ROCO222: Intro to sensors and actuators

Lecture 9

Hydraulic actuation

Hydraulic power transmission

Power transmission:

Hydro = water

Aulos = pipe

Power transmission by liquid

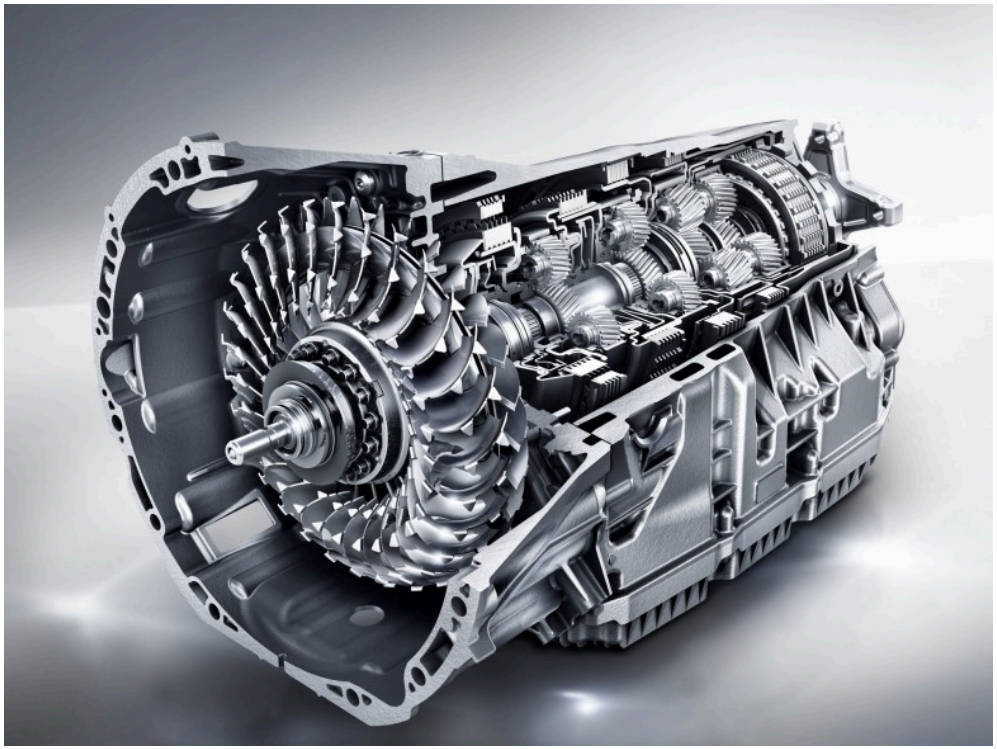
<u>Hydrodynamic</u> power transmission:

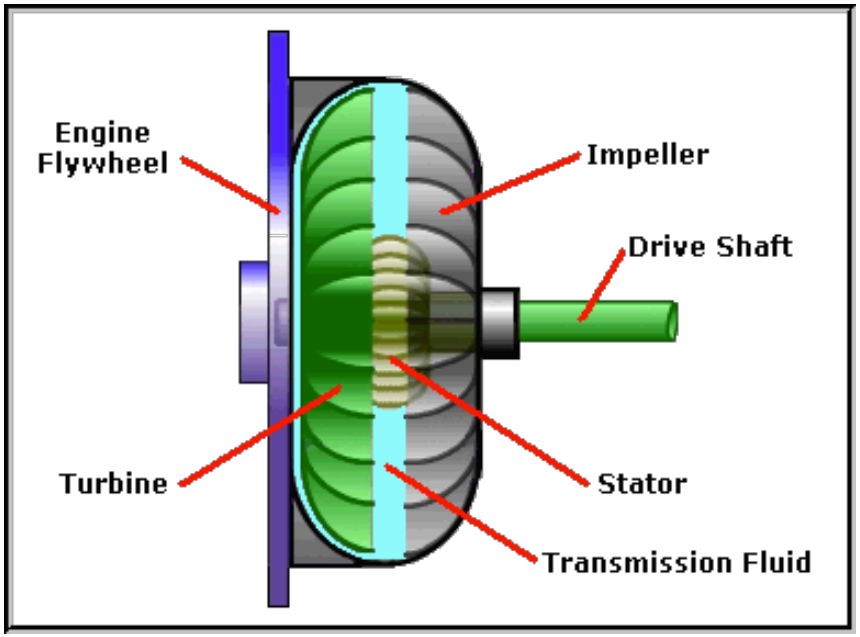
- **Turbo pump and turbine**
- **Power transmission by kinetic energy of the fluid**
- **Fluid coupling**
- **Compact units**

<u>Hydrostatic</u> power transmission:

- **Positive displacement pump**
- **Creates high pressure**
- **Drives an actuator via transmission line**

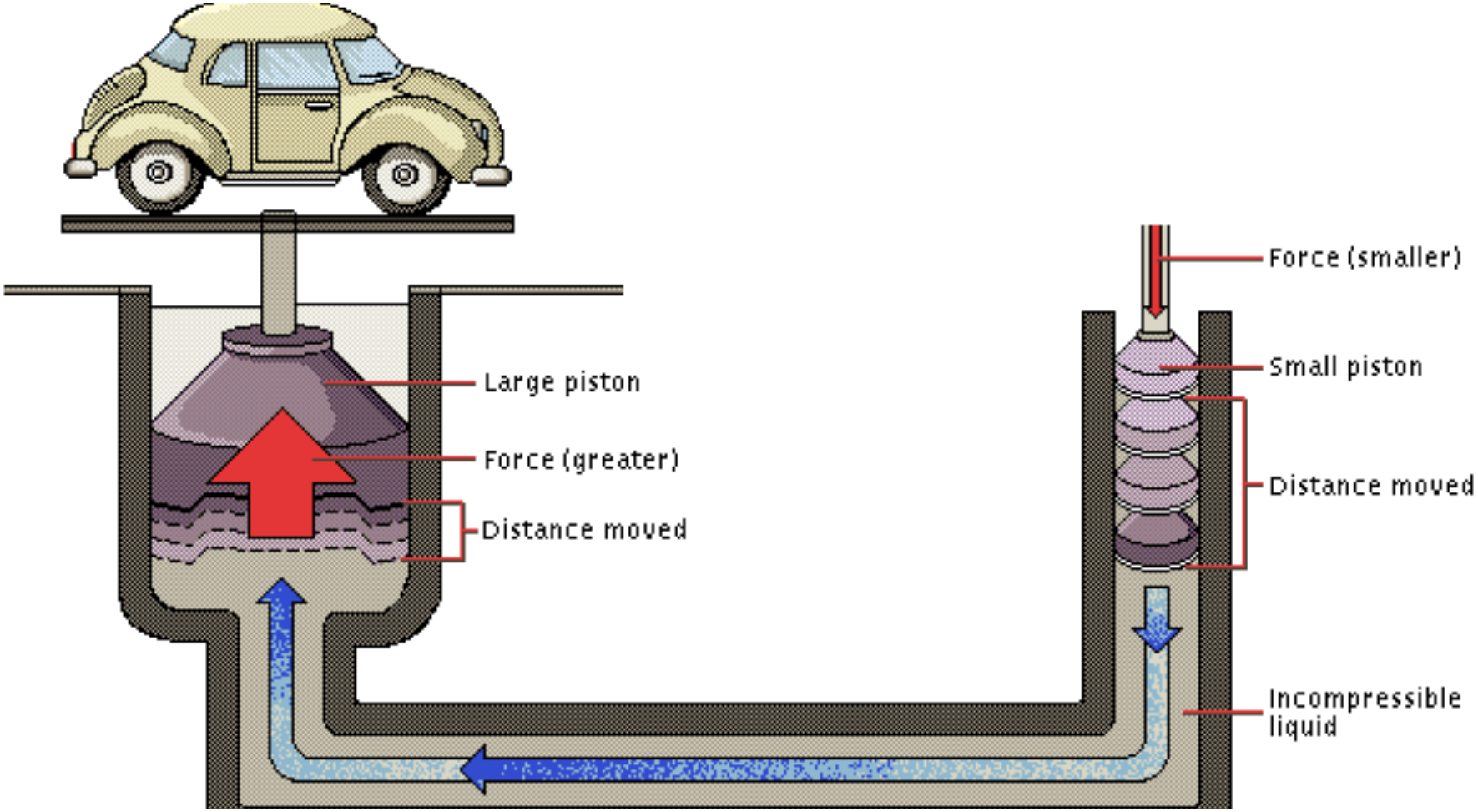
Hydrodynamic transmission





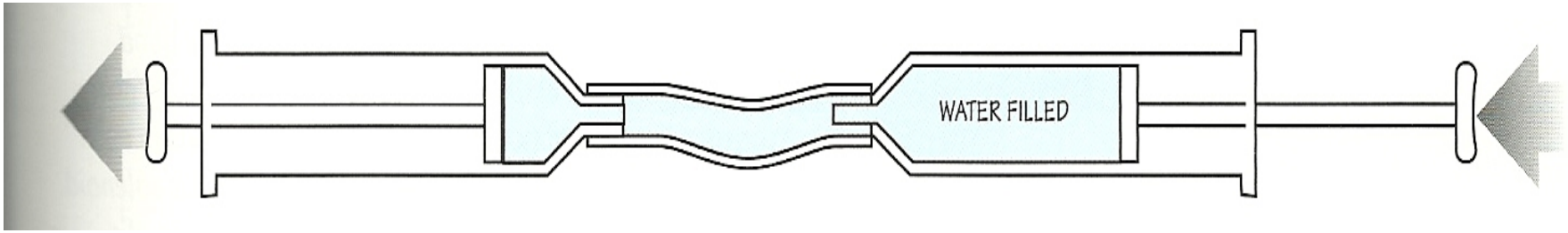
Torque converter in car automatic transmission

Hydraulic principles



Simple hydraulic system

A simple hydraulic system can be made out of syringes and aquarium tubing

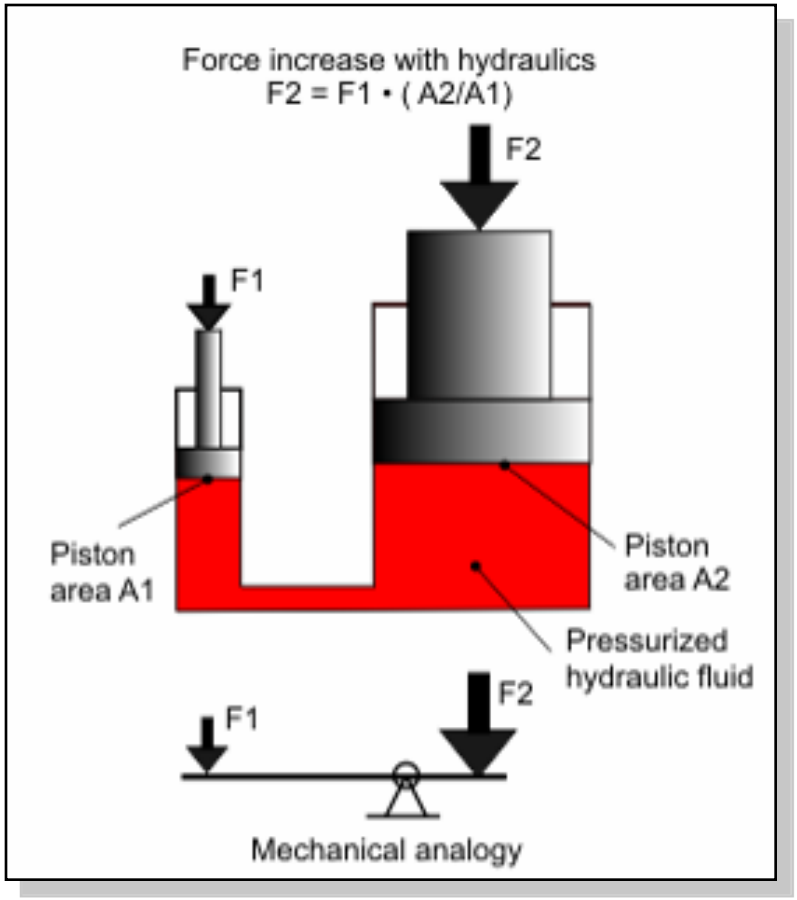


In-class demo

Pascal's Law

Pascal's law states that:

- "A change in the pressure of an enclosed incompressible fluid is conveyed undiminished to every part of the fluid and to the surfaces of its container"
- Force determined by pressure
- Speed determined by flow rate



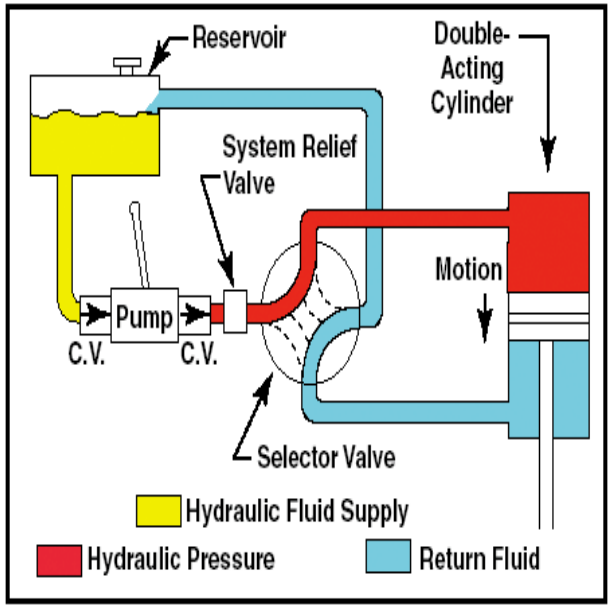
Hydraulic systems

Advantage:

- Can get high operating pressures on hydraulic systems up to 200 bar
- Able to generate extremely large forces from compact actuators
- Easy to control speed
- Easy to implement linear motion
- Huge output forces possible

Disadvantage:

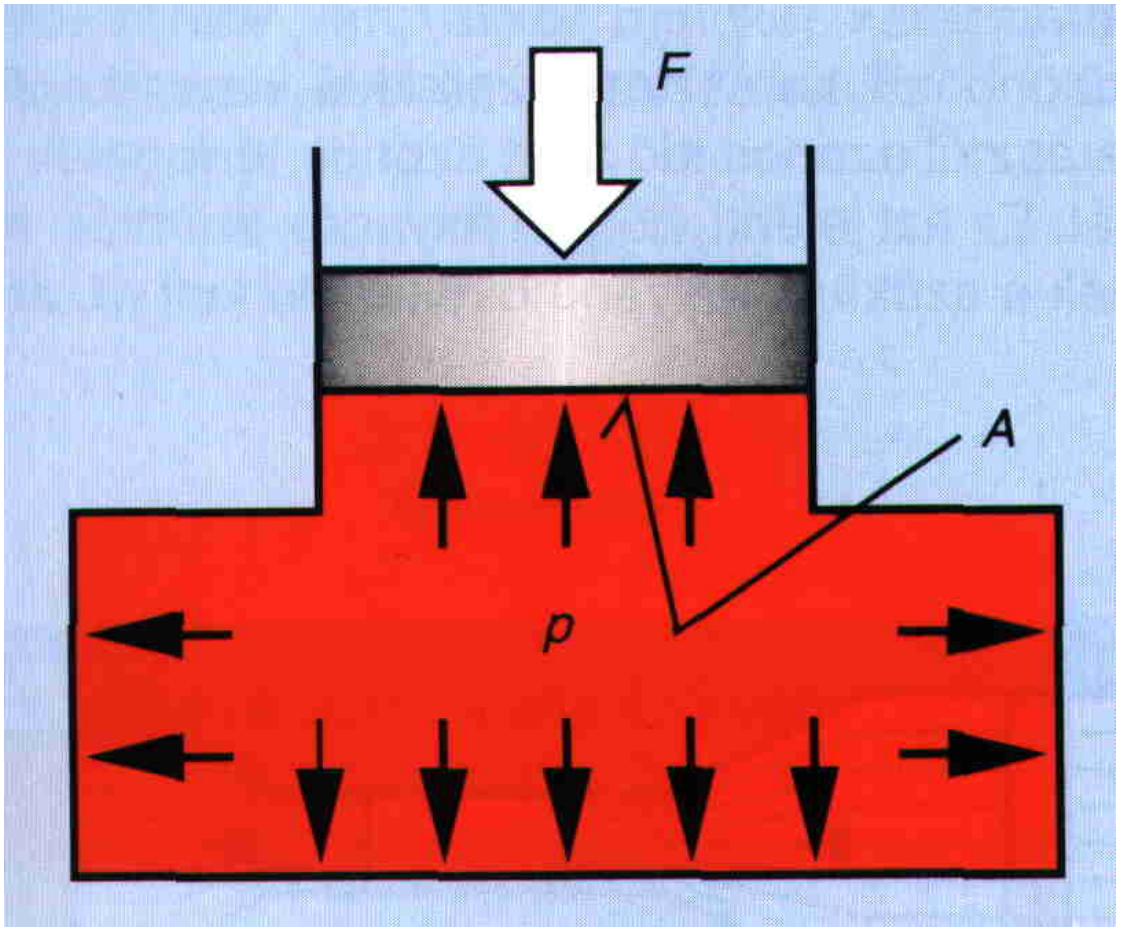
- Large infrastructure (high-pressure pump, tank, distribution lines)
- Potential fluid leaks
- Noisy operation
- Vibration
- Maintenance requirements, expensive
- Characteristics of working fluids change with temperature and moisture



Properties of hydraulic systems

Pascal's law

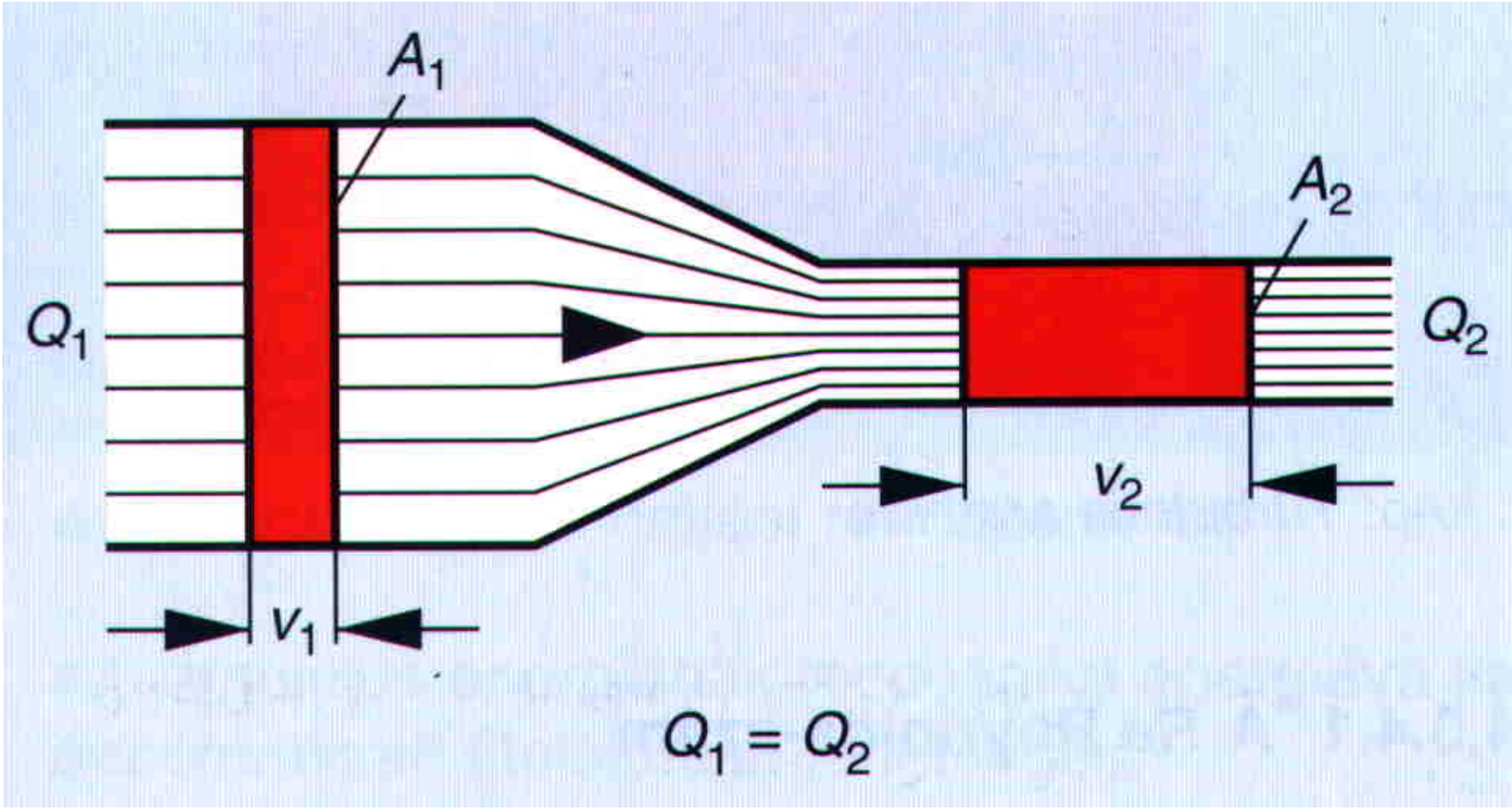
- A pressure change occurring anywhere in a confined incompressible fluid is transmitted throughout the fluid such that the same change occurs everywhere



Properties of hydraulic systems

Flow continuity

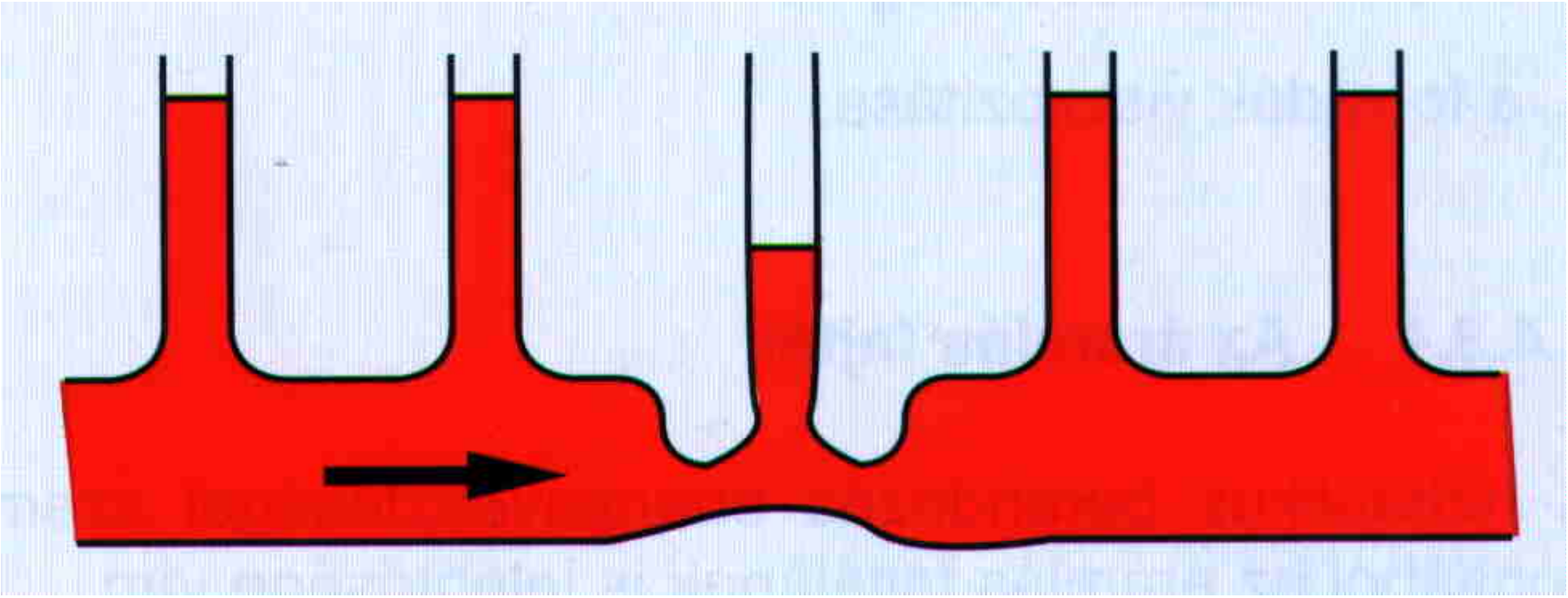
- When a fluid is in motion, it must move in such a way that mass is conserved.



Properties of hydraulic systems

Bernoulli equation

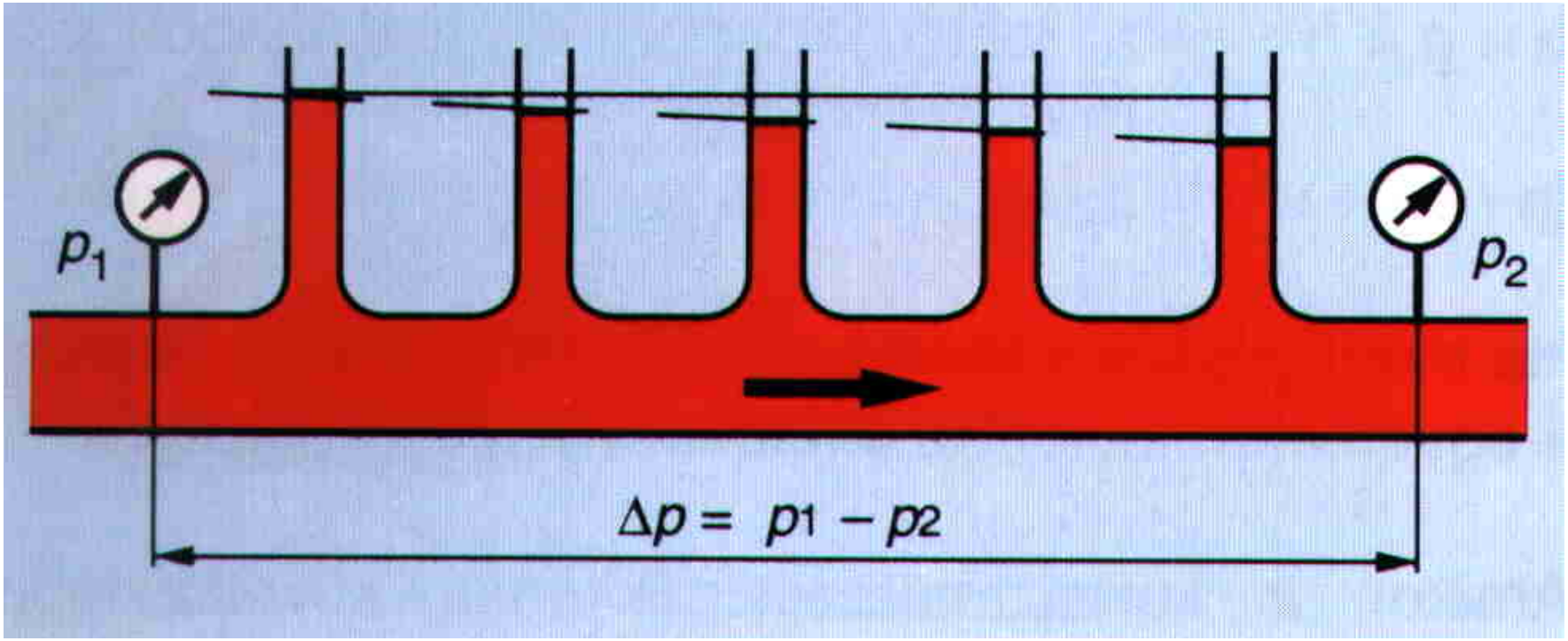
- Increase in the speed of the fluid occurs simultaneously with a decrease in pressure



Properties of hydraulic systems

Flow resistance

- The resistance to flow in a liquid can be characterized in terms of the viscosity of the fluid if the flow is smooth.
- It leads to pressure drop

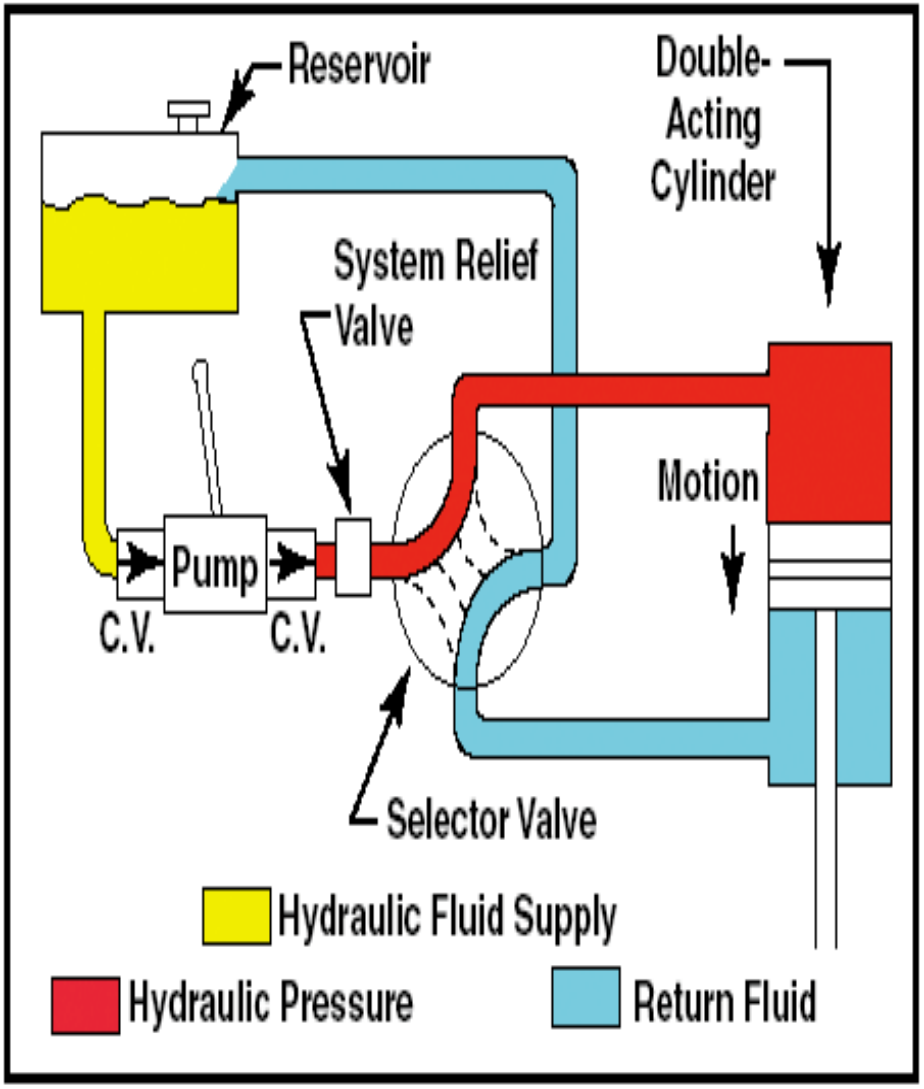


Simple hydraulic system

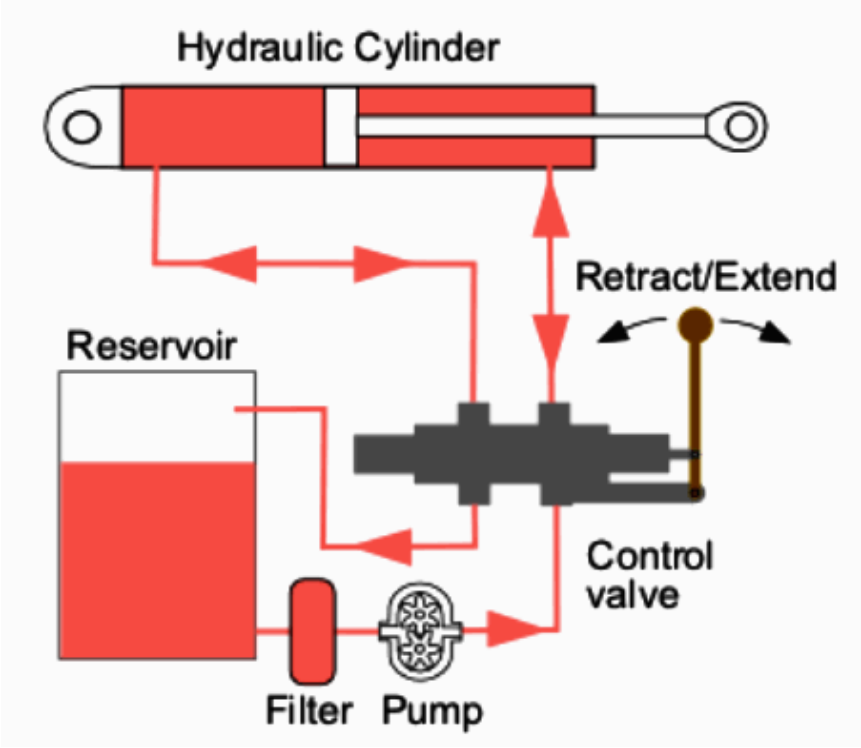
A hydraulic system typically consults of:

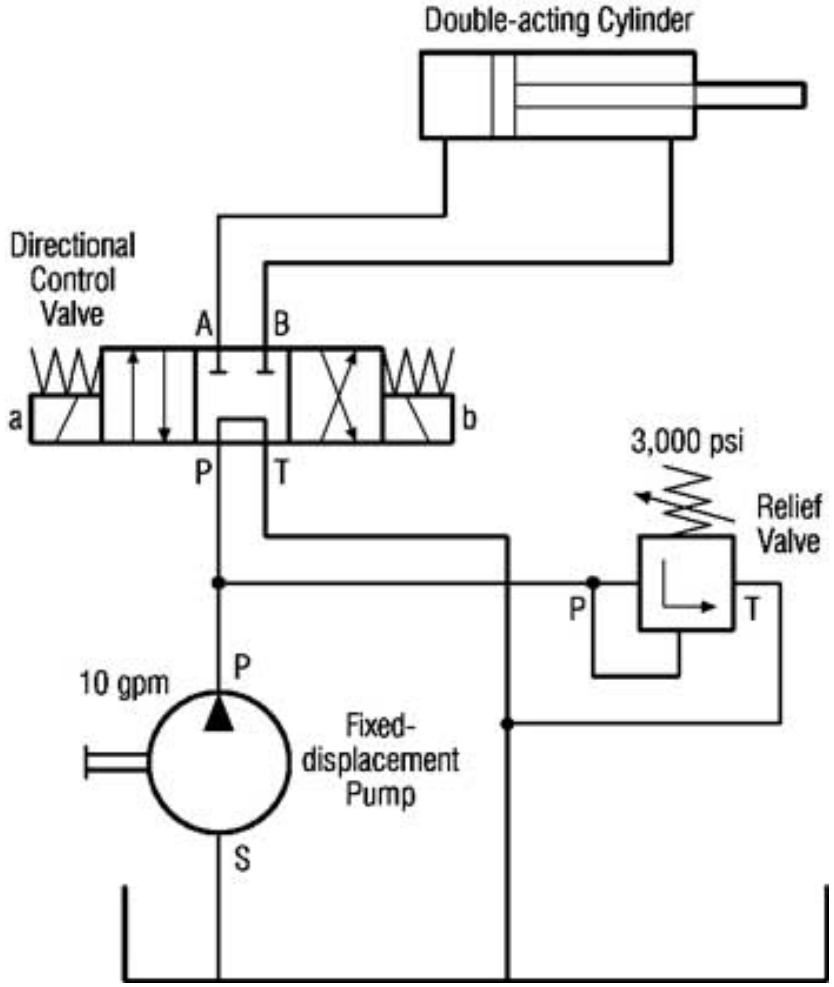
- Fluid reservoir
- Hydraulic fluid
- High pressure pump
- Control values
- Actuator(e.g. cylinder or motor)

- Can also include
- Filtration
- Accumulator



Hydraulic schematic circuit

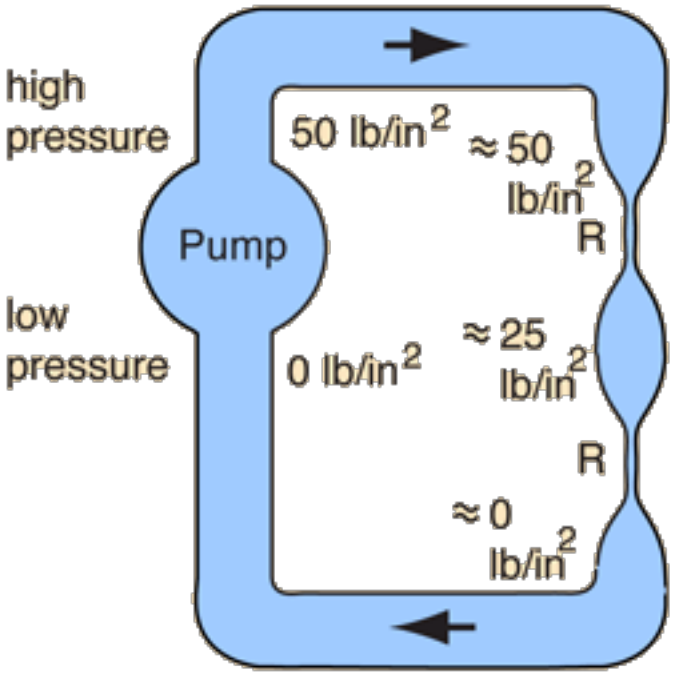




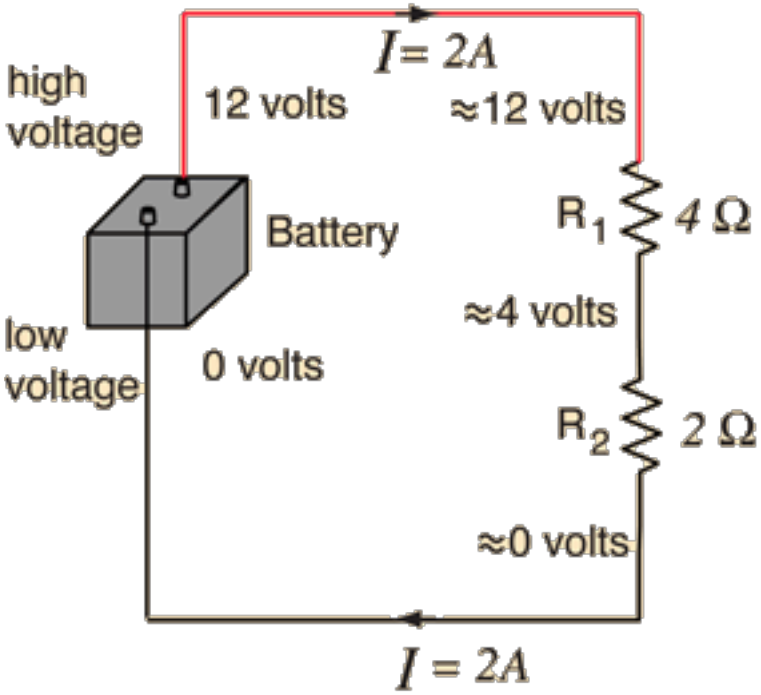
Circuit diagrams just like for electronic circuits!

Hydraulic circuit electrical analogy

Simple series circuit



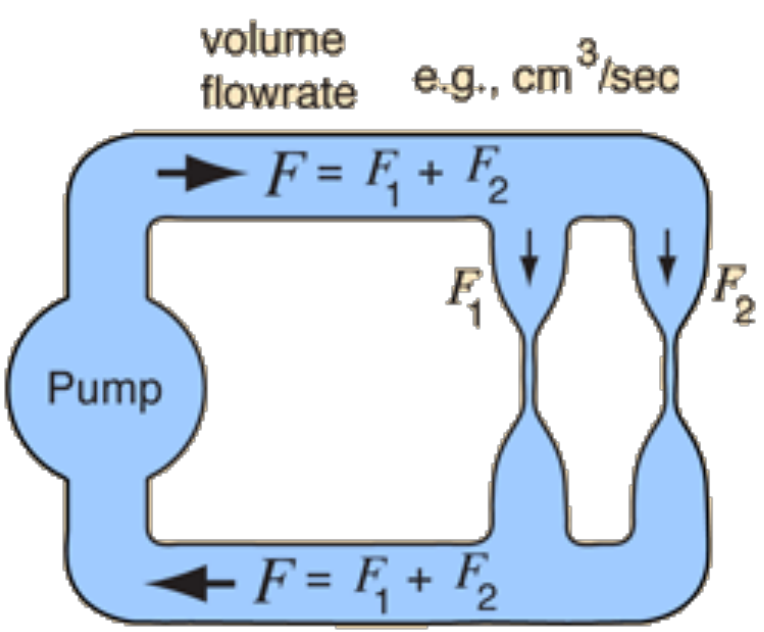
Hydraulic



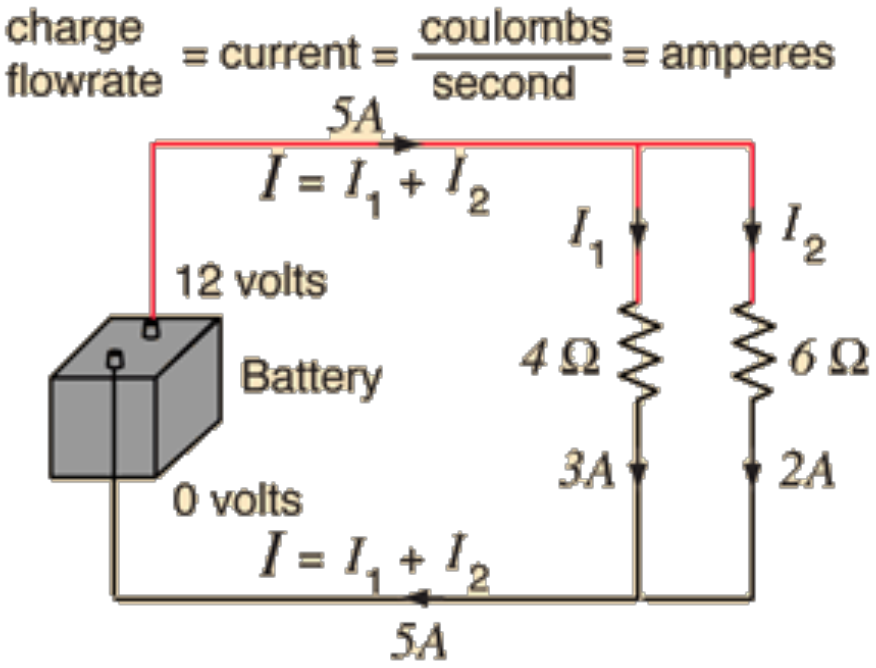
Electrical

Hydraulic circuit electrical analogy

Simple circuit with parallel elements



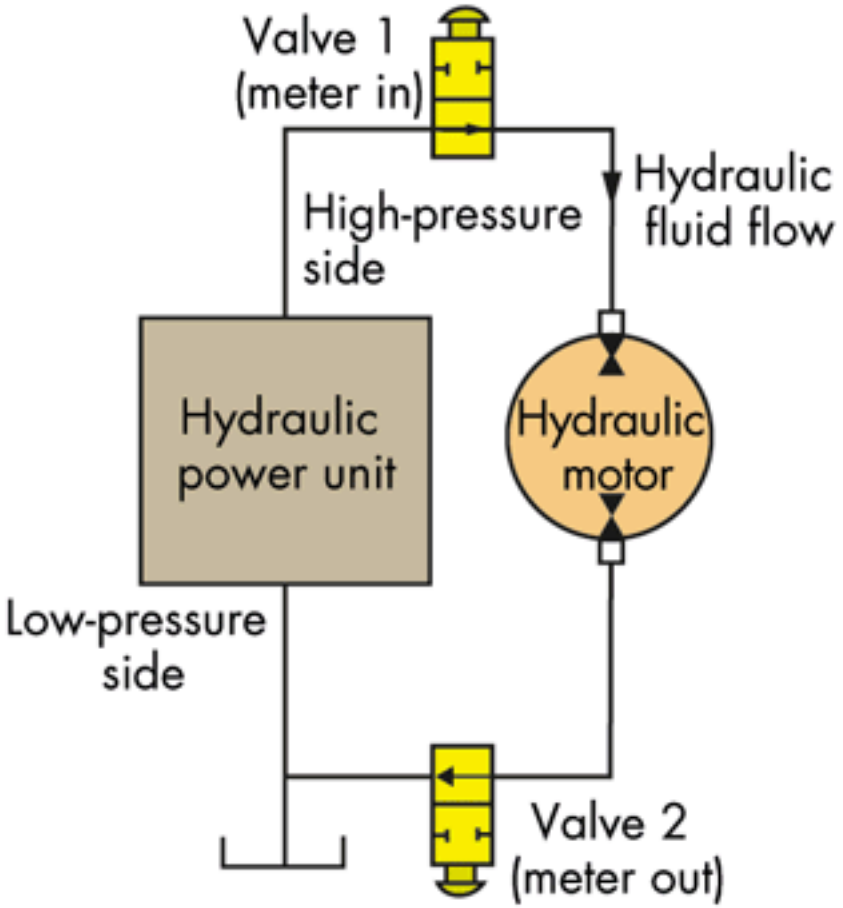
Hydraulic



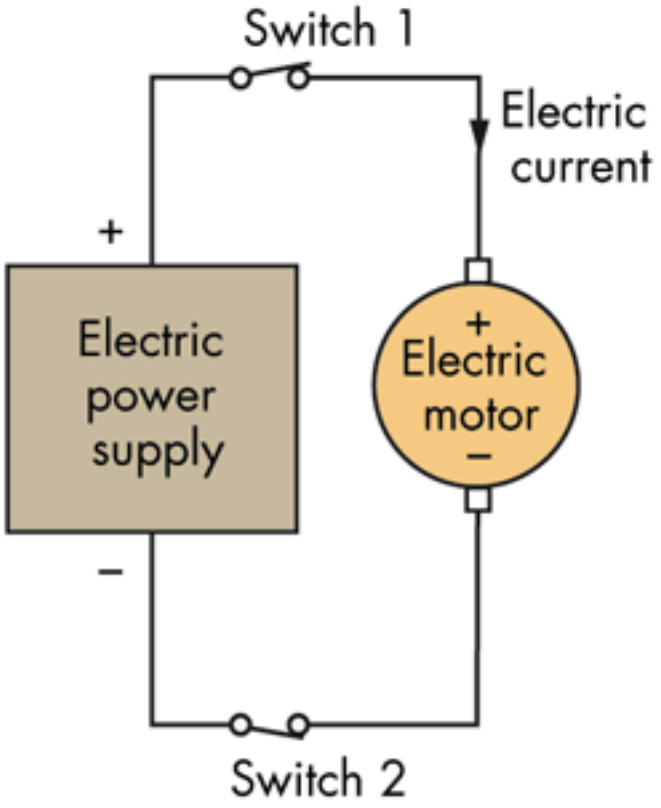
Electrical

Hydraulic circuit electrical analogy

Can also include motors in circuits

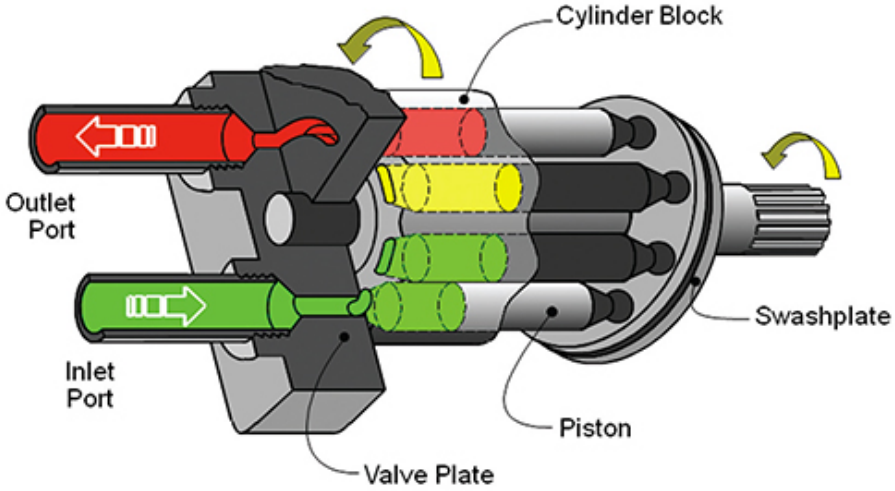


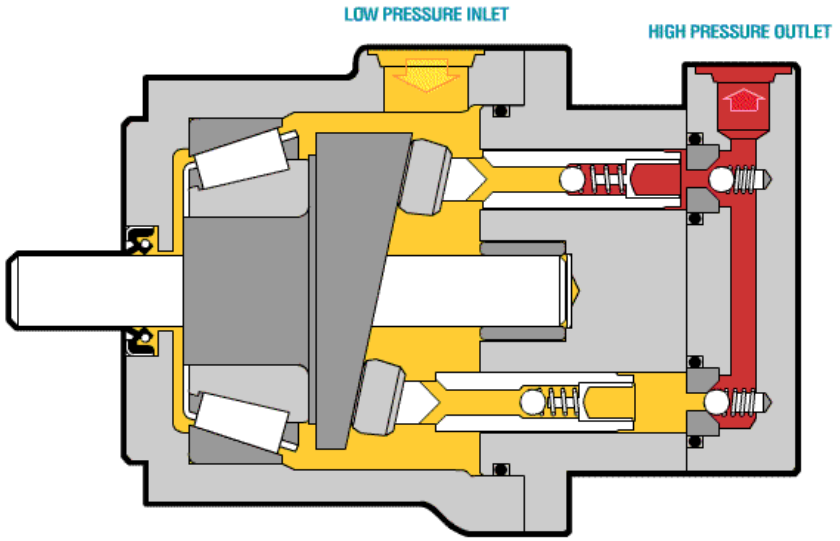
Hydraulic

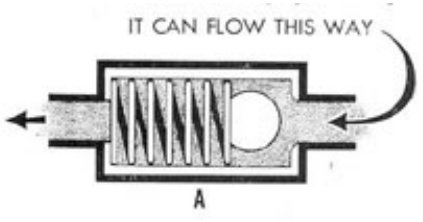


Electrical

Hydraulic piston pump

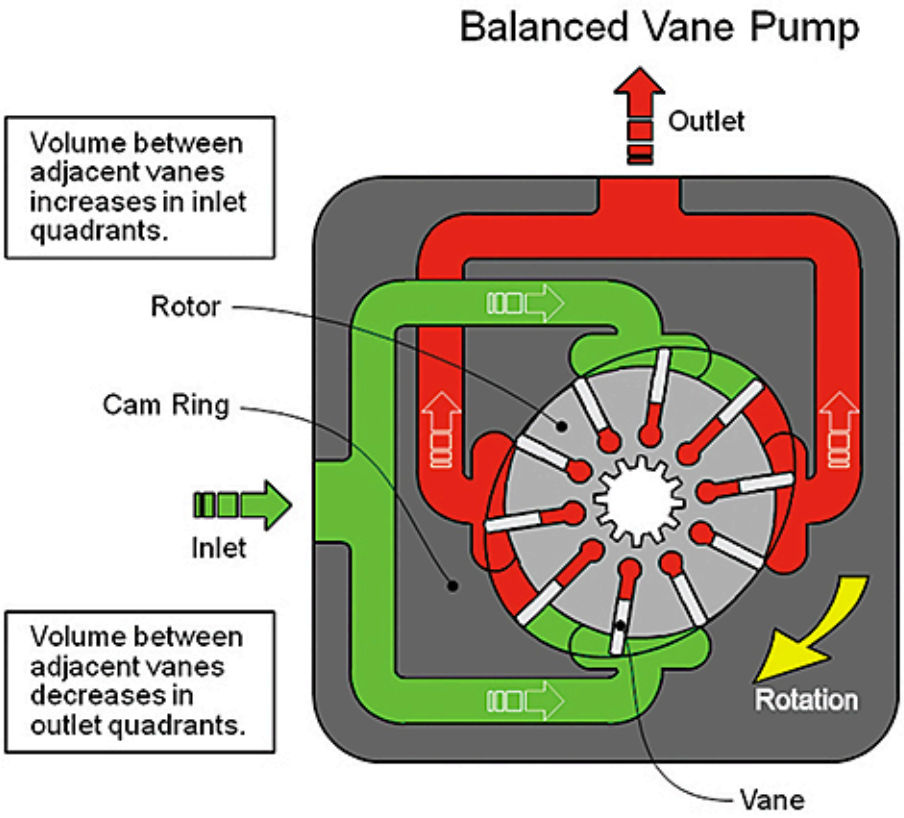


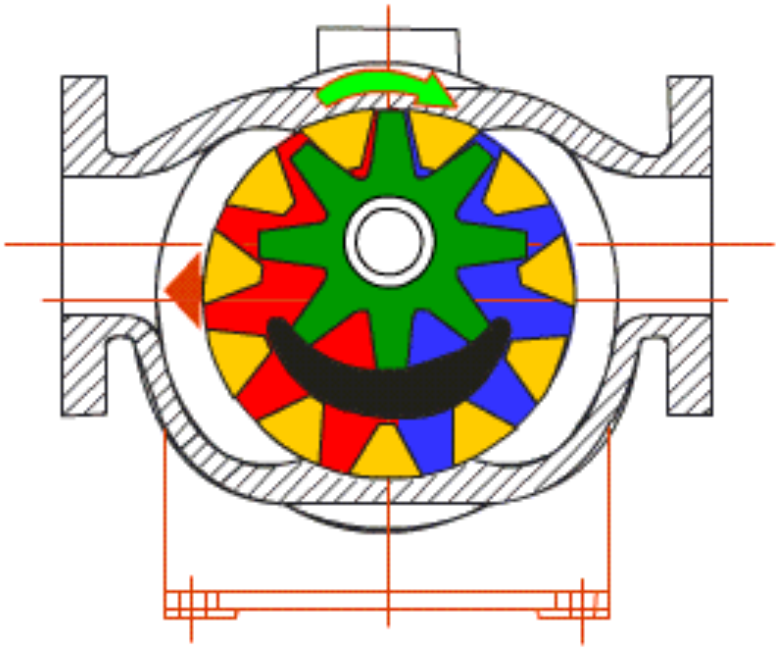




- Set of pistons fitted within a cylinder block
- Driven by an angled swash plate powered by input shaft
- As swash plate rotates pistons reciprocate in cylinders
- This provide the pumping action
- Have highest pressure capabilities
- Highest input speed capabilities
- Some designed with a variable displacement mechanism to vary output flow for control of pressure

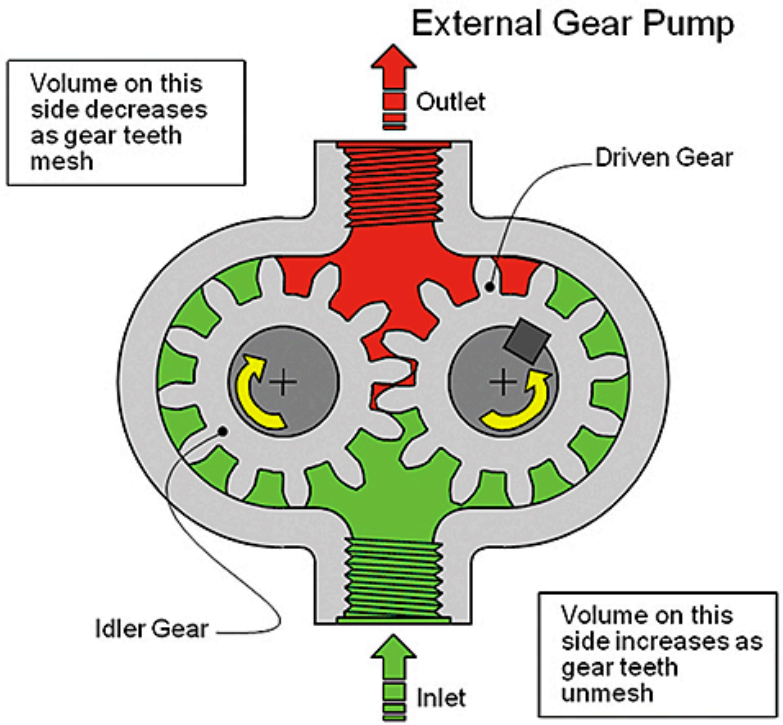
Hydraulic vane pump

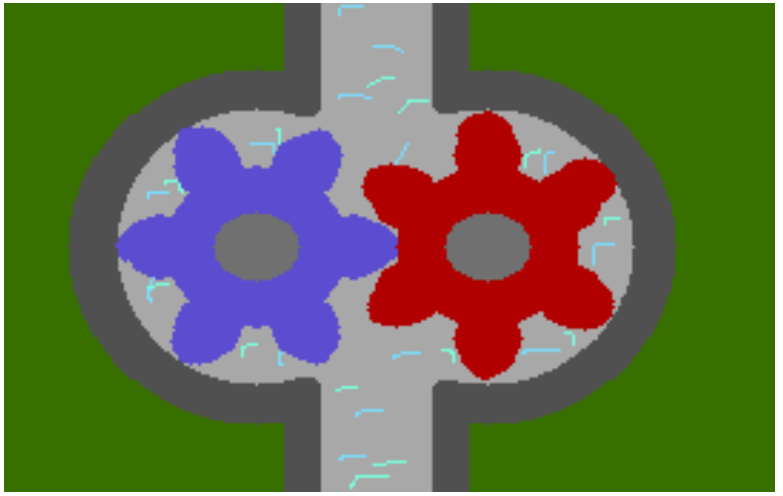




- Generates flow using a set of vanes
- Vanes free to move radially within a slotted rotor in elliptical chamber
- Changing volume of the cavity between vanes creates the pumping action
- Quietest and most vibration-free
- Piston and vane pumps offer longest service life

Hydraulic gear pump



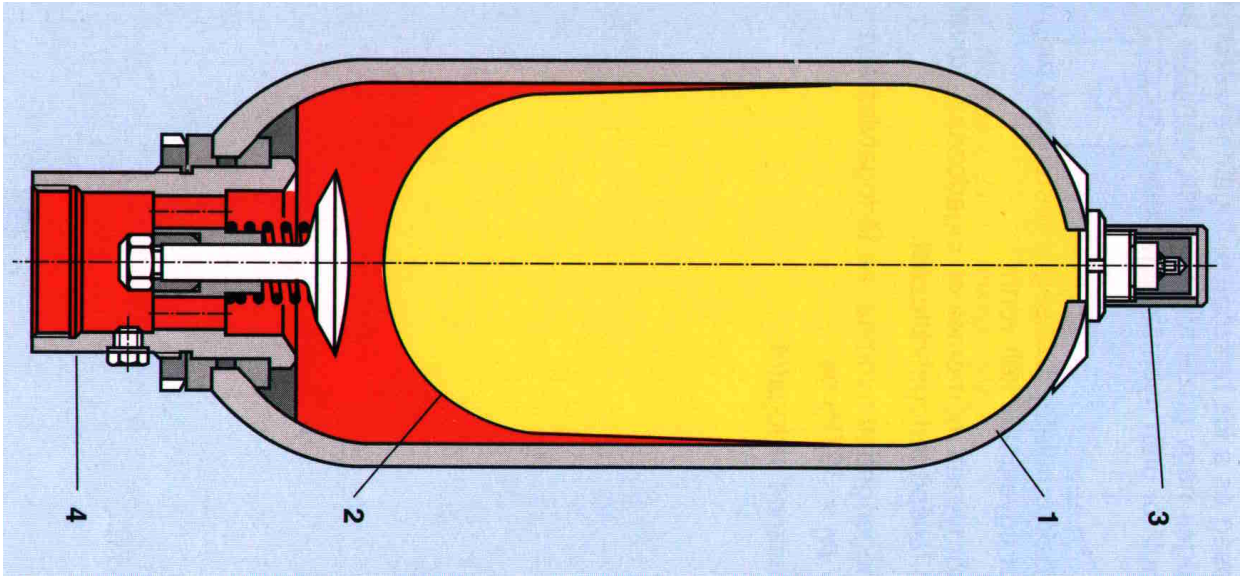


- Uses a pair of mating gears
- Gears rotate in chamber to produce flow
- As the gears rotate meshing changes size of the chambers
- This provides pumping action
- Most dirt tolerant
- Lightest for a given displacement

Hydraulic accumulator

Serve three purposes:

- Bladder filled with gas e.g. carbon dioxide
- Bladder placed in a tank made out of steel
- Damping of pressure and volumetric flow rate oscillations
- Stabilizes pressure
- Supplying the flow rate at variable demand
- Provides reserve energy
- Hydropneumatic spring.
- Assists recovery of braking energy



Hydraulic accumulator

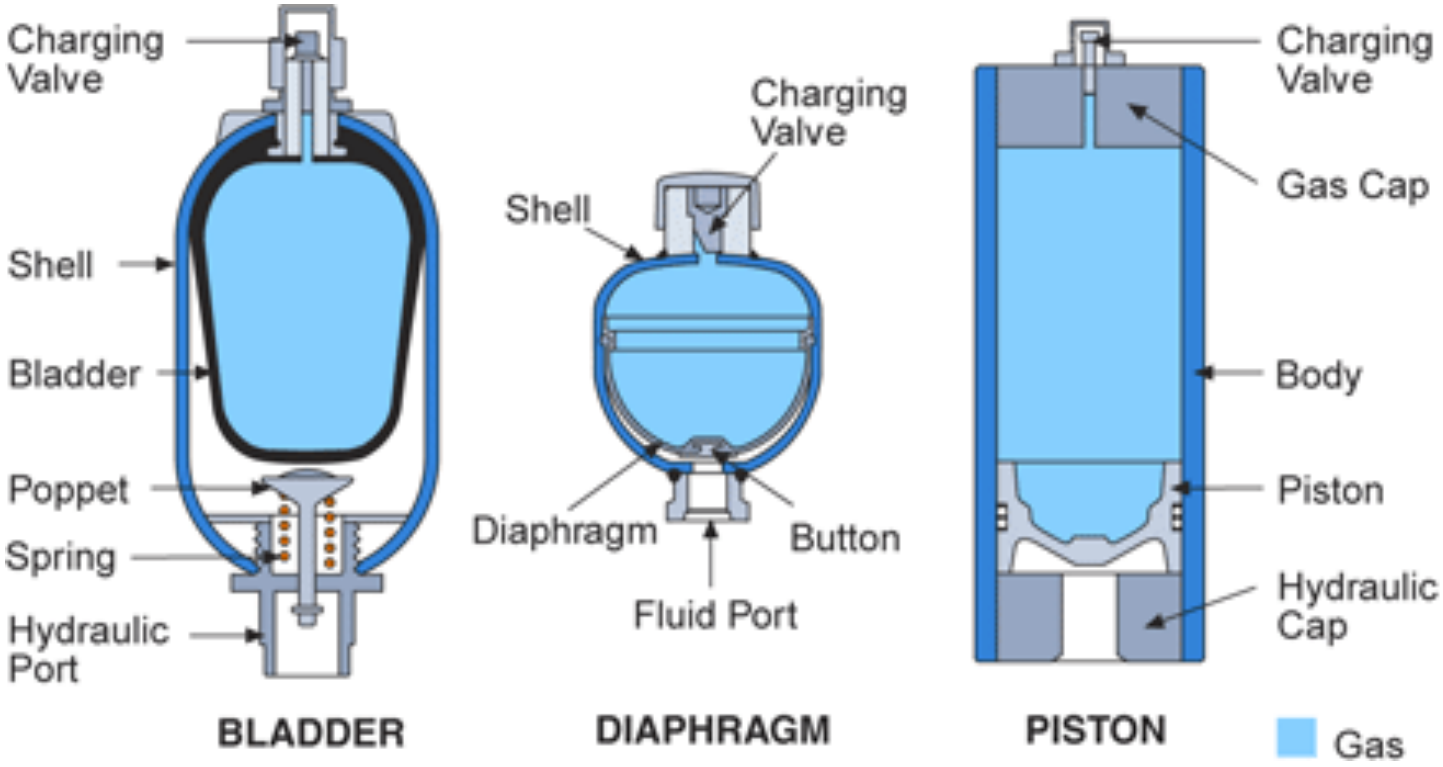
They use the compressibility of a gas but the gas and liquid surface may not touch because then the gas will be dissolved in the liquid.

Three constructions:

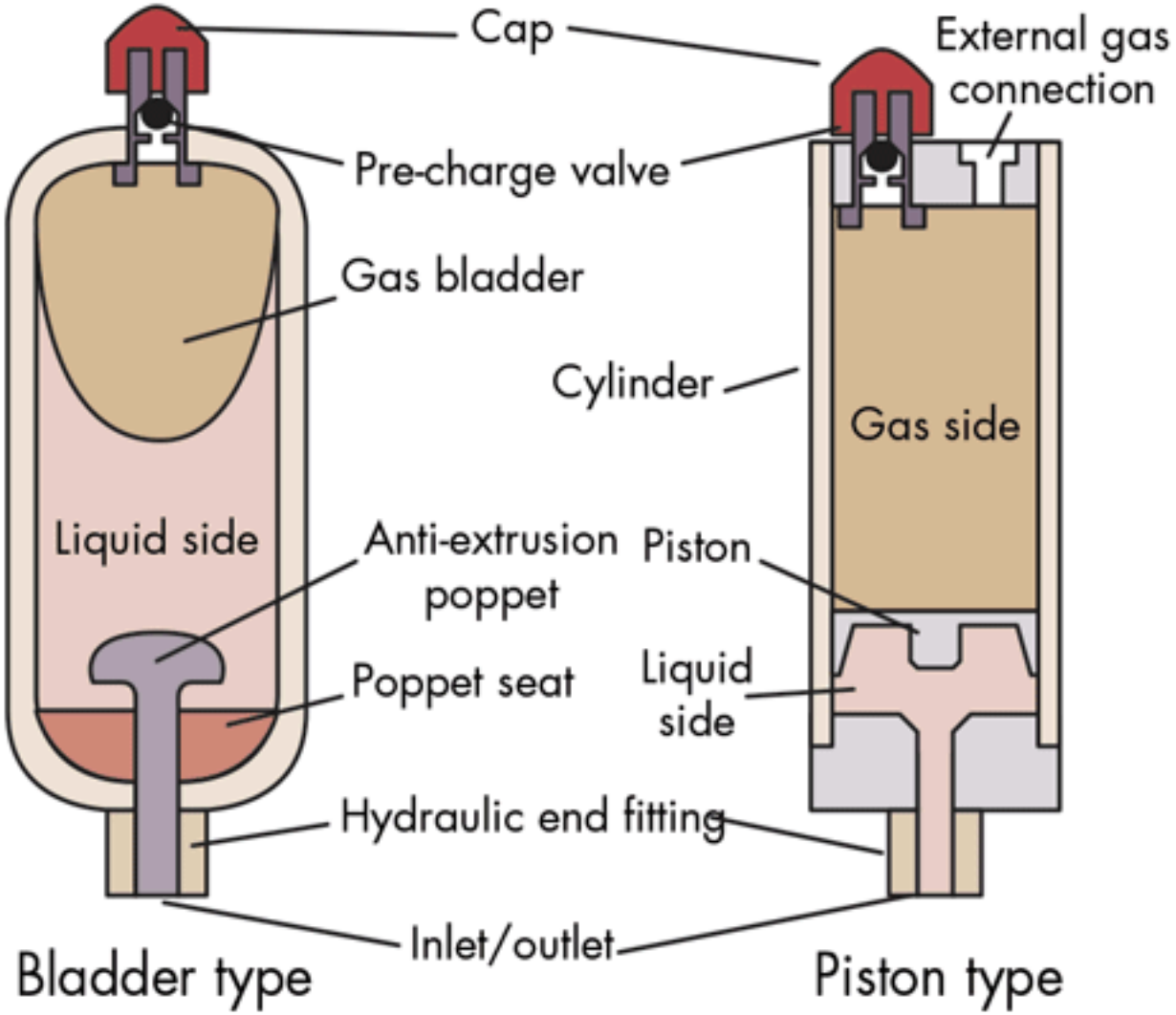
Bladder (bag)

Membrane

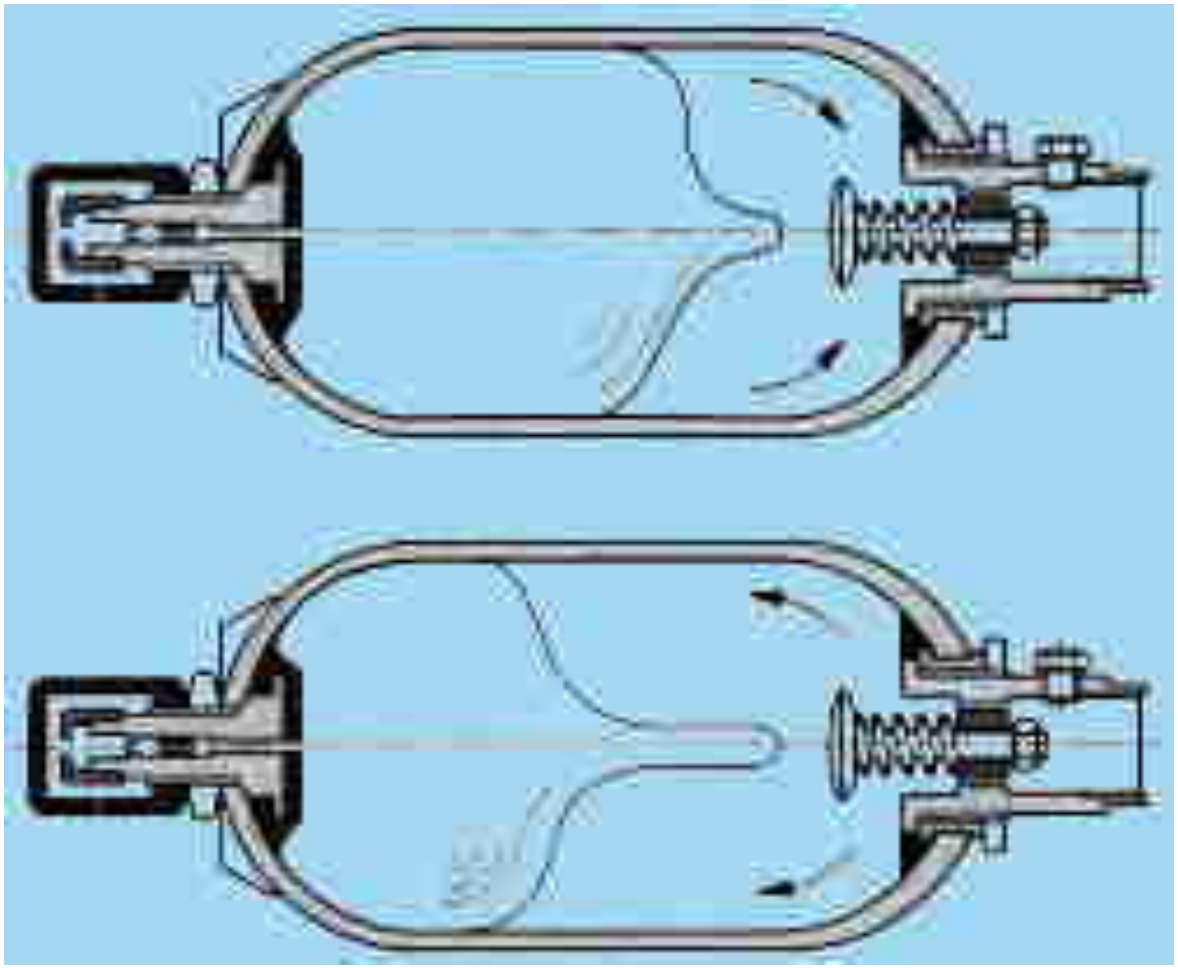
Piston



Hydraulic accumulator

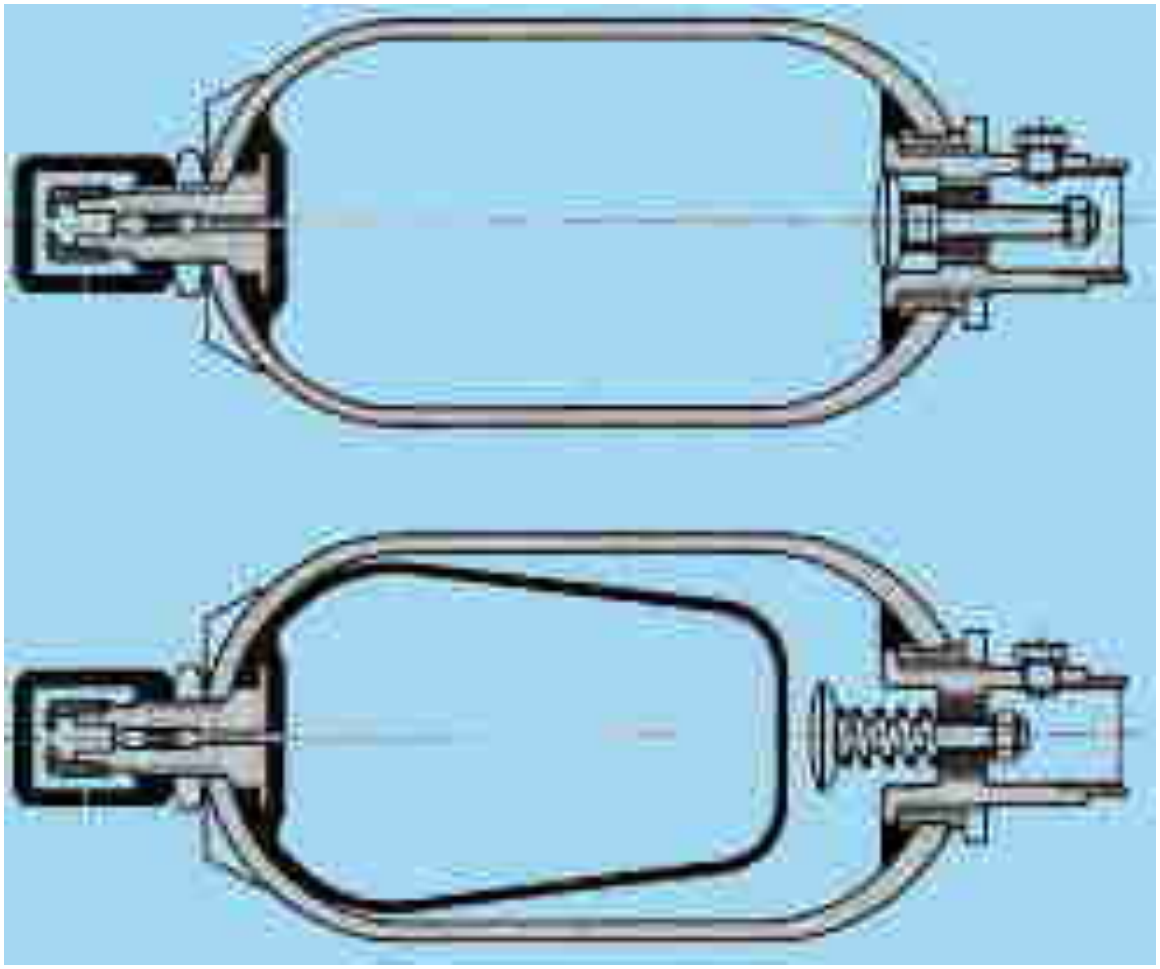


Accumulator operation



When pump activated fluid flows in the tank and compresses the gas

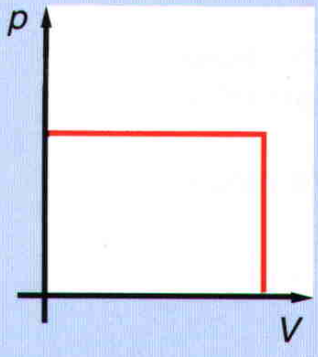
Accumulator operation



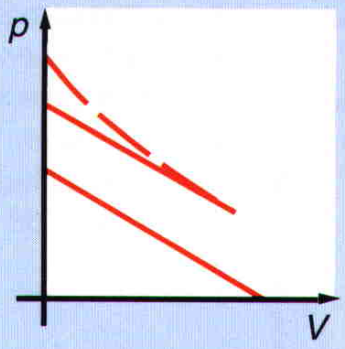
- When required fluid flows very quickly back in the system

Hydraulic accumulator properties

Using weight

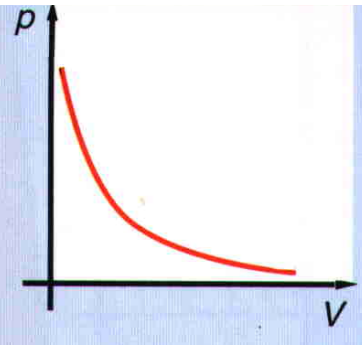


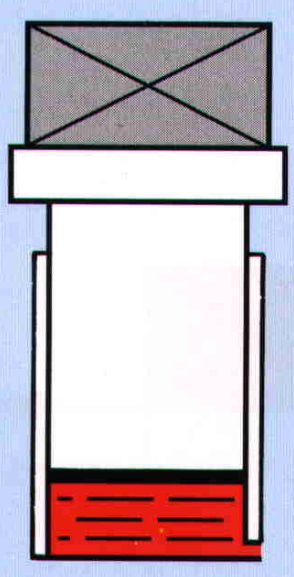
Using spring



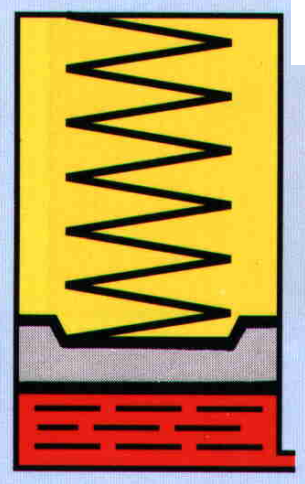
With gas

hydro pneumatic accumulator

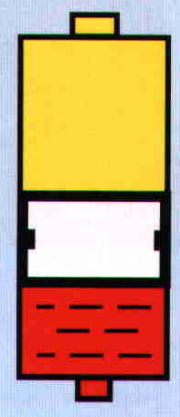




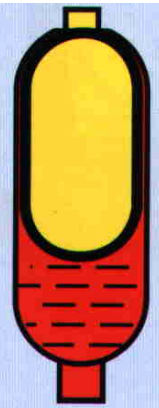
Separating part between gas and fluid



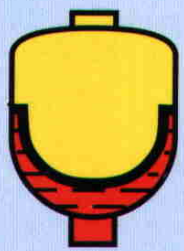
Piston



Bladder

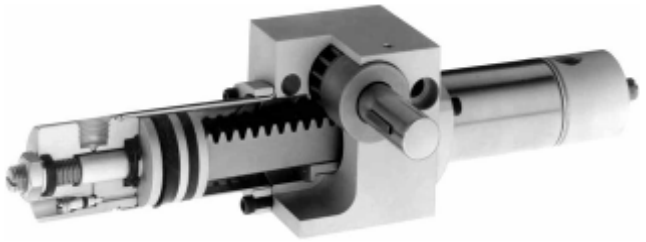


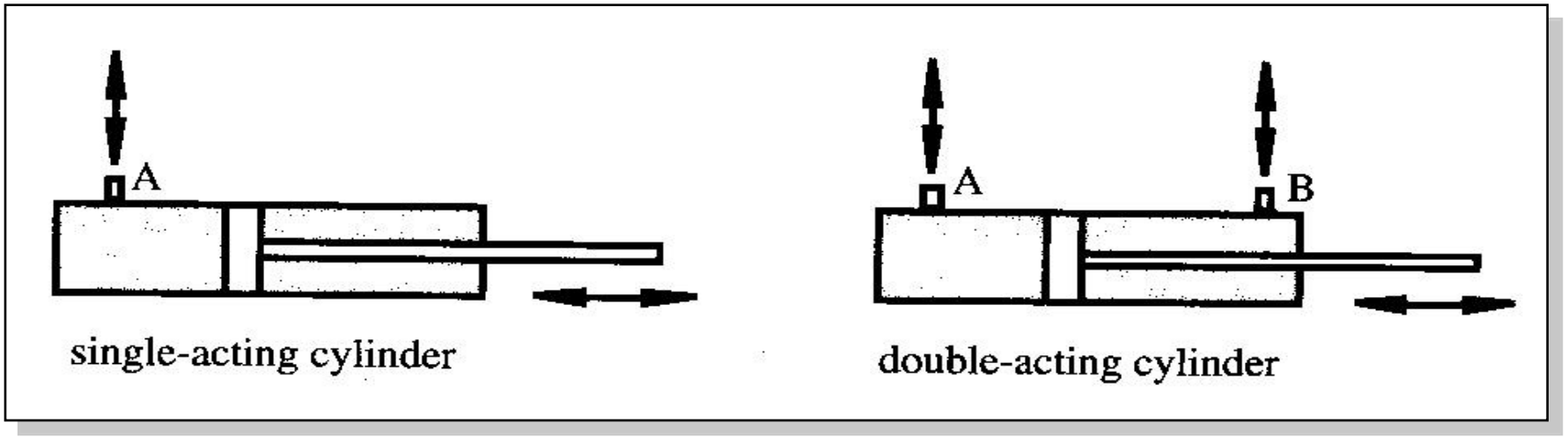
Membrane



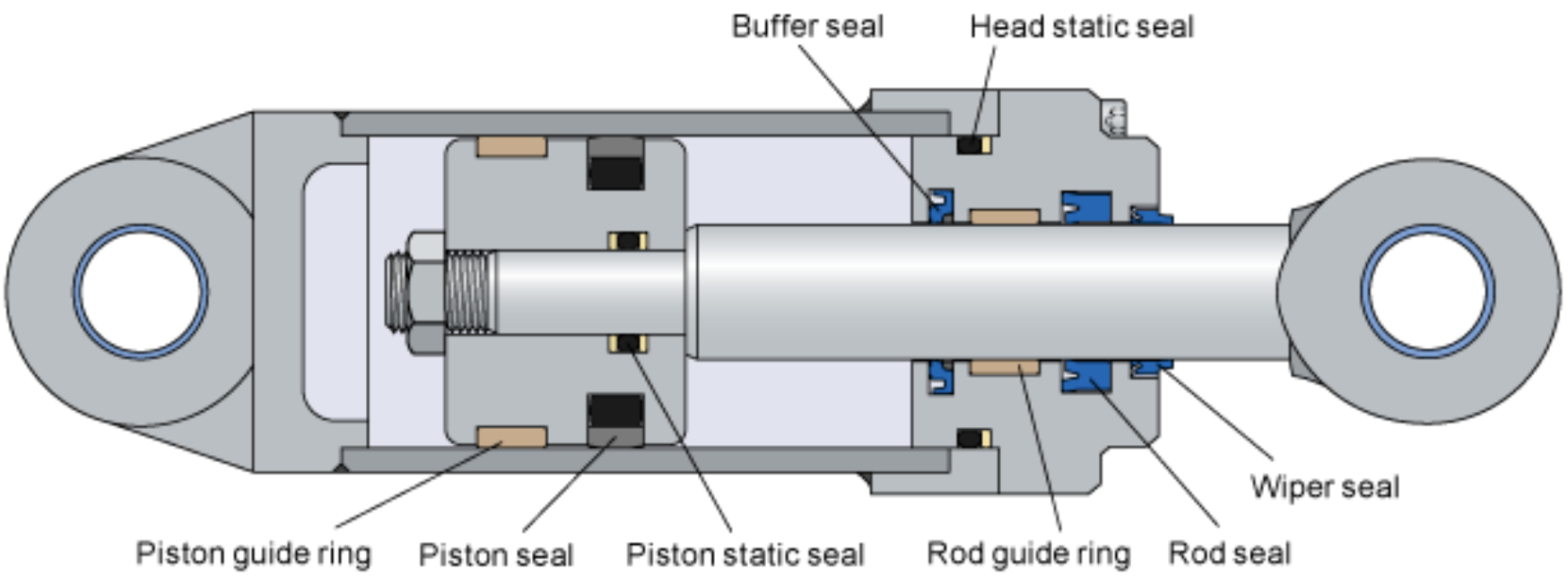
Hydraulic (& pneumatic) actuators

- Cylinders with piston driven by pressurized fluid
- Single acting cylinder (SAC)
- Double acting cylinder (DAC)
- Two well-defined endpoints
- Also rotary units available

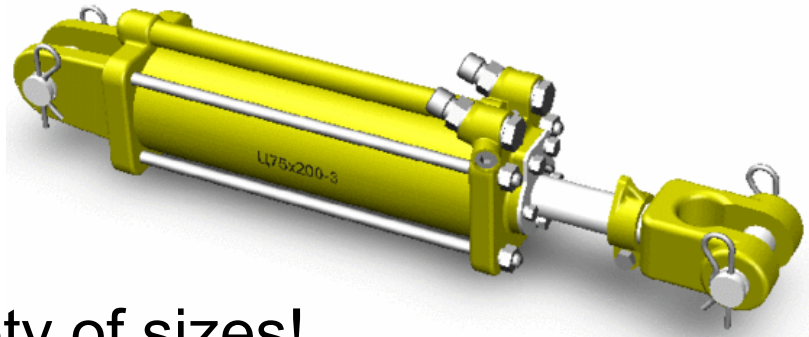




Hydraulic cylinder



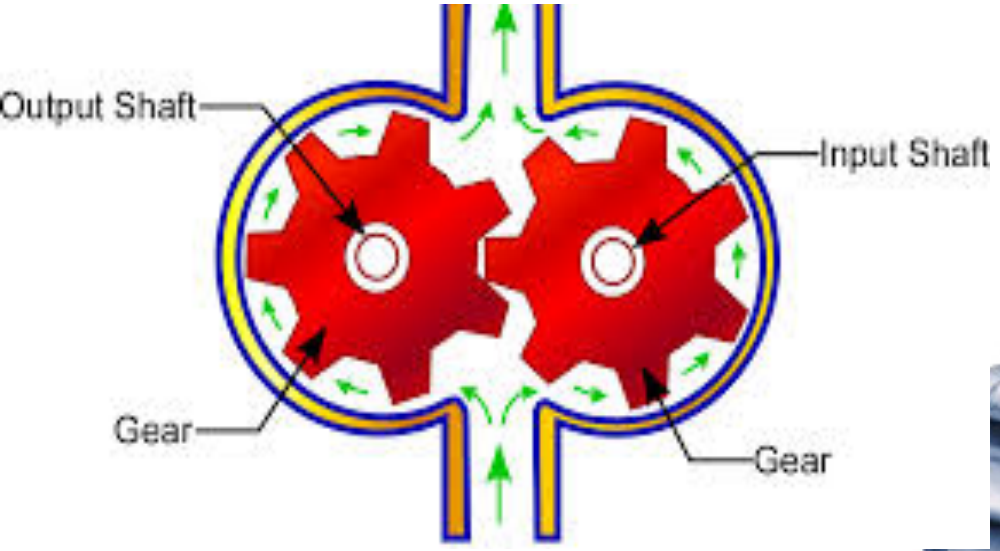
Hydraulic cylinder

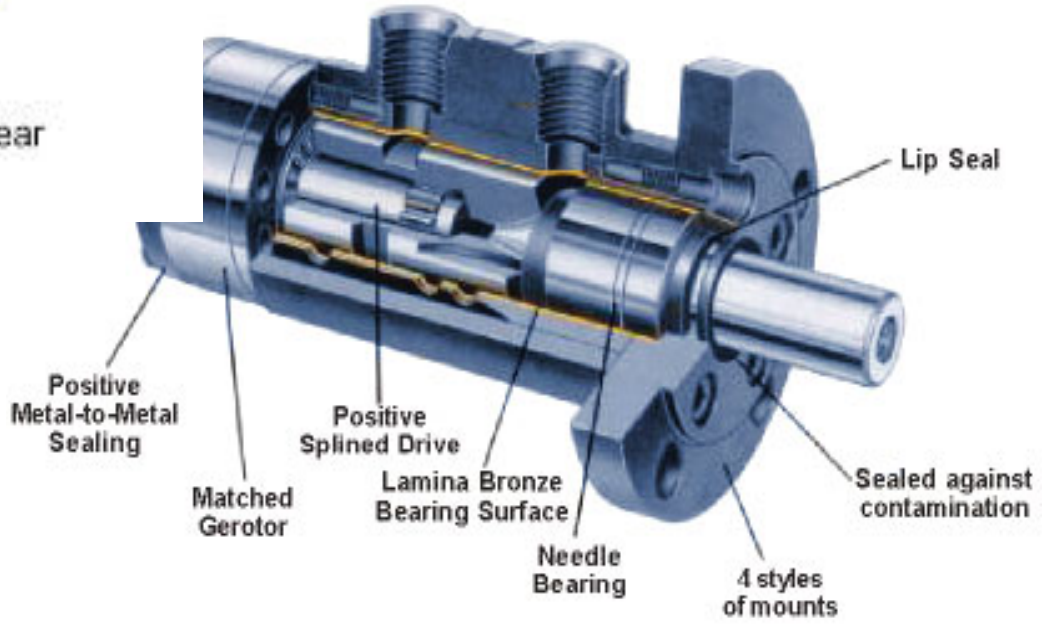


Cylinders come in a variety of sizes!

Hydraulic motor

Hydraulic operation can generate a very high torque





Hydraulic fluid requirements

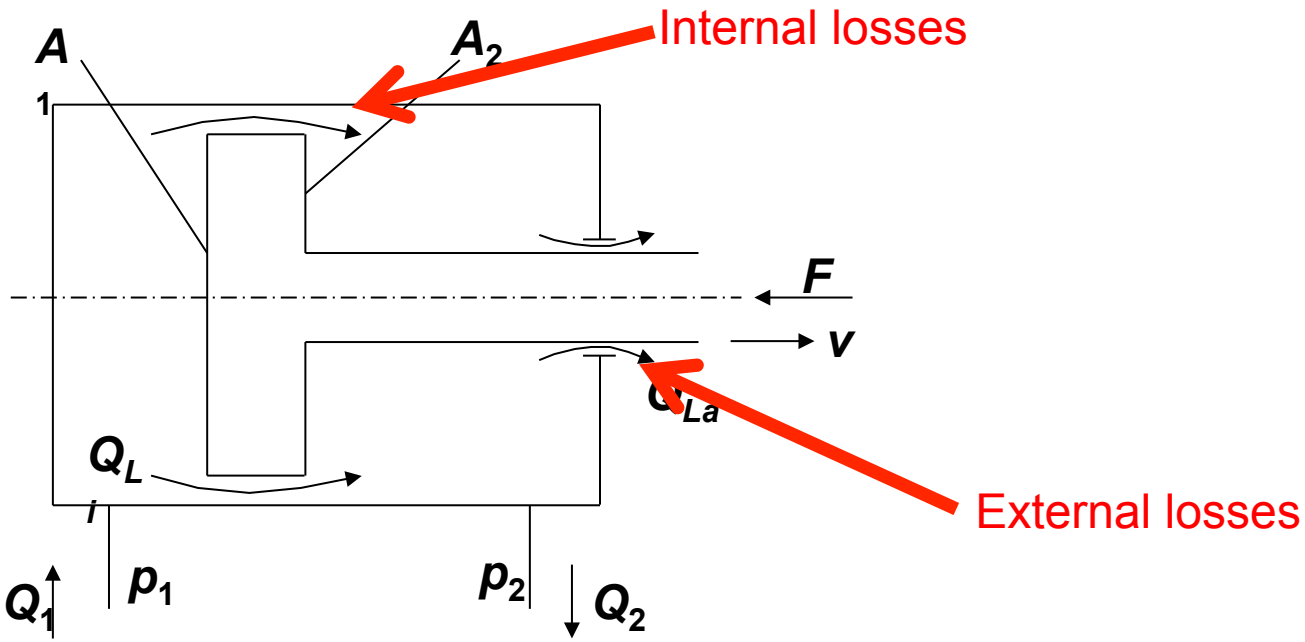
Functional properties
- Good lubrication characteristics
- Viscosity should not depend strongly on temperature and pressure
- Good heat conductivity
- Low heat expansion coefficient
- Large elasticity modulus

Economic properties
- Low price
- Slow aging and thermal and chemical stability
- Long life cycle

Materials
- Water (3%)
- Mineral oils (75%)
- Not inflammable fluids (9%)

Hydraulic leakage losses

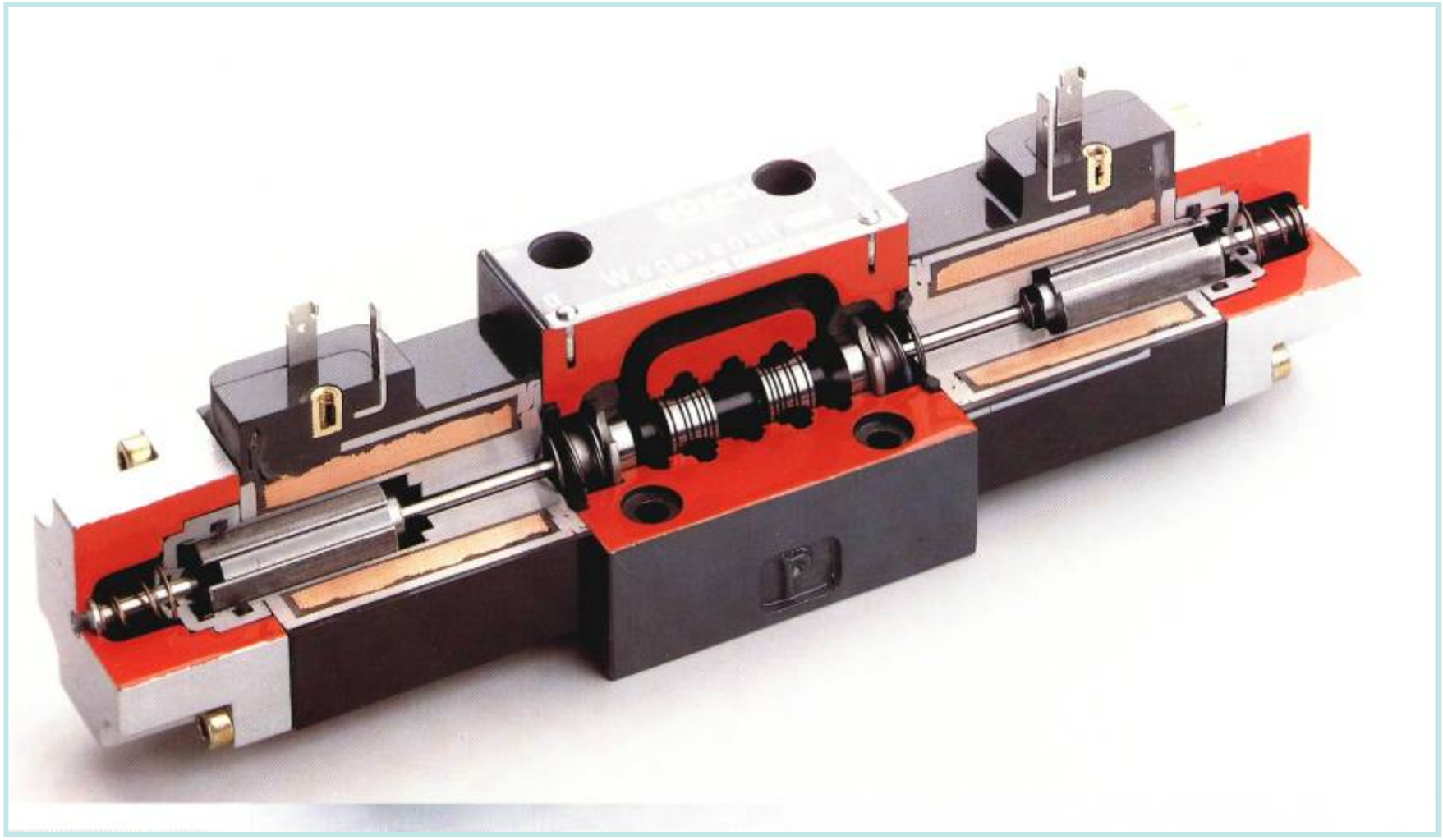
- External losses
- Internal losses
- Occur always when components move relative to each other
- They reduce efficiency
- In case of external leakages there is environmental damage and the lost fluid has to be refilled.
- External losses can be avoided by careful design and maintenance.
- Internal losses cannot be avoided.



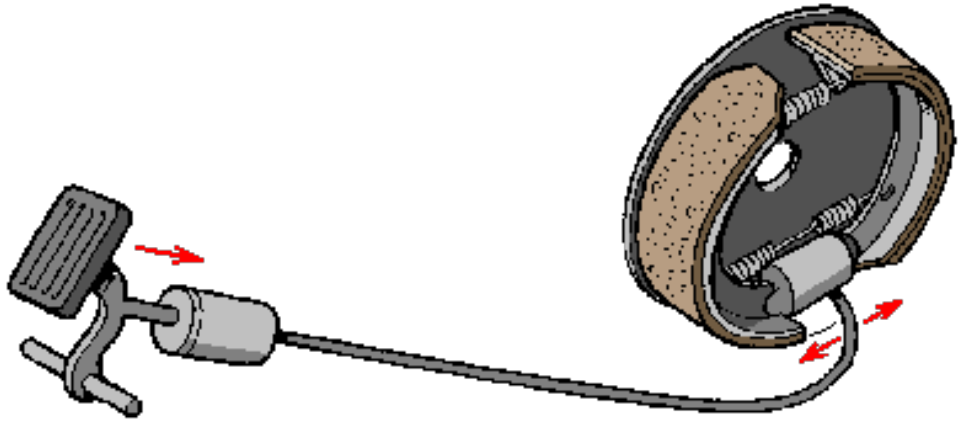
Hand operated hydraulic valves

- Directional control valves
- Used for switching on/off and routing fluid to desired actuator
- Usually consist of a spool inside a cast iron or steel housing
- The spool slides to different positions in the housing
- Intersecting grooves and channels route the fluid based on the spool's position

Solenoid operated hydraulic valves



Fluid power applications



- Vehicle steering
- Vehicle brake system
- Automatic transmissions of cars and trucks
- Controlling airplanes and spacecraft
- Harvesting crops
- Mining coal
- Driving machine tools
- Processing food

Precautions using hydraulic systems