Speed control of hydraulic actuators

Simo Sinkko
Saimaa UAS
Lappeenranta, Finland

International Engineering Week in Schmalkalden 2013 – IEW SM13

Aim of the lectures

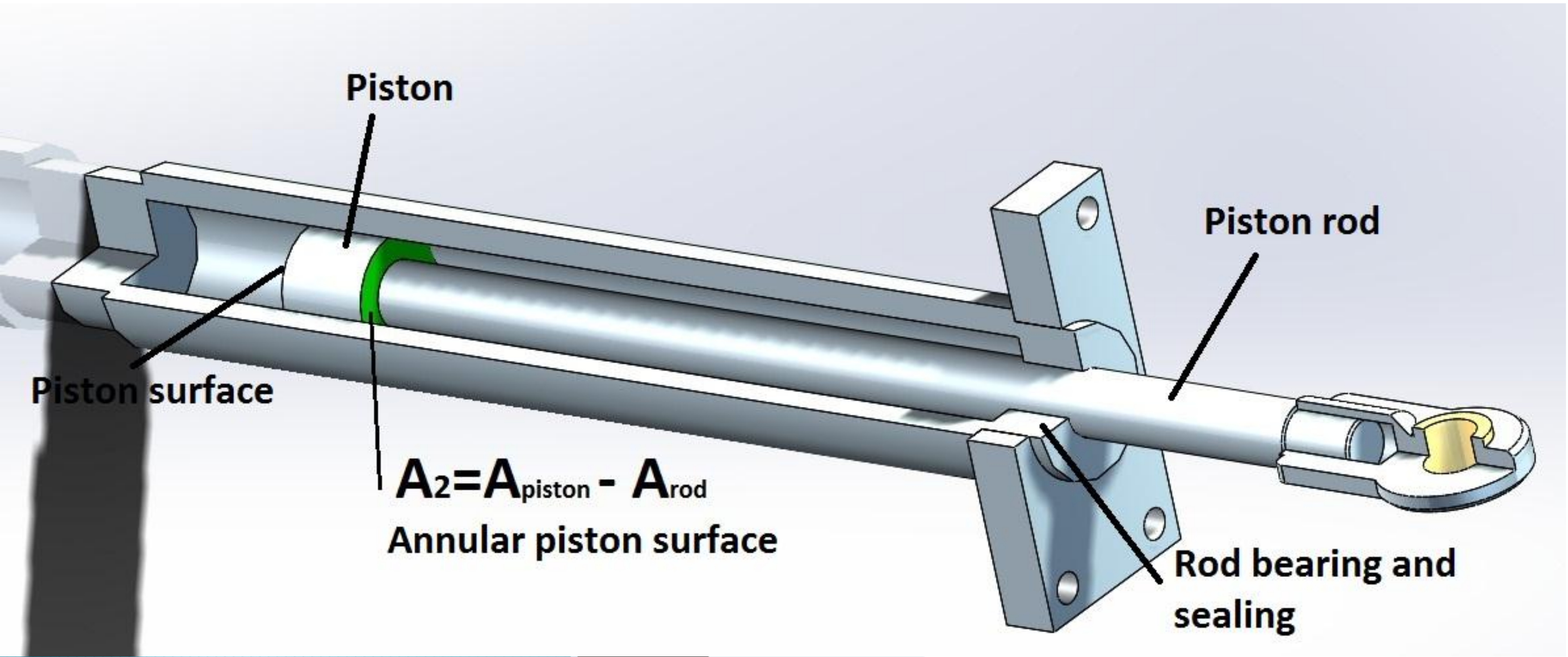
- Understand the basic rules of hydraulics → what are the things that affects the speed of an actuator
- To know what different ways there are available for controlling the speed
- To understand what are the benefits and disbenefits of each controlling method

Basic rules of hydraulics

- Actuator can be either hydraulic cylinder or hydraulic motor. In this lecture, we will mainly concentrate into cylinder.
- Force: $F = pA$
- Speed: $v = Q/A$

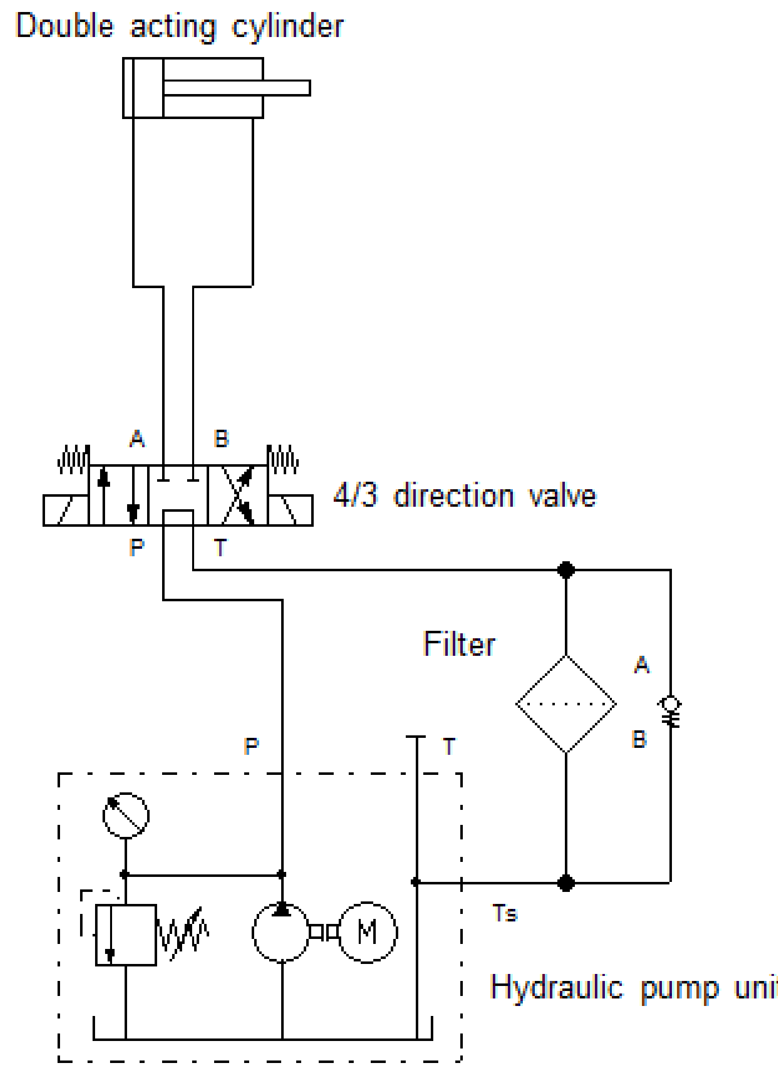
Hydraulic cylinder

- Single acting vs. double acting
- Piston diameter D
- Rod diameter d
- Different force & speed in extending vs. retracting.



Example; no speed control

- There is a simple hydraulic system with pump, directional valve and a cylinder.
- Calculate maximum force and speed for both operating directions.
  - System max. pressure: 190 bar
  - Flow rate: 25 l/min
  - Piston diameter: 40 mm
  - Rod diameter: 20 mm

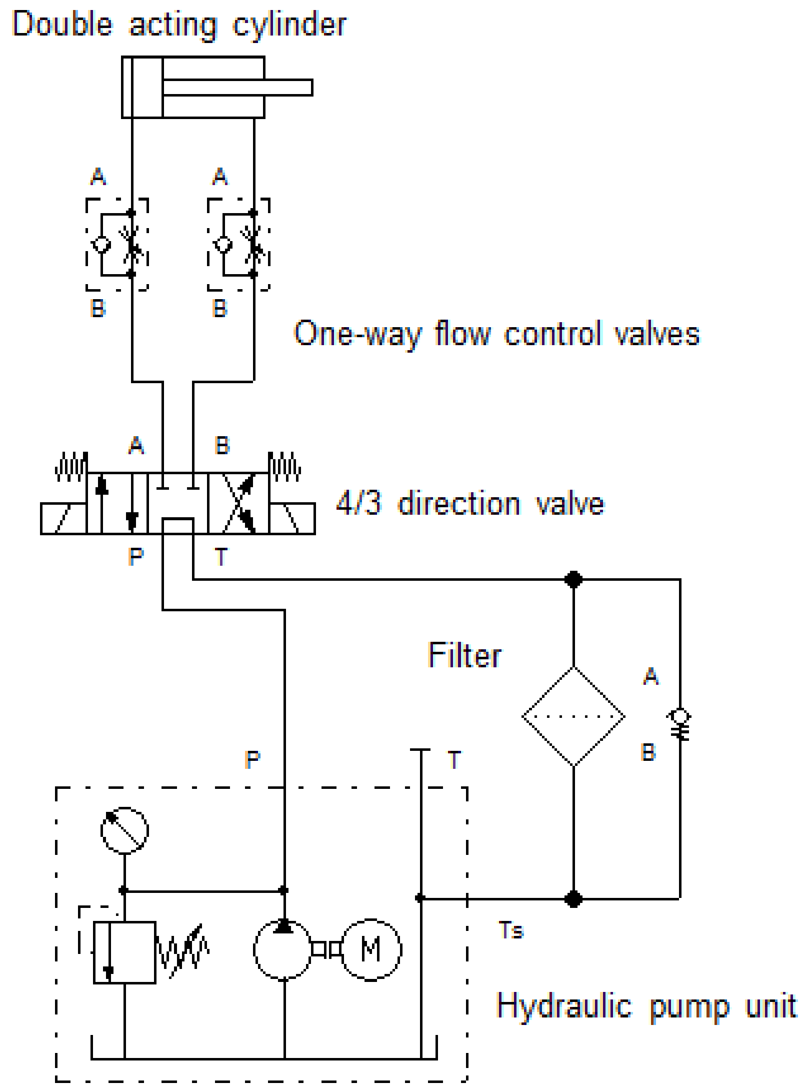


Example 2; simpliest way to adjust speed

- Hydraulic cylinder speed is adjusted by throttles (one way flow control valve)
- Flow through throttle can be calculated with Poiseuille's formula:

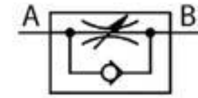
$$Q = \alpha A_0 \sqrt{\frac{2\Delta p}{\rho}}$$

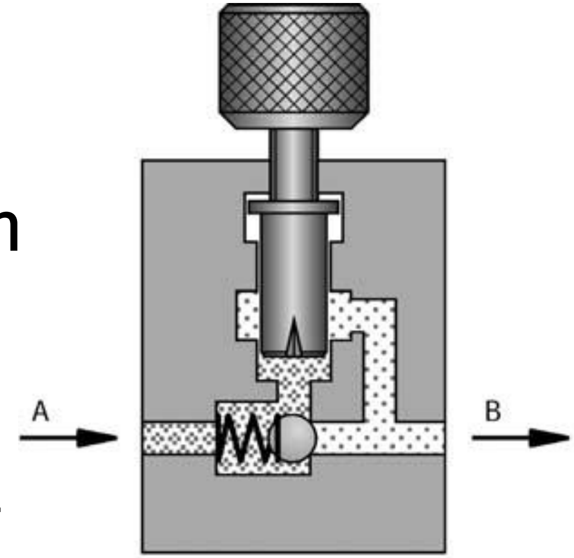
- α = Flow reference number= 0,611 (approx.)
- A = Throttle cross-section [m2]
- Δp = Pressure drop [Pa]
- ρ = Density of the oil [kg/m3]
- Q = Volumetric flow rate [m3/s]

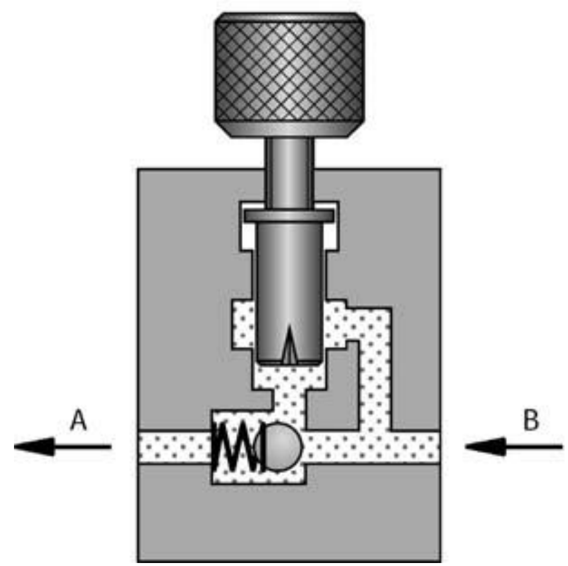


One way flow control valve

- Restrictor is only effective in one direction
- Flow is throttled only in flow direction A→B
- Flow goes through non-return valve in flow direction B→A



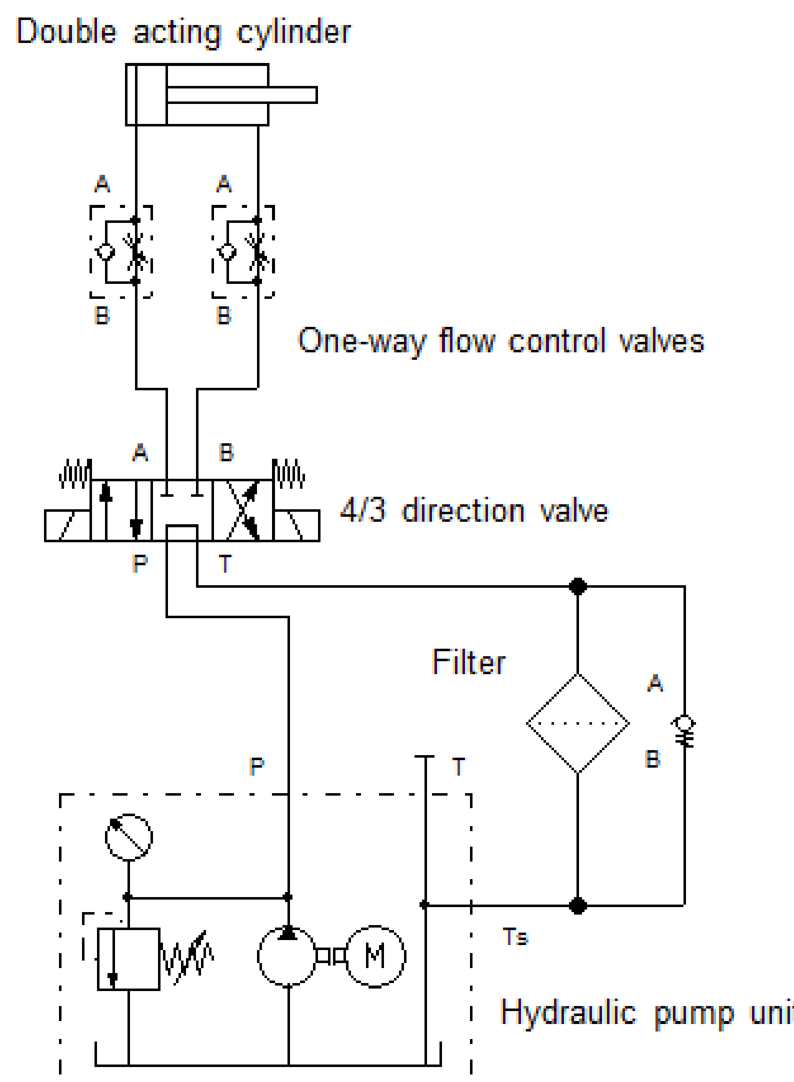




Source of the picture: Merkle D., Schrader B., Thomes M., Festo Hydraulics Basic Level

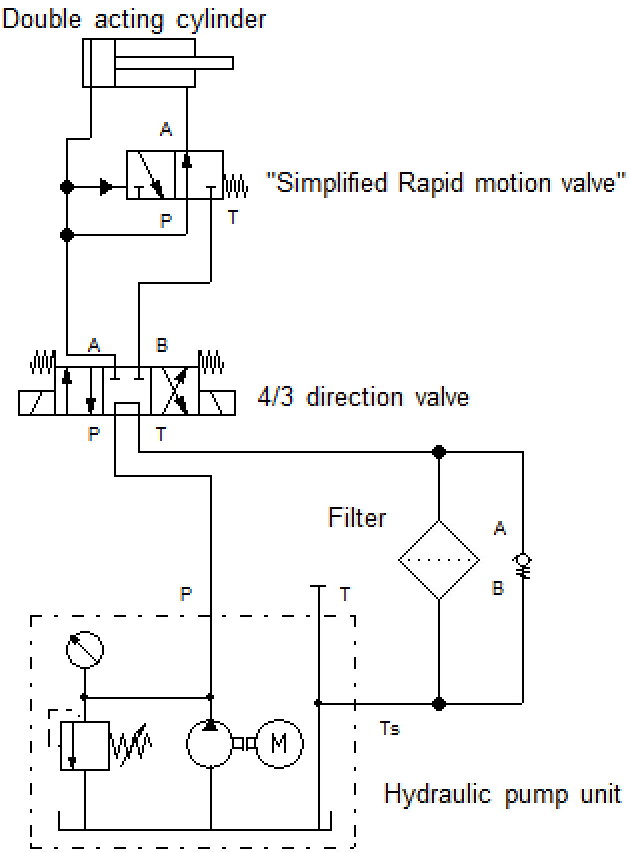
Power consumption

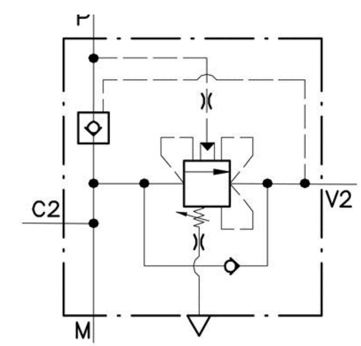
- Hydraulic power can be calculated with formula:
- $P = Qp$
- If speed is adjusted with simple throttling, what happens to flow rate and pressure?



Rapid motion

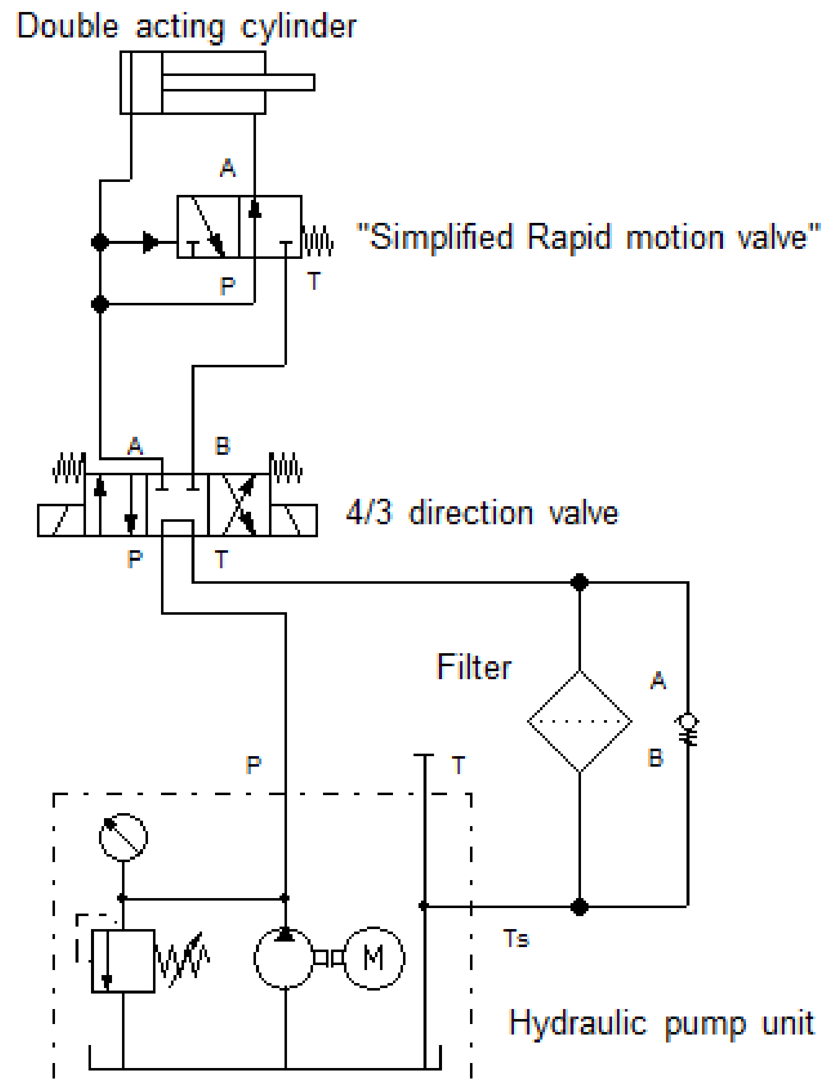
- Sometimes rapid motion is needed before the actual work begins. By guiding returning oil (from rod side) to pressure line, we can get boost for speed but reduction to force.
- Counterbalance valves with regenerative function
- Applied e.g. in wood cleaving machines





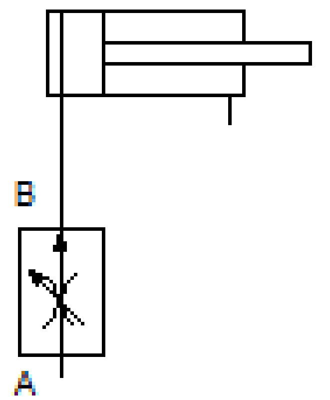
Calculation exercise:

- Calculate extending speed of the cylinder (same initial values as earlier), with rapid motion valve activated (returning oil is directed back to piston side).



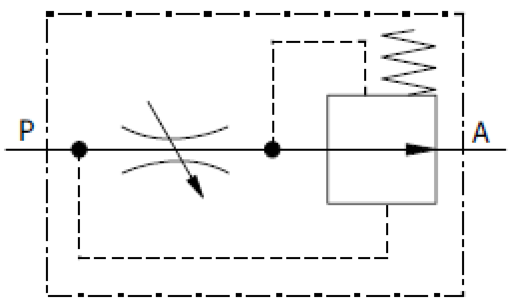
Regulating valves

- With regulating flow control valves some benefits can be achieved.
- Due to pressure compensation, flow rate through valve remains constant even if external load is changing
- 2-way flow control valve
- 3-way flow control valve

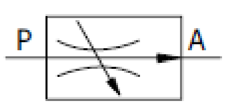


2–way flow control valve

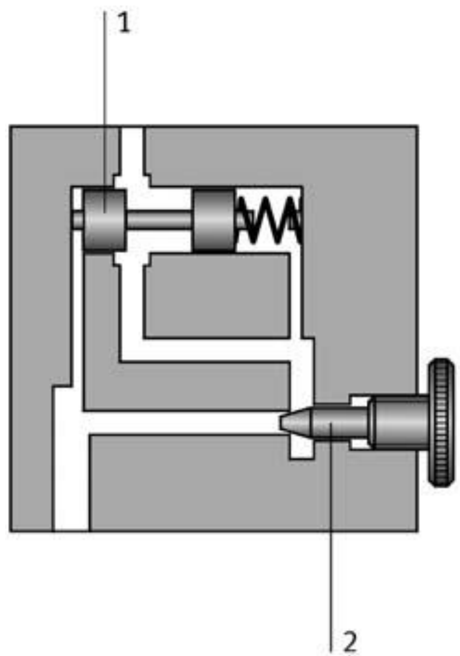
- Regulating restrictor finds hydraulic equilibrium which makes flow control indepent from load.
- Power consumption?

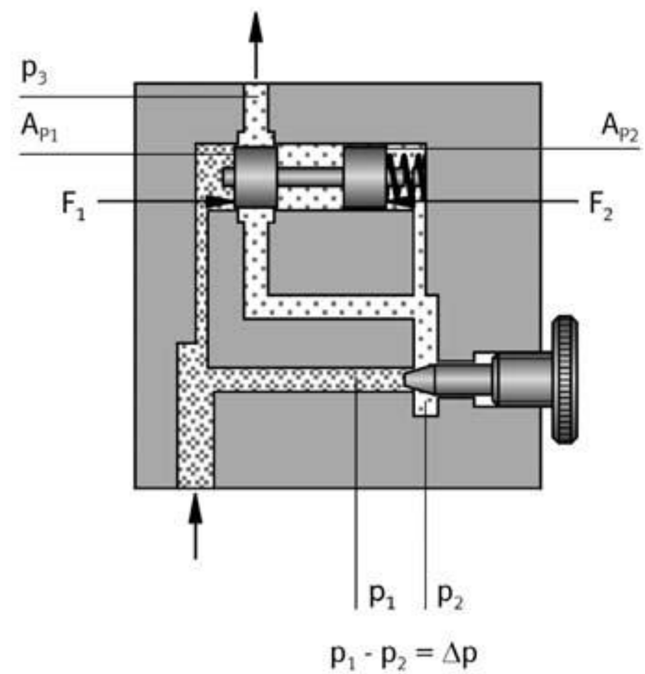


Complete symbol



Simplified symbol

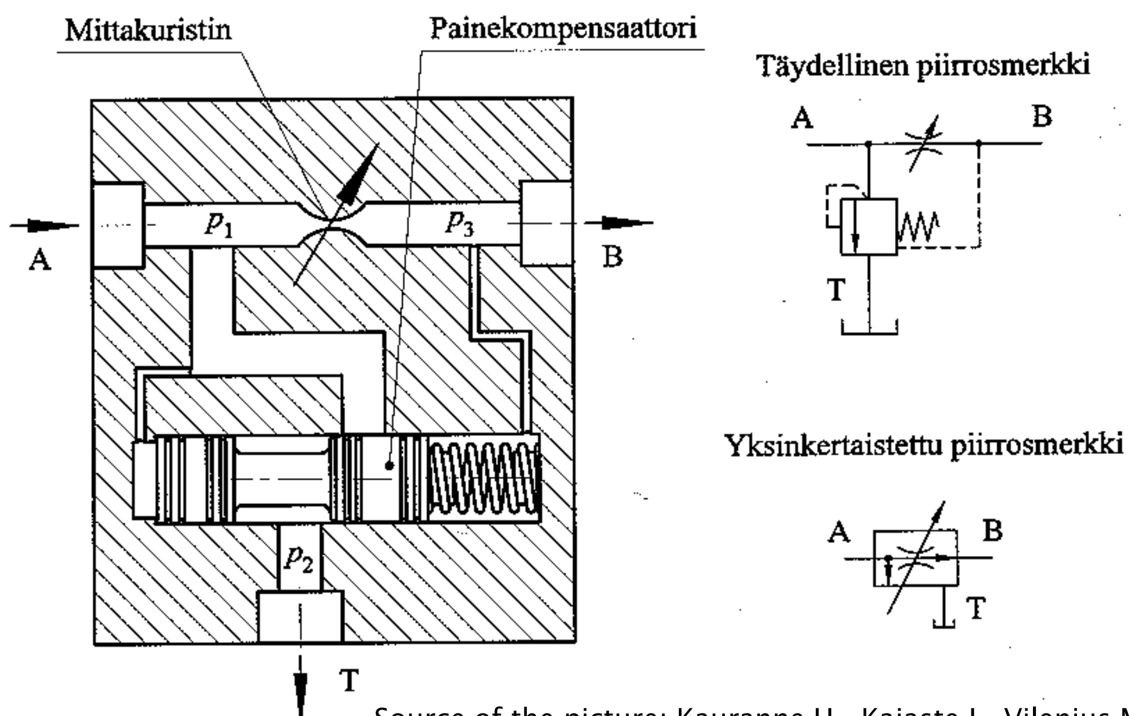




Source of the picture: Merkle D., Schrader B., Thomes M., Festo Hydraulics Basic Level

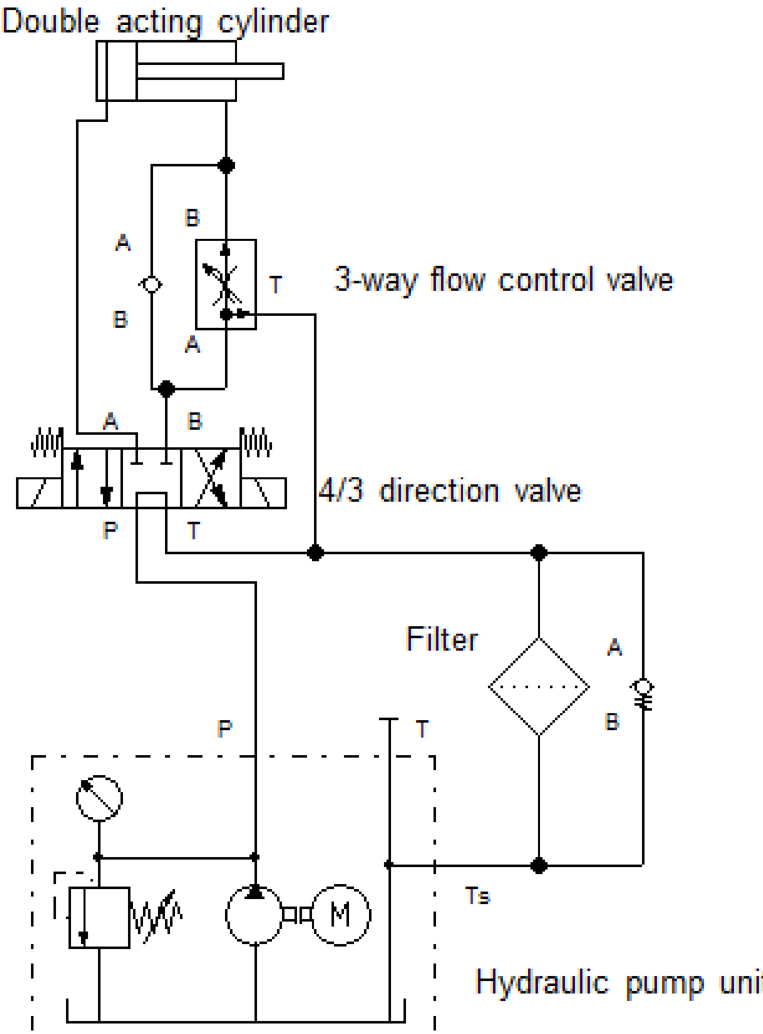
3-way flow regulator

- 3-way flow regulator has tank connection where extra oil is directed → oil doesn't have to go through pressure relief valve → lower pressure level → less heat → better efficiency compared to other flow control valves



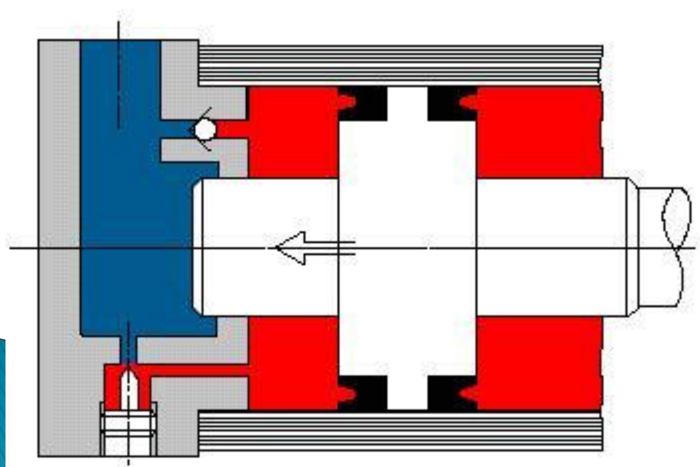
Source of the picture: Kauranne H., Kajaste J., Vilenius M. Hydraulitekniikan perusteet

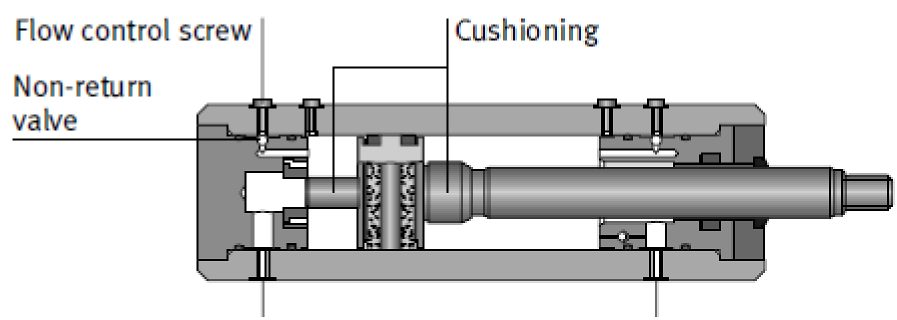
Flow regulating valves in hydraulic circuit



End position cushioning

- If piston moves faster than 0,1 m/s, end position cushioning is normally needed to avoid heavy impacts
- Suggested max. velocity for hydraulic cylinders is 0,2 m/s
- End postion cushioning brakes piston speed just before collision to the end
- With non-return valves it is possible to get non-cushioned start





Source of the picture: Merkle D., Schrader B., Thomes M., Festo Hydraulics Basic Level

Flow rate of the hydraulic pump

- Theoretical flow rate:

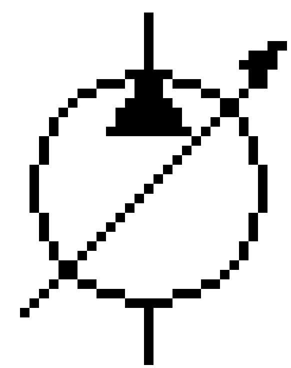
- $Q = nV_{rev}$ / $Q = \omega V_{rad}$

- n=rotating speed of the pump [rps or rpm]
- V_{rev}=pump displacement volume per one revolution [m^3/r]
- V_{rad}=pump displacemetn volume per one radian [m^3/rad]
- $\omega = 2\pi n$
- $V_{rad} = V_{rev}/2\pi$

Speed control with variable volume pumps

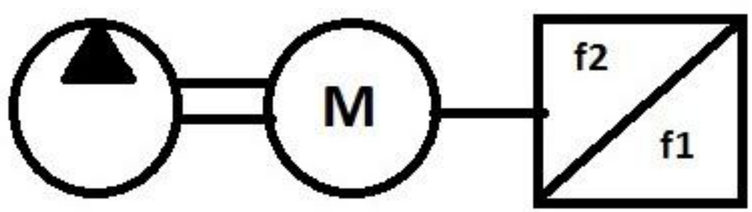
- By adjusting displacement volume of the pump we can adjust flow rate and thus the speed of the actuator
- Both electric control and manual control are possible

$$Q = nV_{rev}$$



Speed control with frequency converte

- Frequency converters are built for controlling the speed of electric motors.
- If we have fixed volume hydraulic pump that is rotated by electric motor, we can adjust the hydraulic cylinder speed by adjusting the rotating speed of the electric motor



Speed control of Hydraulic motors

- Possibility to control flow same way as in the case of cylinders
- Variable displacement motors (compare to pump) → easy speed control

$$Q = nV_{rev}$$