

Construction & Mining Technique



Division Construction & Mining Technique



Basic Hydraulics

Fluid Power System



- 4 Fluid Power Systems are power transmitting assemblies employing pressurised liquid or gas to transmit energy.**

- 4 Fluid power can be divided into two basic disciplines**
 - > Hydraulics – Employing pressurised liquid**

 - > Pneumatics – Employing compressed gas**

What is Hydraulic?



4 Hydraulics is derived from the Greek word

- Hydor meaning Water**

- Aulos meaning Pipe**

Definition of Hydraulic



In simple language:

Confined liquids under pressure made to do work.

OR

Science of transmitting force / motion through the medium of confined liquid

Definition of Hydraulic



Hydraulics can be divided in to two Sciences :

- 7 **Hydrodynamic** : The science of moving liquid. The kinetic energy of the moving fluid is used to do work. Water wheel / Turbine is the example.
- 7 **Hydrostatics** : The science of confined liquid under pressure. The force generated due to creation of pressure on confined liquid is used to do work. Hydraulic cylinders is the example.

Pascal Law

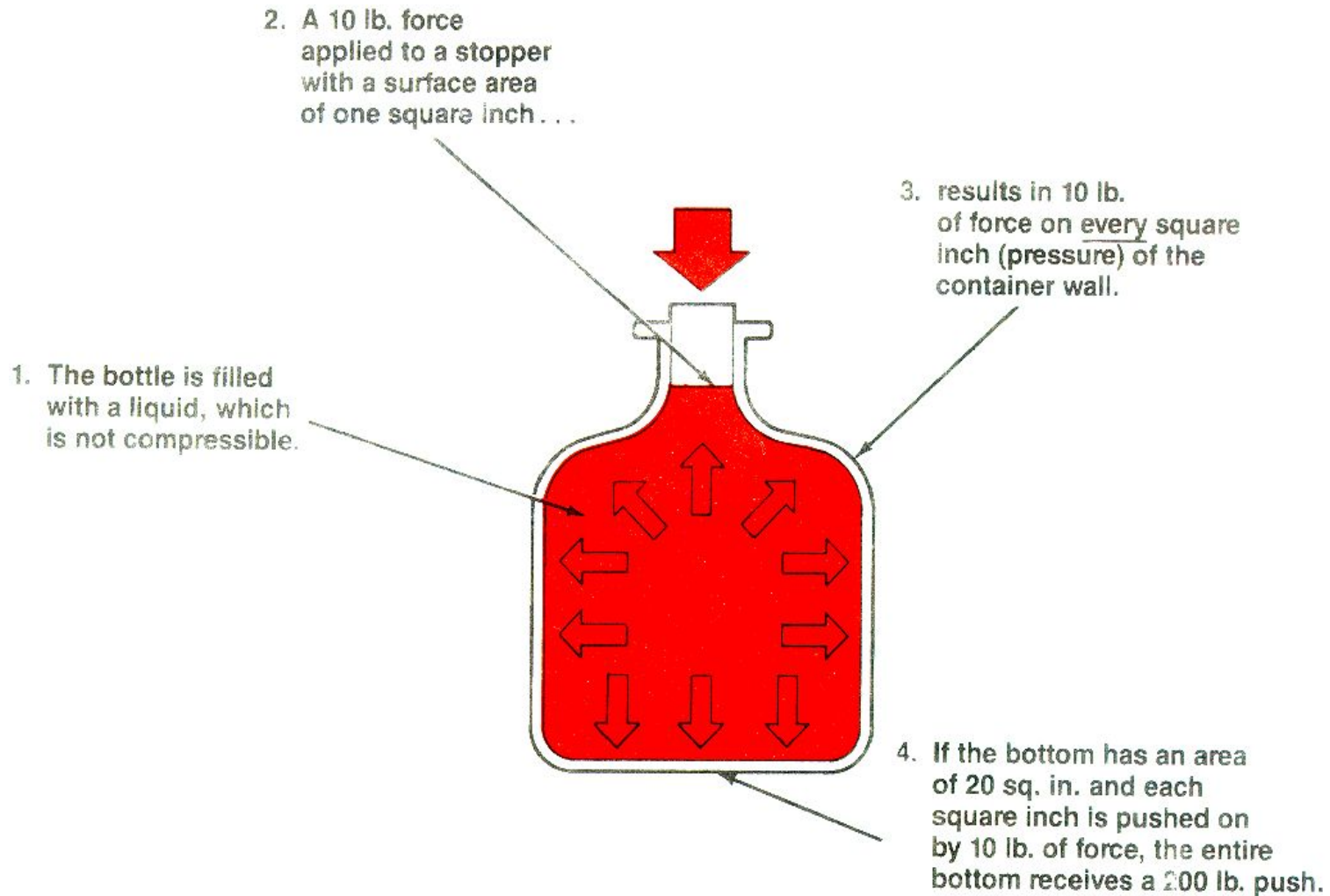


Hydraulic system is based on Pascal's law.

- 4 Pressure applied on a confined fluid is transmitted in all directions and acts with equal force on all equal areas and at right angles to them**

Pascal Law was named after the French Scientist – Blaise Pascal

Pascal's Law - illustration

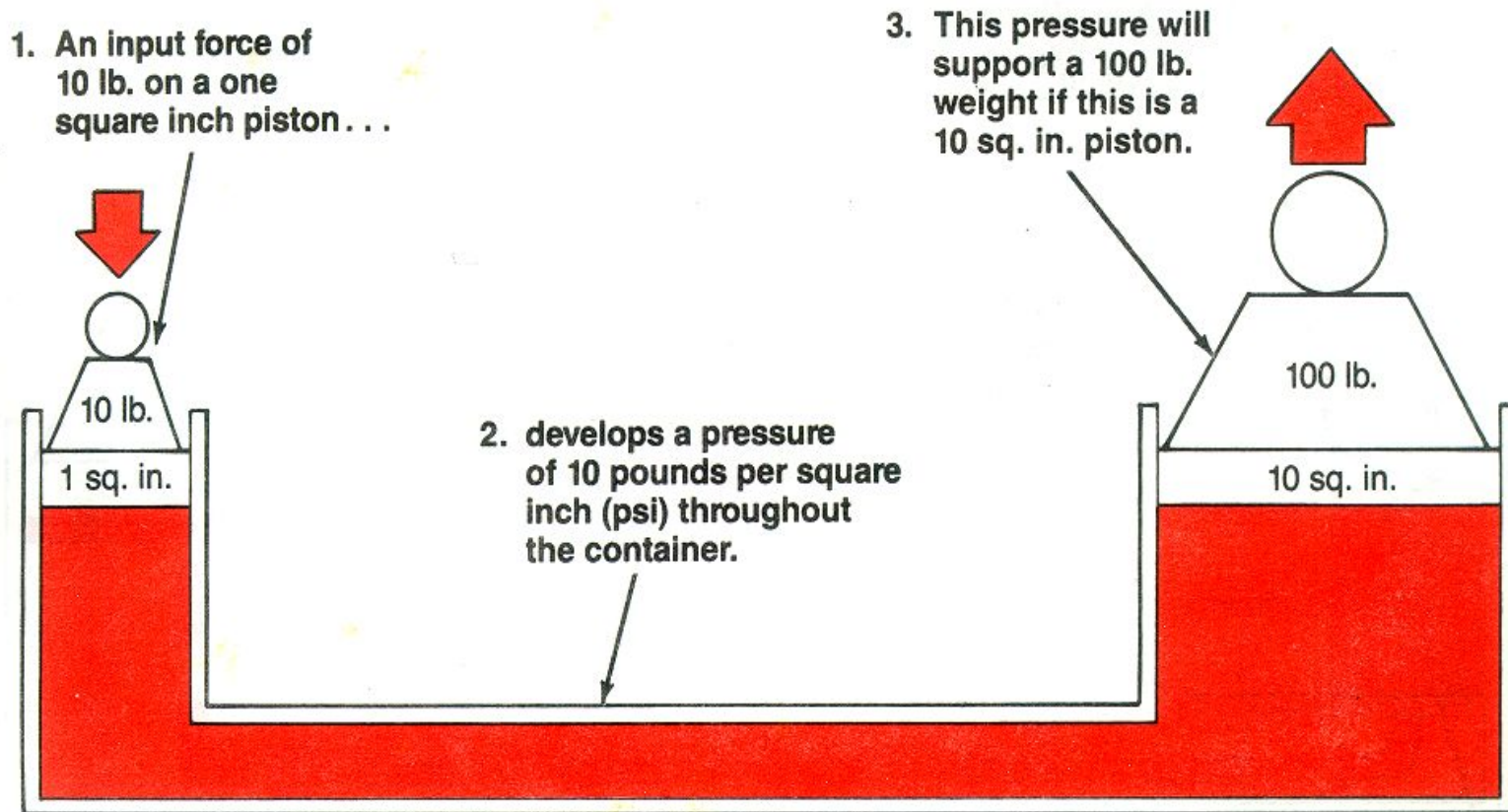


Hydraulic Press – working principle



- 4 Realising that a small force on a small area would create a proportionately larger force on a larger area, a British mechanic named Joseph Bramah applied Pascal's Law in developing an Hydraulic Press.

Hydraulic Press – working principle



Advantages of oil in Hydraulics



- 4 **Variable speed** : Possible to control speed through valve.
- 4 **Reversible** : Instant reverse motion is possible. No need to stop the system to change direction.
- 4 **Over load protection** : Protected through relief valve from over-loading.
- 4 **Small package** : Components are smaller than other power transmitting system.
- 4 **Can be stalled** : Not possible on direct drive system from Electric motor / Diesel engine.
- 4 **Simple design** : Pre-engineered components available.
- 4 **Self lubricated** : Hydraulic oil lubricates the parts.
- 4 **Flexible** : Flexible hoses virtually eliminate the location problem of the hydraulic components.
- 4 **Smooth** : Incompressible, no vibration.
- 4 **Acts as coolant** : It dissipates heat / cools the component,
- 4 **Acts as seal** ; It seals clearances between two mating parts.
- 4 **Noise free** : No noise.

Functions of Hydraulic Oil



- 4 It transmits power.**
- 4 It lubricates moving parts**
- 4 It seals clearances between moving parts**
- 4 It dissipates heat**

Hydraulic System



- 4 Reservoir
- 4 Filter
- 4 Hydraulic Pump
- 4 Directional Control Valve
- 4 Pressure Control Valve
- 4 Actuator (Cylinder/Motor)

Reservoir

First a tank is needed to store the hydraulic oil

Tank / Reservoir

Reservoir



- 4 Storing oil**
- 4 Compensates difference in volume when actuators are used**
- 4 It dissipates heat**
- 4 It allows foreign particles to settle down**
- 4 Baffle separates inlet line with the return line and allows the air bubbles to escape to the surface of the oil**

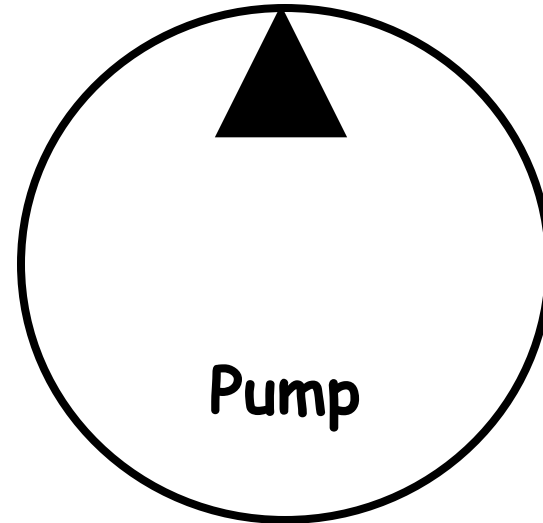
Reservoir



- 4 It allows condensed water to settle at the bottom of the tank**
- 4 Breather on the top of the tank allows to maintain atmospheric pressure and avoid creation of vacuum**
- 4 Sight glass will indicate the level of the oil. Mercury bulb in it will indicate the oil temperature**
- 4 Oil filling inlet will have a filter for avoiding contamination.**

Pump

Now we need a pump to create flow



Pump



- 4 **Hydraulic Pump is the most important component in the hydraulic system.**
- 4 **Function of the Hydraulic Pump is to convert Mechanical Energy to Hydraulic Energy**
- 4 **Hydraulic Pump are classified in two categories:**
 - **Hydro-dynamic**
 - **Hydro-static**

Pump



4 Two types of hydraulic pumps are most commonly used:

- Rotary Pumps**

- Reciprocating Pumps**

Rotary Pumps



4 Common Pumps in Rotary type are:

- Gear Pumps**

- Vane Pumps**

Reciprocating Pumps

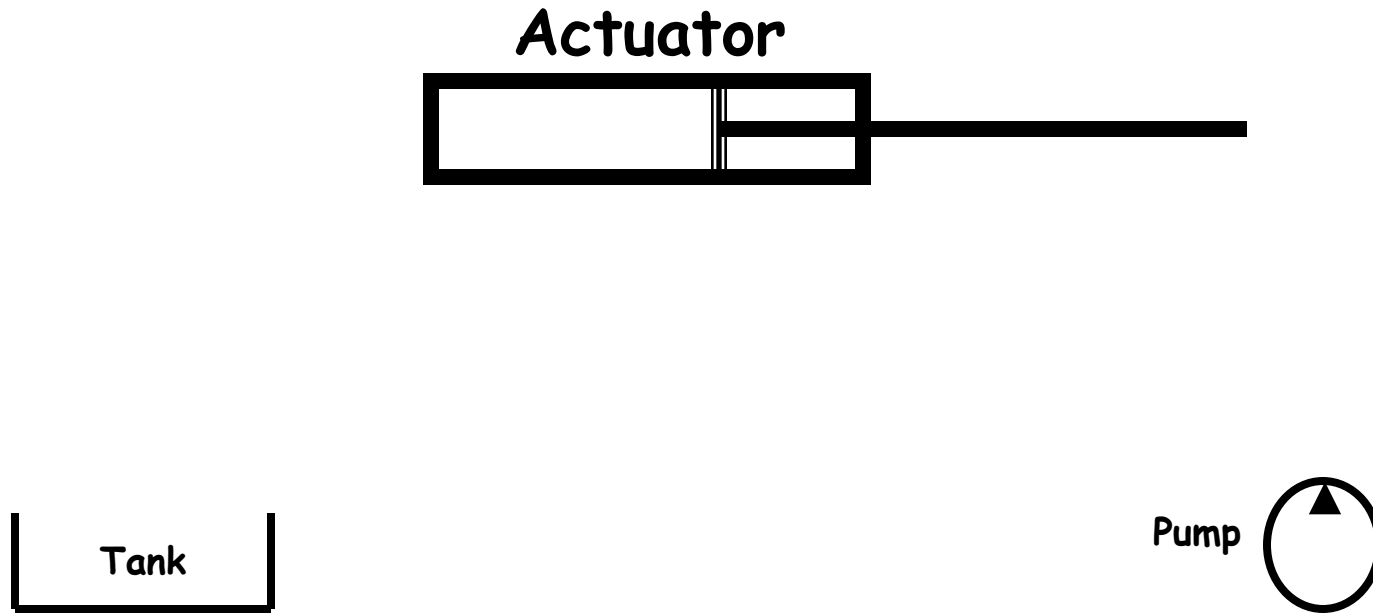


4 Common Pumps in Reciprocating type are:

- Axial Piston Pump**
- Radial Piston Pump**

Actuators

The Actuator (Motor / Cylinder) to work



Actuators



4 There are mainly two types of Actuators:

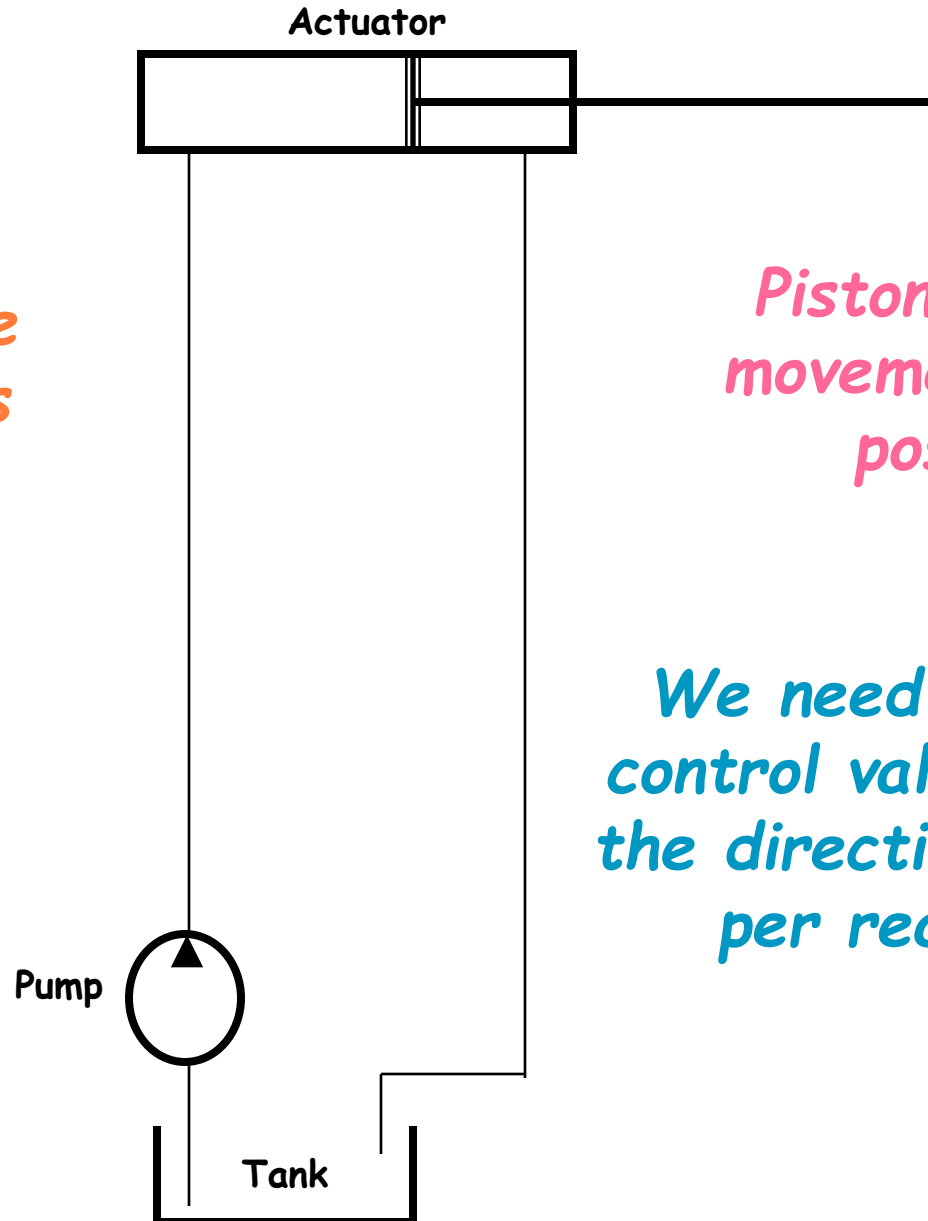
- Linear actuators (single acting cylinders, double acting cylinders)**
- Rotary actuators (vane motors, gear motors, piston motors etc.)**

Hydraulic System

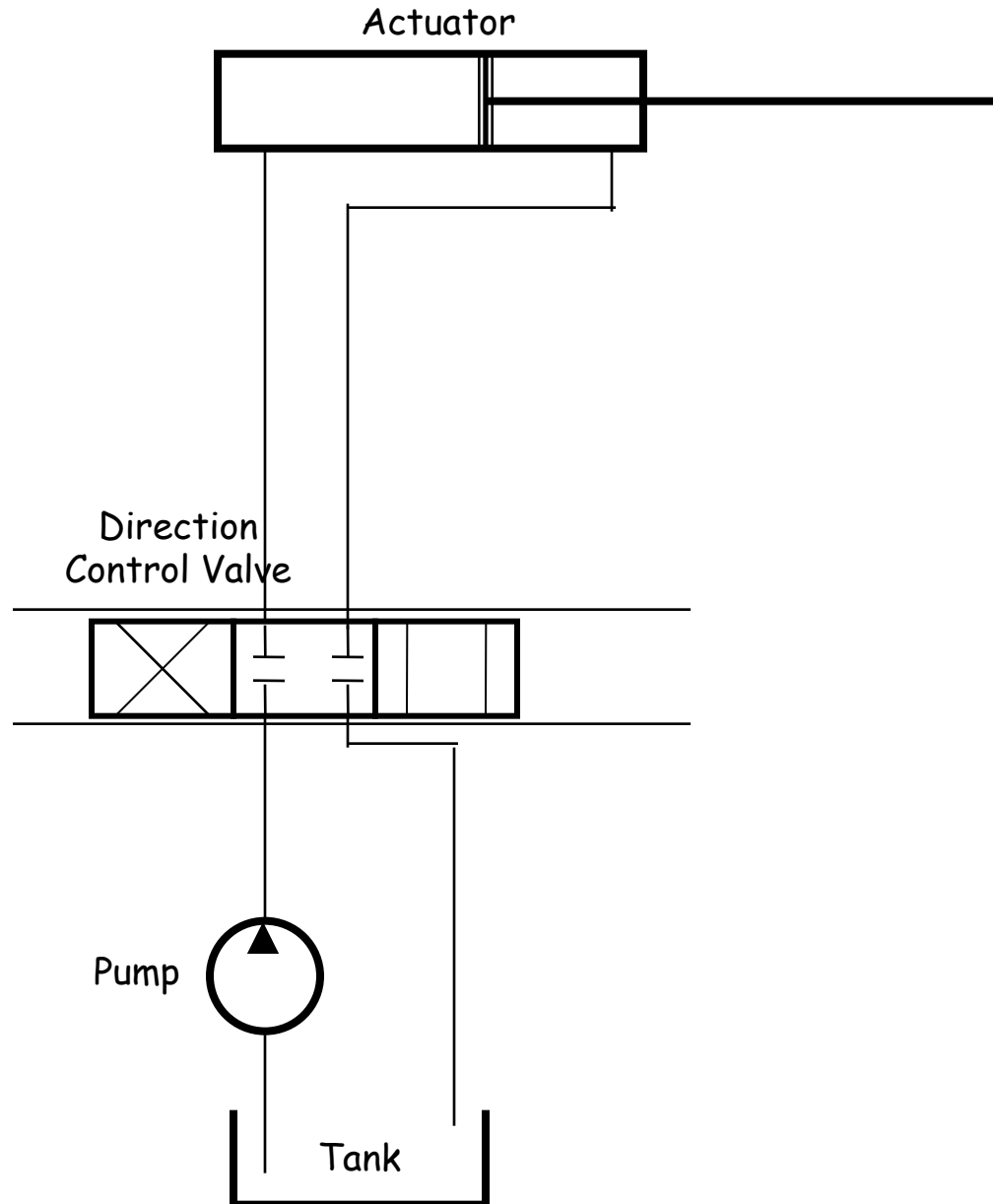
Hoses to connect the components

Piston reverse movement is not possible

We need a direction control valve to change the direction of flow as per requirement



Hydraulic System



Valves



- 4 Valves are components which guide hydraulic oil delivered by the Pump to the actuators.**

- 4 Valves regulate the hydraulic oils**
 - Volume rate of flow**

 - Pressure**

 - Direction**

Valves design



4 There are mainly two design principles for valves

- Spool valves**

- Poppet valves**

Types of Valves



4 There are three main types of Valves:

- Pressure Control Valves (relief valves, pressure regulating valve, pressure reducing valve etc.)
- Directional Control Valves (check valve, axial spool valve, ball valve etc.)
- Flow Control Valves (needle valve, throttle check valve etc.)

Two way Spool valve

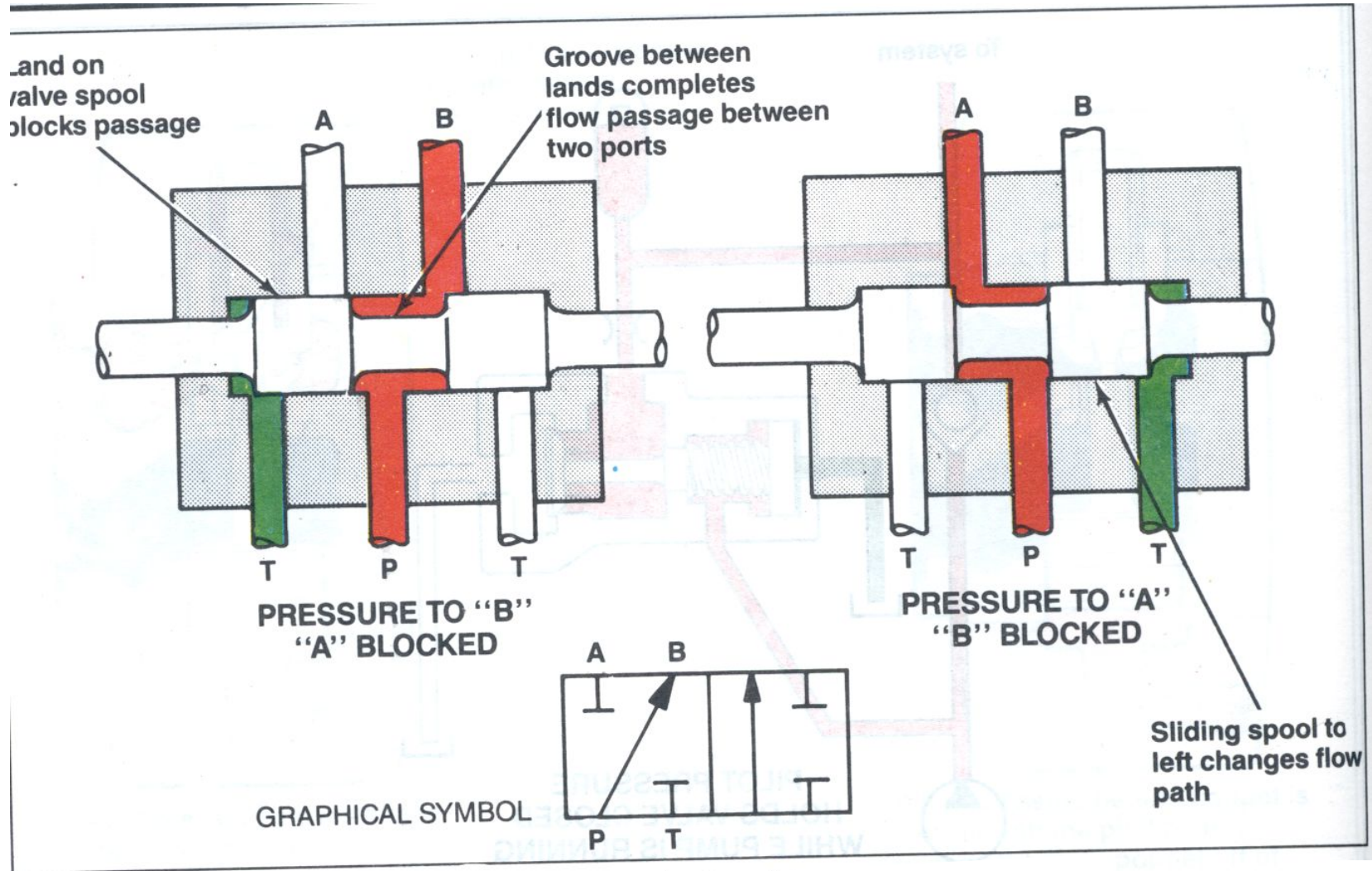
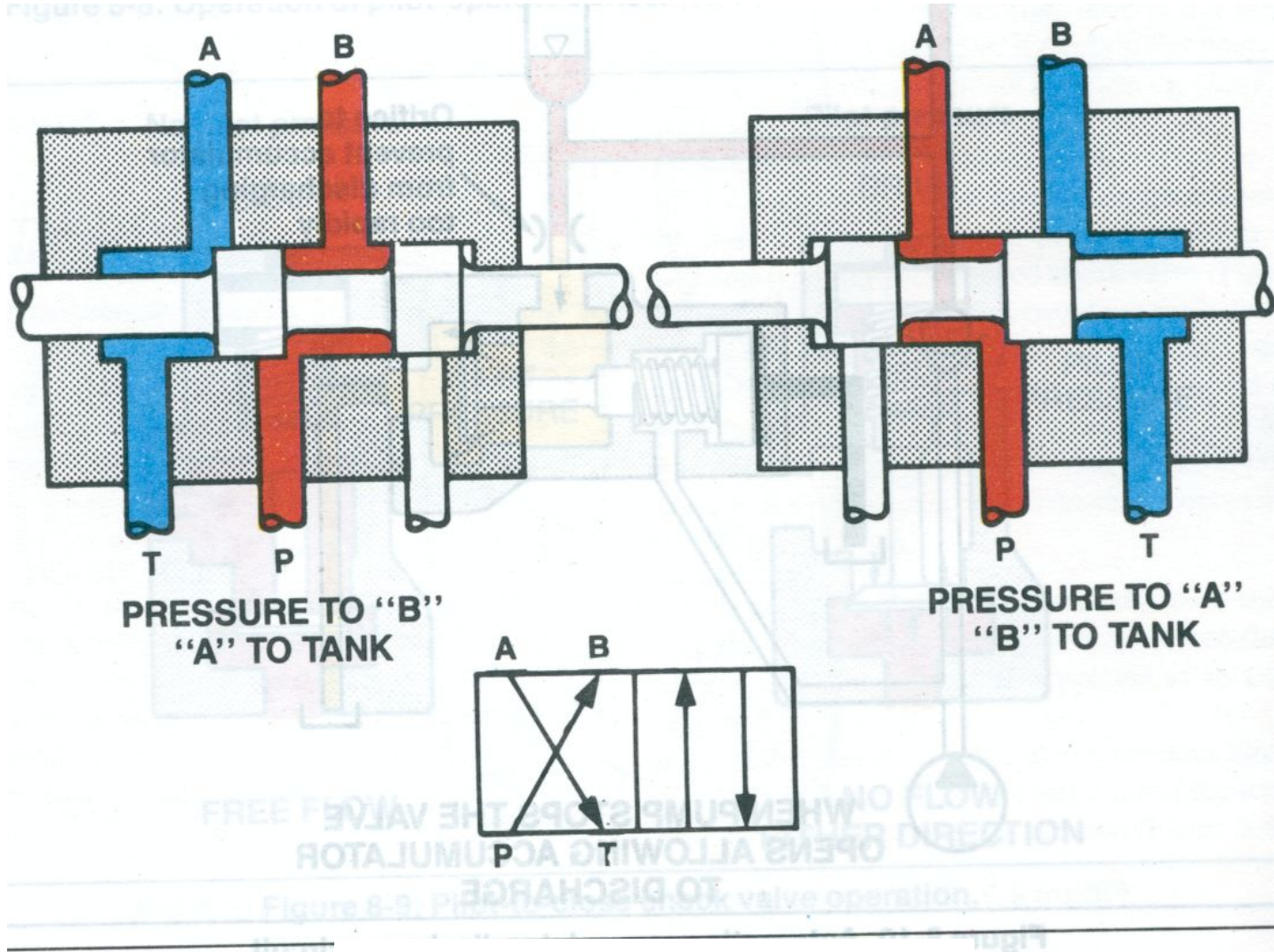
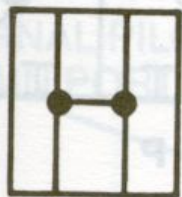


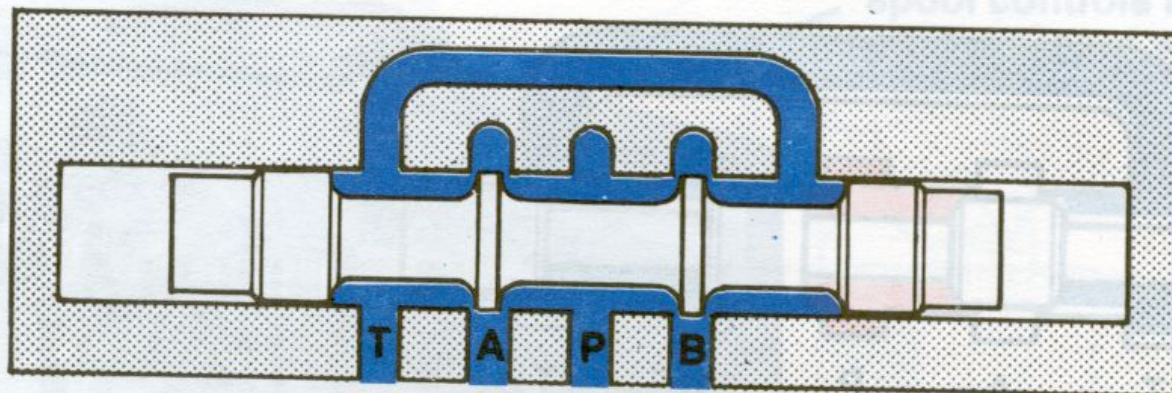
Figure 8-11

Spool type Four way valve

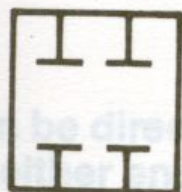




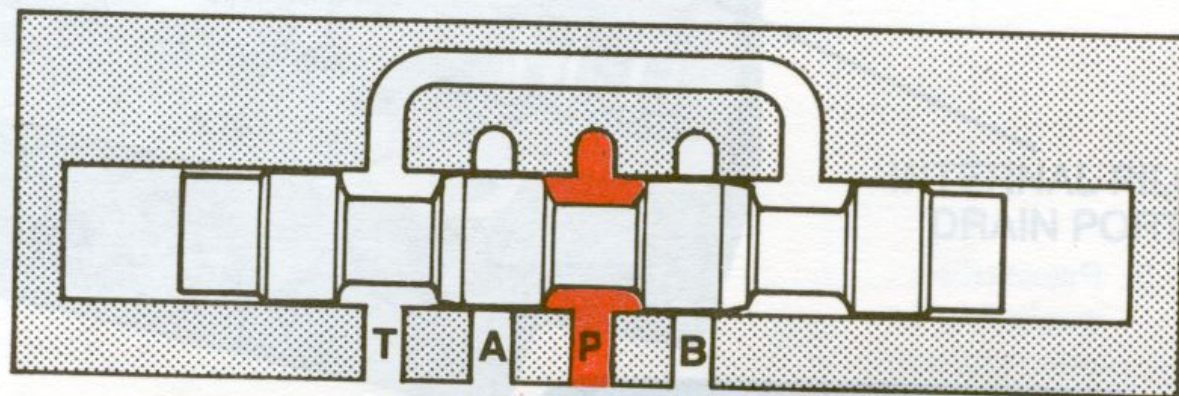
**OPEN
TYPE**



OPEN CENTER



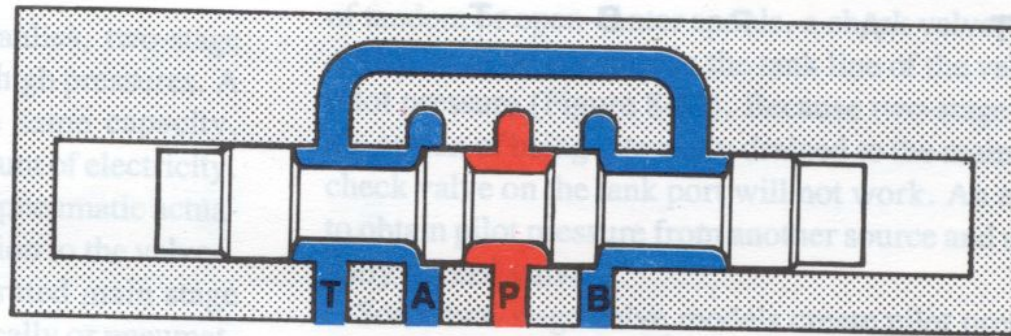
**CLOSED
TYPE**



CLOSED CENTER—ALL PORTS CLOSED



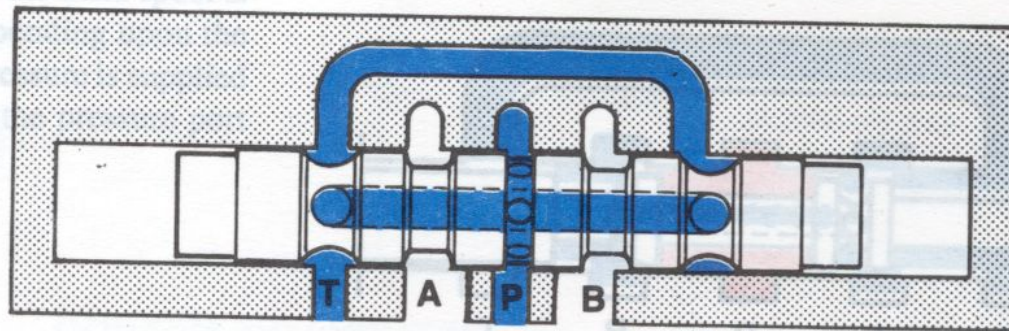
**FLOAT
TYPE**



Pressure Close - “A” & “B” open
to tank

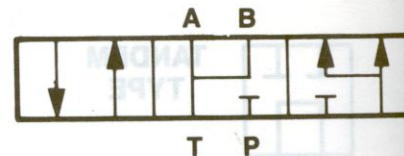
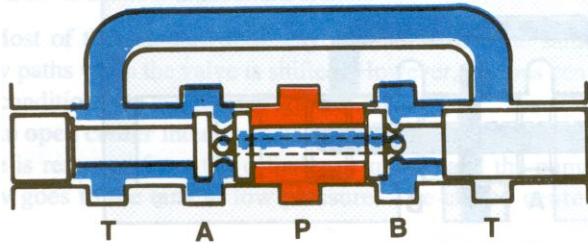
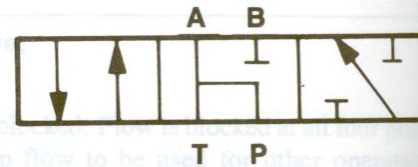
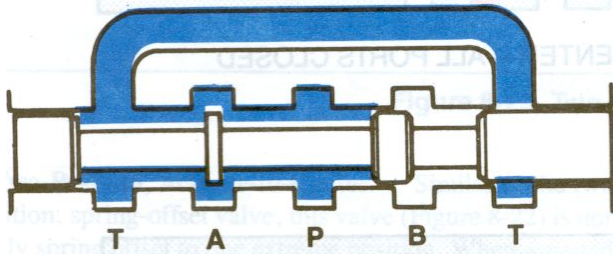
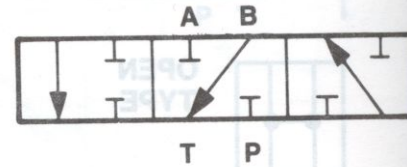
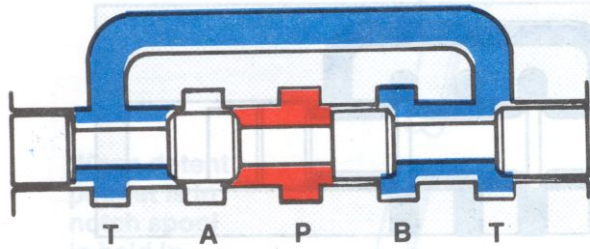


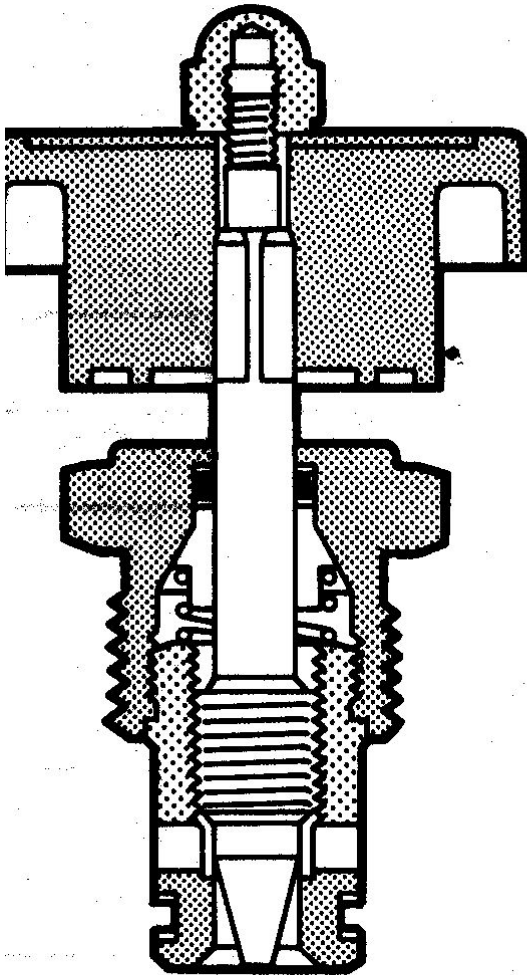
**TANDEM
TYPE**



“A” & “B” Close - Pressure open to
tank

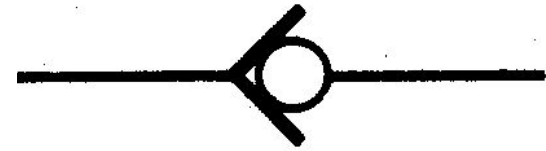
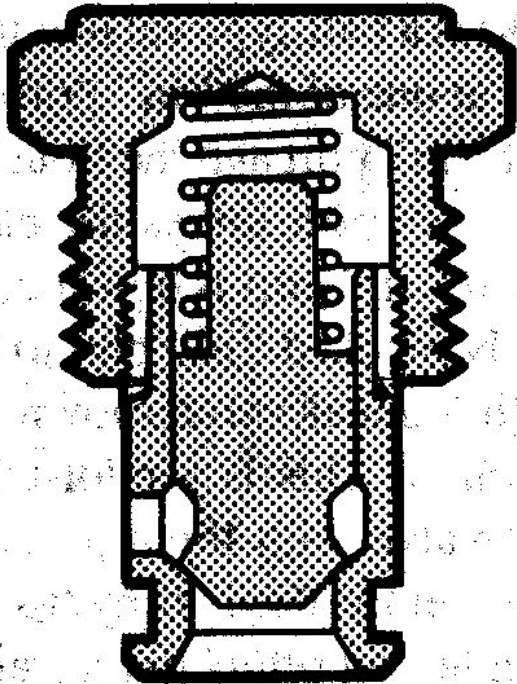
Three position Valve



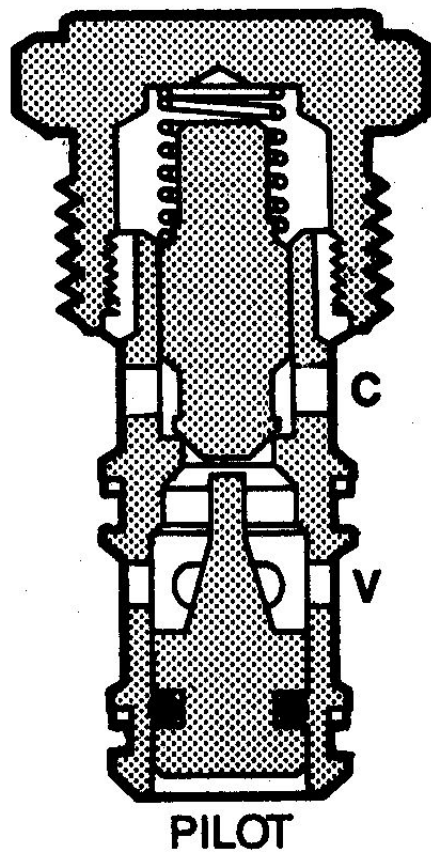


Variable restrictor type Flow control valve

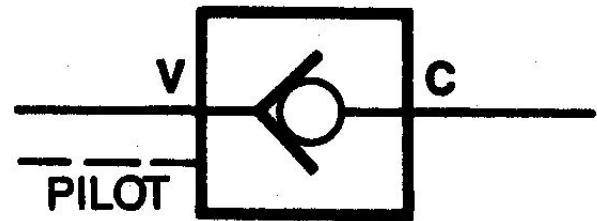


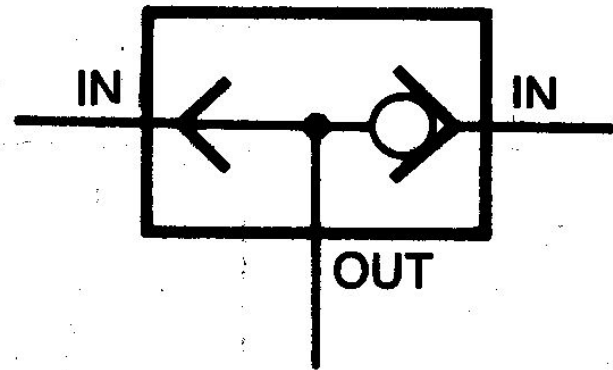
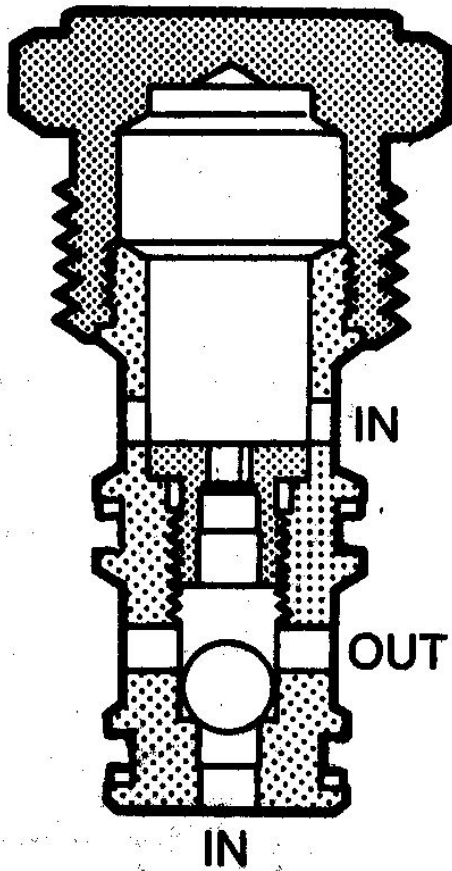


**Simple Poppet type
Check valve**



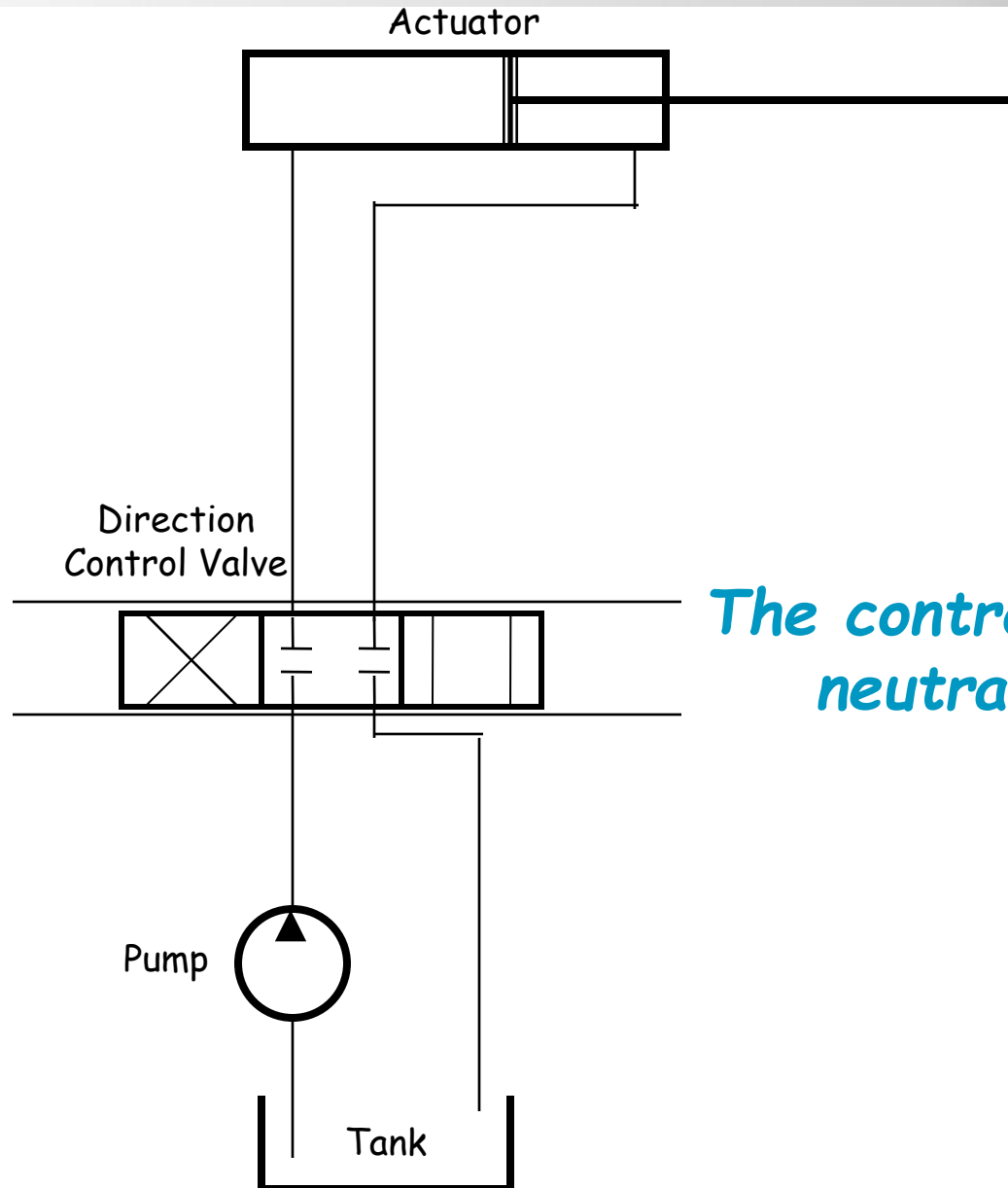
Pilot operated check valve





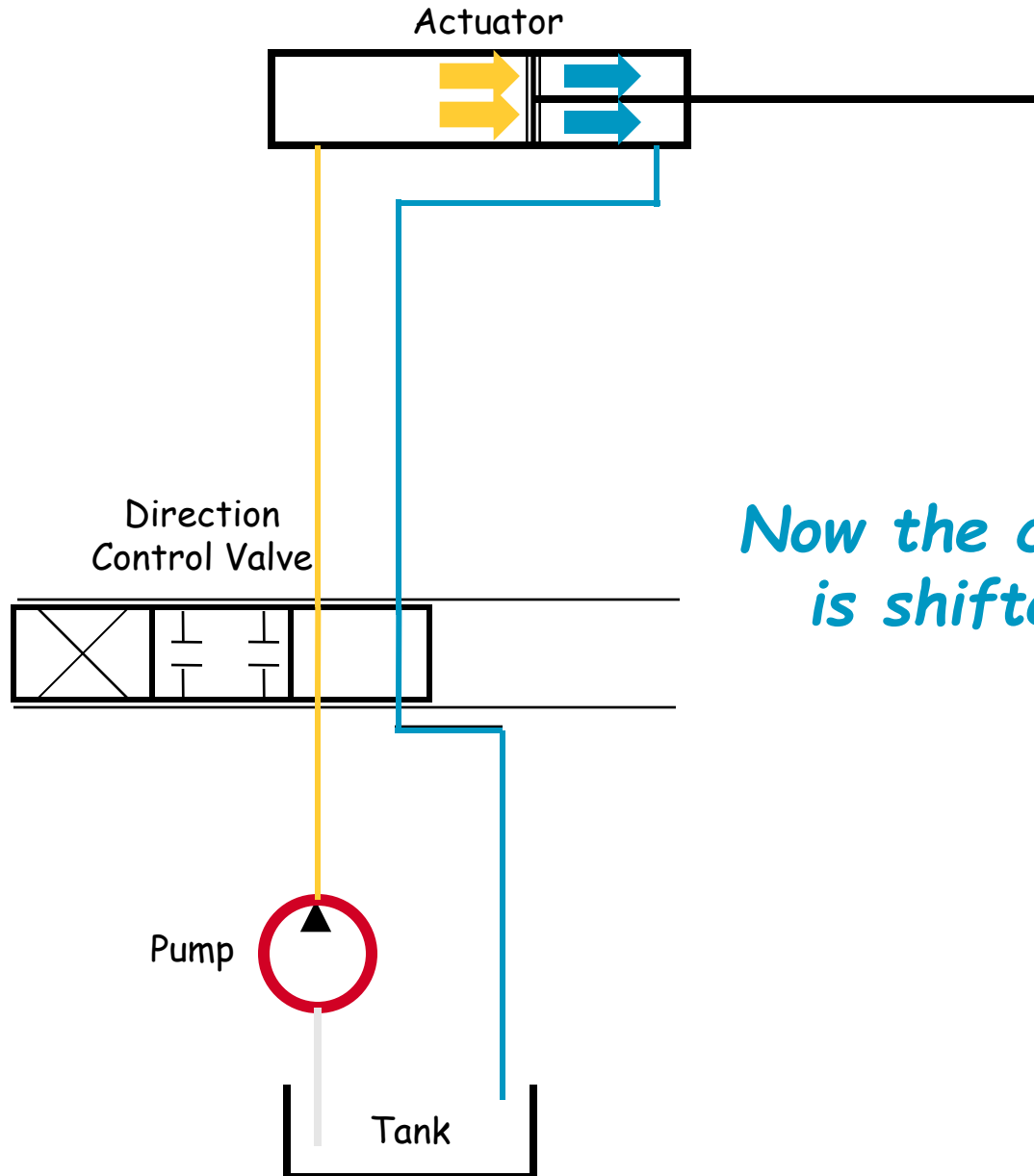
Shuttle valve

Hydraulic System



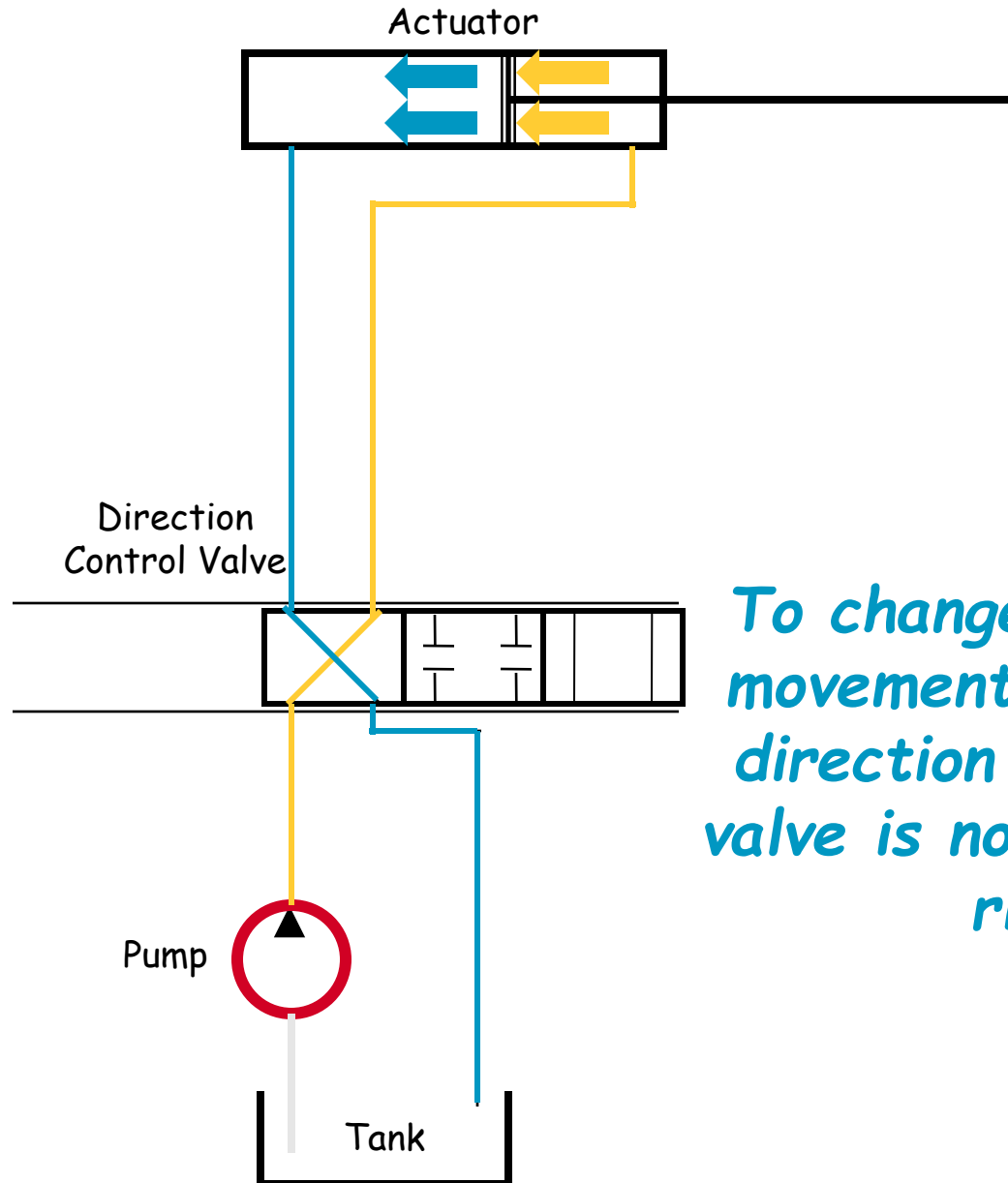
The control valve is at neutral position

Hydraulic System



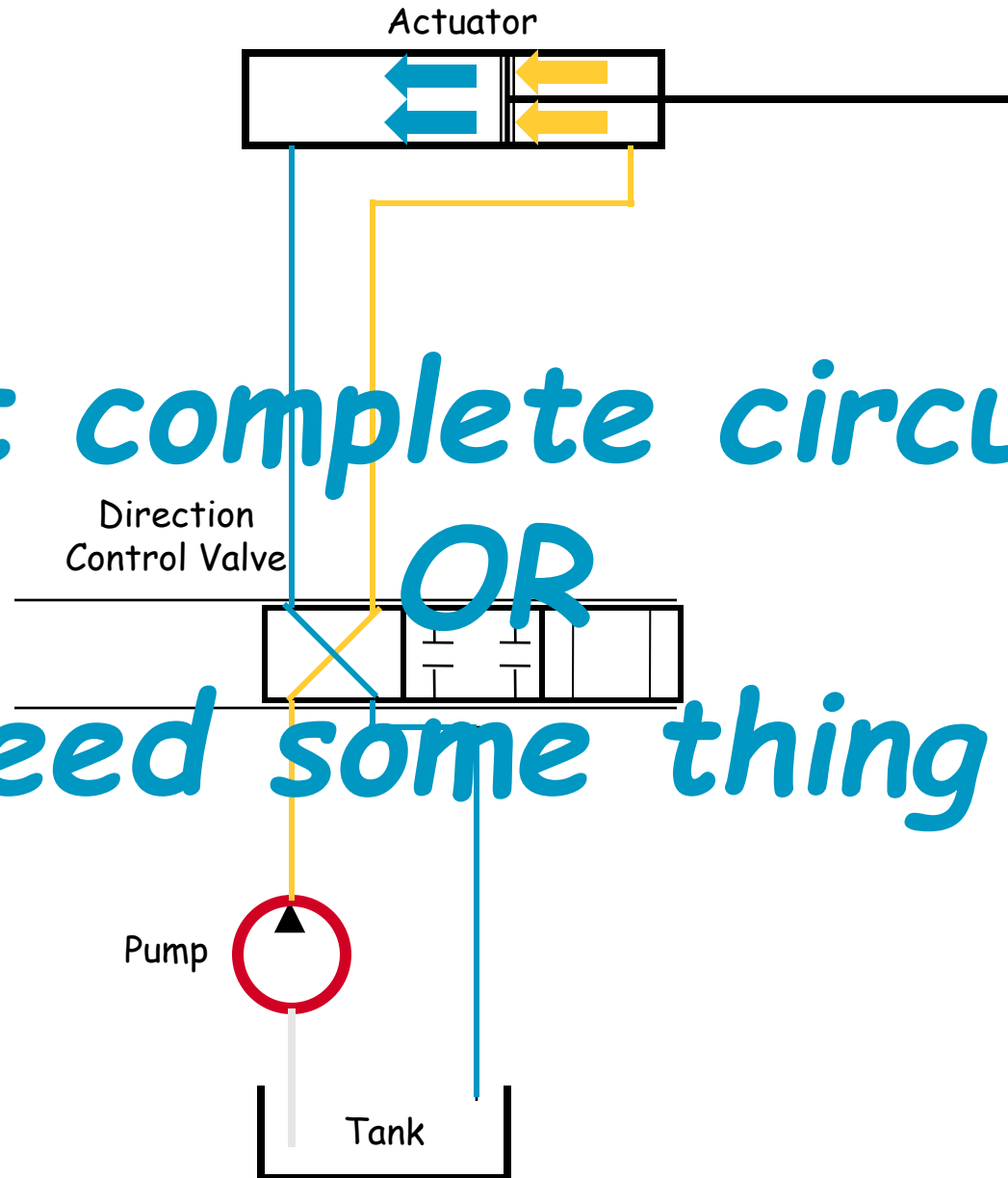
Now the control valve is shifted to left

Hydraulic System



To change the piston movement in opposite direction the control valve is now shifted to right

Hydraulic System

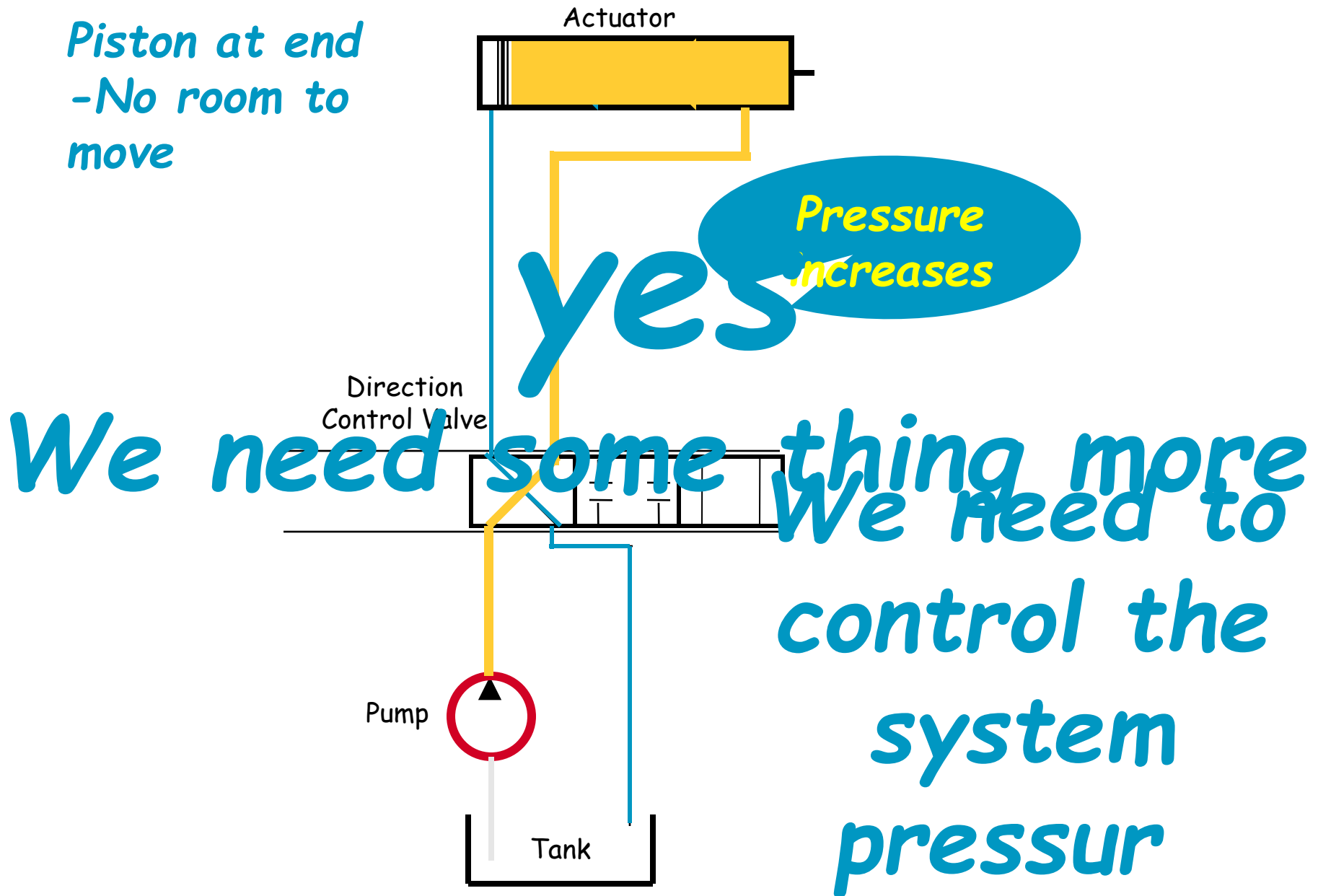


Is it complete circuit ?

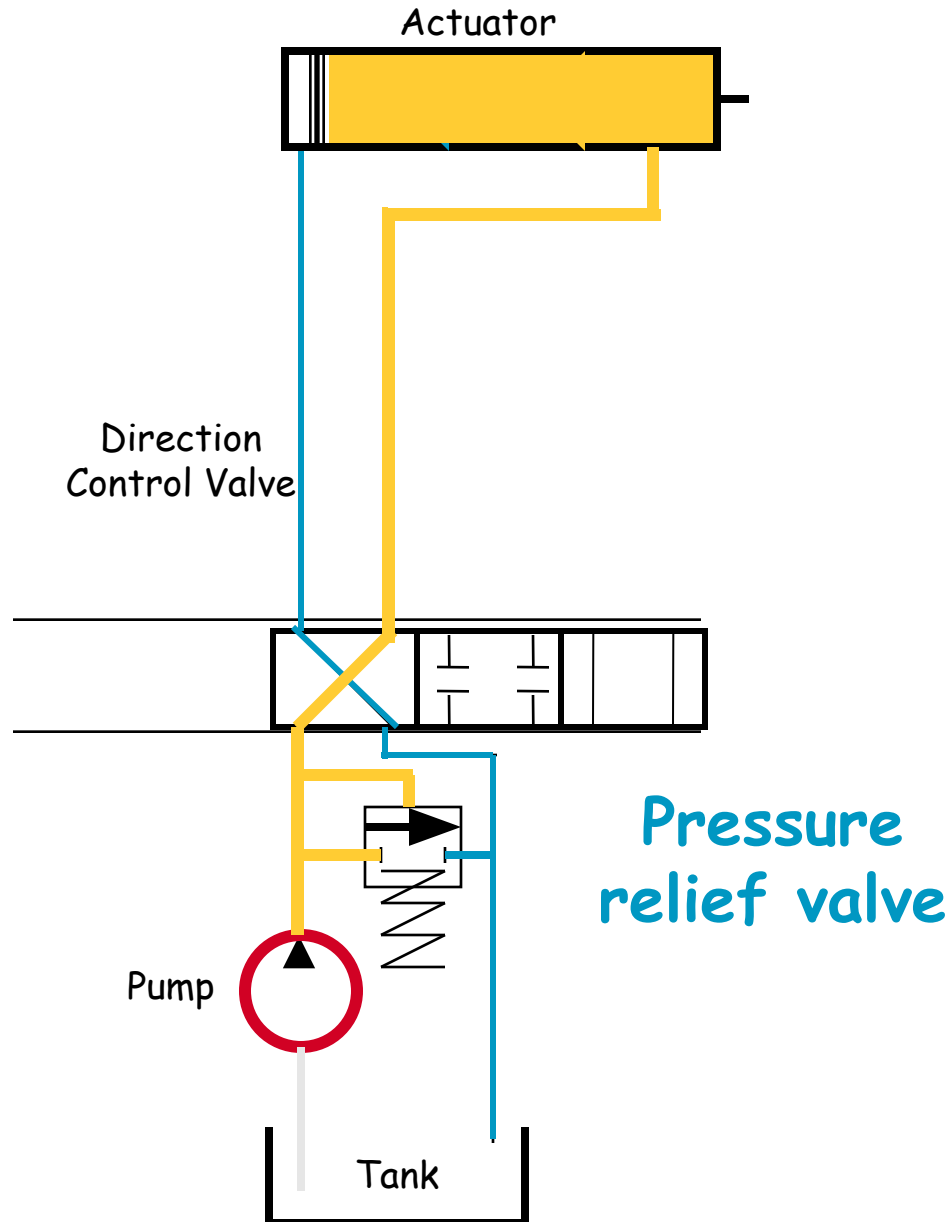
We need some thing more

Hydraulic System

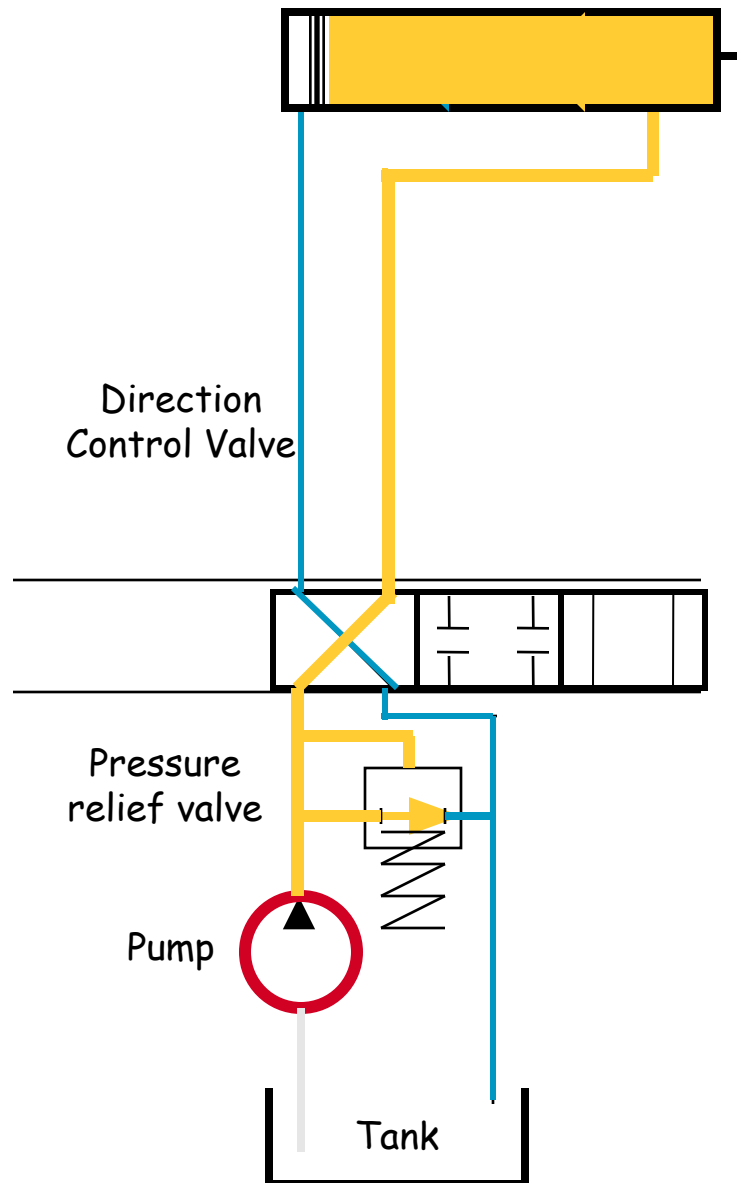
*Piston at end
-No room to
move*



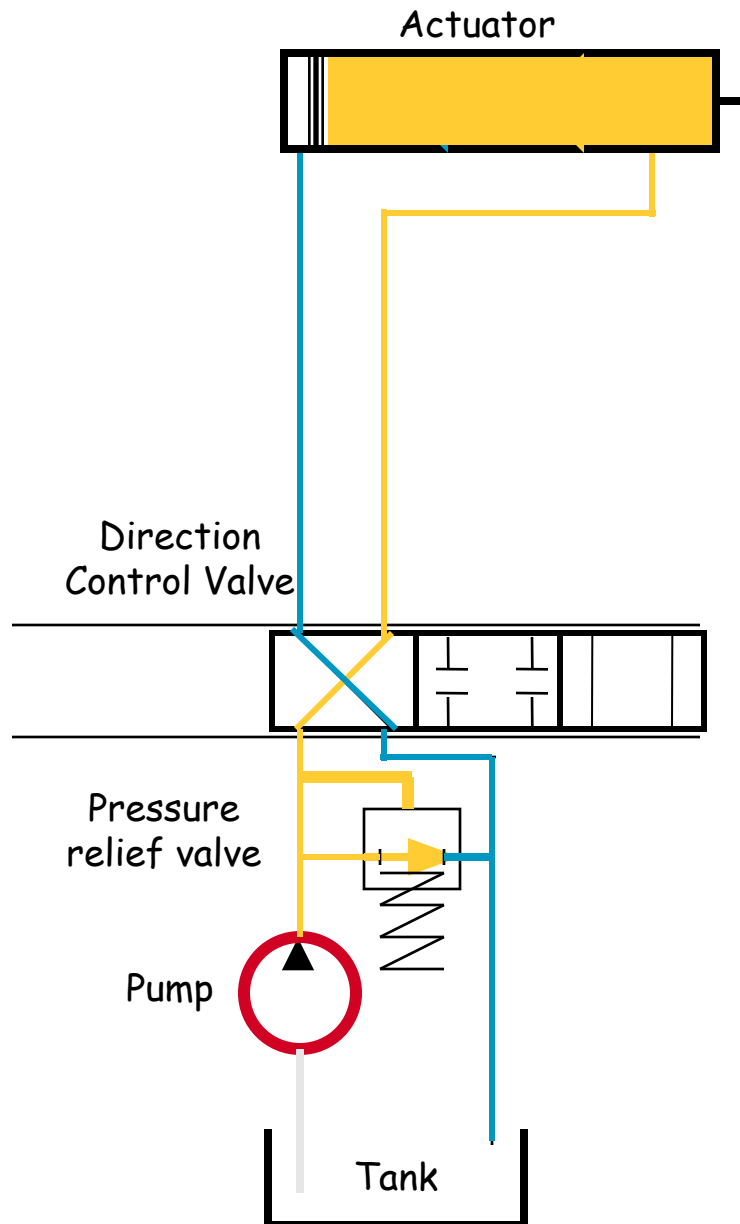
Hydraulic System



Hydraulic System

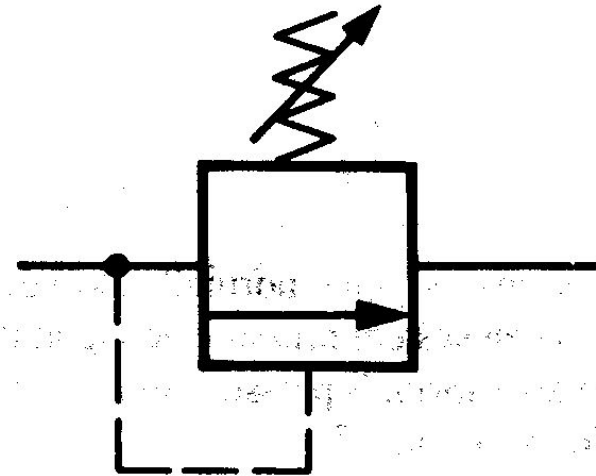
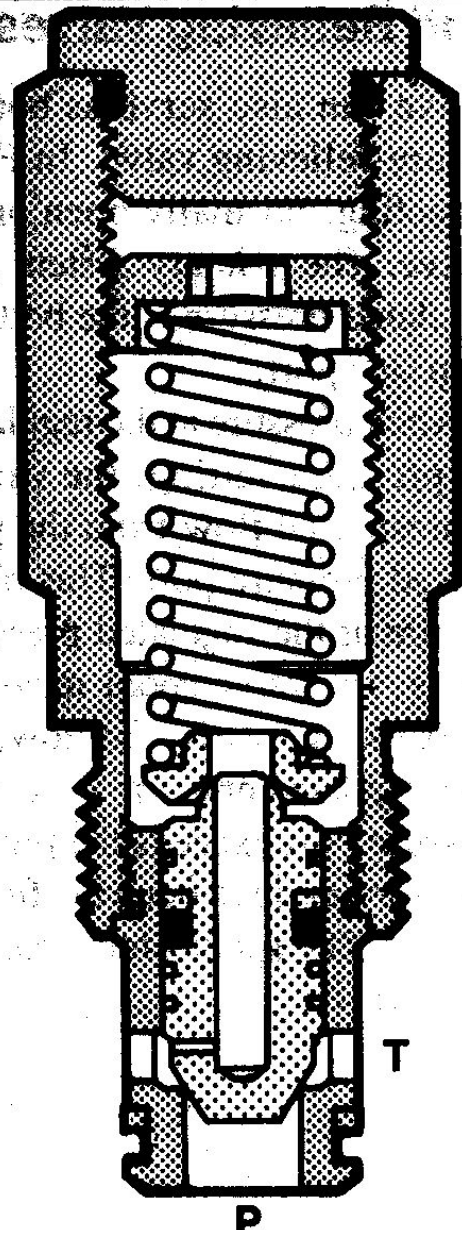


Hydraulic System

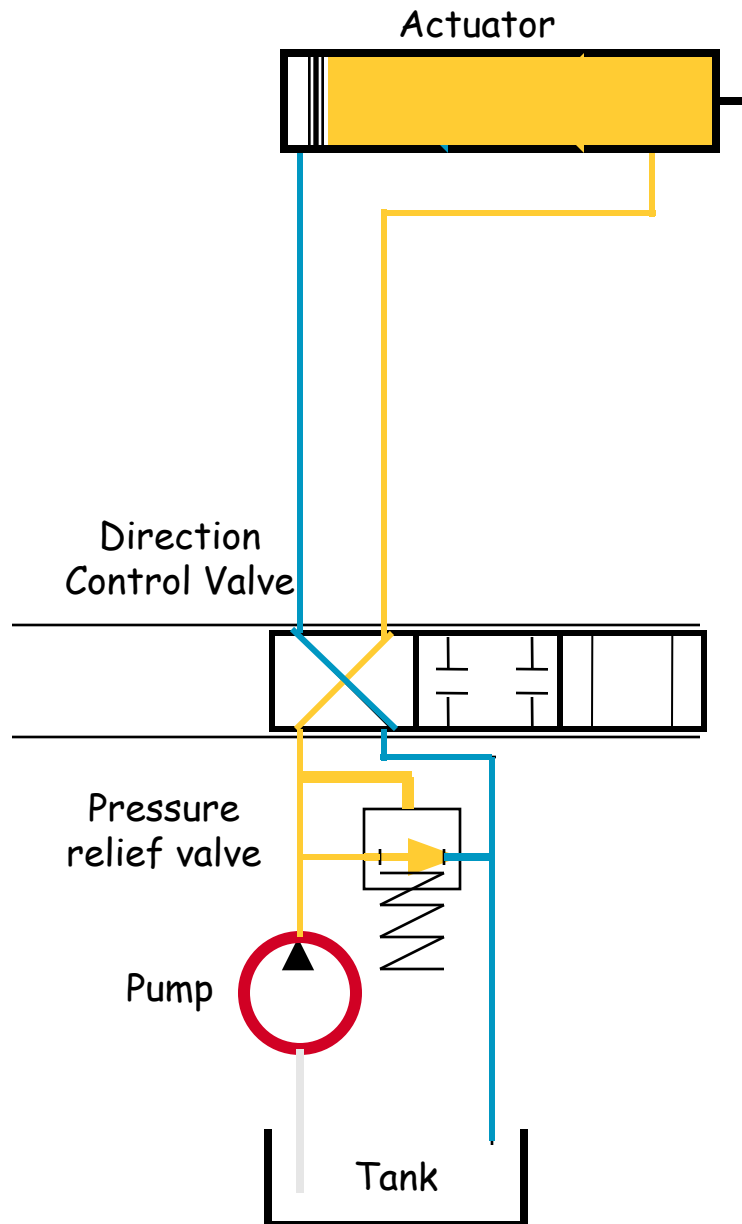


**Stops pressure increasing
beyond the preset value**

Direct acting Relief valve



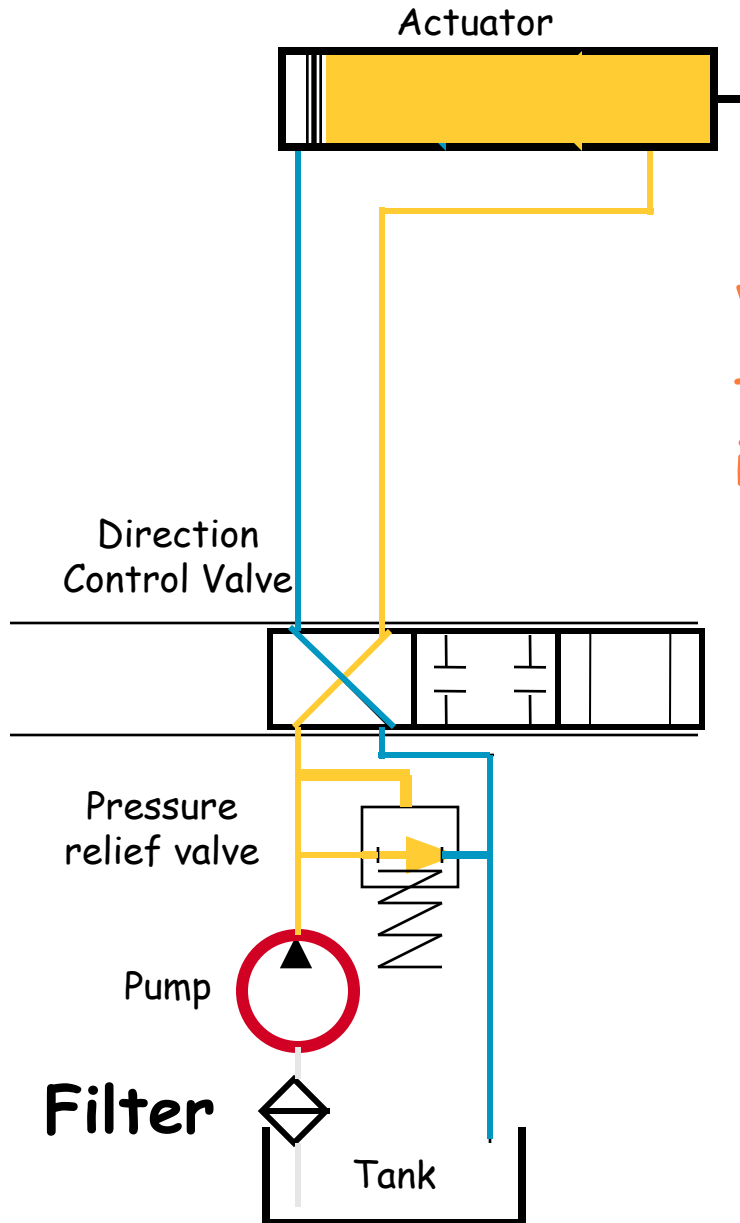
Hydraulic System



Now we have a system
which can work

But is this system protected
from dirt!!!!

Hydraulic System



We need to protect the system from dirt by installing a **FILTER** in the system

We have a system now which can work safely

Is filtration necessary?



- 4 Impurities in the Hydraulic system affect the the components of the hydraulic system and shorten the service life.
- 4 Reduction in service life of the components occur in two ways
 - Wear and Tear
 - Breakdown of component

Filters are used to remove the smallest insoluble particles and keep the hydraulic system clean

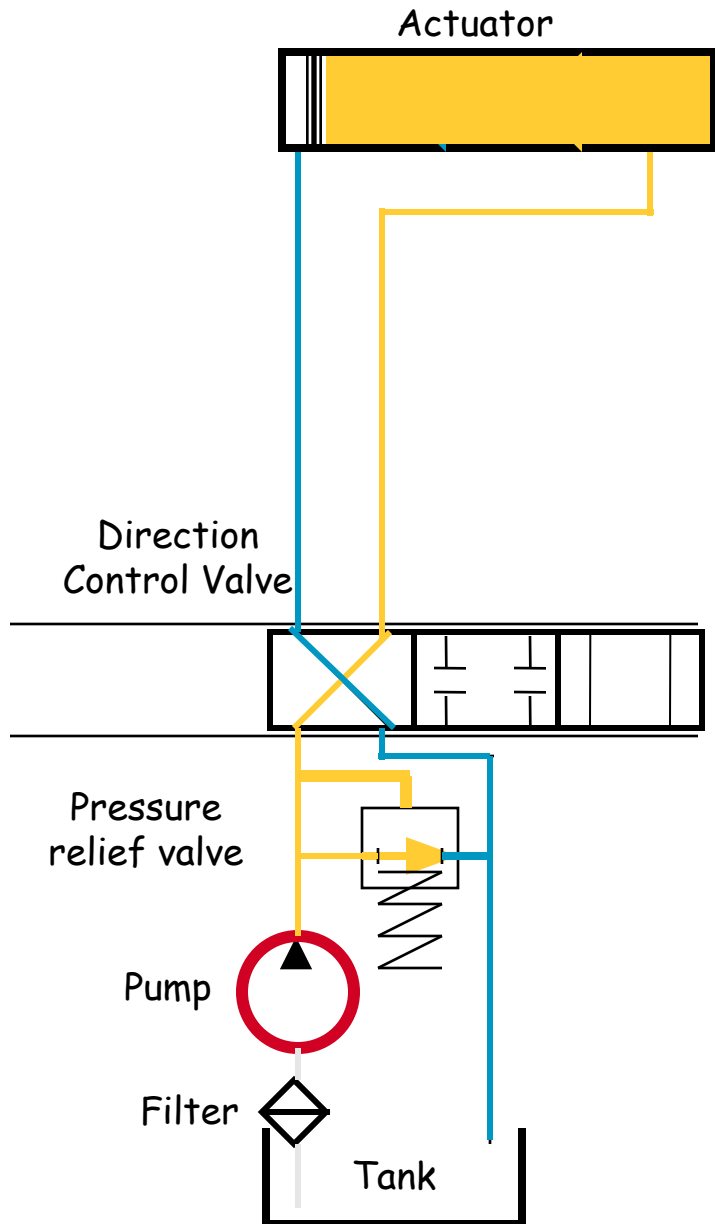
Filters



4 There are basically three types of Filters

- Suction line filters**
- Pressure line filters**
- Return line filters**

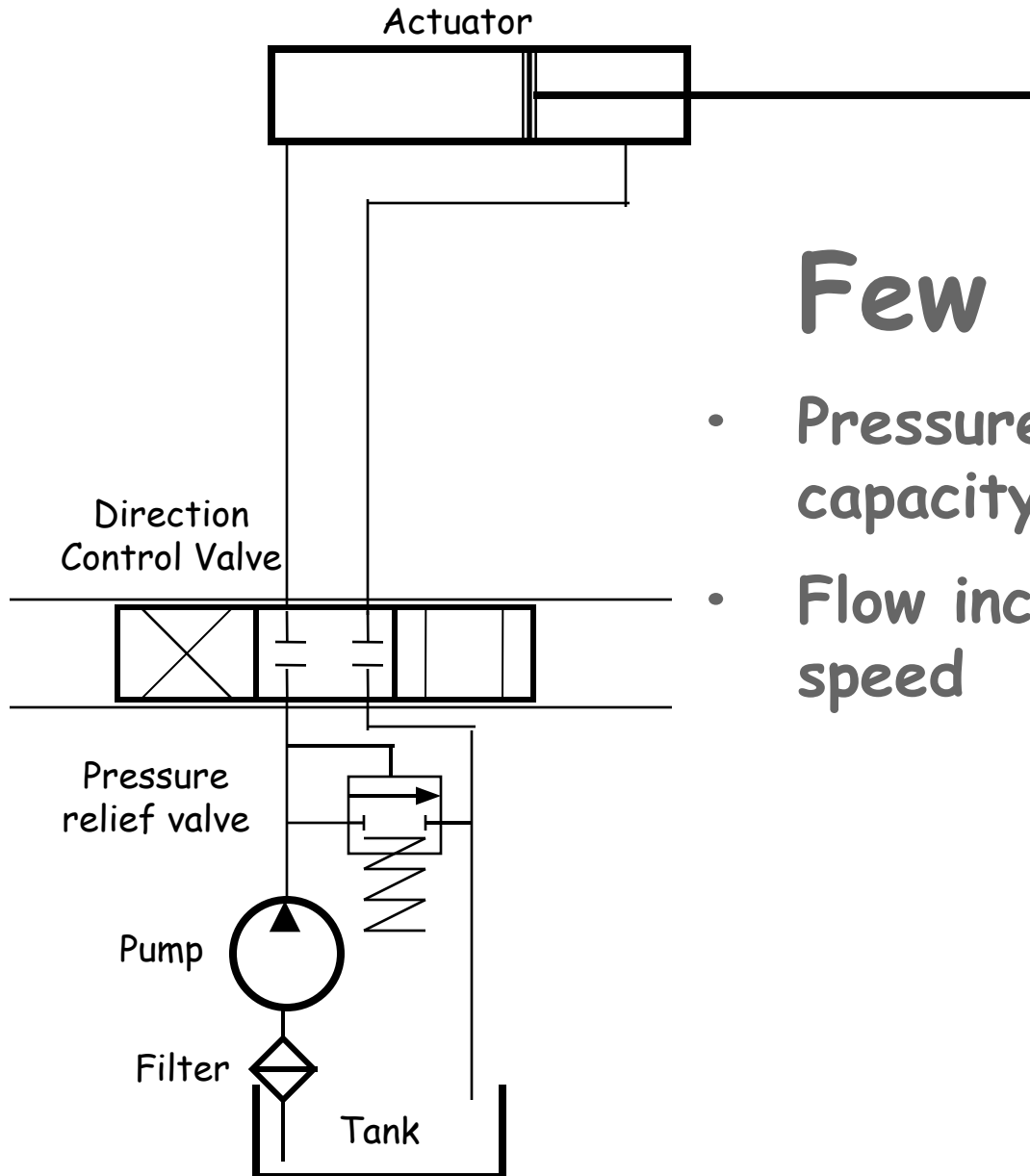
Hydraulic System



Now we know :

- Tank contains oil
- Filter cleans the system
- Pump creates flow
- Resistance creates pressure
- Actuator to perform the work
- Hoses to transmit the oil
- D.C. Valve to change direction of oil flow
- Relief valve to control the maximum system pressure.

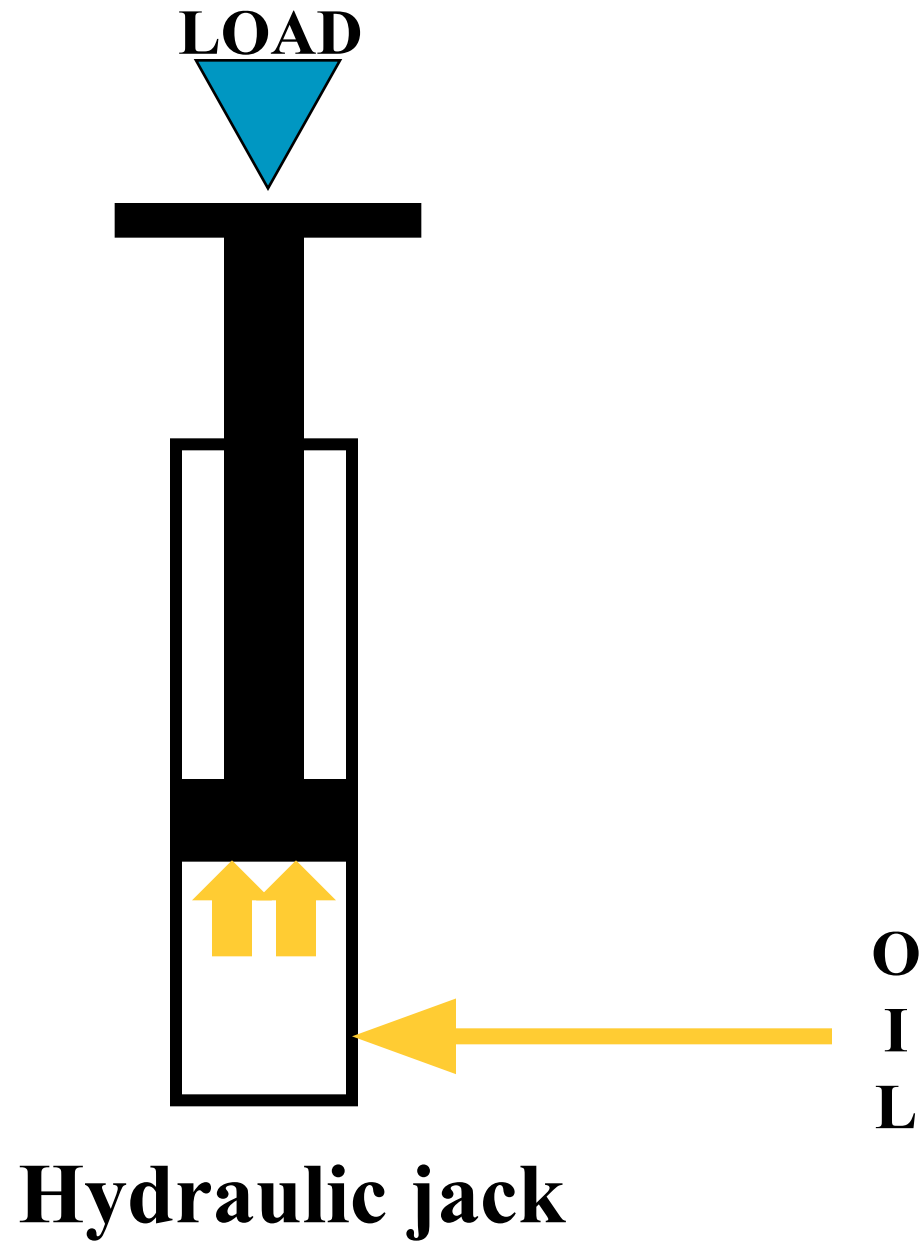
Hydraulic System



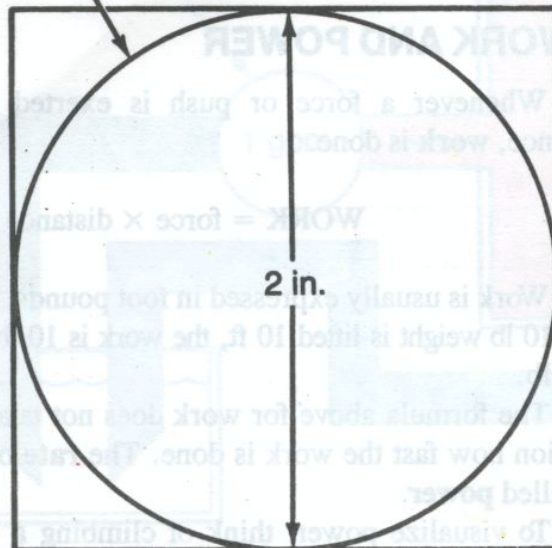
Few more facts :

- Pressure increases the system capacity
- Flow increases the system speed

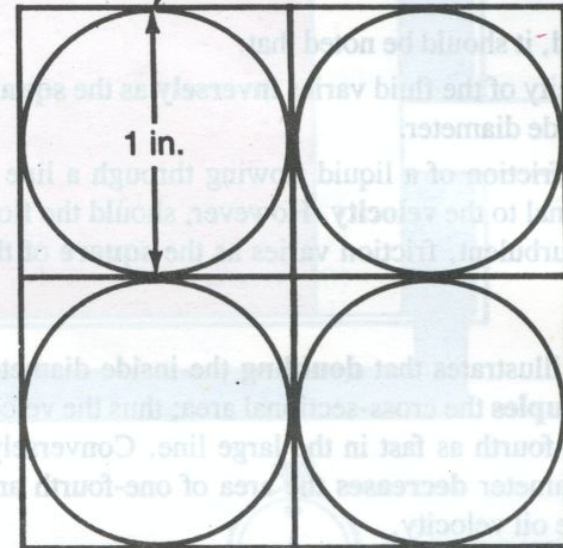
Hydraulic System

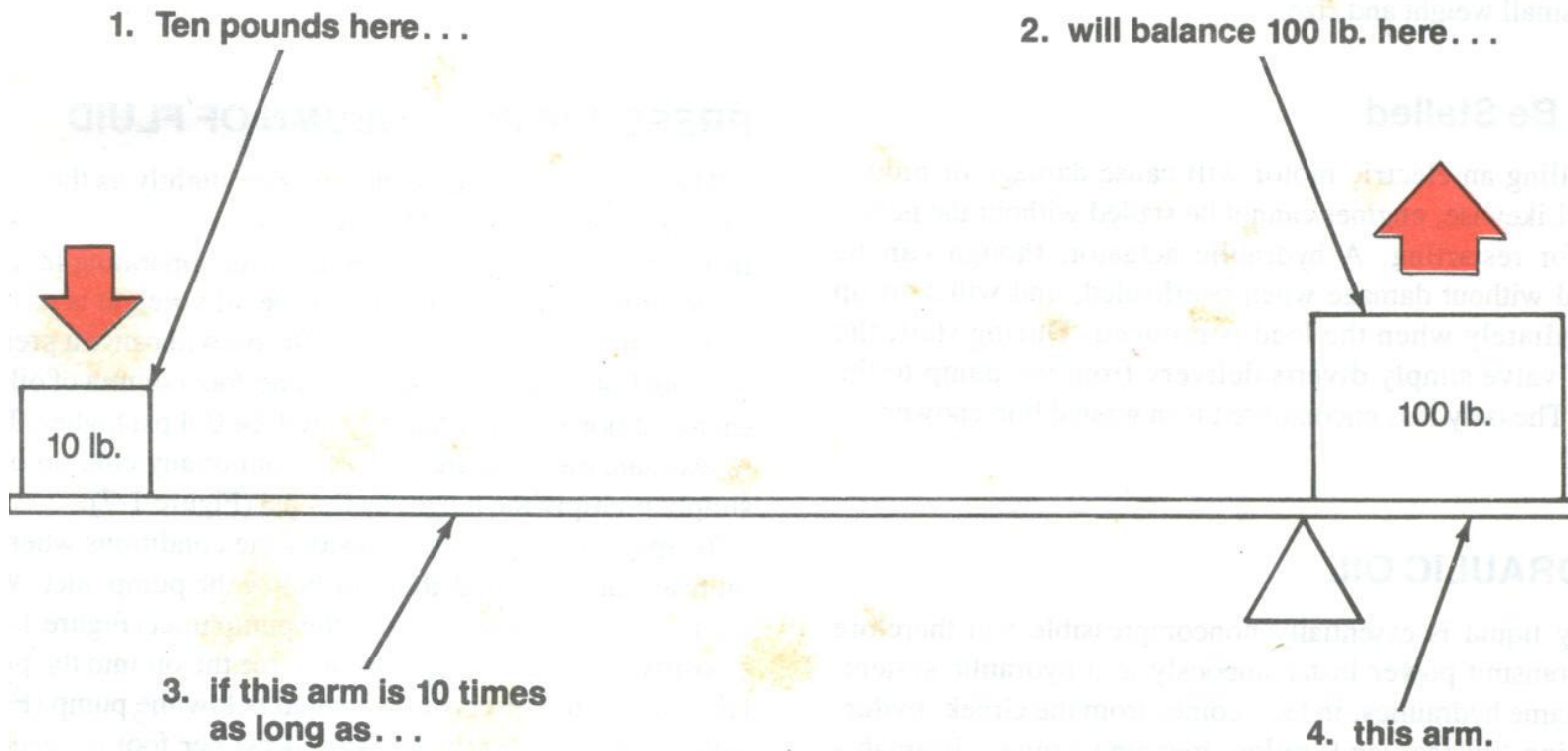


- 1. This pipe is twice the diameter of the smaller pipe.**



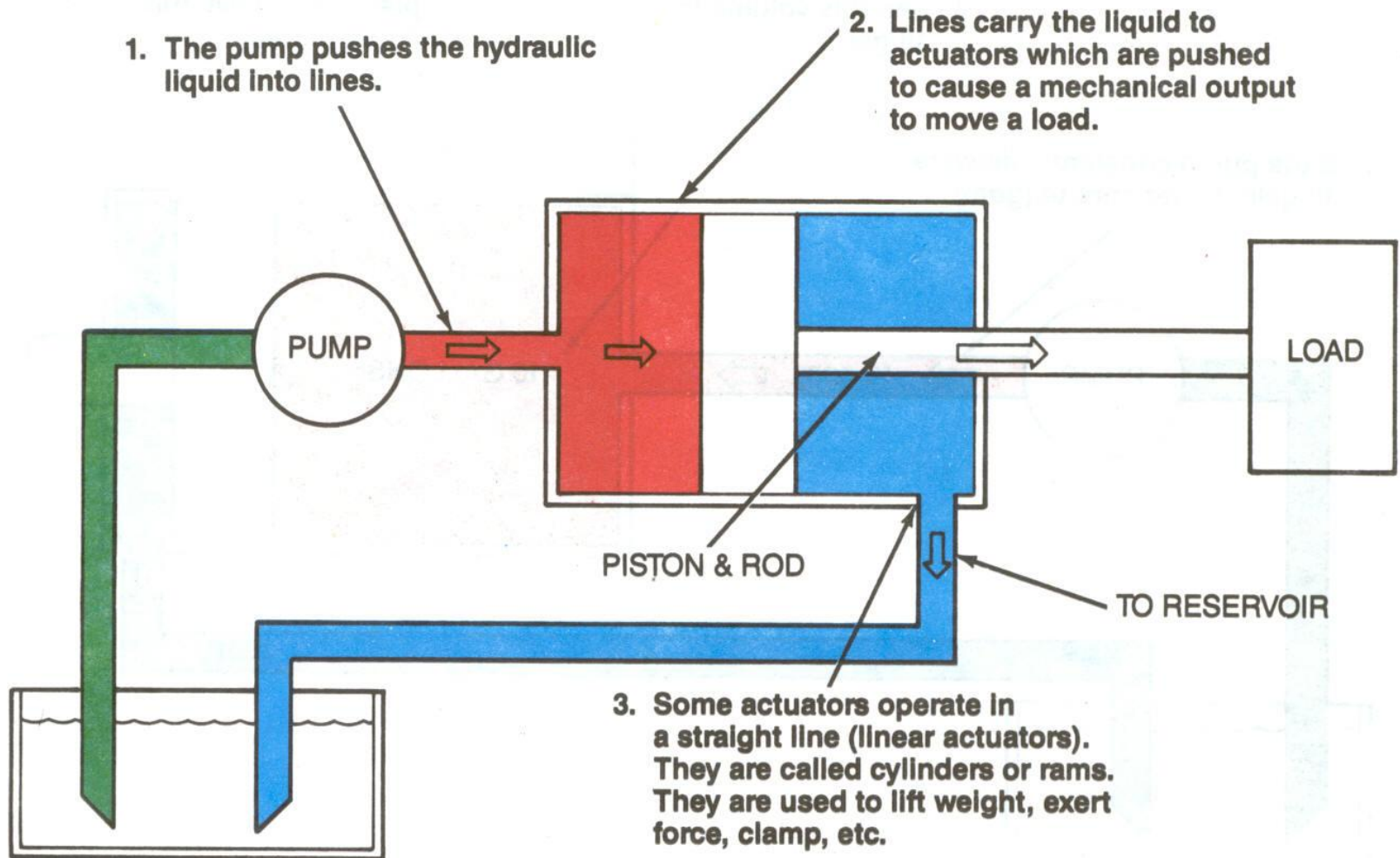
- 2. It would take four pipes this size to equal the cross-sectional area of the large pipe.**





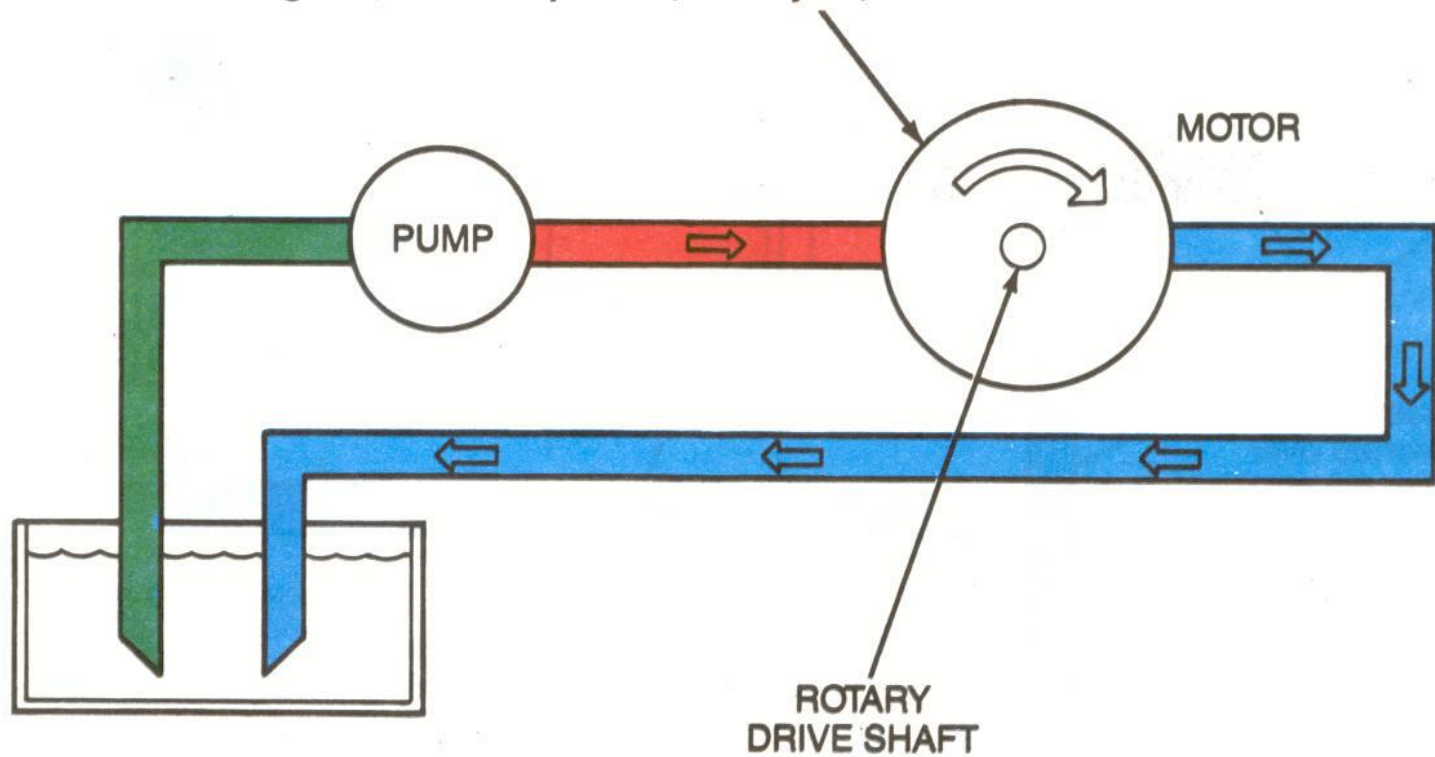
B. SIMPLE MECHANICAL LEVER

Figure 1-2. Hydraulic leverage.



A. LINEAR ACTUATOR

4. Rotary actuators or motors give the system rotating output. They can be connected to pulleys, gears, rack-and-pinions, conveyors, etc.



B. ROTARY ACTUATOR

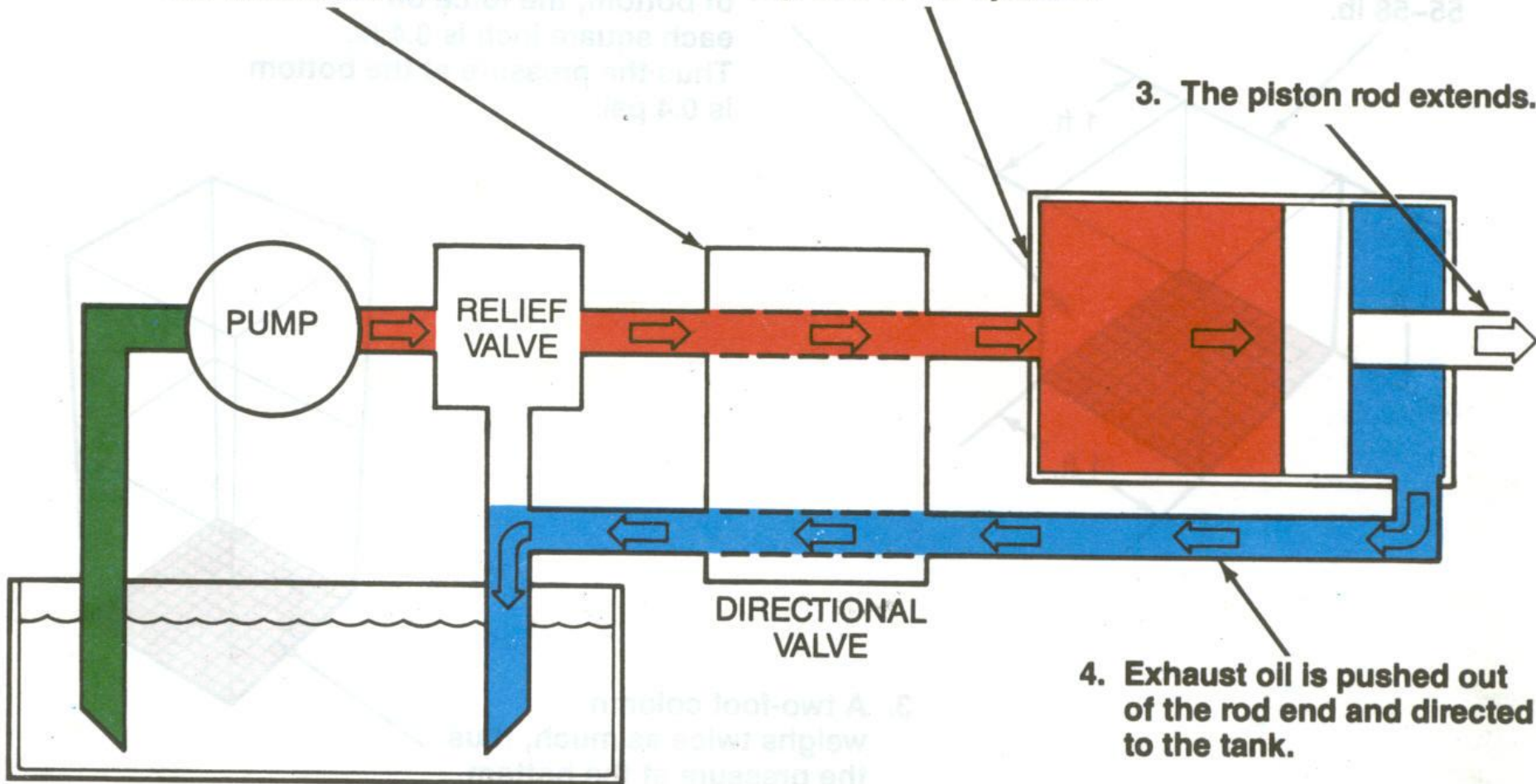
Figure 1-4. Hydraulic power transmission.

1. In this position of the directional valve...

2. pump delivery is directed to the cap end of the cylinder.

3. The piston rod extends.

4. Exhaust oil is pushed out of the rod end and directed to the tank.



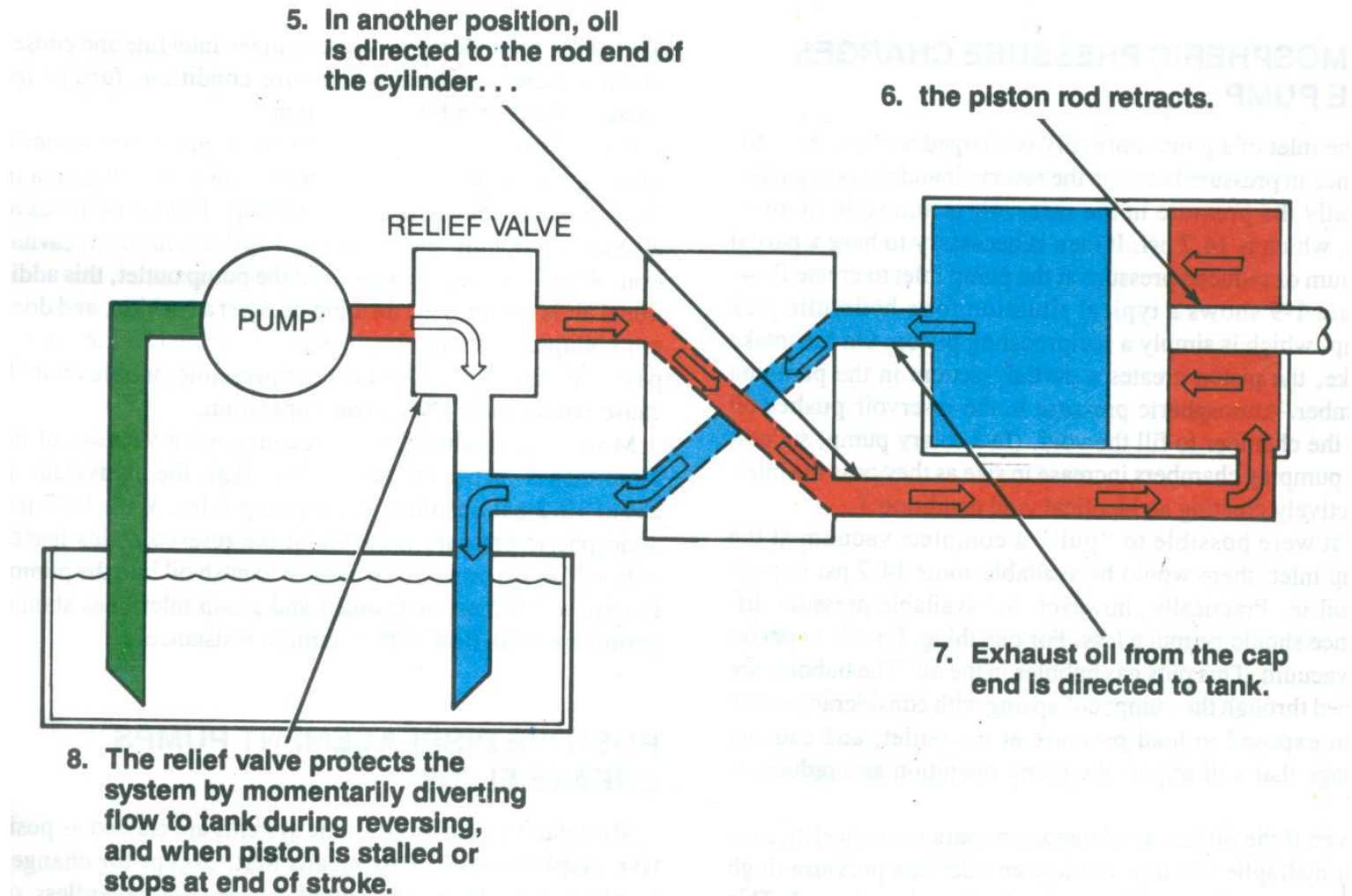
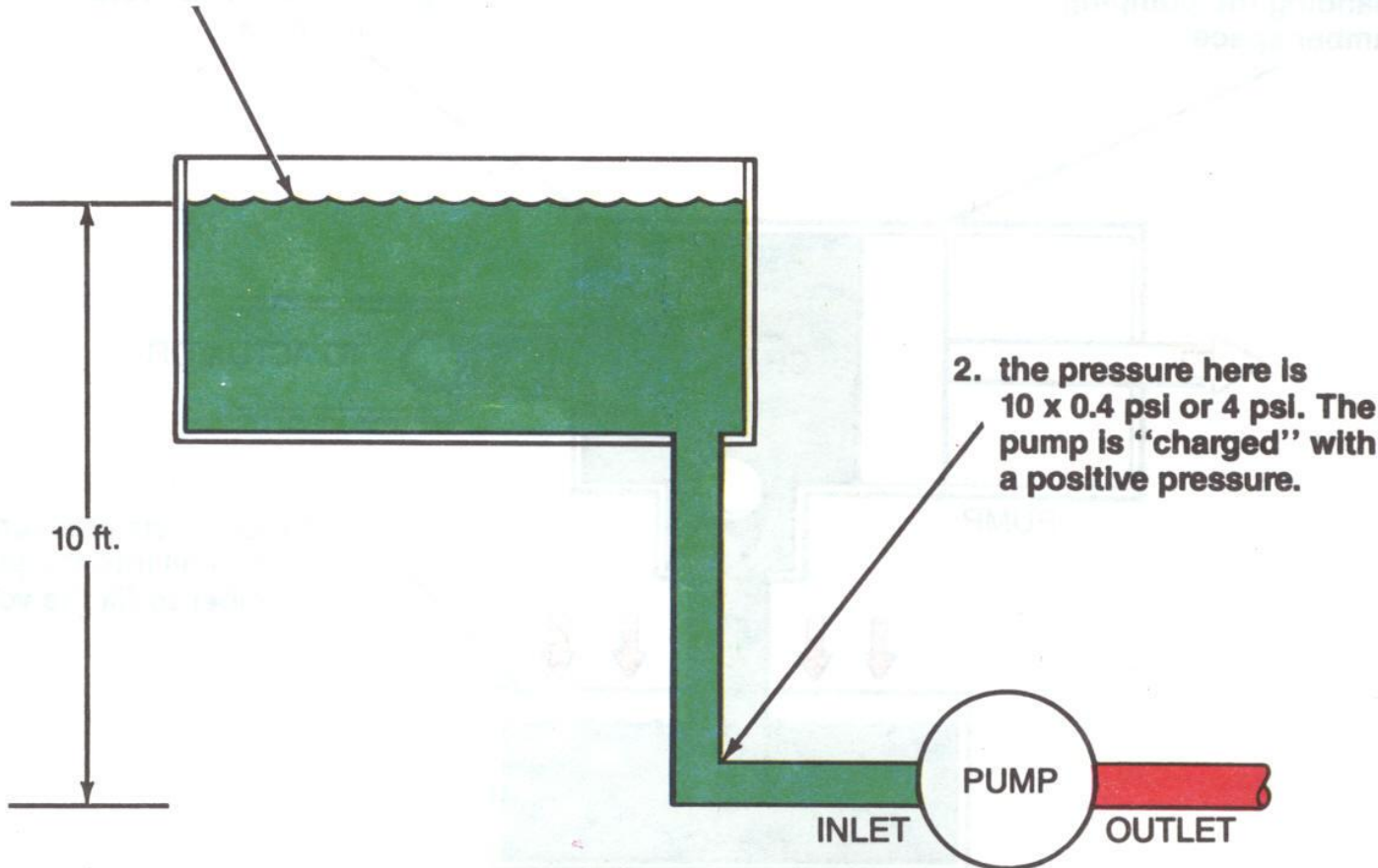
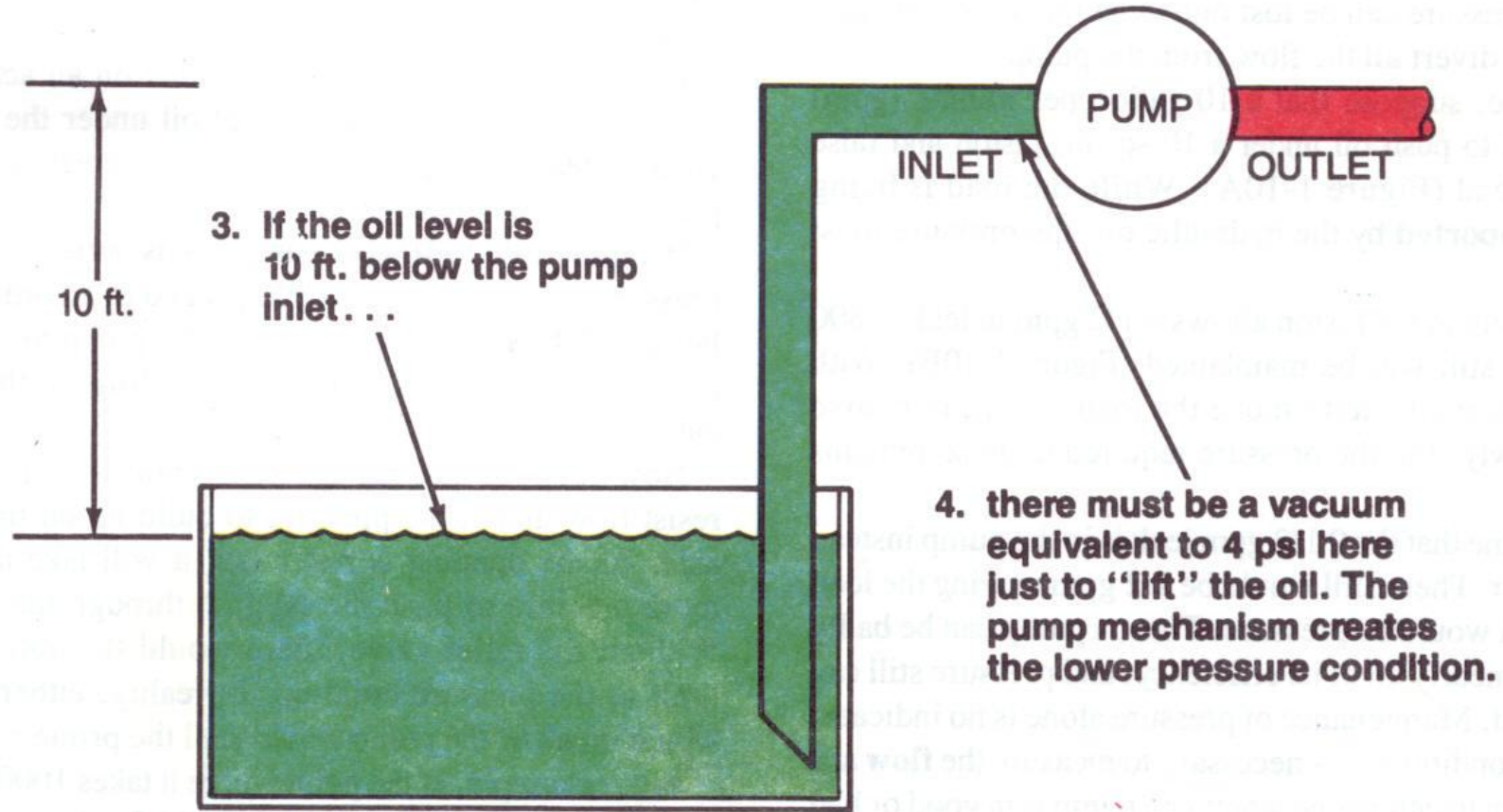


Figure 1-6. Hydraulic drives are reversible.

1. If the oil level is 10 ft. above the pump inlet...



A. OIL LEVEL ABOVE PUMP CHARGES INLET



B. OIL LEVEL BELOW REQUIRES VACUUM TO "LIFT" OIL

Figure 1-8. Pump inlet locations.

On its intake stroke, the pump piston moves out expanding the pumping chamber space.

2. A partial vacuum or void is created here.

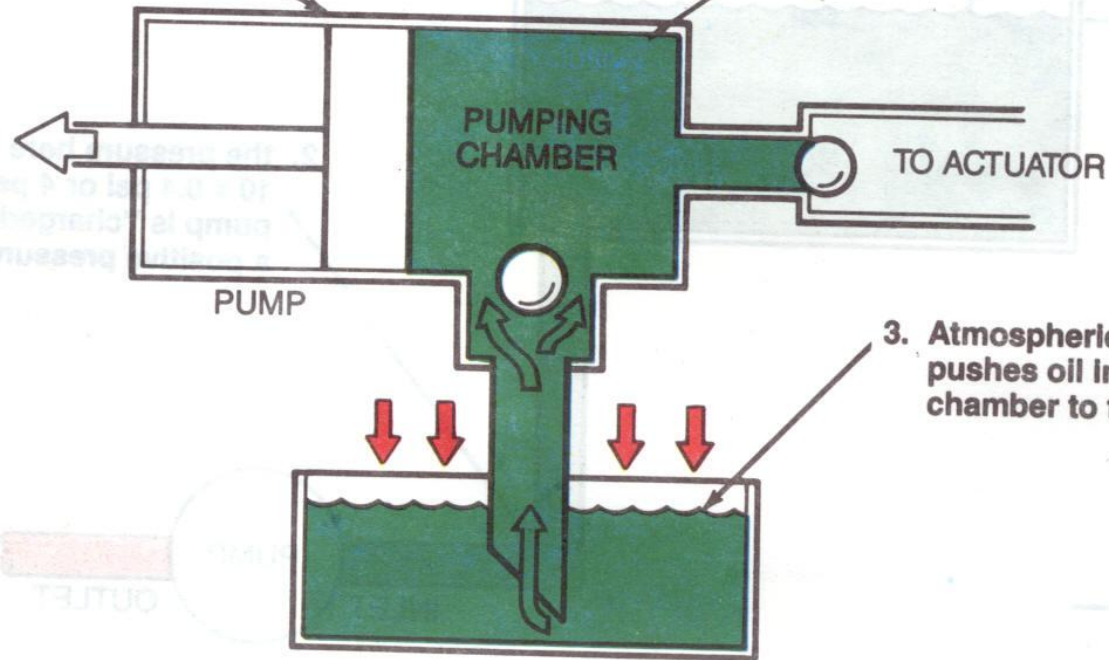
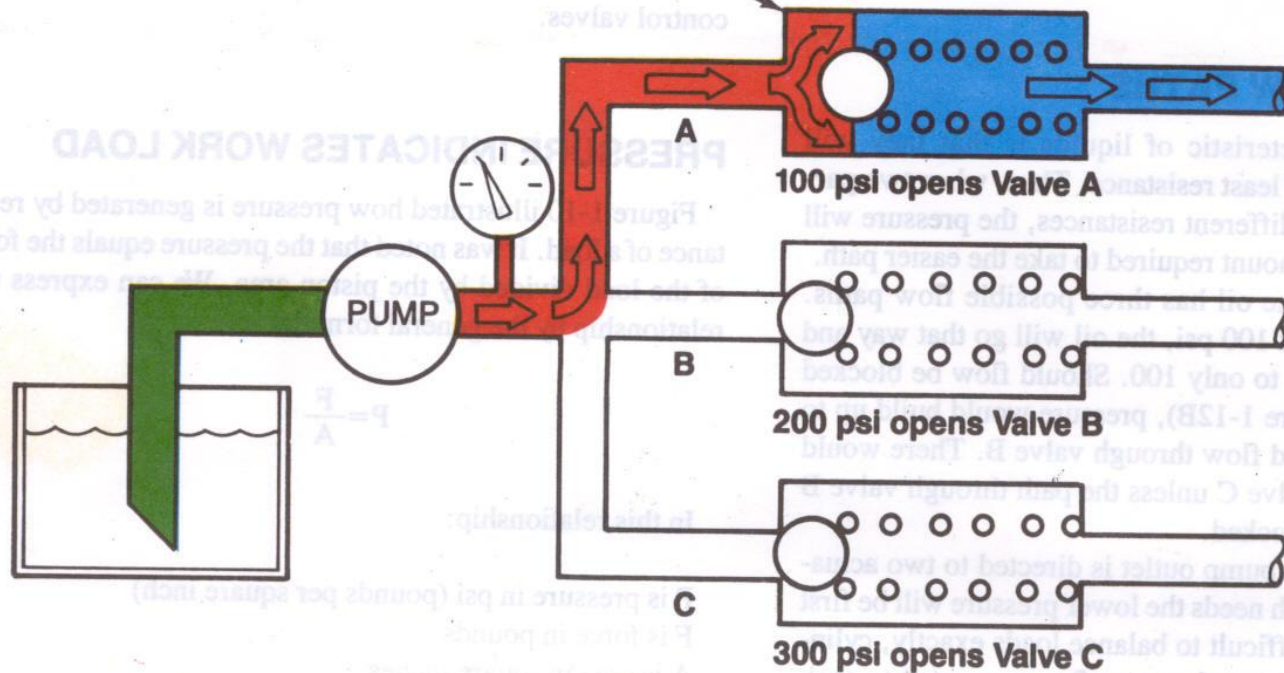


Figure 1-9. Pressure difference pushes oil into pump.

1. The oil can choose three paths.
2. It first chooses Valve A because only 100 psi is required. A pressure gauge at the pump will read 100 psi.



A. FLOW IS THROUGH 100 psi VALVE

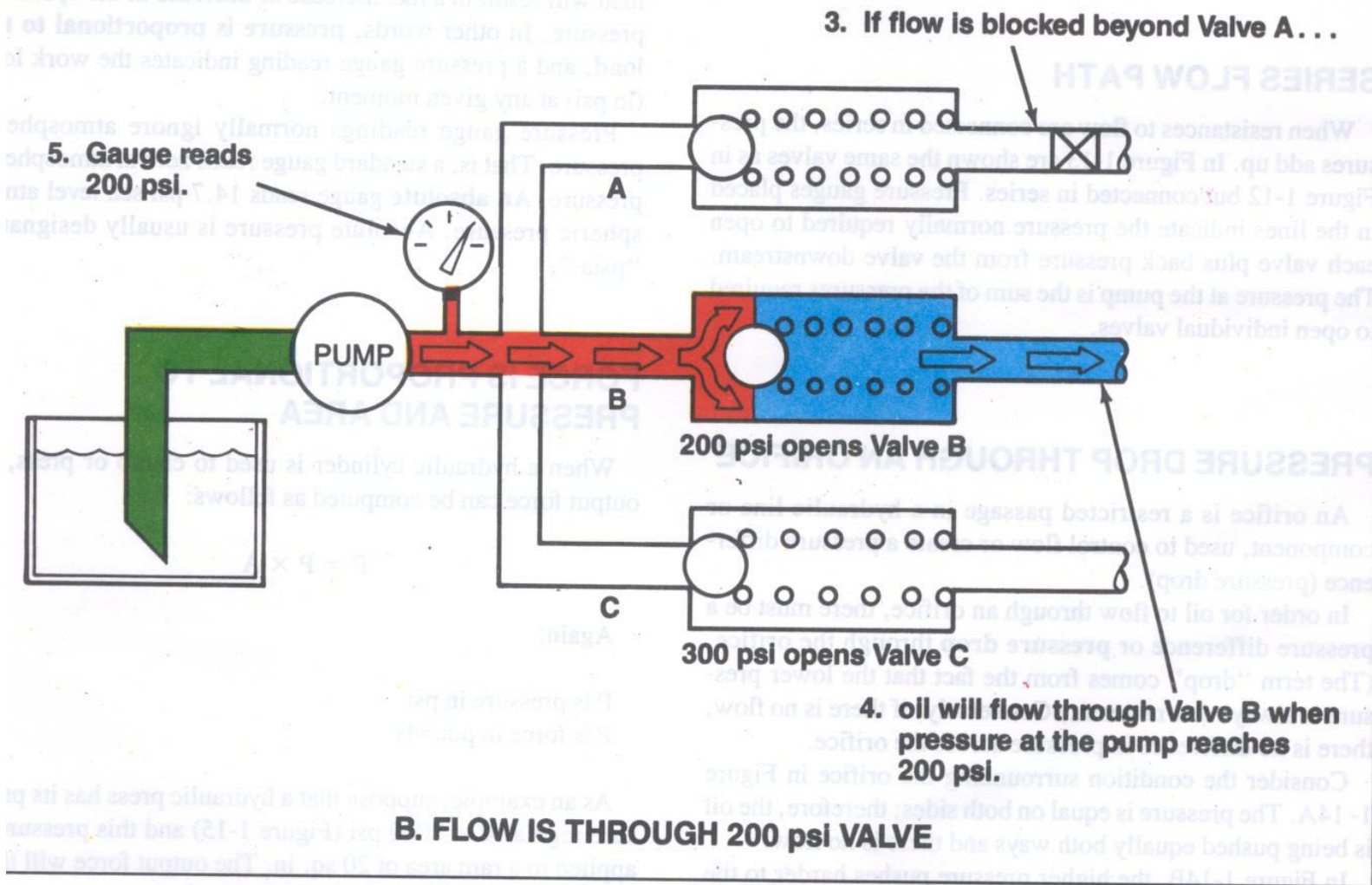


Figure 1-12. Parallel flow paths.

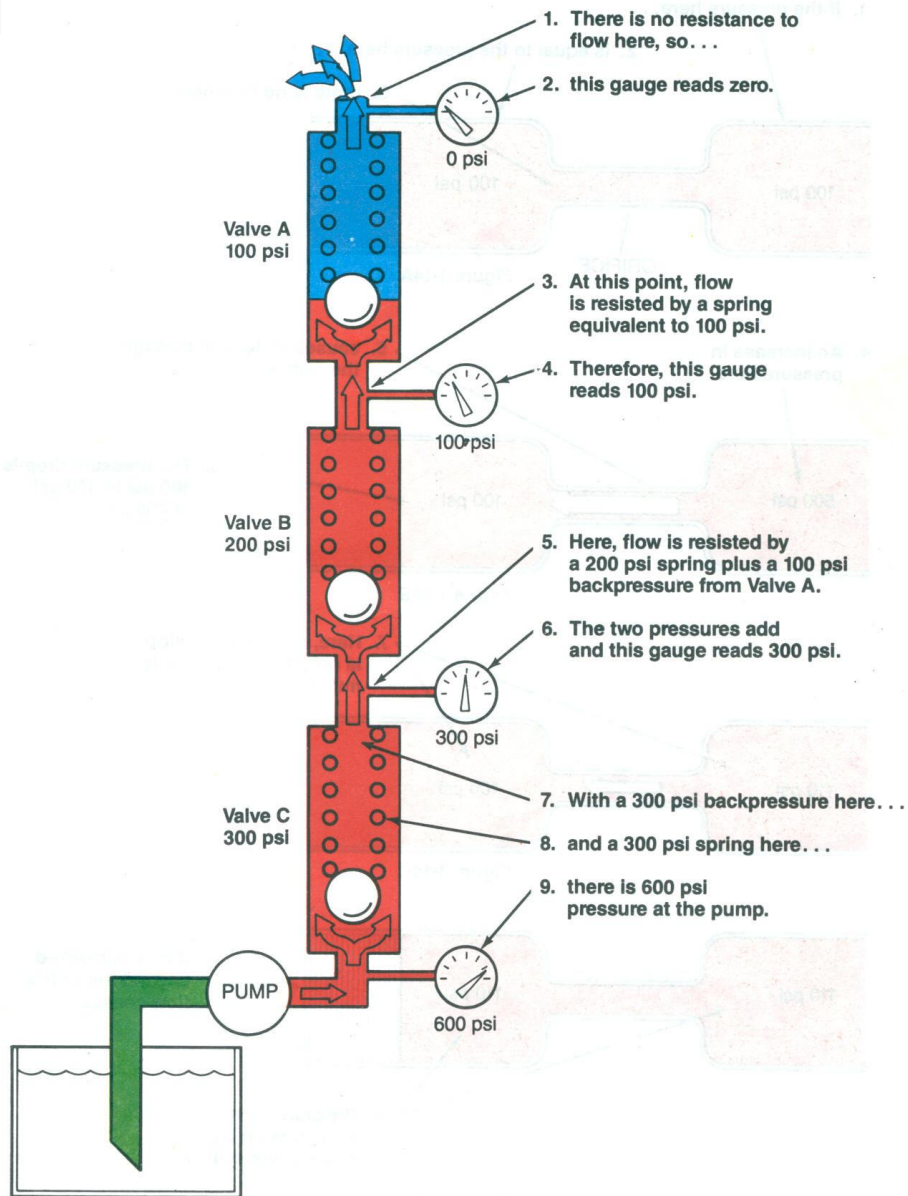


Figure 1-13. Series resistances add pressure.

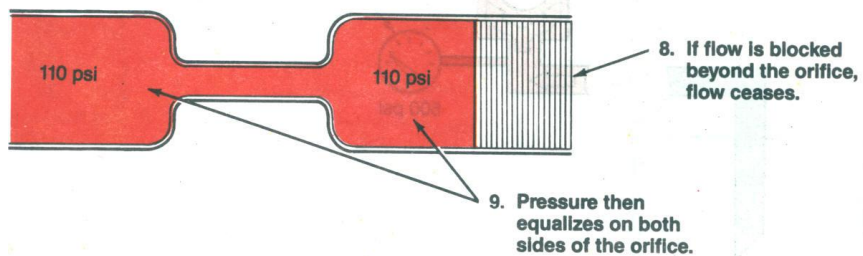
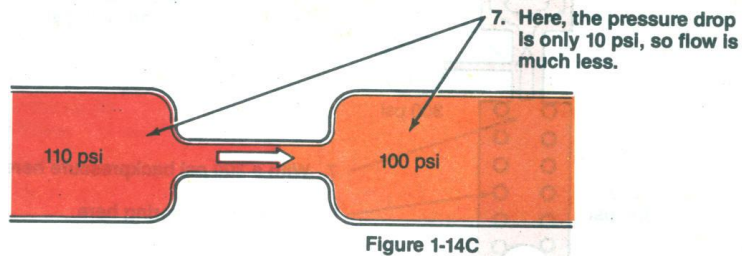
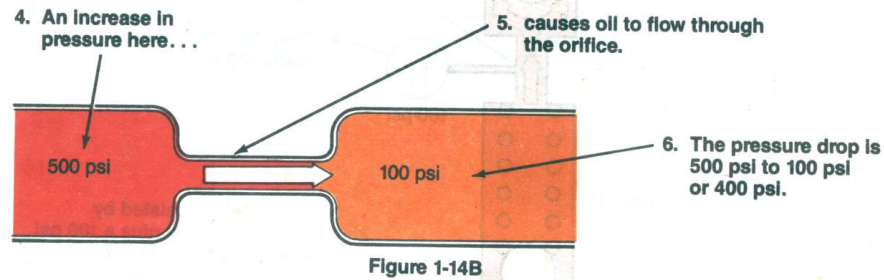
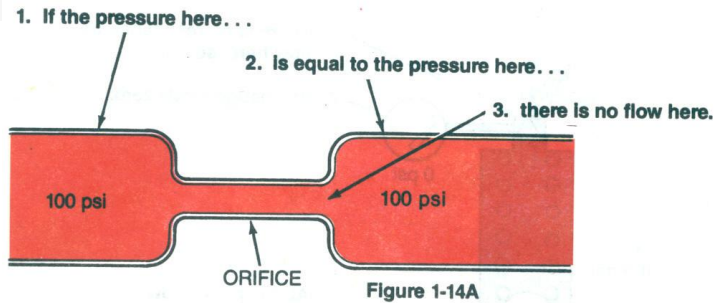


Figure 1-14. Pressure drop and flow through an orifice.

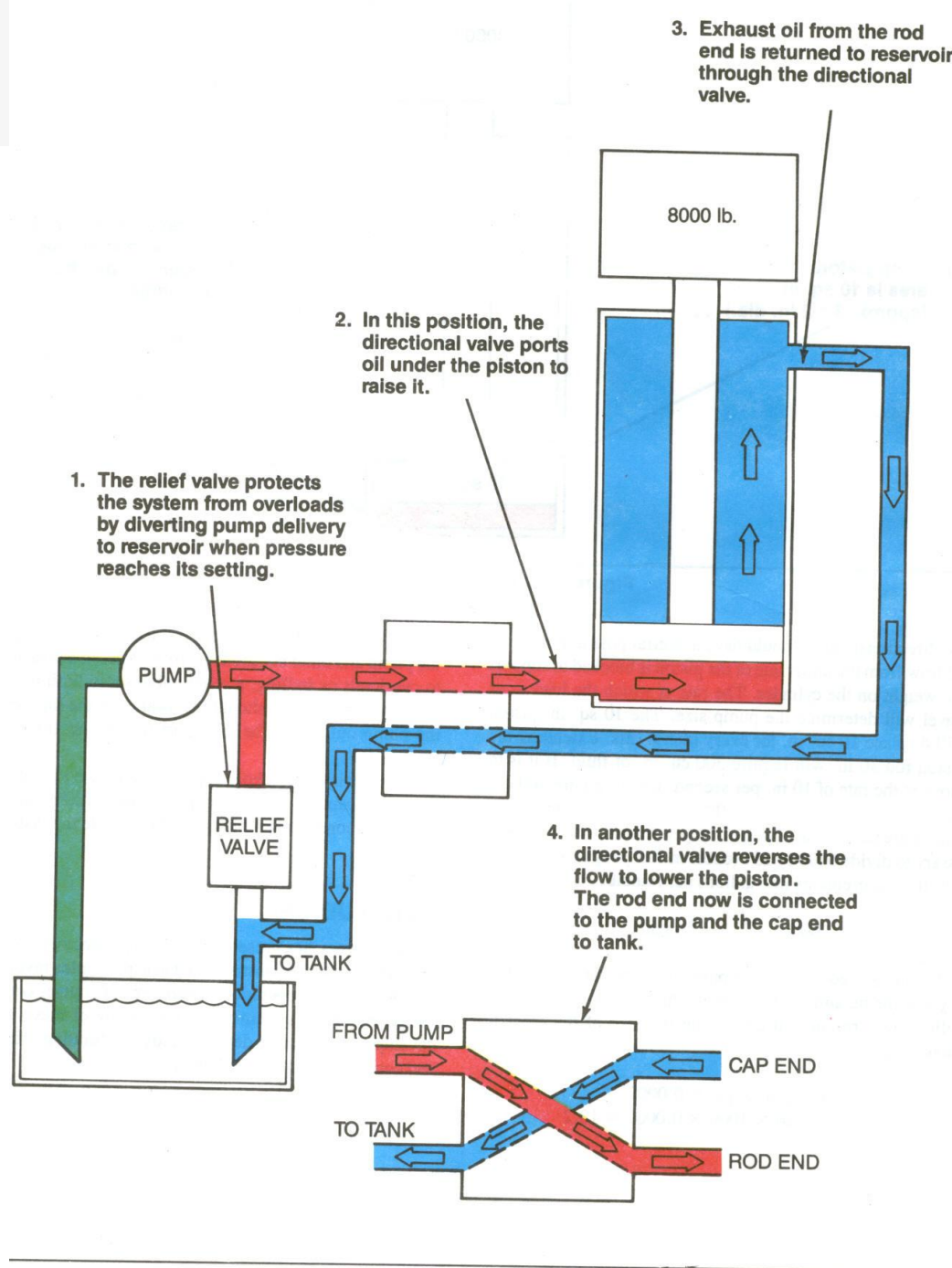


Figure 1-21. Valving to protect and control the system.

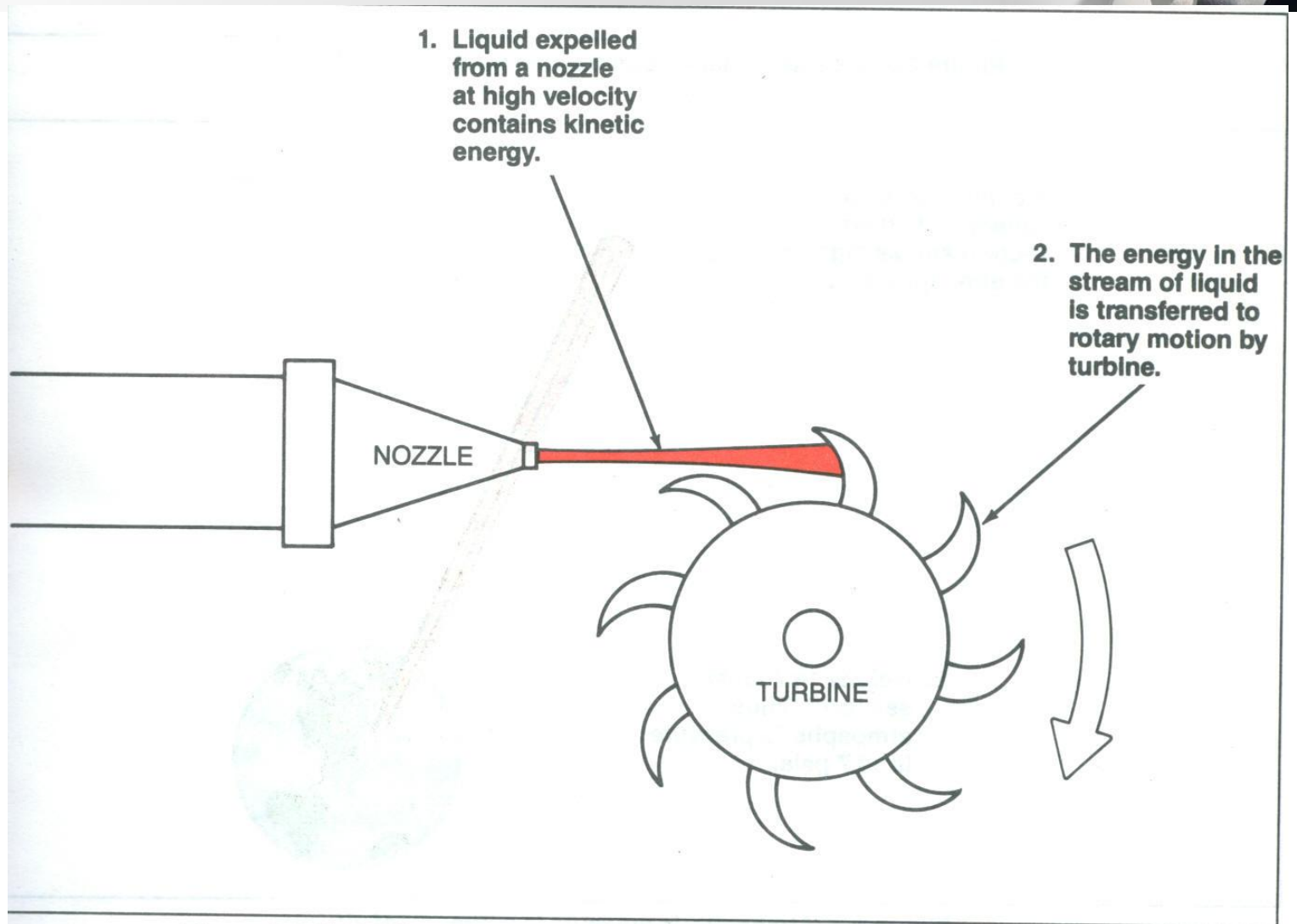
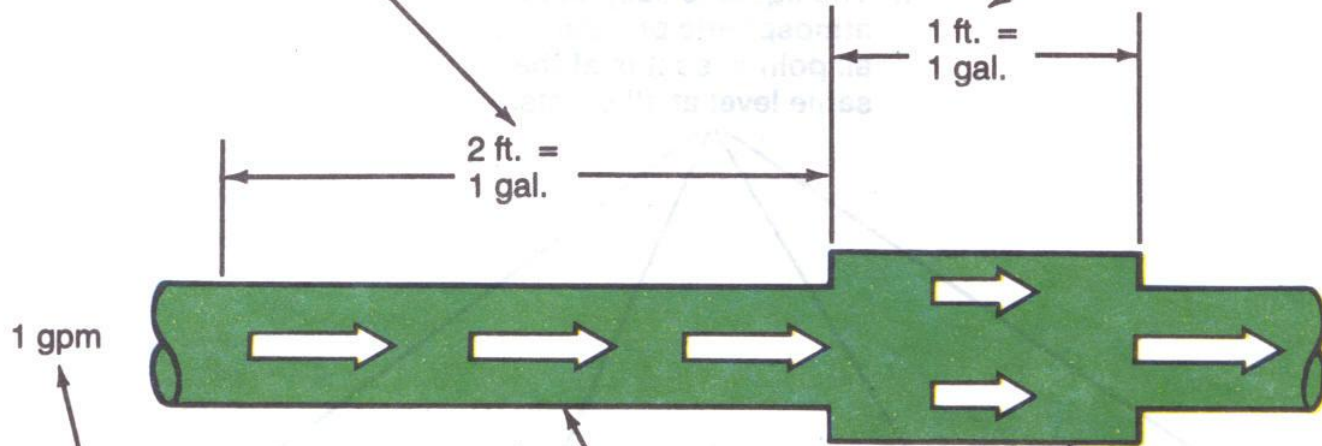


Figure 2-1. Hydrodynamic device uses kinetic energy rather than pressure.

1. It takes two feet of the small pipe to hold one gallon of oil...

2. but only one foot of the large pipe.



1 gpm

2 ft. =
1 gal.

1 ft. =
1 gal.

3. With a constant flow rate of one gpm...

4. the oil must travel two fpm in this pipe...

5. but must travel only one fpm in this pipe.

Figure 2-6. Flow is volume per unit of time; velocity is distance per unit of time.

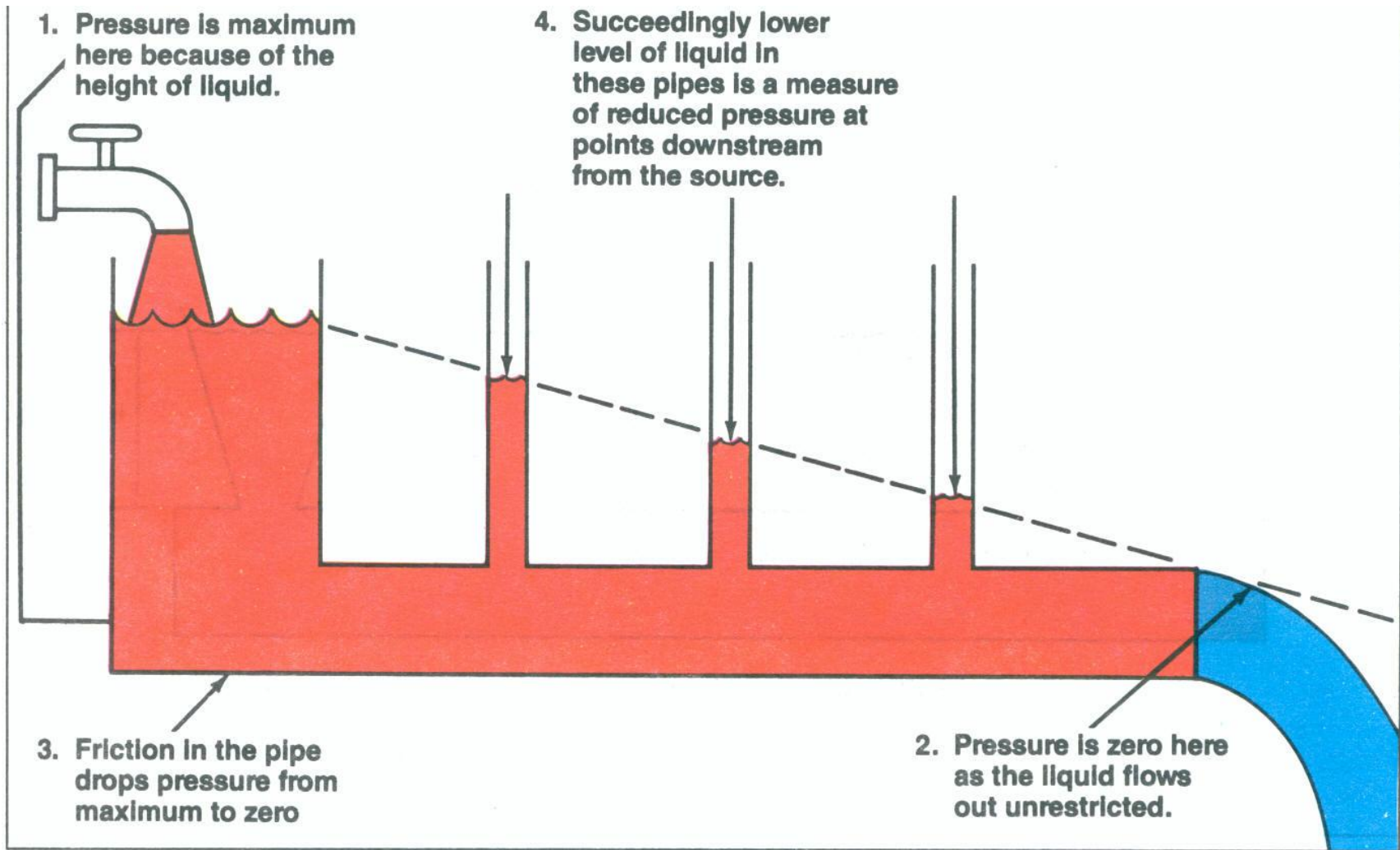
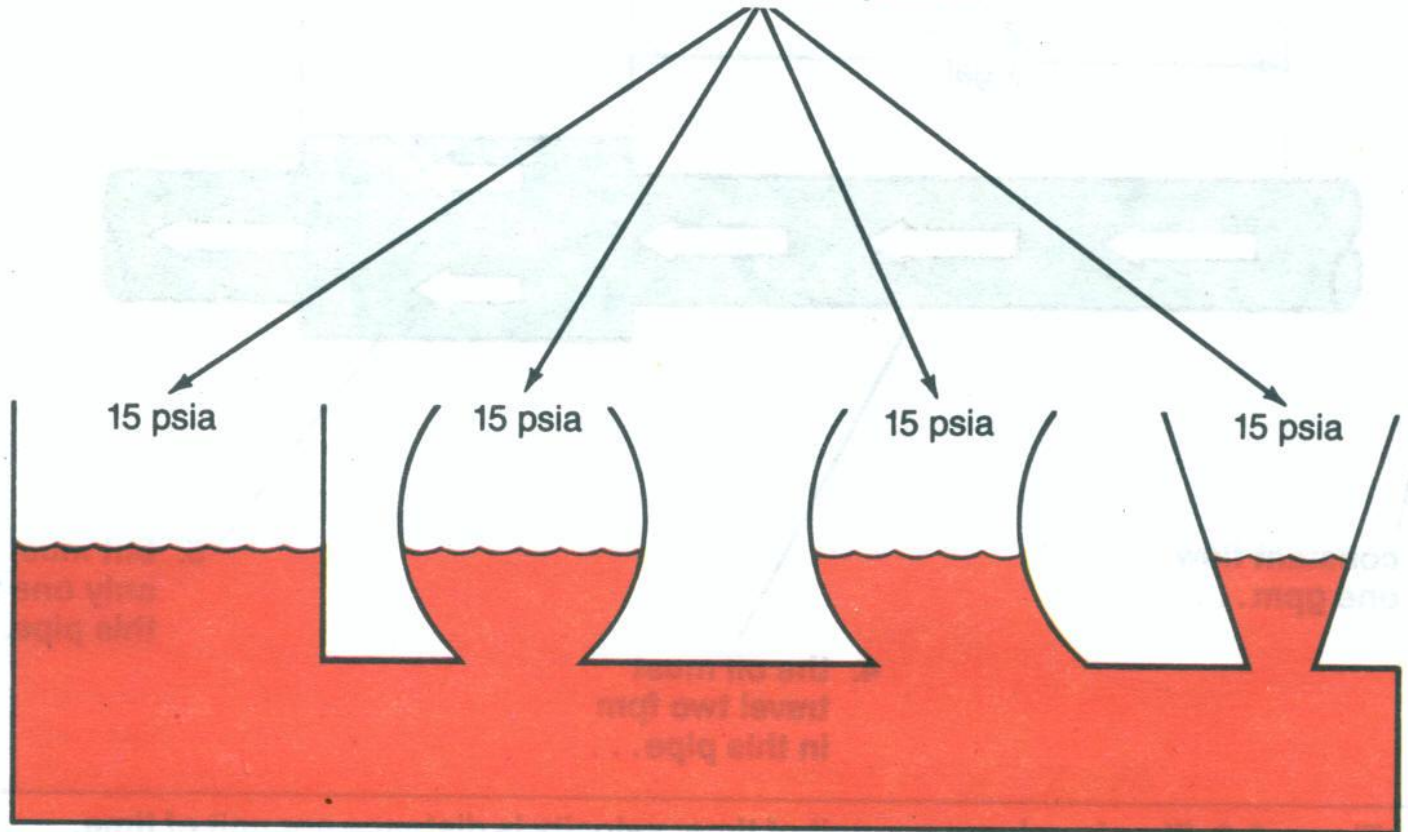


Figure 2-7. Friction in pipes results in a pressure drop.

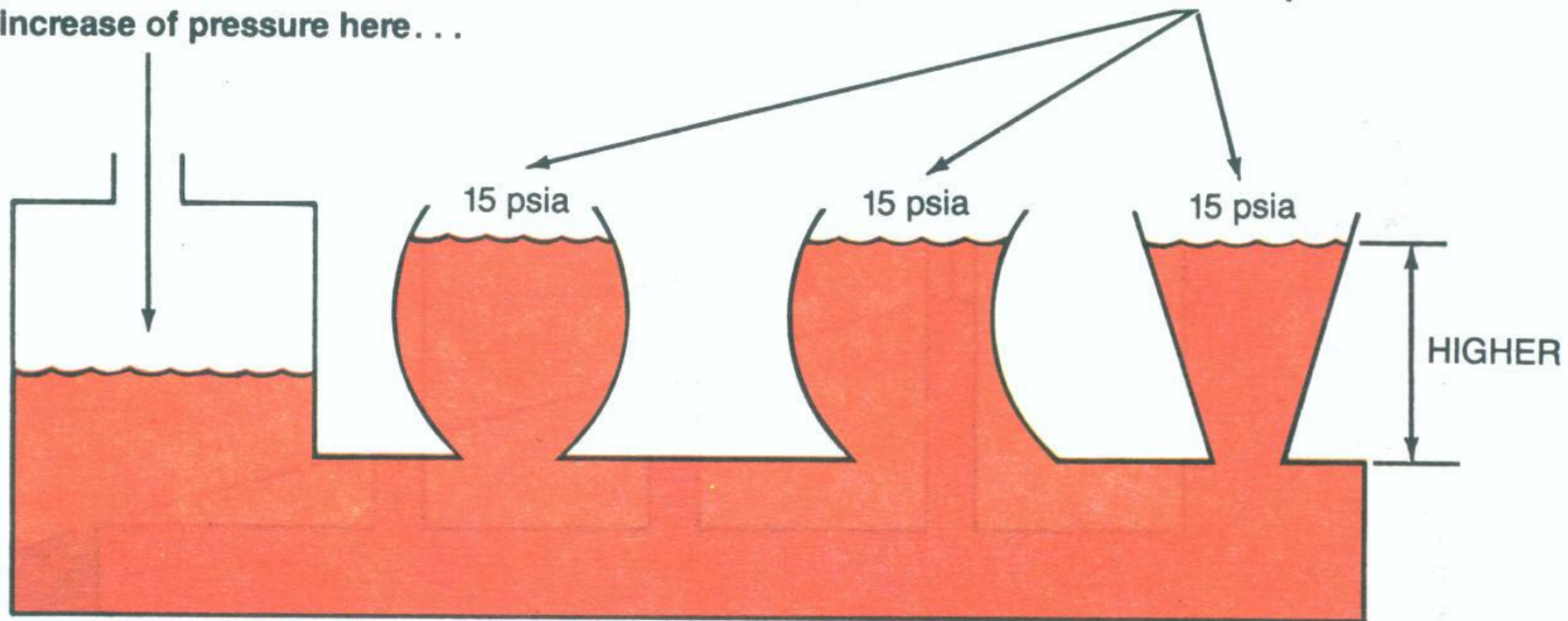
1. The liquid is subject to atmospheric pressure at all points, so it is at the same level at all points.



A. NO DIFFERENCE IN PRESSURE

2. An increase of pressure here . . .

3. results in a higher level at these points.



B. PRESSURE INCREASED AT ONE POINT

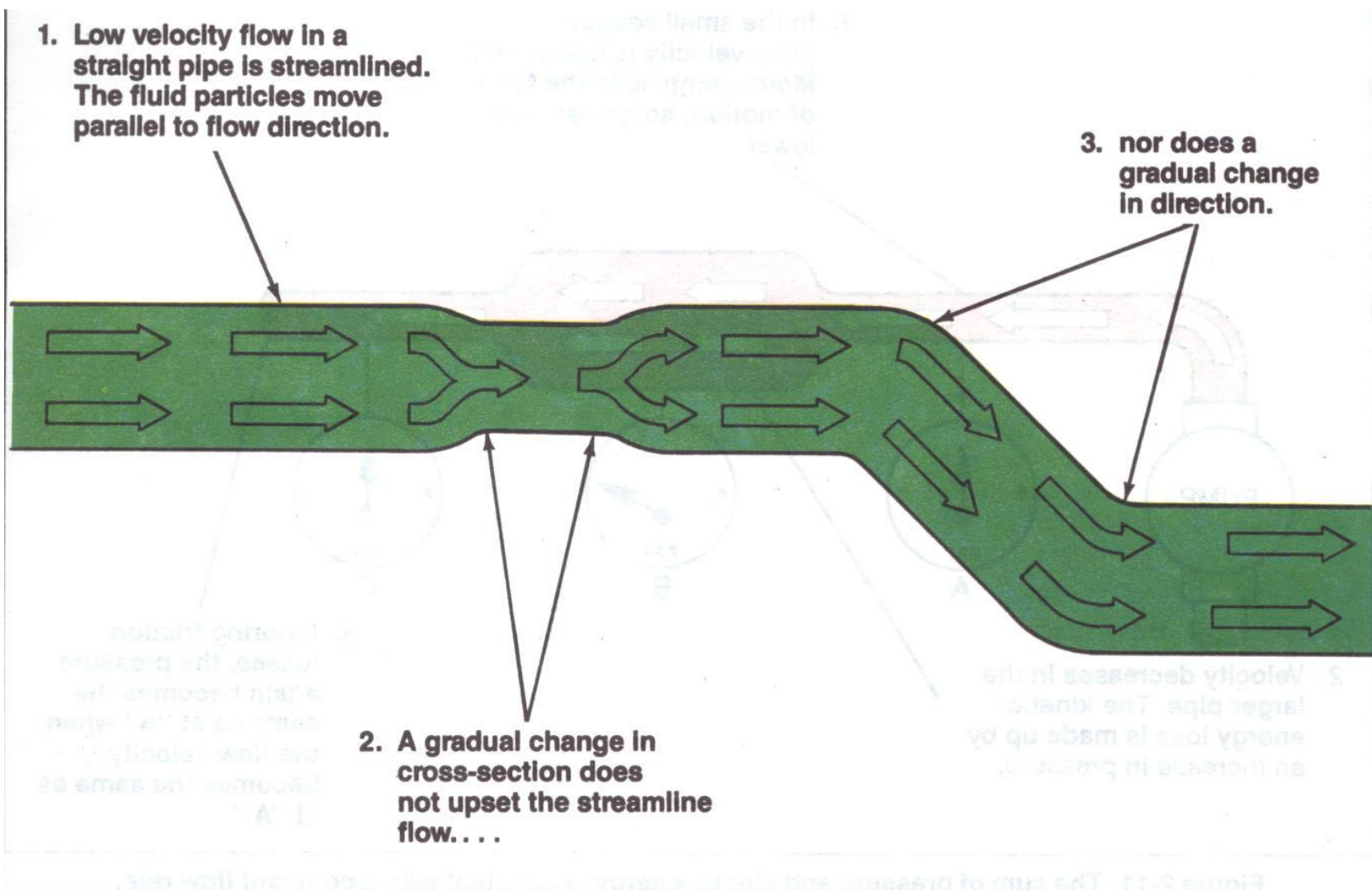


Figure 2-9. Laminar flow is in parallel paths.

1. The flow may start out streamlined.

2. An abrupt change in cross-section makes it turbulent.

3. So does an abrupt change in direction.

4. Nonparallel paths of particles increase resistance to flow (friction).

Figure 2-10. Turbulence results in flow resistance.

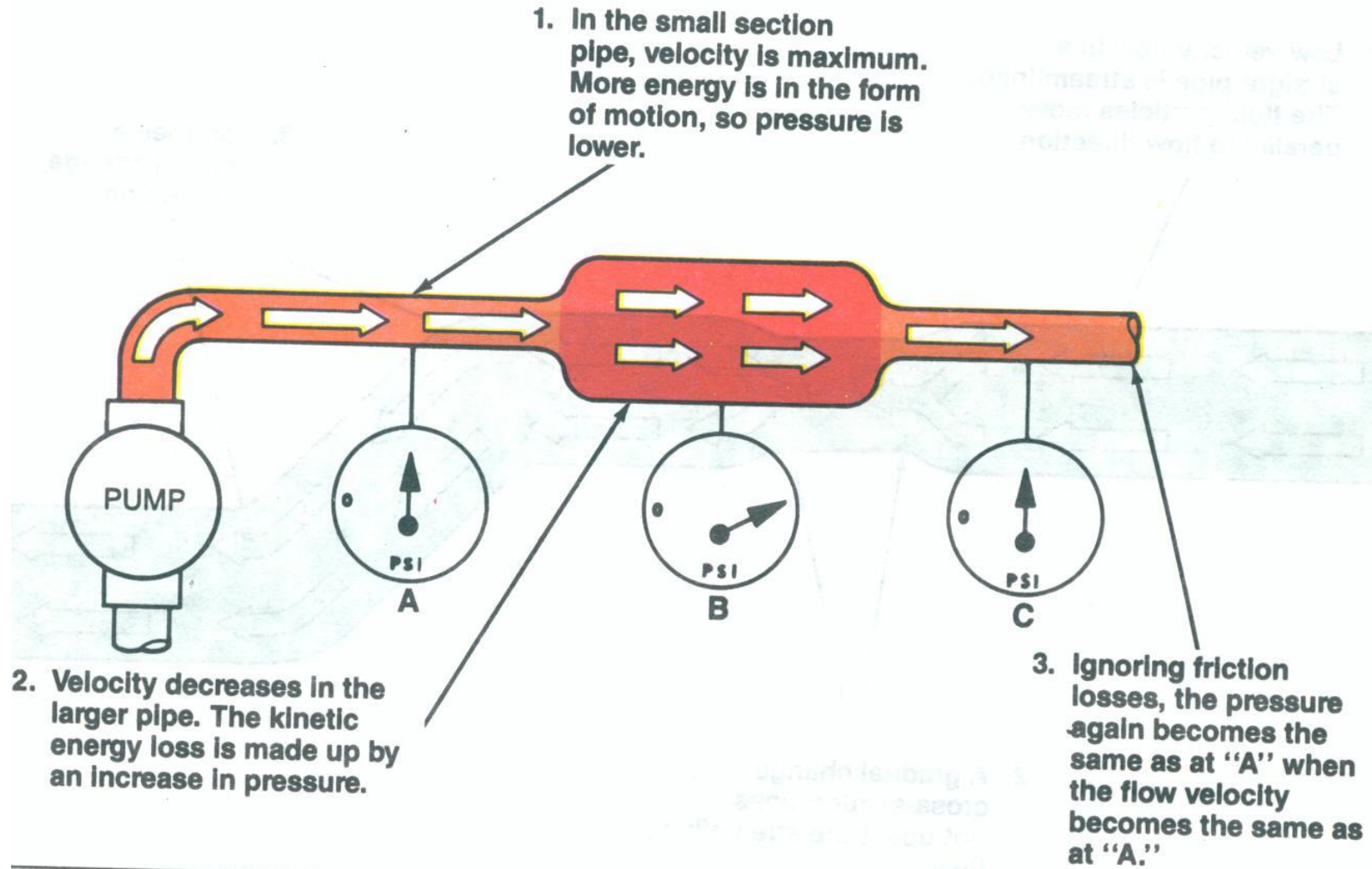


Figure 2-11. The sum of pressure and kinetic energy is constant with a constant flow rate.

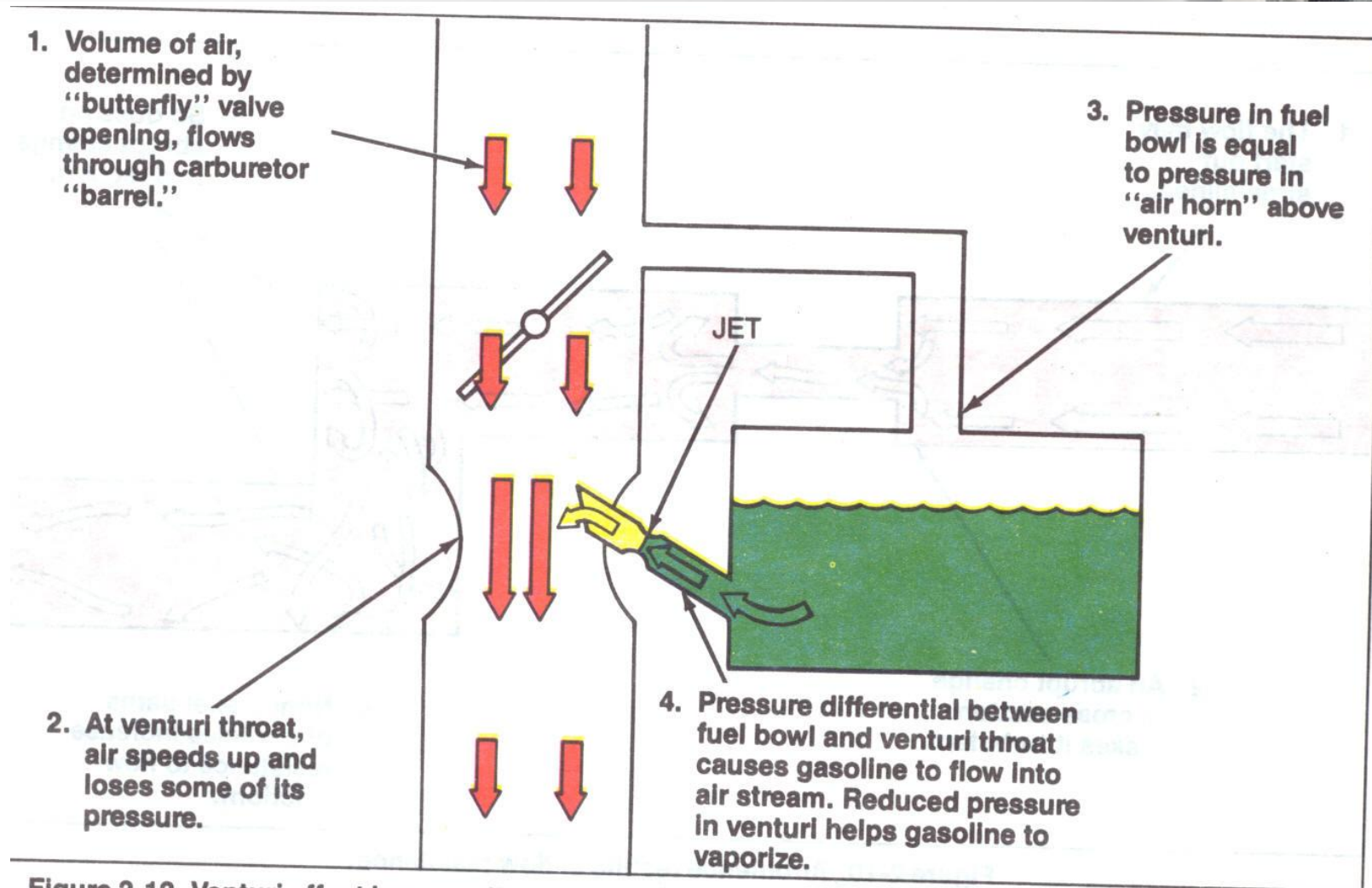
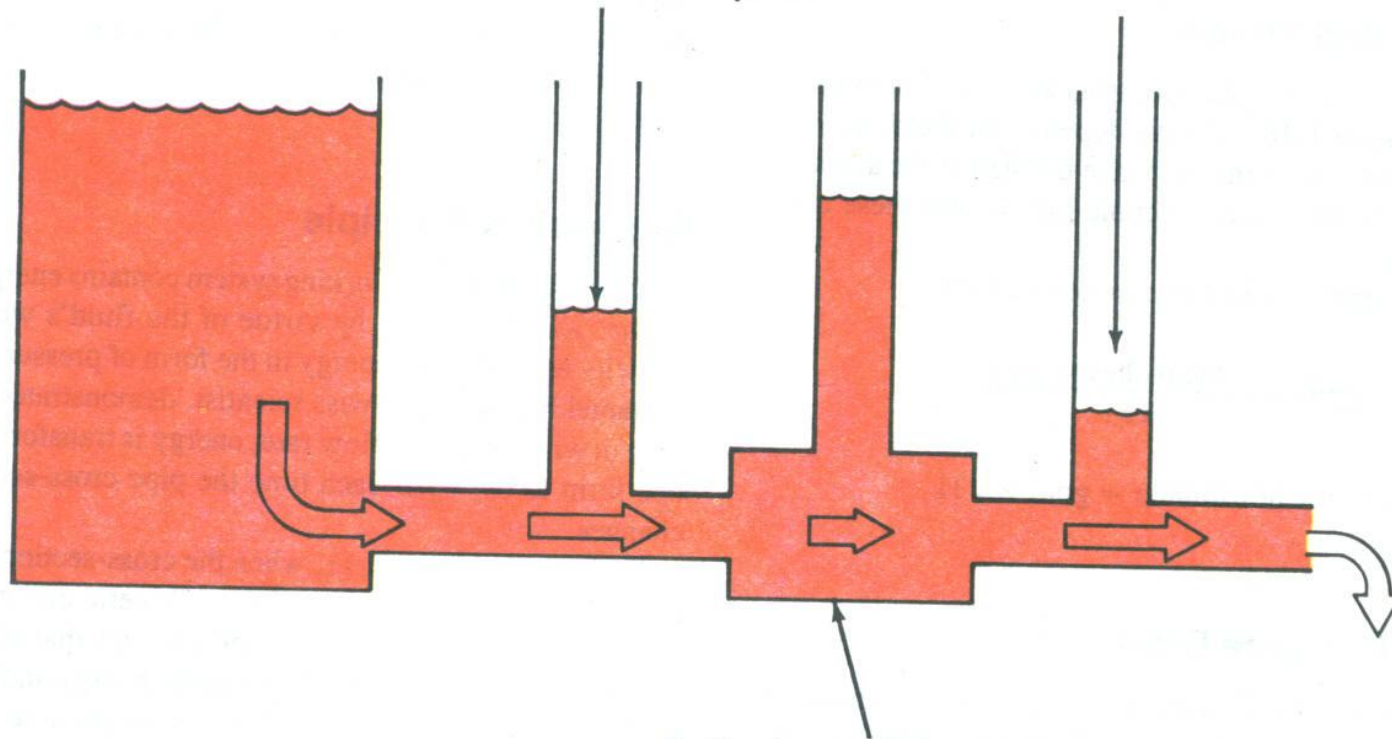


Figure 2-12. Venturi effect in a gasoline engine carburetor is an application of Bernoulli's principle.

1. Friction reduces the head at succeeding points downstream as in Figure 2-7 except where . . .



2. the larger pipe reduces velocity of the flow.

Figure 2-13. Friction and velocity affect pressure.

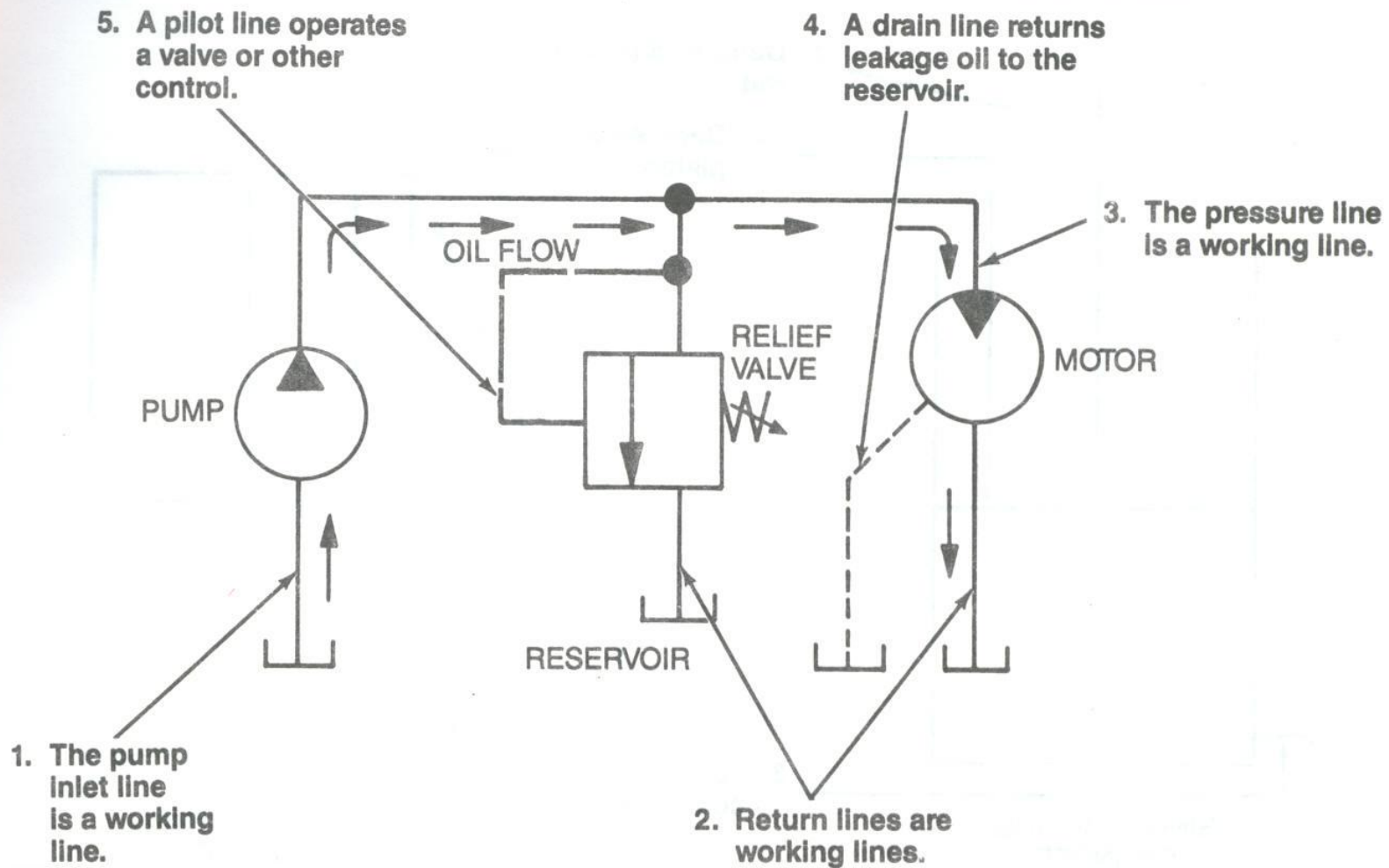
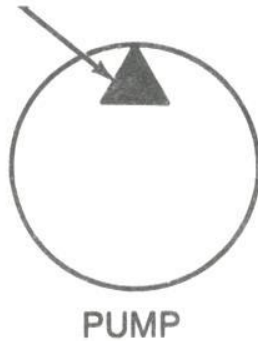


Figure 2-14. Three classifications of lines.

1. The energy triangle points out, showing the pump as a source.



3. The triangle points in. The motor receives energy.



2. Two triangles indicate that the pump can operate in reverse.



4. Two triangles denote reversibility.



Figure 2-15. A circle with energy triangles symbolizes a pump or motor.

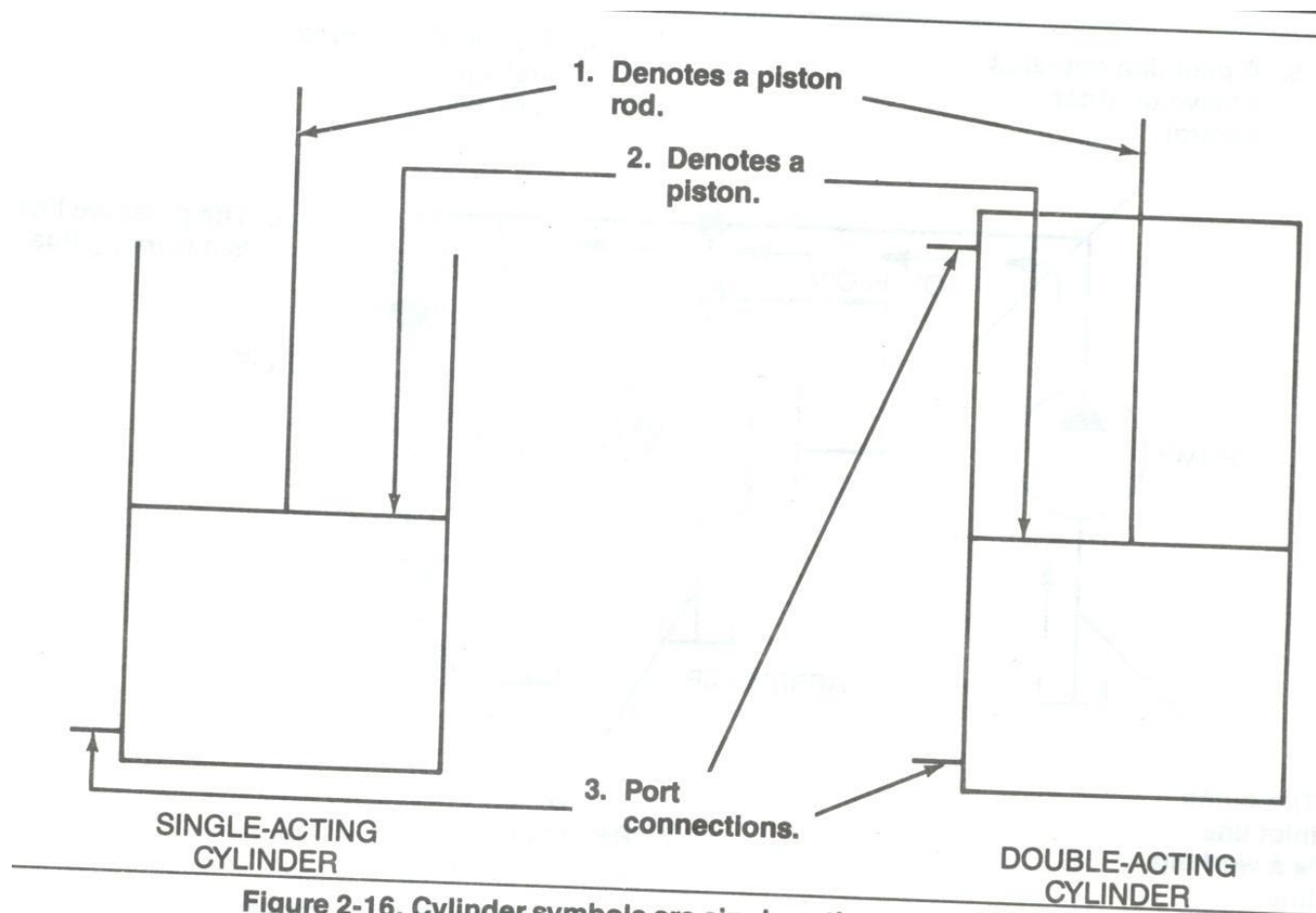
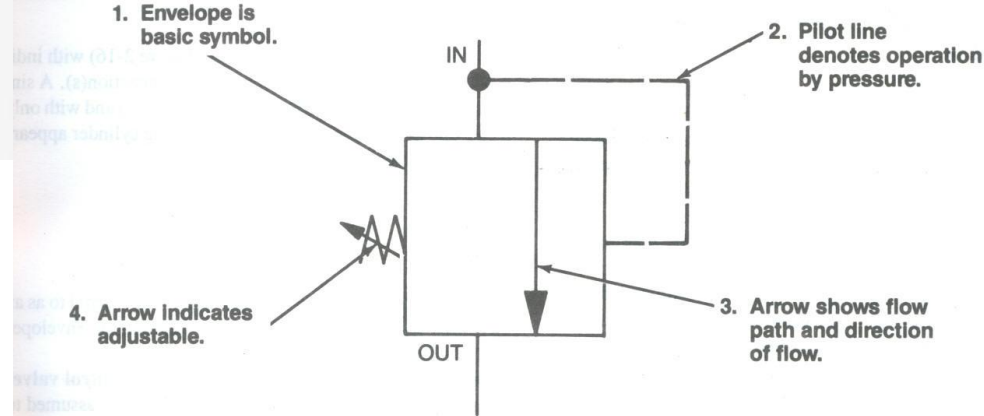
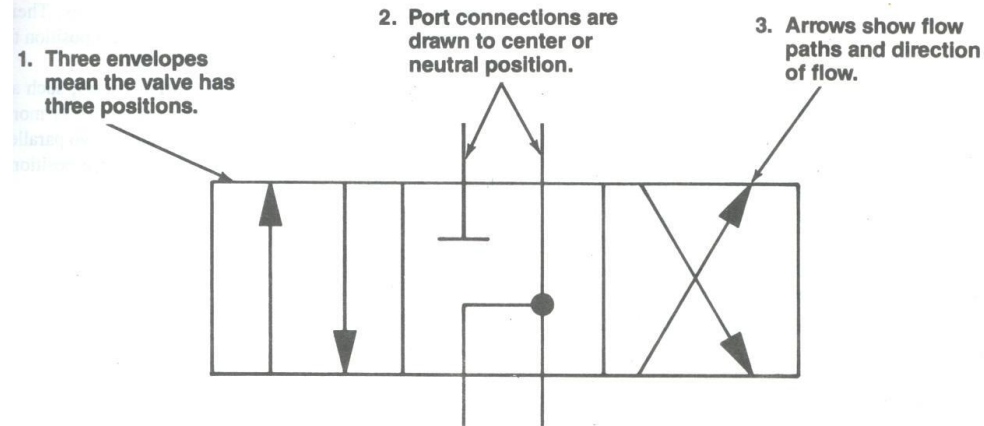


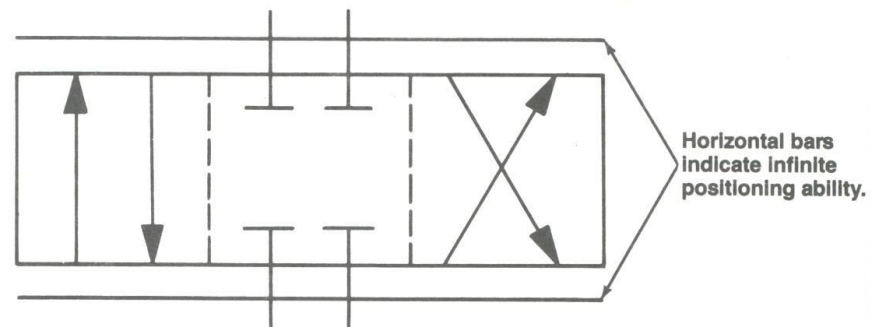
Figure 2-16. Cylinder symbols are single acting or double acting.



A. RELIEF VALVE (INFINITE POSITIONING)



B. DIRECTIONAL VALVE (FINITE POSITIONING)



C. DIRECTIONAL VALVE (INFINITE POSITIONING)

Figure 2-17. An envelope is the basic valve symbol.

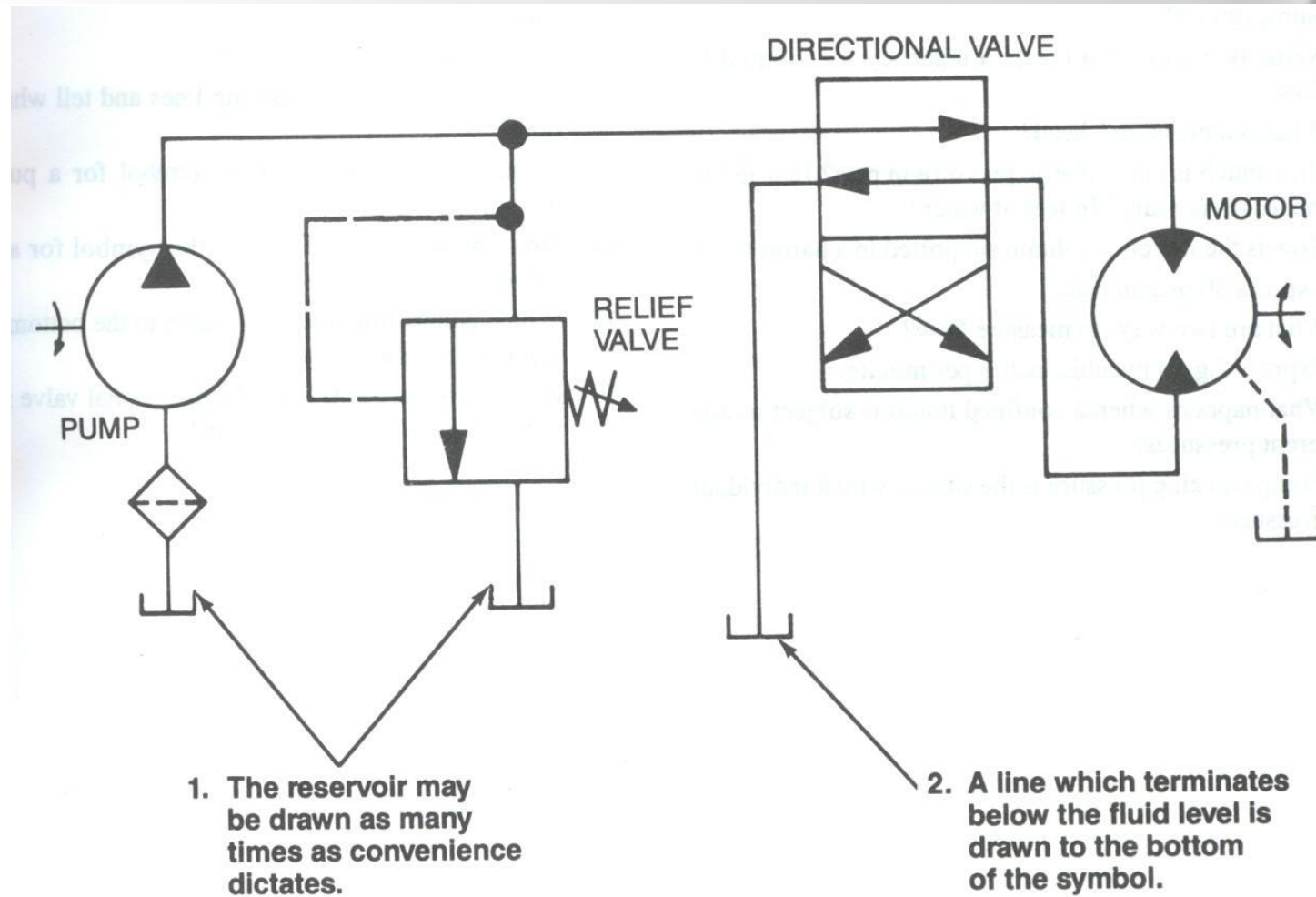


Figure 2-18. Graphical diagram of motor-reversing circuit.

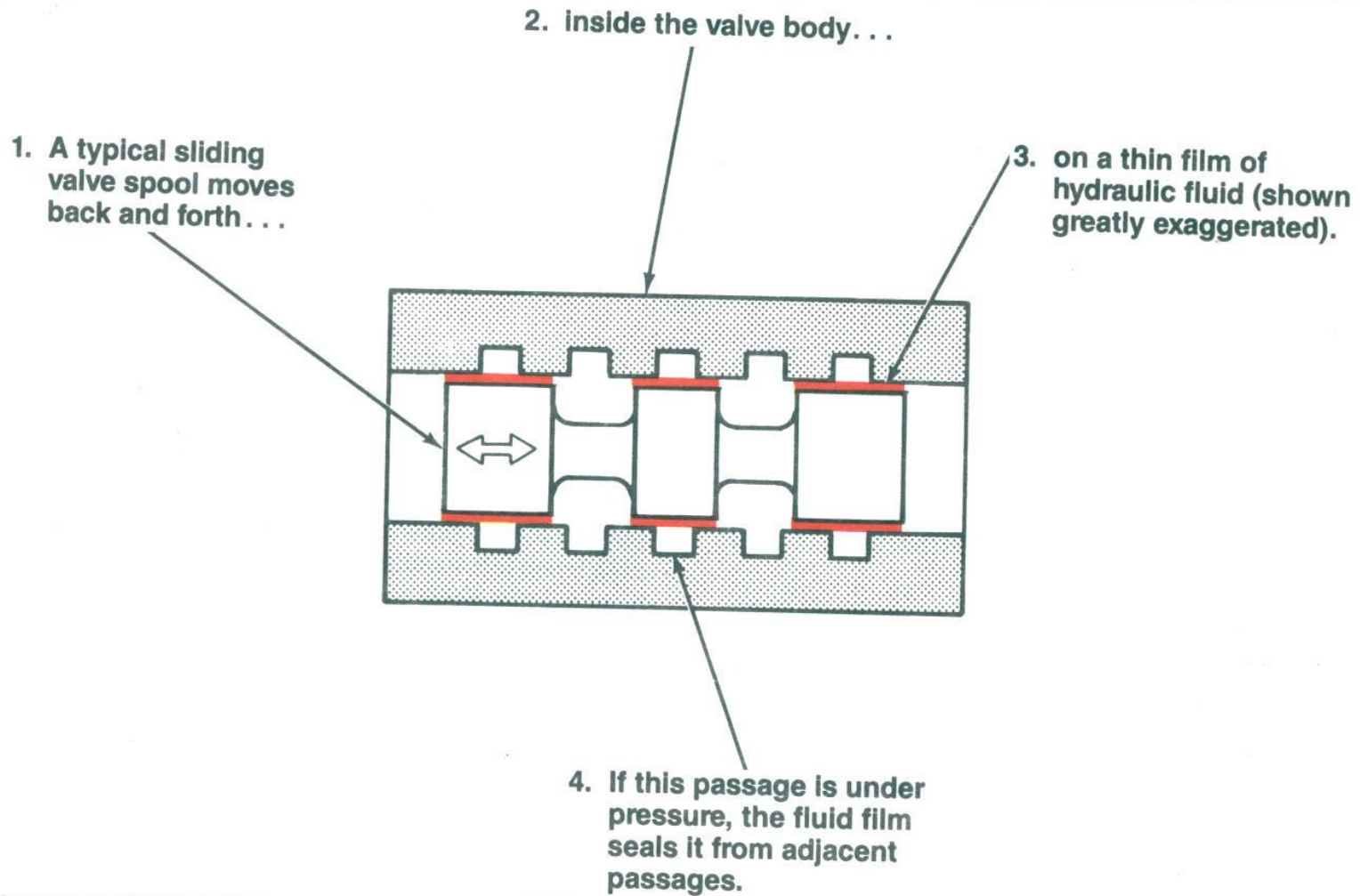


Figure 3-1. Fluid lubricates working parts.

1. A measured quantity of oil is heated to the test temperature. . .

THERMOMETER

2. by a surrounding oil bath. . .

HEATING ELEMENT

3. and then allowed to drain through an orifice of a particular size.

60 ML

4. The elapsed time in seconds equals the viscosity in SUS.

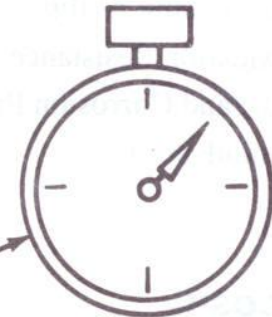
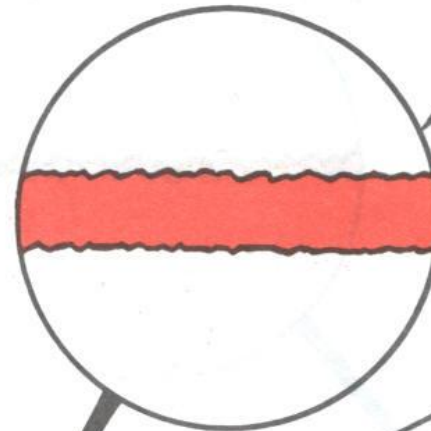
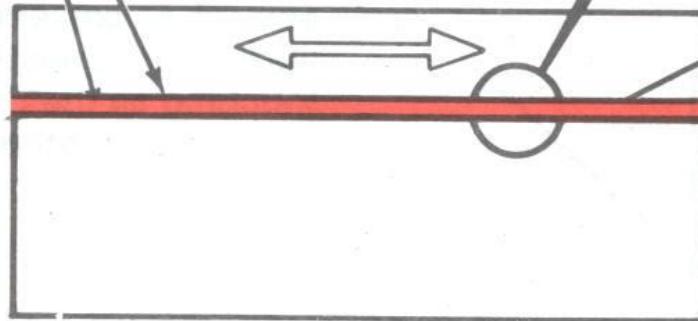


Figure 3-3. Saybolt viscosimeter measures relative viscosity.

1. Microscopic imperfections of the mating parts are separated . . .



2. by a film of fluid . . .



3. where clearance between the parts is caused by dynamic forces and fluid viscosity.

Figure 3-7. Full film lubrication prevents metal-to-metal contact.

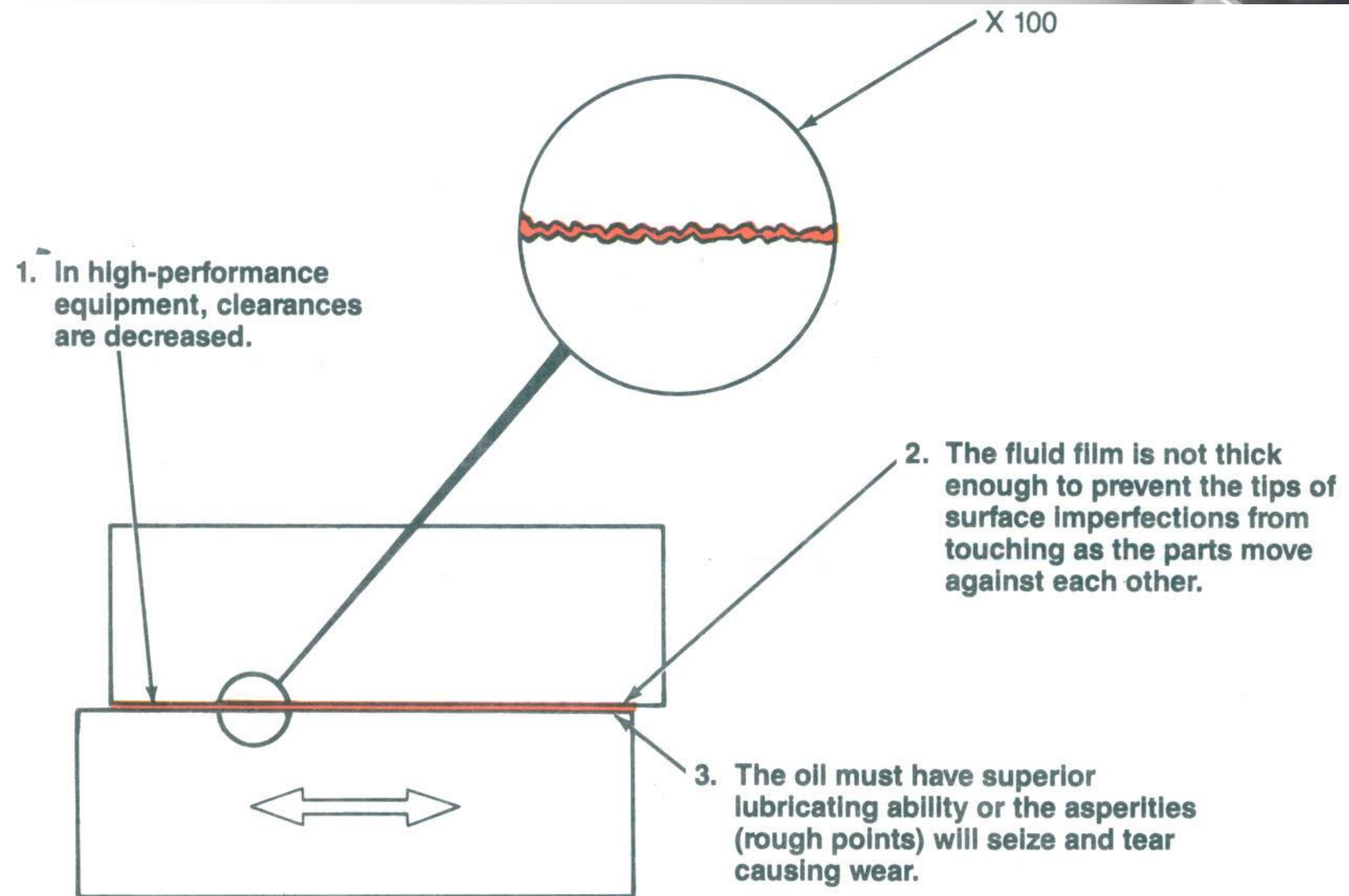


Figure 3-8. Boundary lubrication requires chemical additives.



Figure 3-9. Rust caused by moisture in the oil.

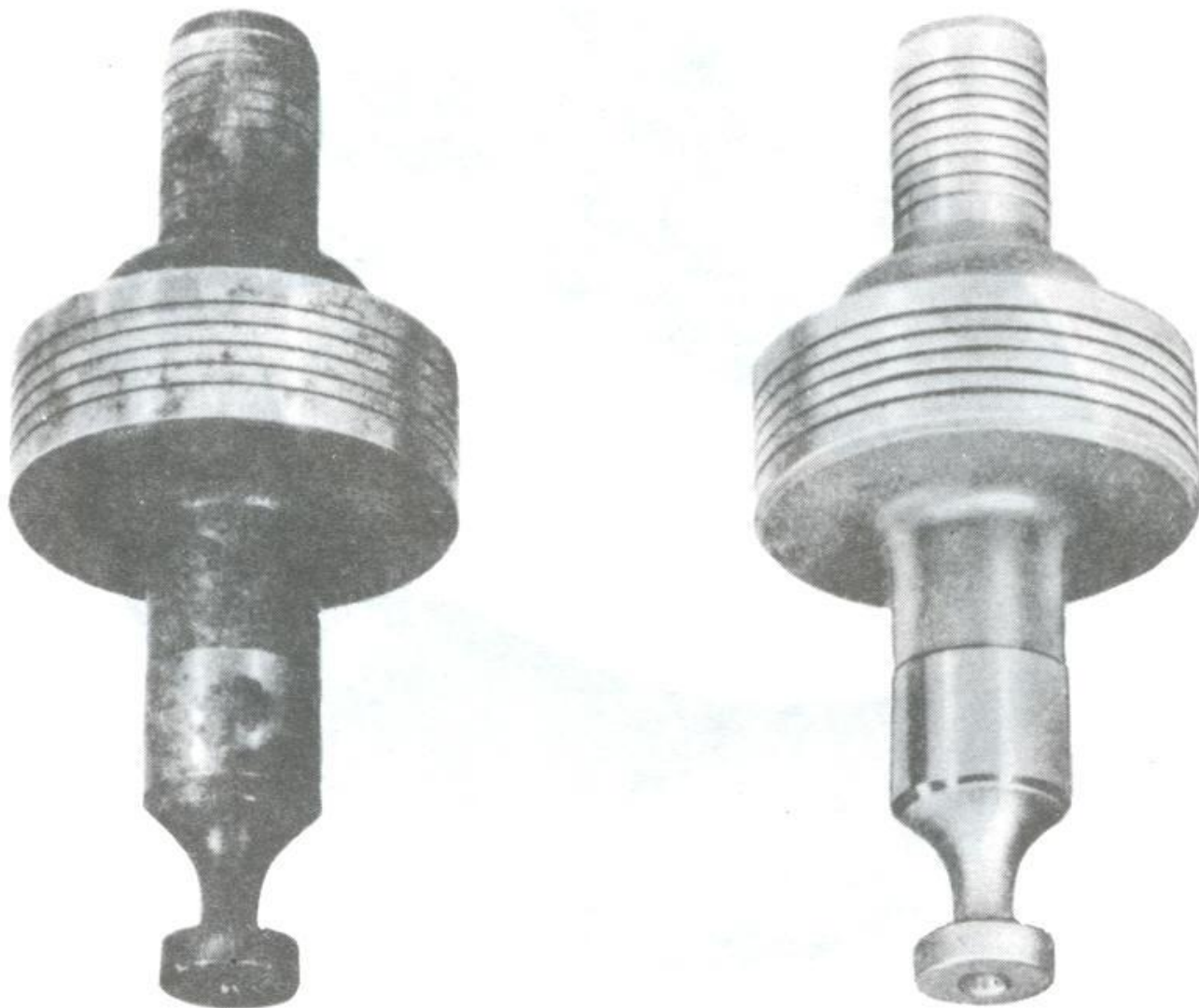


Figure 3-10. Corrosion caused by acid formation in the hydraulic oil.

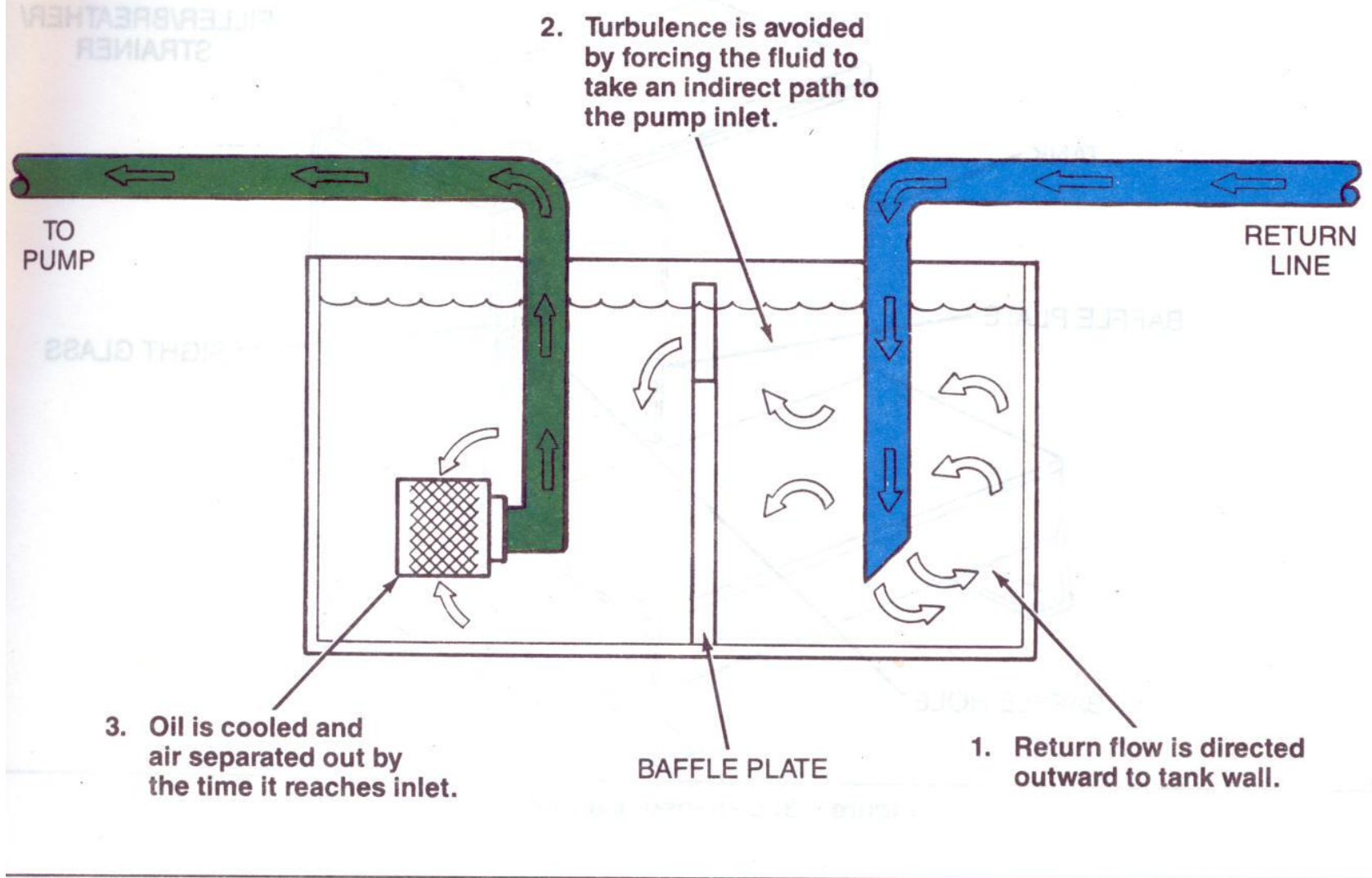


Figure 5-2. Baffle plate controls direction of flow in tank.

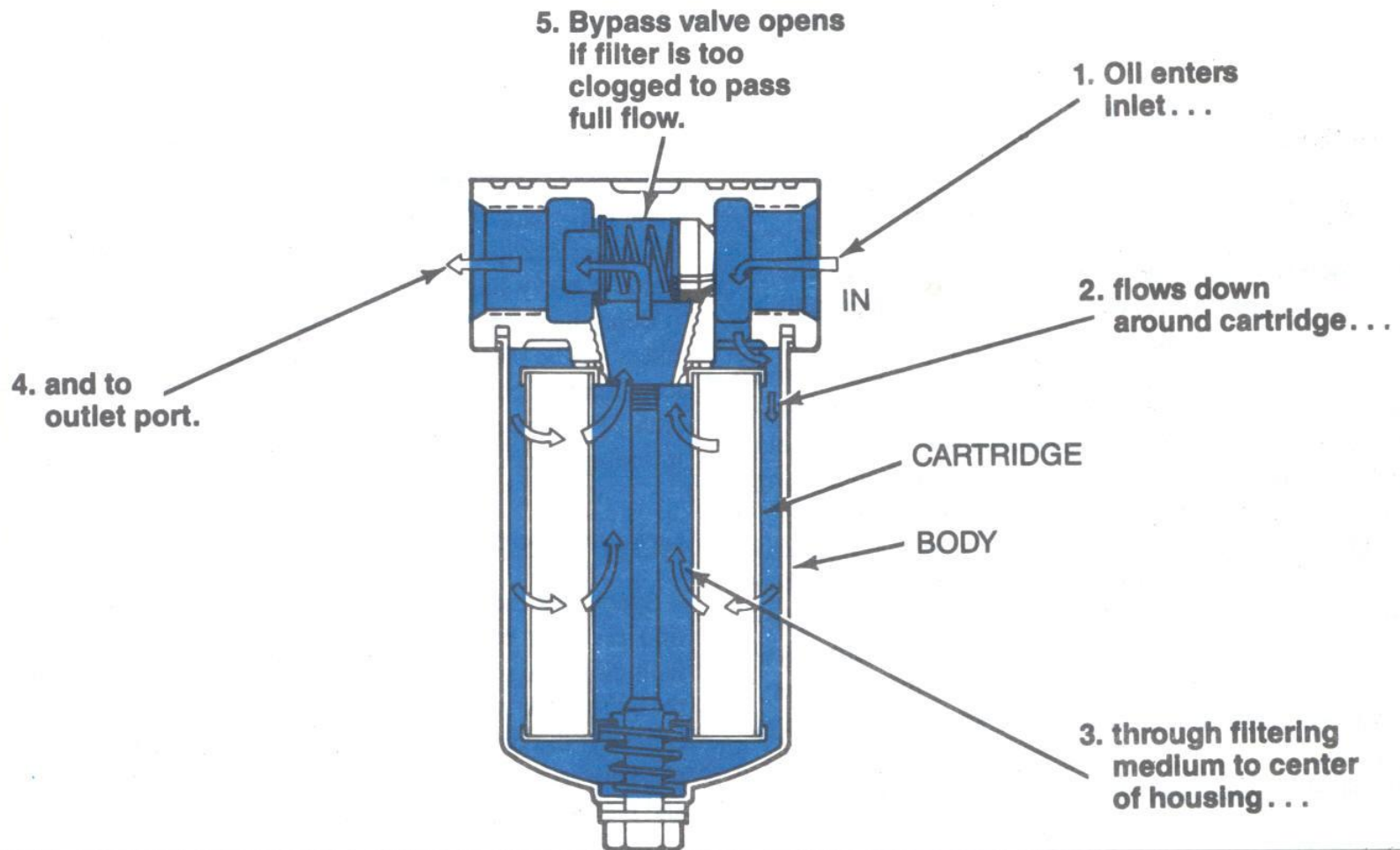


Figure 6-28. Full-flow filter.

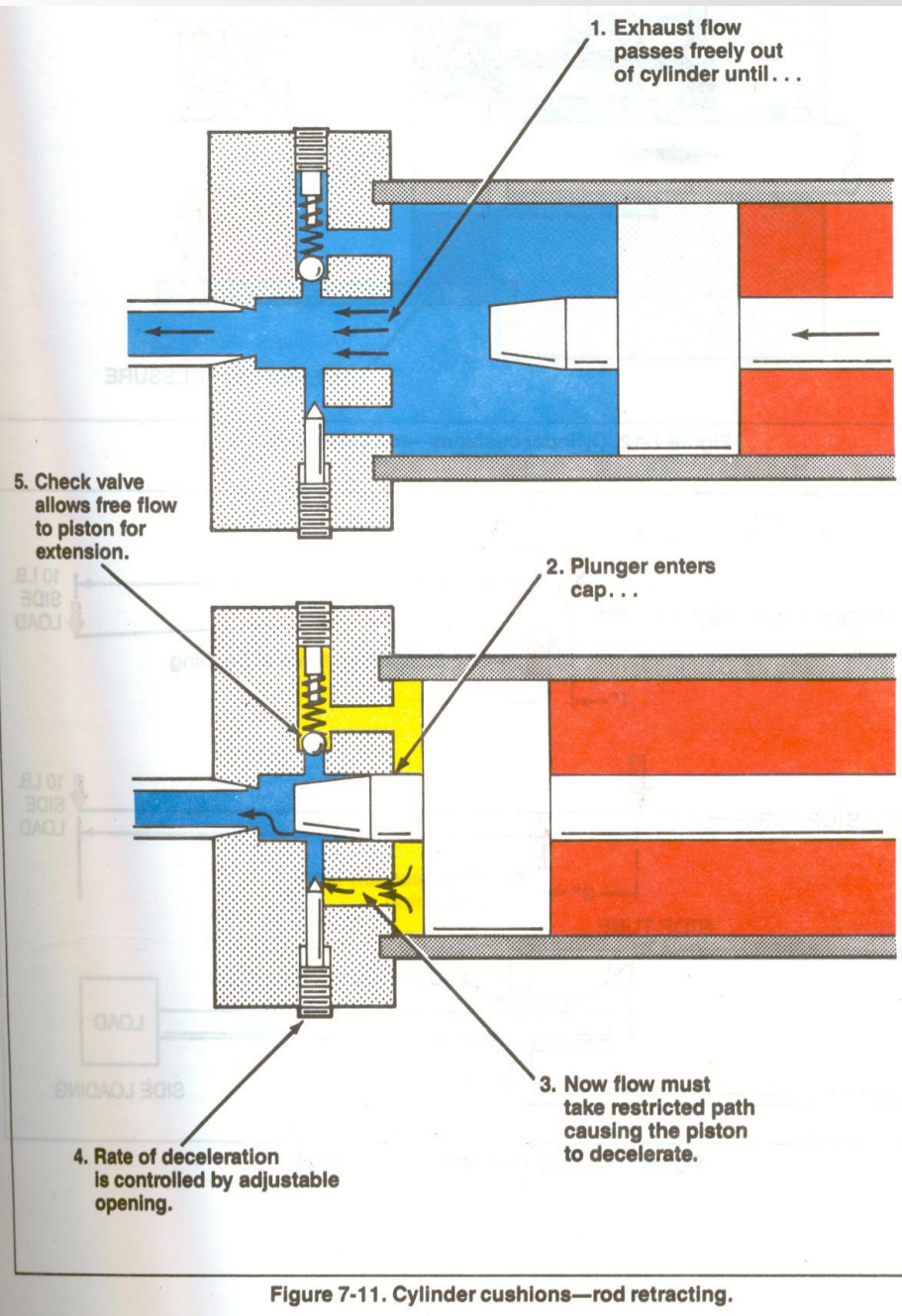
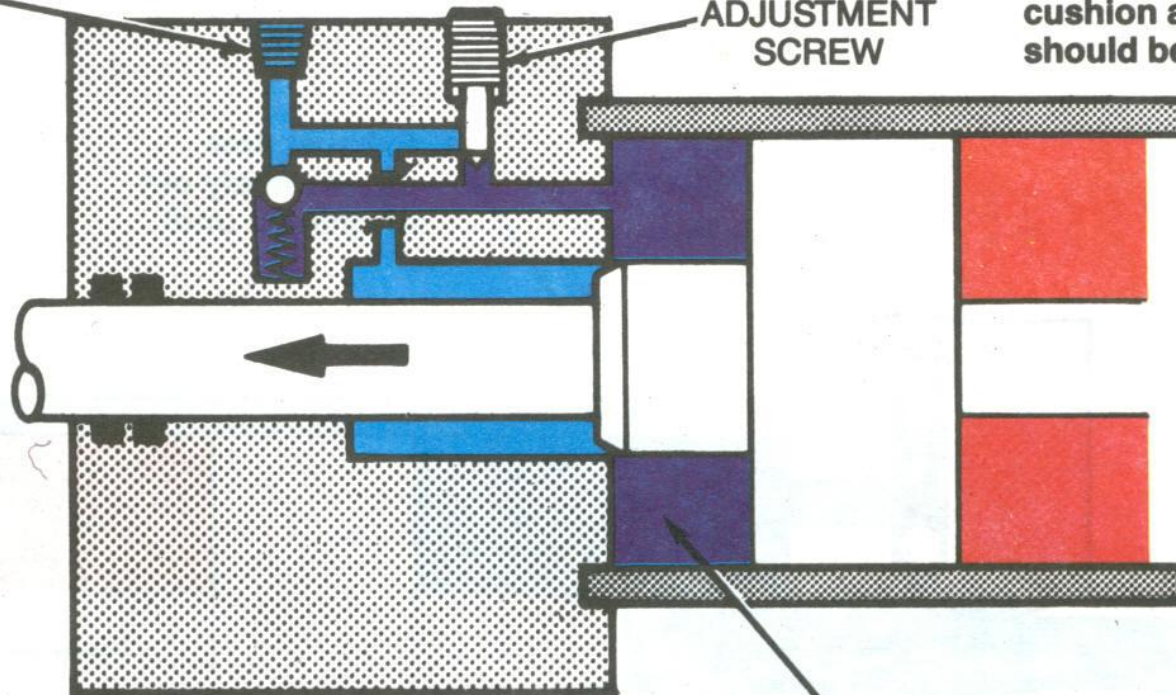


Figure 7-11. Cylinder cushions—rod retracting.

CYLINDER
PORT

CUSHION
ADJUSTMENT
SCREW

**NOTE: Closing of the
cushion adjustment screw
should be done with care.**



INTENSIFIED PRESSURE

Figure 7-12. Cylinder cushions—rod extending.

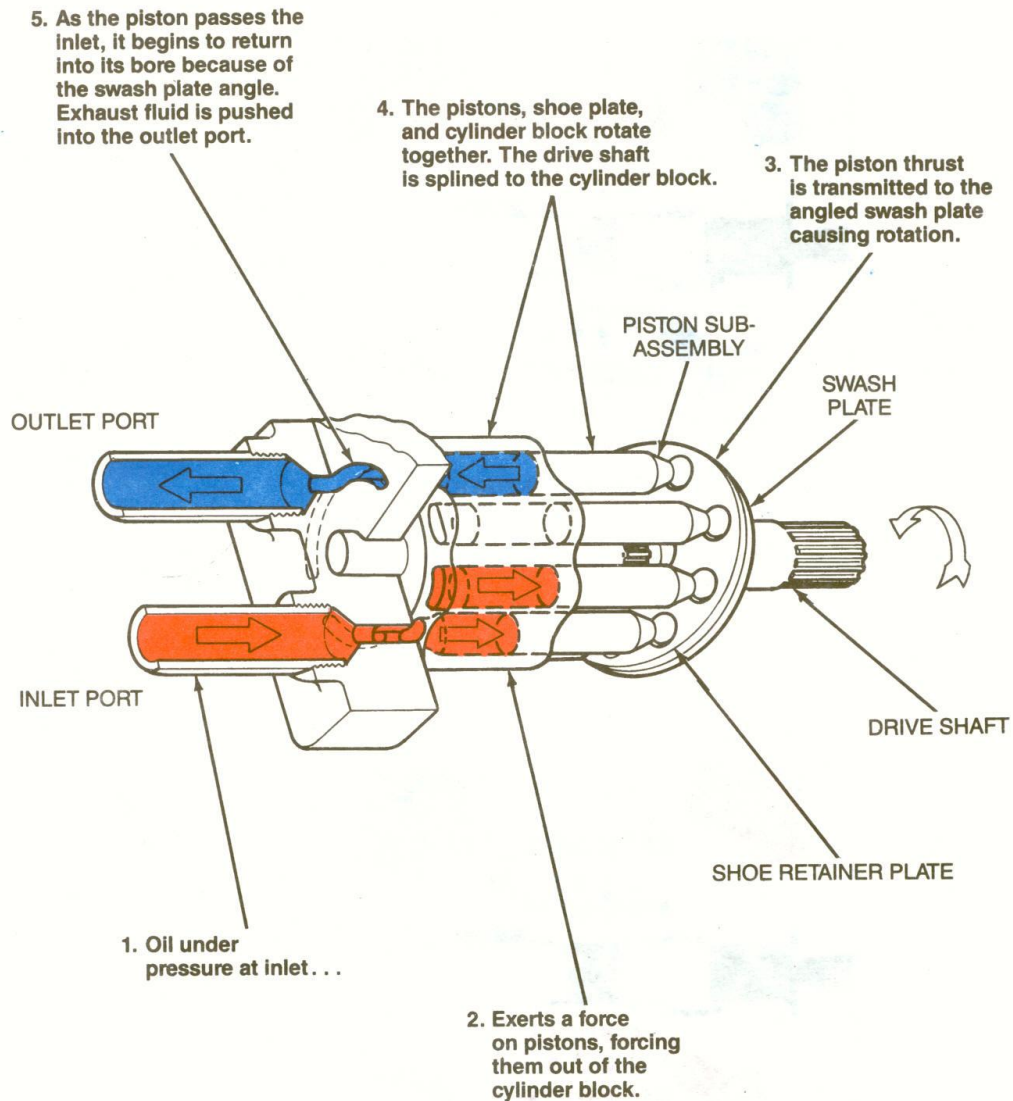
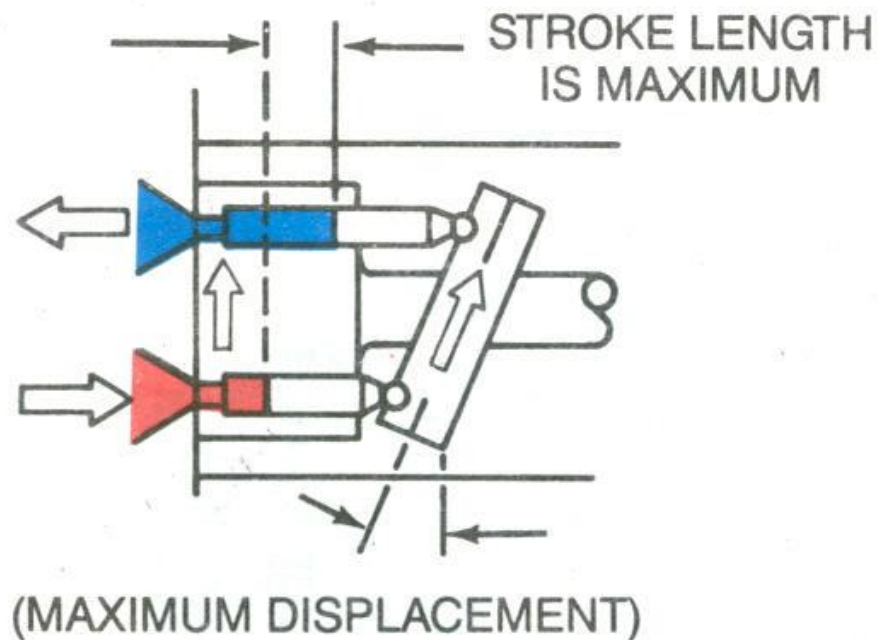
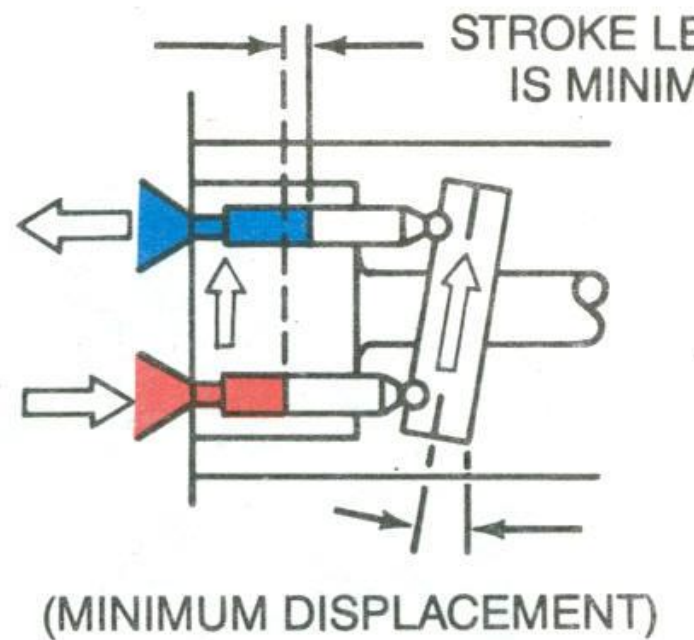


Figure 7-29. In-line piston motor operation.



**MAXIMUM SWASH
PLATE ANGLE
AND
MAXIMUM TORQUE
CAPABILITY**



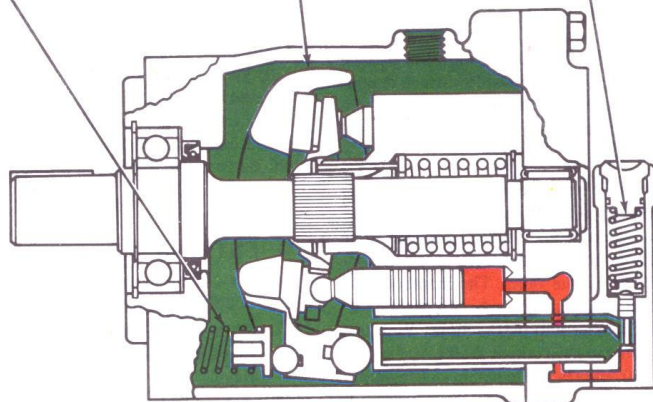
**MINIMUM SWASH
PLATE ANGLE
AND
MINIMUM TORQUE
CAPABILITY**

Figure 7-32. Motor displacement varies with swash plate angle.

1. Yoke return spring initially moves yoke to minimum displacement position for maximum speed and minimum torque.

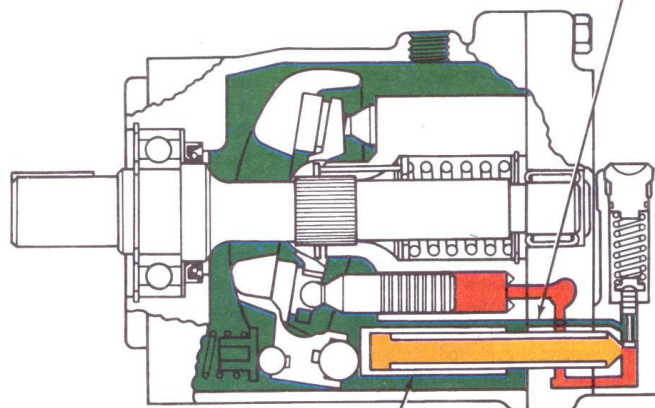
YOKE

2. Adjustment spring sets initial compensating pressure.



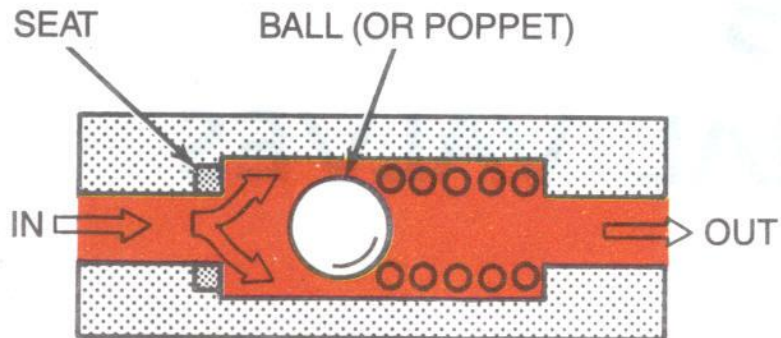
3. Compensator spool is forced open against spring by system pressure and ports oil to yoke piston at its pressure setting.

5. Drain passage carries control oil back to motor case.

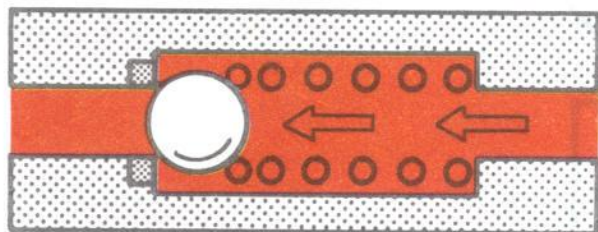


4. Yoke actuating piston responds to pressure to increase displacement and reduce speed and increase torque.

Figure 7-42. Variable displacement control.



**FREE FLOW ALLOWED
AS BALL UNSEATS**



**FLOW BLOCKED AS
VALVE SEATS**

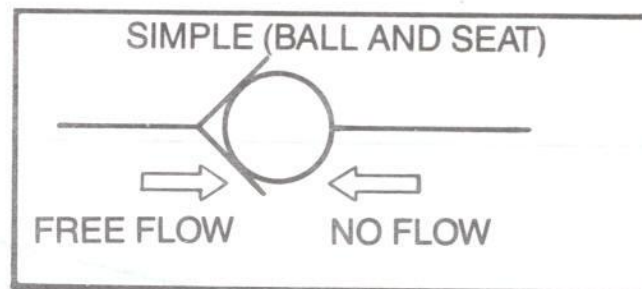


Figure 8-2. A check valve is a one-way valve.

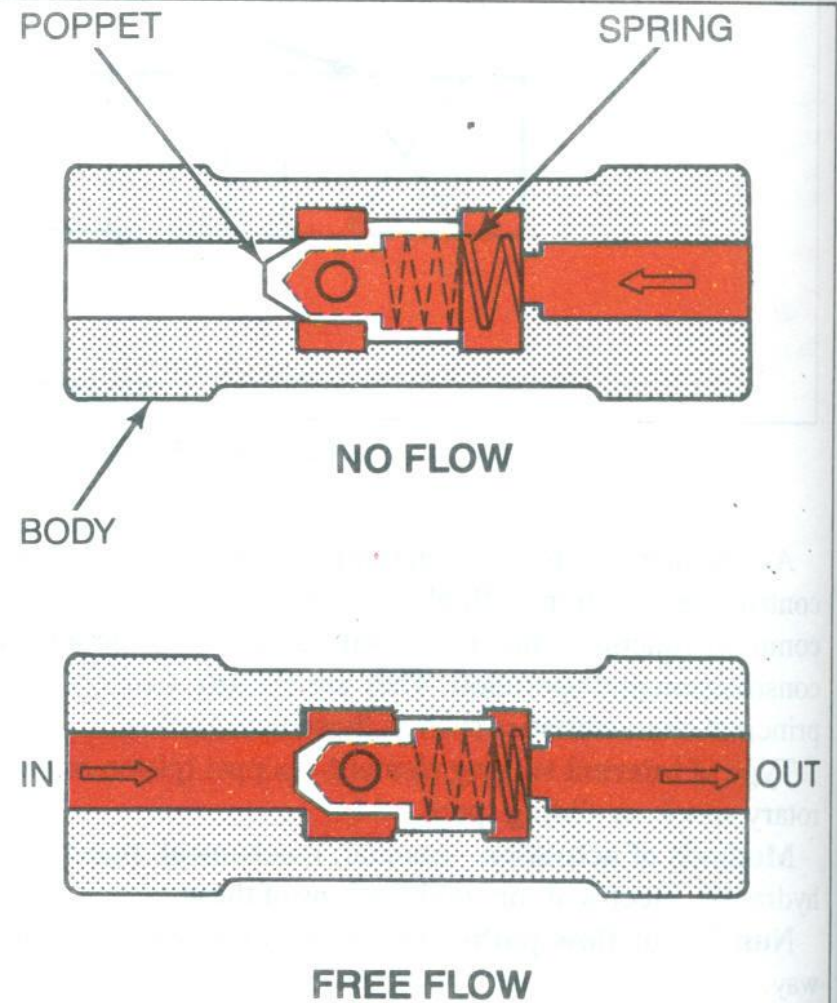
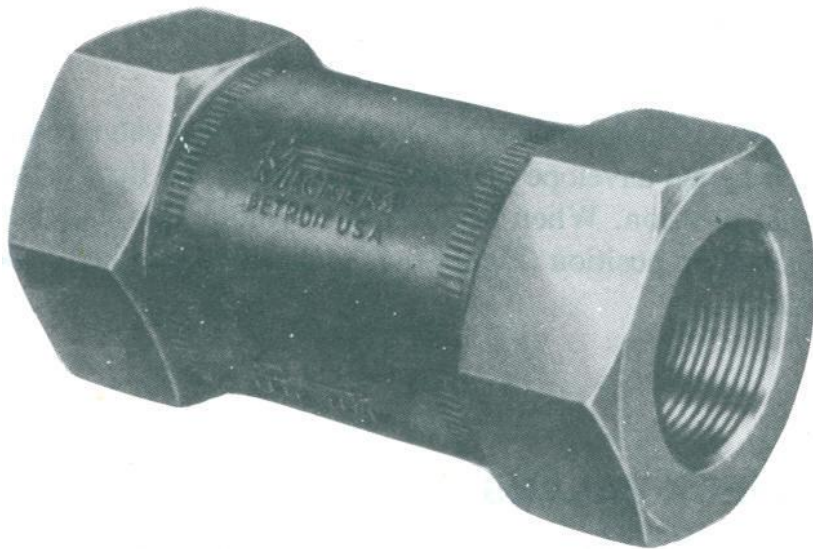


Figure 8-3. In-line check valve operation.

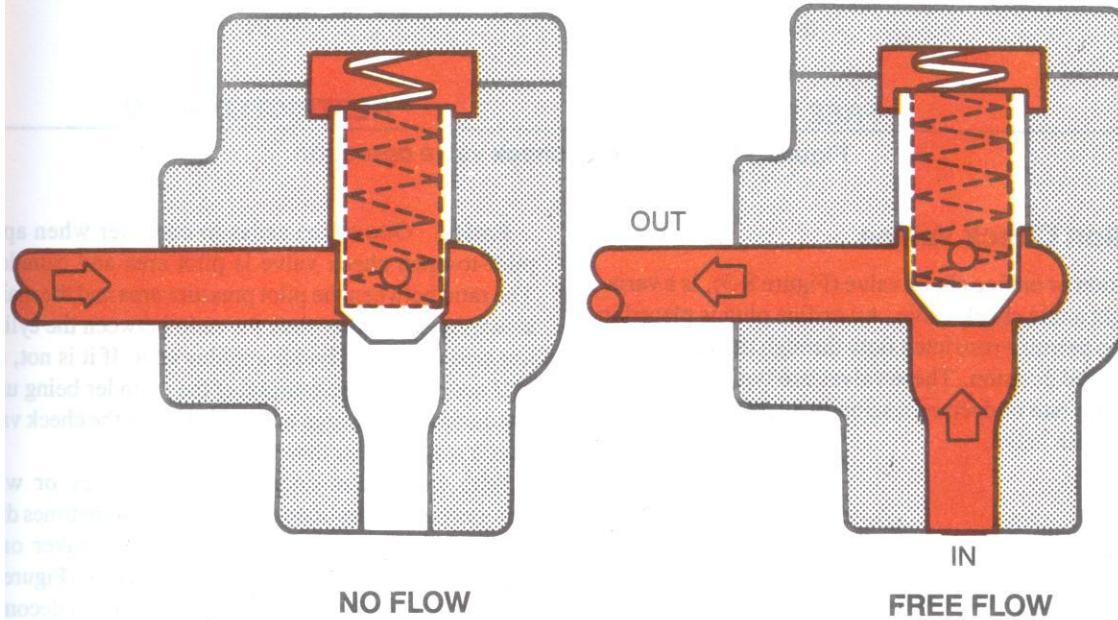
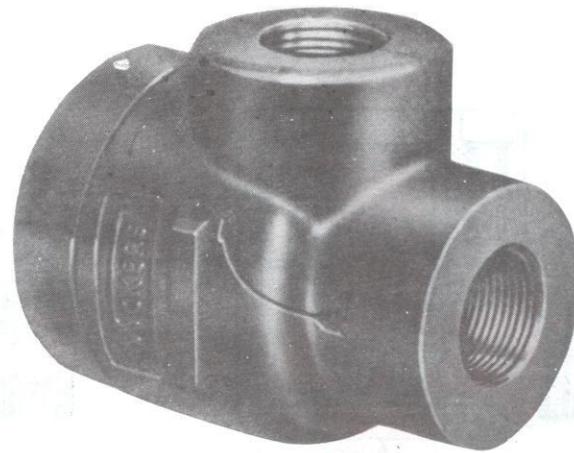
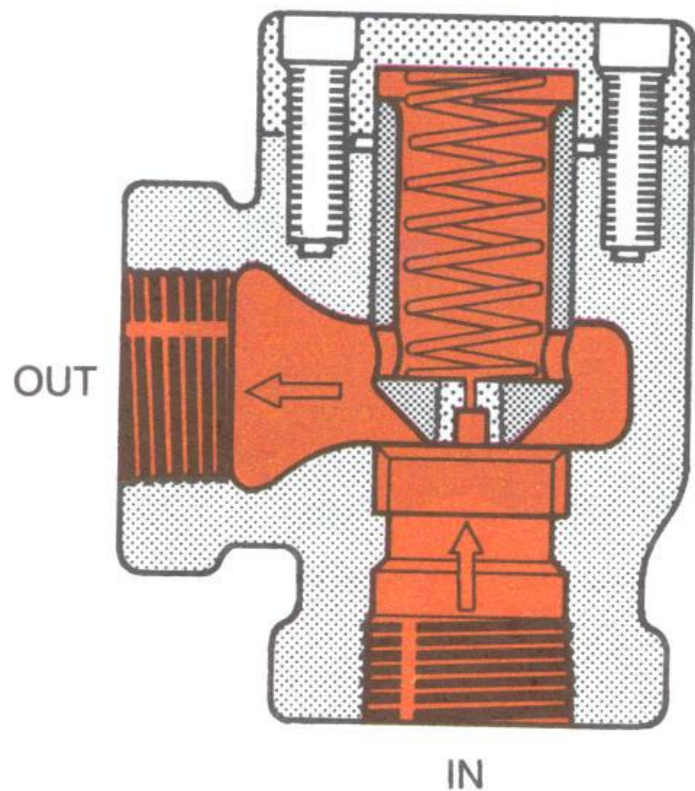
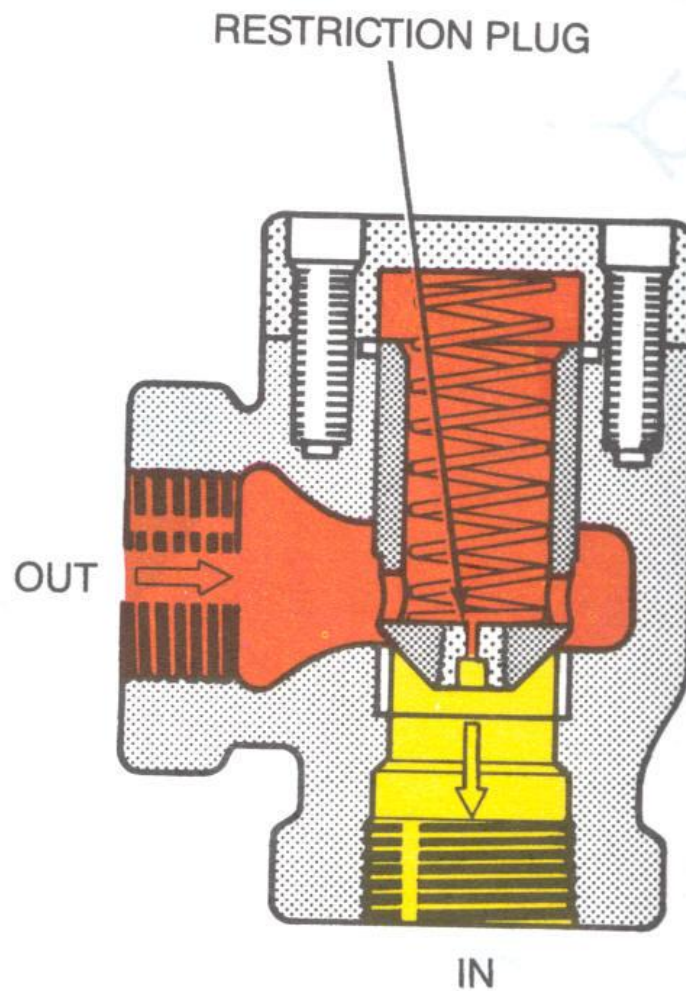


Figure 8-4. Typical right angle check valve.

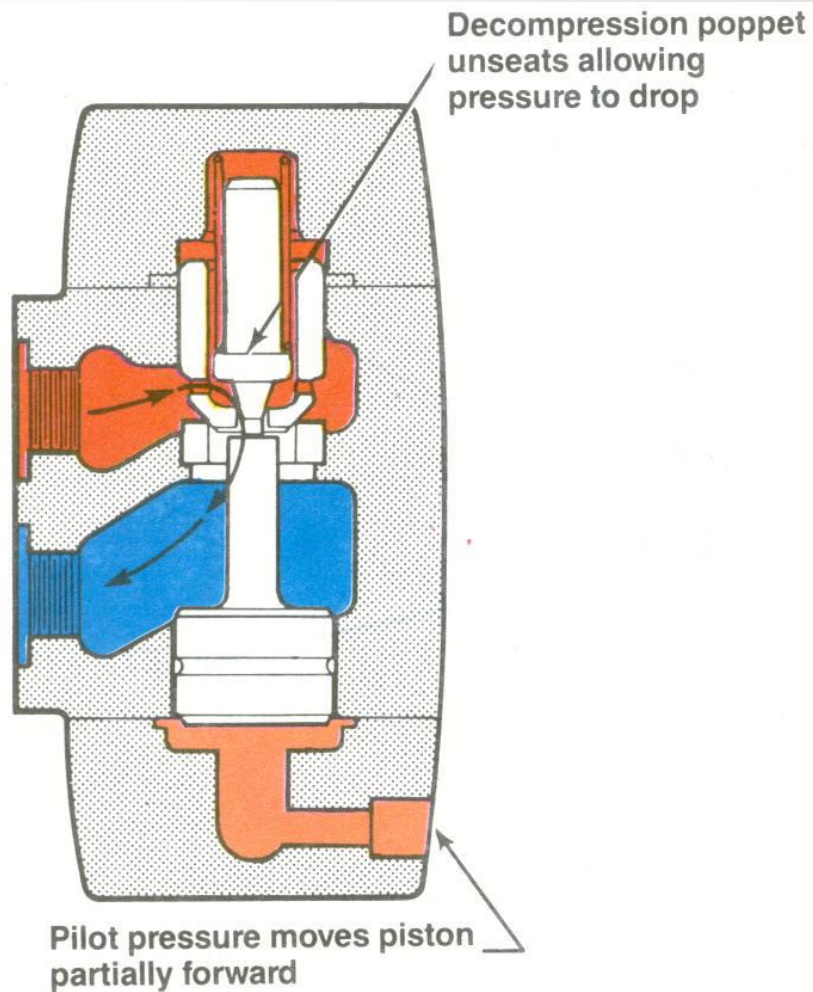


FREE FLOW

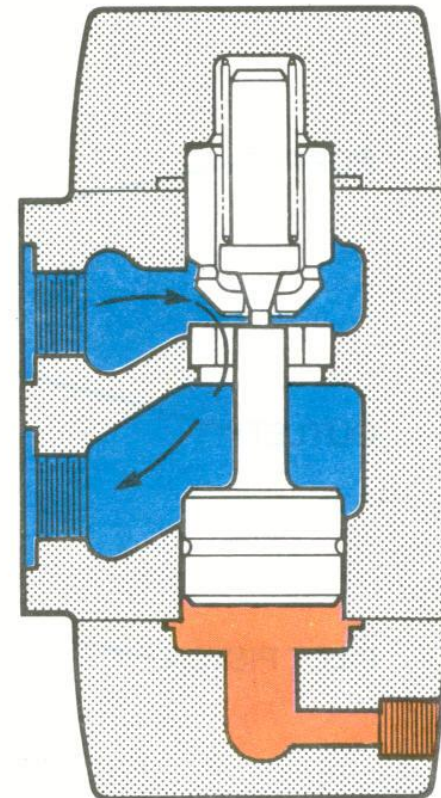


RESTRICTED FLOW

Figure 8-5. Restriction check valve operation.



A.



B.

Figure 8-8. Operation of pilot-operated check valve with decompression poppet.

No pilot pressure

Pilot pressure

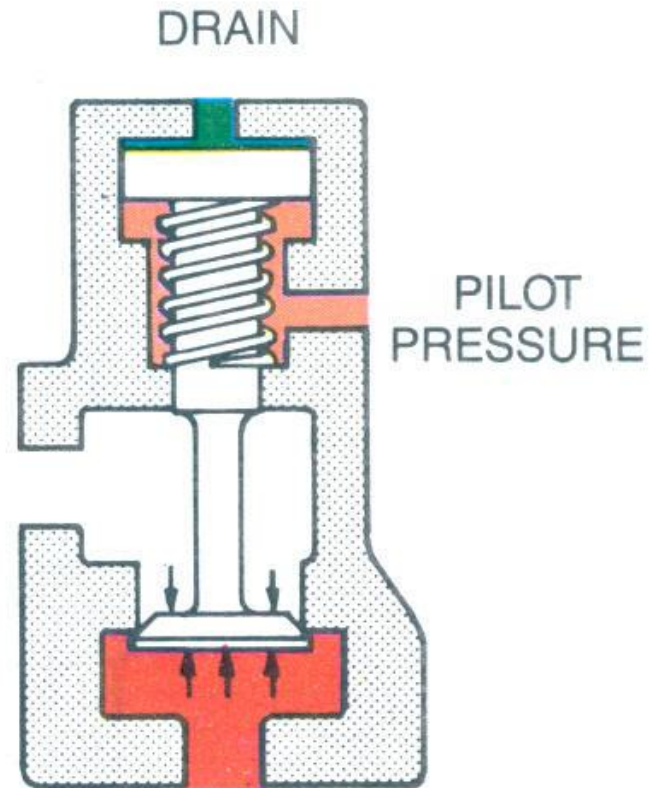
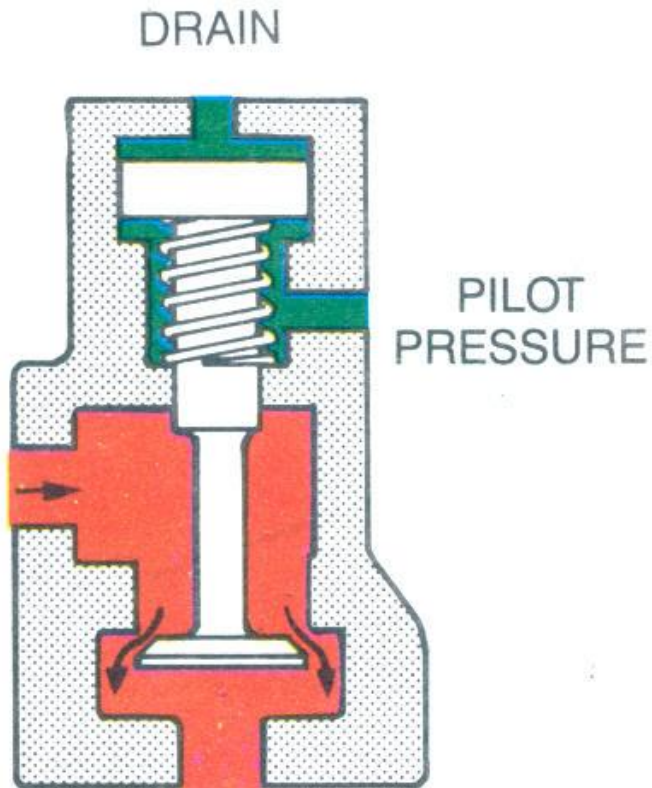


Figure 8-9. Pilot-to-close check valve operation.

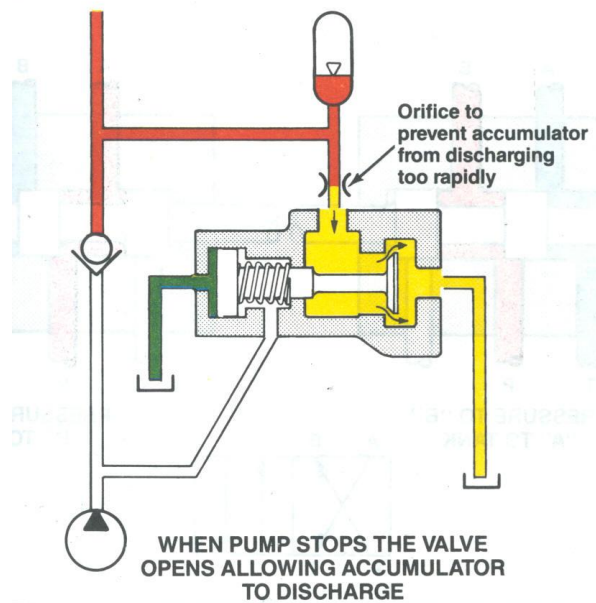
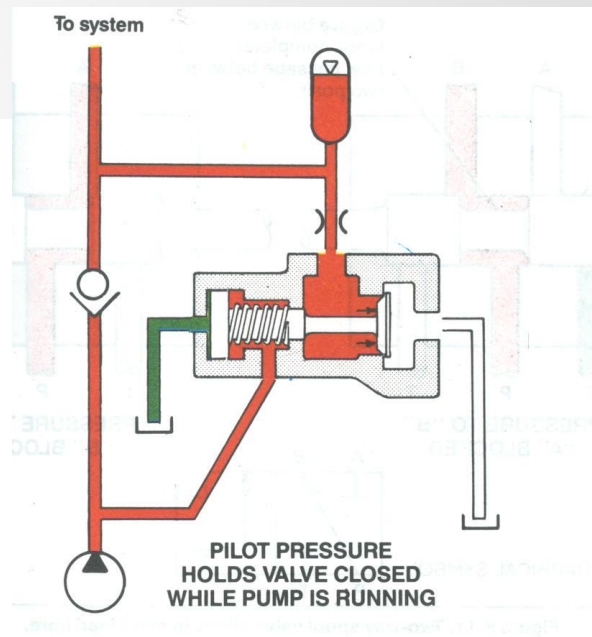
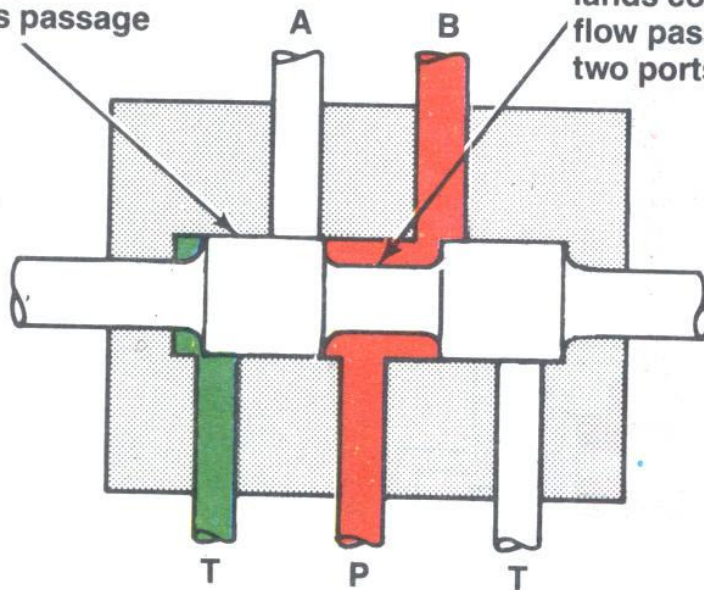


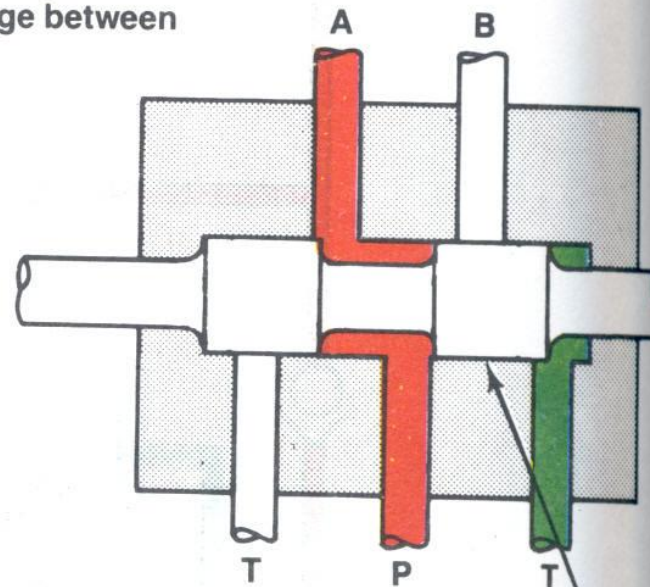
Figure 8-10. Automatic accumulator discharge circuit.

Land on
valve spool
blocks passage

Groove between
lands completes
flow passage between
two ports

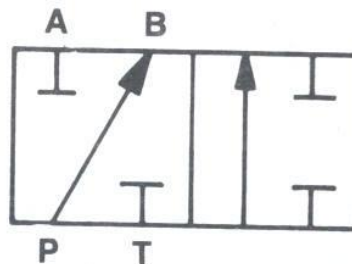


PRESSURE TO "B"
"A" BLOCKED



PRESSURE TO "A"
"B" BLOCKED

GRAPHICAL SYMBOL



Sliding spool to
left changes flow
path

Figure 8-11. Two-way spool valve slides in machined bore.

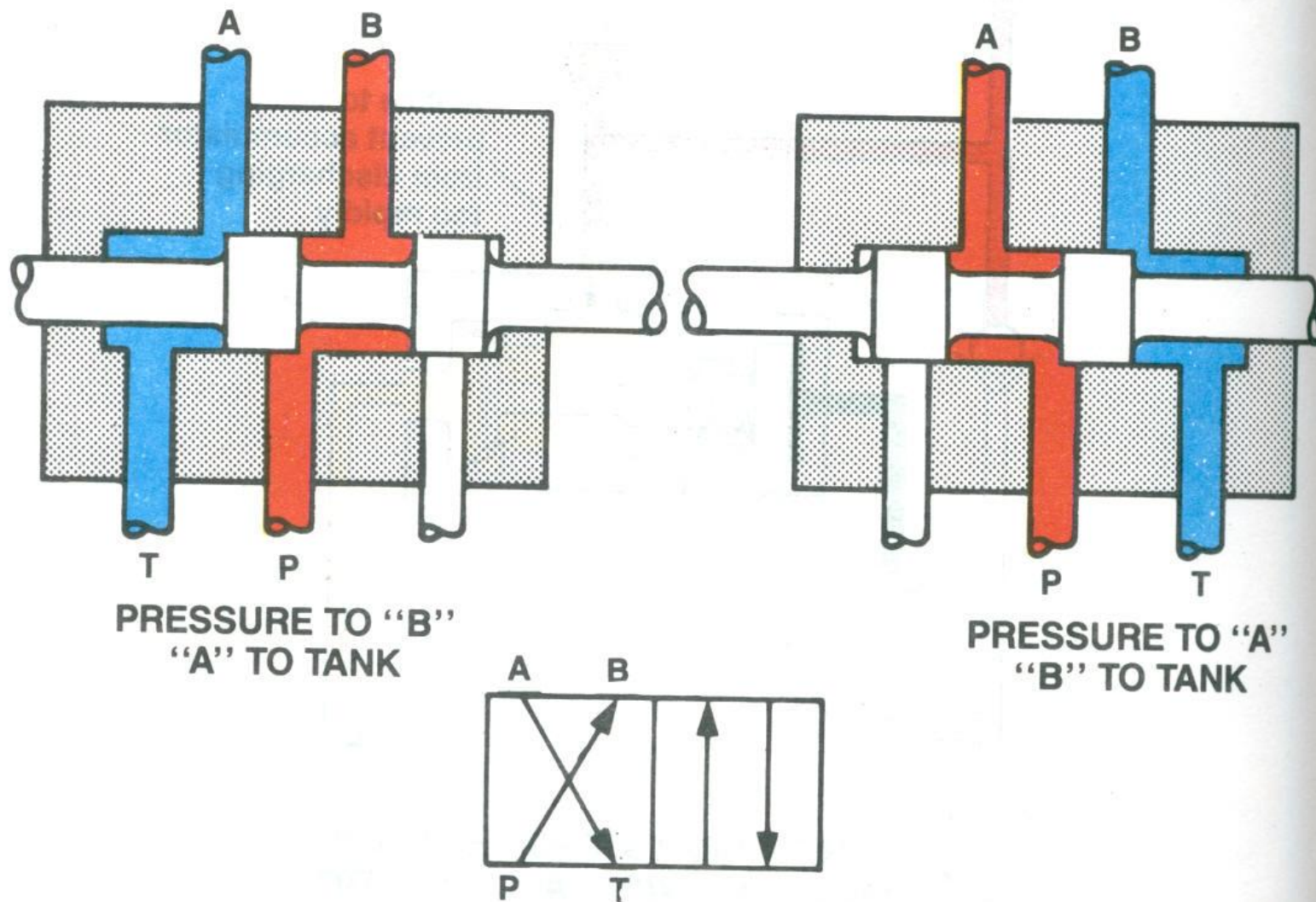
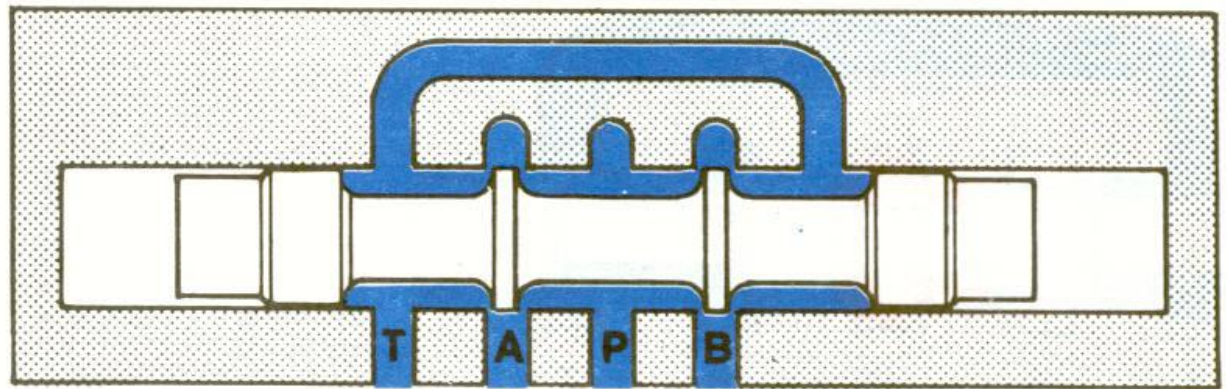


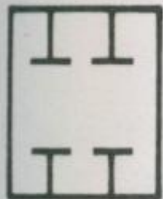
Figure 8-12. Spool type four-way valve.



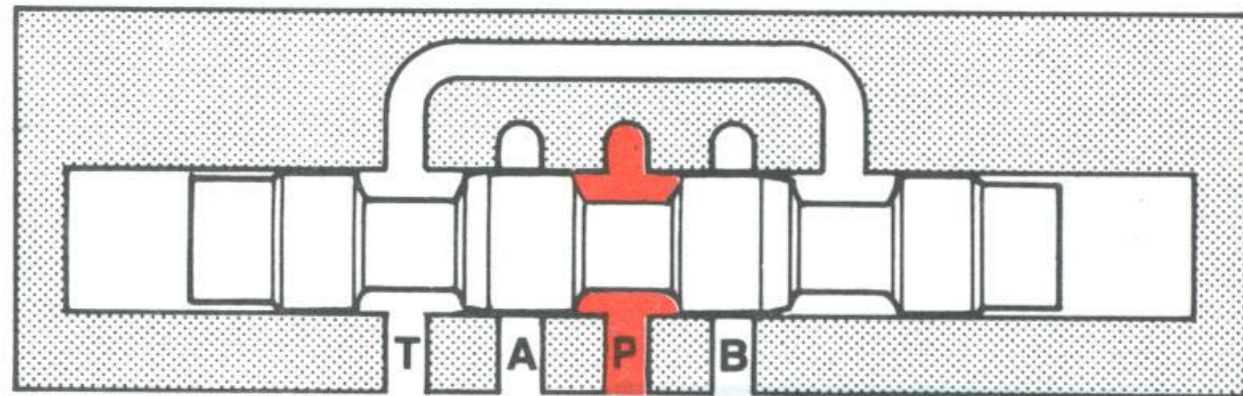
**OPEN
TYPE**



OPEN CENTER



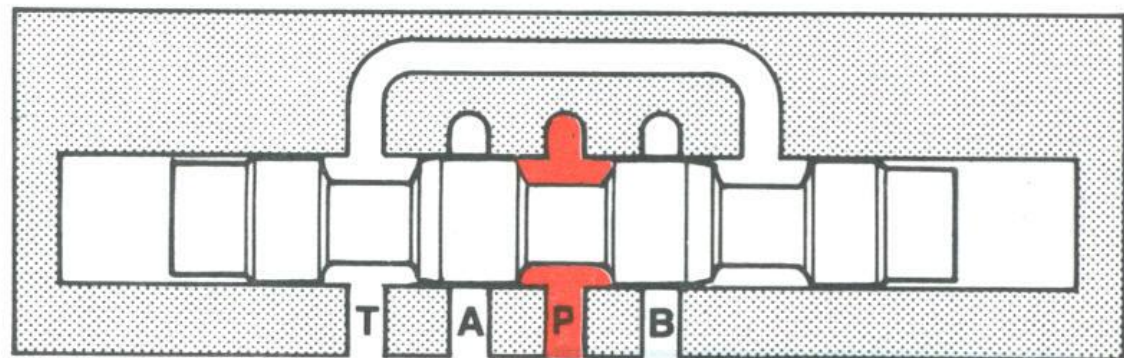
**CLOSED
TYPE**



CLOSED CENTER—ALL PORTS CLOSED

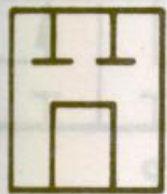


**CLOSED
TYPE**

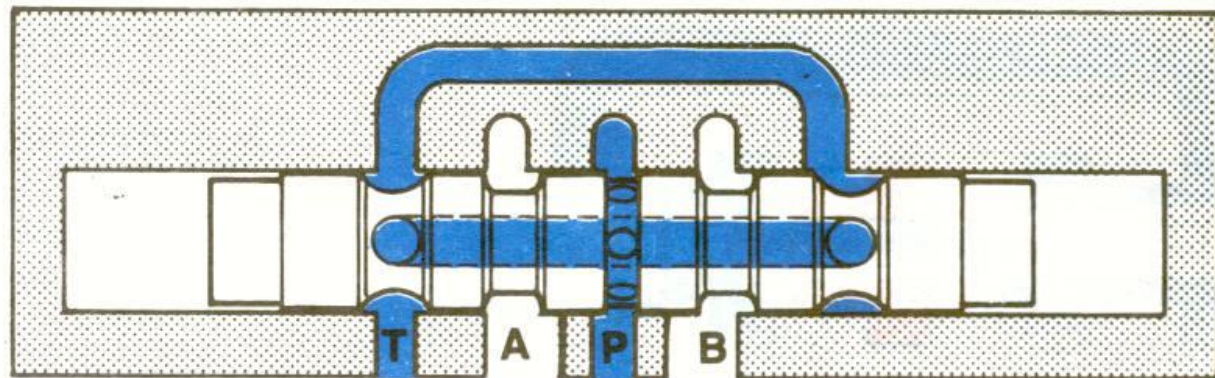


CLOSED CENTER—ALL PORTS CLOSED



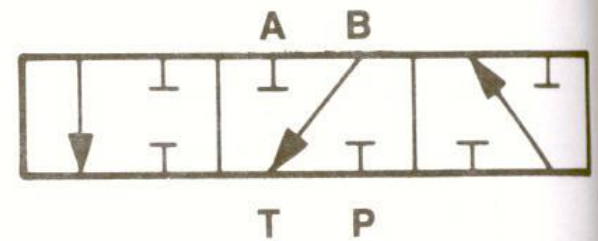
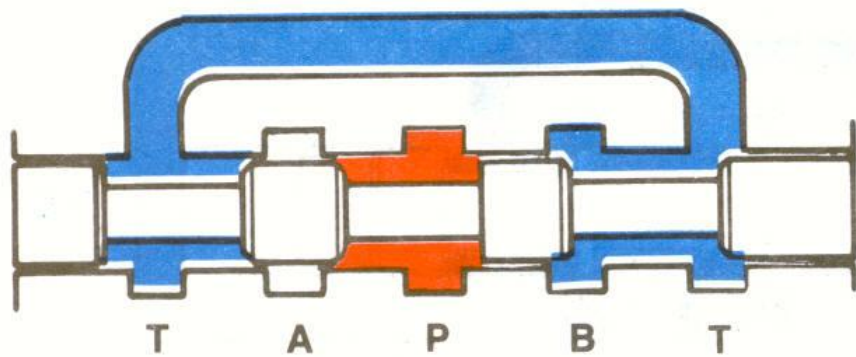


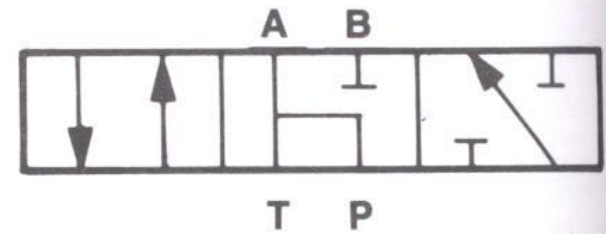
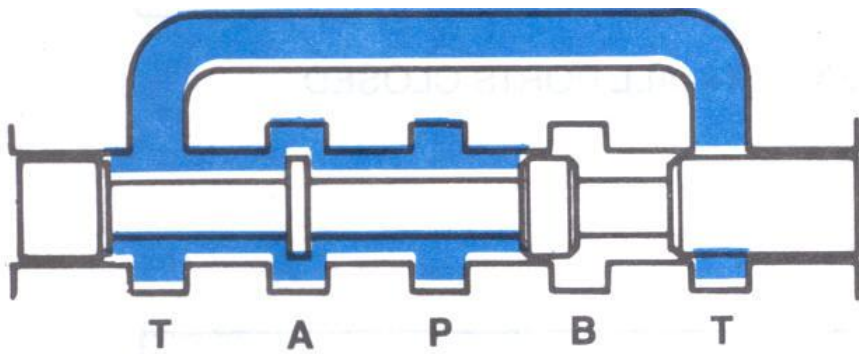
**TANDEM
TYPE**

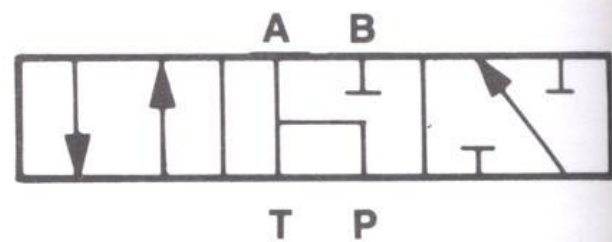
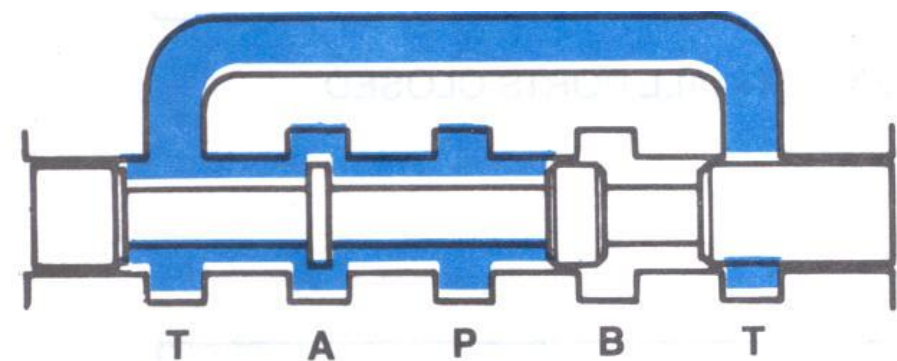


TANDEM

Figure 8-24. Four-way valve center conditions.







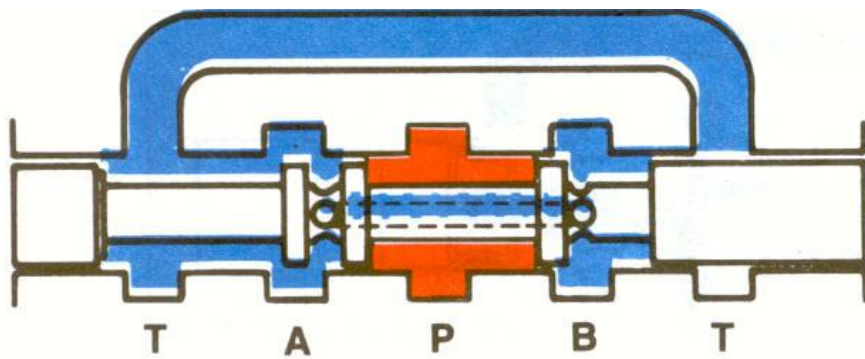


Figure 8-25. Special circuit spool configurations.

2. Exhaust flow must pass thru small opening which is adjustable by moving check valve off seat.

1. Pilot oil flows in freely over check valve.

ADJUSTING
SCREW

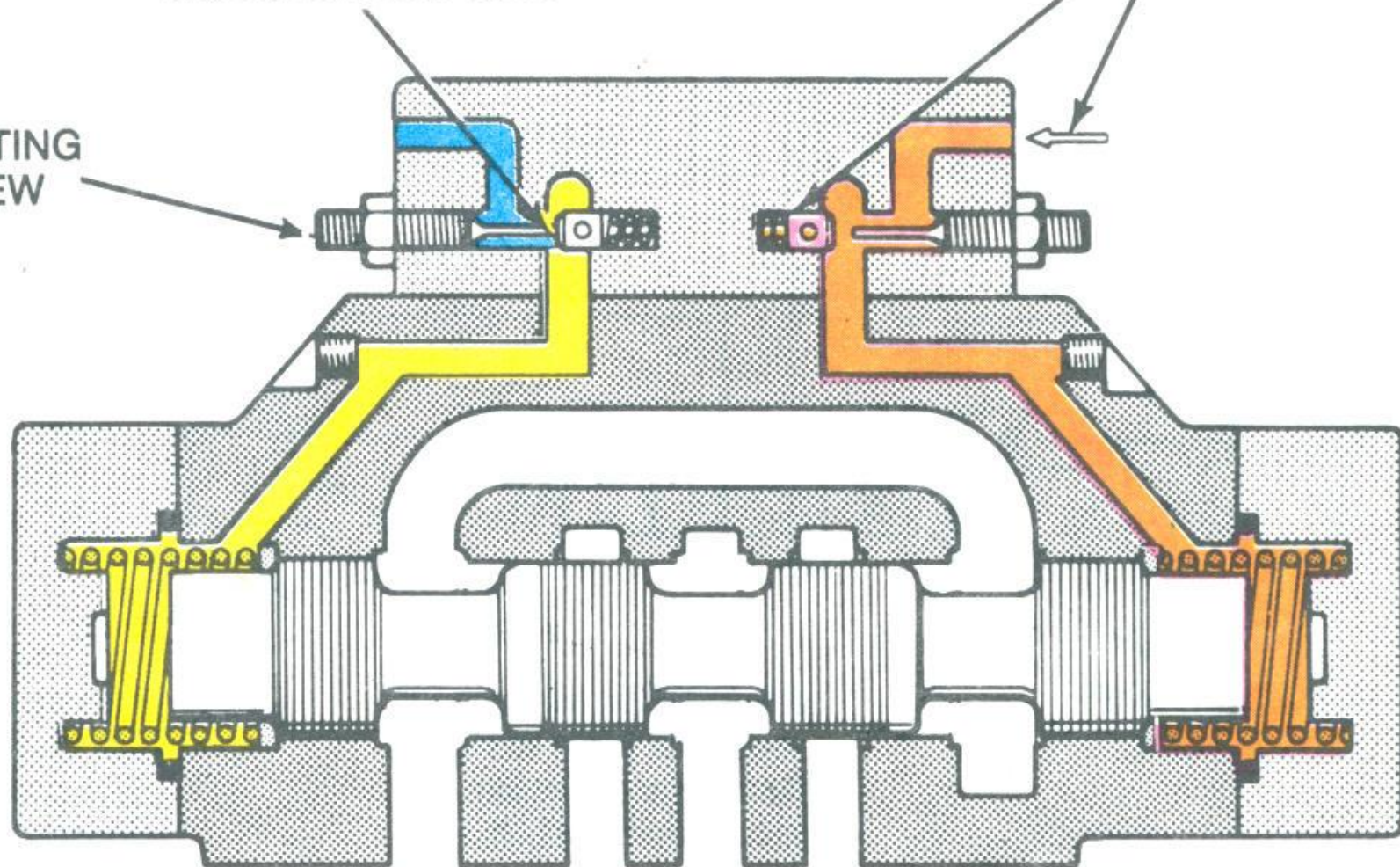


Figure 8-30. Pilot choke controls spool movement.

Large volume fills
slowly so valve
shifts slower
to right

Small volume fills
rapidly so valve
shifts quickly
to left

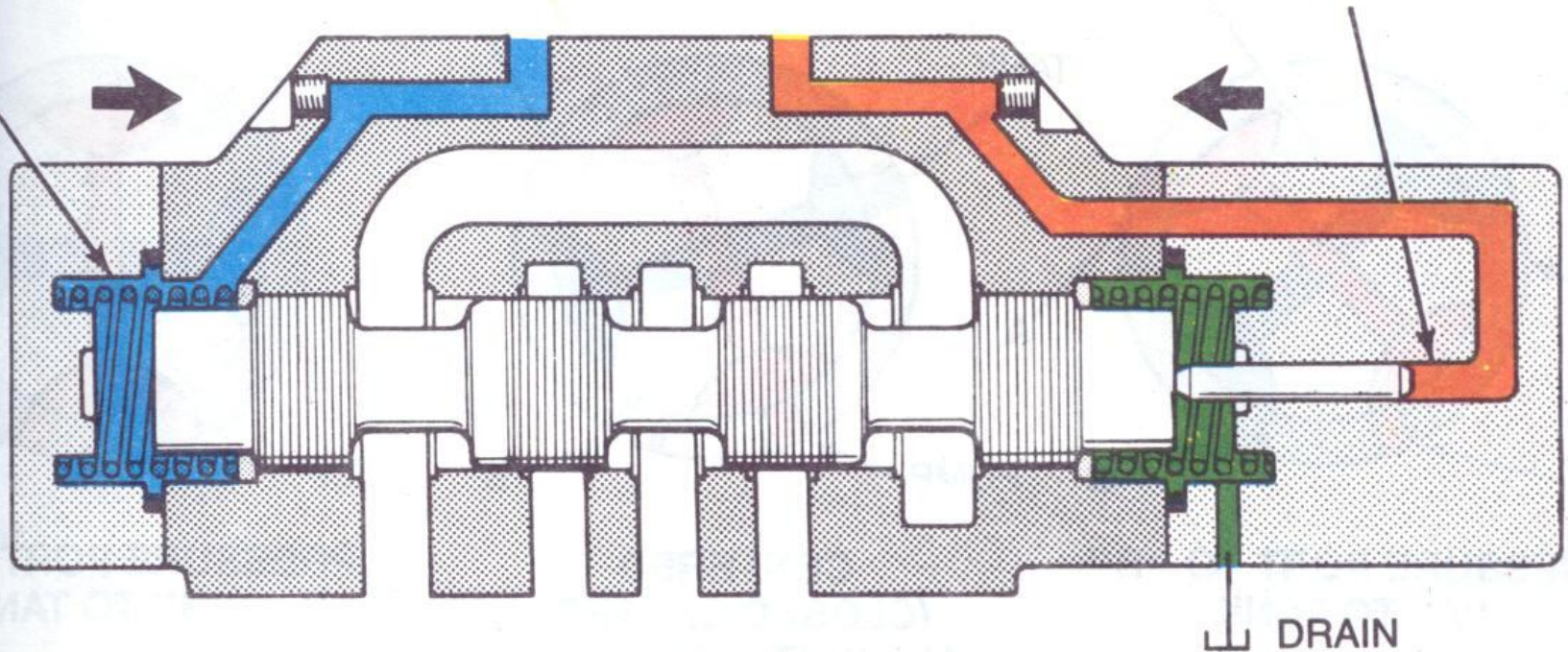


Figure 8-32. Pilot piston speeds valve shifting.

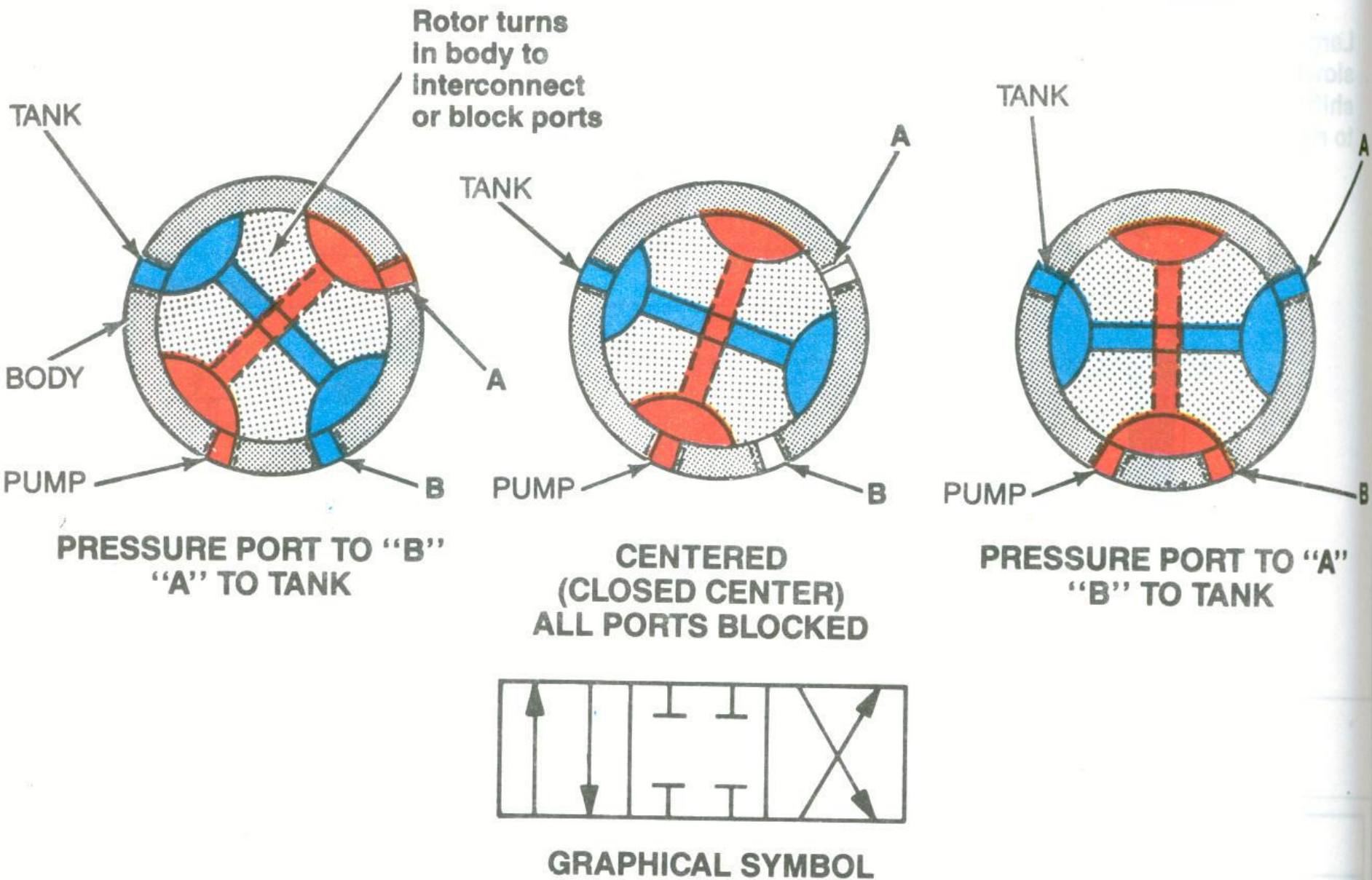


Figure 8-34. Rotary four-way valve operation.

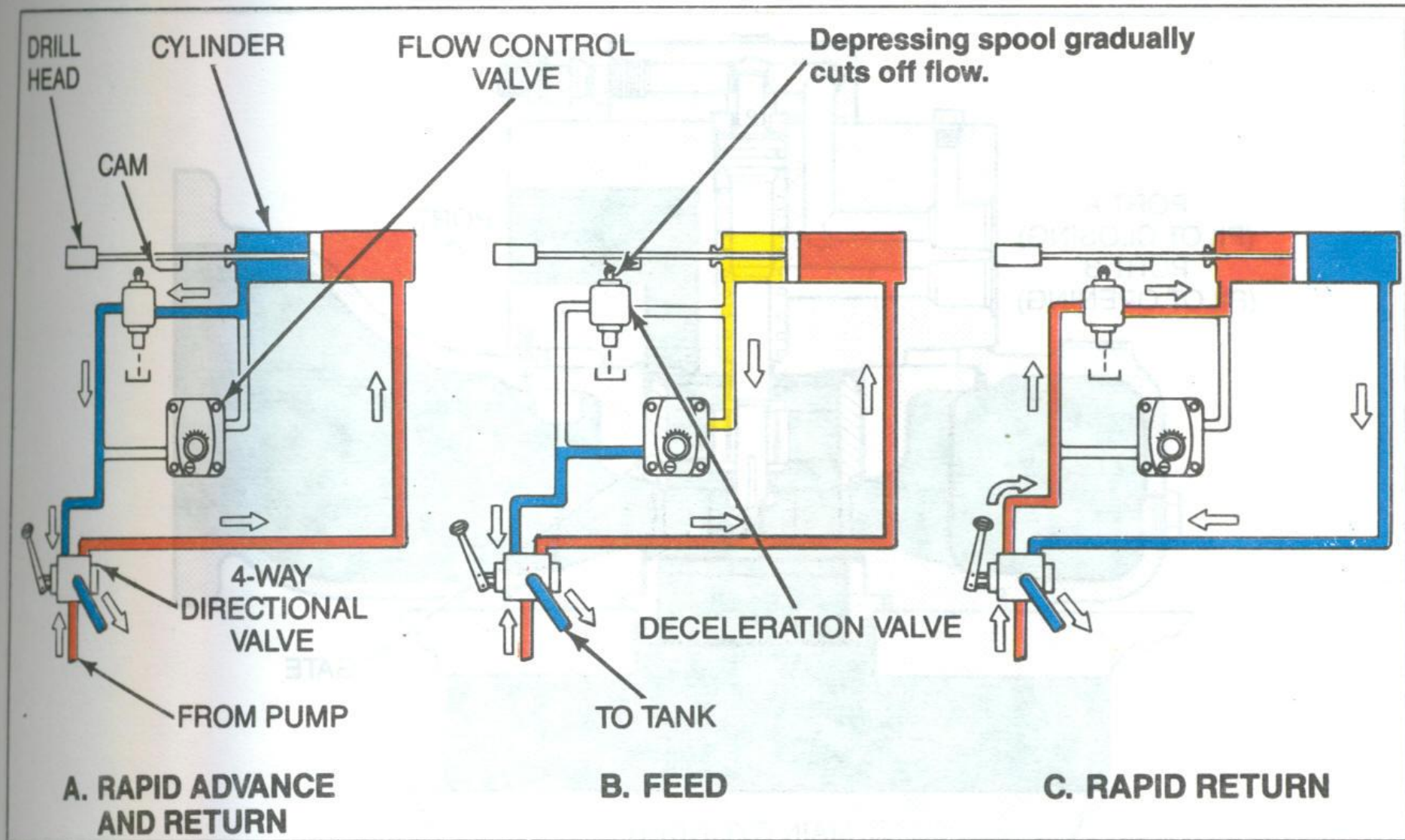


Figure 8-37. Deceleration valve in feed control system.