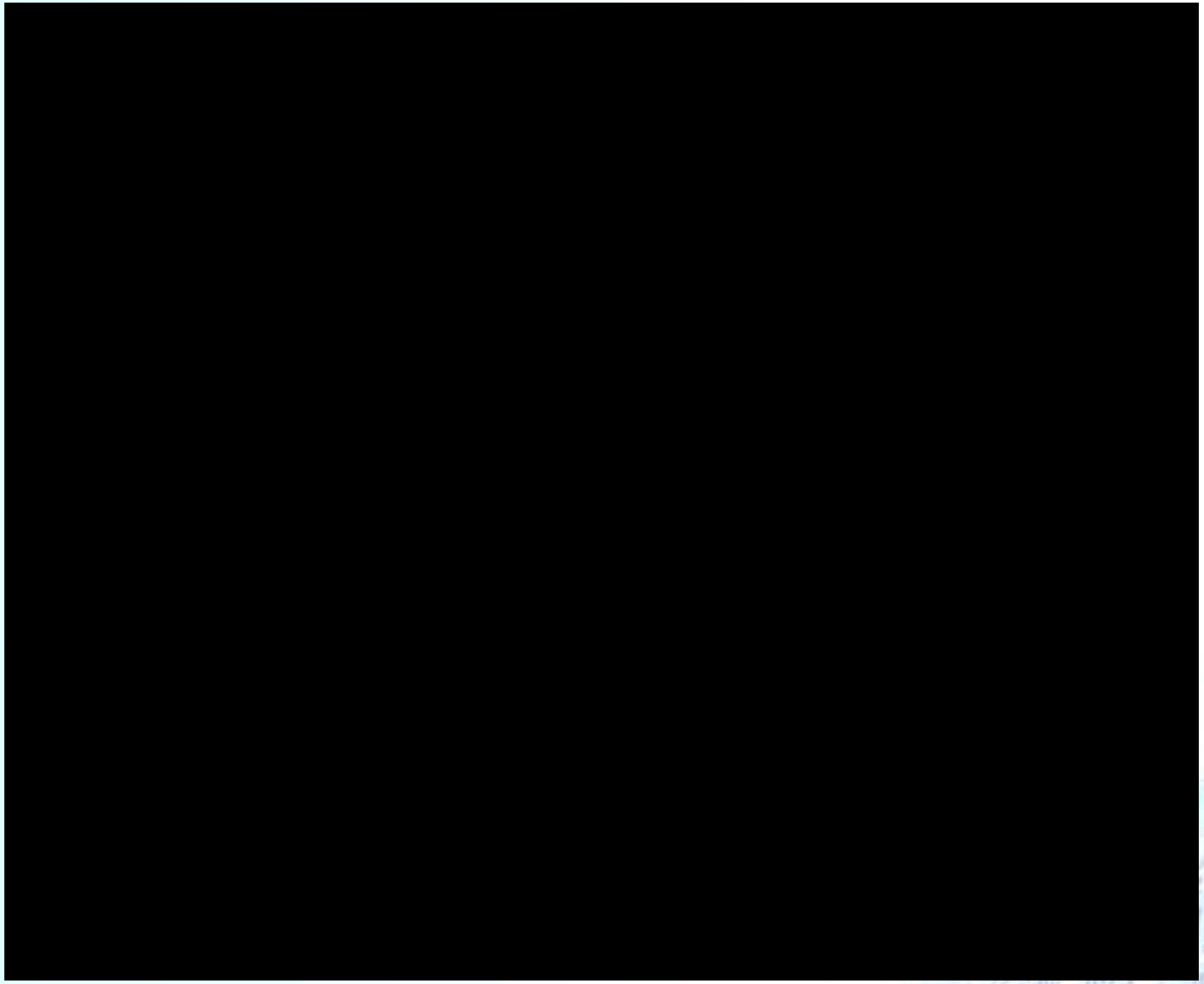
Applications of Directional Control Valve



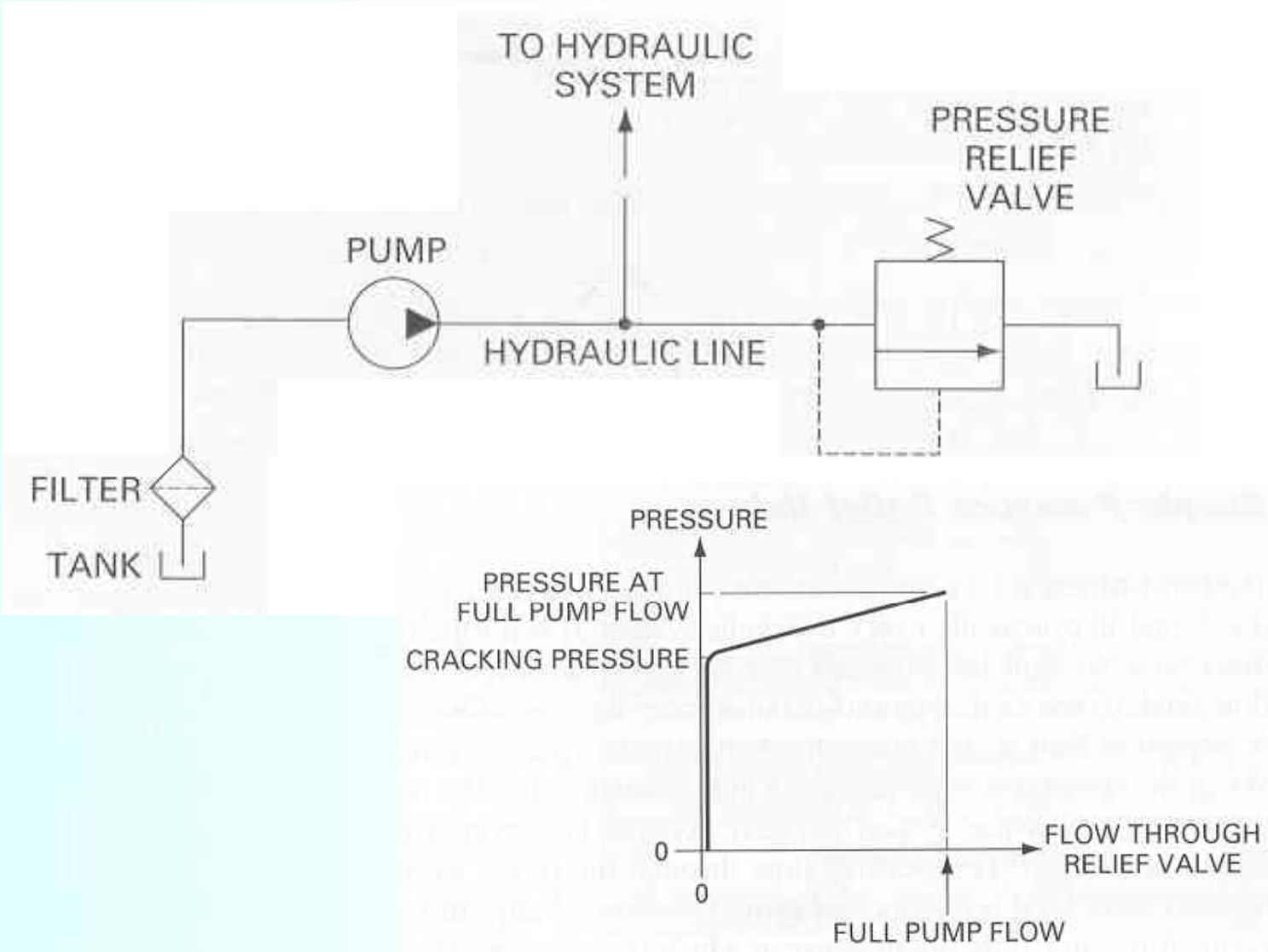
8.3 Pressure Control Valves: Relief Valve



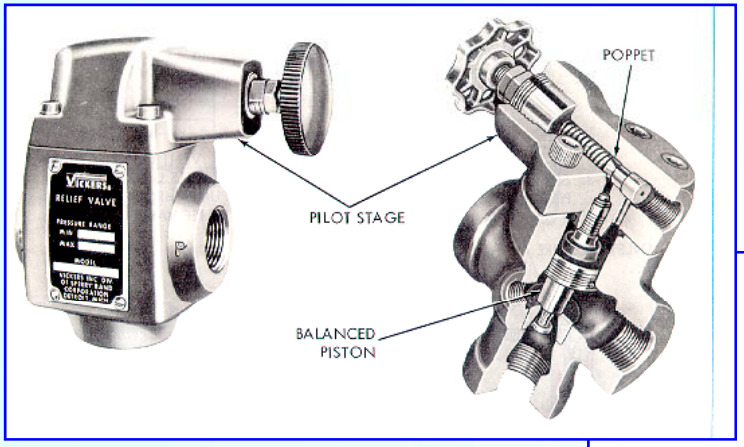
압력 제어 밸브

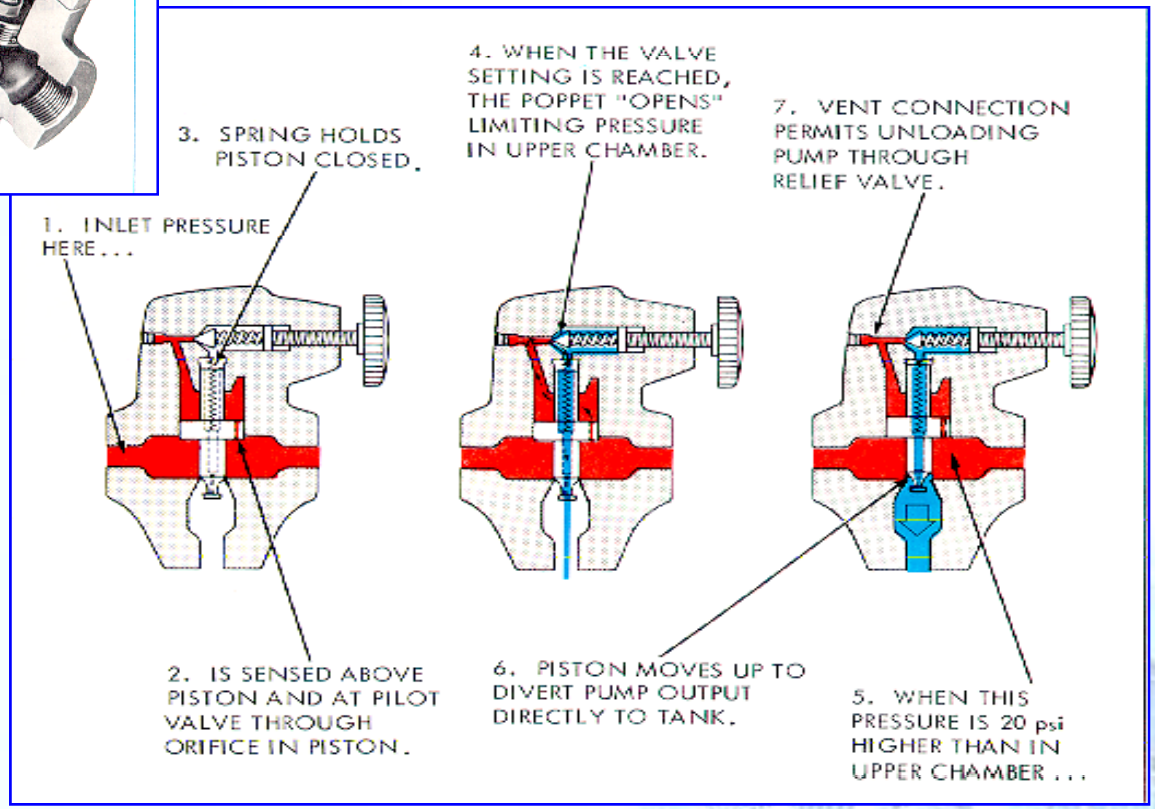


Pressure vs. Flow Curve for Simple Relief Valve

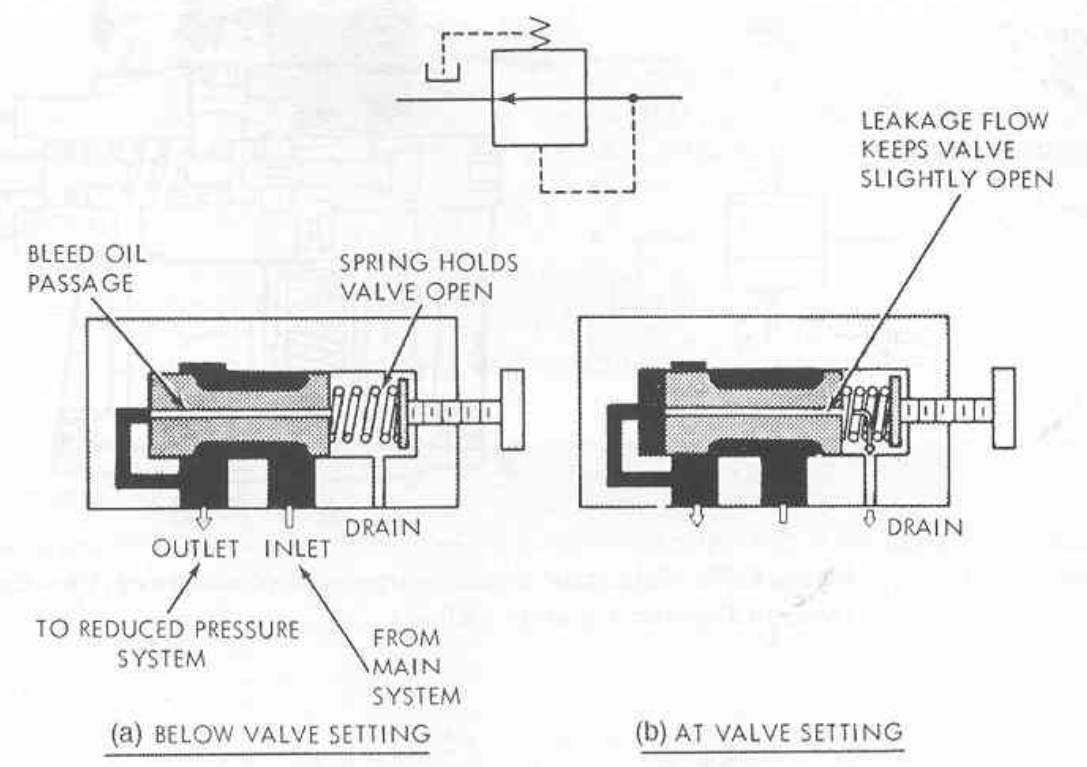


Compound Pressure Relief Valve



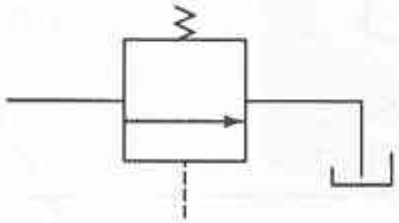


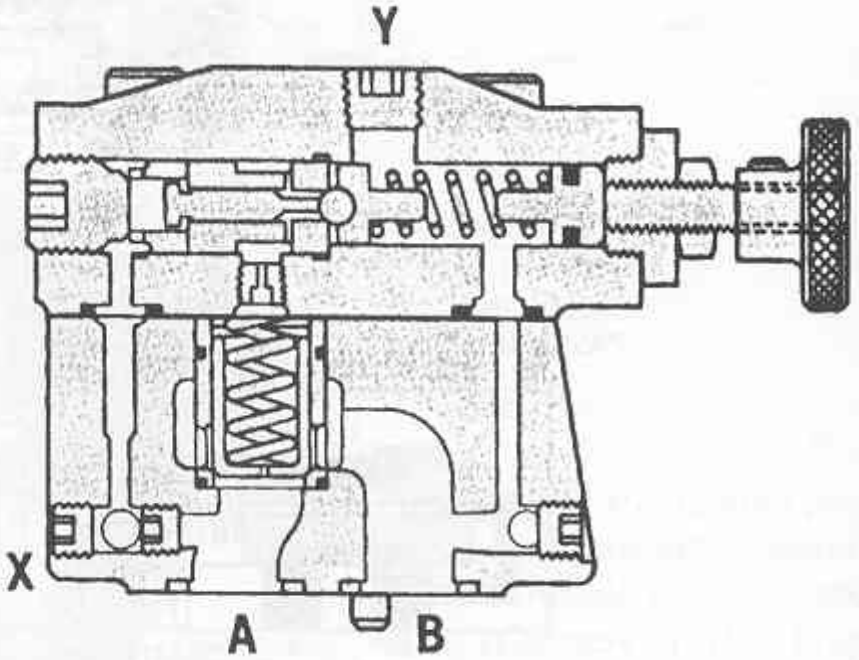
Pressure Reducing Valve



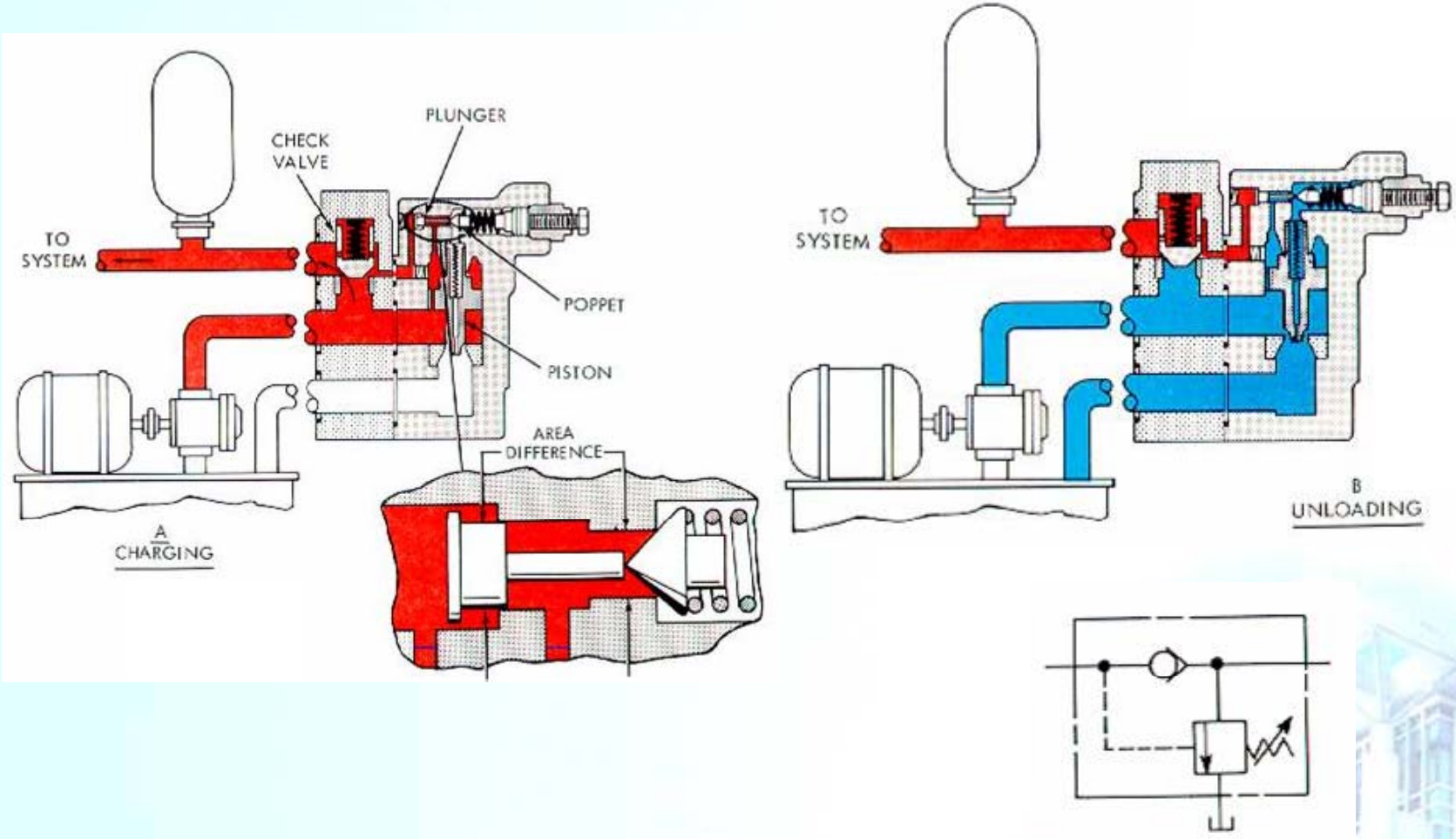
- **Relief Valve**와 차이점
  - 보통은 열려있는 상태이다.
  - 출력측 압력이 **sensing**된다.
  - 출력측 압력을 낮추는 경우에 사용된다.

Unloading Valves

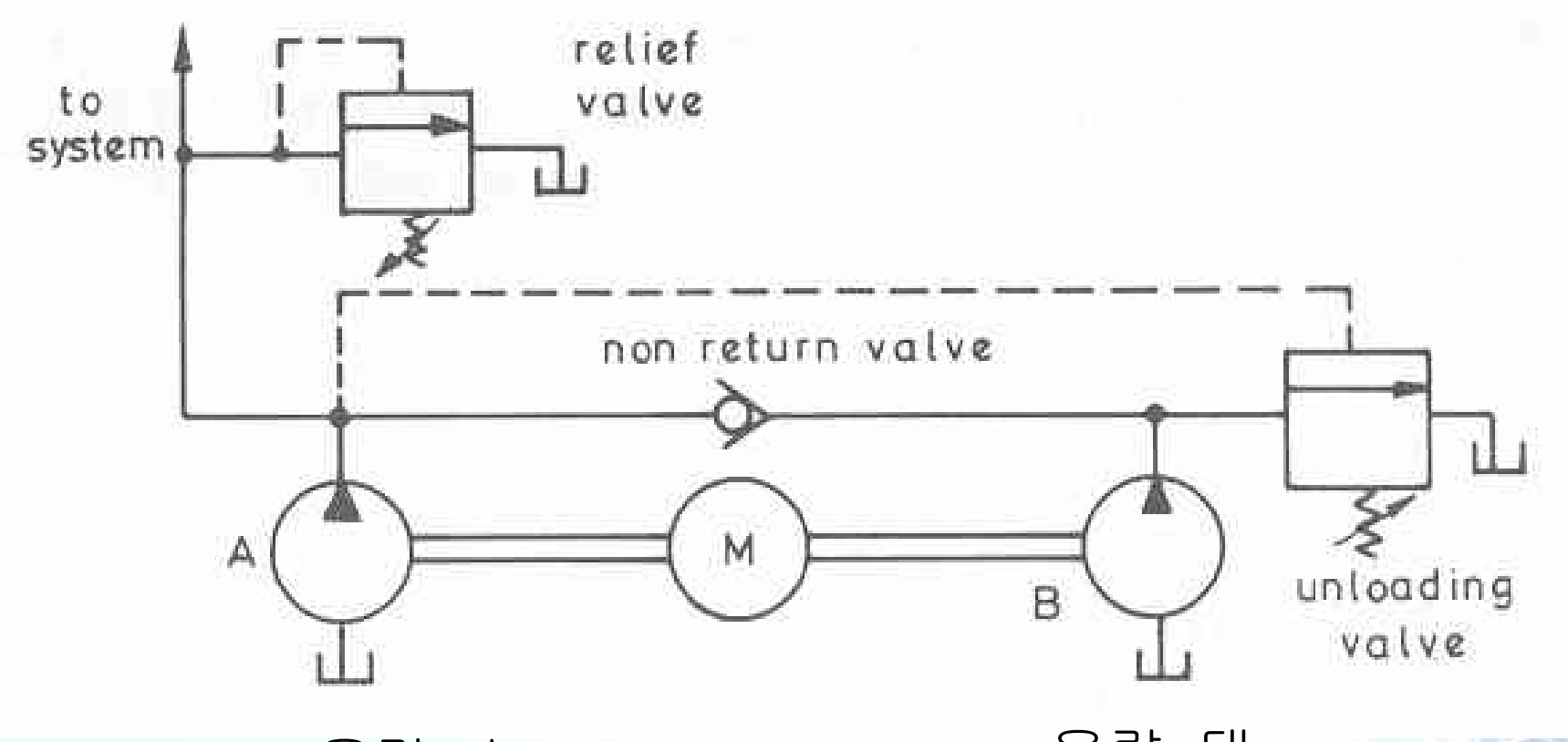




Operation of Unloading Relief Valve



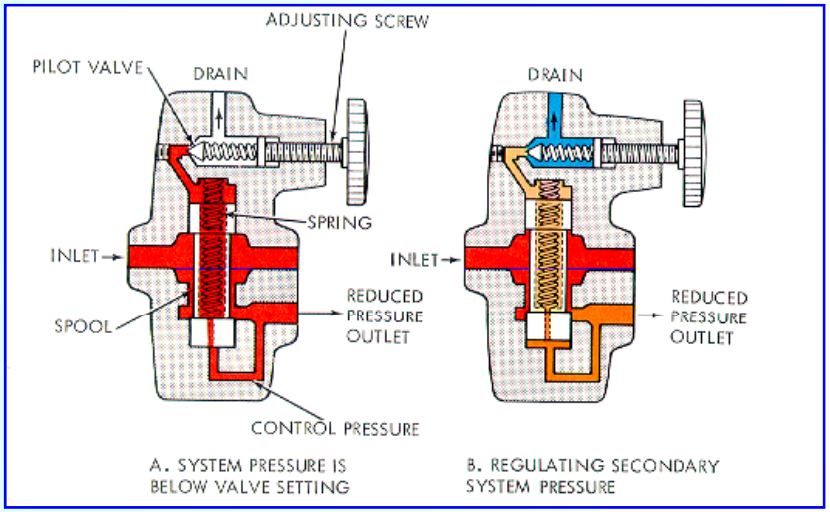
Unloading Valve in a Dual Pump System

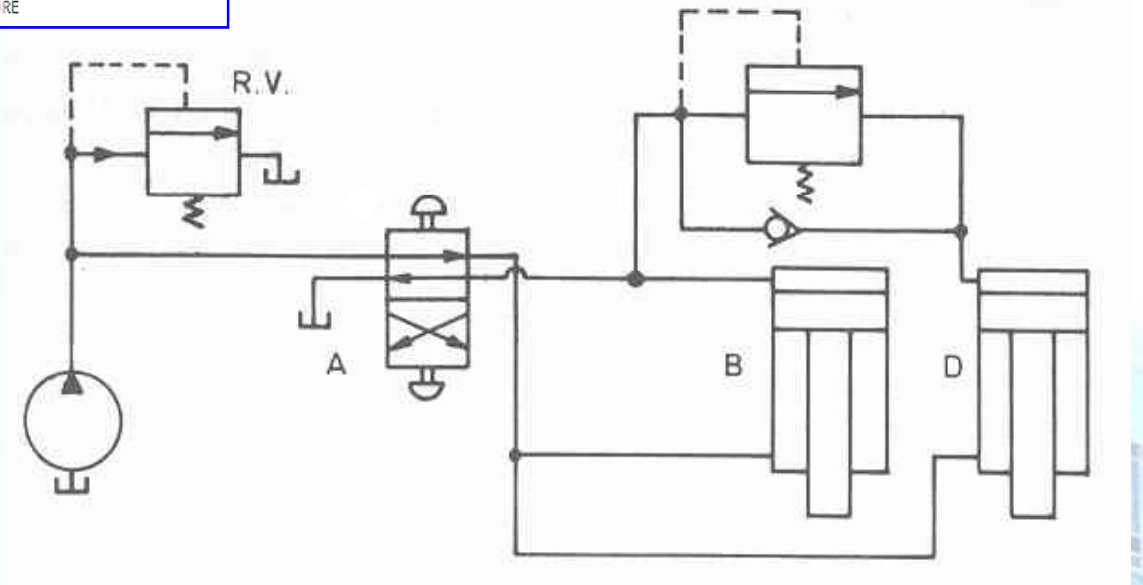


용량: 소
압력: 고

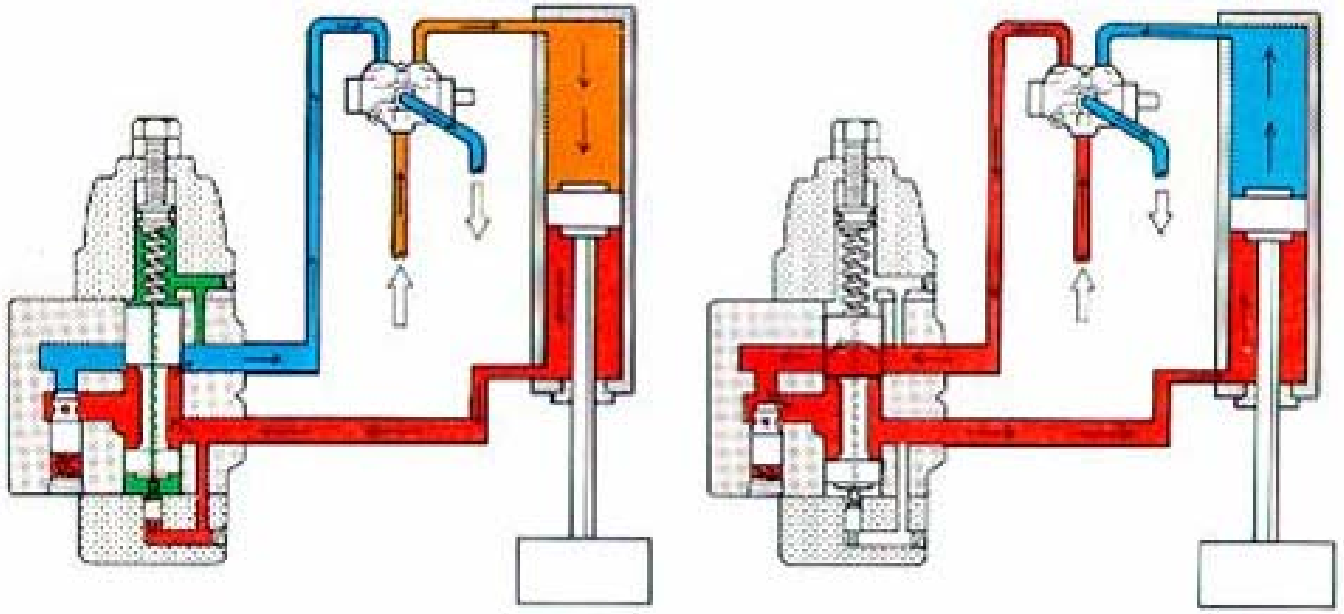
용량: 대
압력: 저

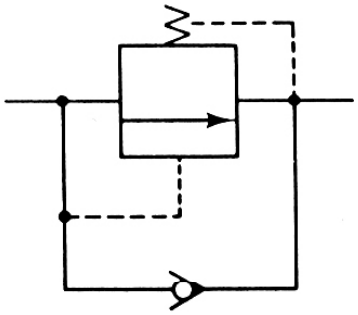
Sequence Valve





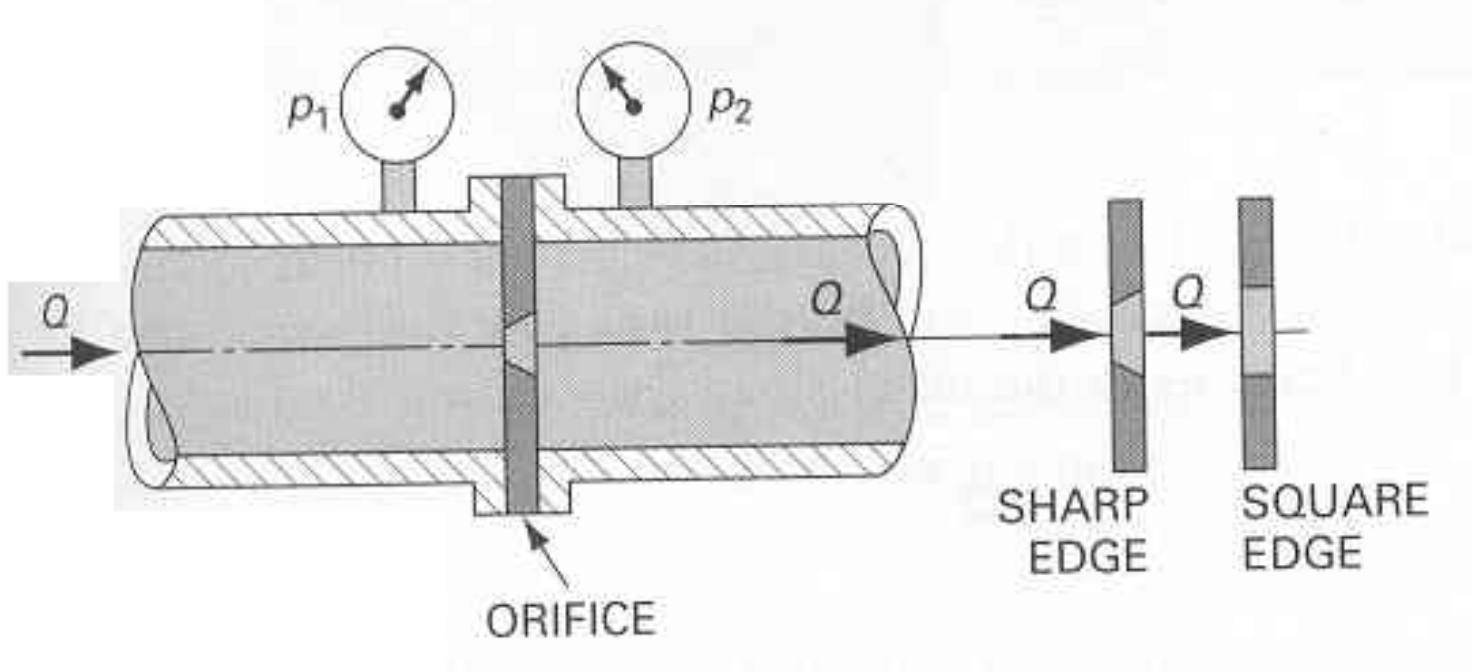
Counterbalance Valves





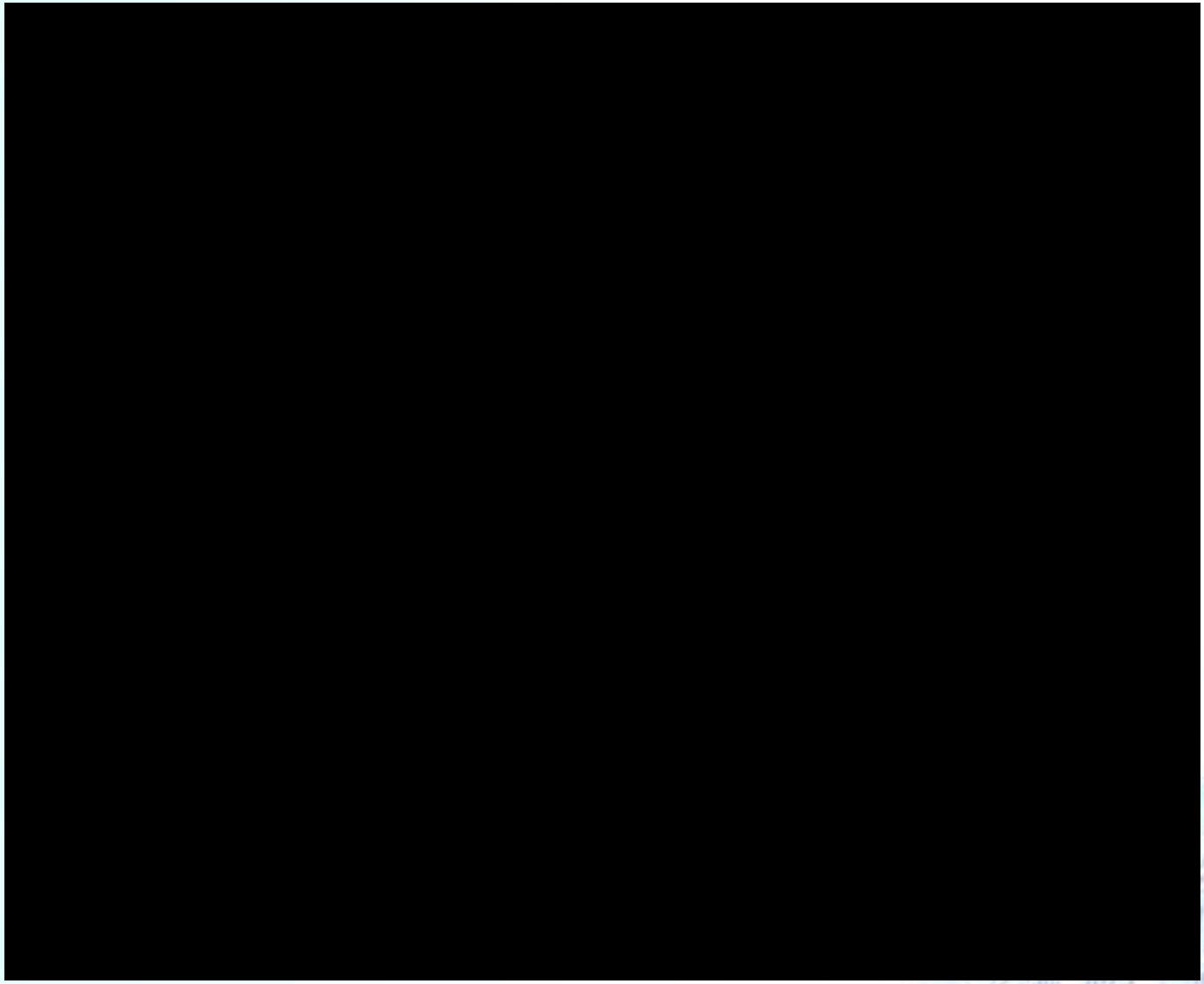
8.4 Flow Control Valves

Orifice flowmeter

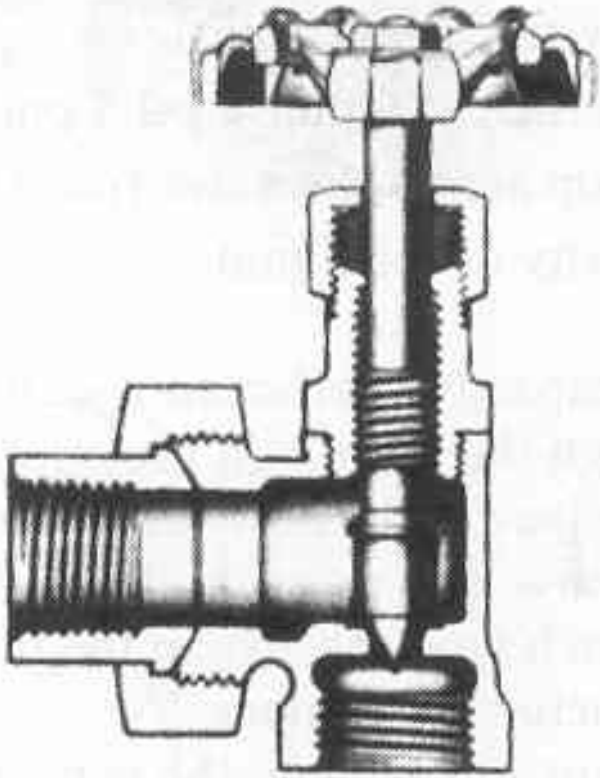


$$Q = C_d A \sqrt{\frac{2\Delta p}{\rho}} = 0.0851 C_d A \sqrt{\frac{\Delta p}{SG}}$$

유량 제어 밸브

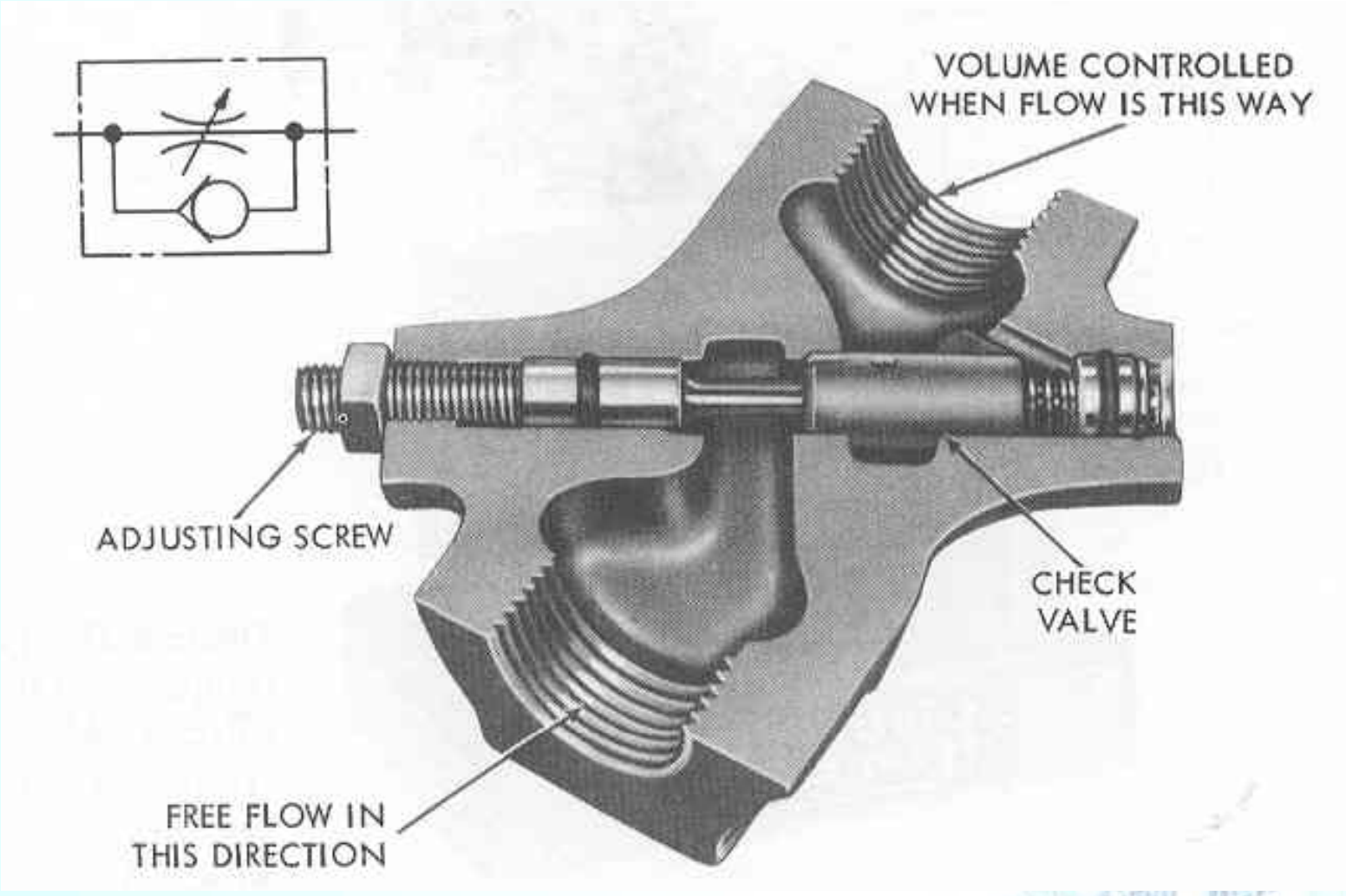


Needle Valve



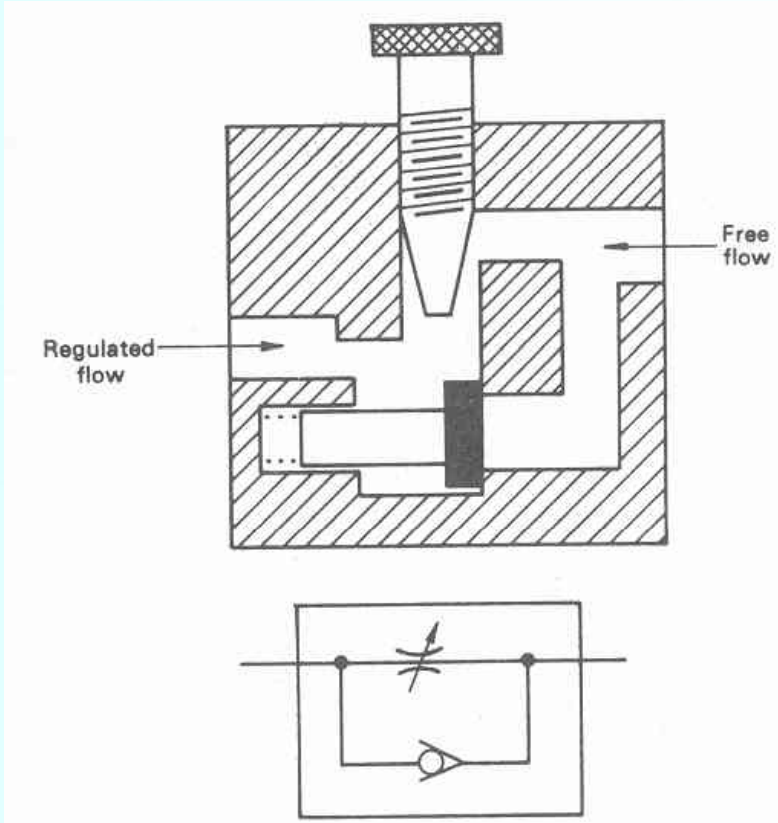
$$Q = C_d A \sqrt{\frac{2\Delta p}{\rho}} = C_v \sqrt{\frac{\Delta p}{SG}}$$

Non-pressure-compensated Flow Control Valve

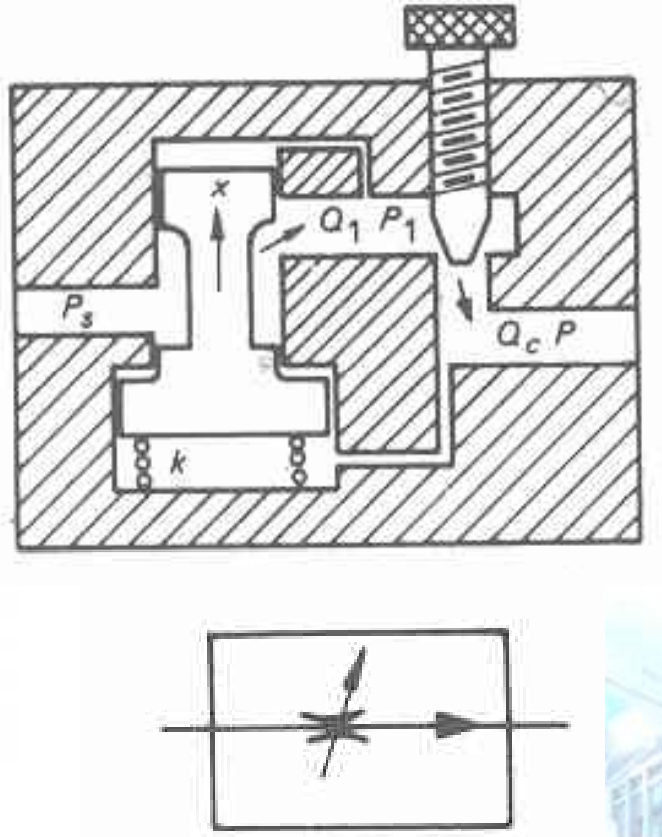


Flow Control Valves

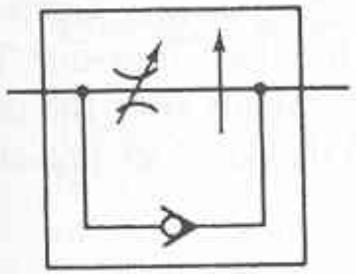
Non-pressure-compensated

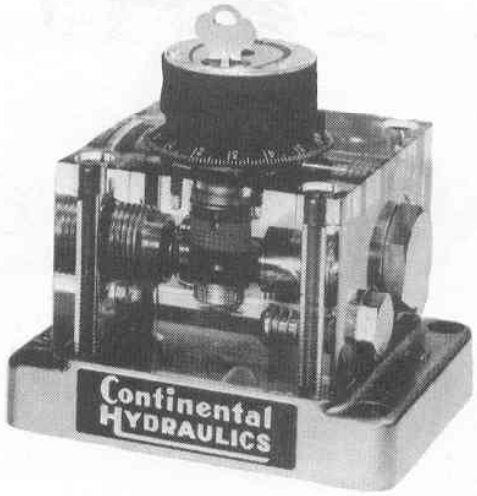


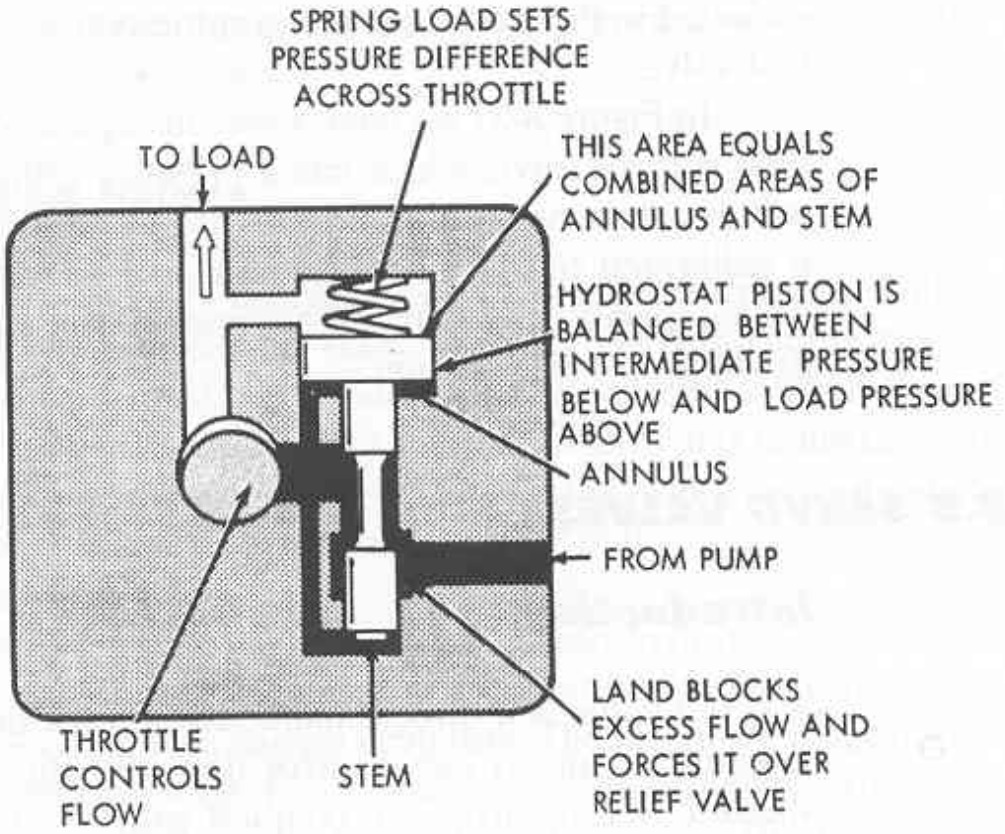
Pressure-compensated



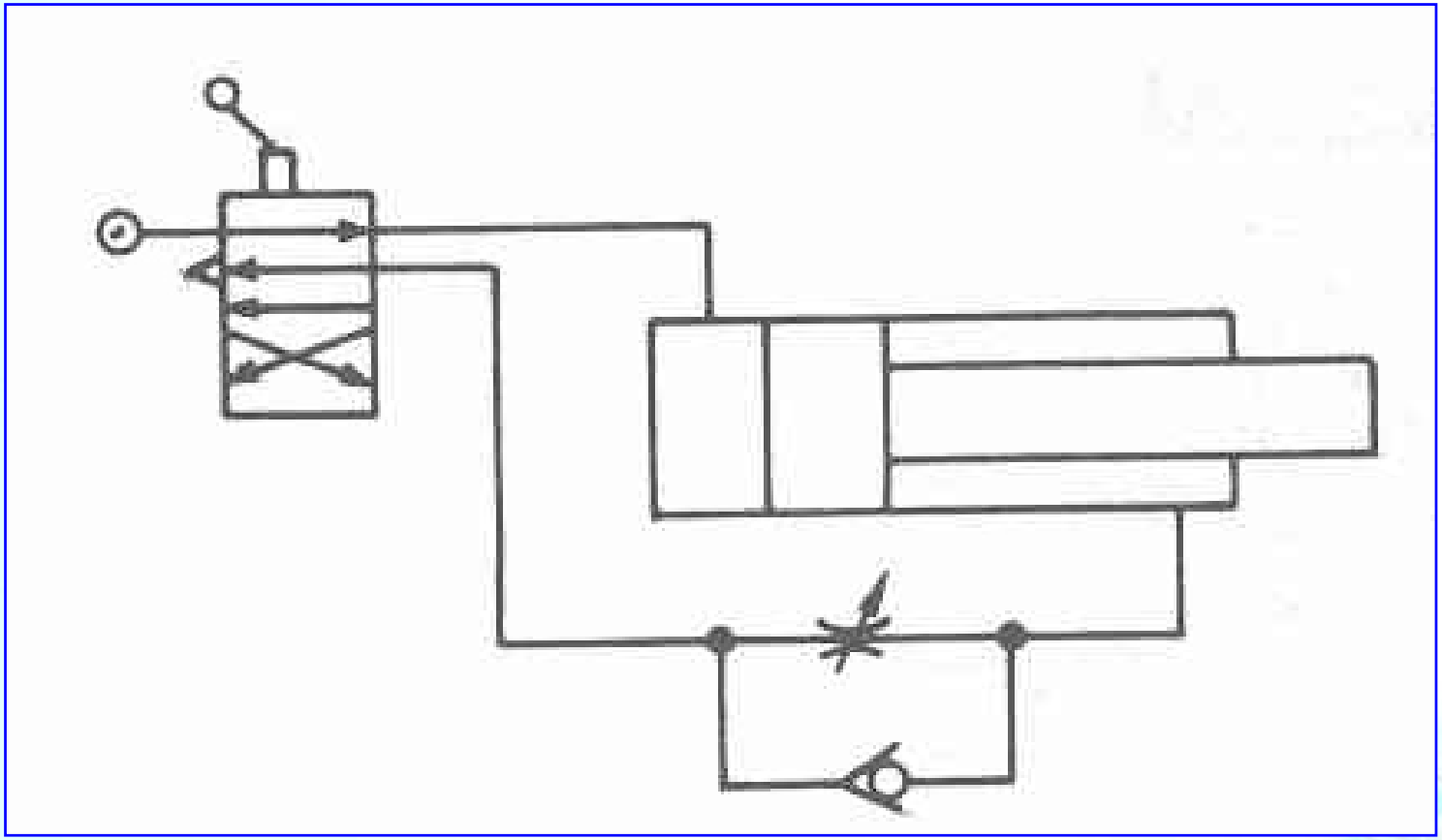
Pressure-compensated Flow Control Valve







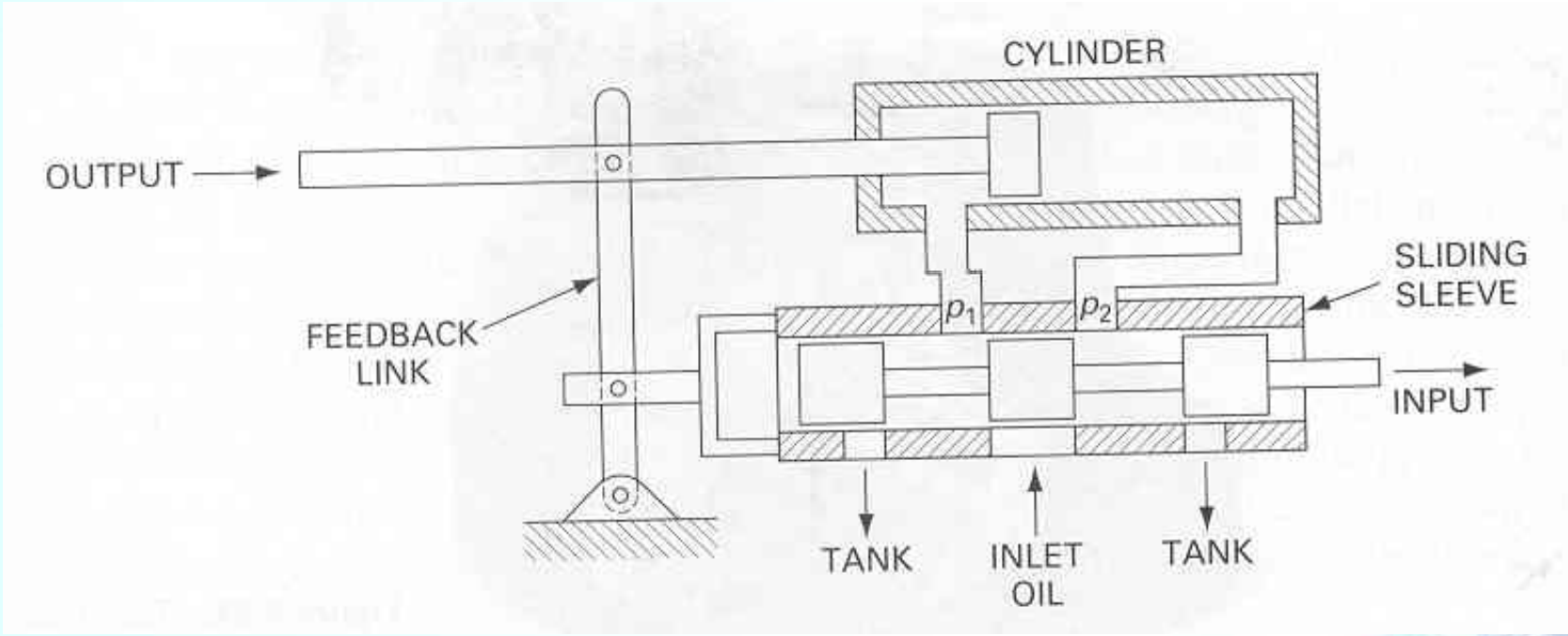
Application of Flow Control Valve



Meter-out 속도제어 회로

8.5 Servo Valves

Mechanical-type servo valves



Electrohydraulic Servo Valves

Single-stage servo valves

- spool valve에 직접 연결되어 spool valve를 이동시키는 torque motor로 구성
- torque motor가 동력이 제한되므로 유량 용량(flow capacity)에 한계 있고 application에 따라 안정성 문제도 유발

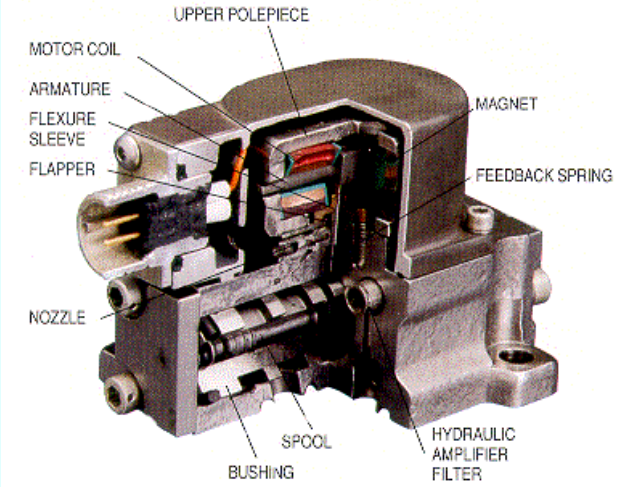
Two-stage servo valves

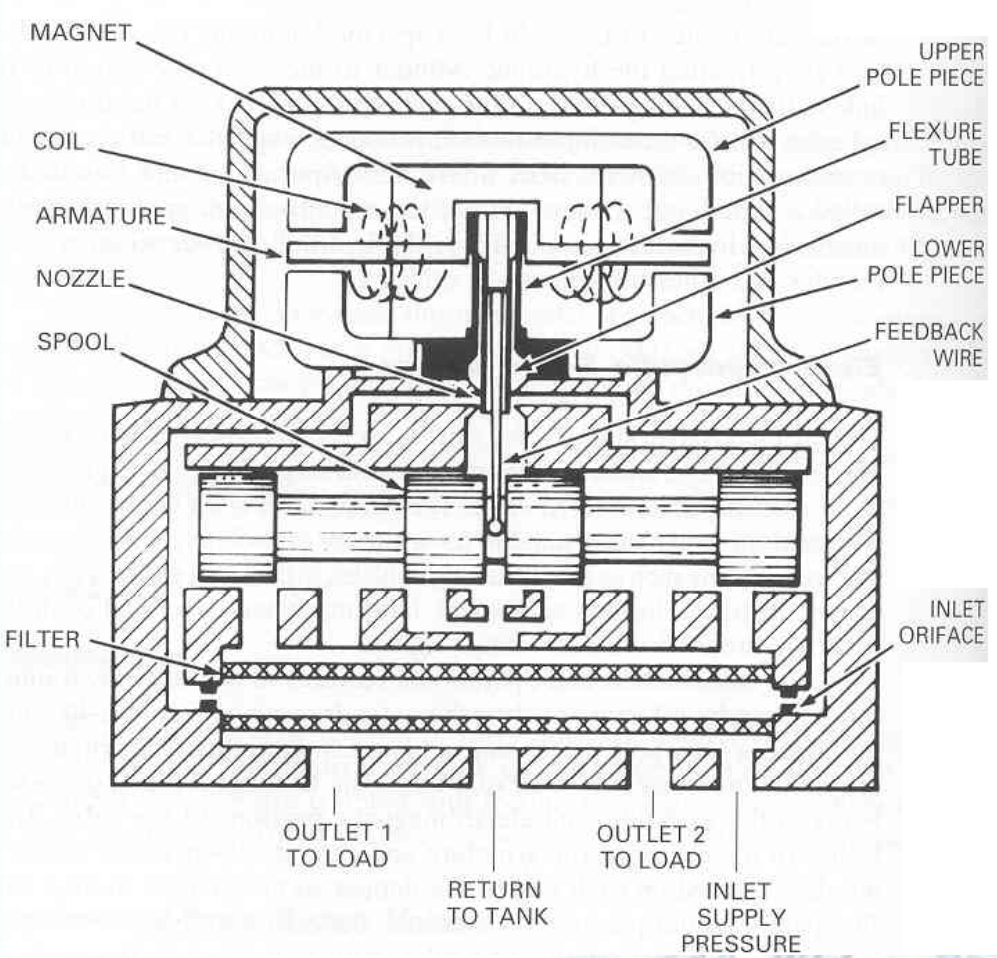
- hydraulic preamplifier(first stage) 가 torque motor force output을 상당히 증폭시켜, flow force, stiction forces, 가속이나 진동에 의한 힘을 극복케 함
- first stage로는 Flapper, jet pipe, spool valves가 사용됨
- second stages valves로는 일반적으로 spool type이 사용됨

Servo Valve Structure

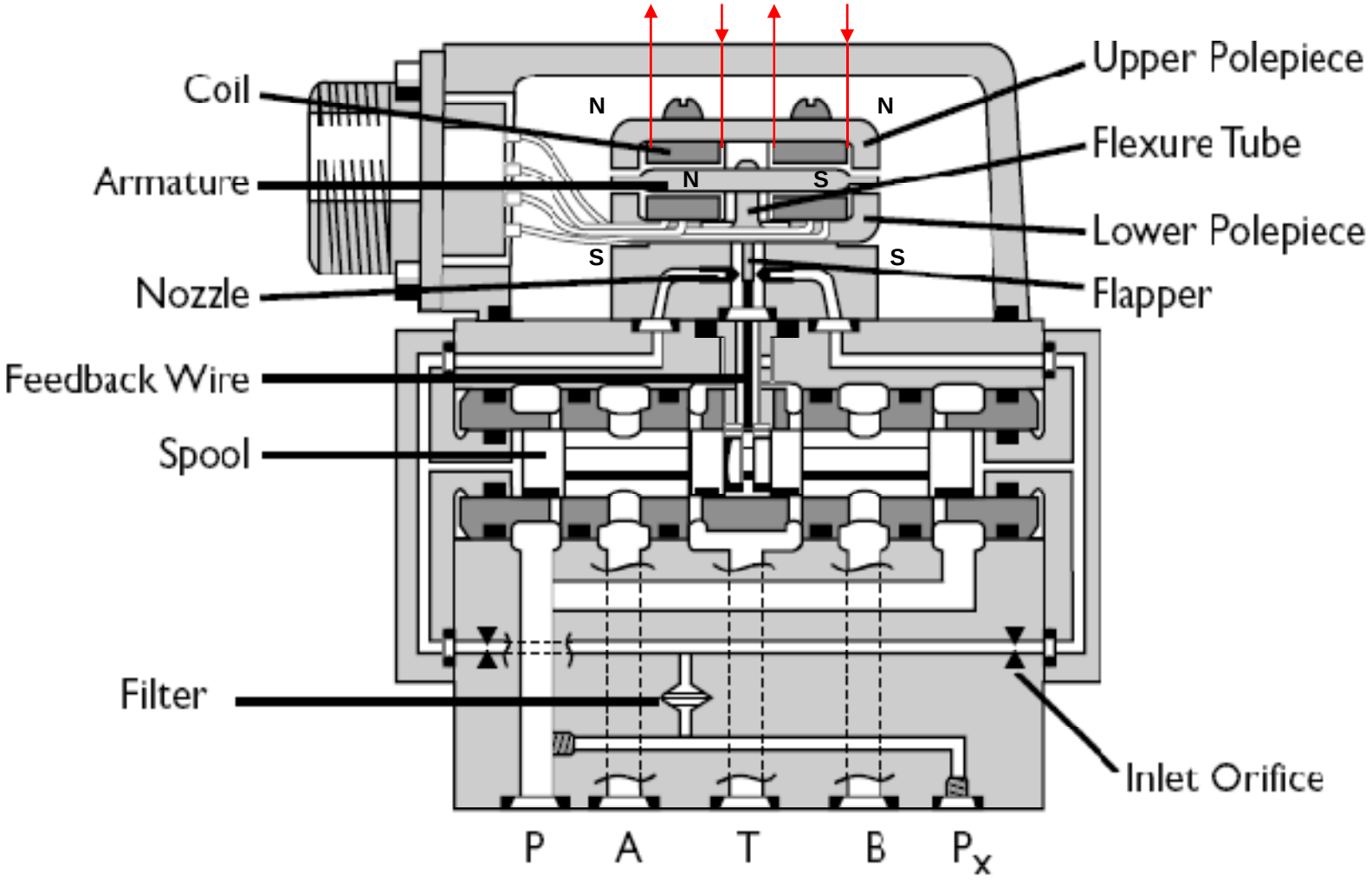
❖Moog 760 Series

❖Moog 30 Series



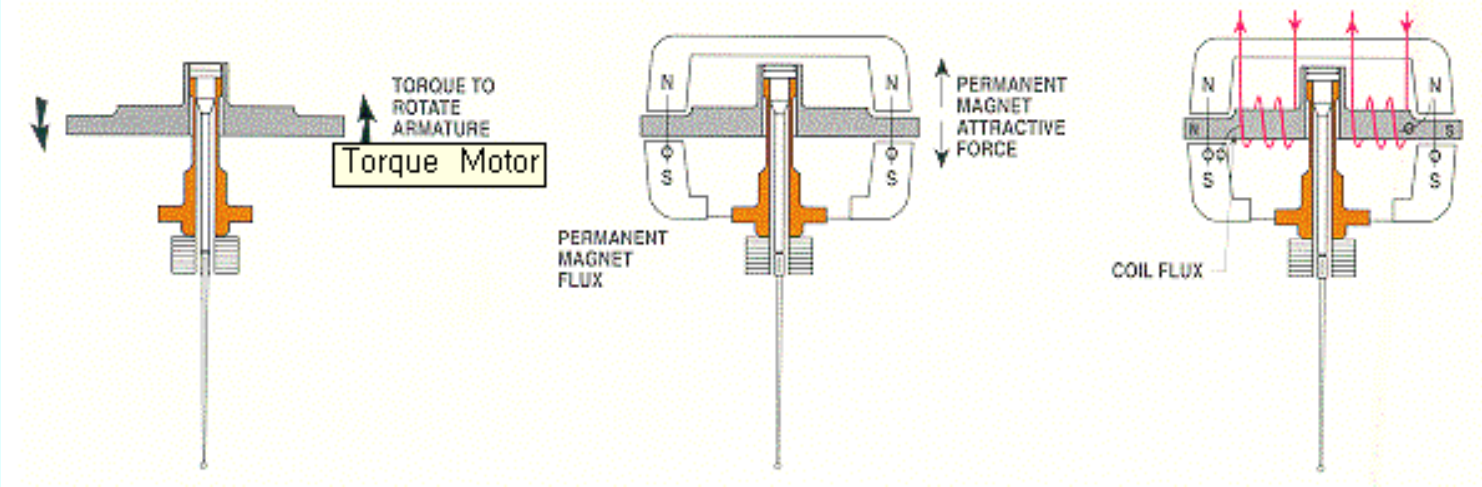


Operation of Servo Valve

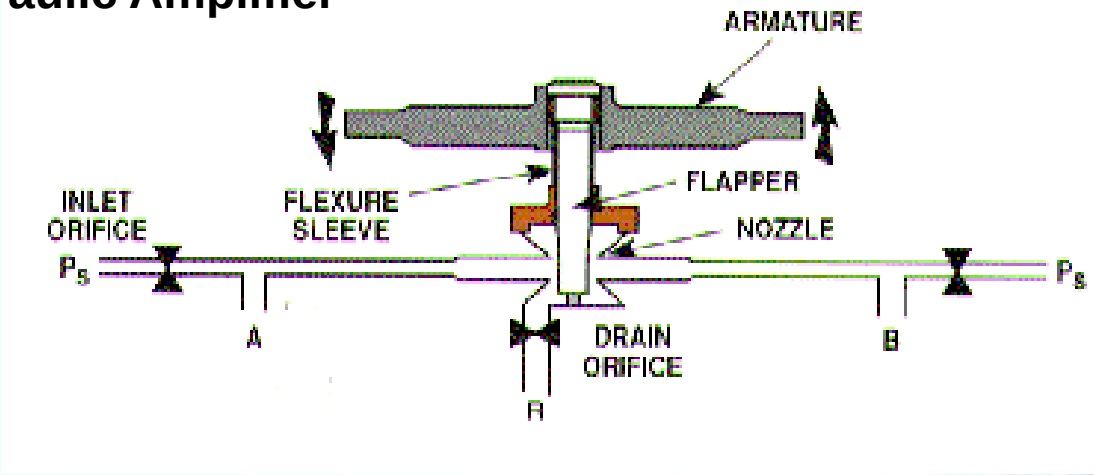


Operation of Servo Valve: Torque Motor

❖Torque Motor

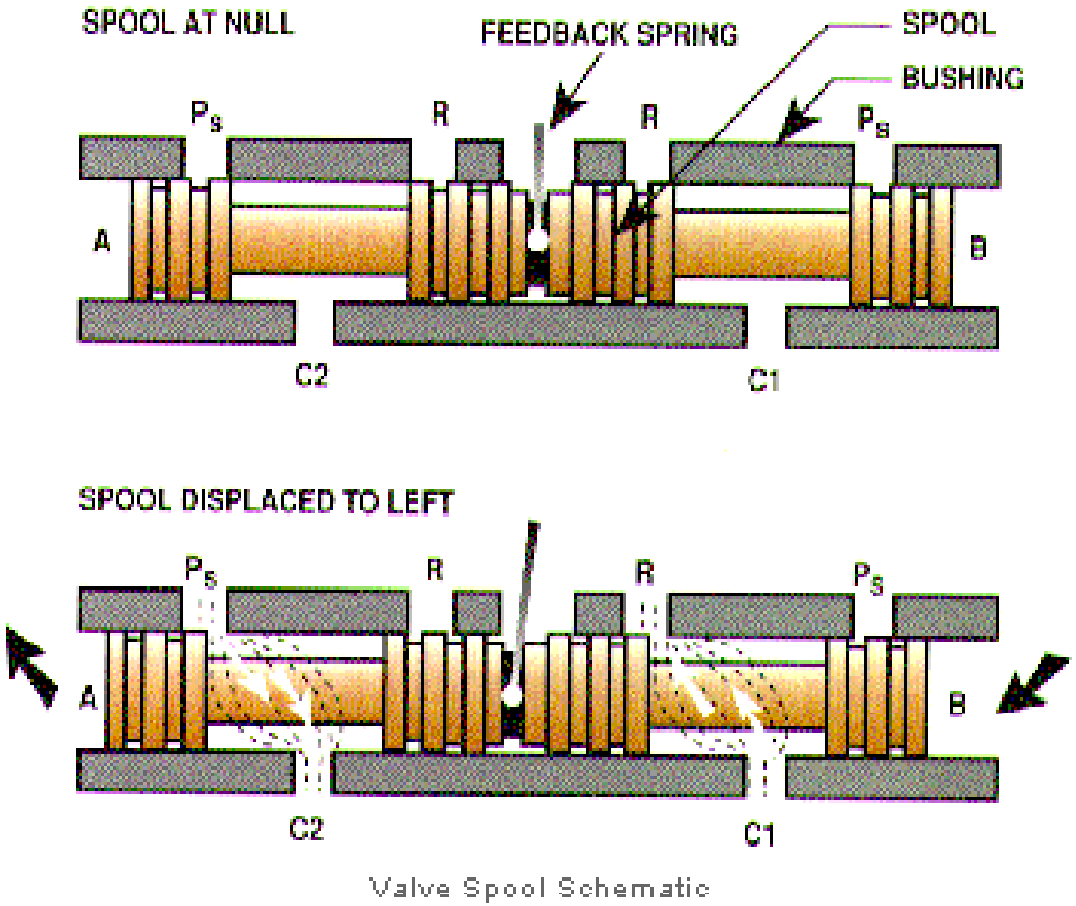


❖Hydraulic Amplifier



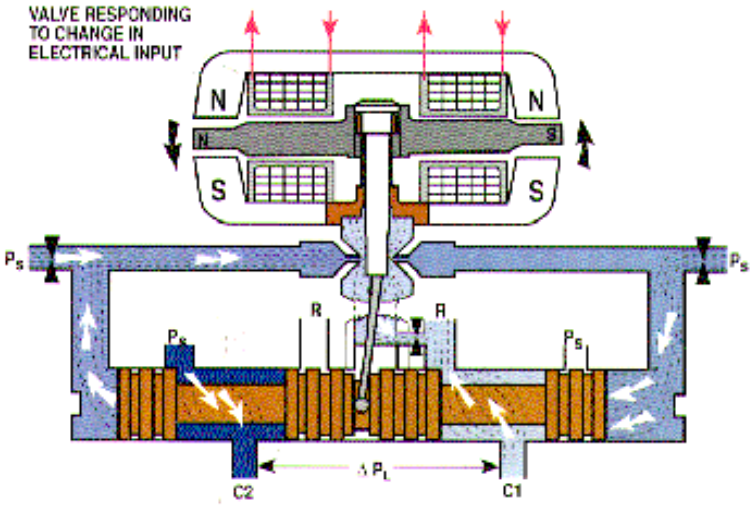
Operation of Servo Valve: Valve Spool

❖Valve Spool

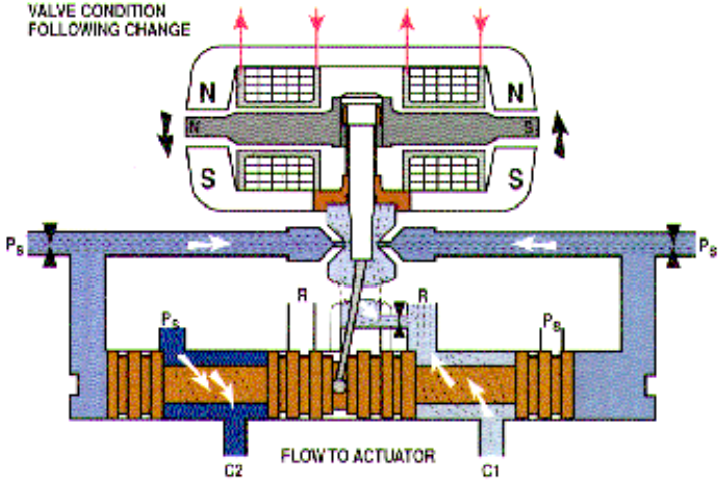


Valve Spool Schematic

Operation of Servo Valve



Valve Spool Schematic



Valve Spool Schematic

- Electrical current in torque motor coils creates magnetic forces on ends of armature
- Armature and flapper assembly rotates about flexure sleeve support
- Flapper closes off one nozzle and diverts flow to that end of spool
- Spool moves and opens Ps to one control port; opens other control port to R
- Spool pushes ball end of feedback spring creating restoring torque on armature/flapper
- As feedback torque becomes equal to torque from magnetic forces, armature/flapper moves back to centered position
- Spool stops at a position where feedback spring torque equals torque due to input current
- Therefore spool position is proportional to input current
- With constant pressures, flow to load is proportional to spool position

Feedback Types of Servo Valves 1

- **Position feedback two-stage servo-valves**
  - 가장 일반적 type, 스풀 위치 감지방법에 따라 3가지 기본 형태
  - Direct position feedback :
    - main spool이 1대1 관계로 first stage valve를 추종(hydraulic follower라 불림)
    - 흔히 사용됨
  - Force feedback
    - main spool position이 feedback spring에 의하여 힘(force)으로 변환됨
    - 이 힘이 torque motor armature에서 입력 전류에 의해 발생된 토크와 균형을 이룬다
  - Spring centered
    - pilot stage에서의 압력차에 의해 움직인 spool을 중립위치로 이동

Feedback Types of Servo Valves 2

- **Flow feedback two-stage servo-valves**
  - 유량(flow)을 측정하여 그것을 힘으로 바꾼 뒤, 이 힘으로 torque motor armature에서 입력 전류에 의한 힘과 균형을 이룸
  - 특수 application에 사용

- **Load pressure feedback two-stage servo-valve**
  - 부하압력(load pressure difference)제어
  - 내부 관로를 통하여, load pressure를 first stage로 보냄으로써, 결과적으로 입력전류에 의한 힘과 균형을 이루게 함

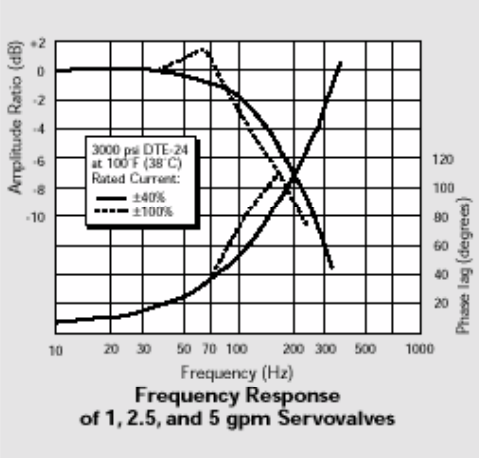
Feedback Types of Servo Valves 3

- **Dynamic pressure feedback servovalve: load pressure feedback servovalve**의 특수형
  - 저주파수에서는 position feedback 특성 소유
  - 고주파수에서는 pressure feedback 특성 소유
  - valve-actuator combination의 damping을 증가 시키기 위한 경우에 유용
- **Pressure-Flow Servo-valves**
  - Flow와 Pressure feedback의 조합이 사용됨
  - pressure-flow curves가 기존의 square-root curve와 비교하여 상당히 선형적
  - 특수 application에 사용

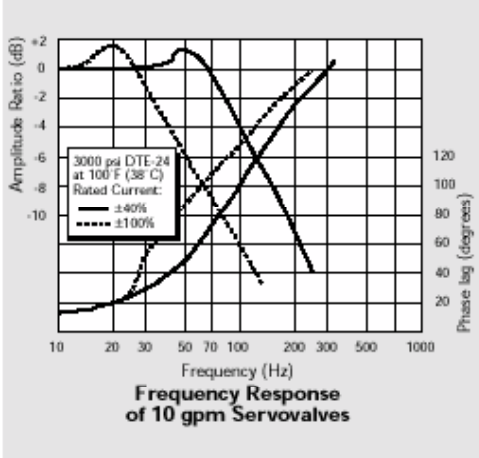
Technical Data: Moog 760 Series

❖Typical Characteristic Curves

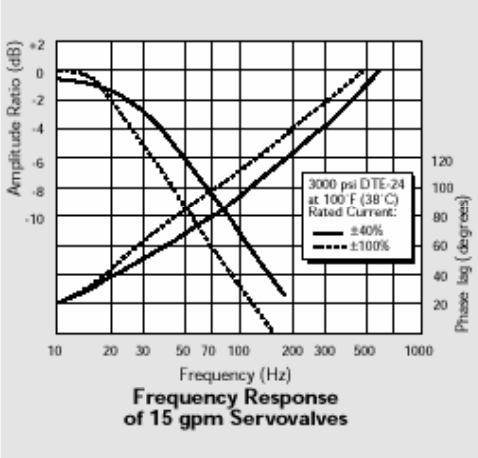
with ±40% and ±100% input signal, measured at 3,000 pilot or operating pressure.



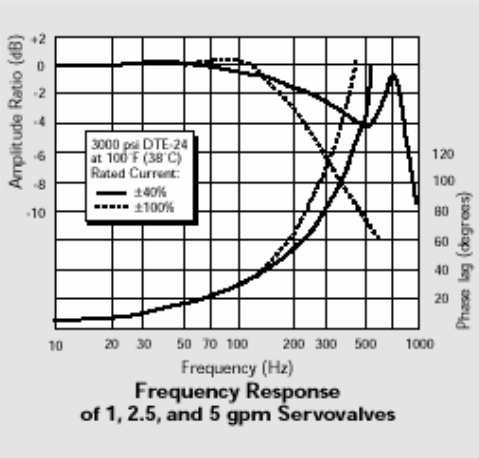
Frequency Response of 1, 2.5, and 5 gpm Servovalves



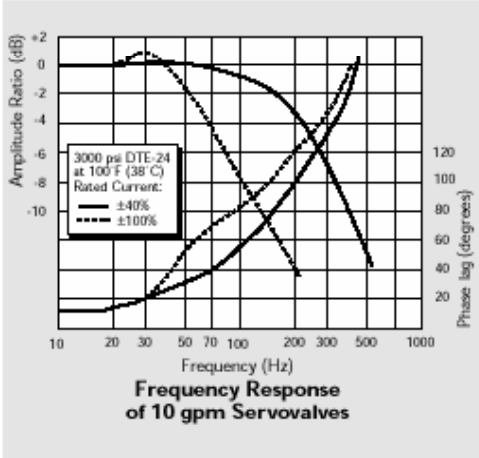
Frequency Response of 10 gpm Servovalves



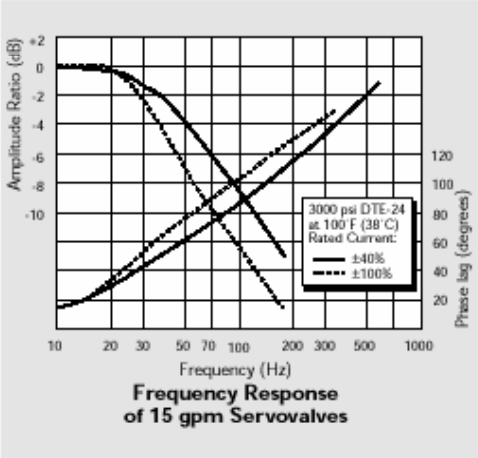
Frequency Response of 15 gpm Servovalves



Frequency Response of 1, 2.5, and 5 gpm Servovalves



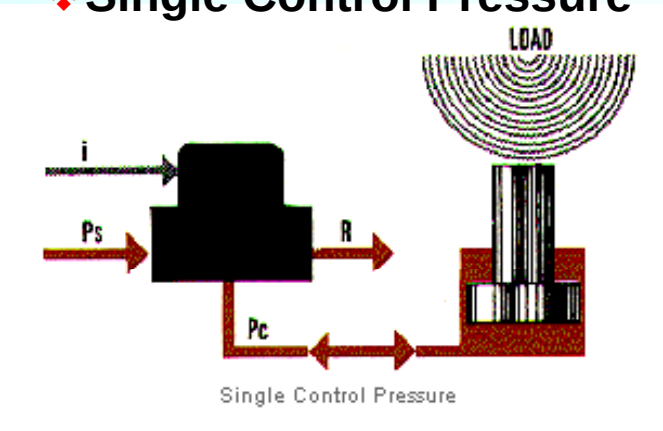
Frequency Response of 10 gpm Servovalves



Frequency Response of 15 gpm Servovalves

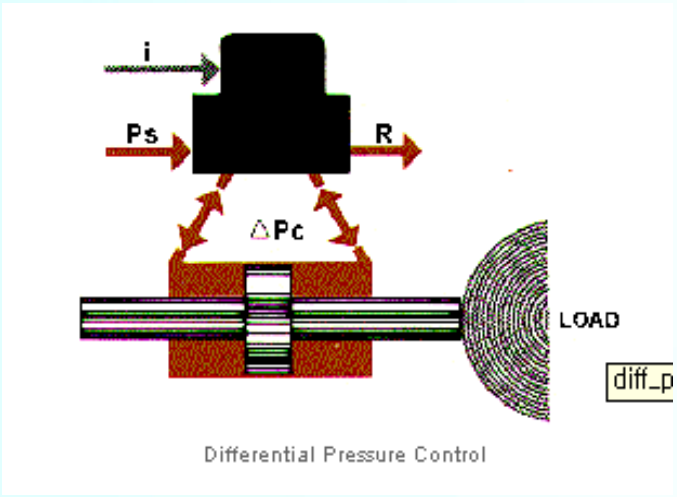
Applications of Servo Valve

❖Single Control Pressure



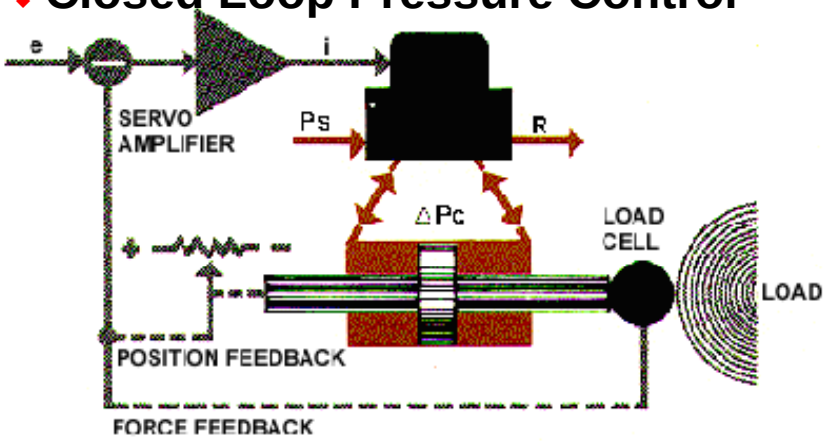
Single Control Pressure

❖Differential Pressure Control



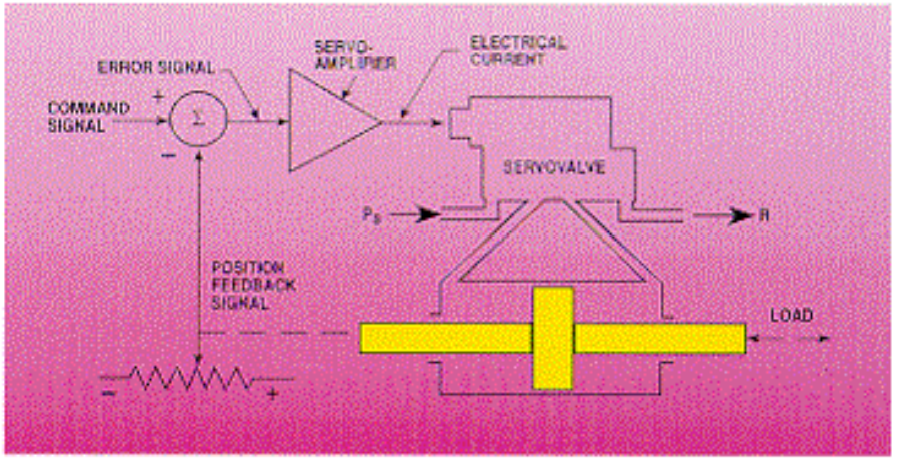
Differential Pressure Control

❖Closed Loop Pressure Control

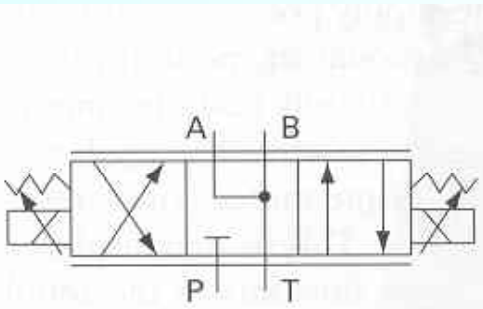


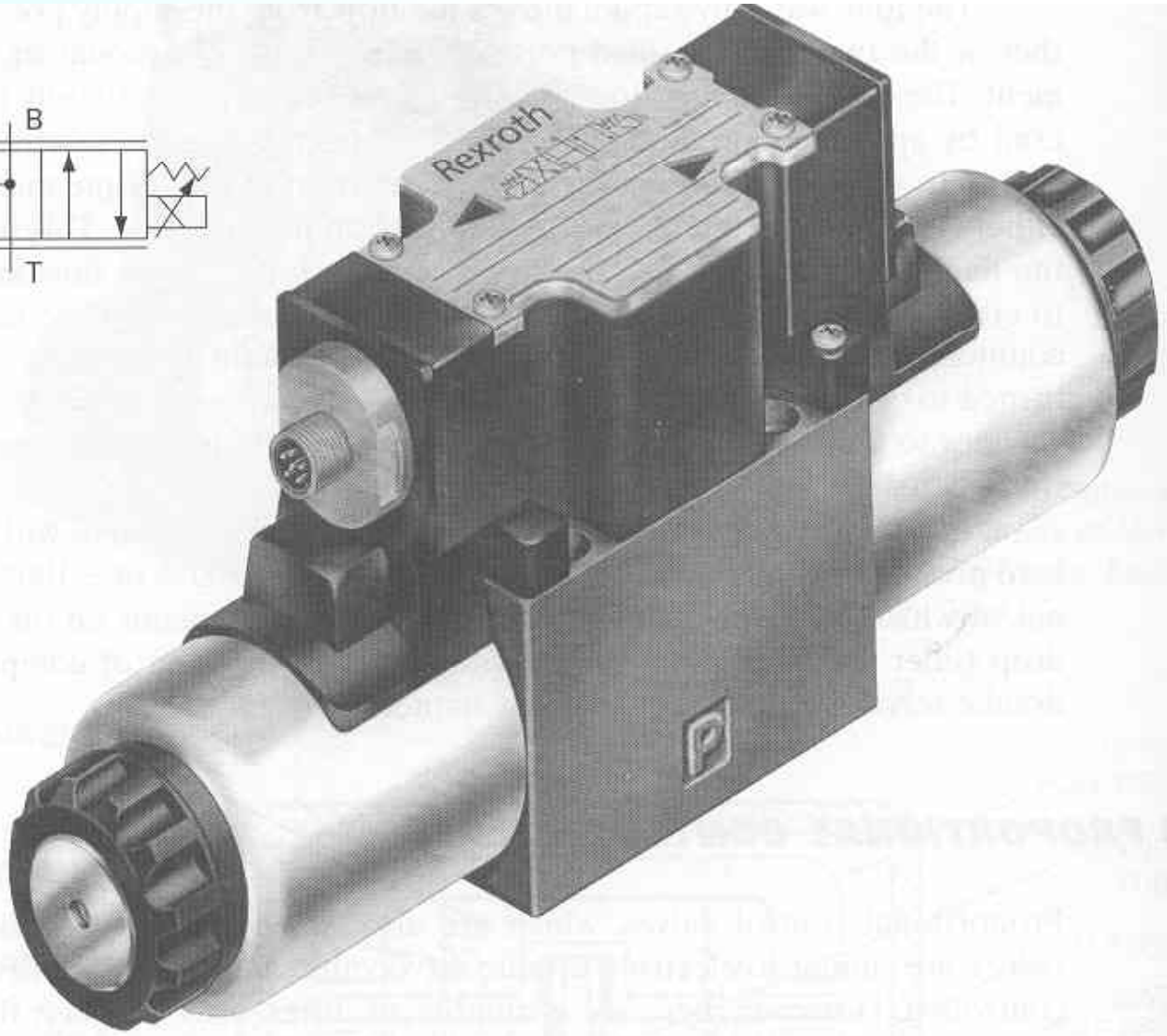
Closed-Loop Control

❖Closed Loop Position Control

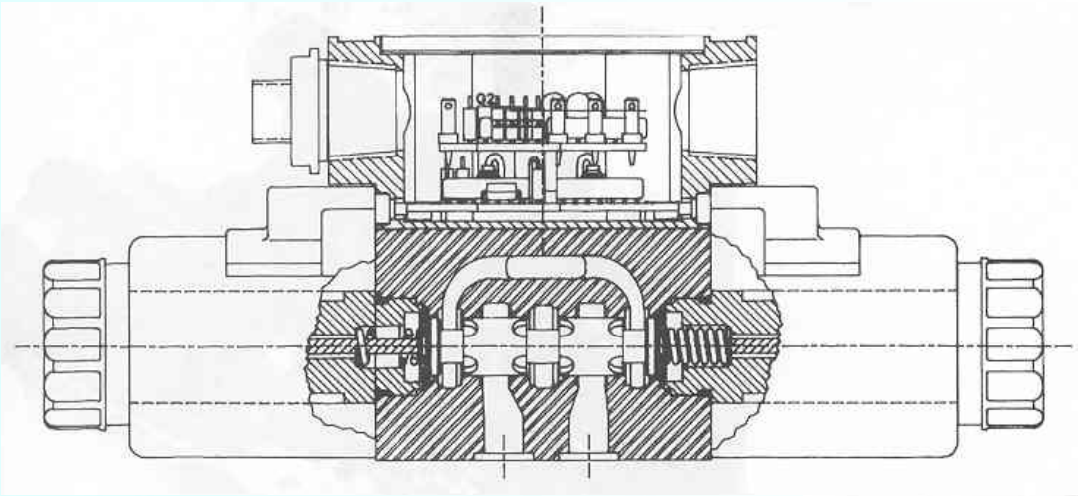


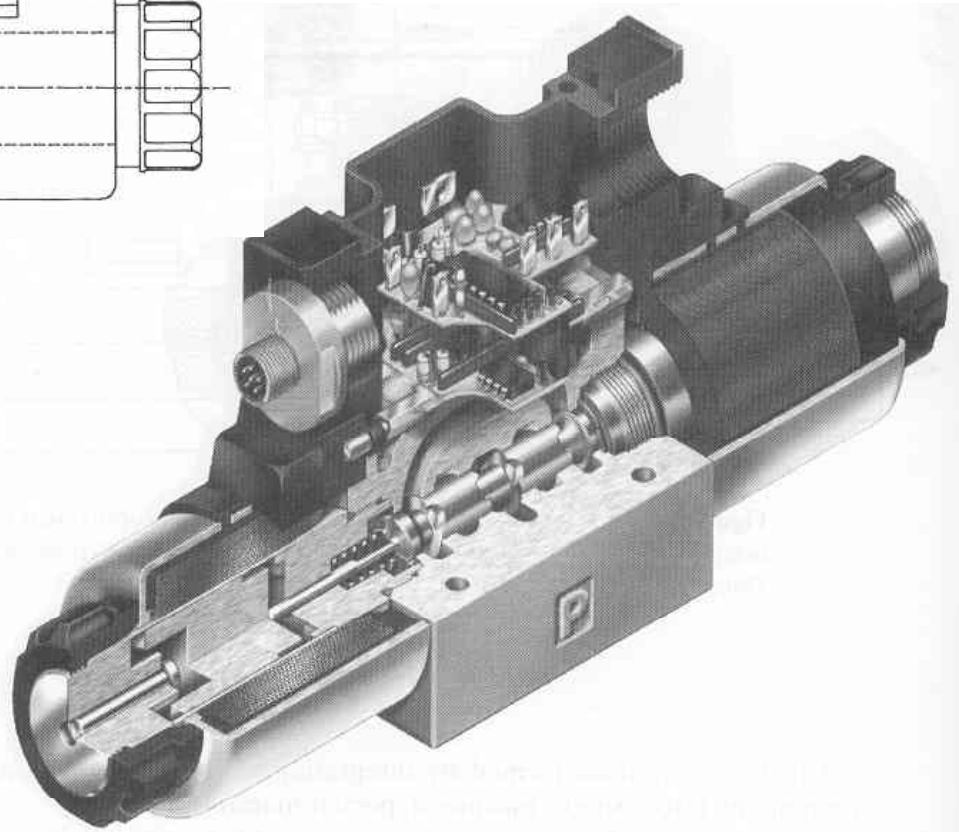
8.6 Proportional Control Valves





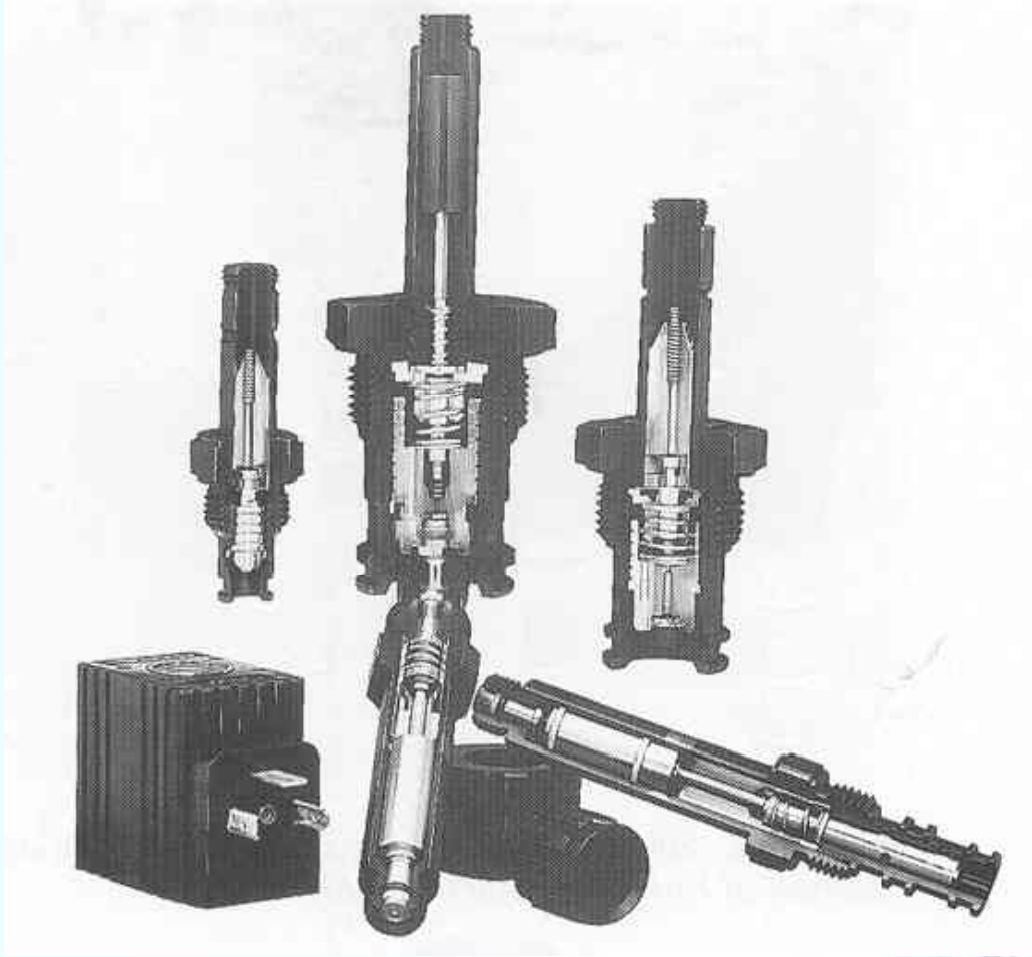
Four-way Proportional Directional Control Valve





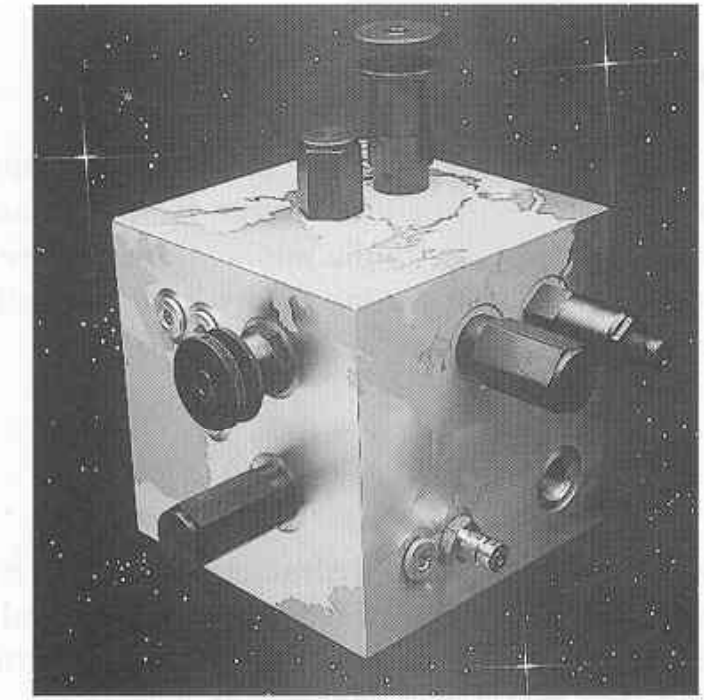
8.7 Cartridge Valves

Threaded cartridge valves

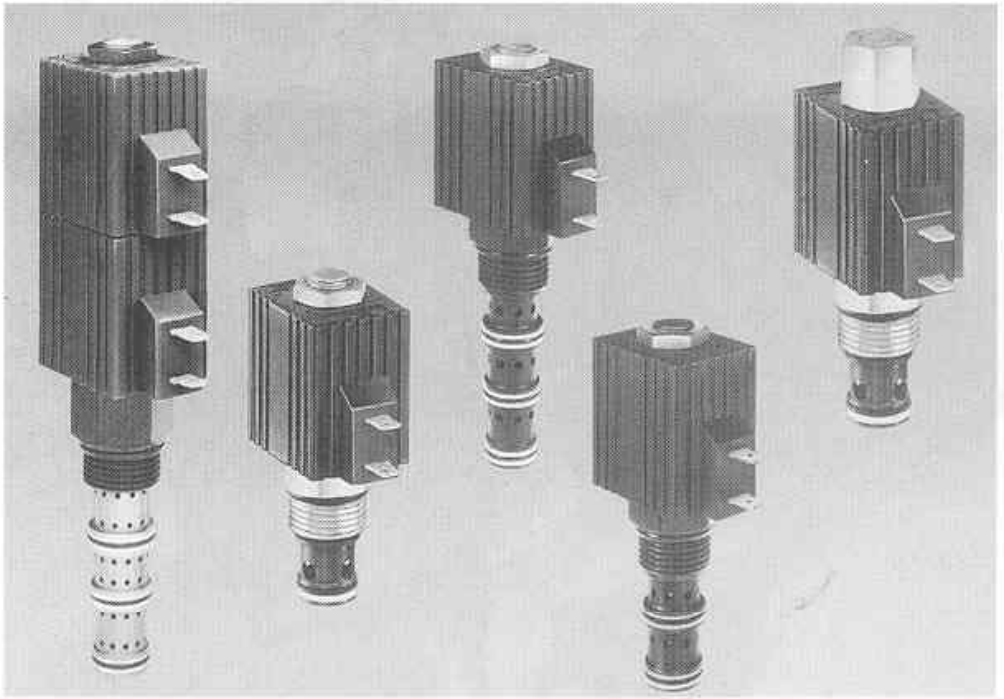


Cartridge Valves

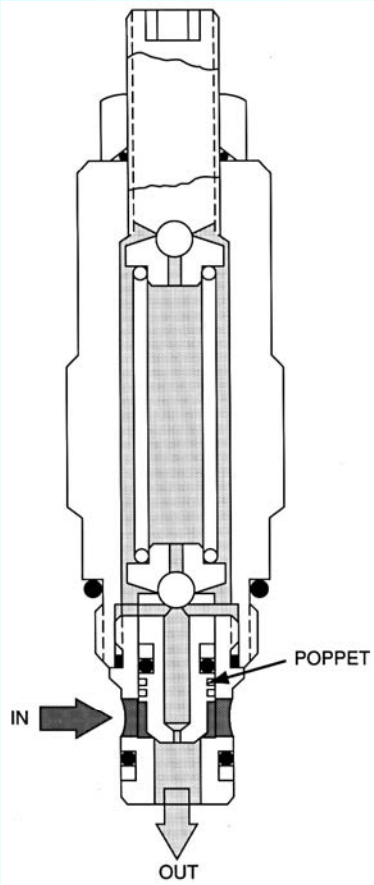
- **Manifold block**



- **Solenoid-operated directional control cartridge valves**

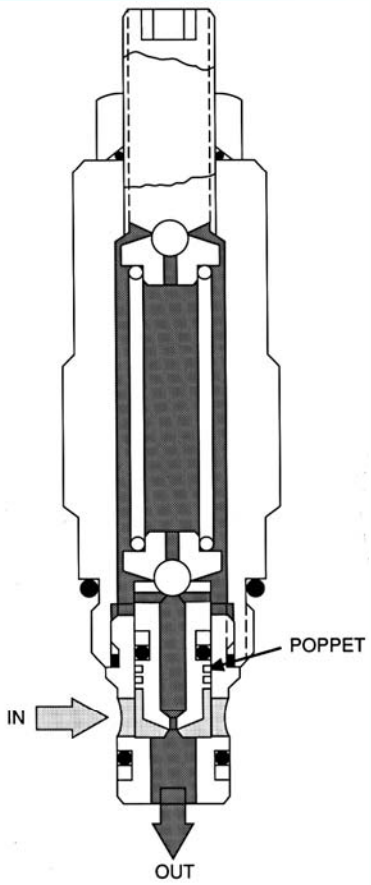


Cartridge Pressure Relief Valves



No Flow Condition

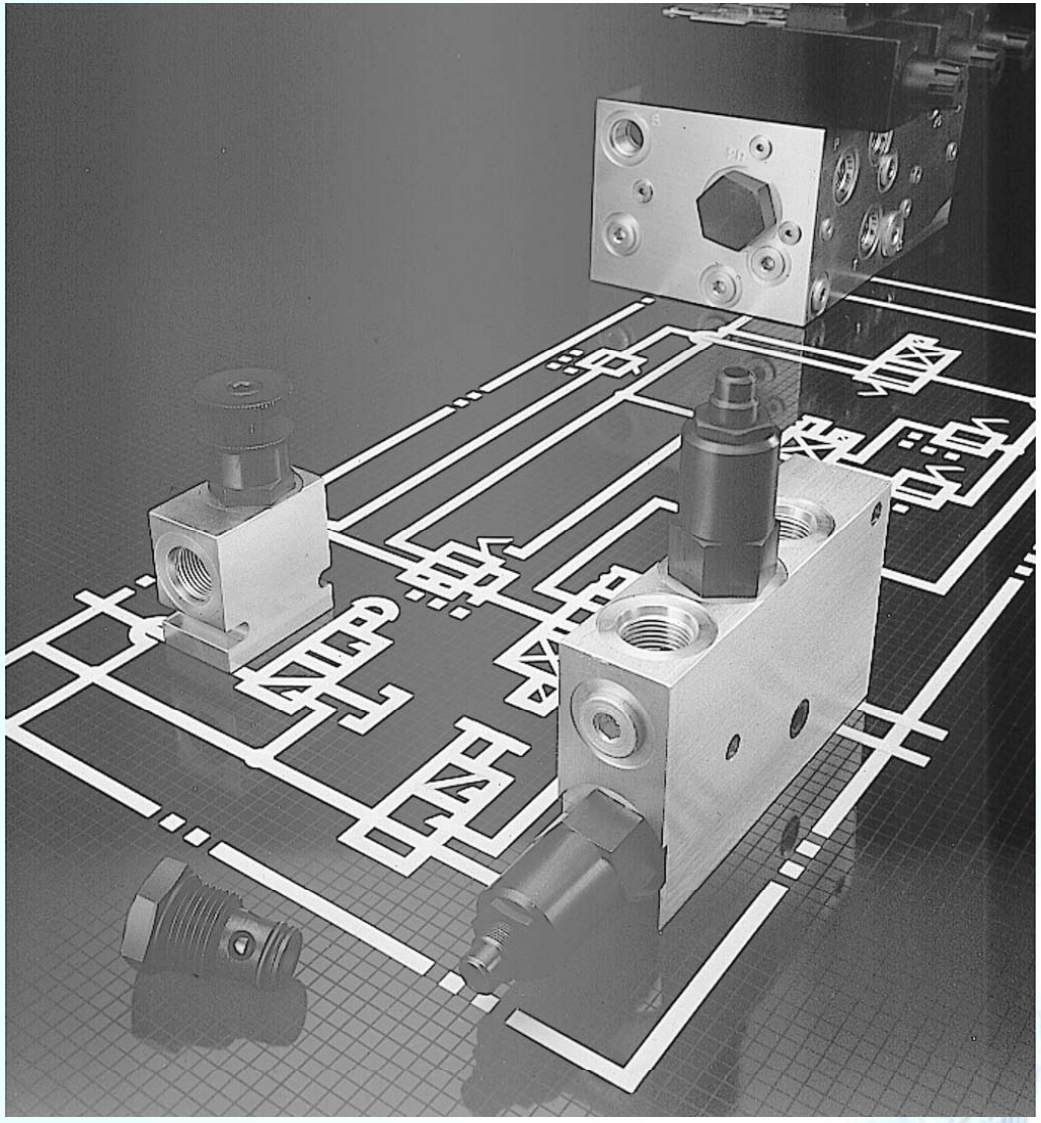
- System pressure is lower than relief valve setting.
- Poppet is seated, held in position by spring force.
- Flow is blocked at Inlet.



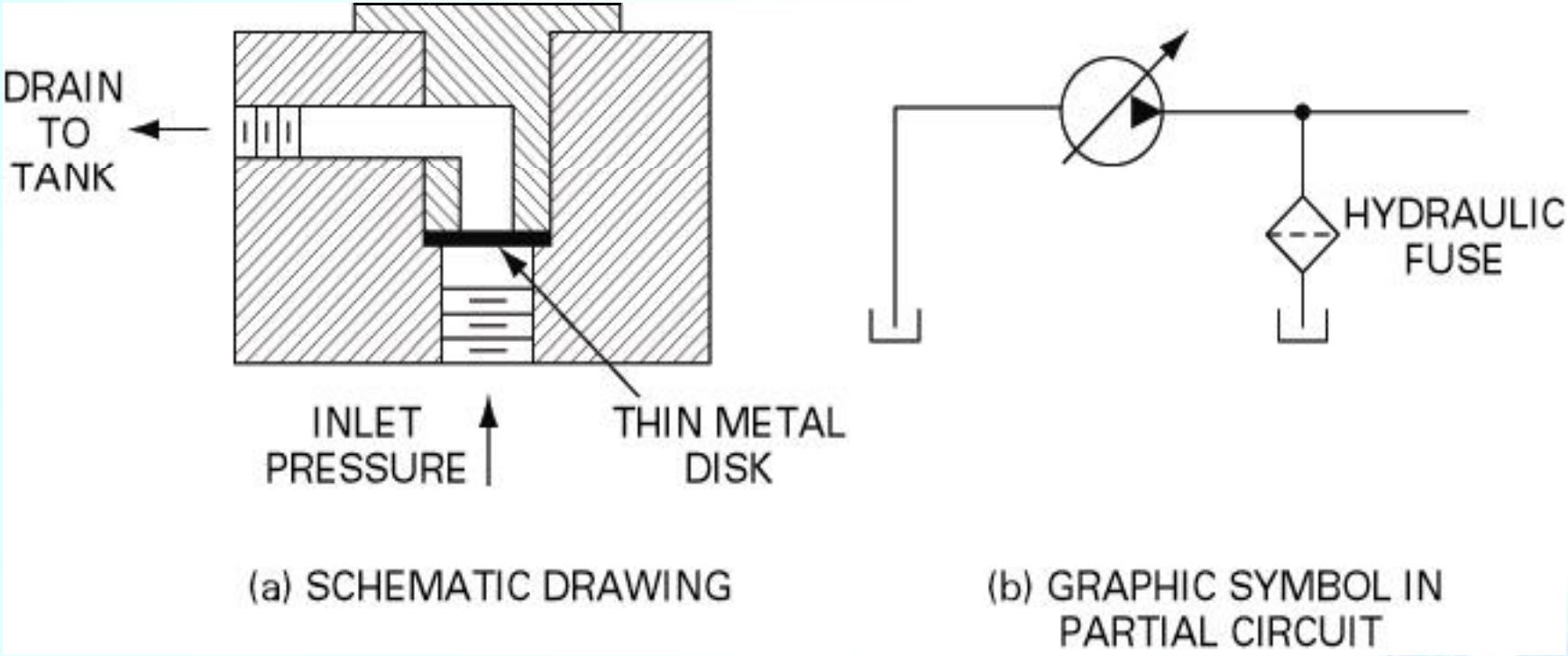
Throttled Flow Condition

- System pressure has reached relief valve setting.
- Pressure has moved Poppet away from Seat, allowing flow to pass through valve.
- Valve is throttling flow to maintain relief pressure at Inlet.

Integrated Hydraulic Circuit



Hydraulic Fuse



(a) SCHEMATIC DRAWING

(b) GRAPHIC SYMBOL IN PARTIAL CIRCUIT

Report

- **Text Problems**
  - **8-45**
  - **8-49**
  - **8-58**
- **Due date: 2주후**