HYDRAULICS

BASIC COURSE
ON
INDUSTRIAL HYDRAULICS
&
AUTOMATION

What is Hydraulics?

a science that deals with practical applications of liquids in motion.

from the Greek word *hydro* - “ water ”, and *aulos* - “ pipe “.

The transmission and control of forces and motions by fluids.

COMPARISON OF SYSTEMS

FESTO

CRITERIUM	HYDRAULICS	PNEUMATICS	ELECTRICS/ ELECTRONICS
Energy carrier	Oil (liquids in general)	Air	Electrons
Energy transmission	Pipes, hoses, tubes, bores	Pipes, hoses, tubes, bores	Electrically conductive materials (cables, etc.)
Conversion from or into mechanical energy	Pumps, cylinders, hydraulic (HY) motors	Compressors, cylinders, pneumatic (PN) motors	Generators, batteries, electric (E) motors, magnets, solenoids, linear (induction) motors
Most important characteristic quantities	Pressure p (30 . . . 400 bar) flow Q	Pressure p (approx. 6 bar) flow Q	Voltage U Electric current I

COMPARISON OF SYSTEMS . . . continued

FESTO

CRITERIUM	HYDRAULICS	PNEUMATICS	ELECTRICS/ ELECTRONICS
Power efficiency	Excellent Compact, reasonably priced components due to high operating pressures of up to approx. 400 bar. Most simple linear Motor=cylinder	Good Limitations though, due to max. Operating pressure of only 6 bar	Fair to good Weigh coefficient of E-motors is approx. 10 times that of HY-motors. Electric switch, though, has considerable advantages compared to directional-control-valve.
Accuracy of motion (this can be improved, though, in all systems by positioning action)	Excellent Because oil can hardly be compressed	Fair to good because air is compressible	Differs considerably On the one hand hysteresis and slippage, on the other hand synchronous motors and stepping motors

COMPARISON OF SYSTEMS . . . continued

FESTO

<table>
<tr><th>CRITERIUM</th><th>HYDRAULICS</th><th>PNEUMATICS</th><th>ELECTRICS/
ELECTRONICS</th></tr>
<tr><td>Efficiency</td><td colspan="2">Fair to good
Volumetric and frictional losses during primary and secondary energy conversion, as well as with the open and closed-loop control of valves</td><td>Good
As long as electricity is available as primary energy</td></tr>
<tr><td rowspan="2">Controllability</td><td>Excellent
By means of valves and variable-displacement pumps
Servo valves for closed-loop techniques</td><td>Excellent
By means of valves (for small to medium powers)</td><td rowspan="2">For small powers:
Excellent,
For larger powers:
Fair to good
By means of switches, relays, semiconductors, variable speed motors and variable resistors, etc.</td></tr>
<tr><td colspan="2">Improvements are possible in combination with electrics</td></tr>
</table>

COMPARISON OF SYSTEMS . . . continued

FESTO

CRITERIUM	HYDRAULICS	PNEUMATICS	ELECTRICS/ ELECTRONICS
Generation of linear movement	Extremely simple By means of cylinders	Extremely simple By means of cylinders	Slightly more complicated By means of linear motors
Signal linkage between hydraulic systems and other systems		Pneumatic operation of directional-control valves	Electromagnetic control of valves (solenoids, proportional valves), limit switches and pressure switches

HYDRAULIC FLUIDS

FESTO

VISCOSITY:

- “resistance to flow “
- the most important property of hydraulic fluids
- the measure of internal friction of hydraulic fluids, i.e. the resistance which must be overcome to move two adjacent layers of liquid against each other

HYDRAULIC FLUIDS

FESTO

LOW VISCOSITY MEANS:

- high leakage rates
- reduced lubrication
- little resistance to flow
- easy to pump
- fast reaction to signals

HIGH VISCOSITY MEANS:

- pressure loss due to resistance
- hard to pump
- excellent lubrication characteristics
- low leakage rates
- slow reaction to signals

1. About Hydraulics

Advantages of Hydraulic Systems:

- force levels can be made very high
- force can be transmitted over moderate distances
- store energy for reserve or emergency use.
- the amount of force or motion can be controlled with a high degree of precision
- motion can be reversed very quickly

Weaknesses of Hydraulic Systems:

- must be totally enclosed
- requiring constant maintenance and clean-up
- entire system must be located close to the point of actual usage
- fire-resistant fluids are expensive

2. The basic hydraulic system

Basic components

1. A fluid, usually oil
2. A tank to hold a supply of fluid
3. Fluid conditioning devices to keep the fluid clean and cool
4. A prime mover (electric motor or engine), to drive the pump
5. A pump, to cause fluid to flow
6. Conductors, usually pipe or tubing, to carry the fluid
7. Valving, to control fluid flow, direction, and pressure
8. One or more actuators, usually cylinders or hydraulic motors

2. The basic hydraulic system

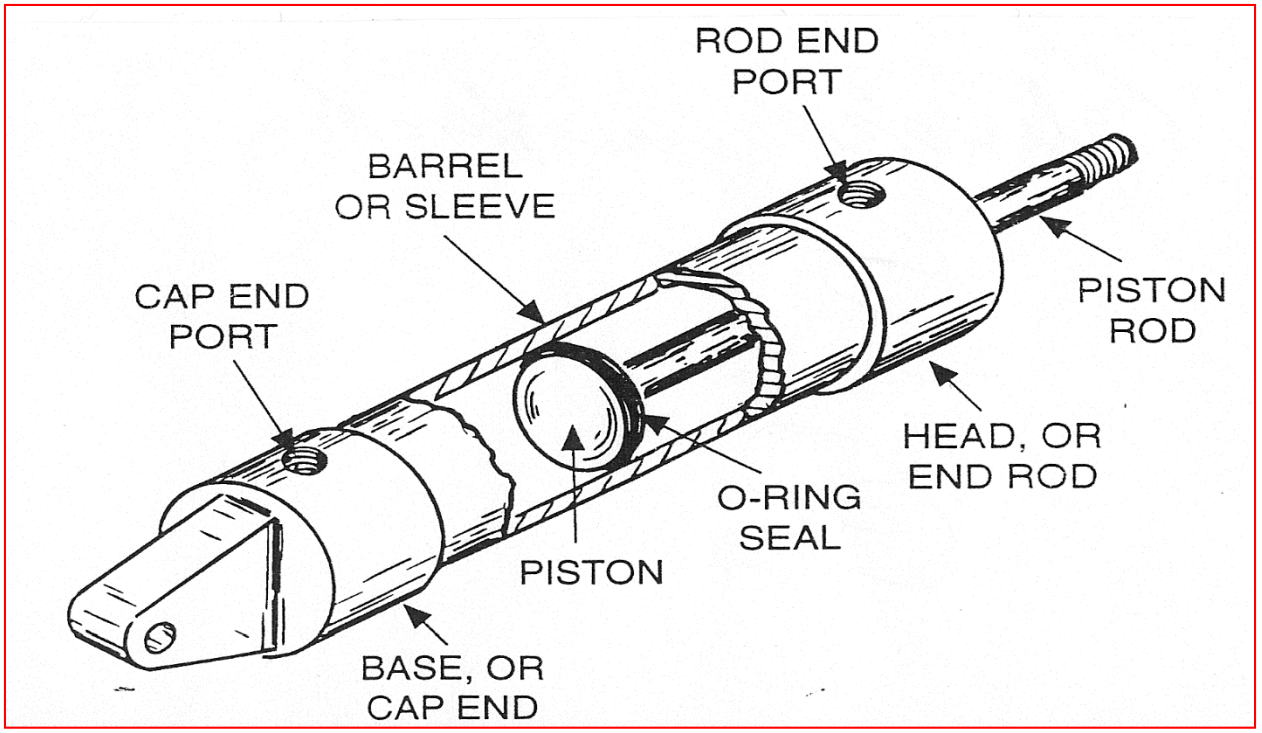
The hydraulic system:

Linear motion of the actuator
(Cylinder)

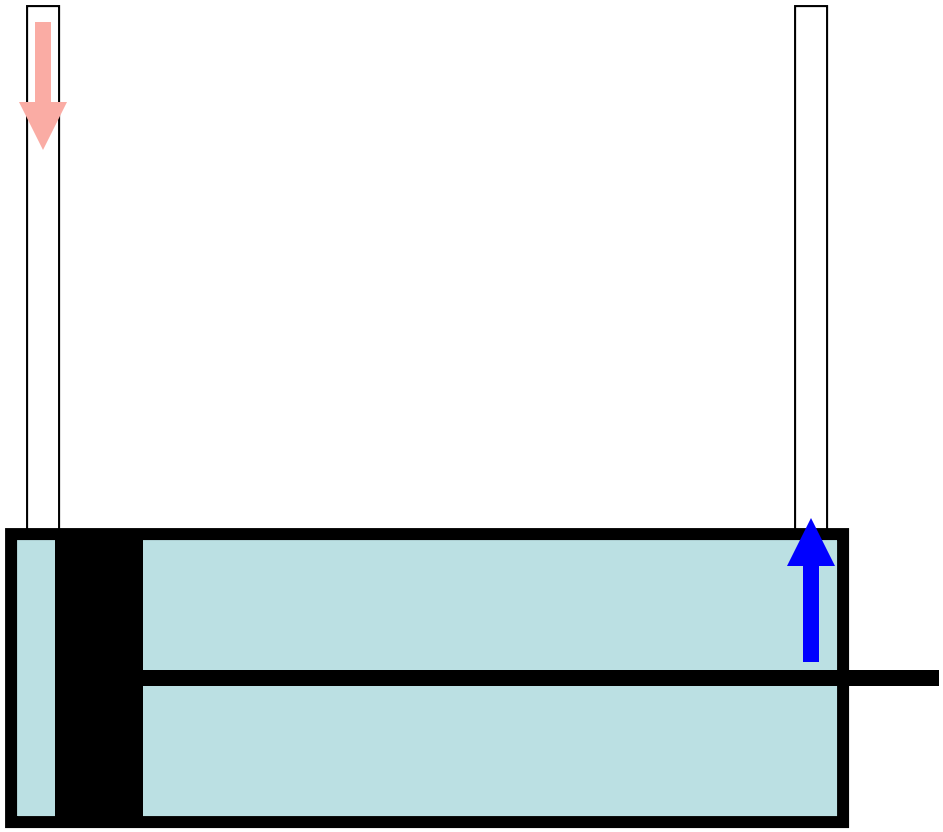
&

Basic oil circuit
(Pump, Conductors, Valving)

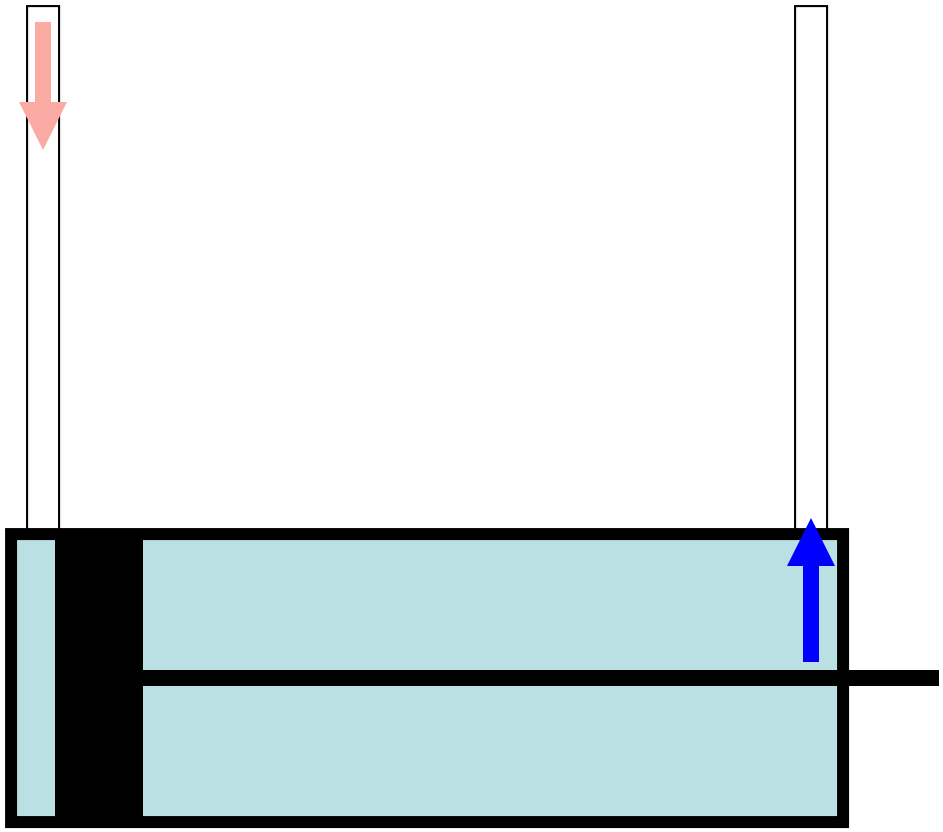
Single acting cylinder



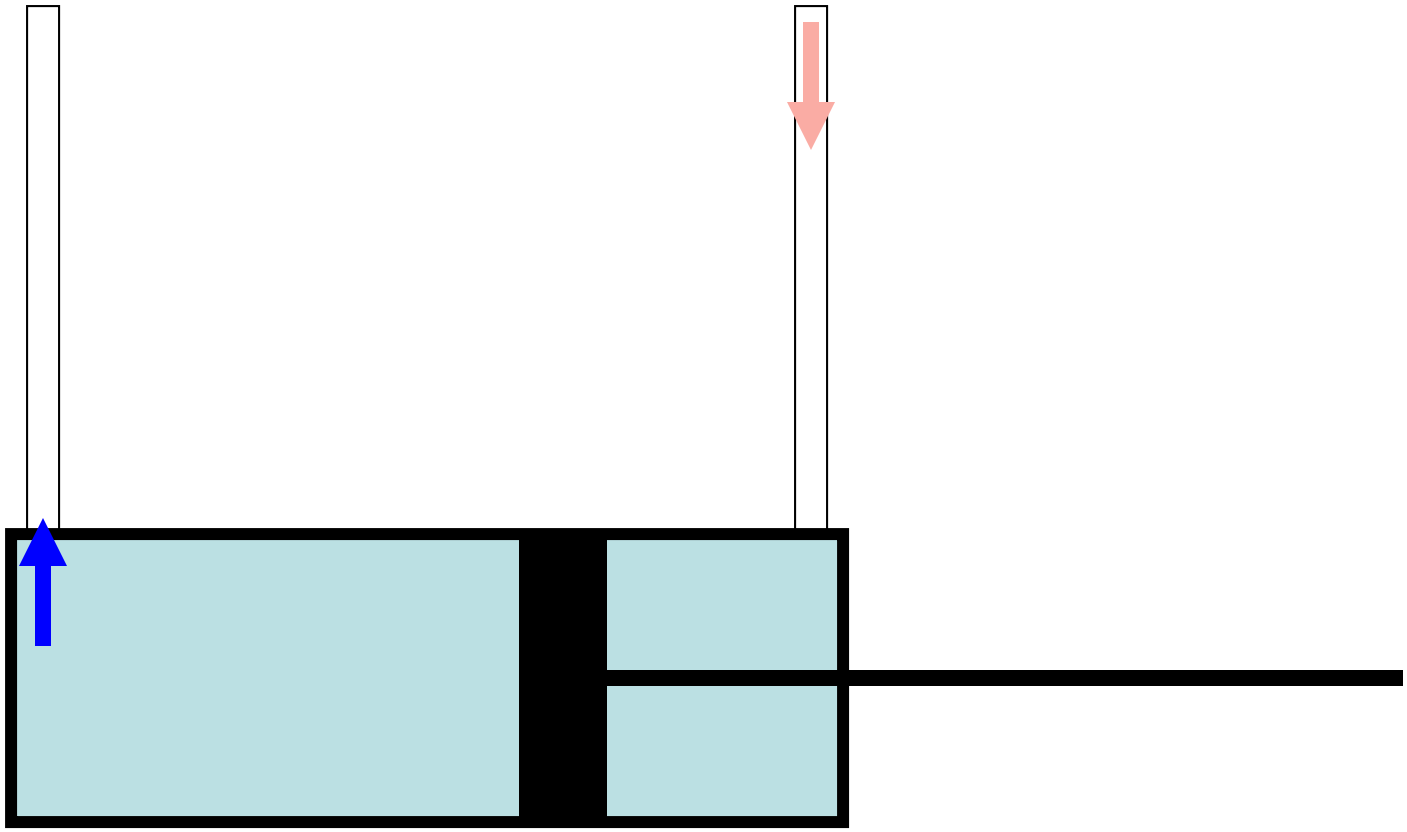
Linear motion



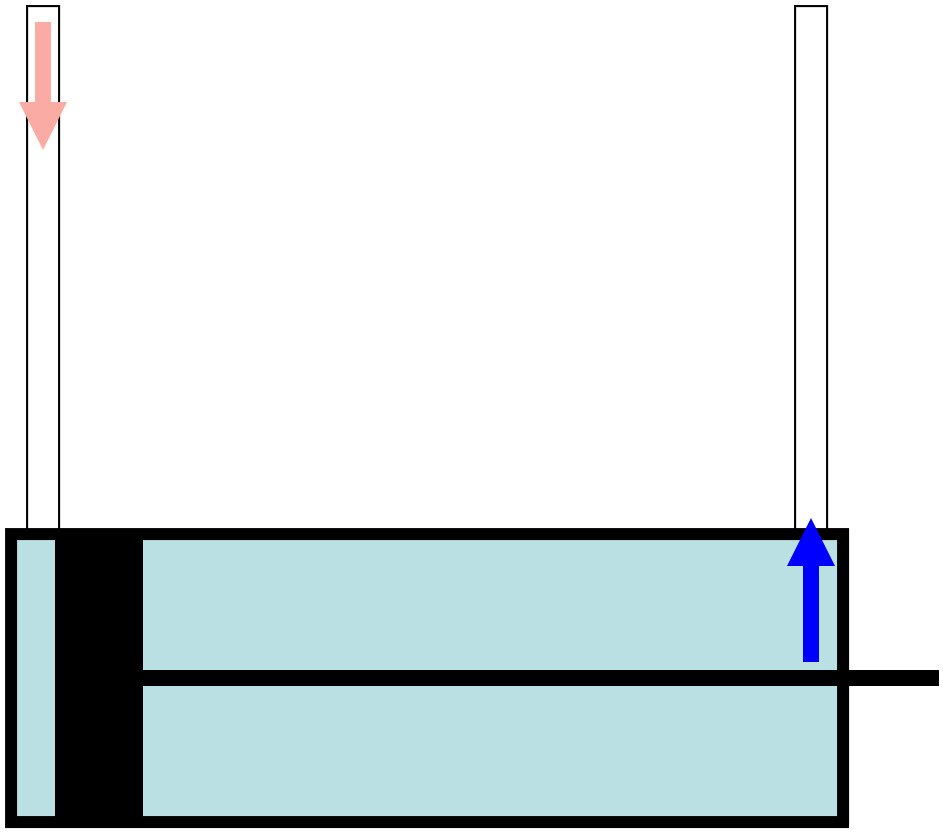
Linear motion



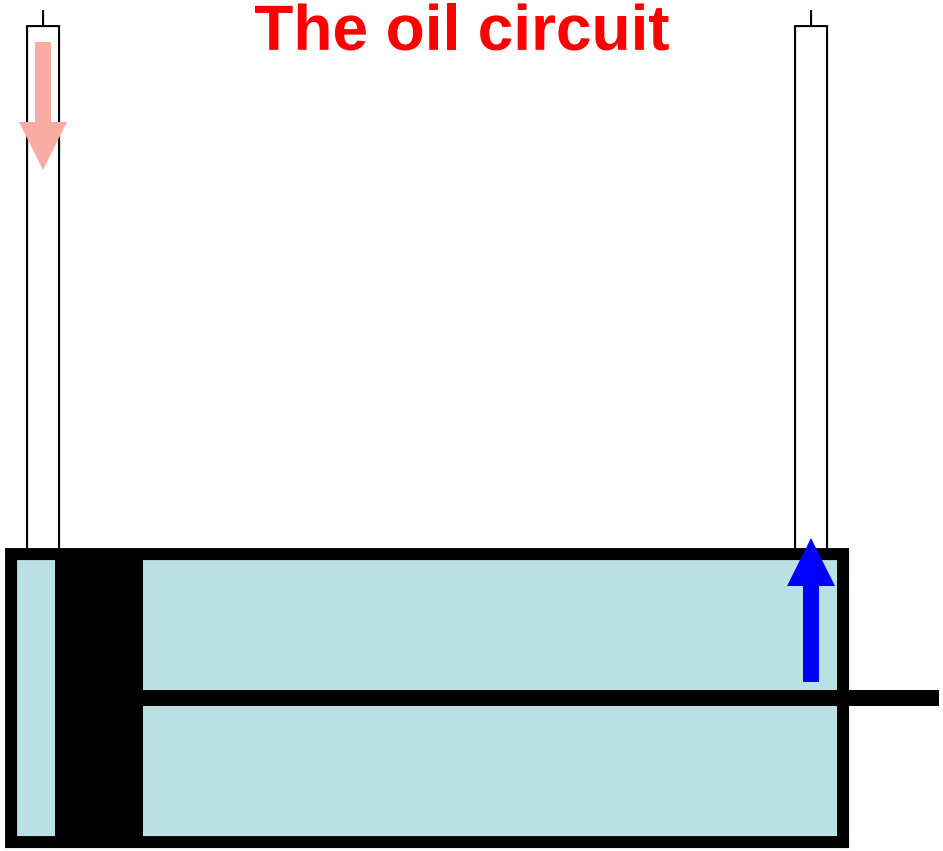
Linear motion

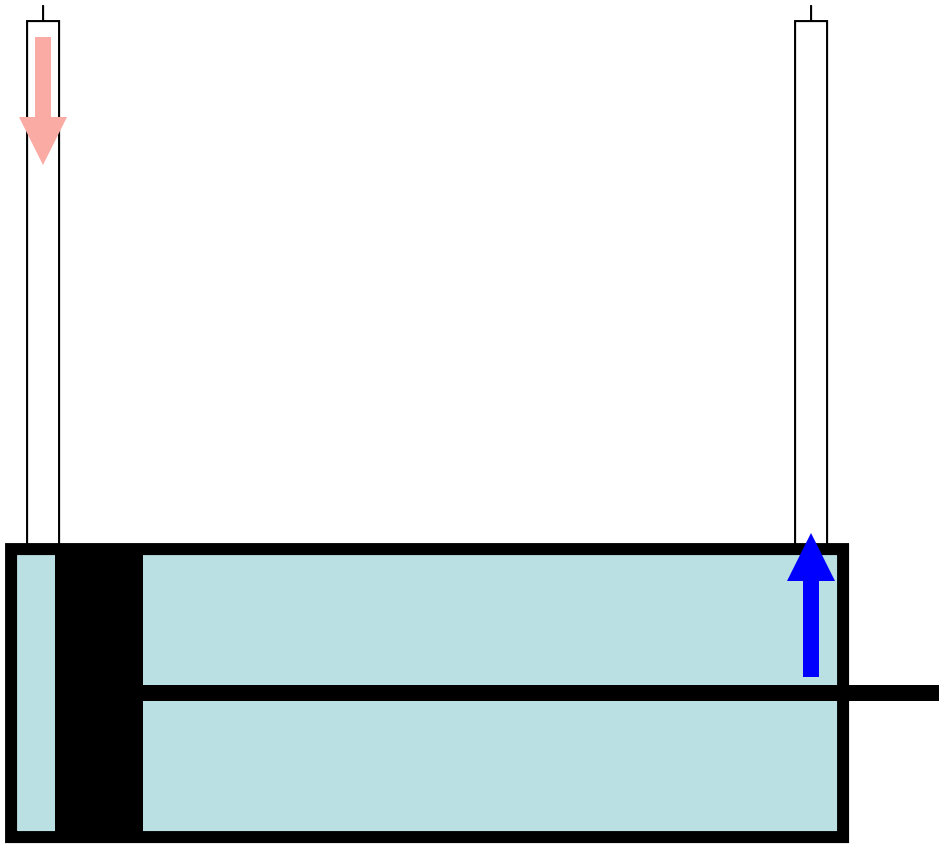


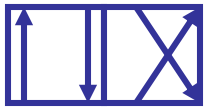
Linear motion



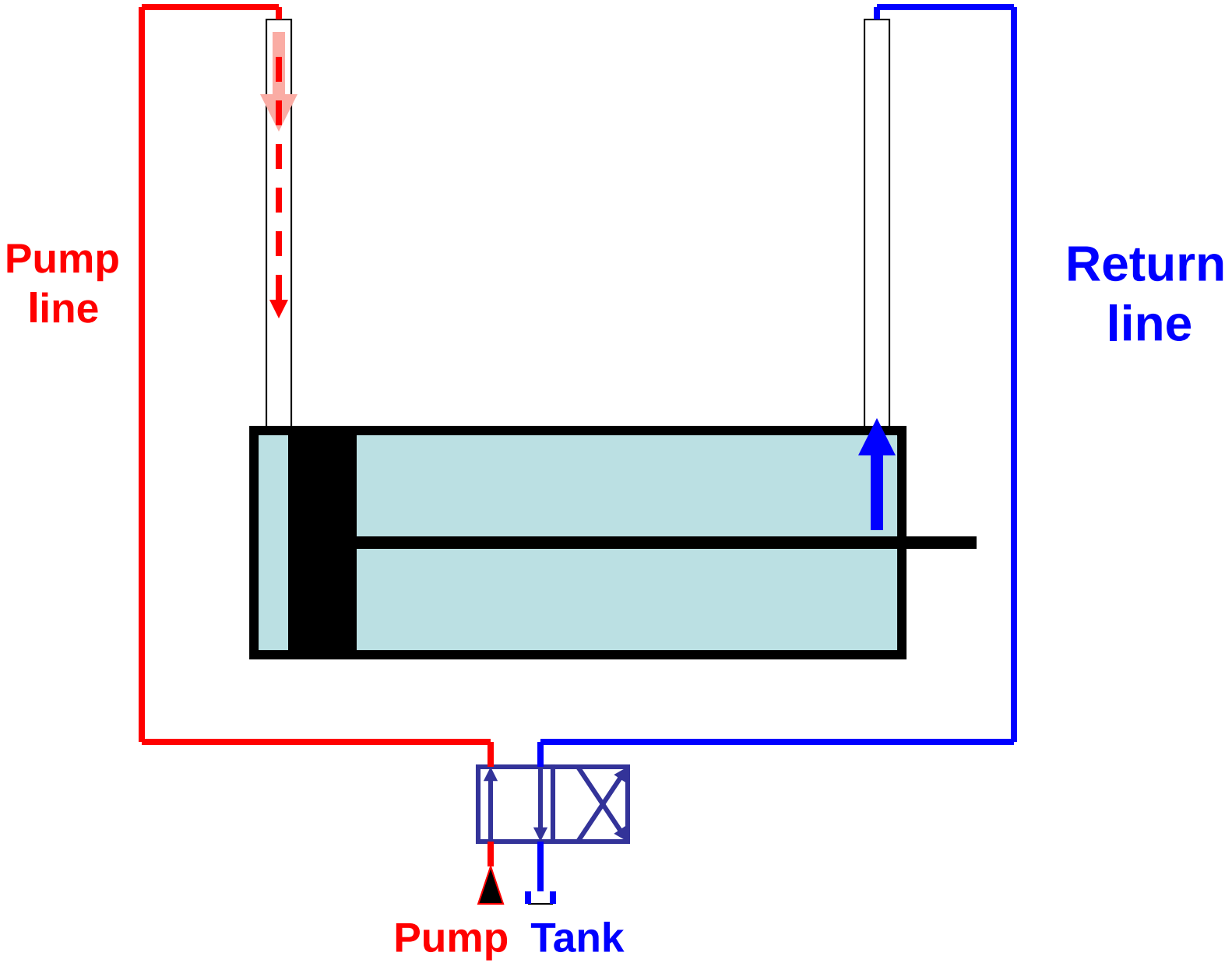
The oil circuit

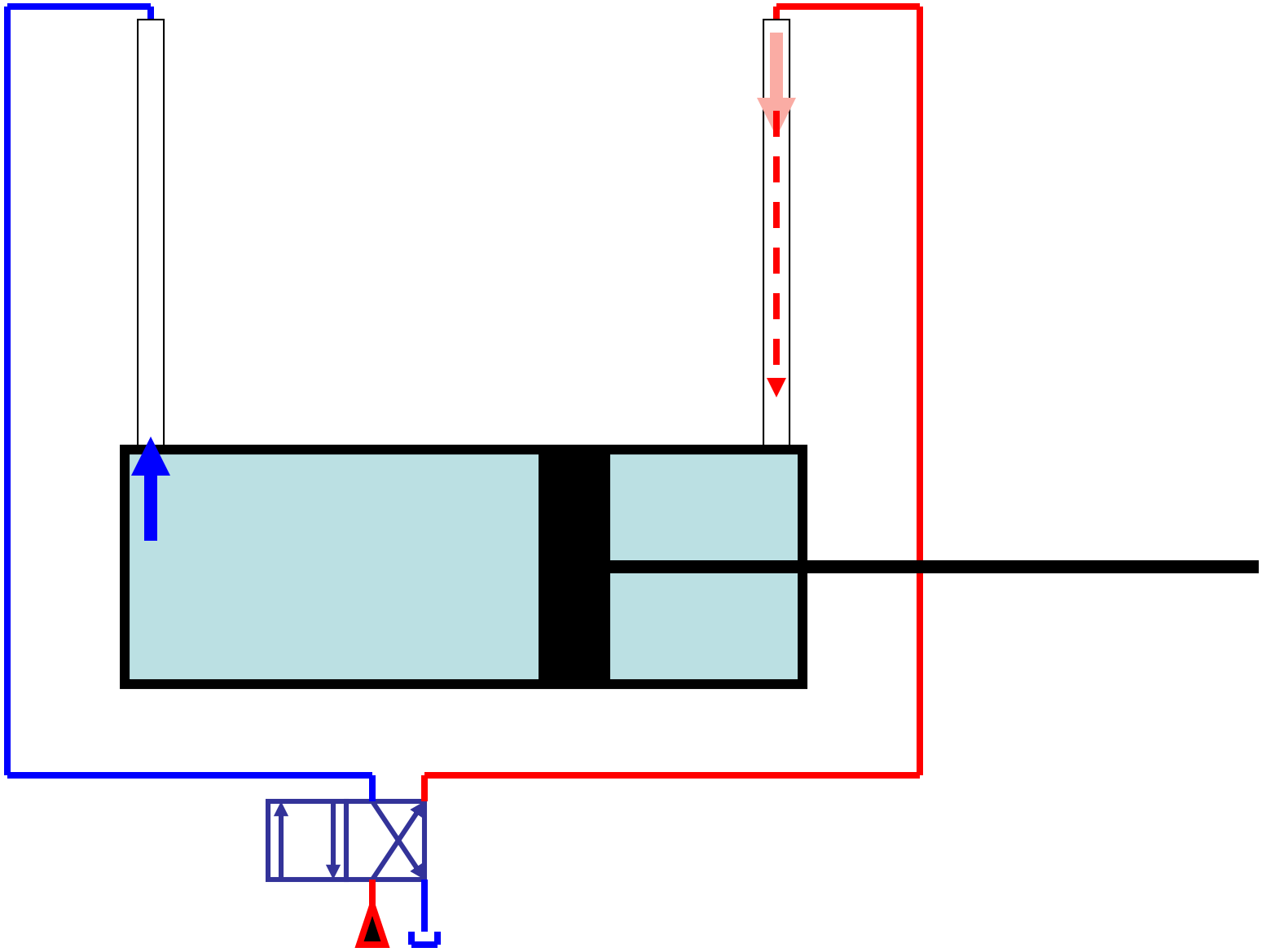


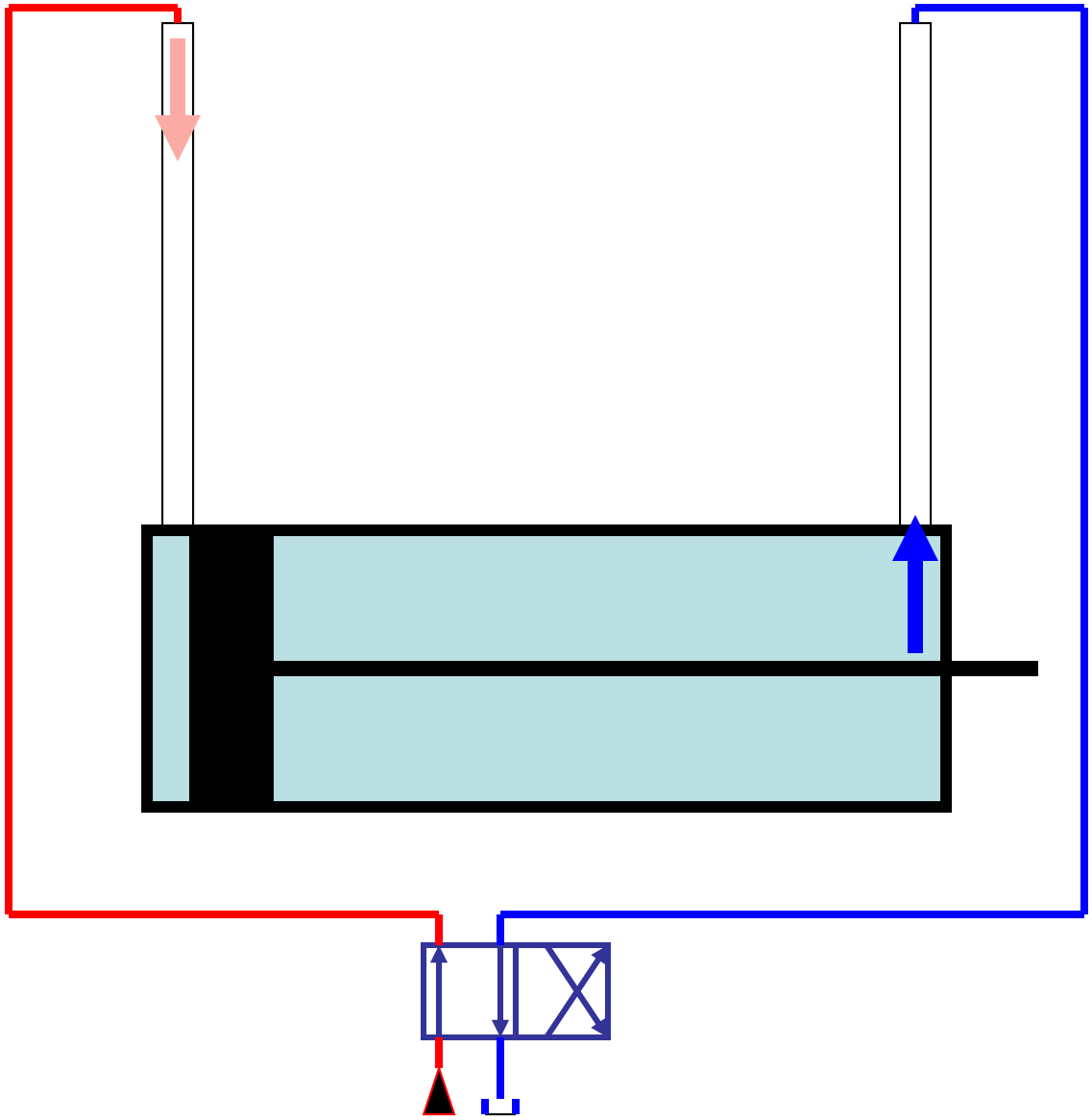


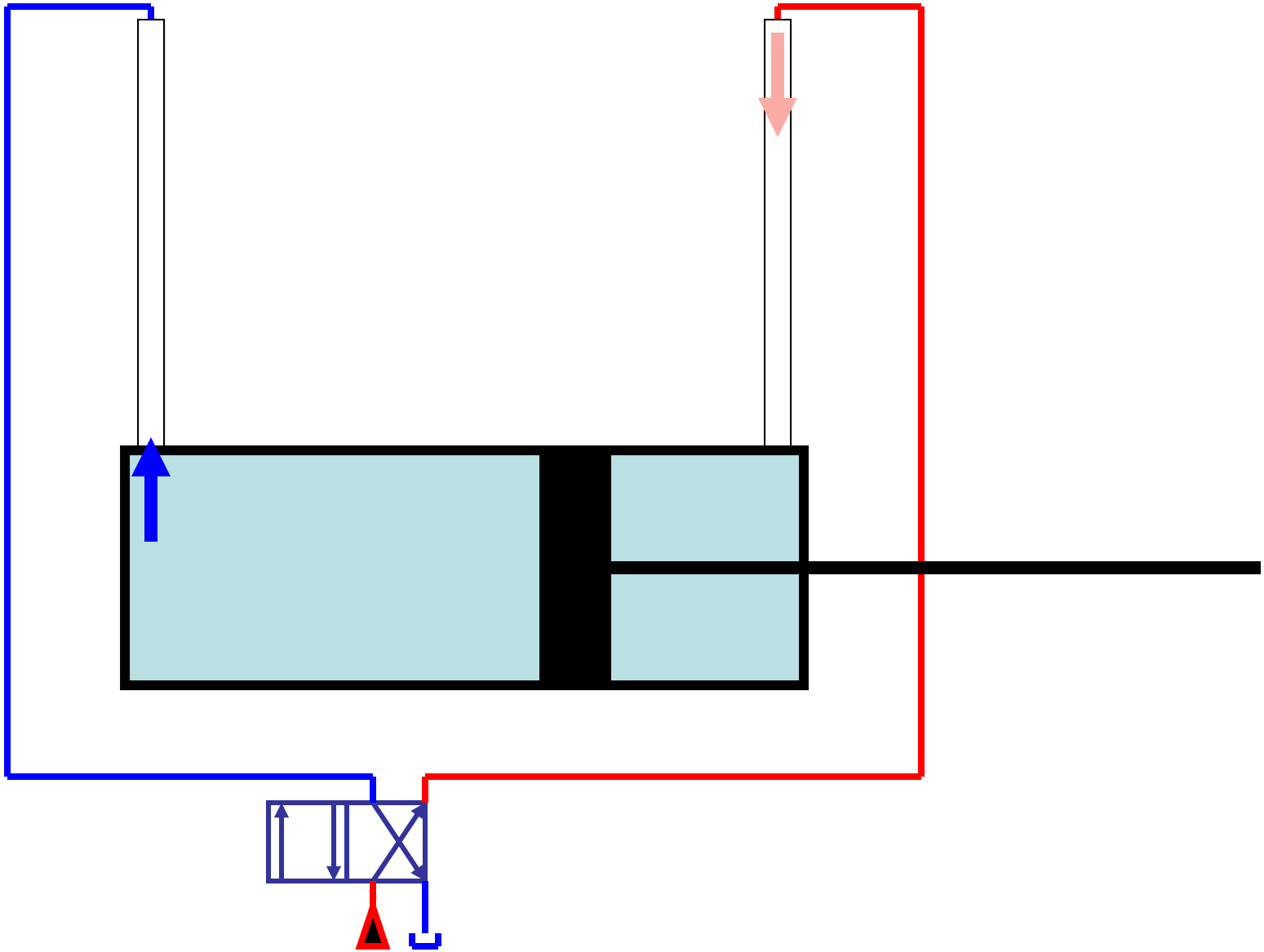


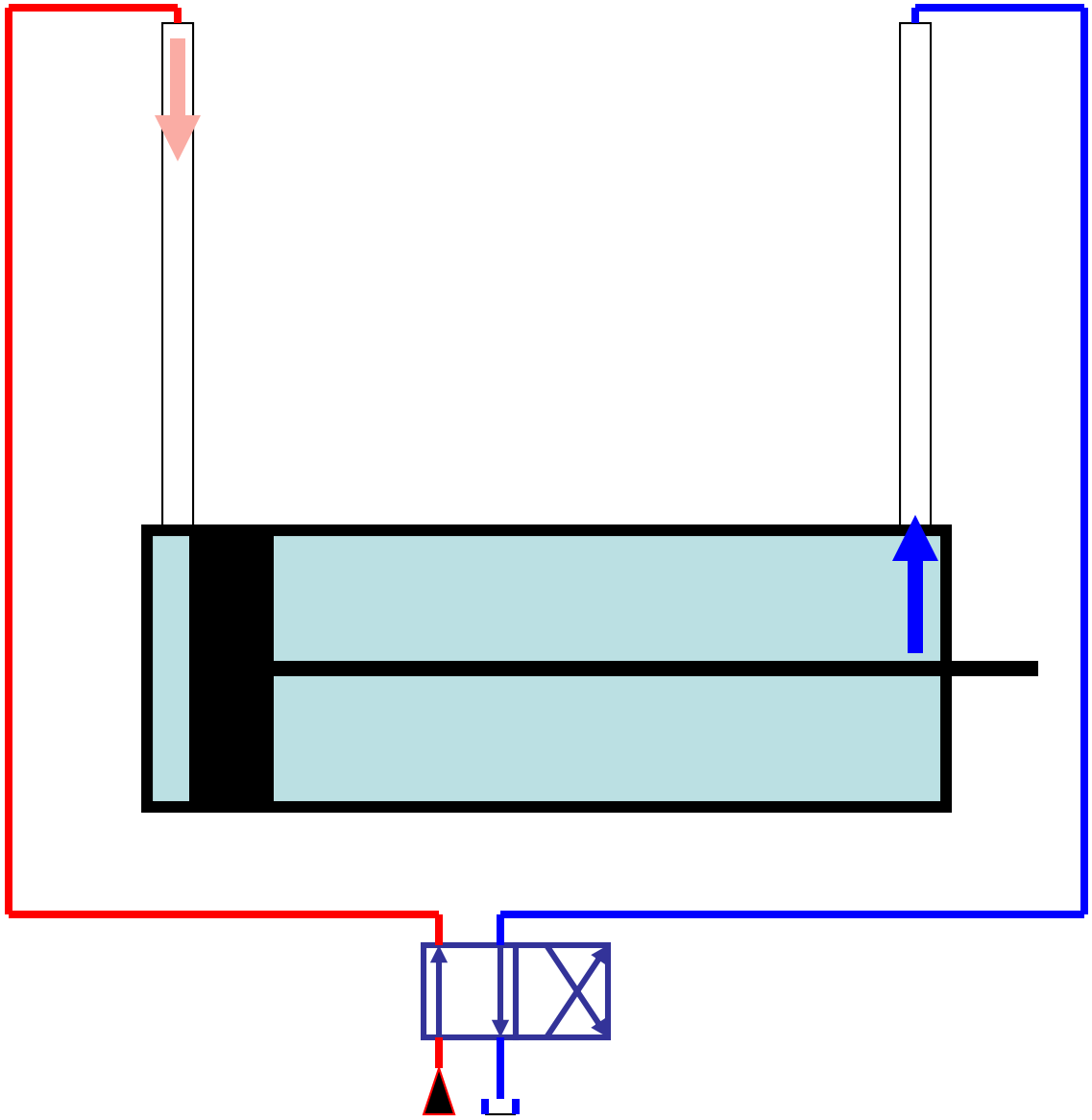
Directional control valve

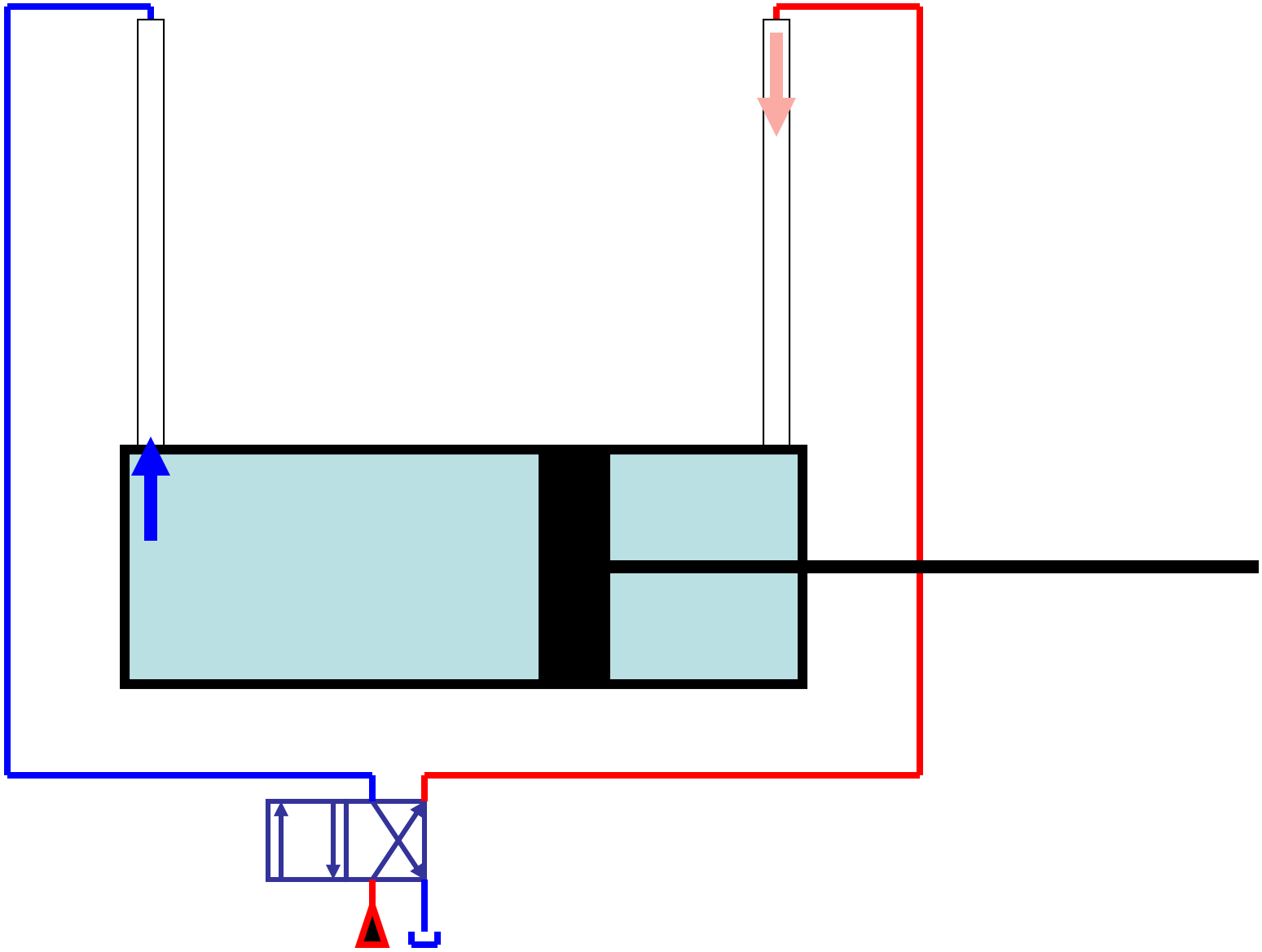

Pump line
Return line
Pump
Tank

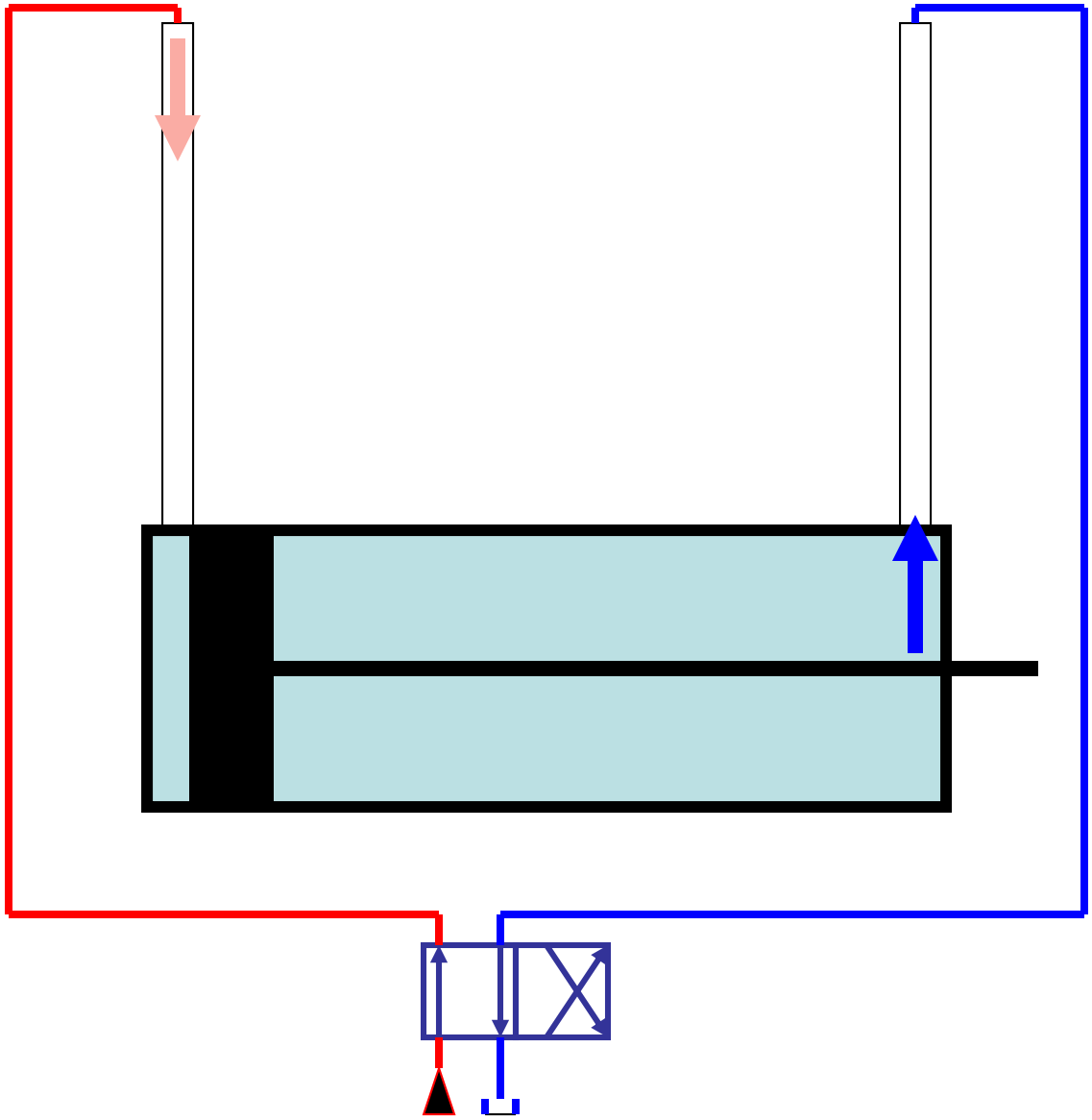












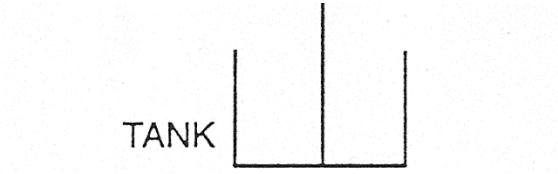
2. The basic hydraulic system

1. Hydraulic fluid

Desired characteristics:

- Appropriate viscosity
- Retain its lubrication abilities even when subjected to high heat
- Should be free of chemicals
- Should be fire-resistant
- Should be resistant to oxidation

2. Hydraulic Tanks

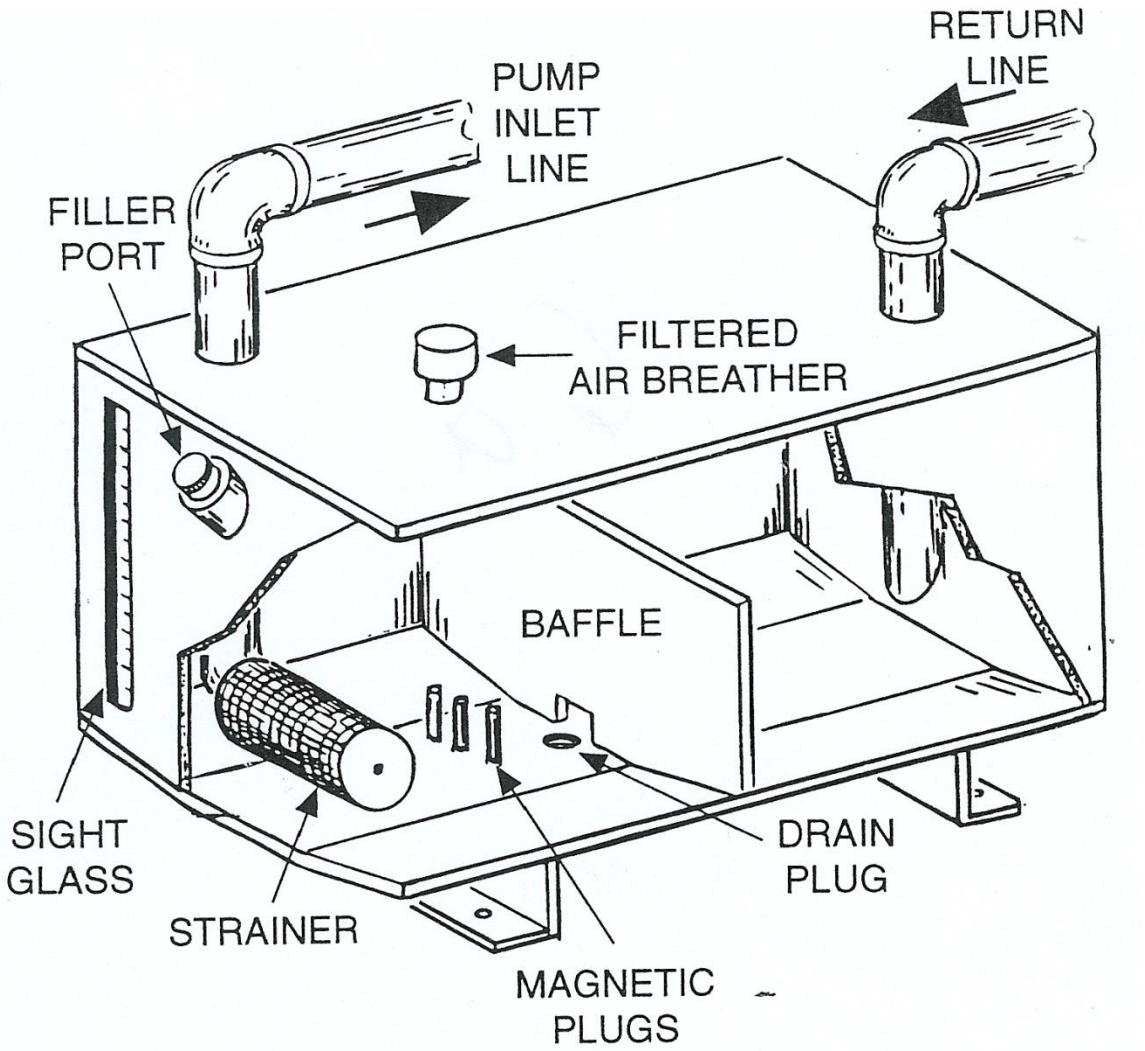


A Tank serves the following functions:

1. Stores the hydraulic fluid of the system, including some reserve;
2. Protects the stored fluid from outside contamination:
3. The amount of fluid in the system can be checked;
4. Fluid can be added or changed when necessary;
5. Cools the fluid as it returns from the actuators; and
6. Removes contaminants such as water, dirt,… from the fluid.

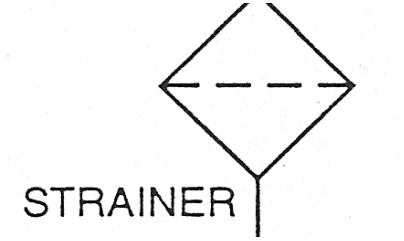
2. The basic hydraulic system

Typical hydraulic tank



2. The basic hydraulic system

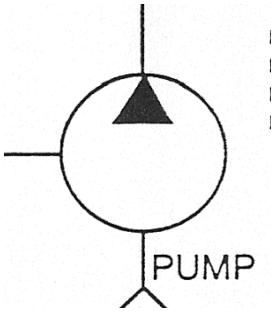
3. Fluid conditioning devices:



Strainer =a fine metal screen which cleans contaminant particles from the system by blocking, or excluding them

Filter = is made of a porous material which allows fluid to flow through, but which traps and holds ("absorbs") very small contaminant particles

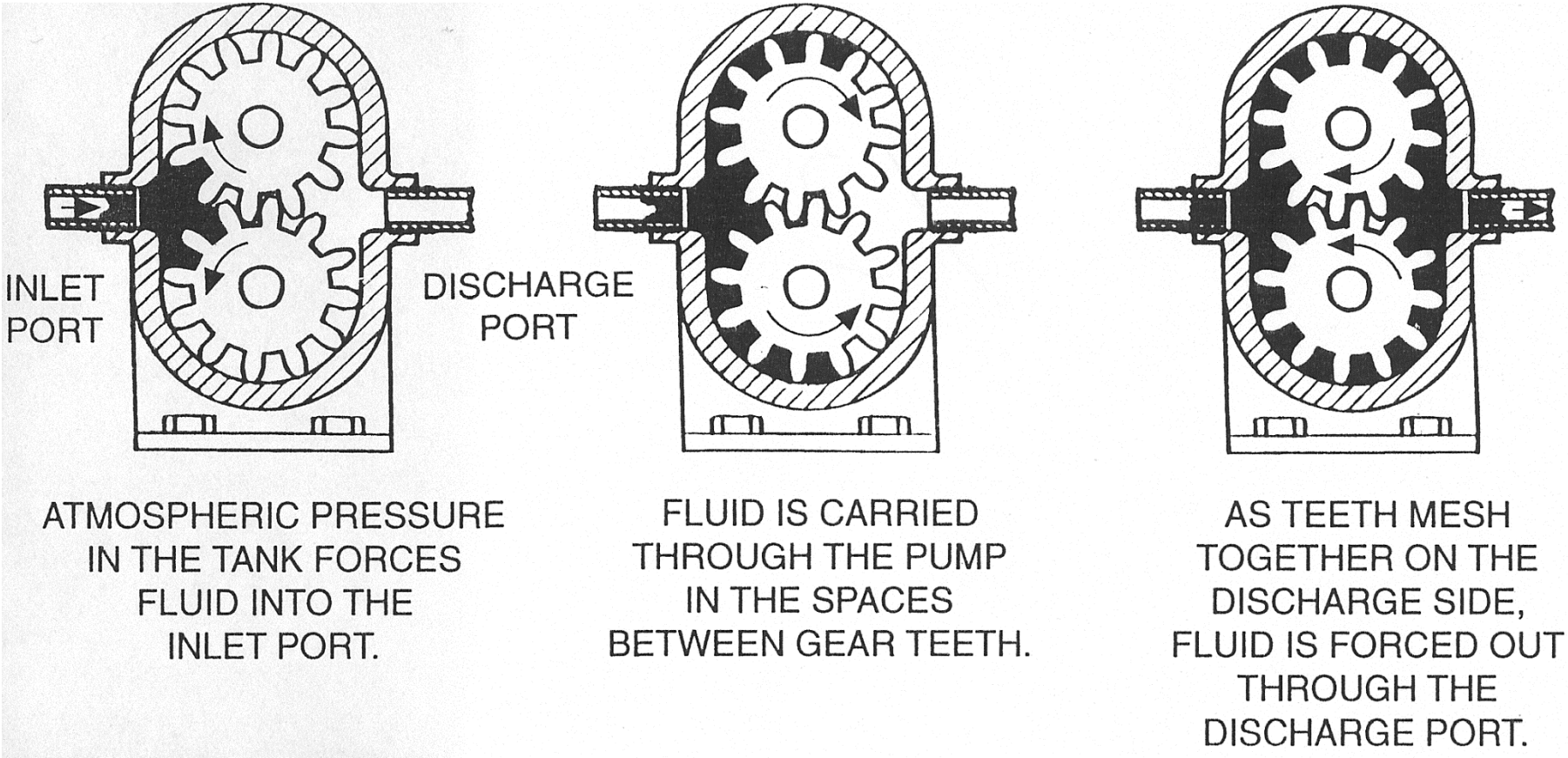
4. Hydraulic Pumps:



A mechanical device which causes **fluid flow** in the system.
The most common type of pump is the **external gear pump.**

2. The basic hydraulic system

External gear pump

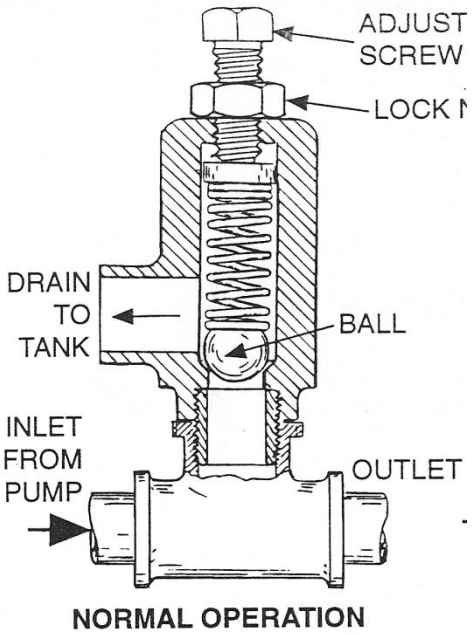


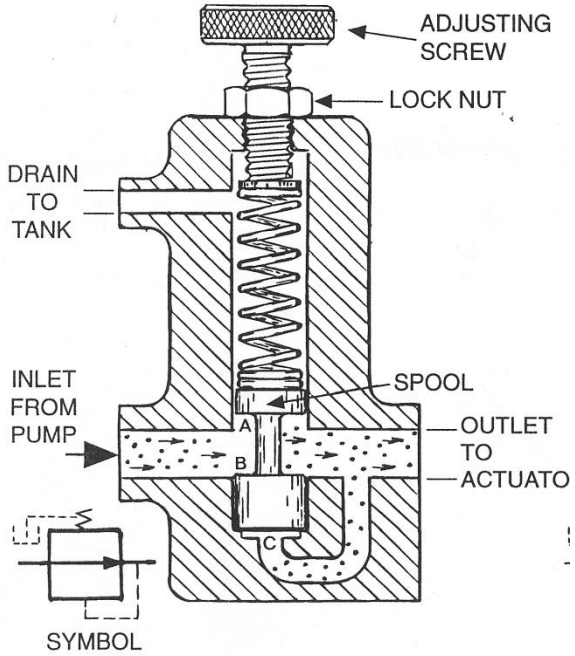
2. The basic hydraulic system

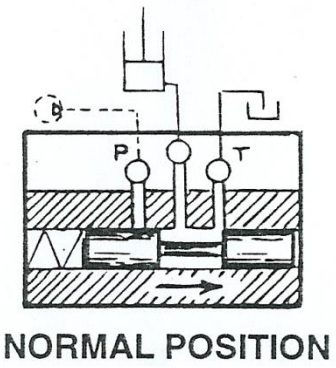
5. Valves

• control fluid flow, direction and pressure

Pressure relieve valves	Pressure reducing valves	Directional control valves
Set a maximum operating Protect system components	serves for individual regulated pressures in individual lines.	

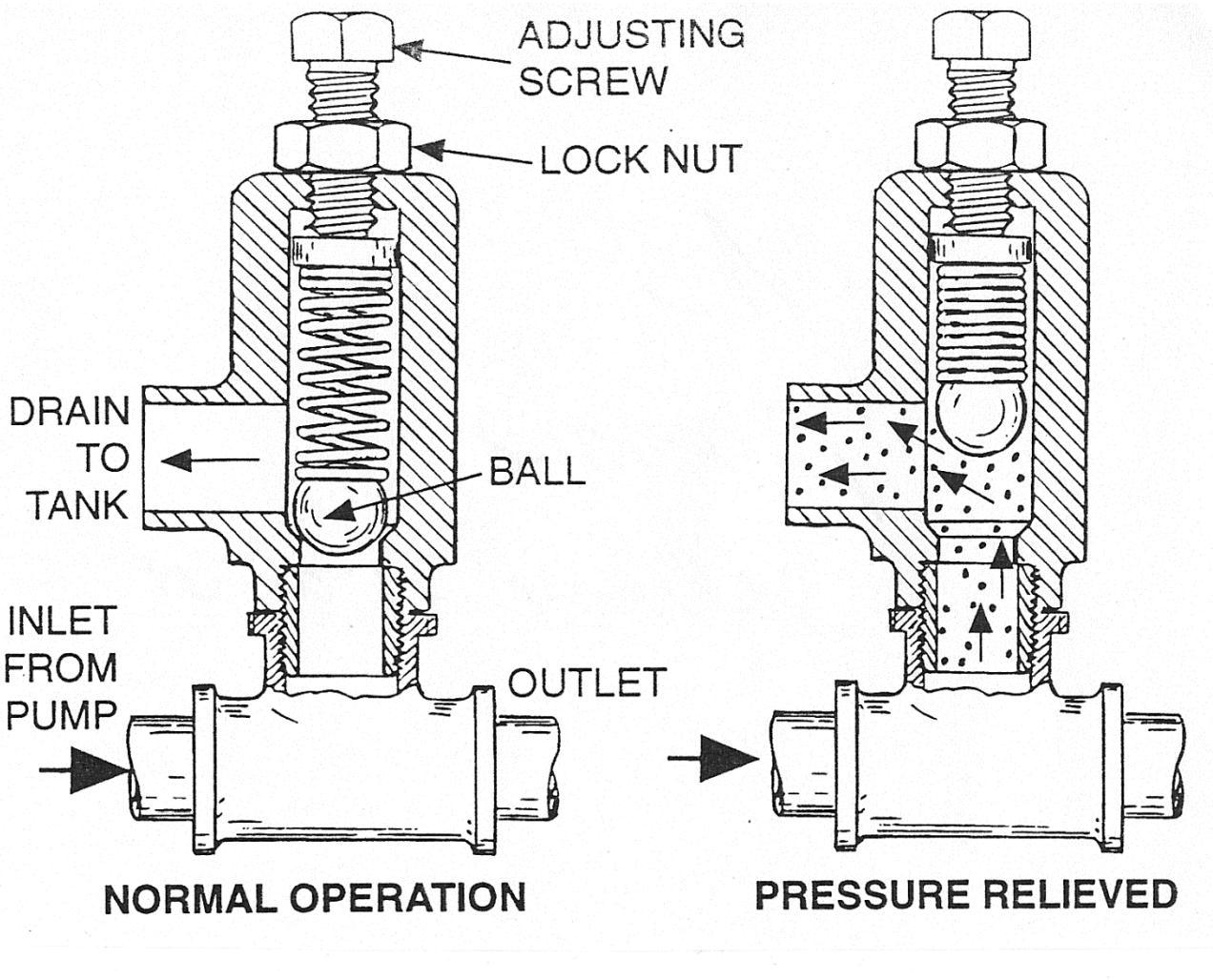


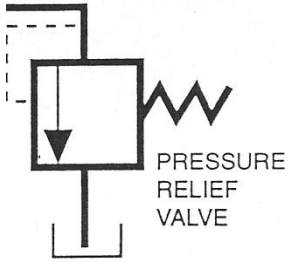




2. The basic hydraulic system

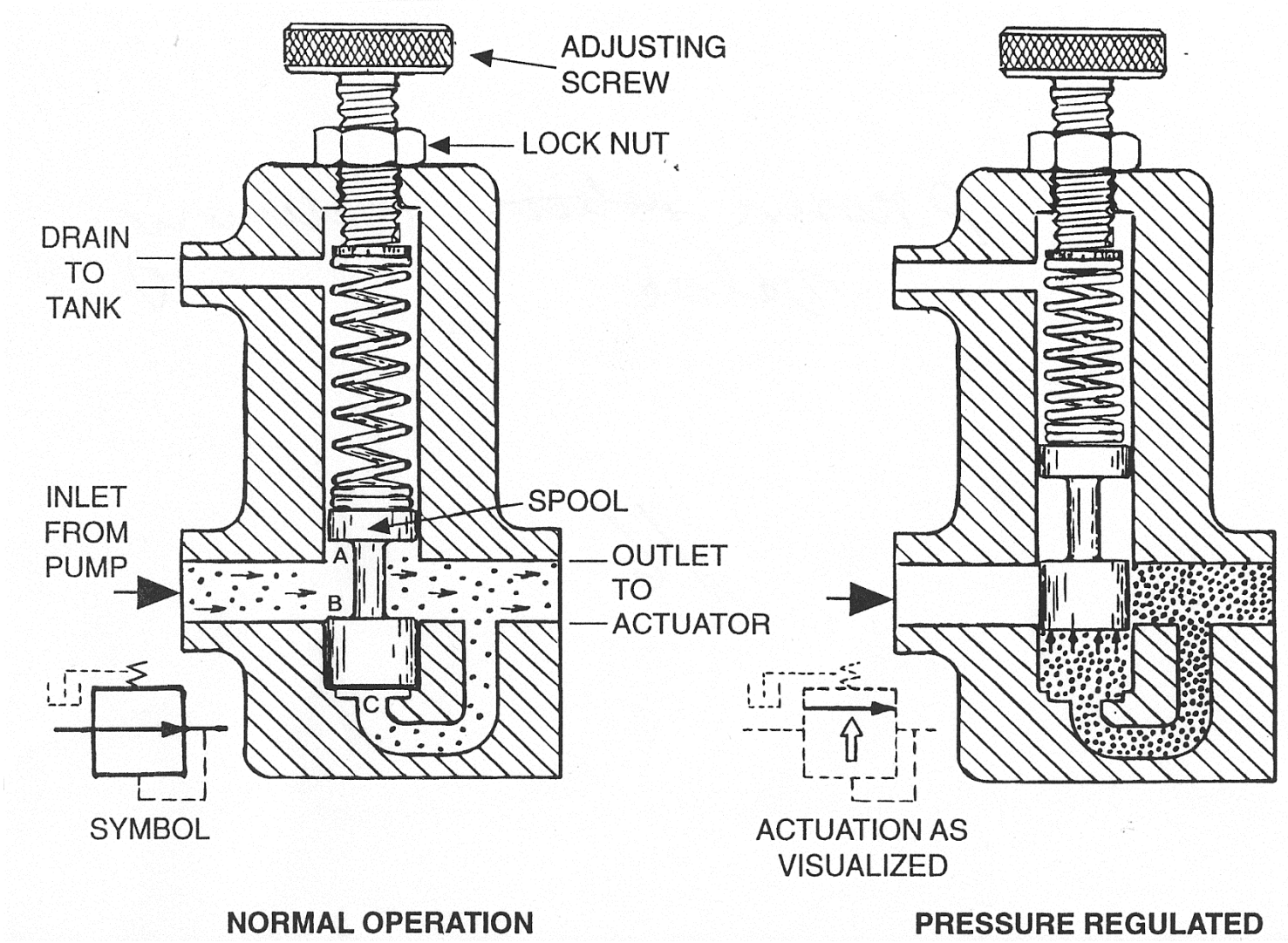
Operation of a pressure relief valve





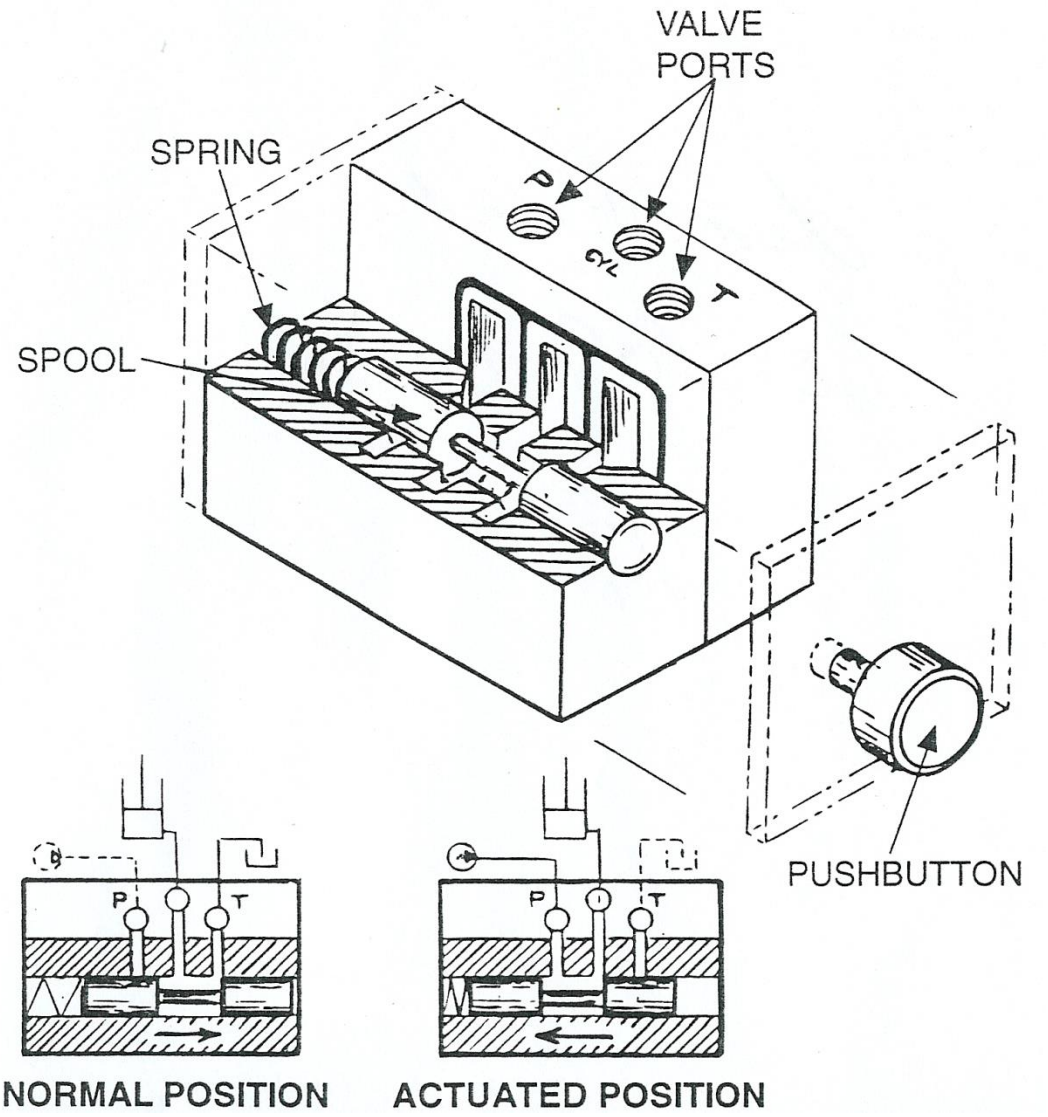
2. The basic hydraulic system

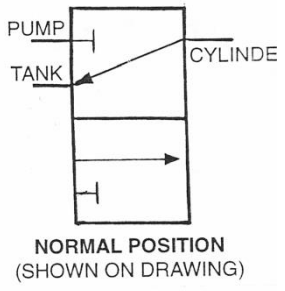
Operation of a pressure reducing valve



2. The basic hydraulic system

Directional control valves





T = Tank
P = Pump
C = Cylinder

2. The basic hydraulic system

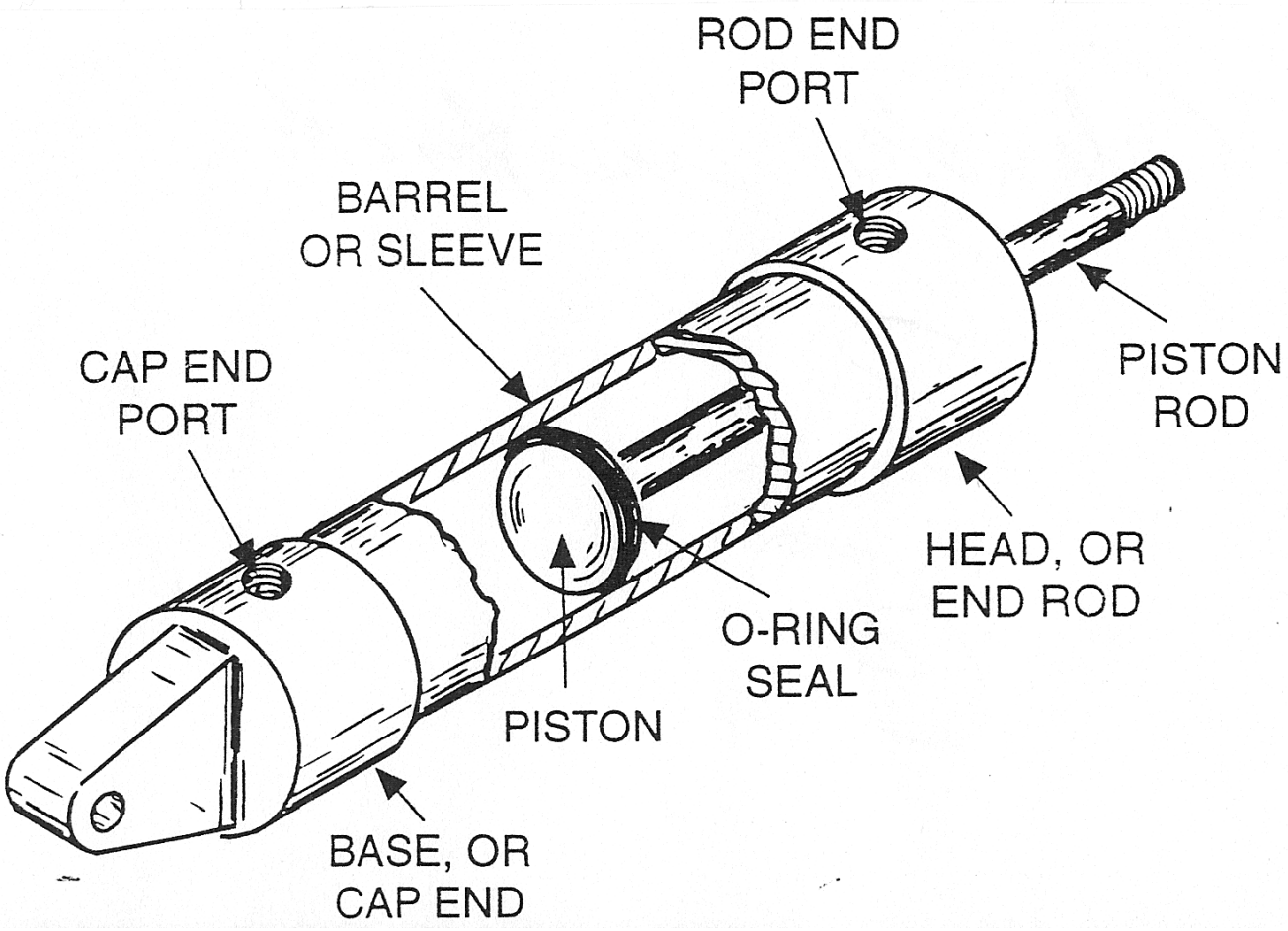
6. Actuators

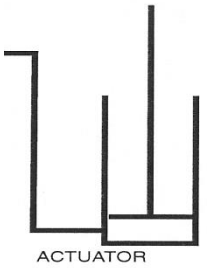
A hydraulic **actuator** is a device which **converts fluid energy into mechanical force and motion**.

- **Cylinders** are used to produce motion in a straight line, which we call **linear motion**.
- **Hydraulic motors** convert hydraulic energy into **rotating motion** The construction of those designed to produce continuous motion is similar to the construction of hydraulic pumps

2. The basic hydraulic system

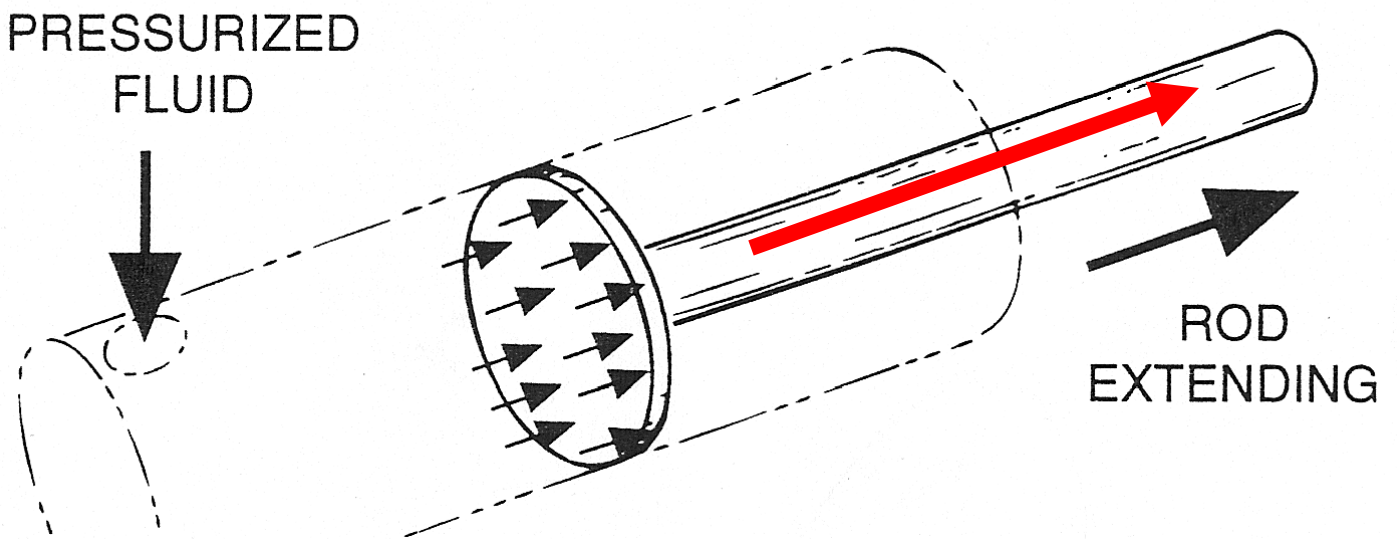
Typical cylinder construction





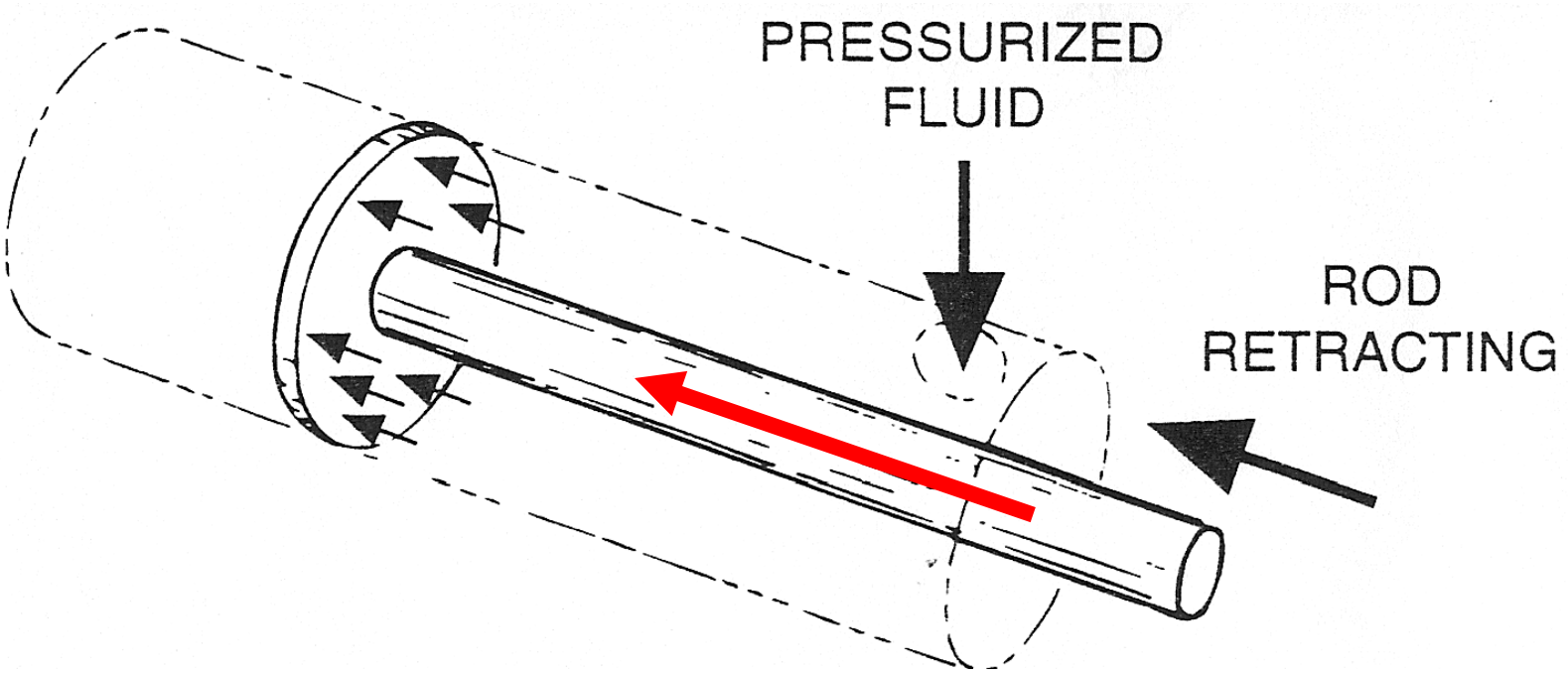
2. The basic hydraulic system

Fluid under pressure applied to the surfaces of the piston transmits **Force " F "** to the rod to do work.



2. The basic hydraulic system

During retraction the pressurized fluid (oil) has less area to push against, there fore less force is developed.



2. The basic hydraulic system

Hydraulic motor

The shaft, which in a pump was the driver of the gears, vanes, or pistons, becomes a driven element in a rotary actuator, or motor.