

SEM0540

Elementos de Automação

Aula #2 e #3 e #4: Hidráulica —
Introdução e sistemas de atuação

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São Carlos, 30/08/22



Conteúdo



- Princípios básicos
- Circuito e componentes
- Aplicações

Hidráulica



- “Take-home messages”
- Próxima aula...

Conclusão

Conteúdo



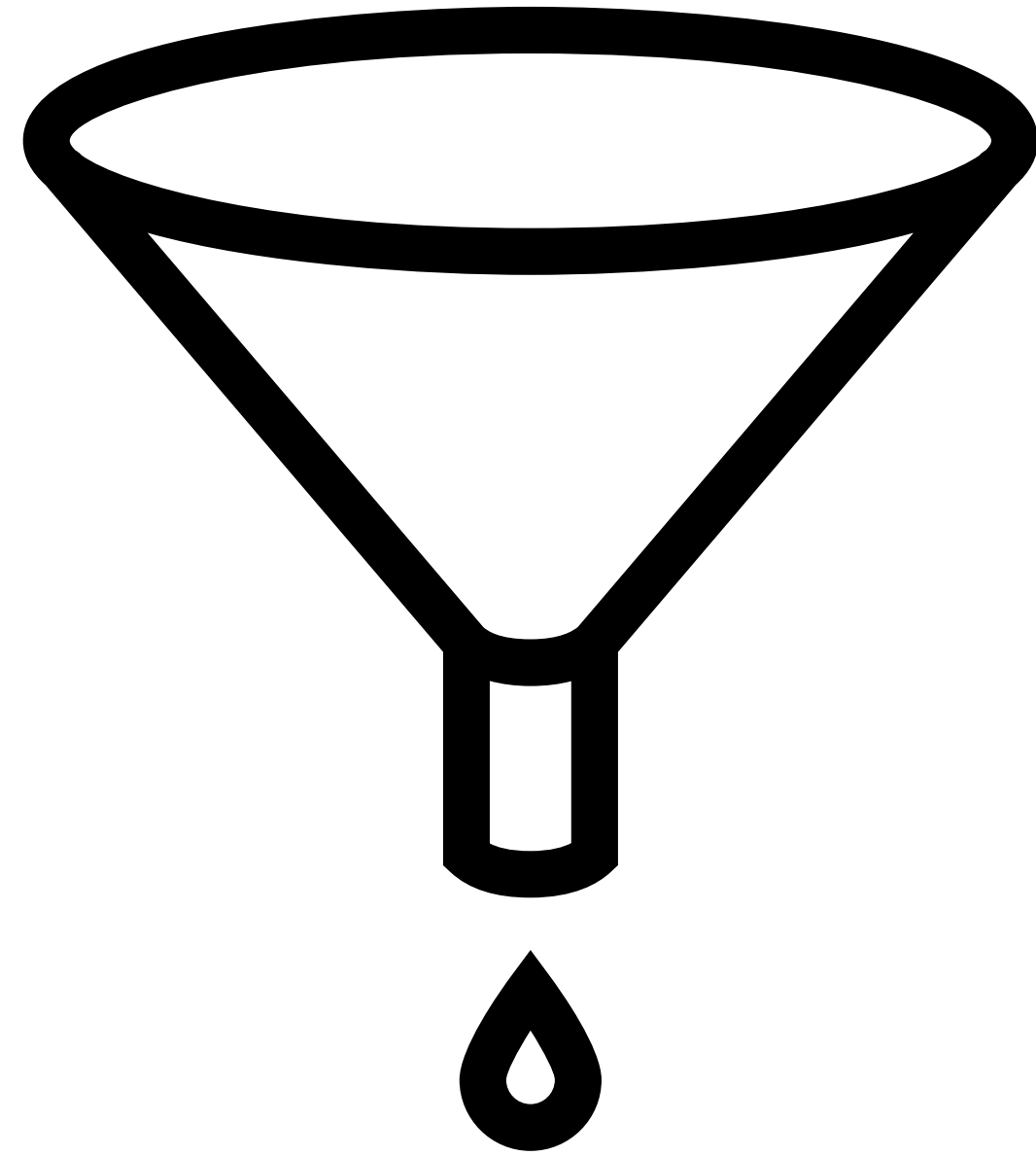
- **Princípios básicos**
- Circuito e componentes
- Aplicações

Hidráulica

Conclusão

Fluidos

Hidráulica



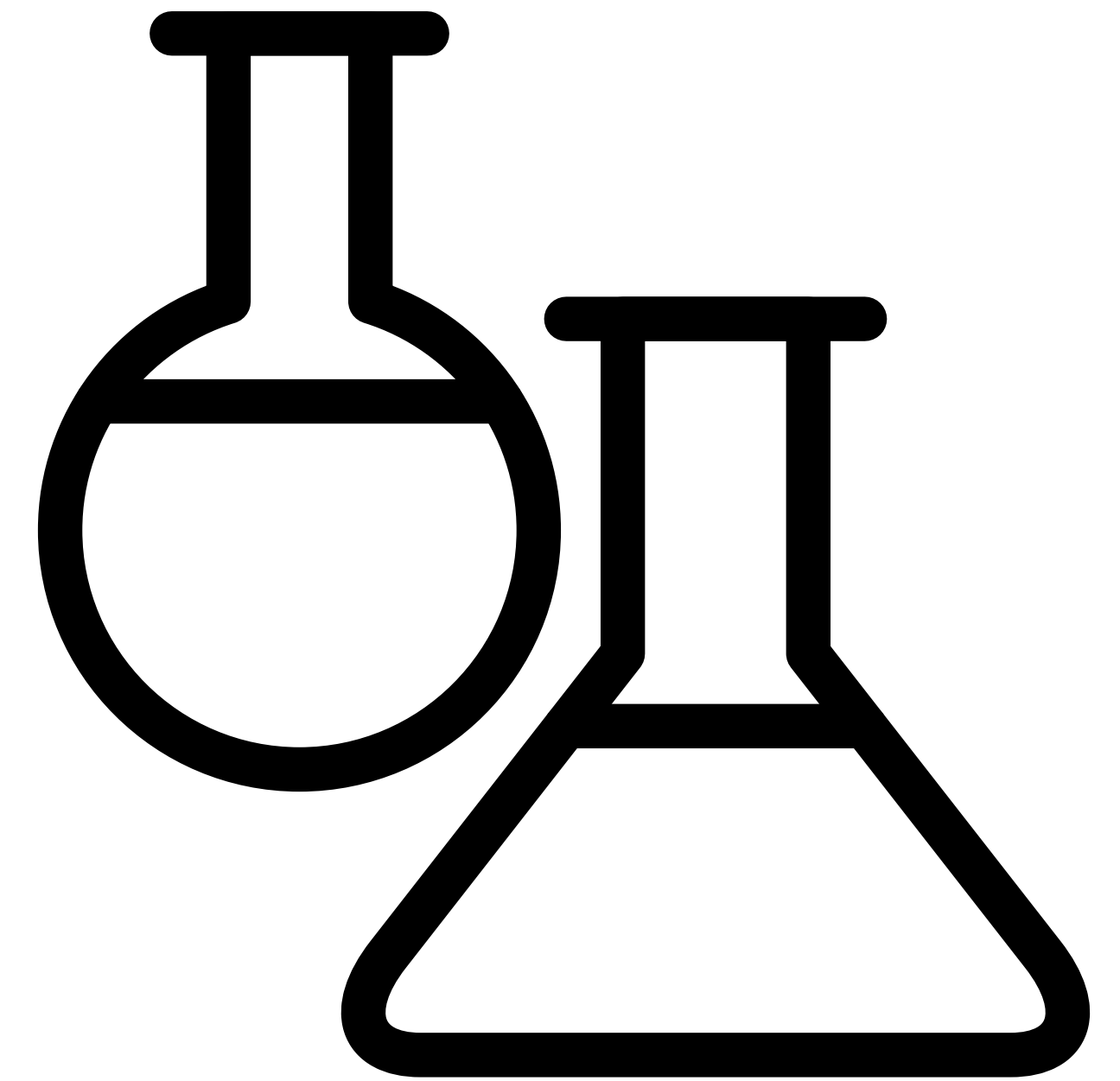
Escoam



Óleo mineral



Água



Deformam-se

Conclusão

Água — Prós e contras

Hidráulica



Não poluente



Baixo Custo

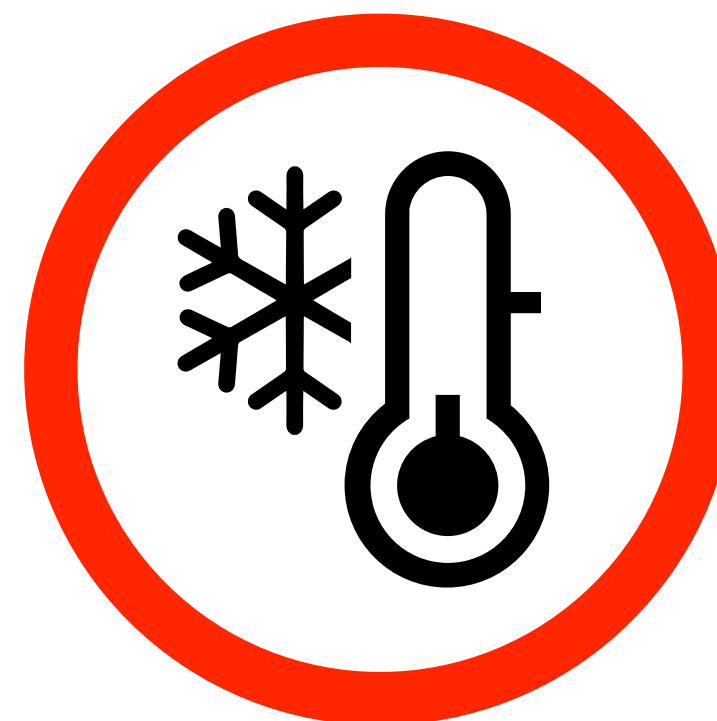


**Baixa
Compressibilidade**

Conclusão



Corrosão



**Congelamento e
evaporação**



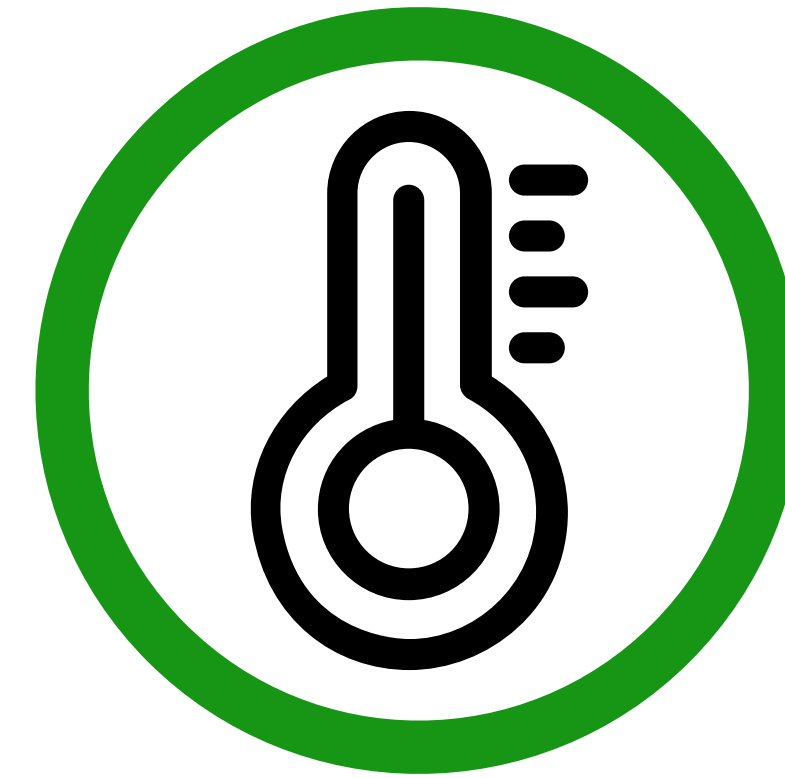
**Vazamentos
Internos**

Óleo mineral — Prós e contras

Hidráulica



Lubrificante



**Temperaturas
de operação**

Conclusão



**Baixa condutividade
térmica**



Inflamável

Densidade

$$\rho = \frac{m}{V}$$

$$[kg/m^3]$$

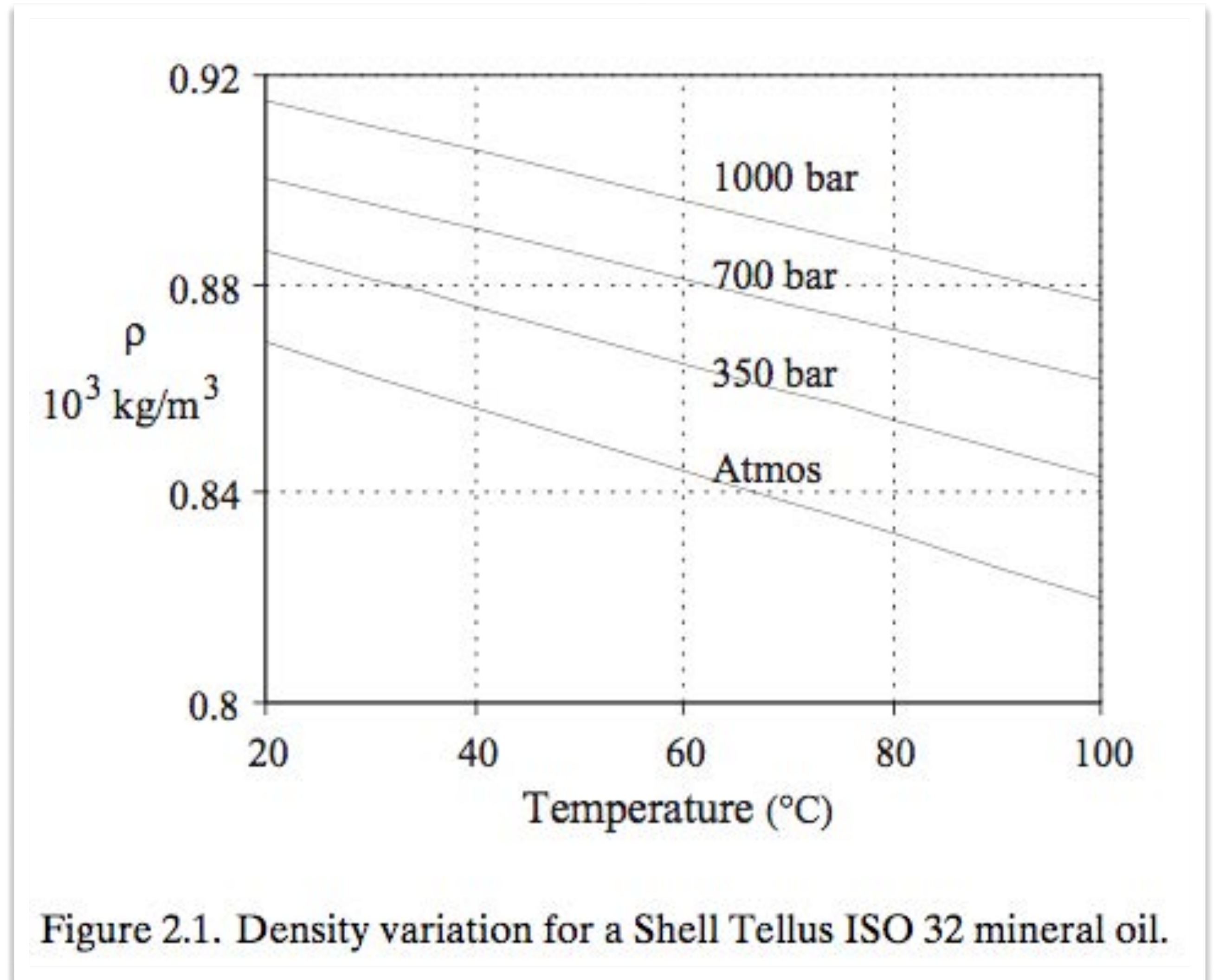


Figure 2.1. Density variation for a Shell Tellus ISO 32 mineral oil.

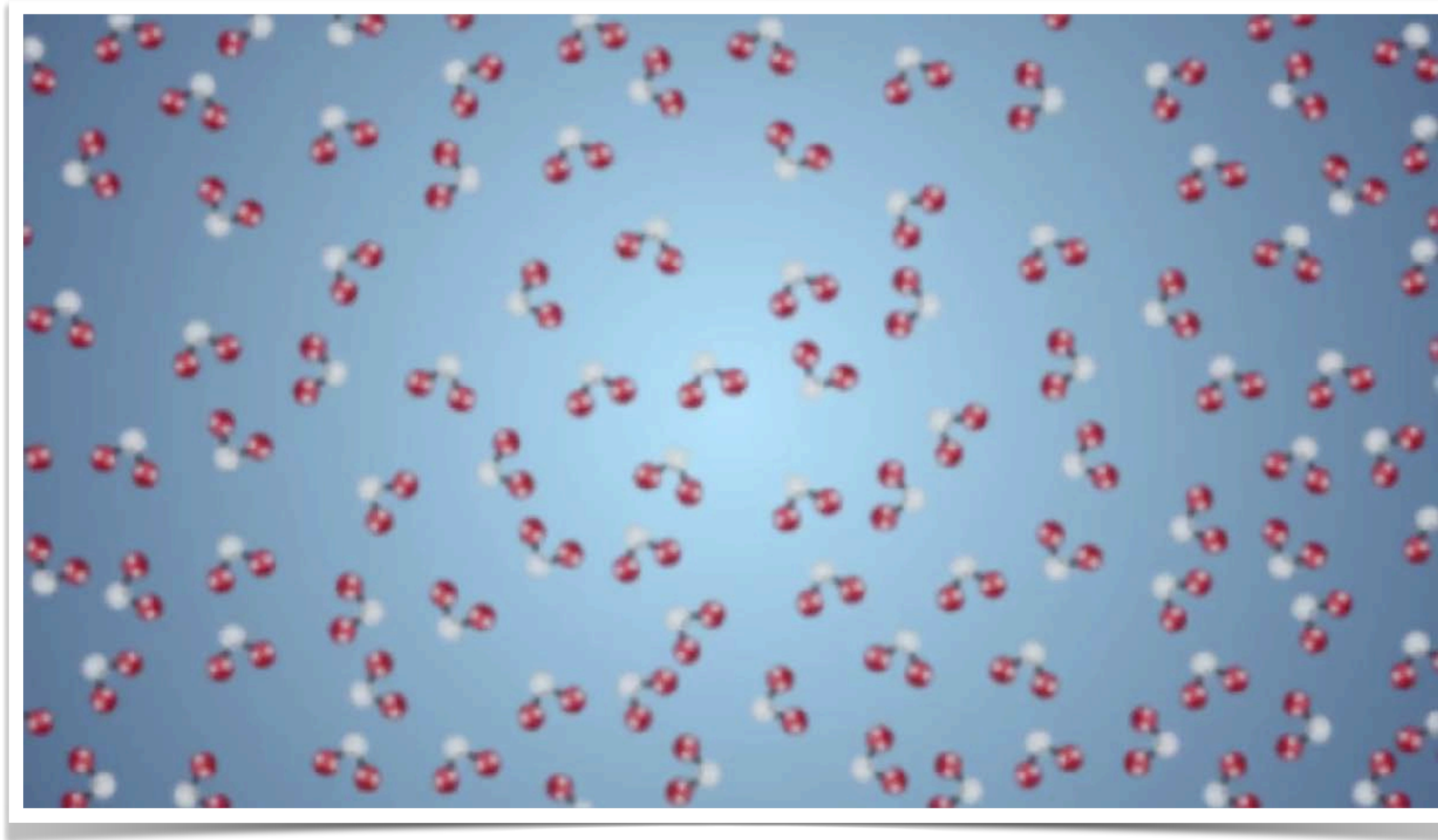
Viscosidade

“Resistência ao escoamento”

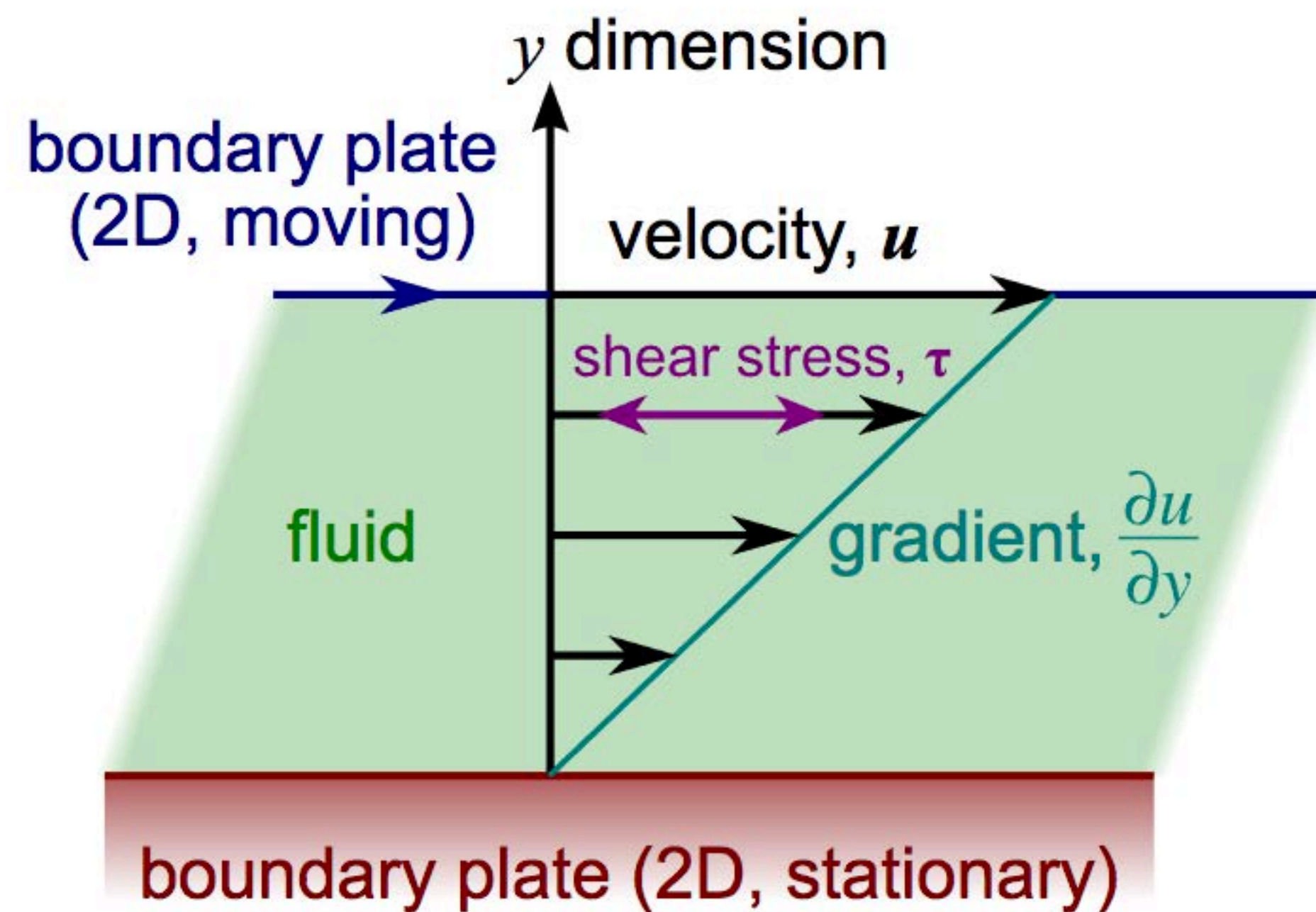


Viscosidade

Ocorre devido a **forças moleculares**



Viscosidade dinâmica



Tensão de cisalhamento:

$$\tau \propto \frac{dv}{dy}$$

$$\tau = \mu \frac{dv}{dy}$$

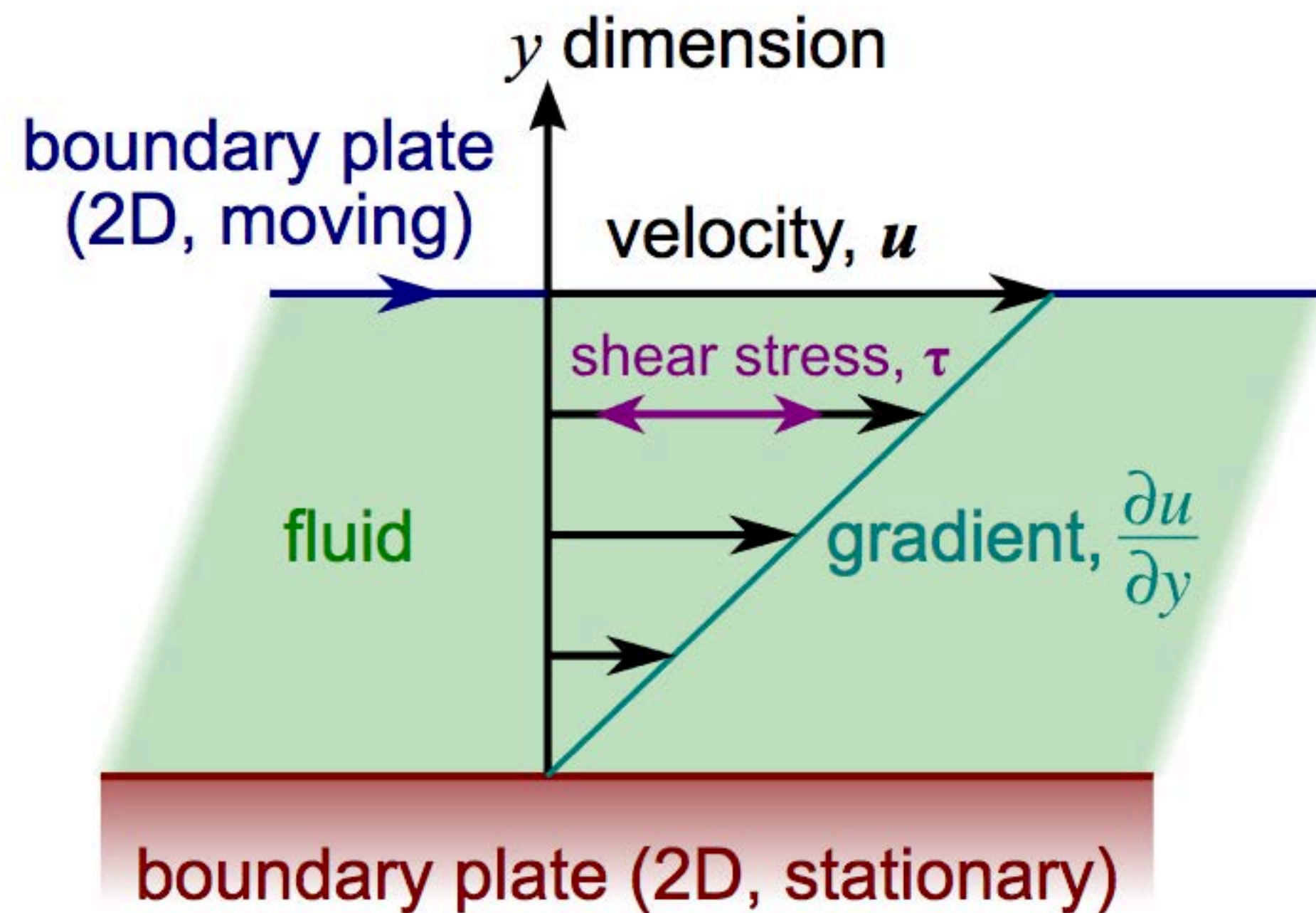
$$[\text{Pa s}] \quad [\text{cP} = 10^{-3} \text{ Pa s}]$$

centi Poise

Viscosidade
Dinâmica
(Absoluta)

Viscosidade estática

Tensão de cisalhamento:



$$\tau \propto \frac{dv}{dy}$$

$$\tau = \mu \frac{dv}{dy}$$

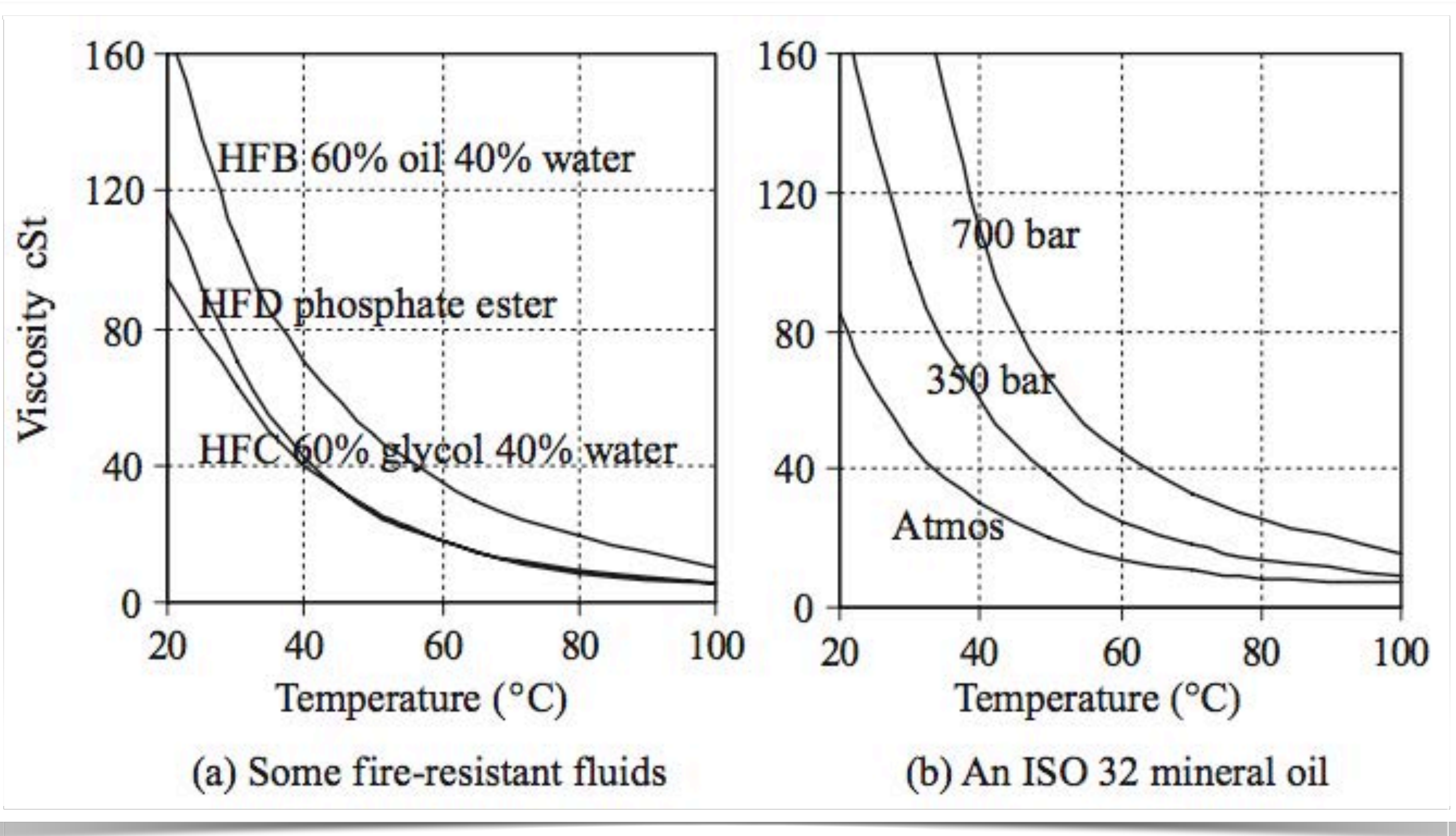
Viscosidade
Cinemática

$$\nu = \frac{\mu}{\rho}$$

$$[m^2/s]$$
$$[cSt = 10^{-6} m^2/s]$$

centi Stokes

Viscosidade e temperatura



Classificação ISO de viscosidade

ISO standard 3448 ASTM D-2422	Ponto médio de viscosidade cSt	Viscosidade cinemática, cSt		Equivalência aproximada SUS
		mínimo	máximo	
ISO VG 2	2,2	1,98	2,42	32
ISO VG 3	3,3	2,88	3,52	36
ISO VG 5	4,6	4,14	5,06	40
ISO VG 7	6,8	6,12	7,48	50
ISO VG 10	10	9,00	11,0	60
ISO VG 15	15	13,5	16,5	75
ISO VG 22	22	19,8	24,2	105
ISO VG 32	32	28,8	35,2	150
ISO VG 46	46	41,4	50,6	215
ISO VG 68	68	61,2	74,8	315
ISO VG 100	100	90,0	110	465
ISO VG 150	150	135	165	700
ISO VG 220	220	198	242	1000
ISO VG 320	320	288	352	1500
ISO VG 460	460	414	506	2150
ISO VG 680	680	612	748	3150
ISO VG 1000	1000	900	1100	4650
ISO VG 1500	1500	1350	1650	7000

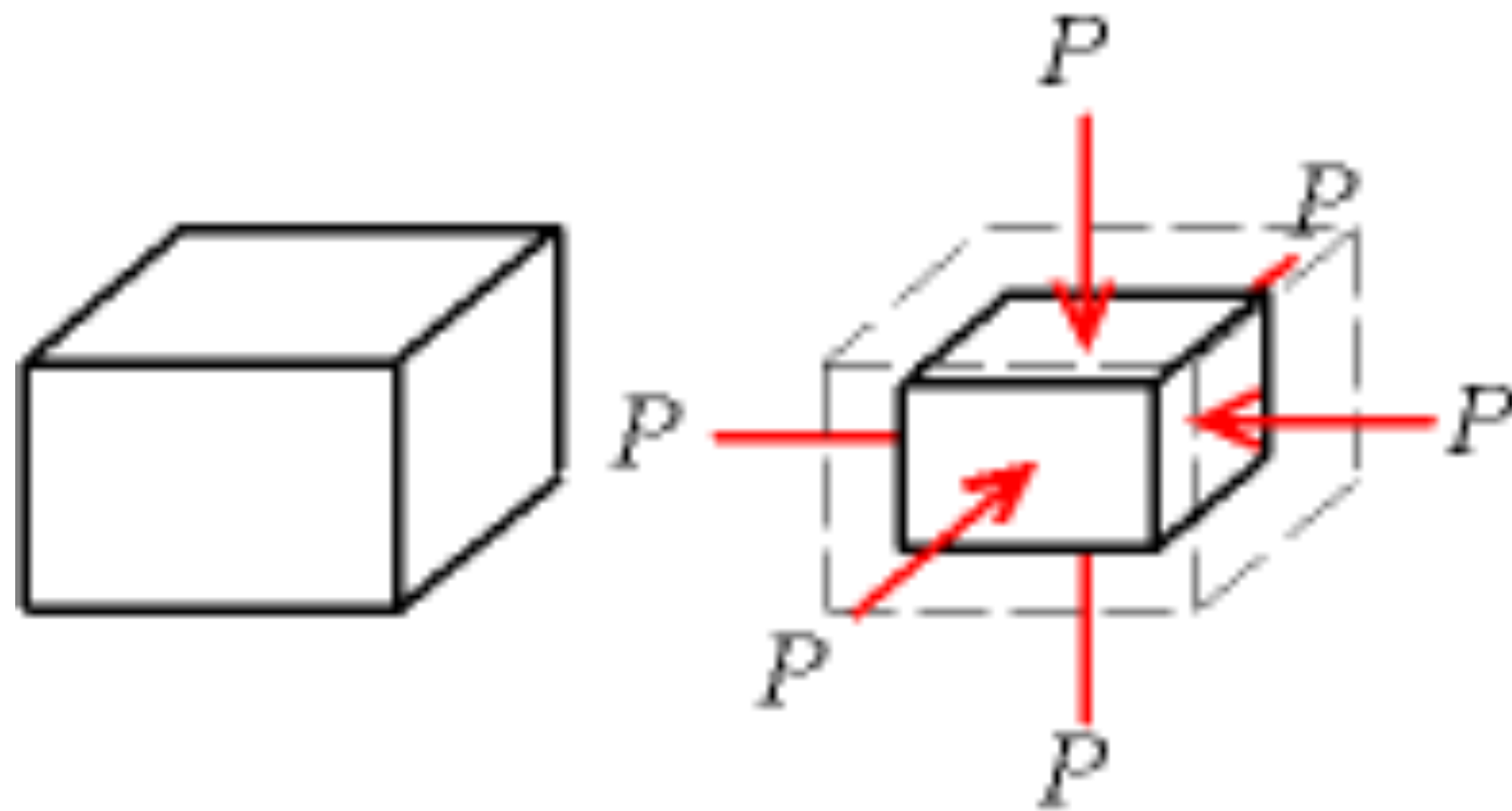
O sistema ISO baseia-se na viscosidade cinemática (centistokes) a 40°C.

Água a 20°C tem uma viscosidade cinemática de cerca de 1 cSt.

Módulo de elasticidade

“Resistência à compressibilidade”

Bulk modulus



$$\beta = -v_0 \left(\frac{\partial p}{\partial v} \right)$$

$$[Pa]$$

Módulo de elasticidade

Valores típicos:

Óleo mineral: $\beta = 1500 \text{ MPa}$

Água: $\beta = 2200 \text{ MPa}$

Ar: $\beta = 0.1 \text{ MPa}$

Módulo de elasticidade

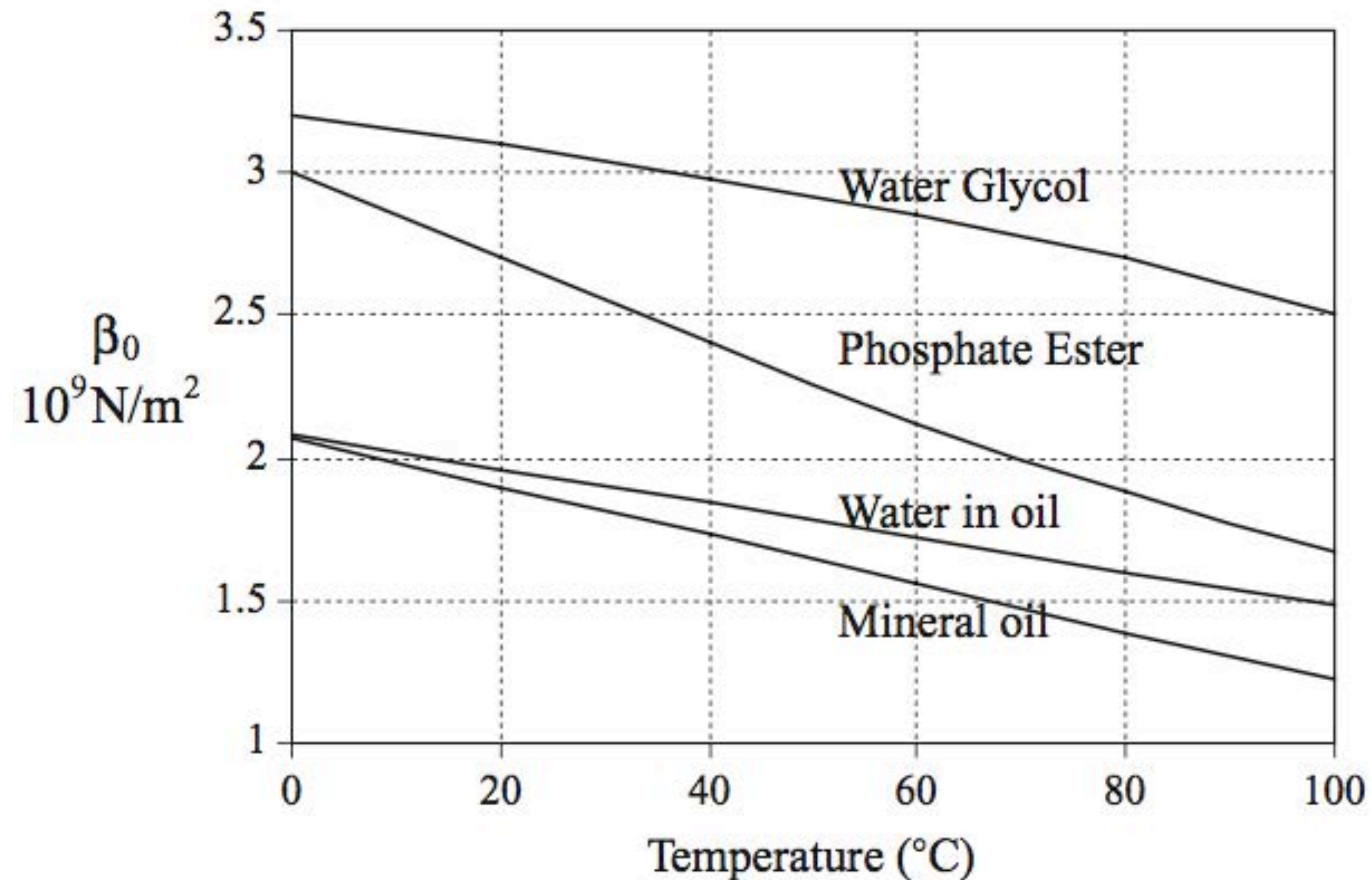


Figure 2.3. Variation of bulk modulus with temperature for different fluids.

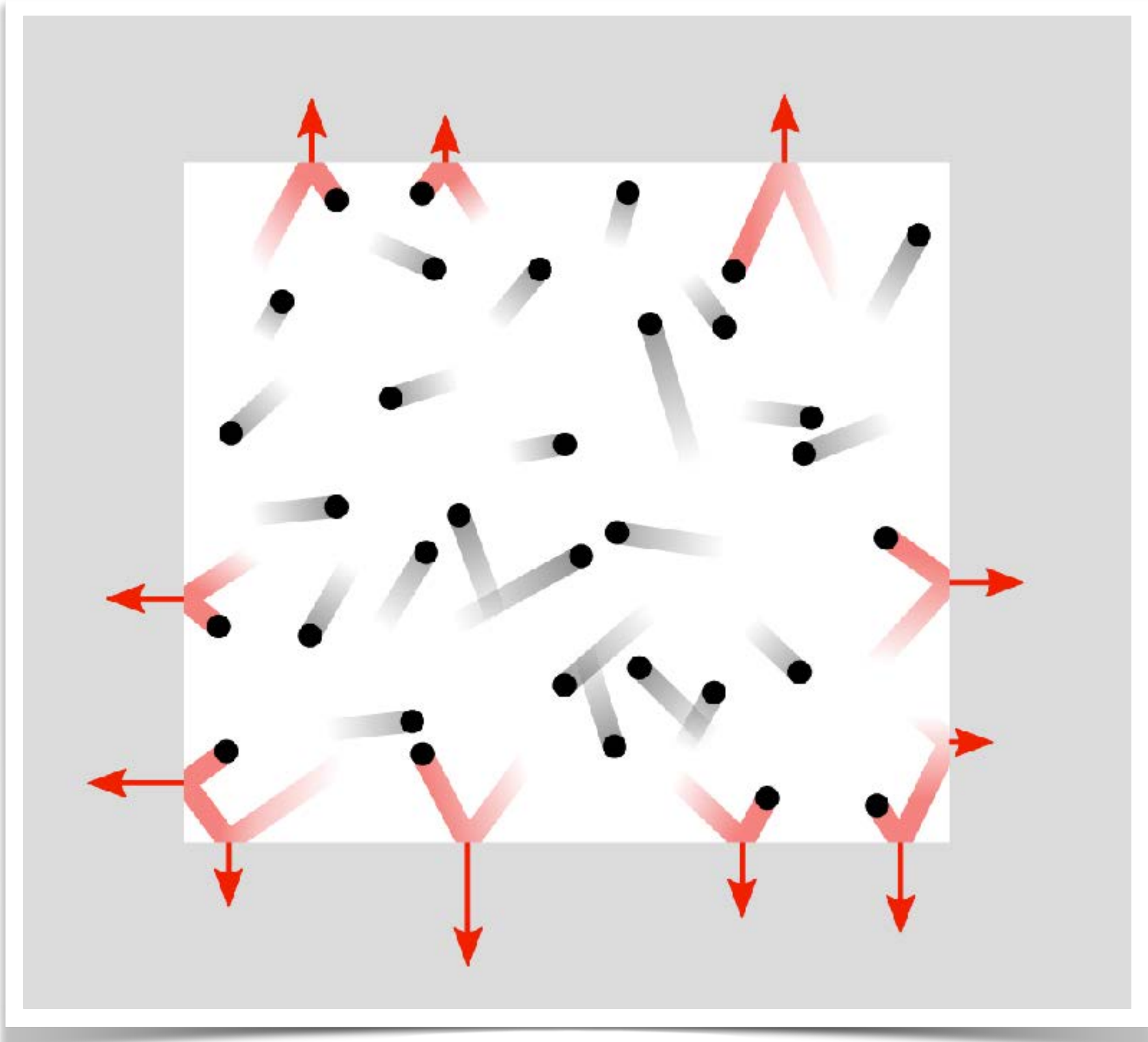
Pressão

$$P = \frac{F}{A}$$

$$[Pa] \quad \left[\frac{N}{m^2} \right]$$

$$[bar] \quad 1 \text{ bar} = 10^5 Pa$$

$$p = mv$$



Vazão volumétrica

$$Q = \frac{\Delta V}{\Delta t} \quad \left[\frac{m^3}{s} \right] \quad \left[\frac{l}{min} \right]$$



$$1.500 \frac{m^3}{s} = 1.5 \cdot 10^6 \frac{l}{s}$$



$$11.000 \frac{m^3}{s} = 11 \cdot 10^6 \frac{l}{s}$$

POTÊNCIA

=

ESFORÇO

X

FLUXO



Mecânico

=

FORÇA

X

VELOCIDADE



Elétrico

=

TENSÃO

X

CORRENTE



Fluidos

=

PRESSÃO

X

VAZÃO

$$\text{POTÊNCIA} = \text{ESFORÇO} \times \text{FLUXO}$$



Fluidos

$$= \text{PRESSÃO} \times \text{VAZÃO}$$

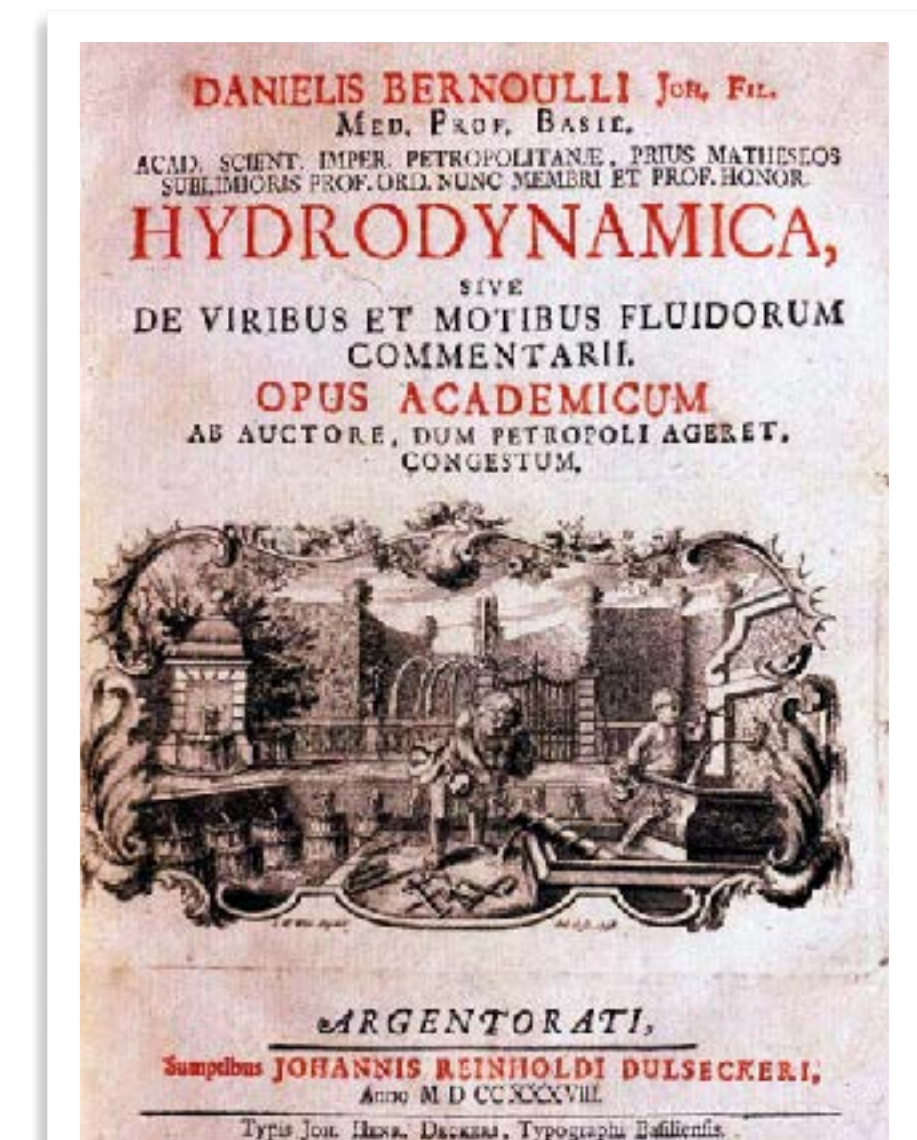
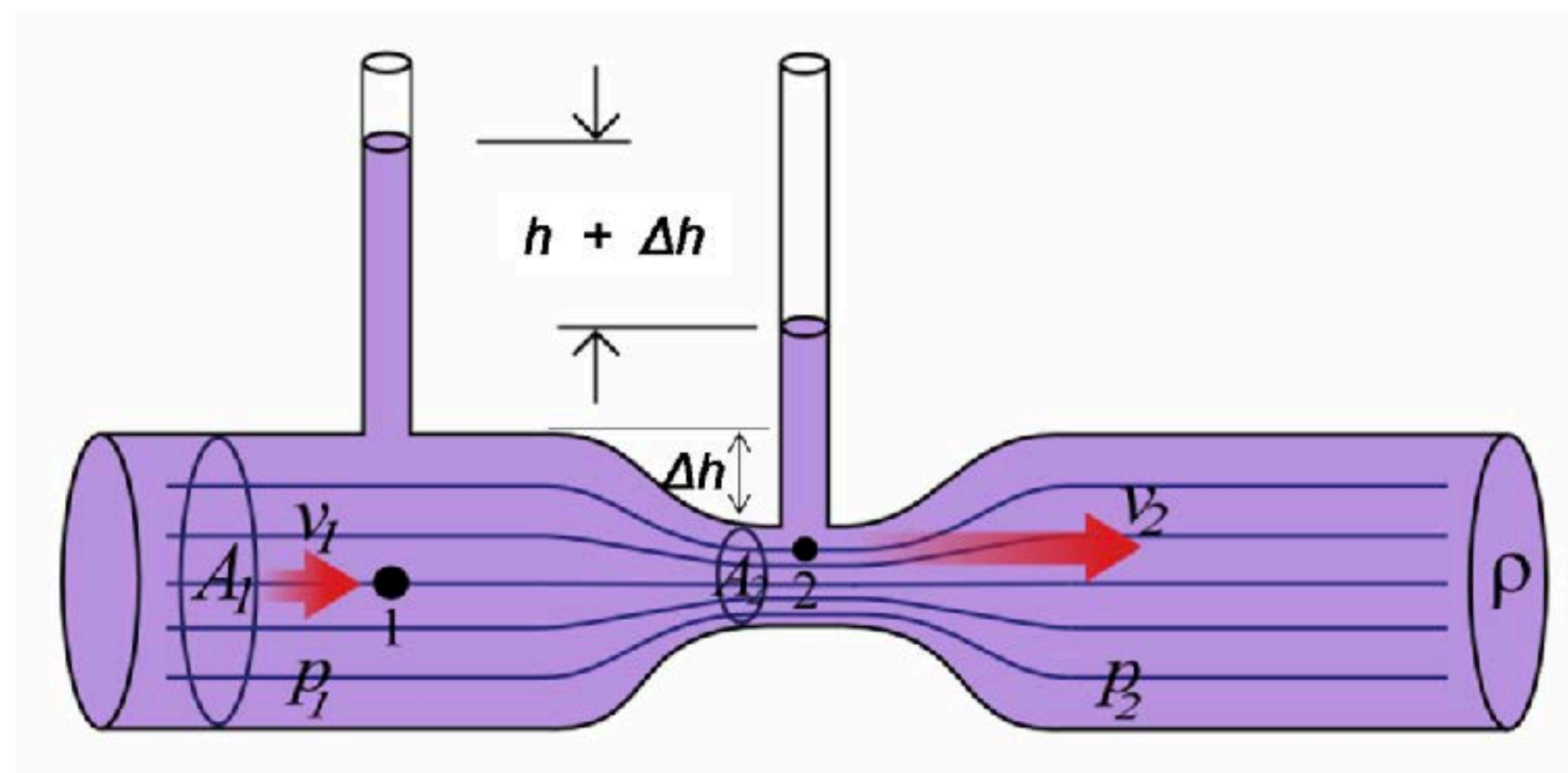


Princípio de Bernoulli

"Se a **velocidade** de uma partícula de um fluido **aumenta** enquanto ela se escoa ao longo de uma linha de corrente, a **pressão** do fluido deve **diminuir** e vice-versa"



Daniel Bernoulli
1700 – 1782



1739

Hidráulica — Vantagens e desvantagens

Hidráulica



Potência/Peso



Rápidos

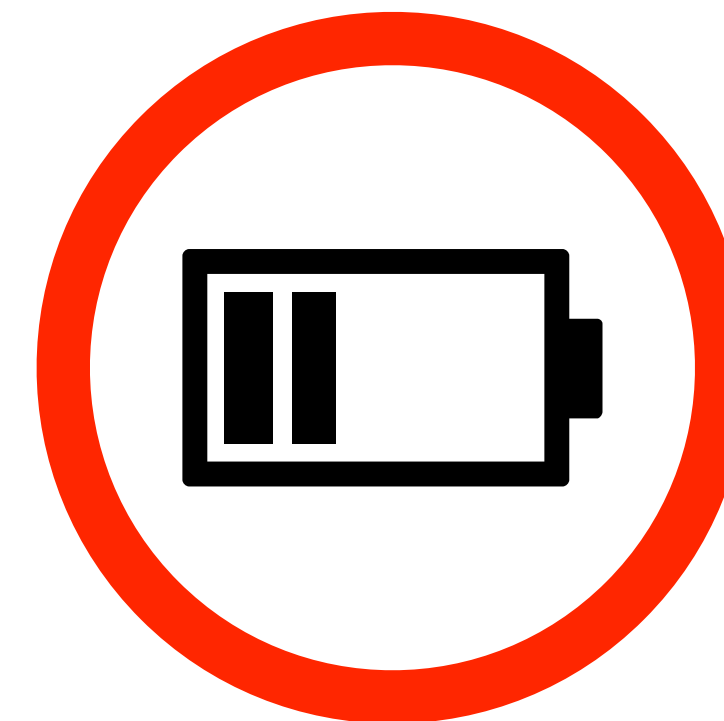


Autolubrificados

Conclusão



Alto custo inicial



Baixo rendimento

Conteúdo

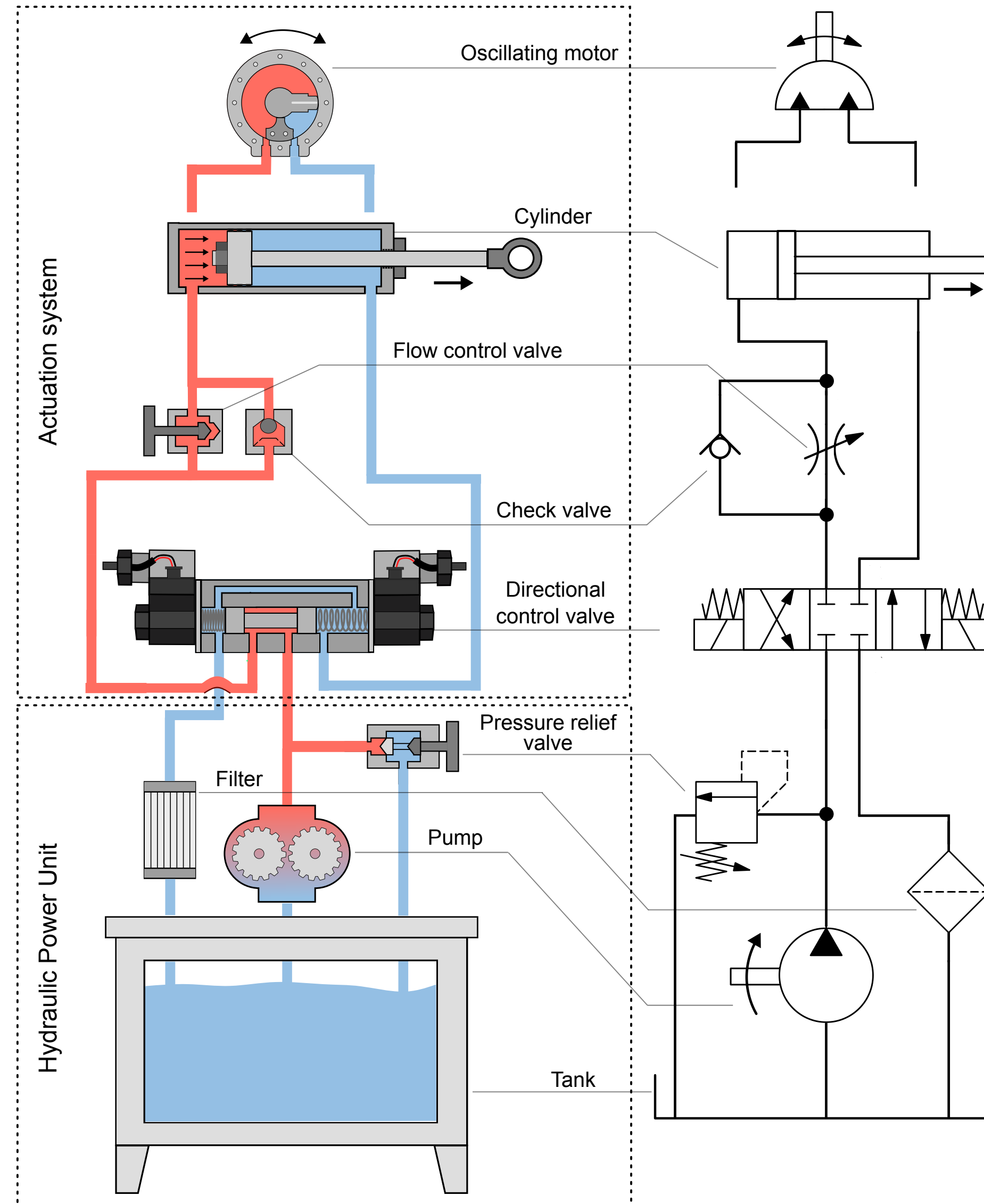


- Princípios básicos
- **Circuito e componentes**
- Aplicações

Hidráulica

Conclusão

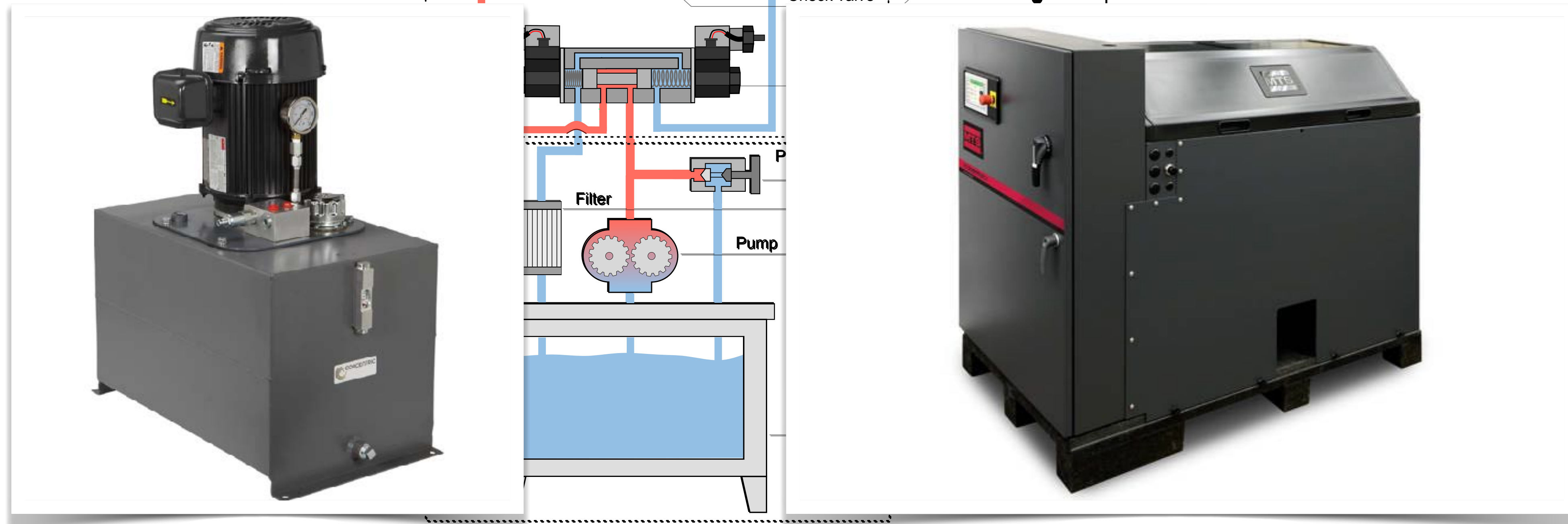
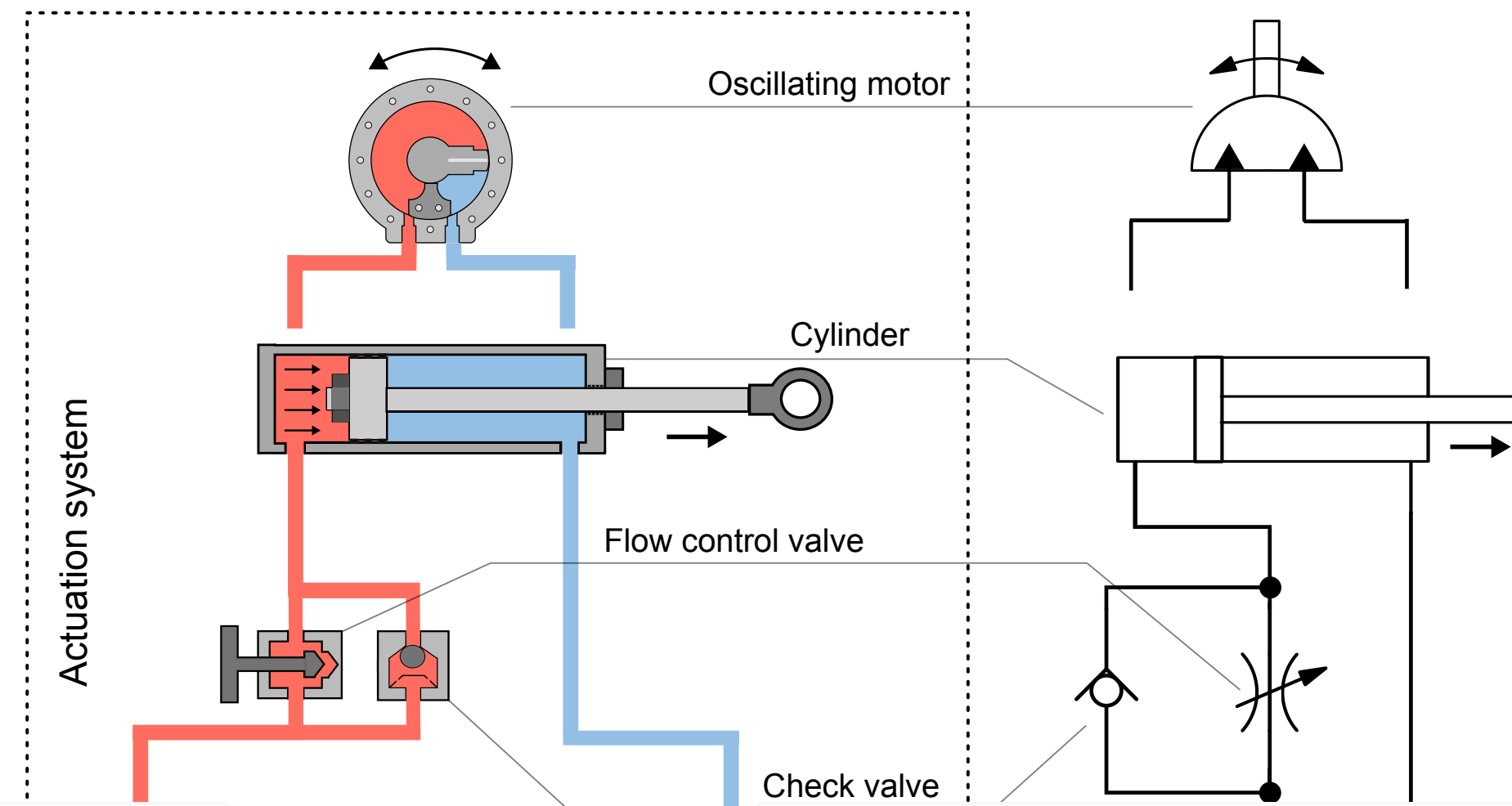
Circuito básico



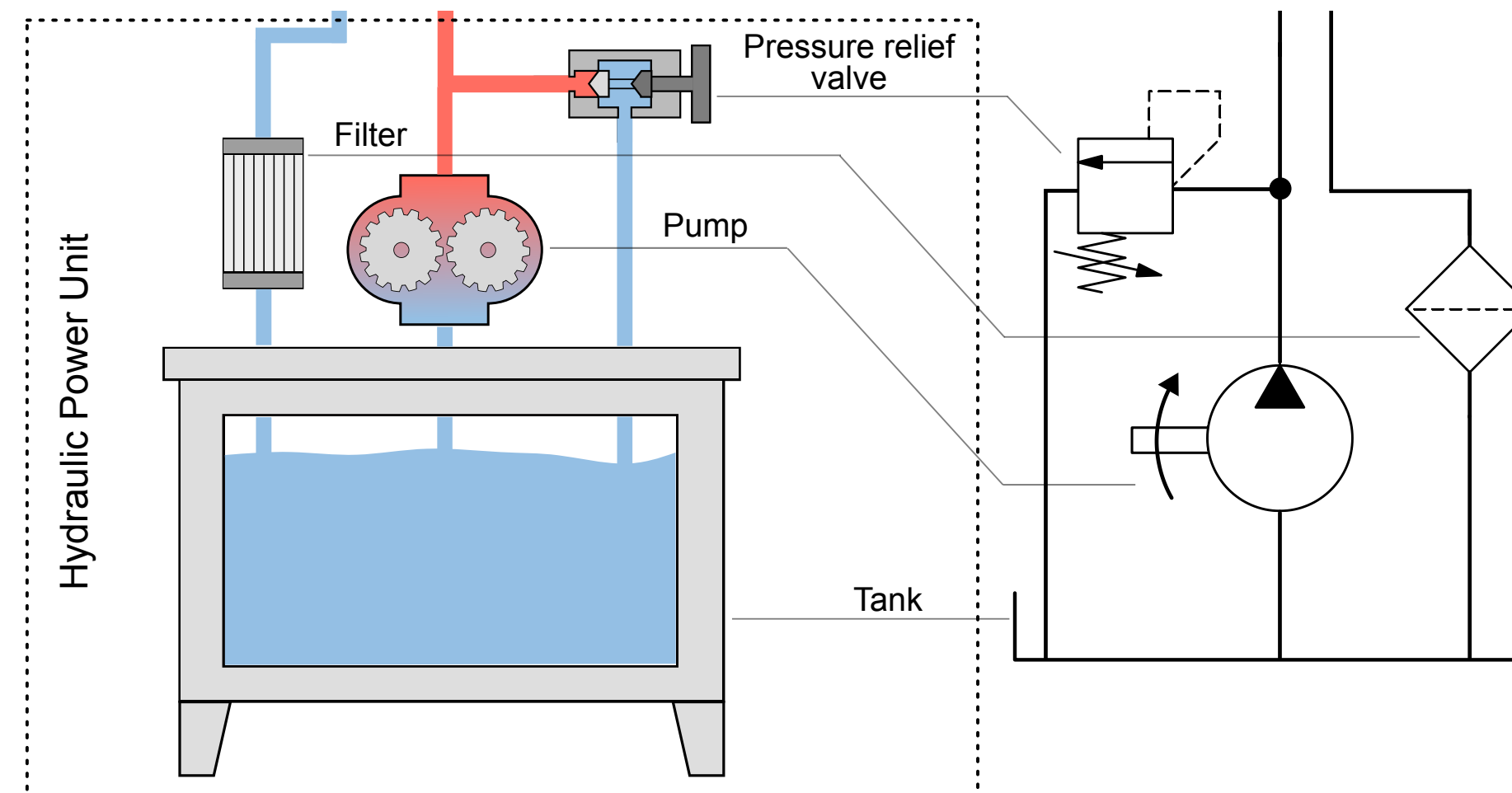
Unidade de potência

Hidráulica

Conclusão



Unidade de potência

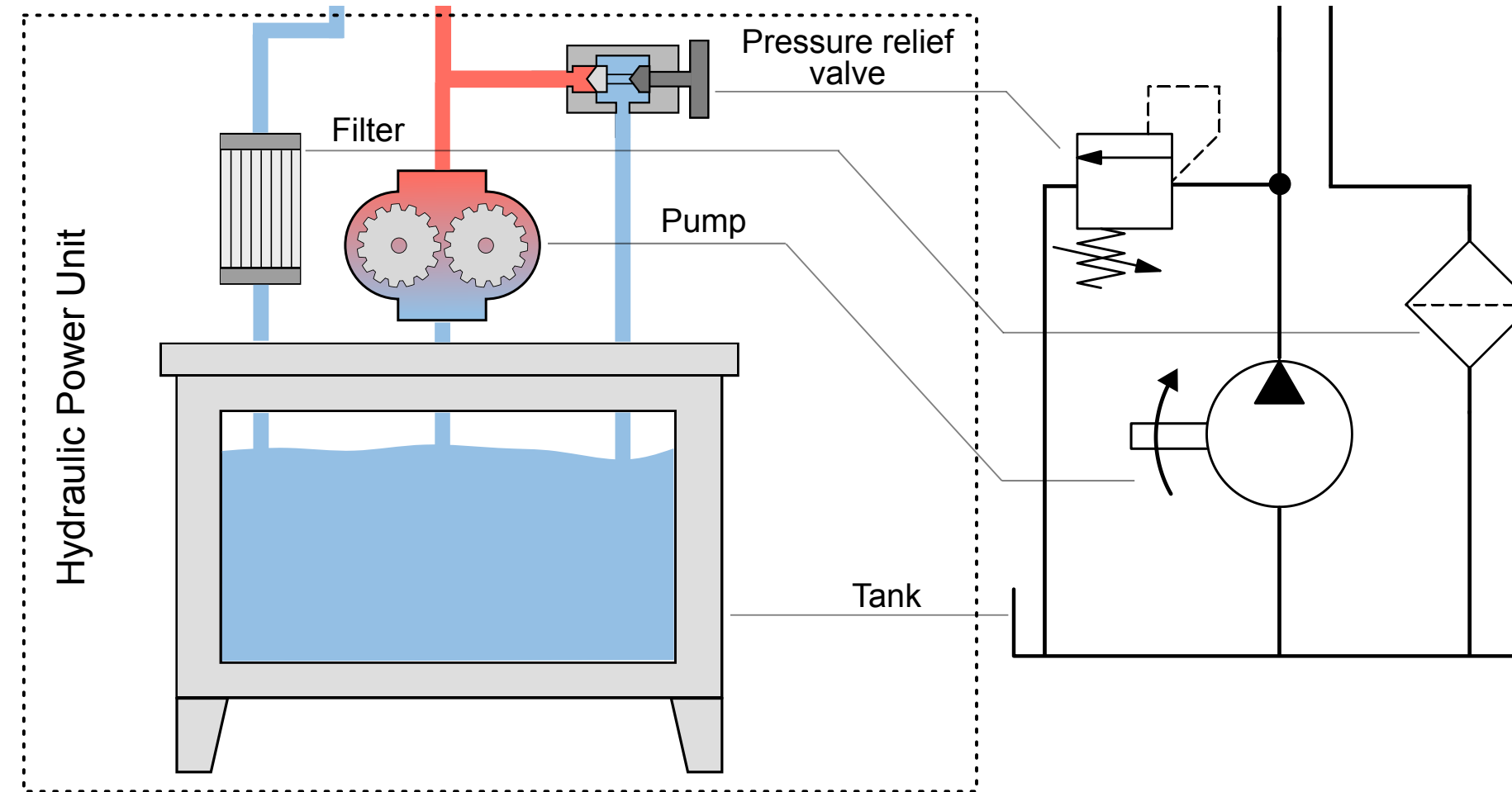


Reservatório



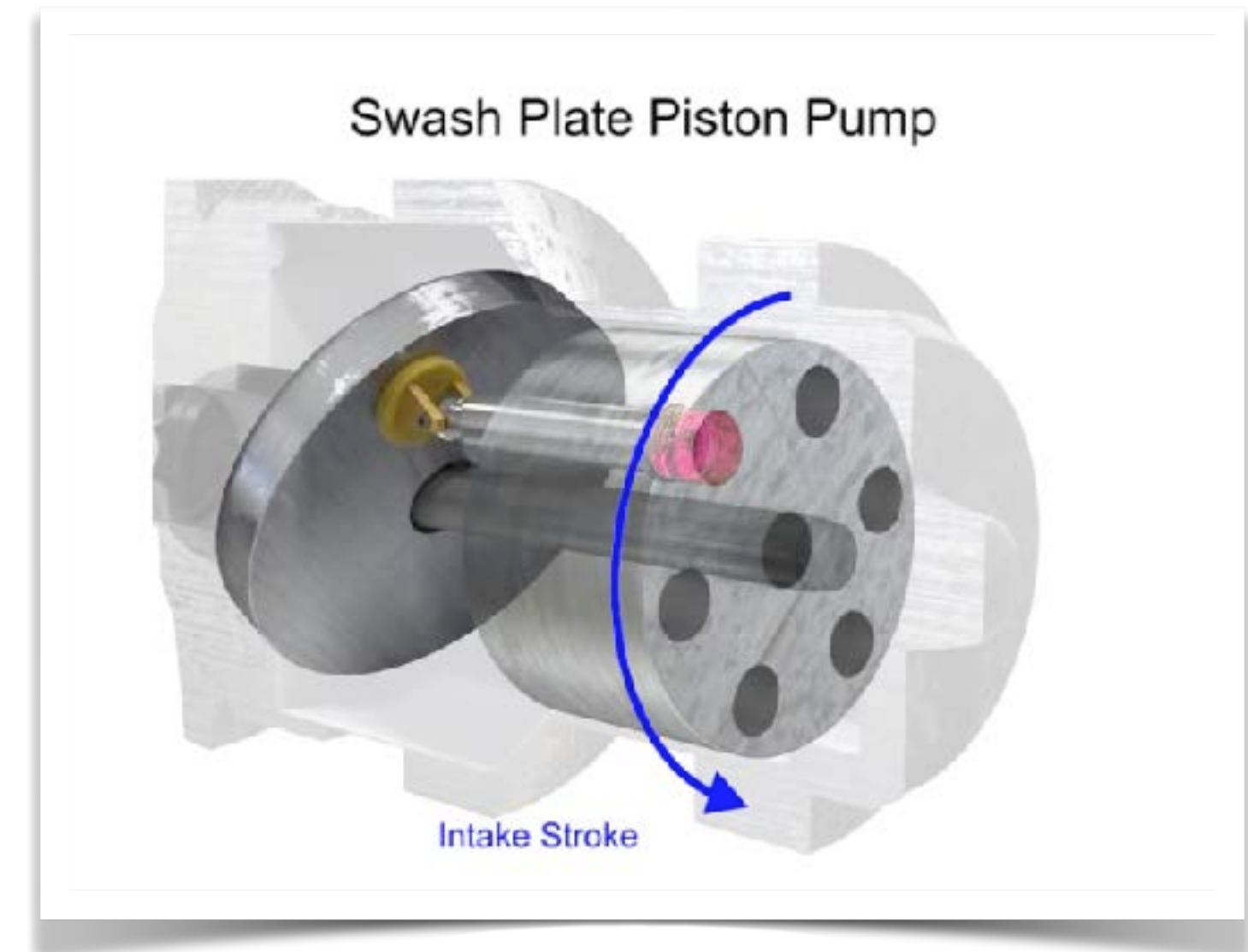
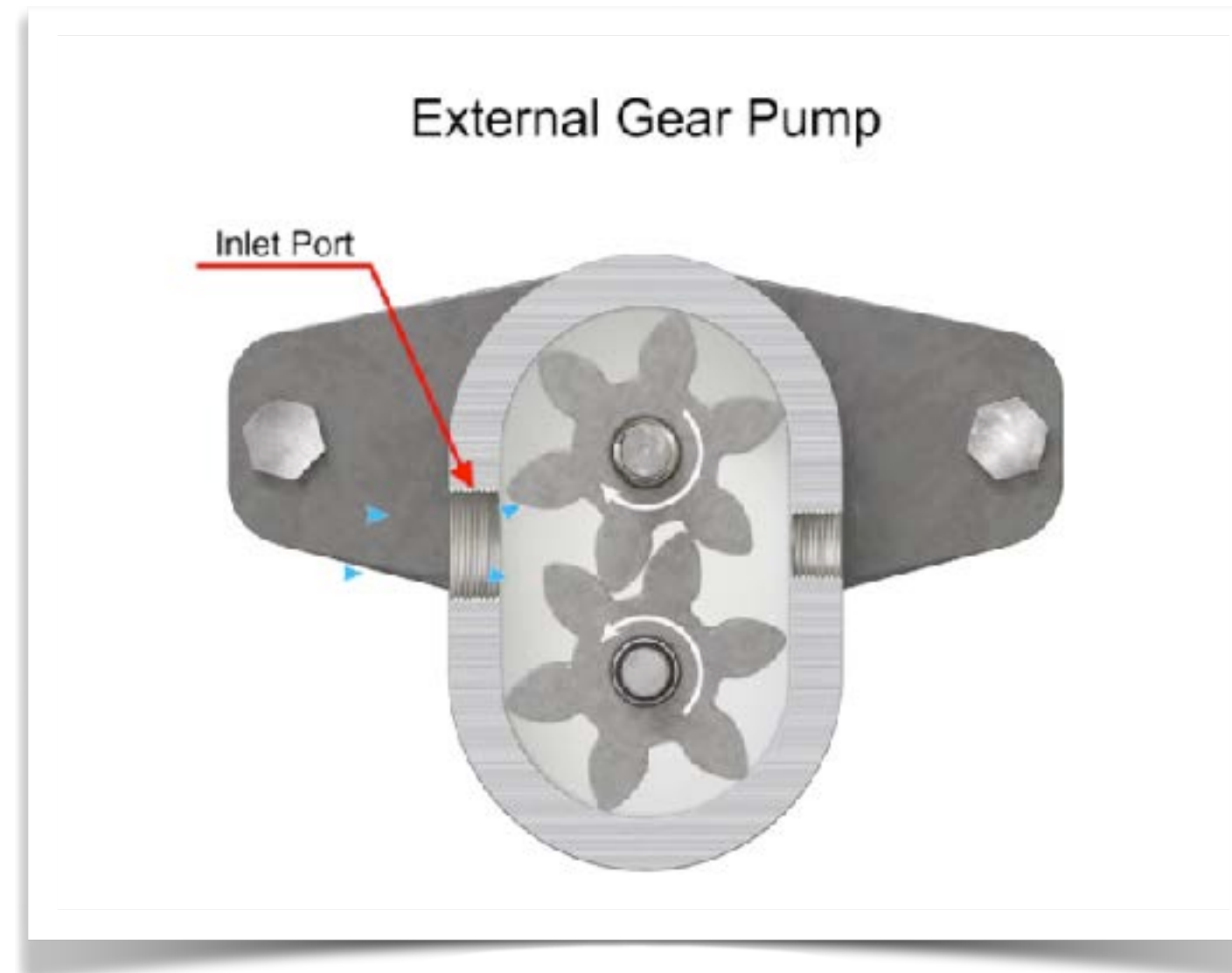
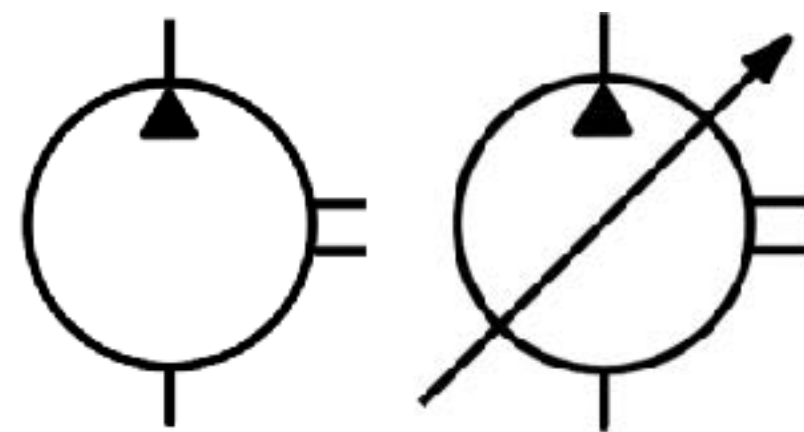
Unidade de potência

Hidráulica

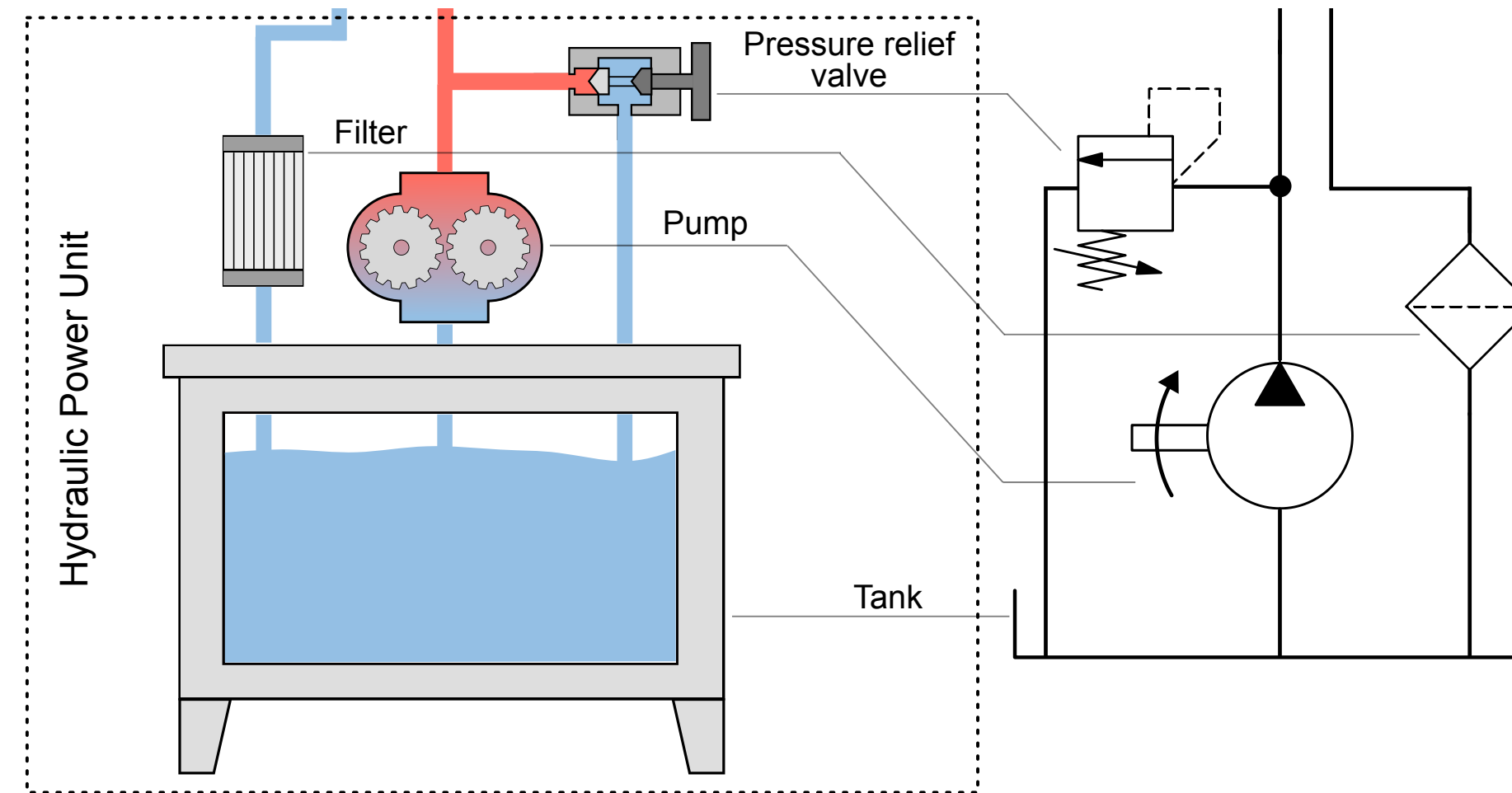


Conclusão

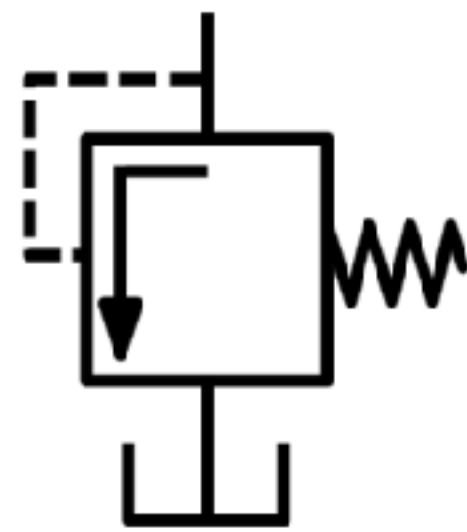
Bomba



Unidade de potência



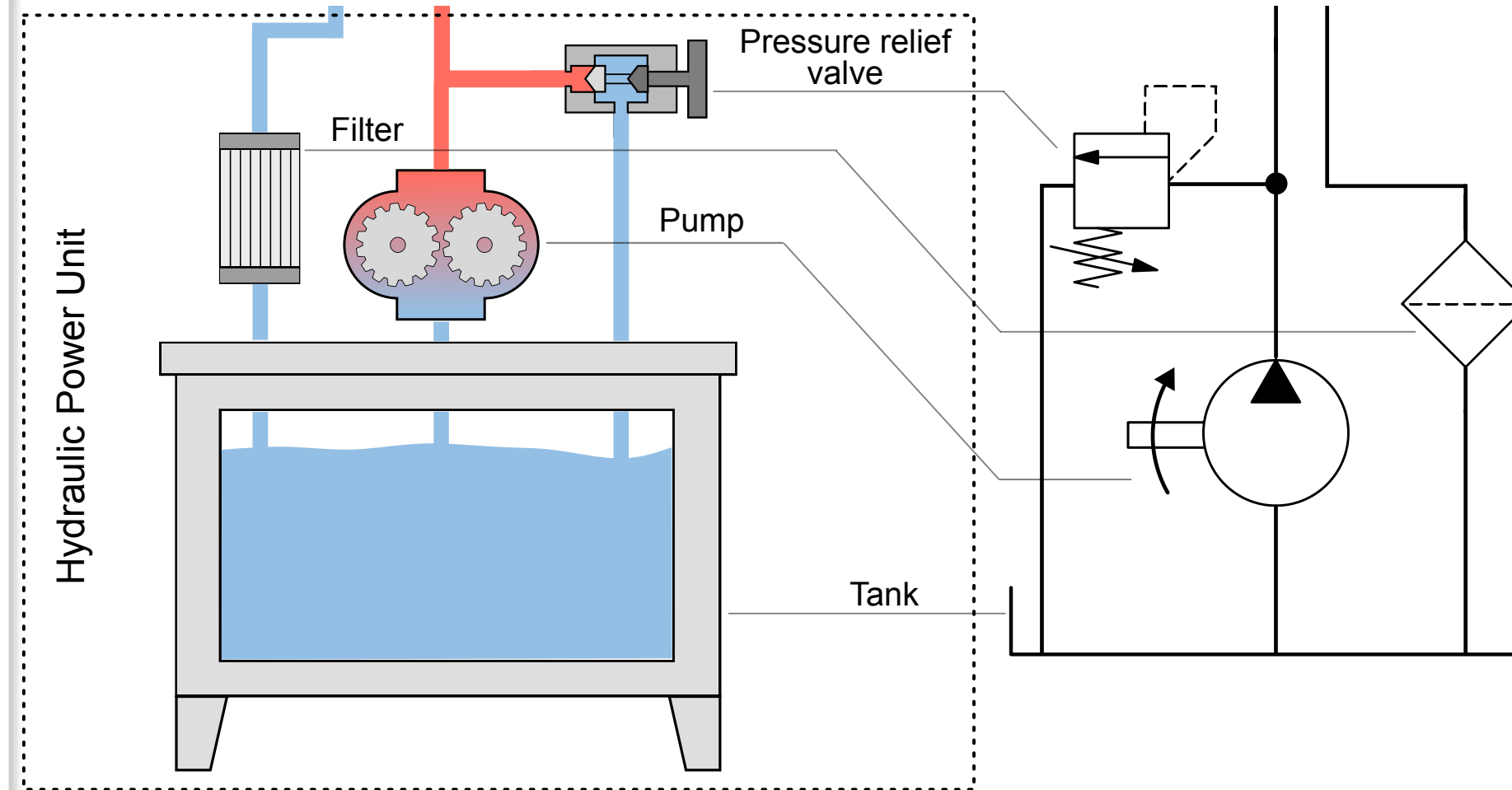
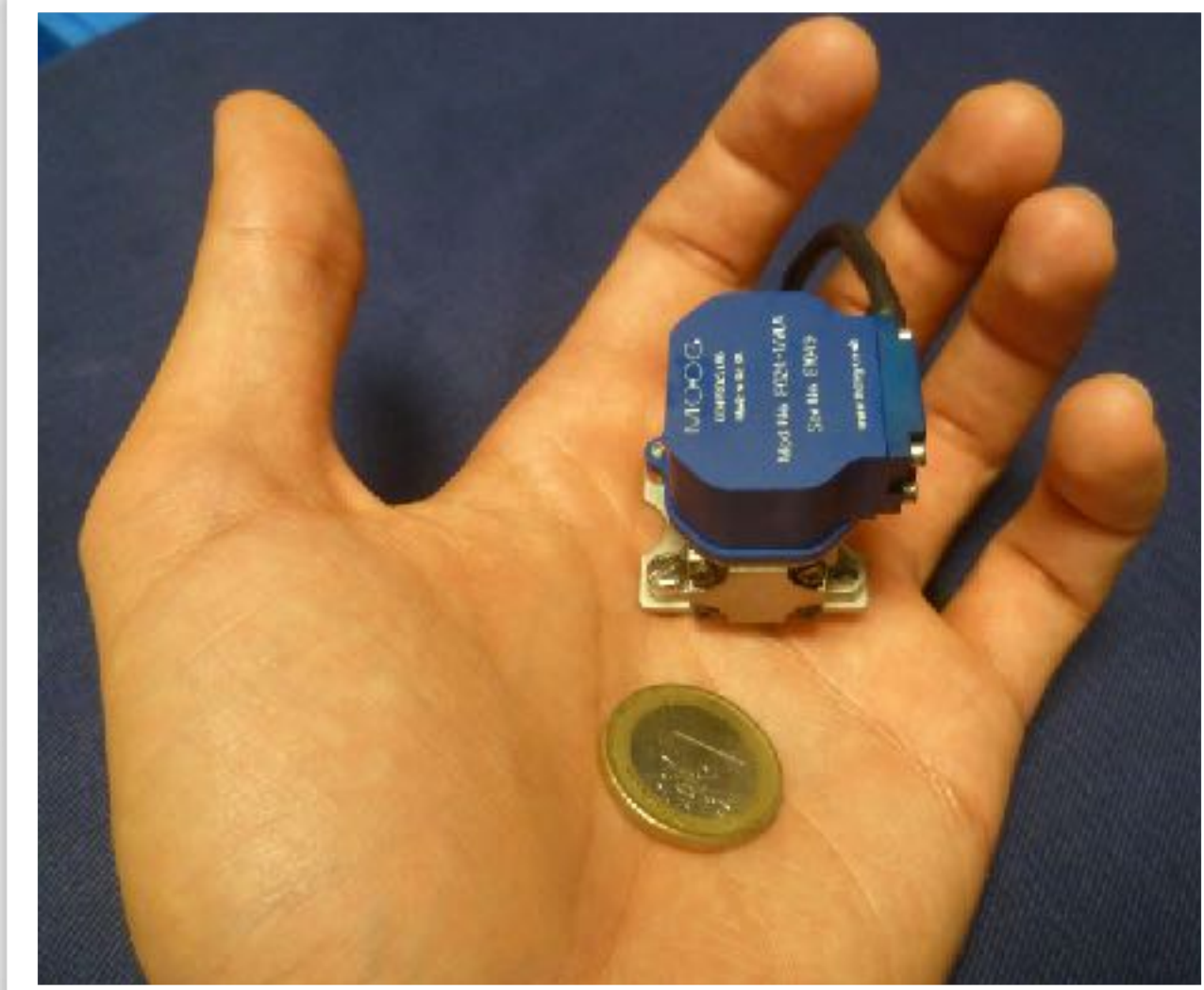
Válvula de alívio



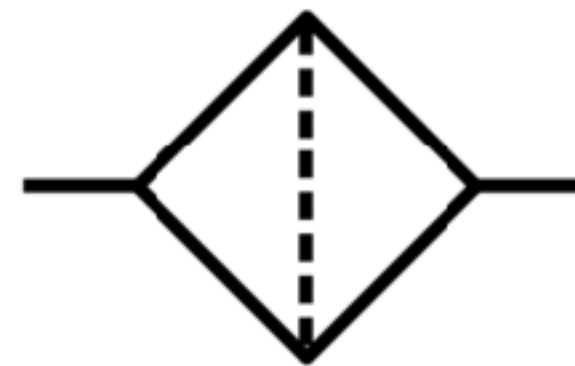
Direct Acting Relief Valve



Unidade de potência

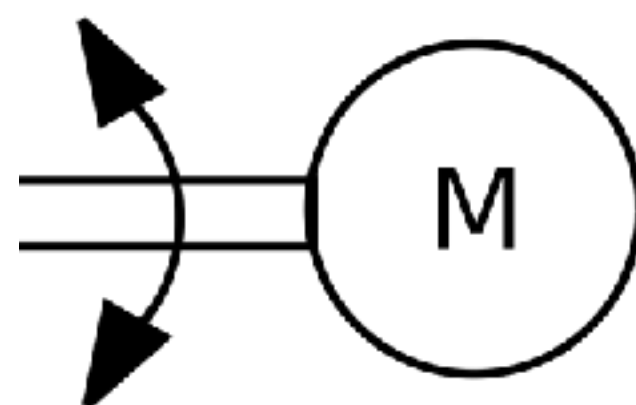


Filtro

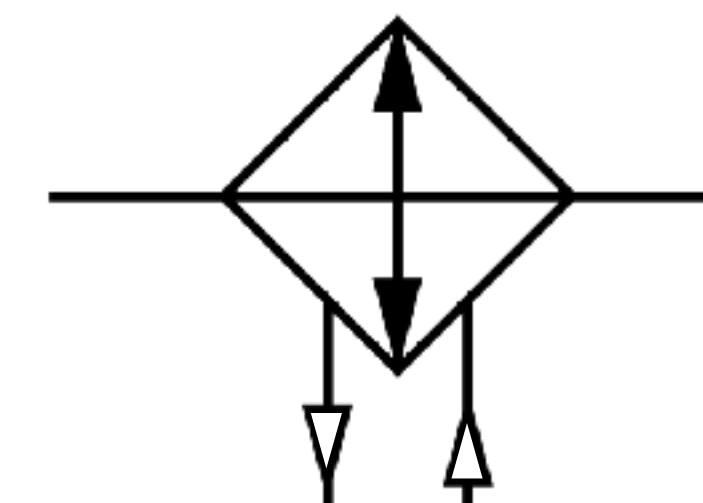
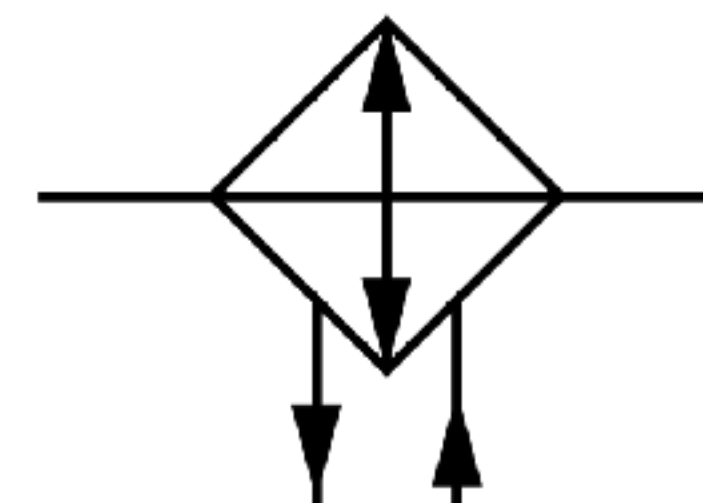


Unidade de potência

Motor elétrico



Resfriador



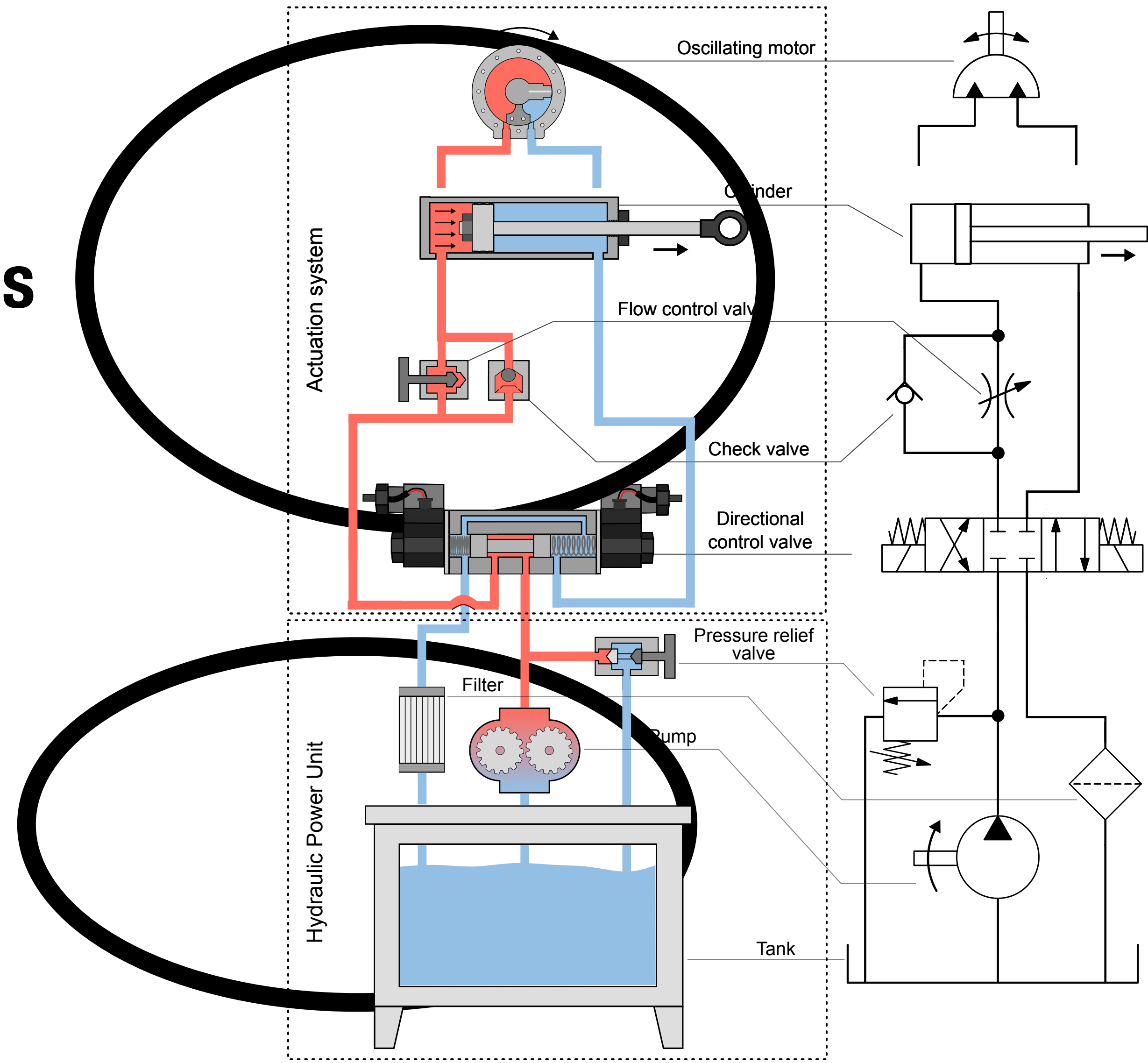
Circuito de atuação

Hidráulica

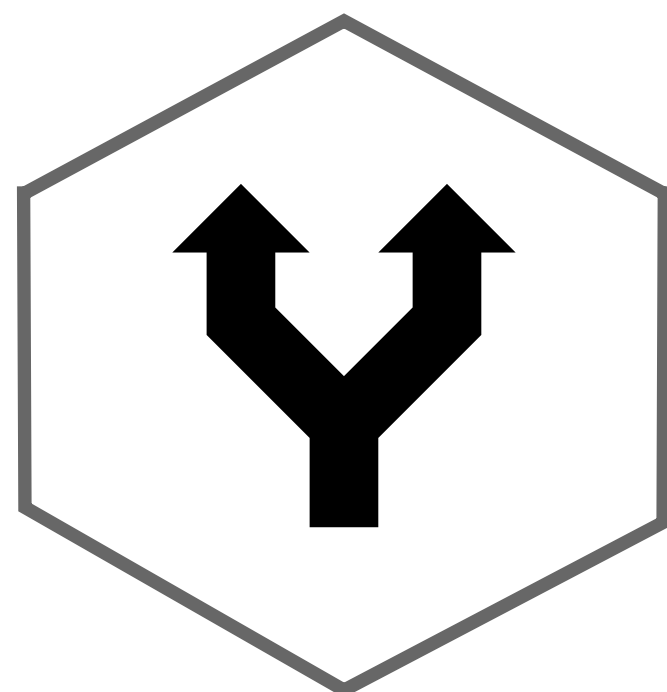
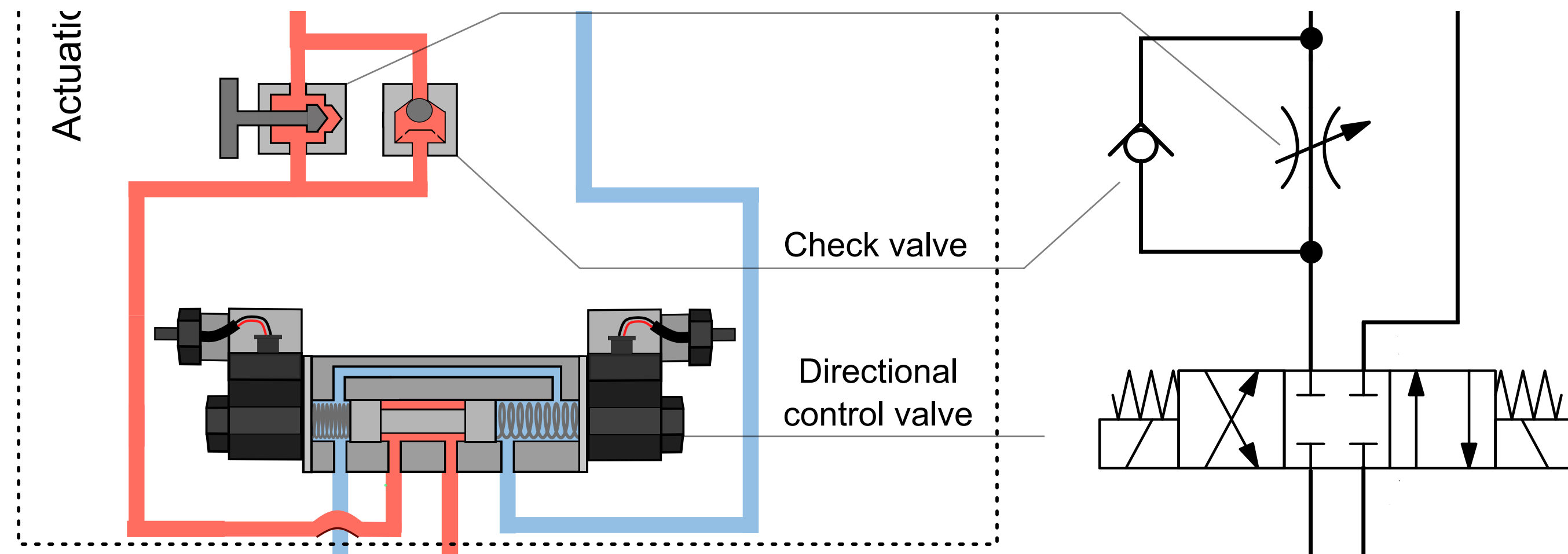
Conclusão

Atuadores

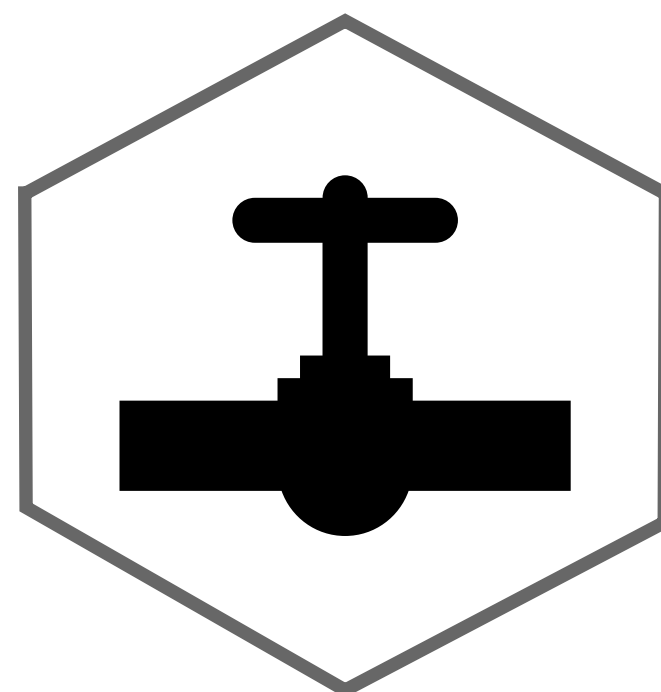
Válvulas



Válvulas



Válvulas de controle direcional



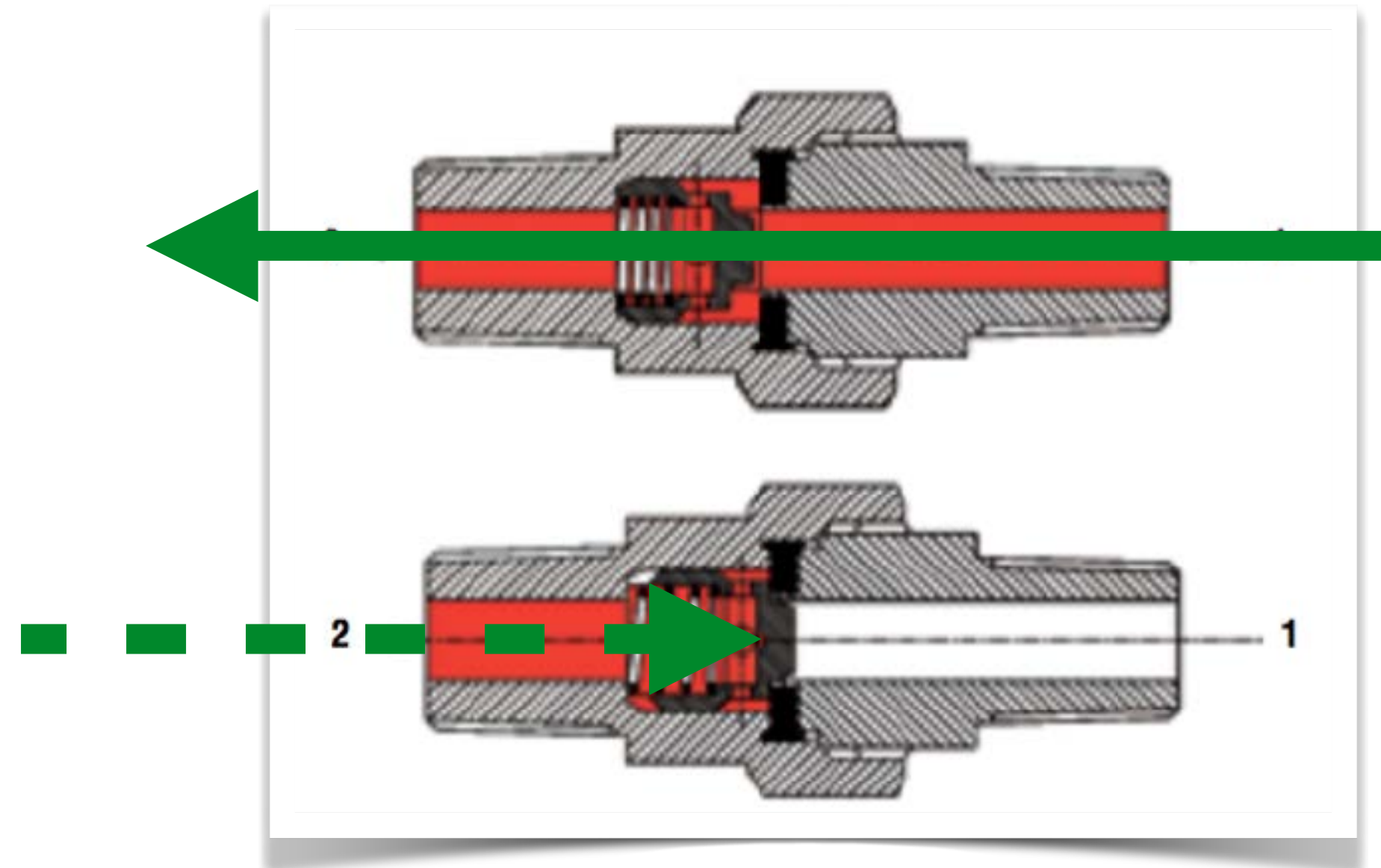
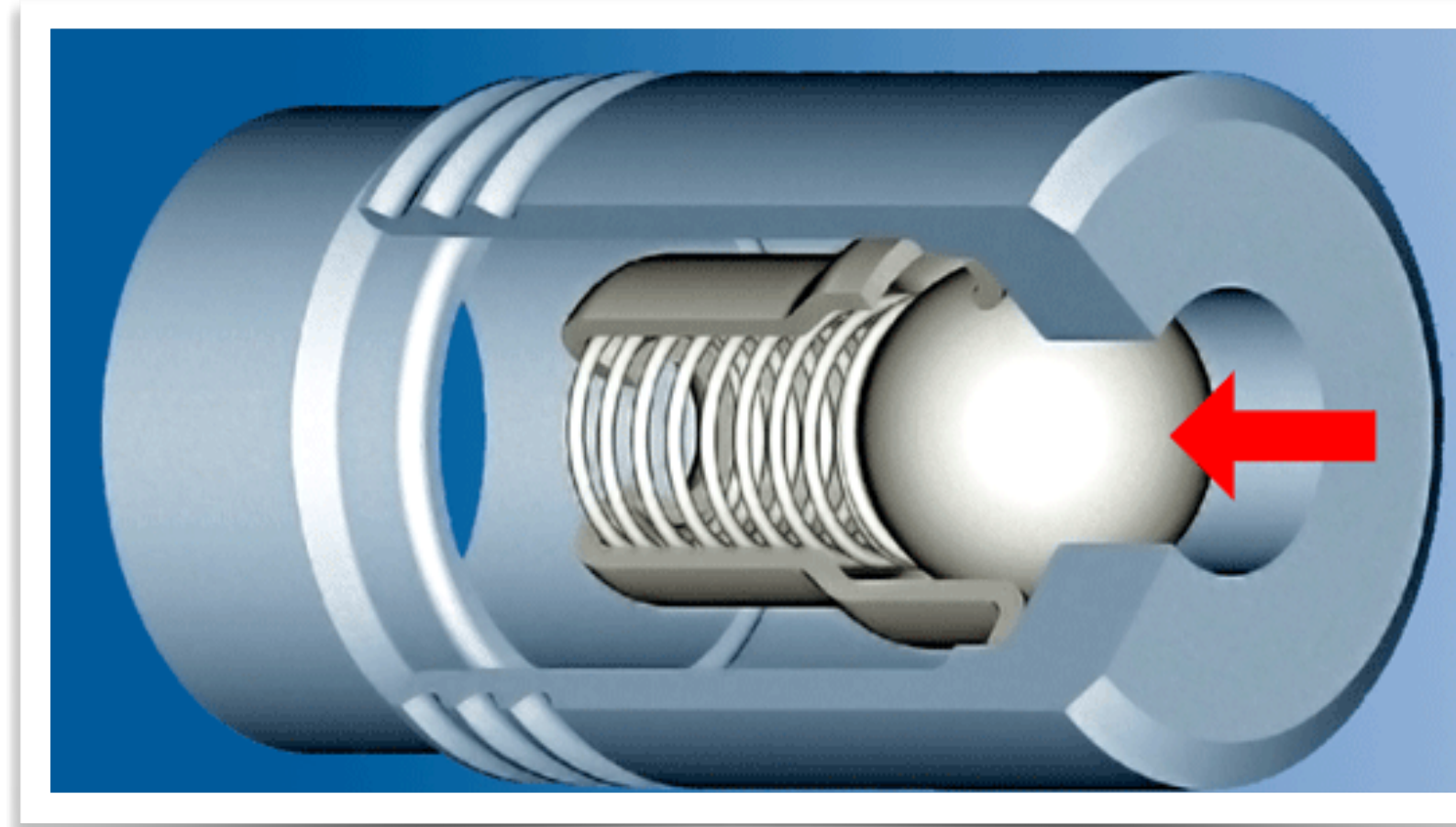
Válvulas auxiliares

Válvula de retenção

Hidráulica



Simbologia

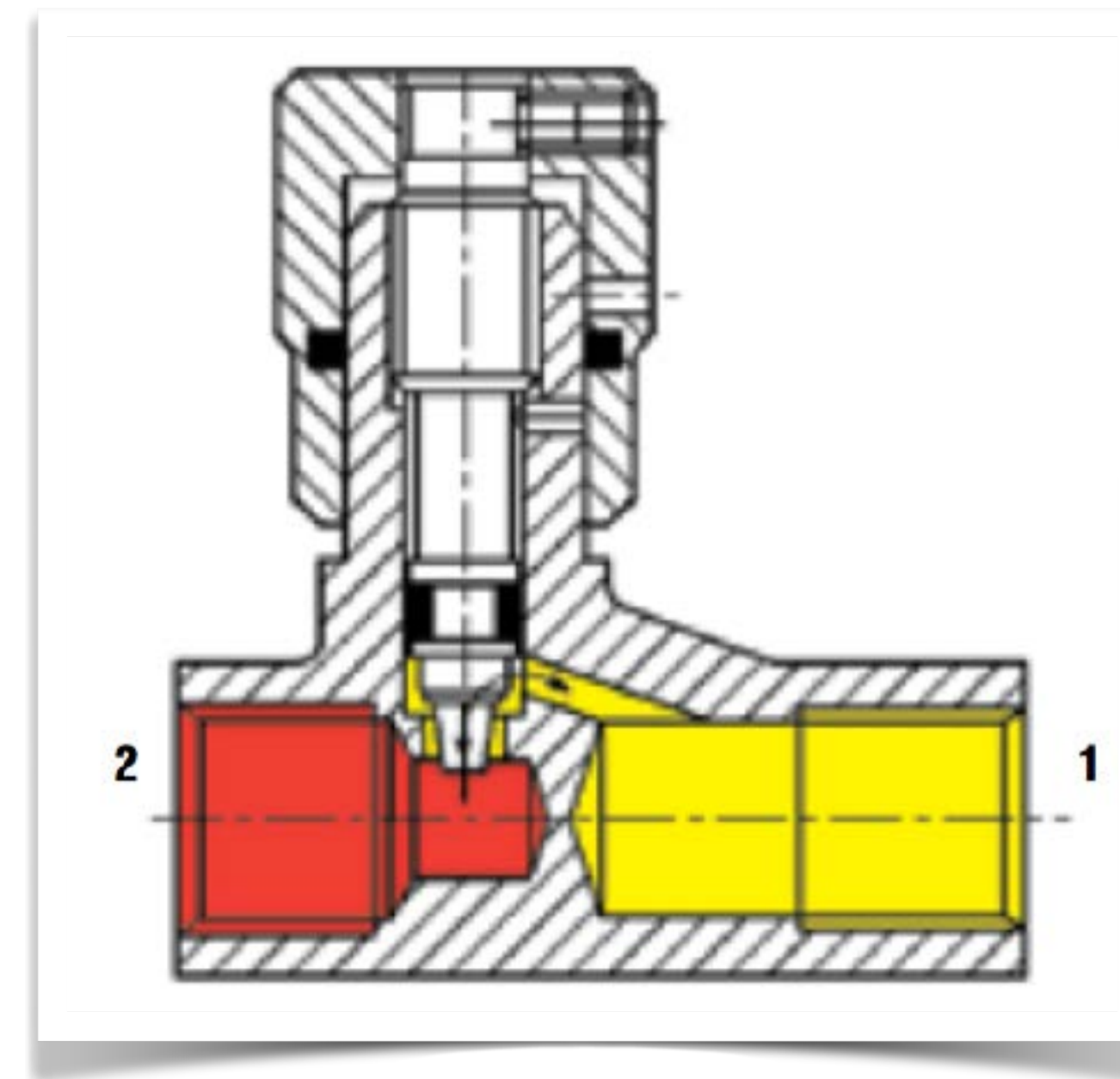


Conclusão

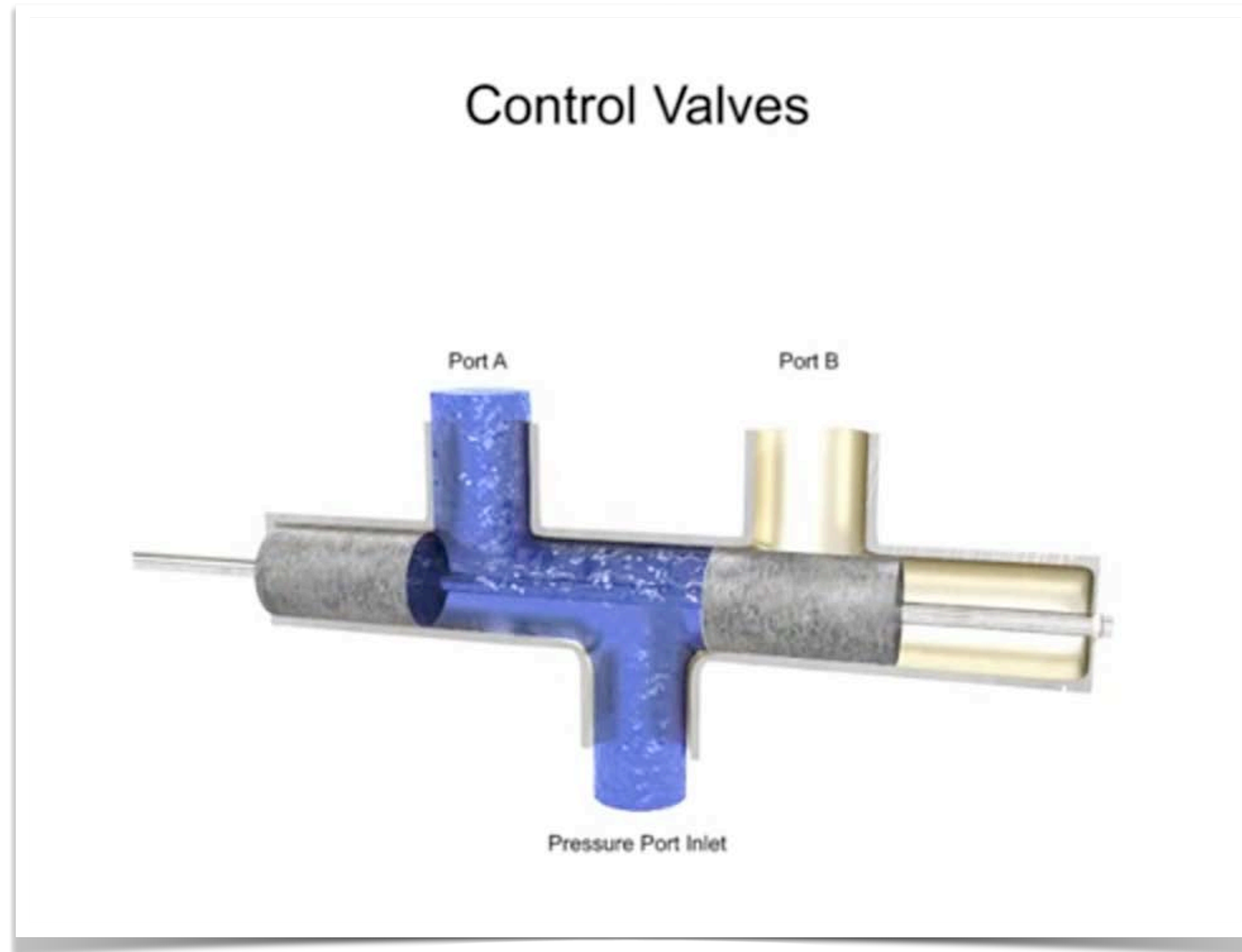
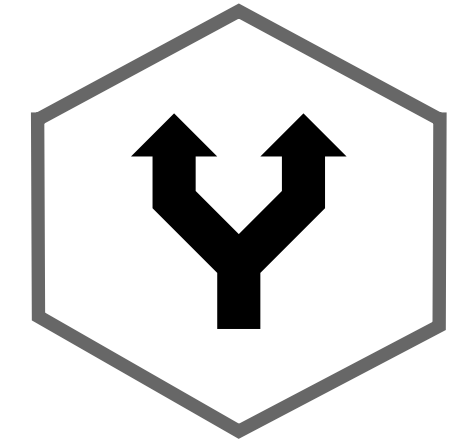


Válvulas
auxiliares

Válvula reguladora de vazão



Válvulas direcionais

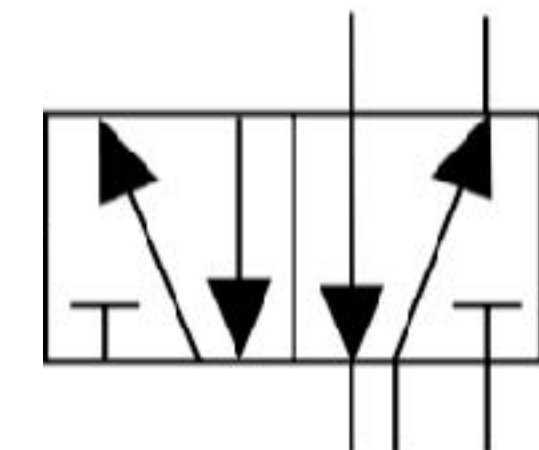
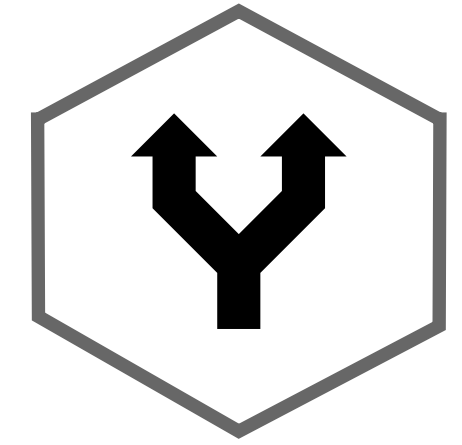
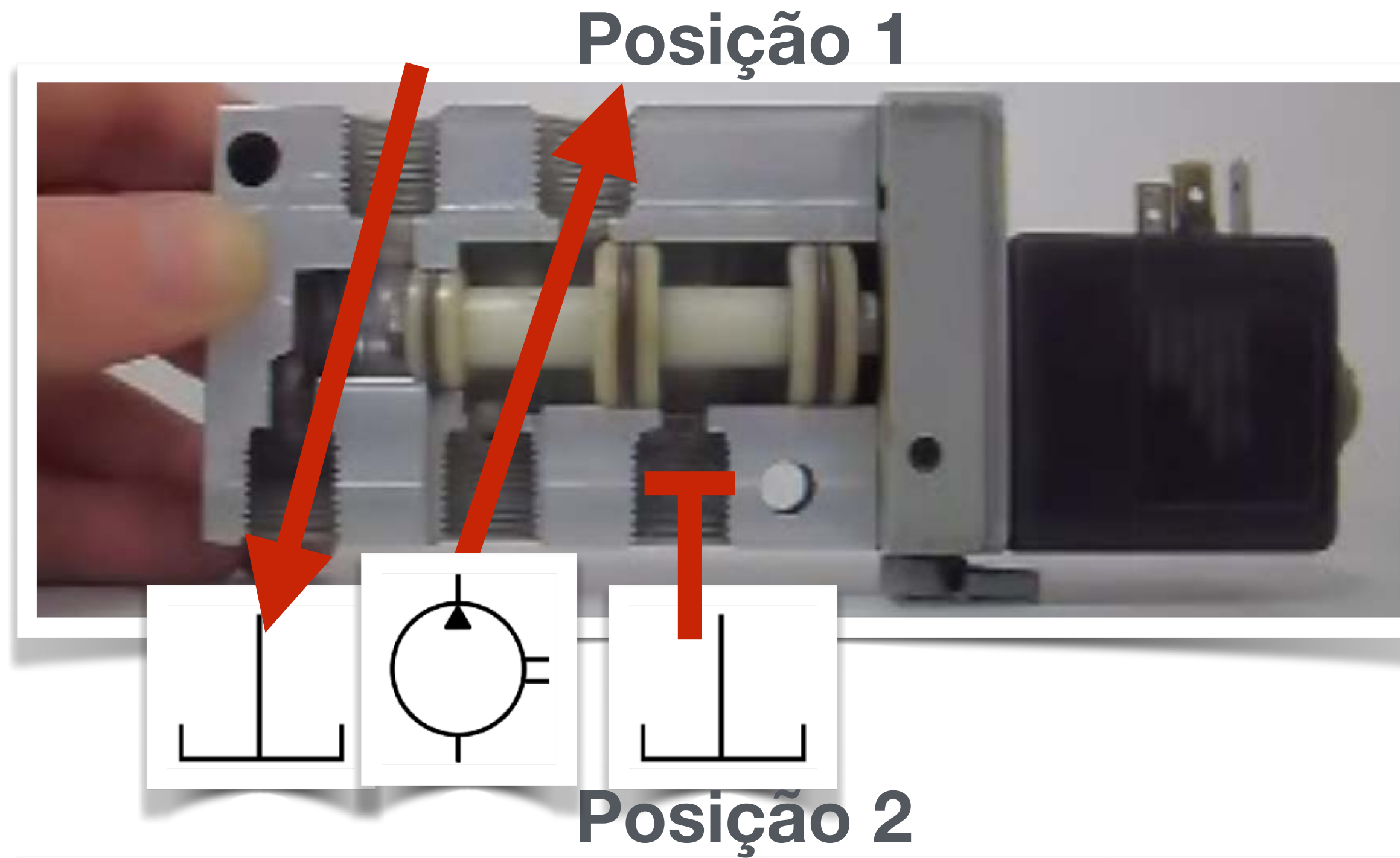


Válvulas direcionais

Hidráulica



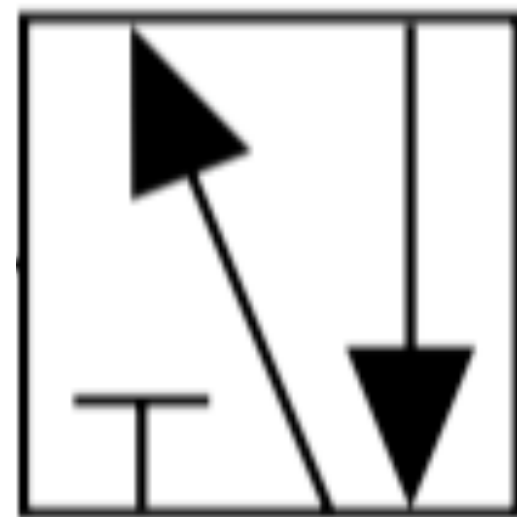
5 vias
(portas)



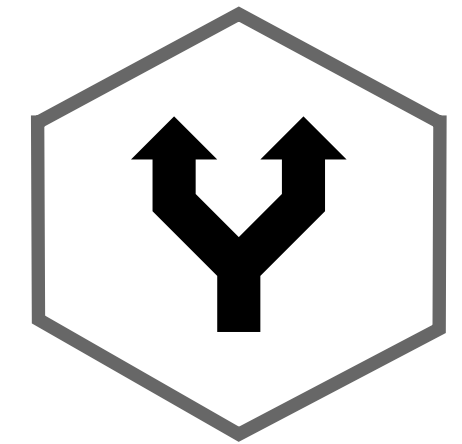
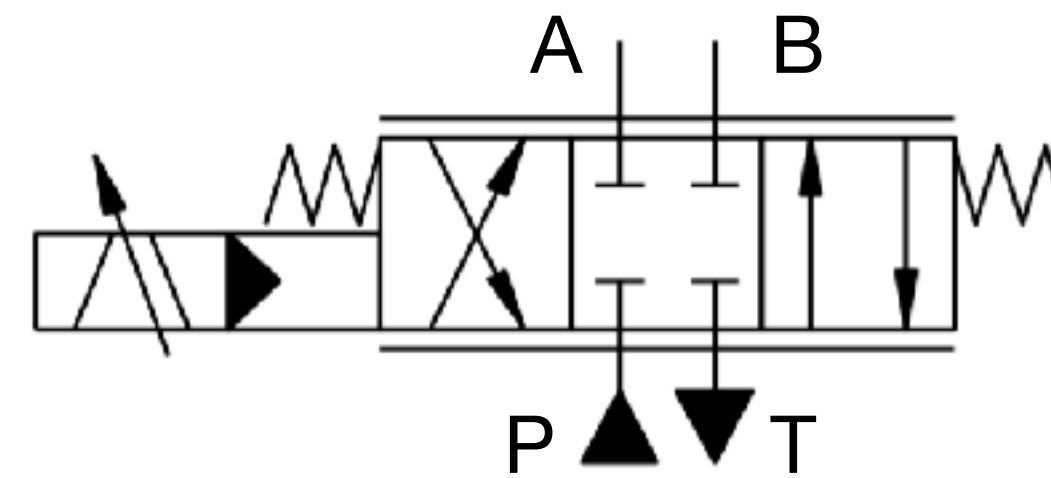
Simbologia

Válvula direcional 5/2

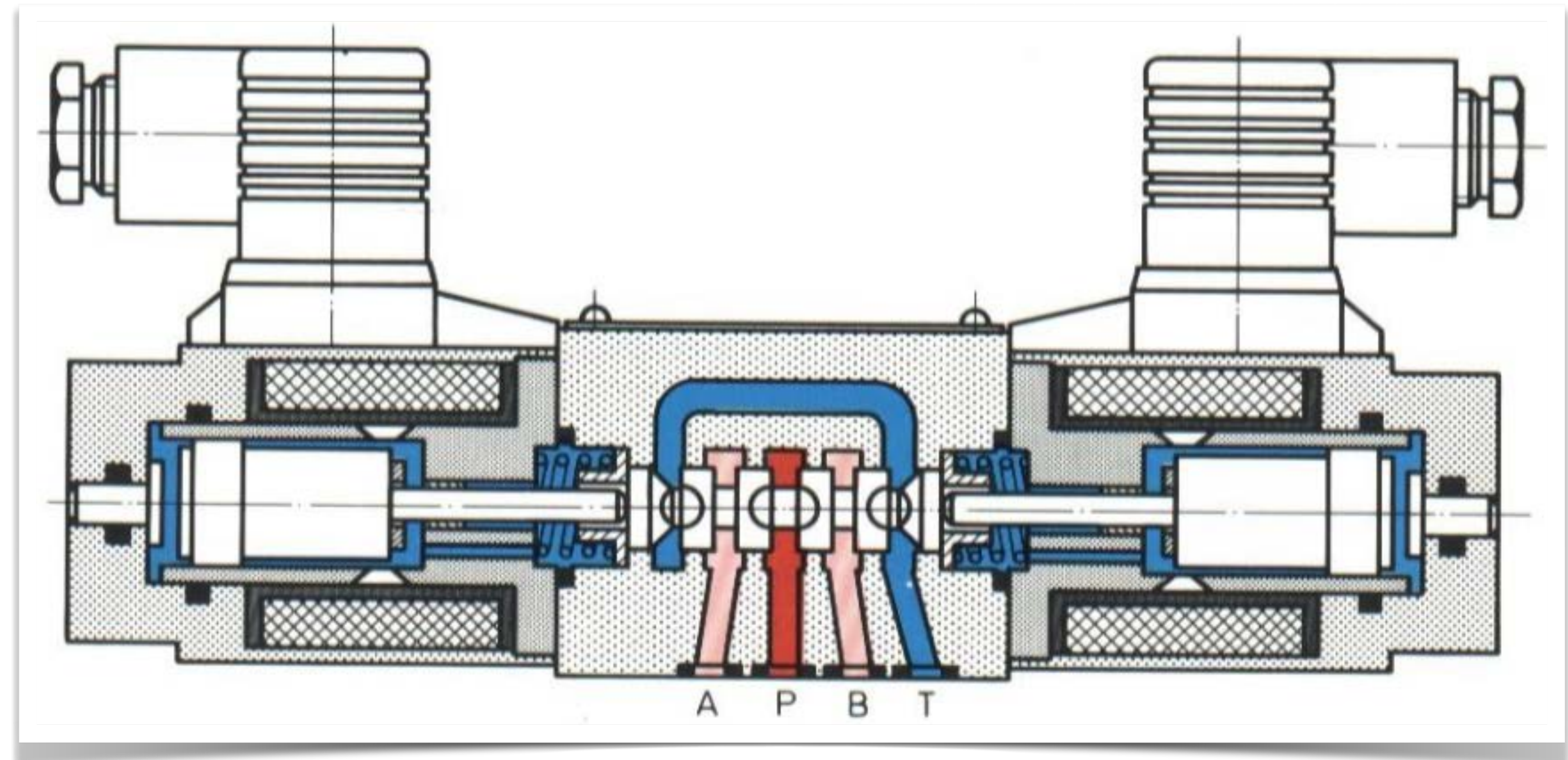
Conclusão



Válvulas direcionais



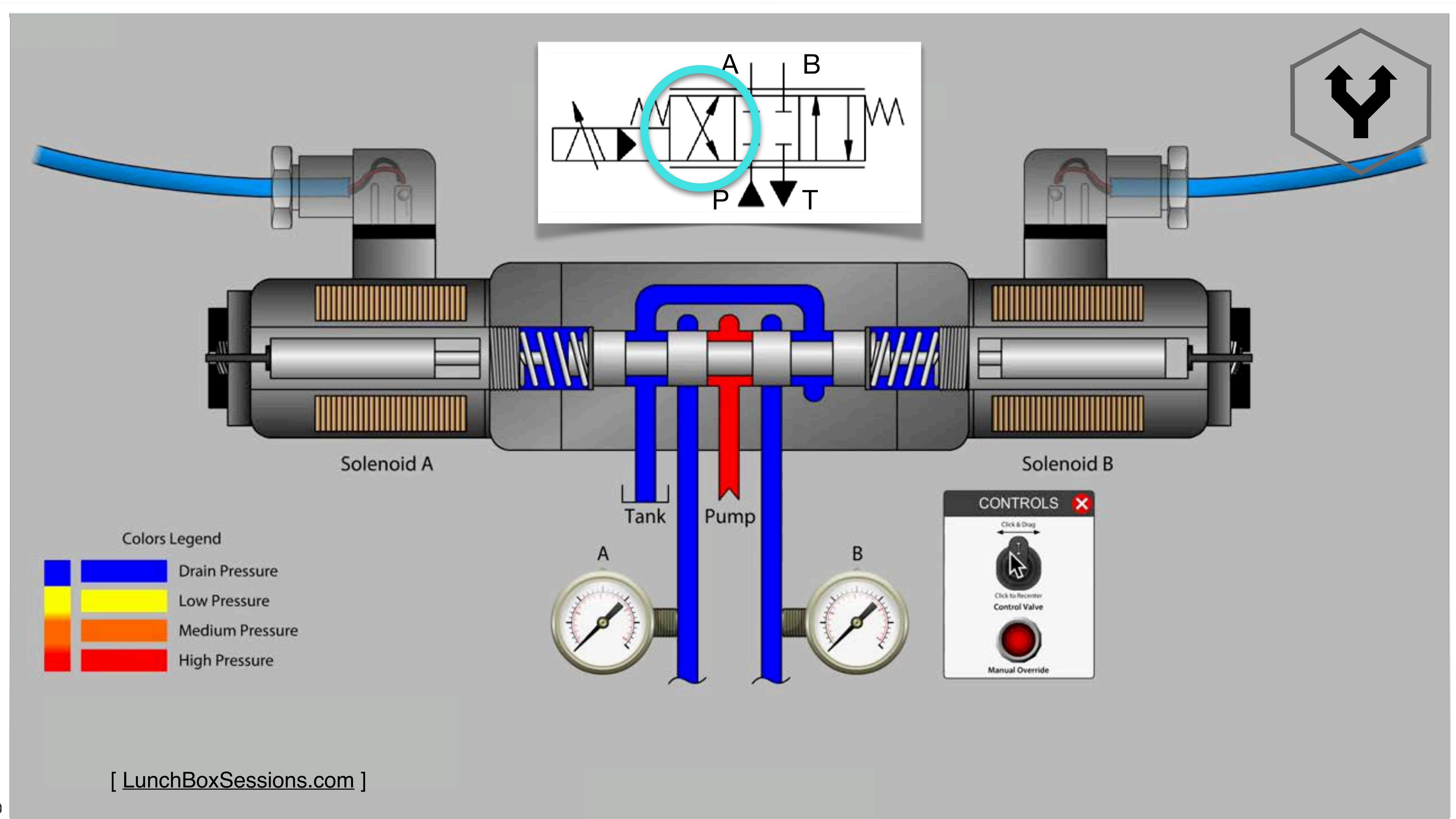
4/3 acionada por **duplo solenóide** e centralização por mola



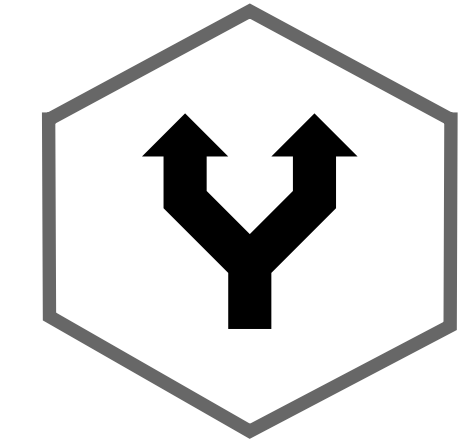
Válvulas direcionais

Hidráulica

Conclusão



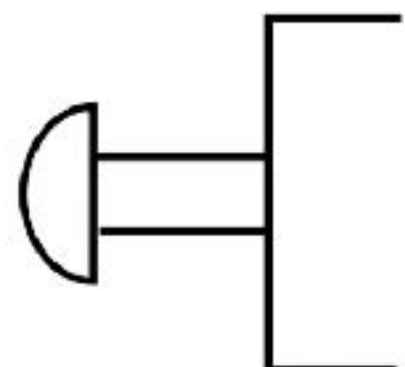
Válvulas direcionais



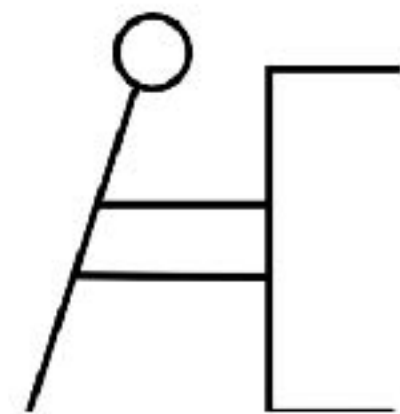
Hidráulica



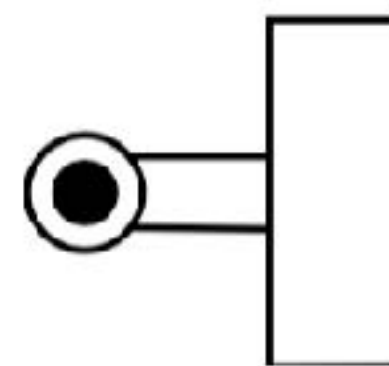
Conclusão



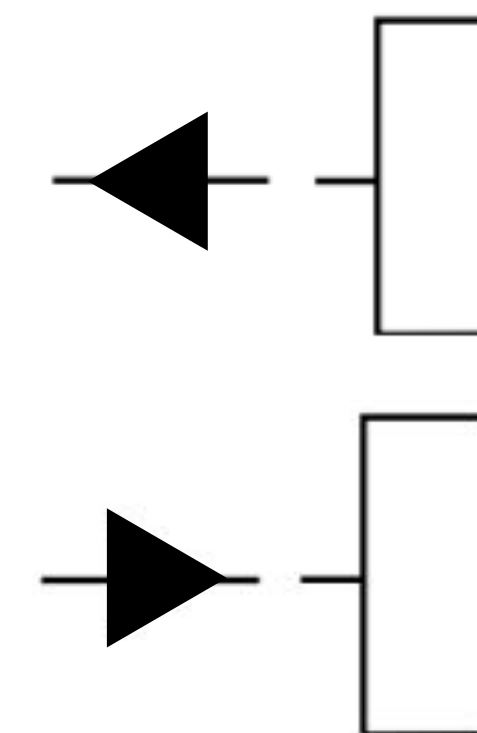
Simbologia



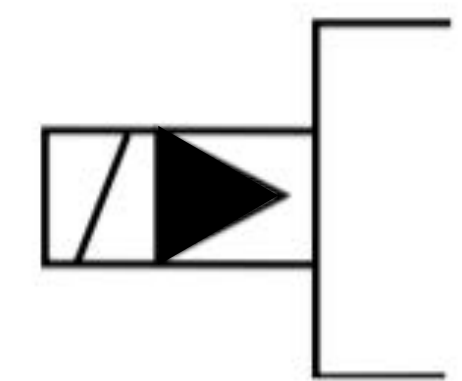
Simbologia



Simbologia



Simbologia

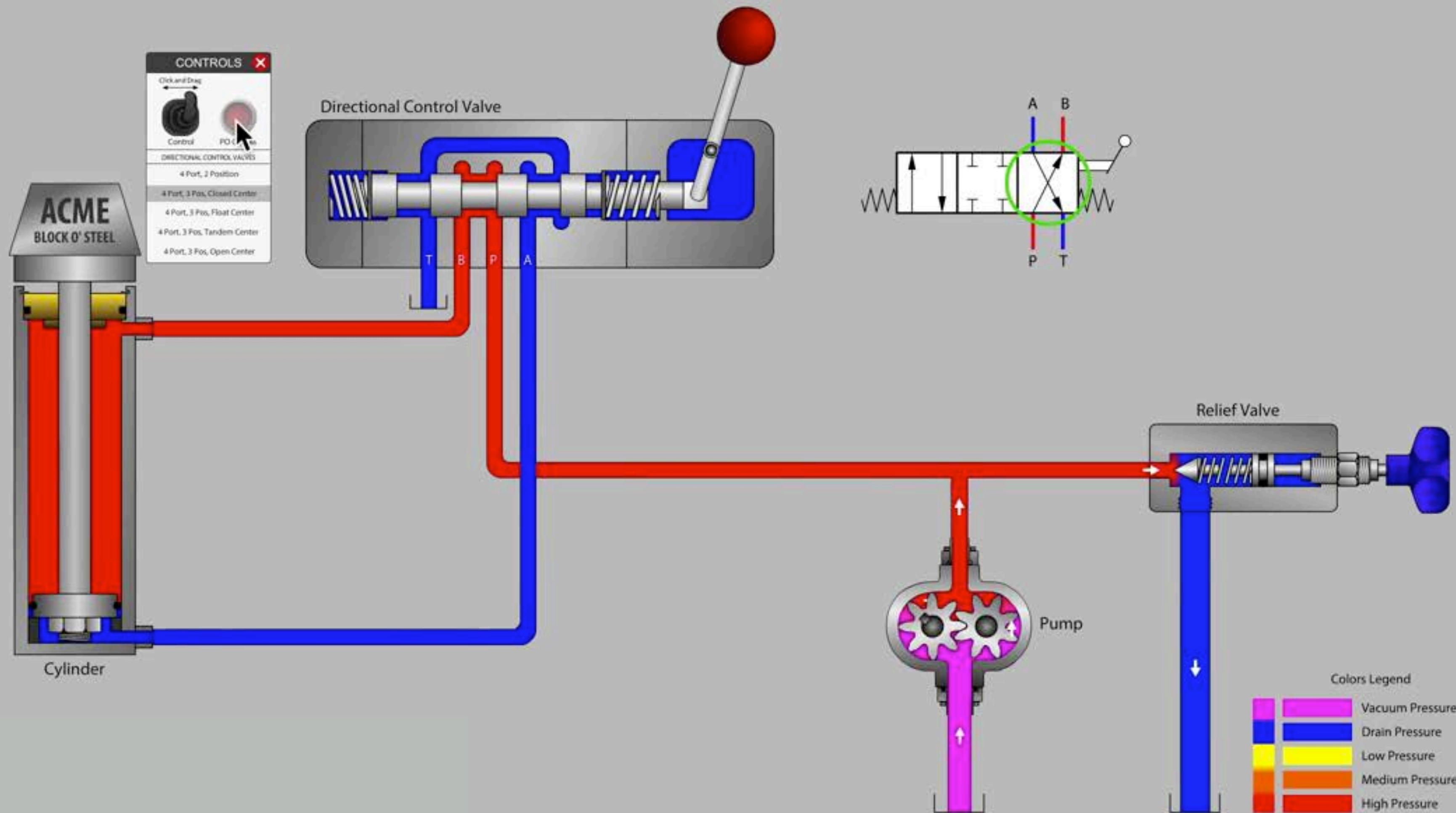


Simbologia

Válvulas direcionais

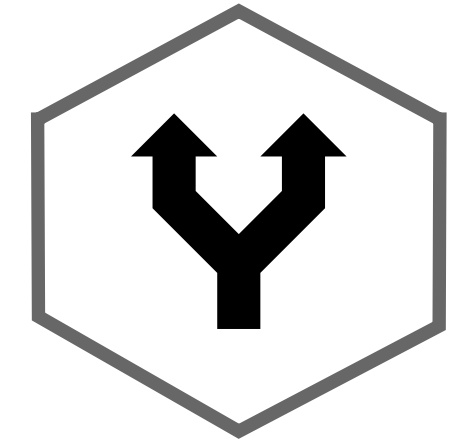
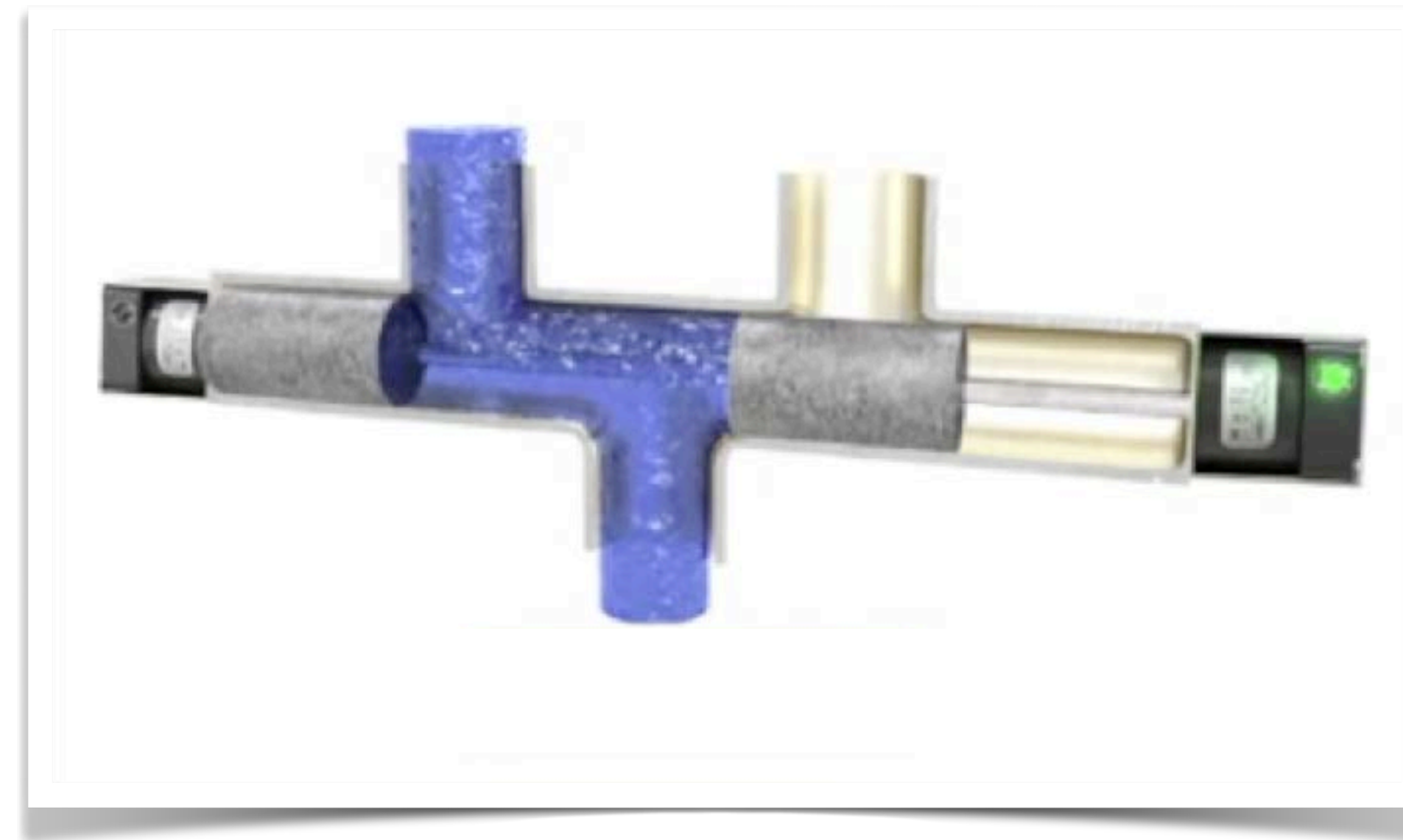
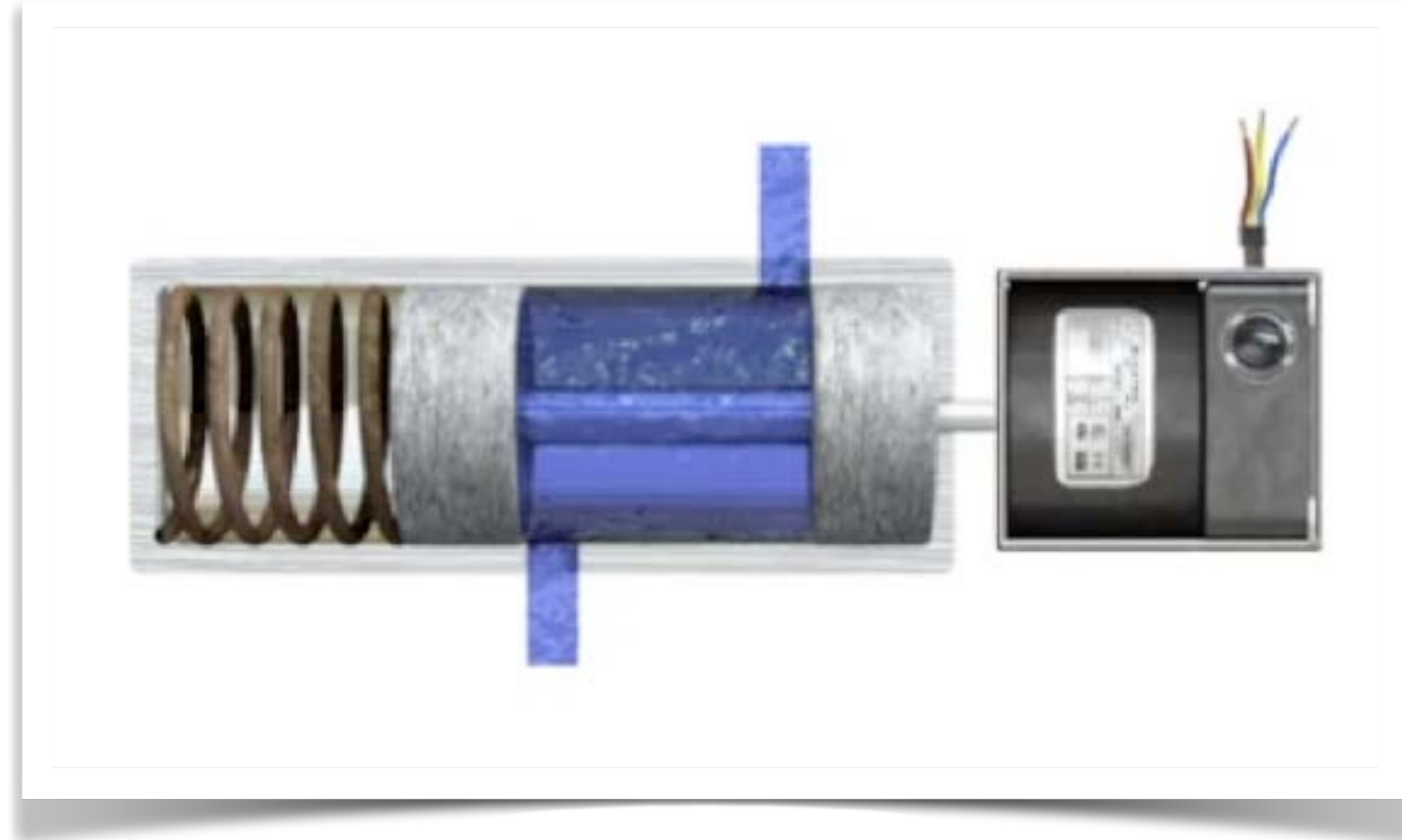
Hidráulica

Conclusão



Válvulas on/off

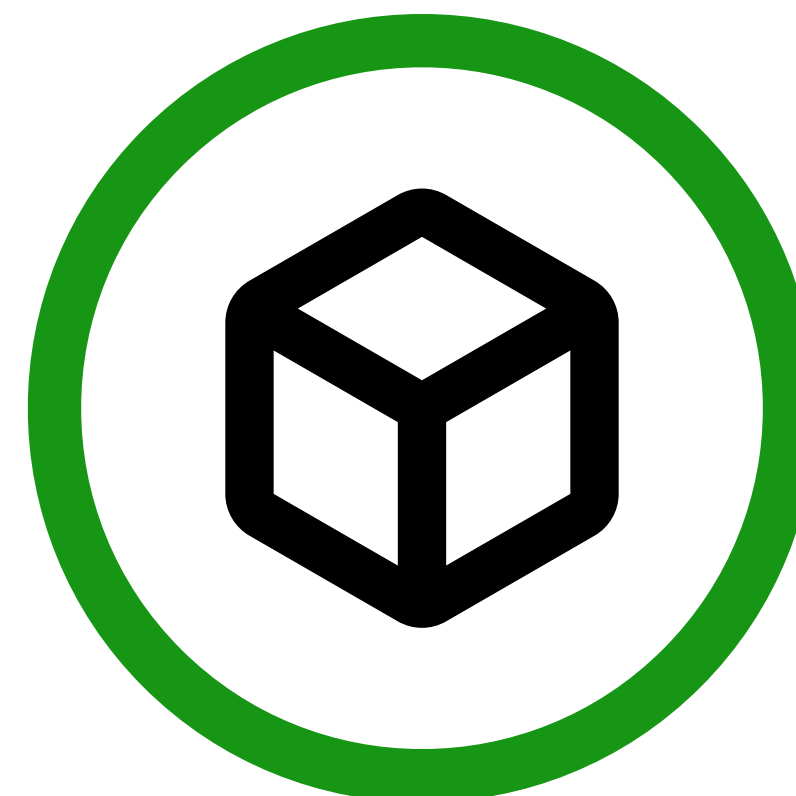
Hidráulica



Conclusão



Baixo custo



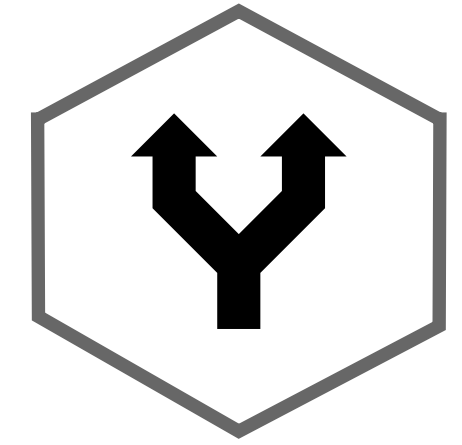
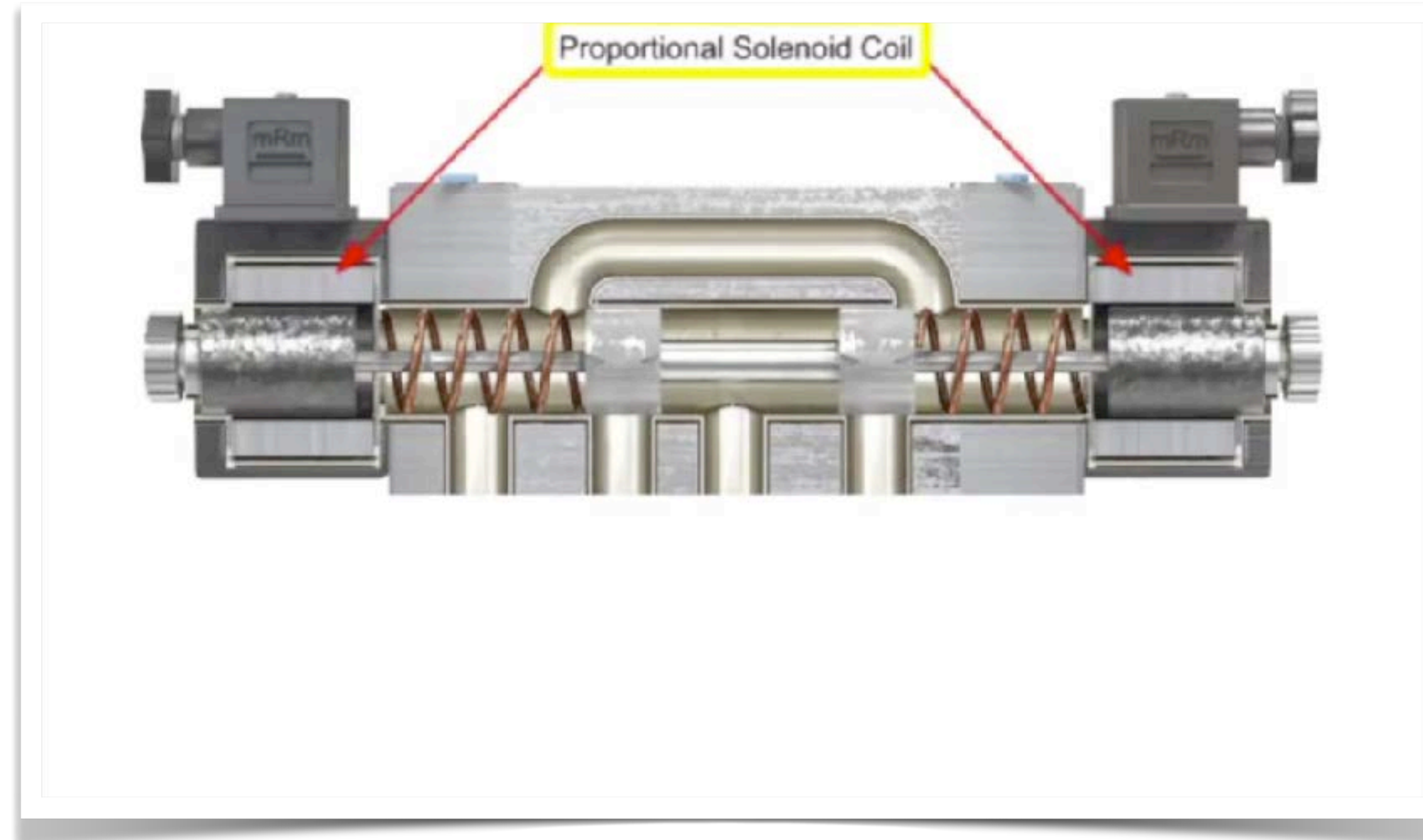
Design simples



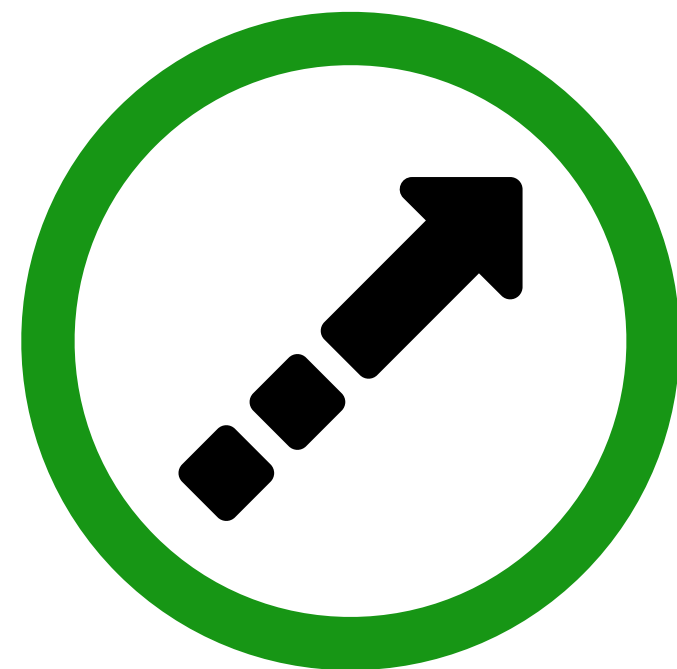
Inflexibilidade

Válvulas proporcionais

Hidráulica



Conclusão



Aceleração gradual



Versatilidade



Baixa Precisão

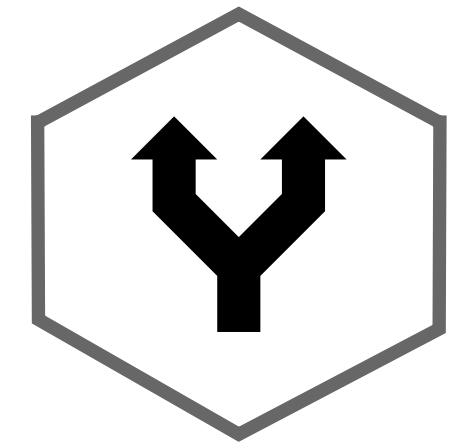
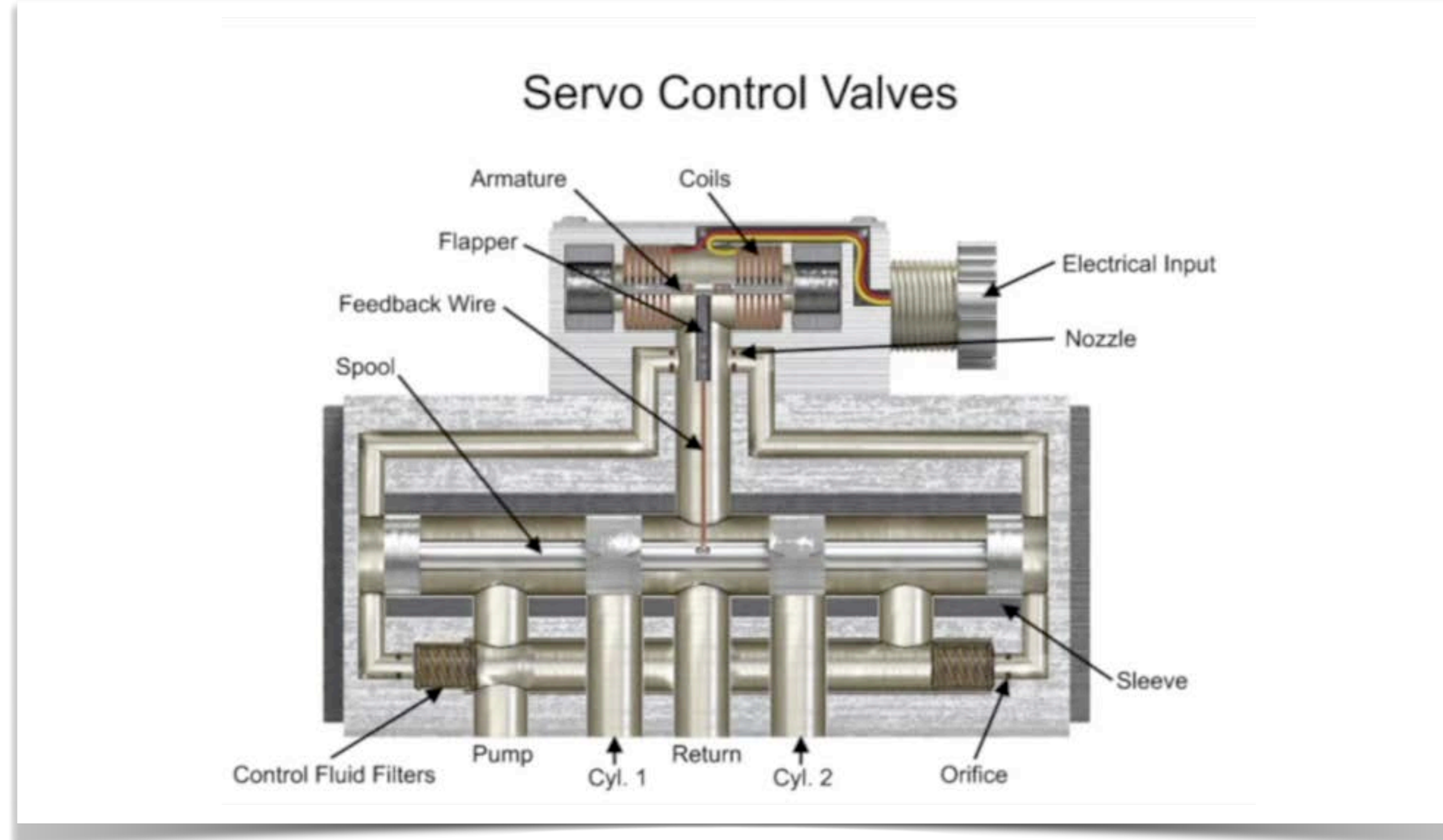


Largura de banda limitada

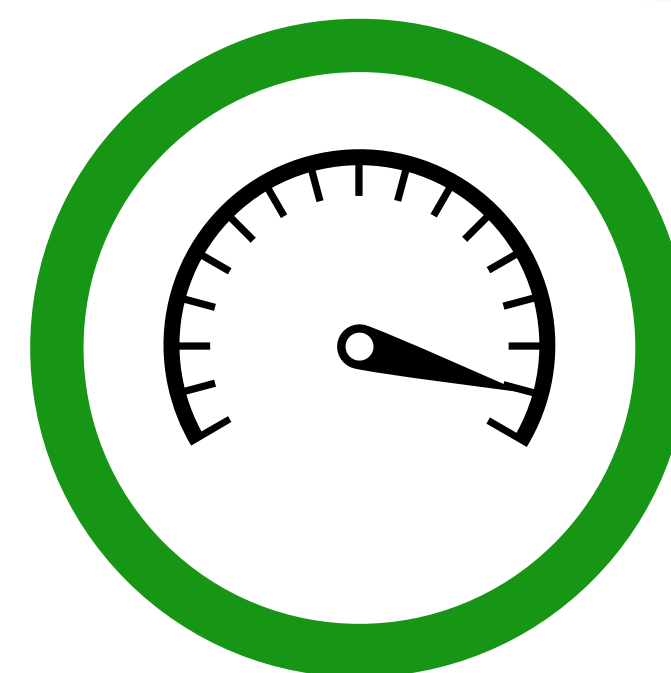
Servo válvulas

Hidráulica

Conclusão



Alta precisão



Largura de banda elevada

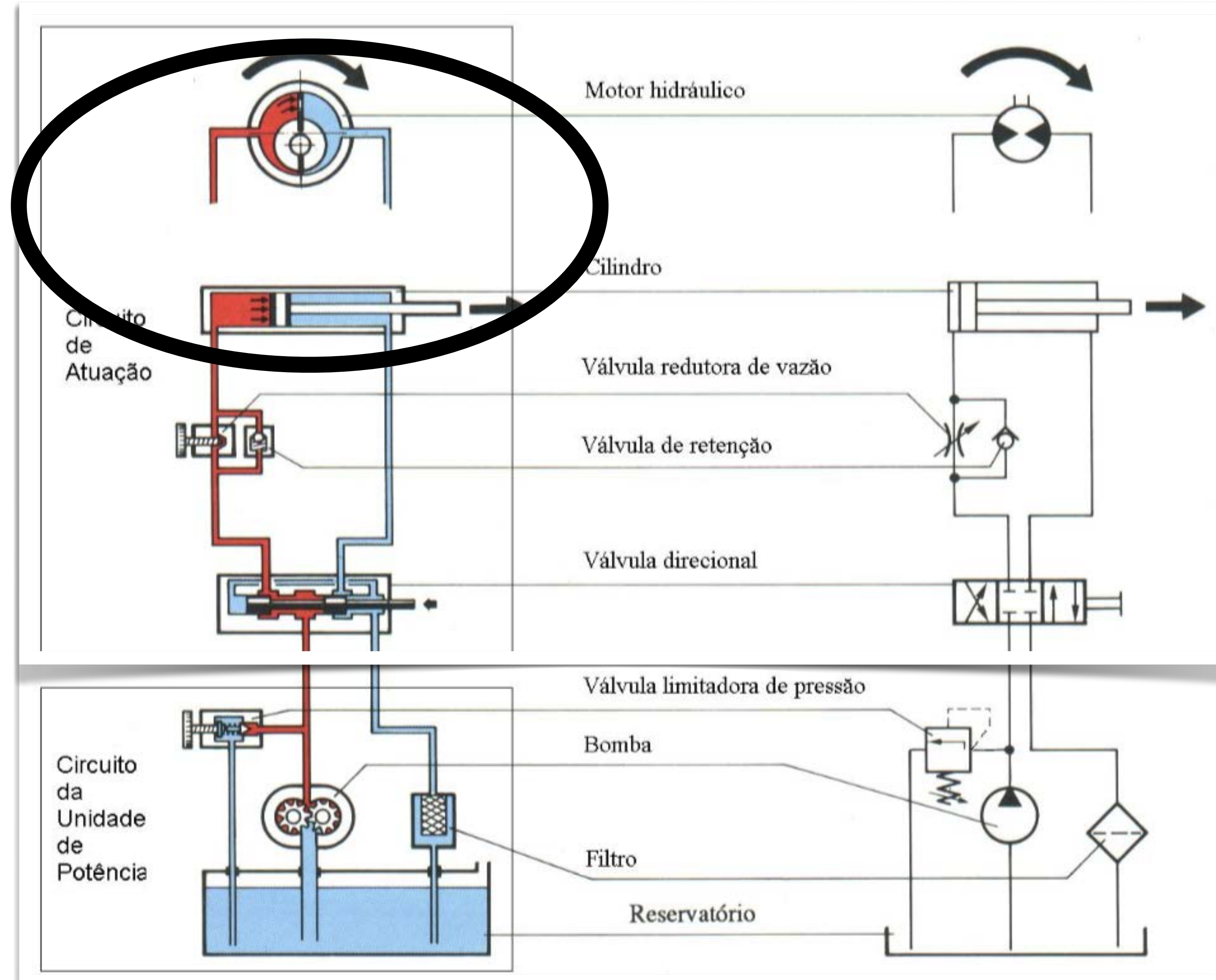


Alto custo



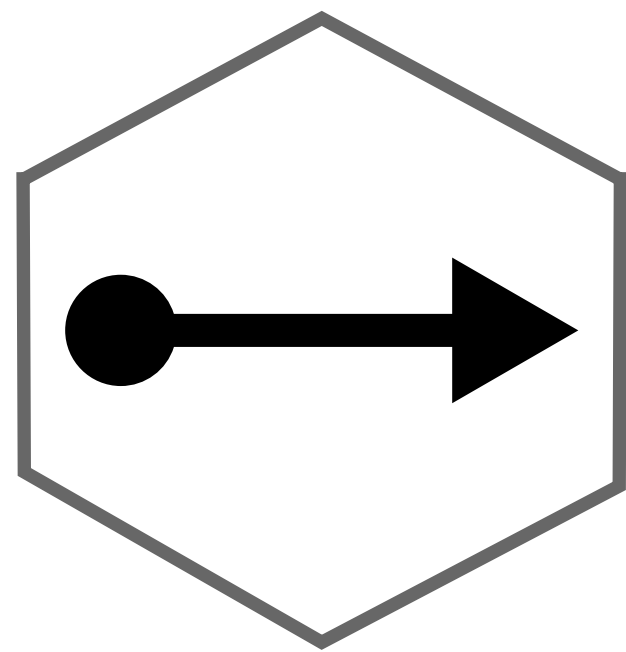
Circuito de atuação

Atuadores

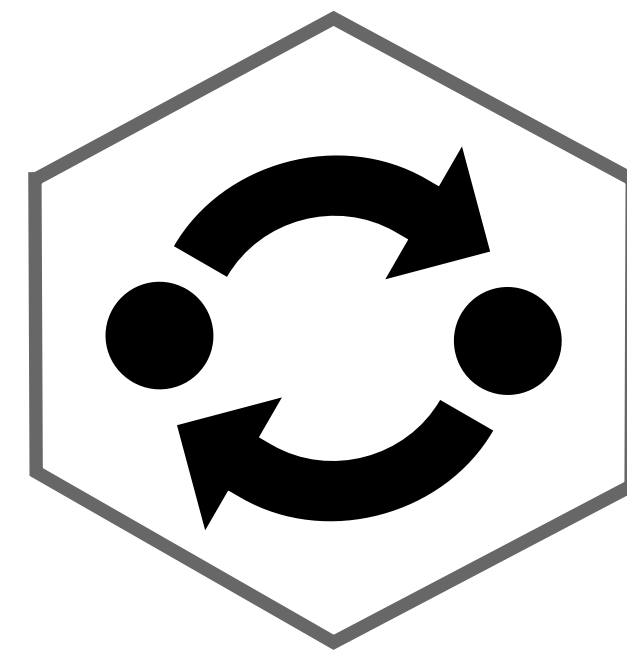


Atuadores

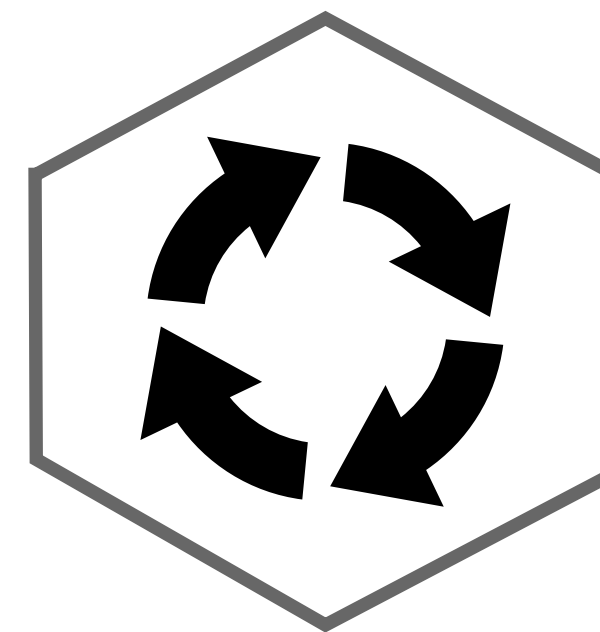
Hidráulica



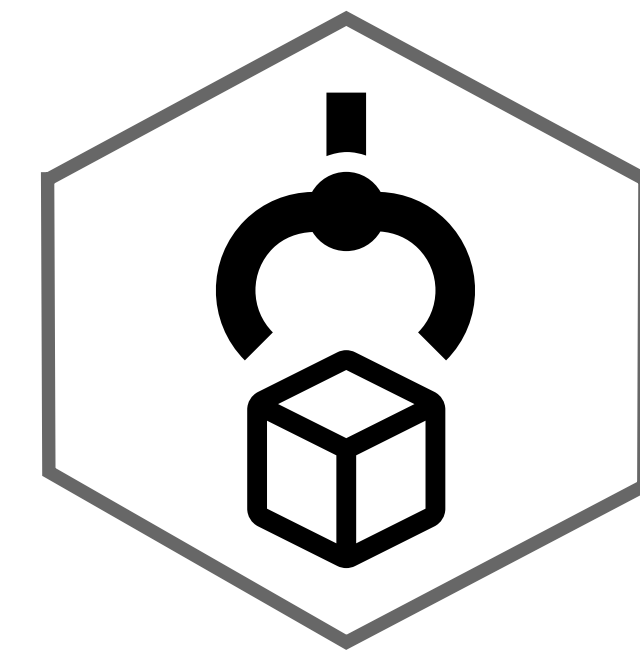
Lineares



Oscilantes



Rotativos



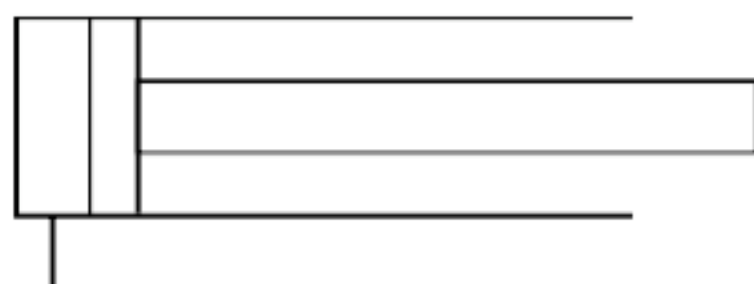
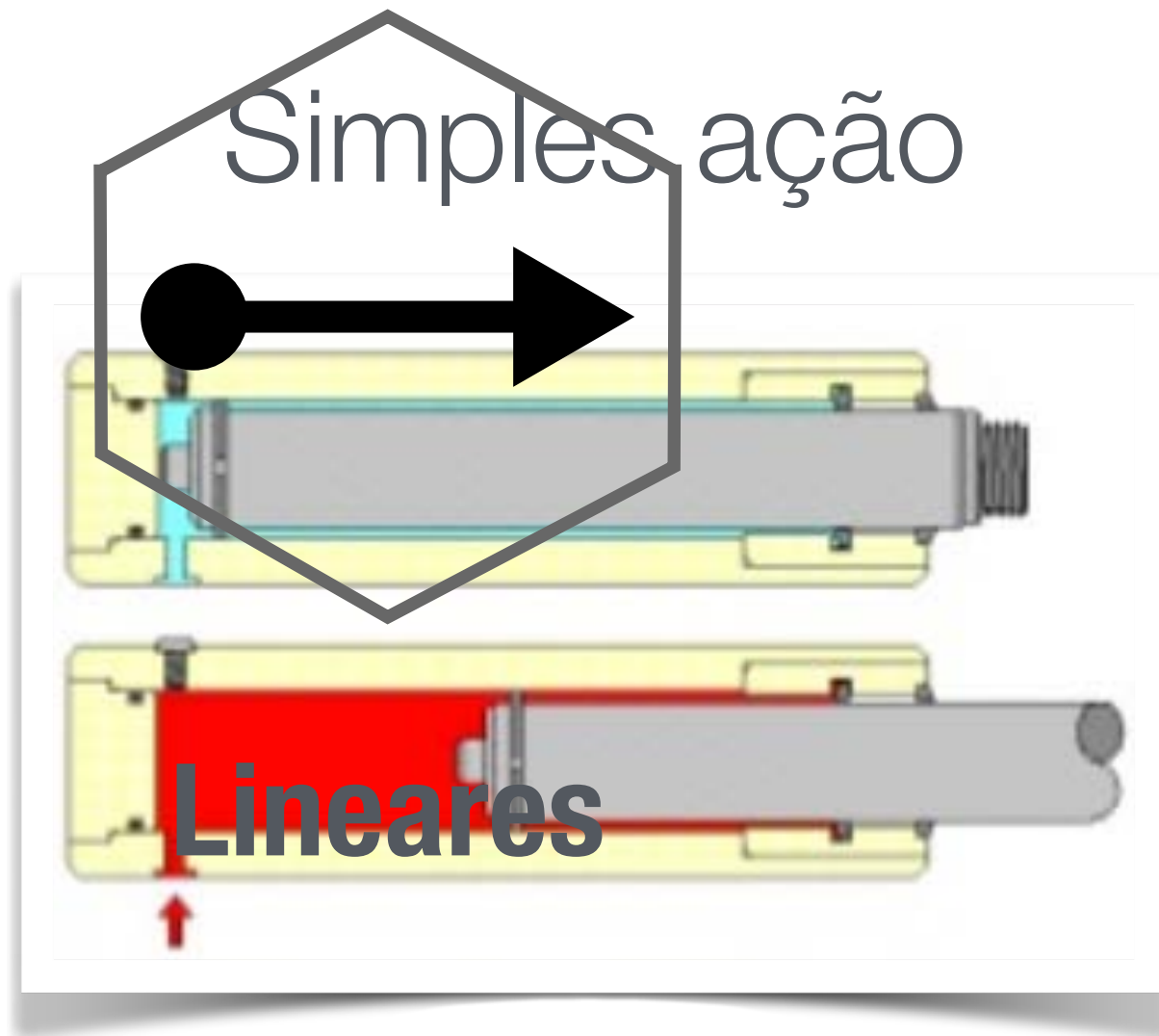
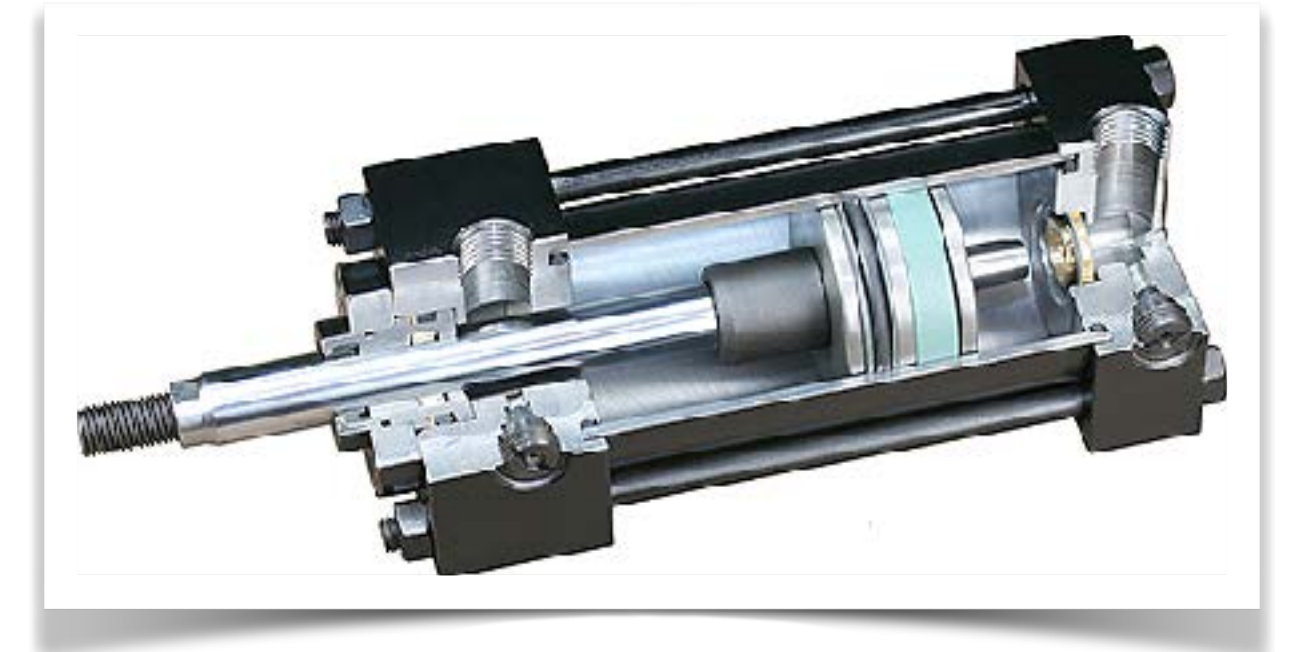
Especiais

Conclusão

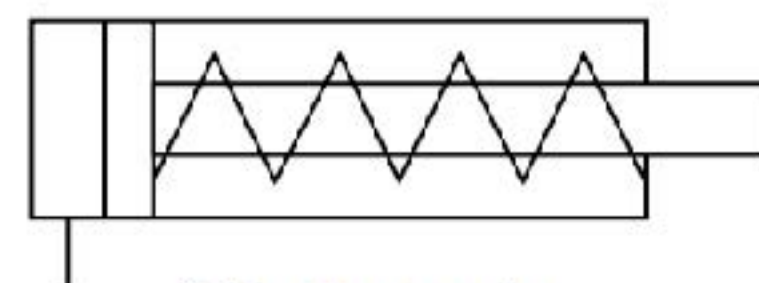
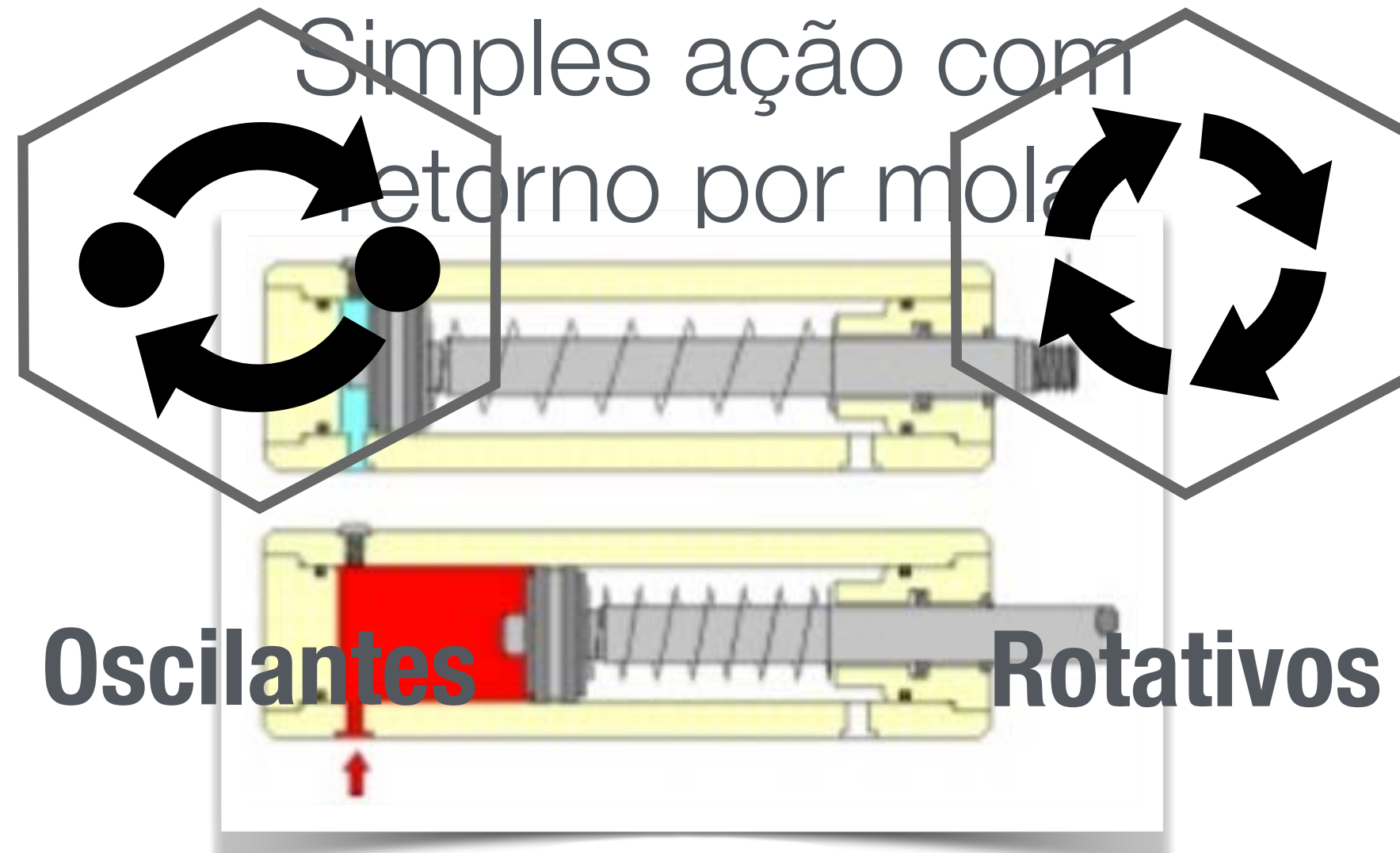
Cilindros hidráulicos

Hidráulica

Conclusão



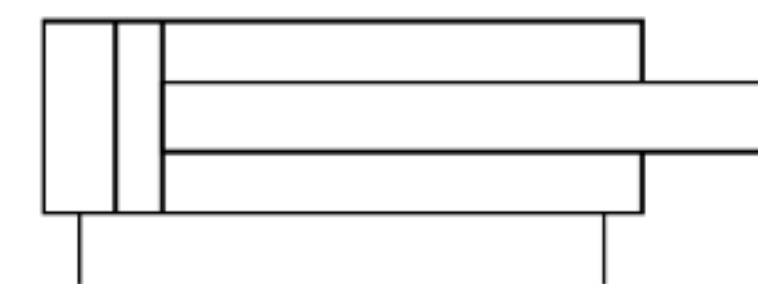
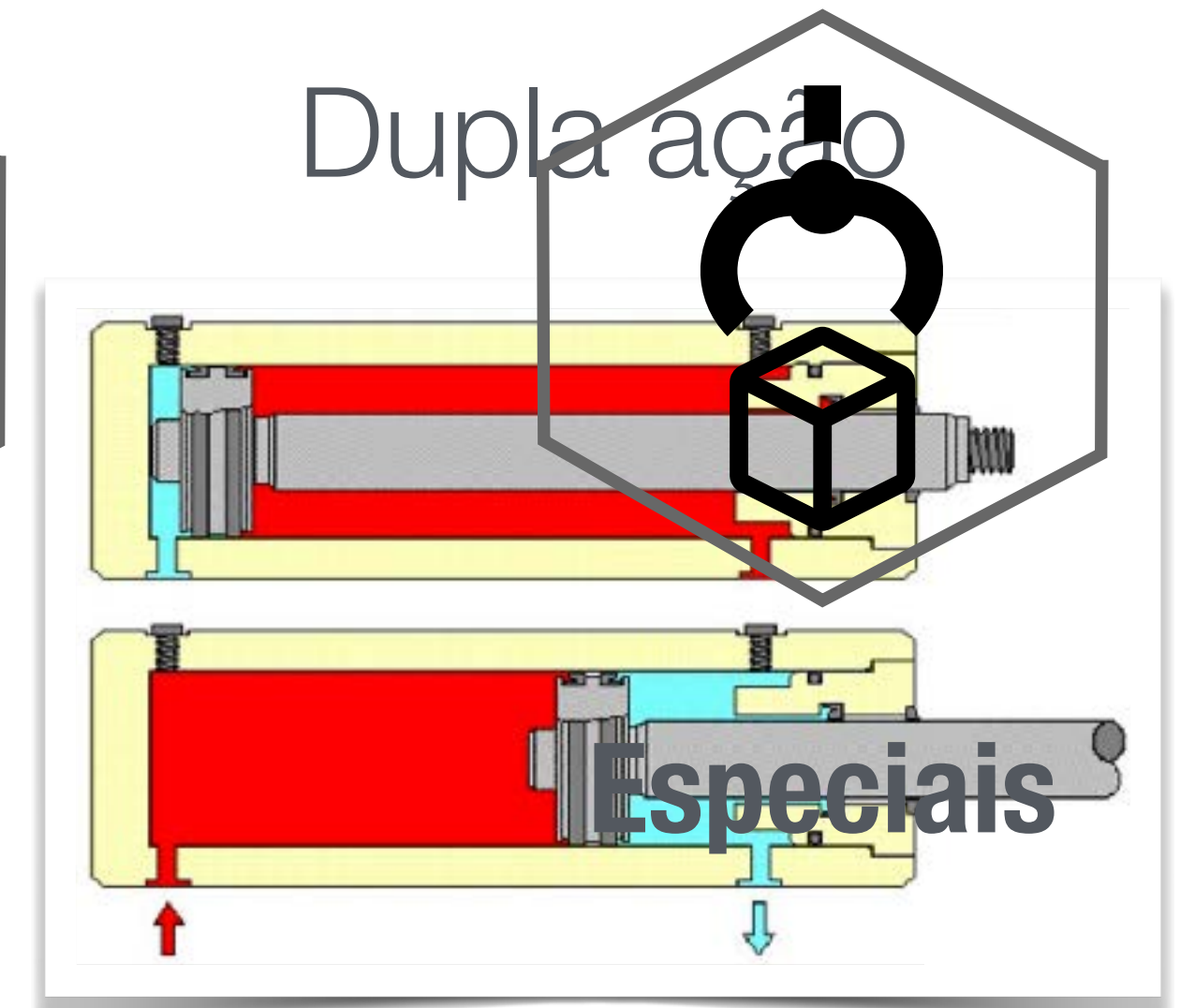
Simbologia



SEM054C

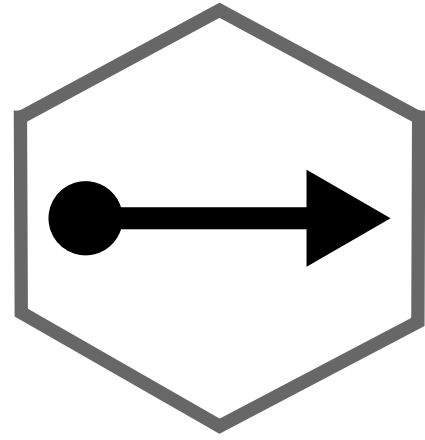
Simbologia

ura



Simbologia

Cilindros hidráulicos



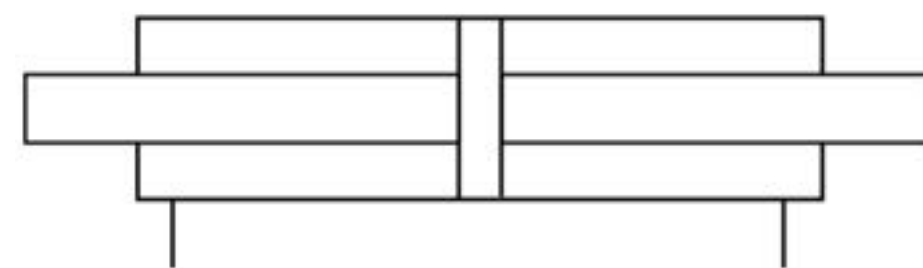
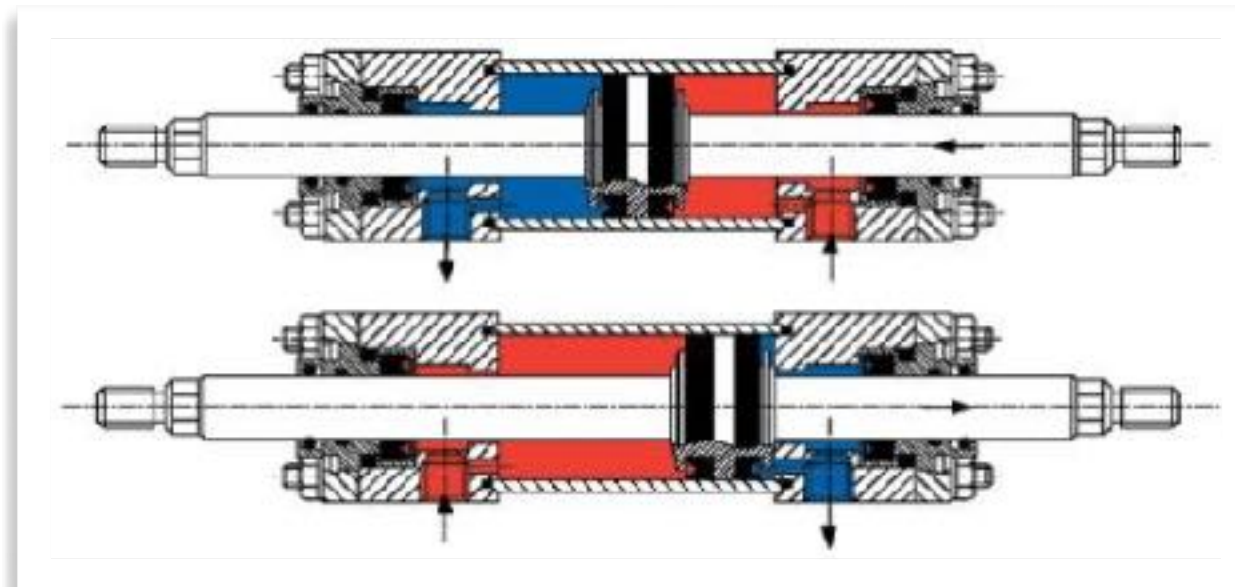
Hidráulica



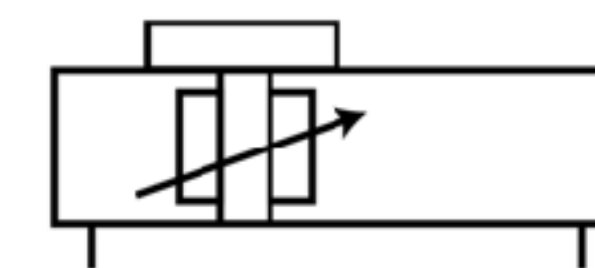
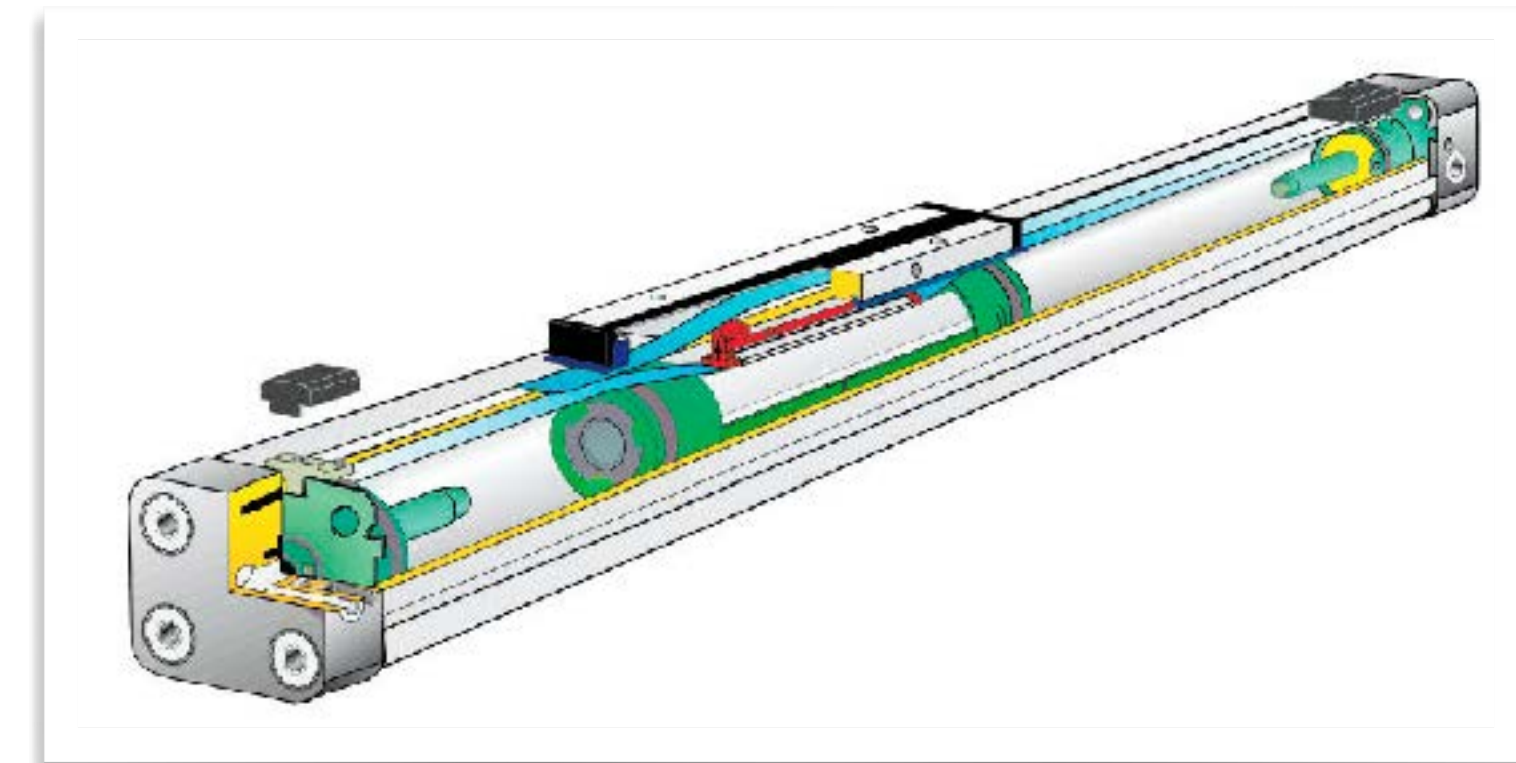
Haste dupla



Sem haste



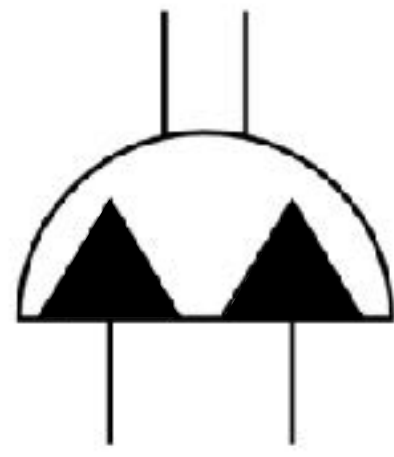
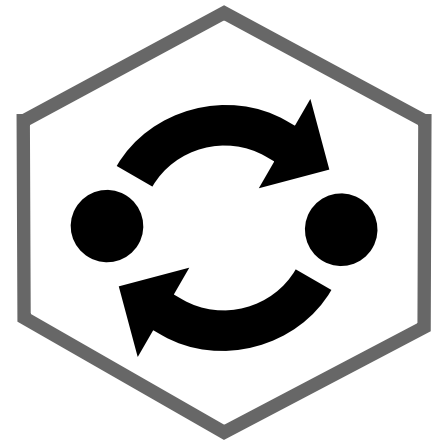
Simbologia



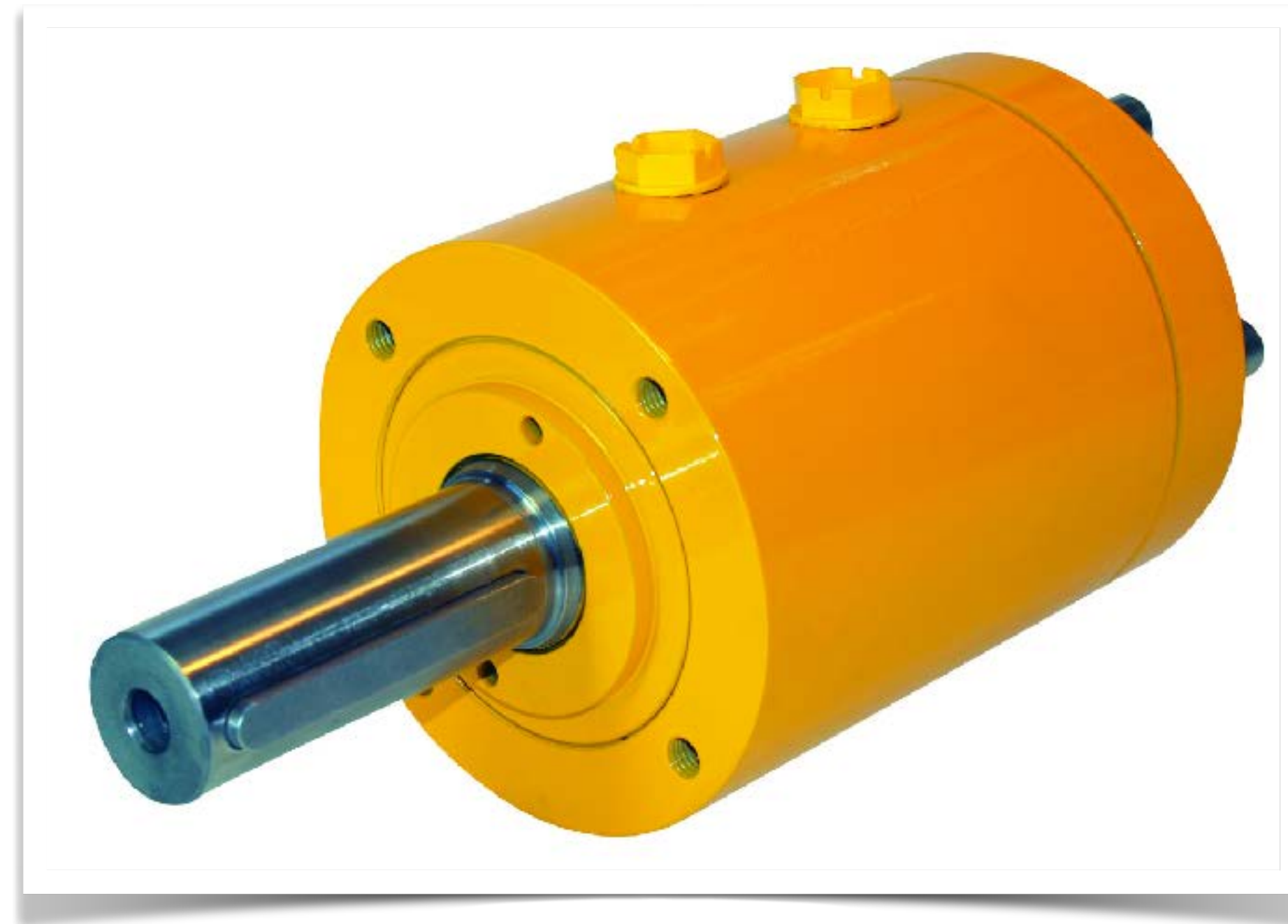
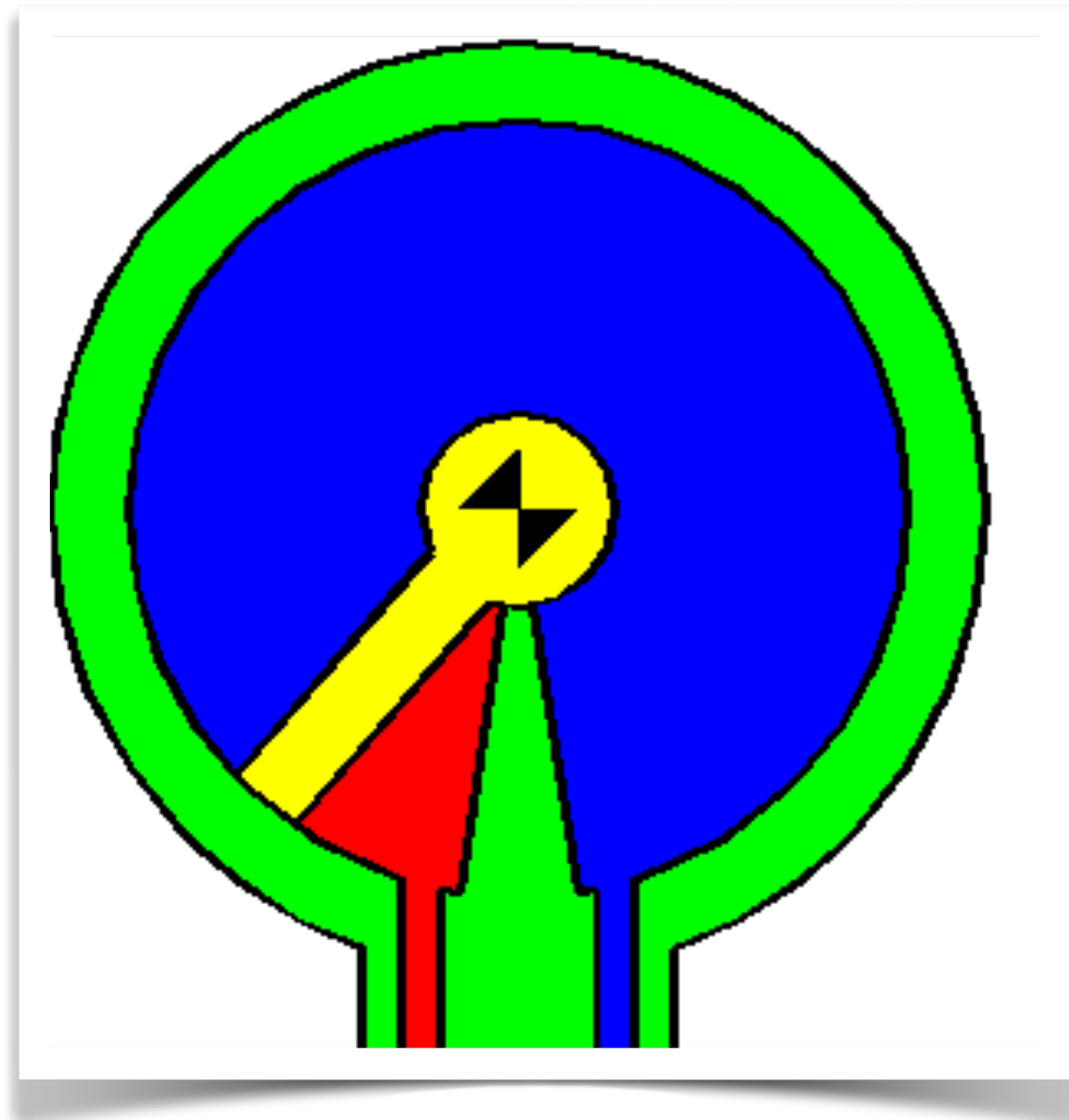
Simbologia

Conclusão

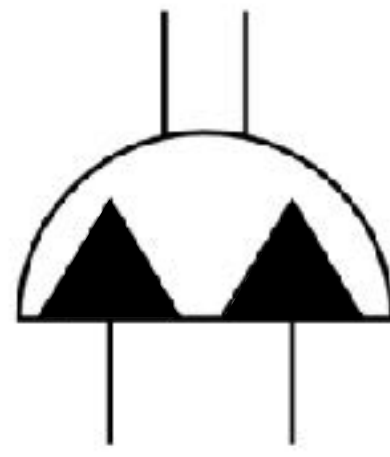
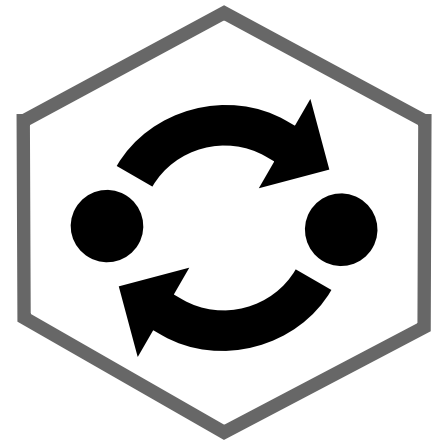
Osciladores hidráulicos



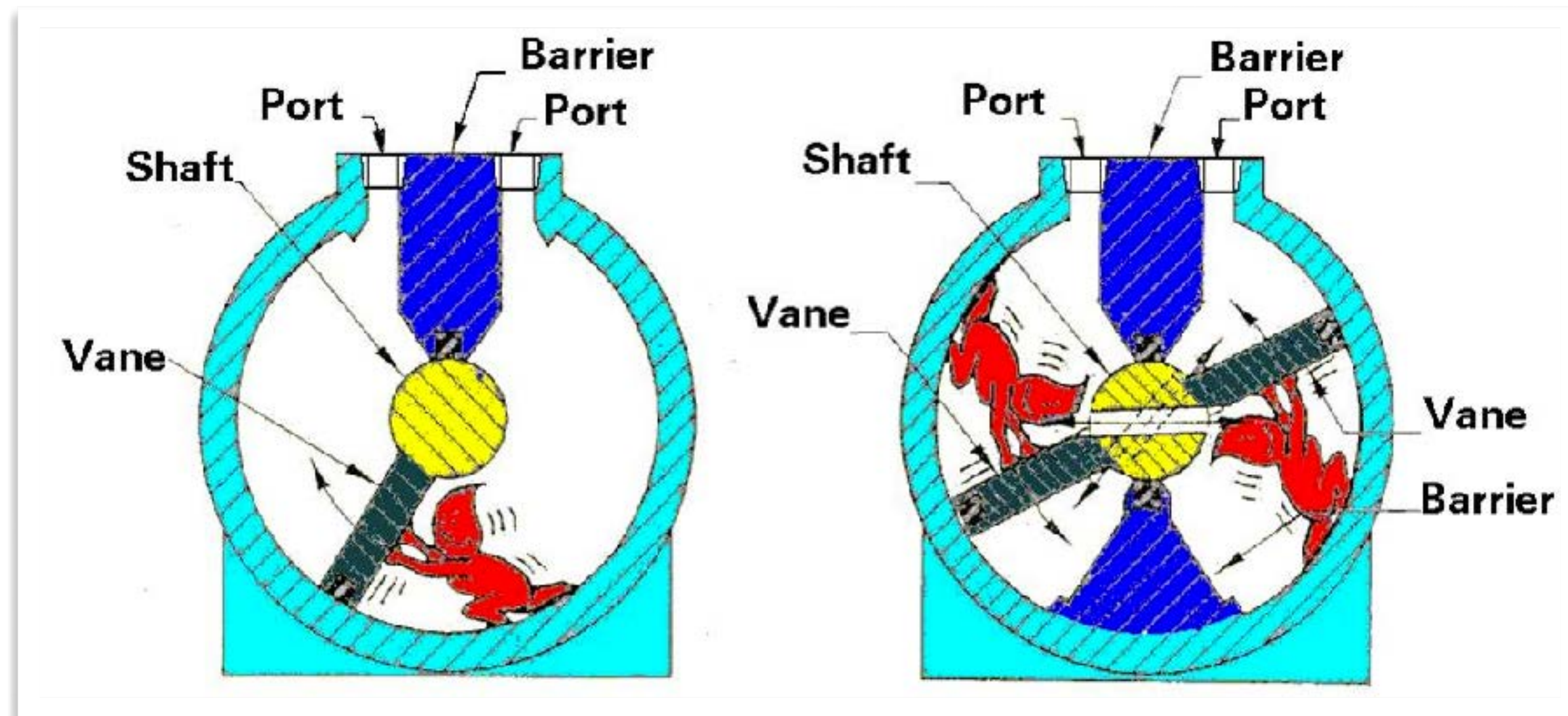
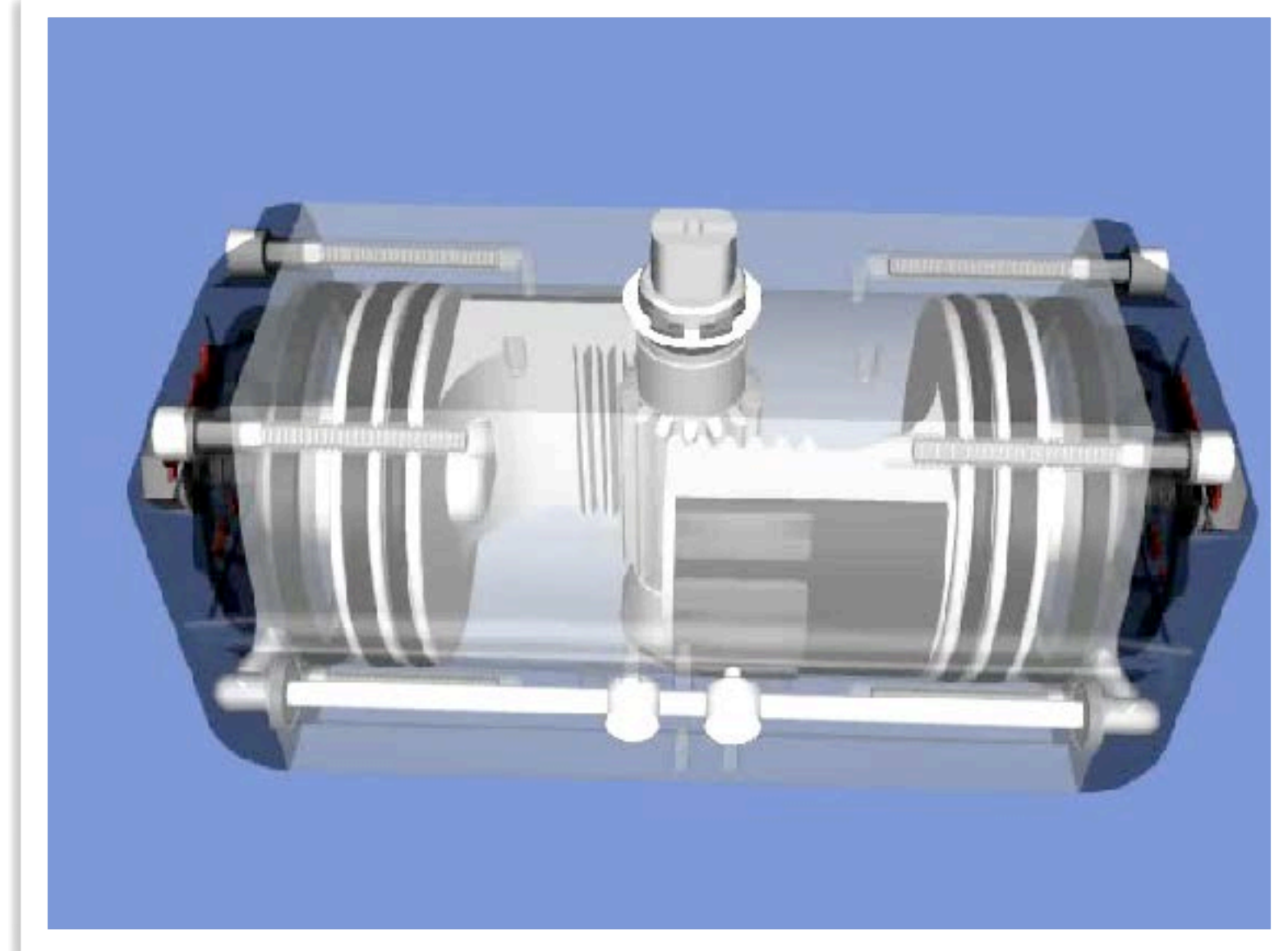
Simbologia



Osciladores hidráulicos



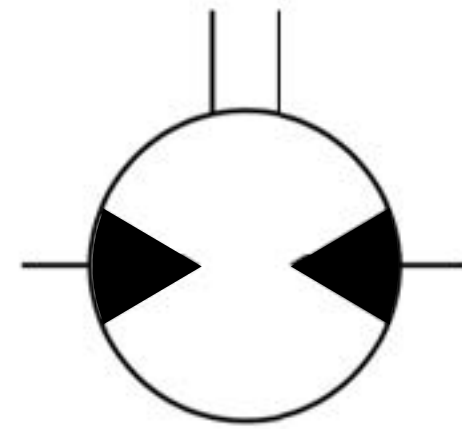
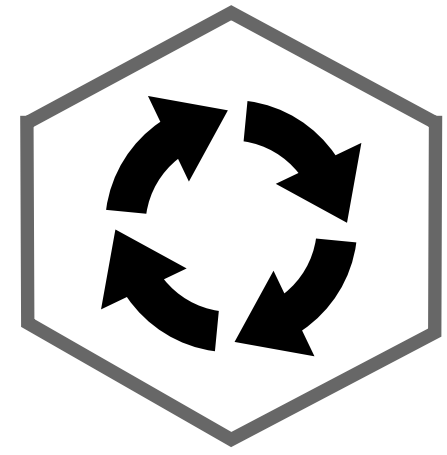
Simbologia



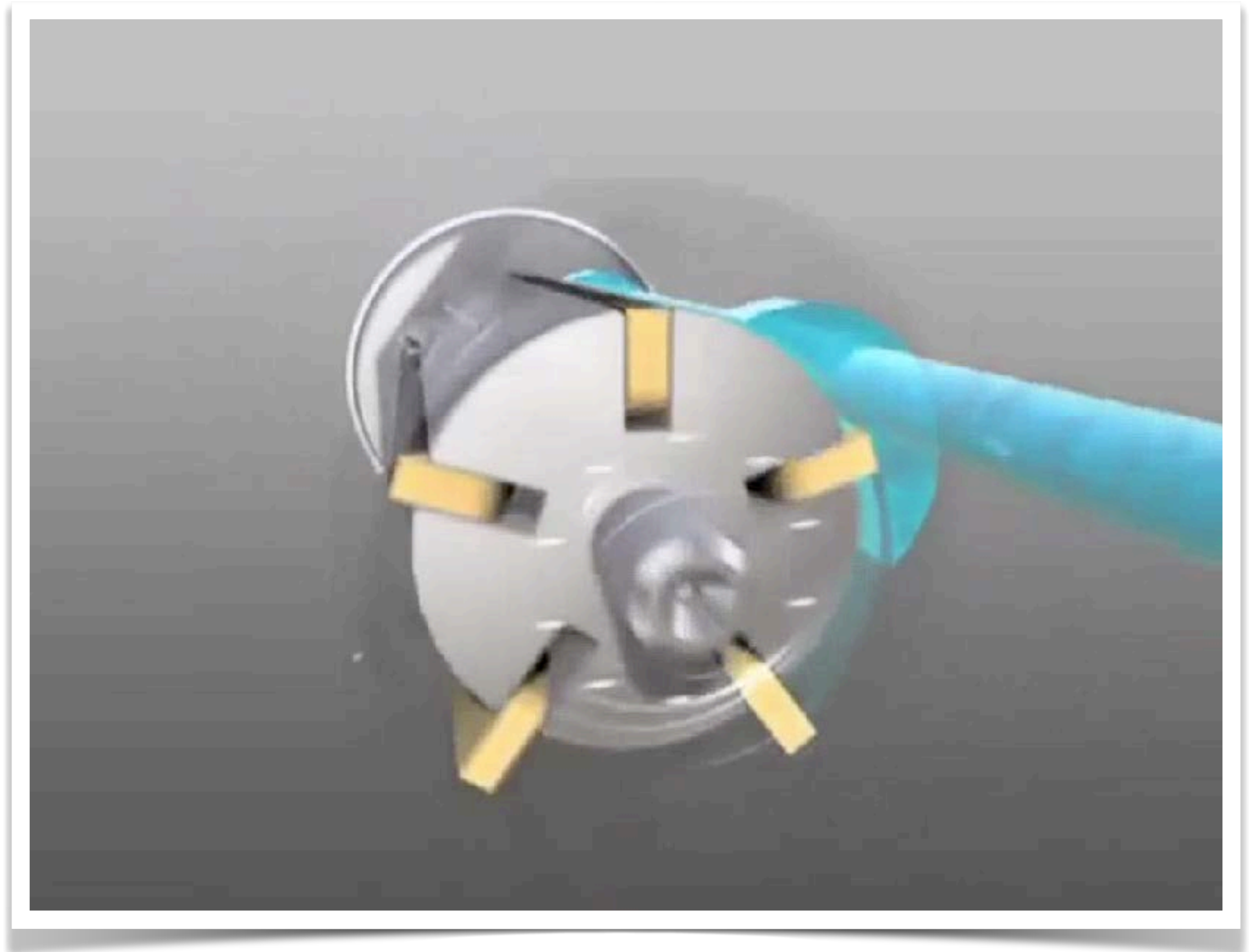
Palhetas

Cremalheira e pinhão

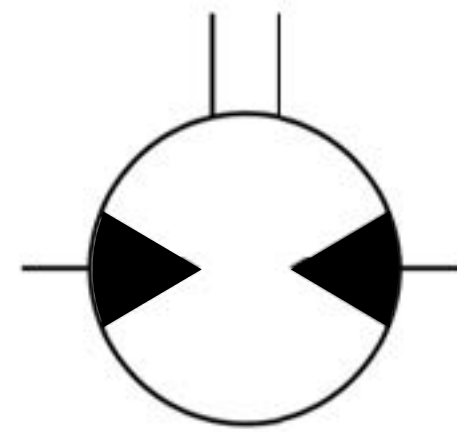
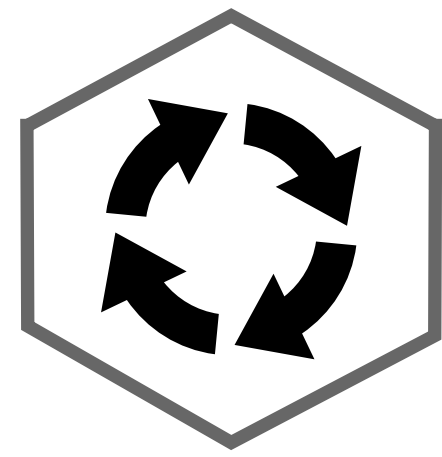
Motores hidráulicos



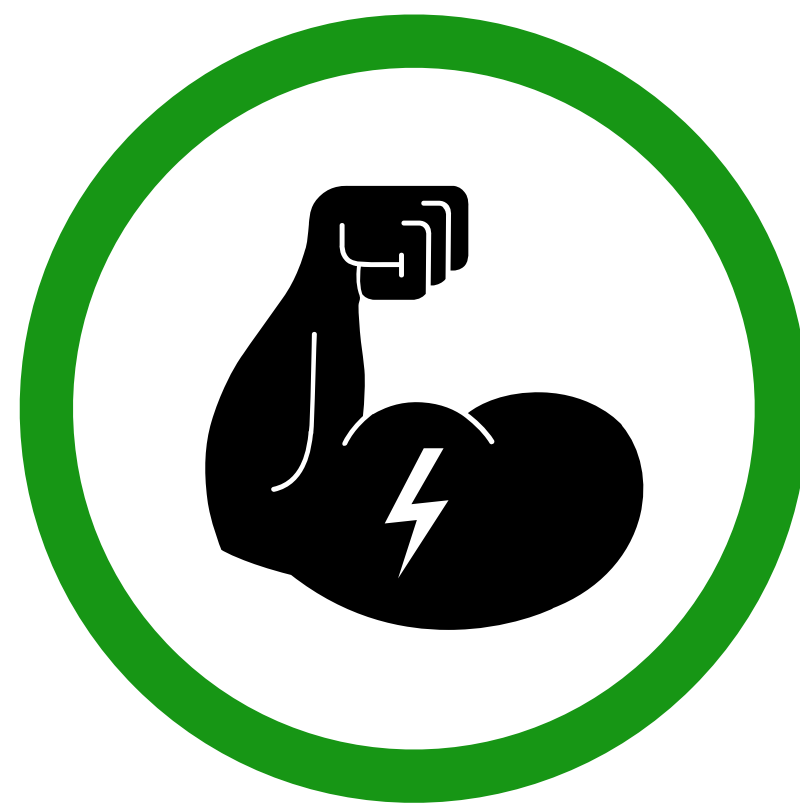
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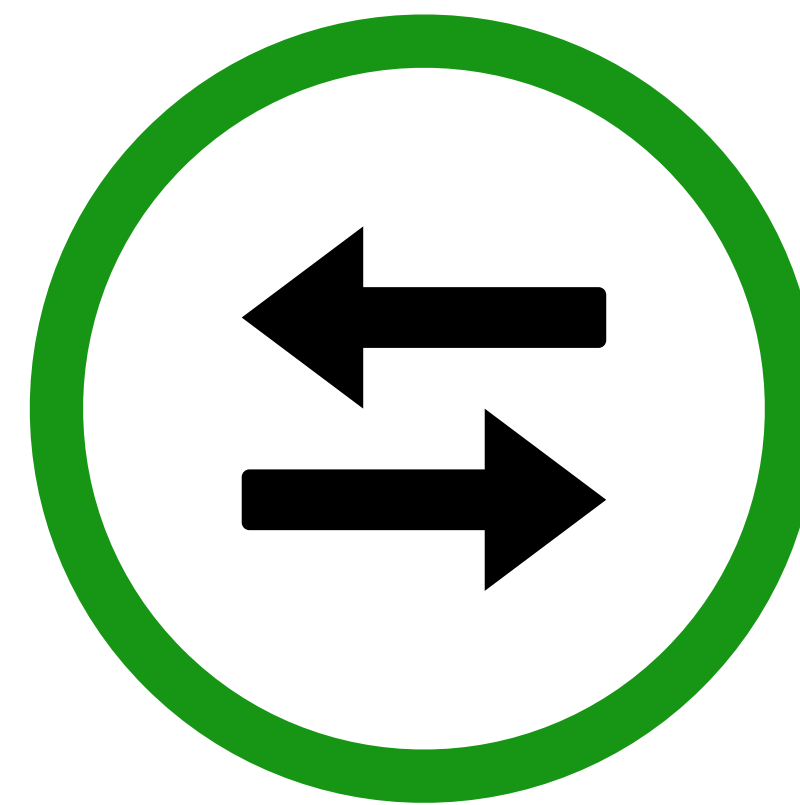
Motores hidráulicos



Simbologia



Densidade de potência



Reversíveis

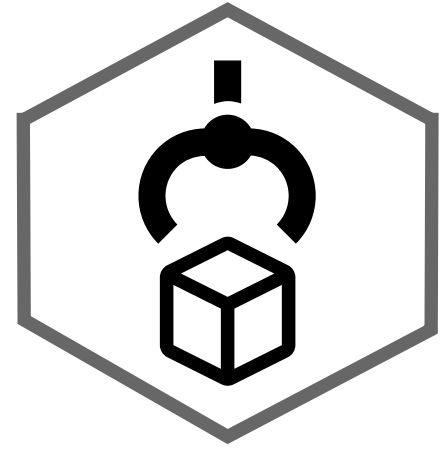


Carga máxima estática

Hidráulica

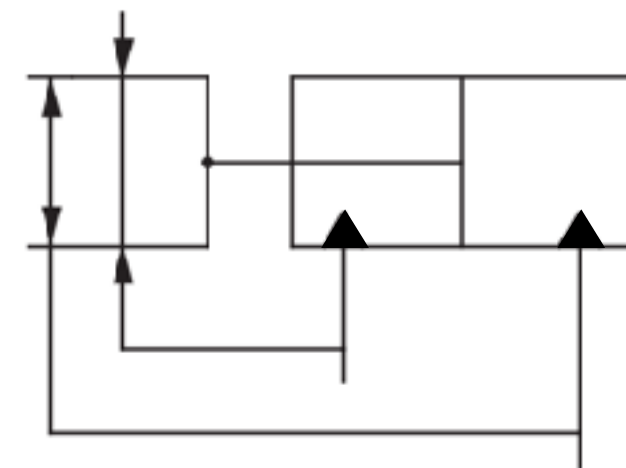
Conclusão

Atuadores especiais

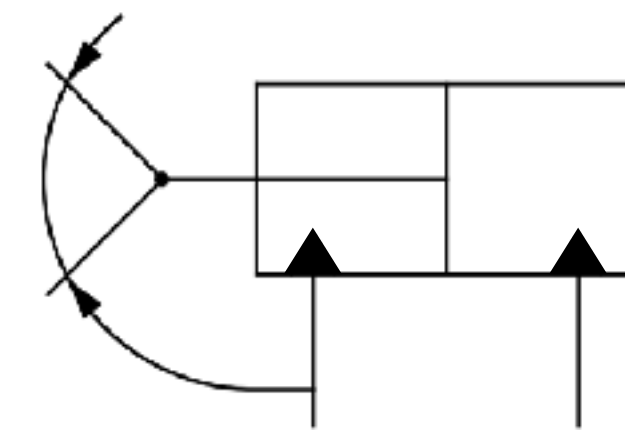


Hidráulica

Conclusão



Simbologia



Simbologia

Conteúdo



- Princípios básicos
- Circuito e componentes
- **Aplicações**

Hidráulica

Conclusão

Hidráulica na indústria

Hidráulica



Conclusão



Hidráulica móvel

Hidráulica

Conclusão



Hidráulica na construção

Hidráulica



4x

Conclusão



Hidráulica na demolição

Hidráulica

Conclusão



2x

Hidráulica na mineração

Hidráulica



Conclusão

Hidráulica no campo

Hidráulica



Conclusão

Hidráulica nos carros

Hidráulica



Conclusão

Hidráulica nos aviões

Hidráulica

Conclusão

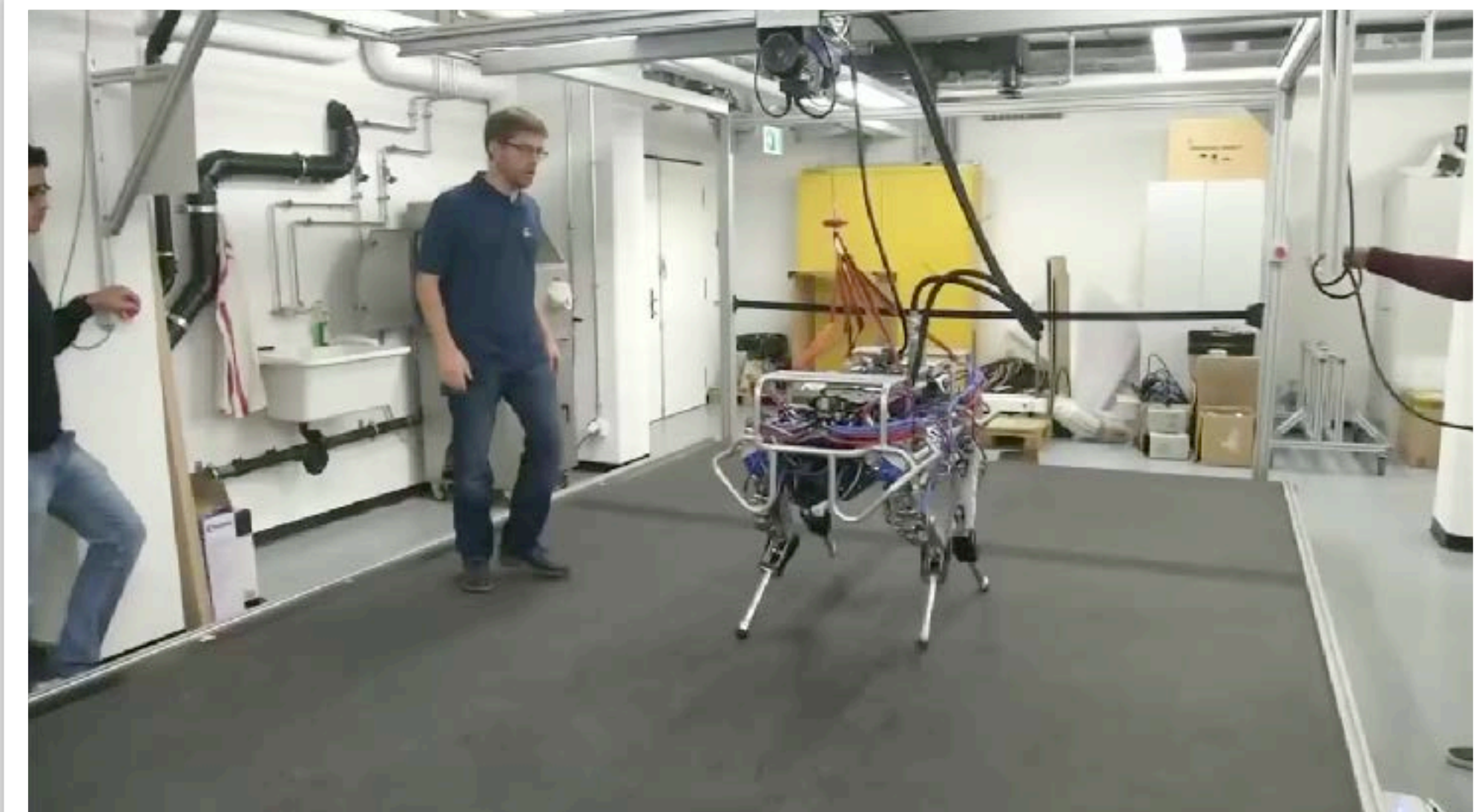
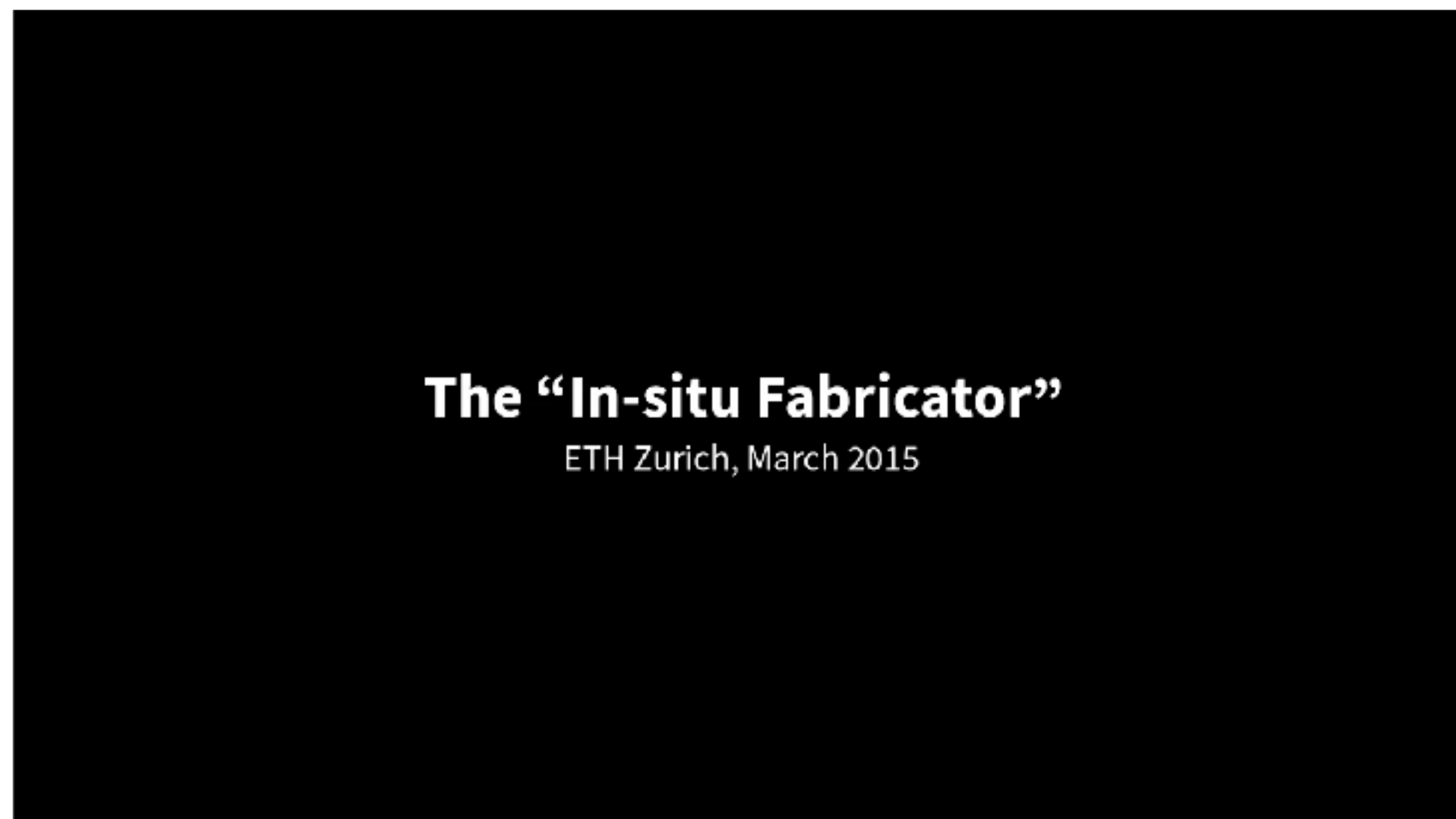


Hidráulica na robótica

Hidráulica



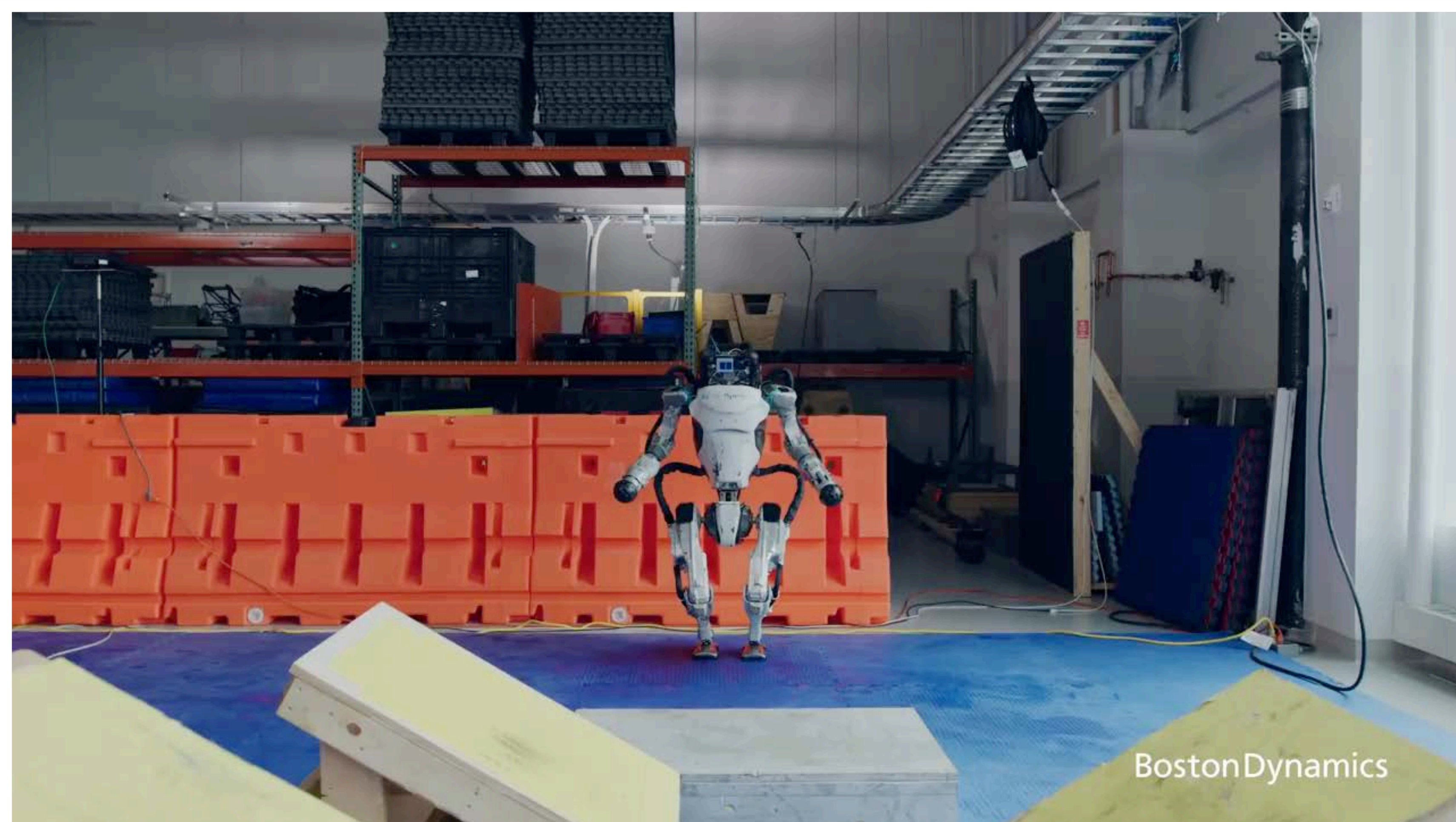
Conclusão



Hidráulica na robótica

Hidráulica

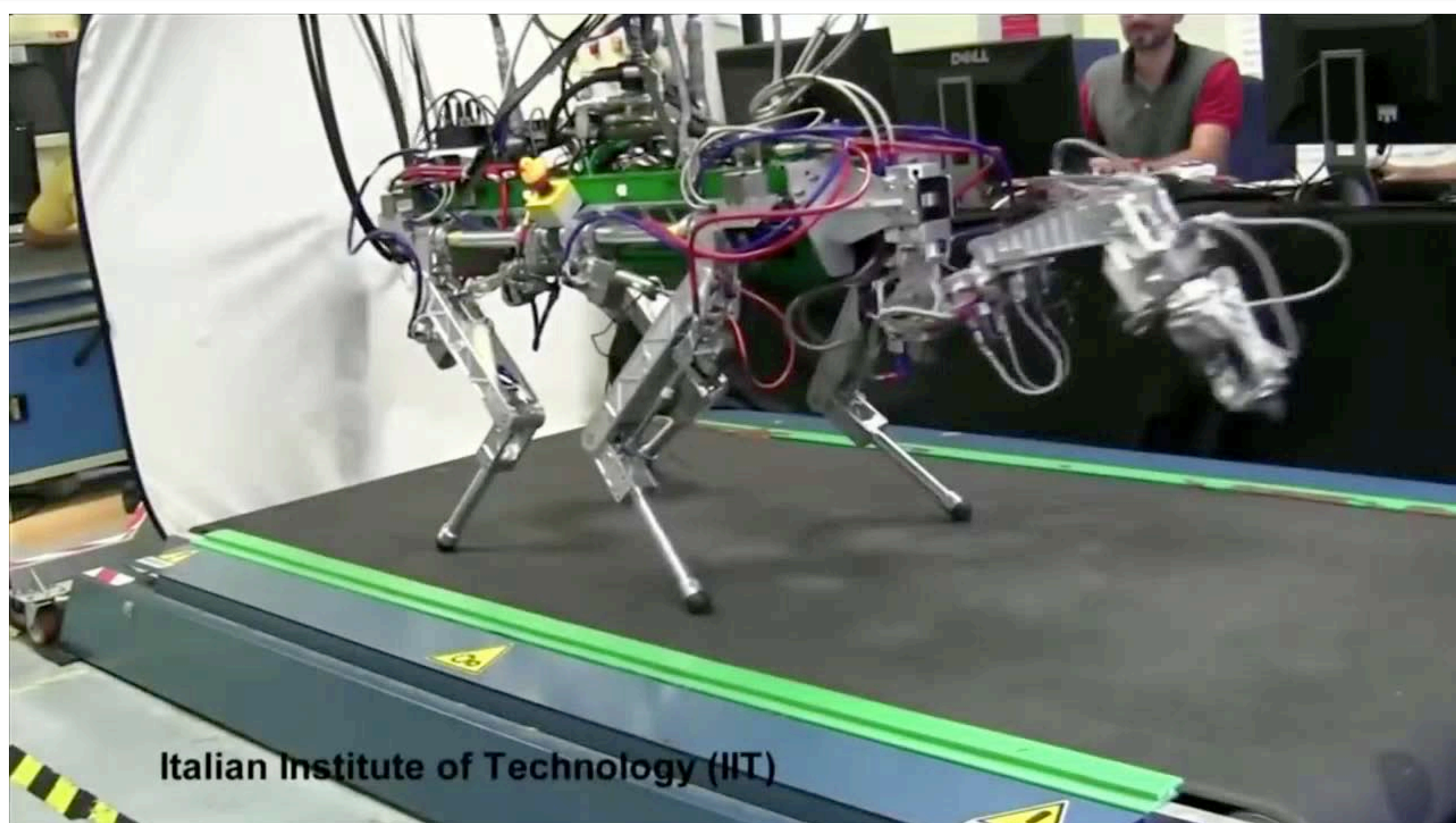
Conclusão



Hidráulica na robótica

Hidráulica

Conclusão



Hidráulica na robótica

Hidráulica

Conclusão



Conteúdo

Hidráulica



- “Take-home messages”
- Próxima aula...

Conclusão

“Take-home messages”

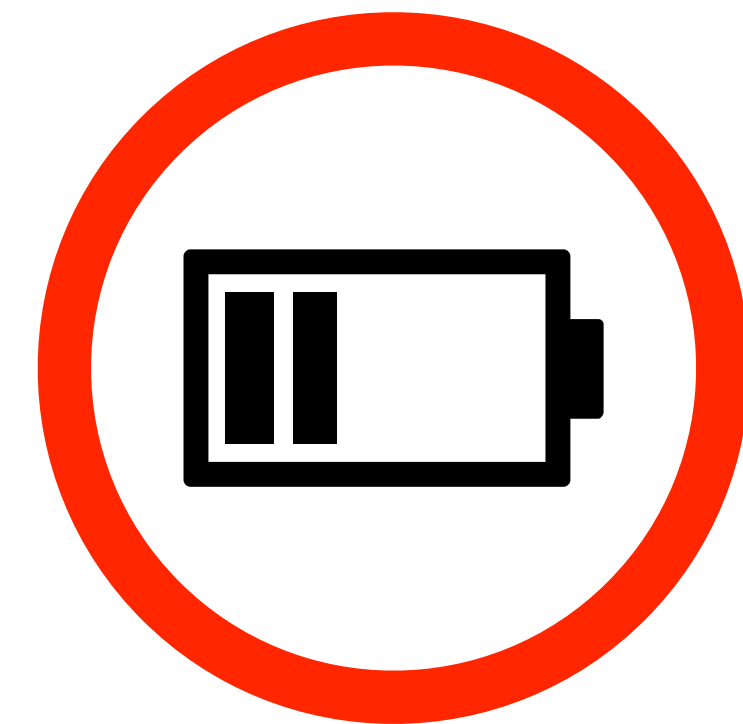
Hidráulica



Potência/Peso



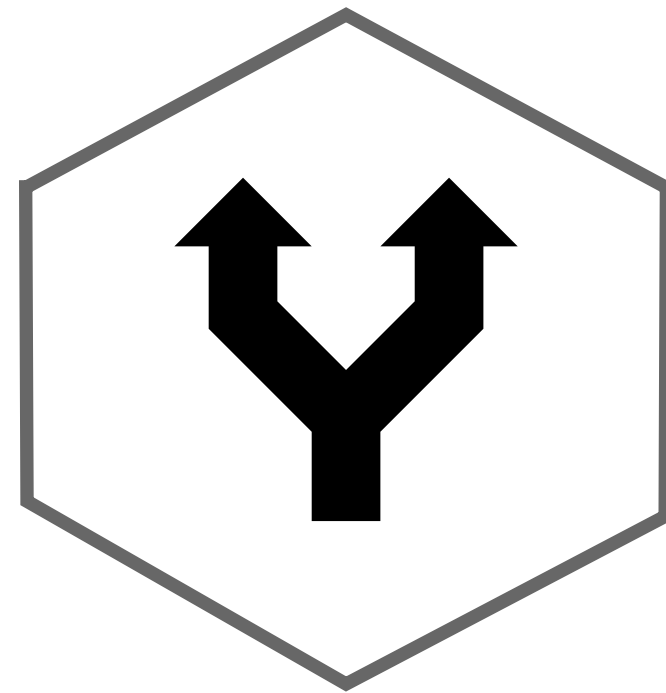
Rápidos



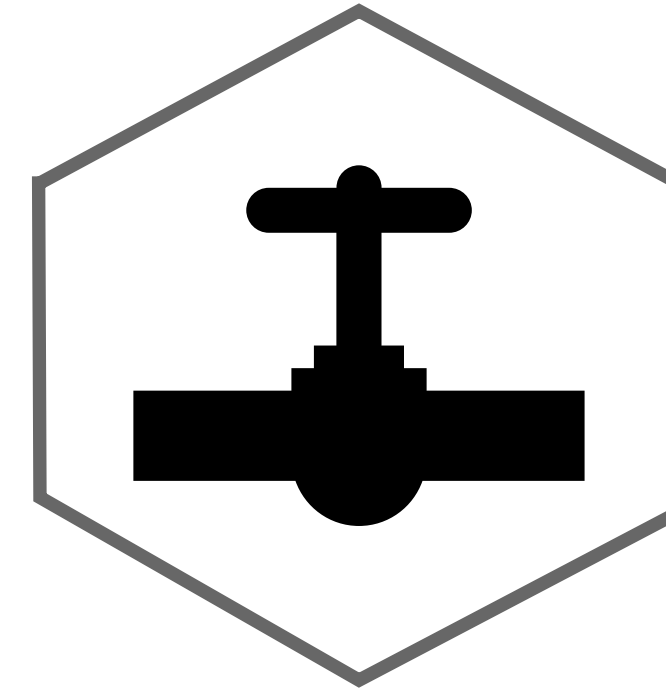
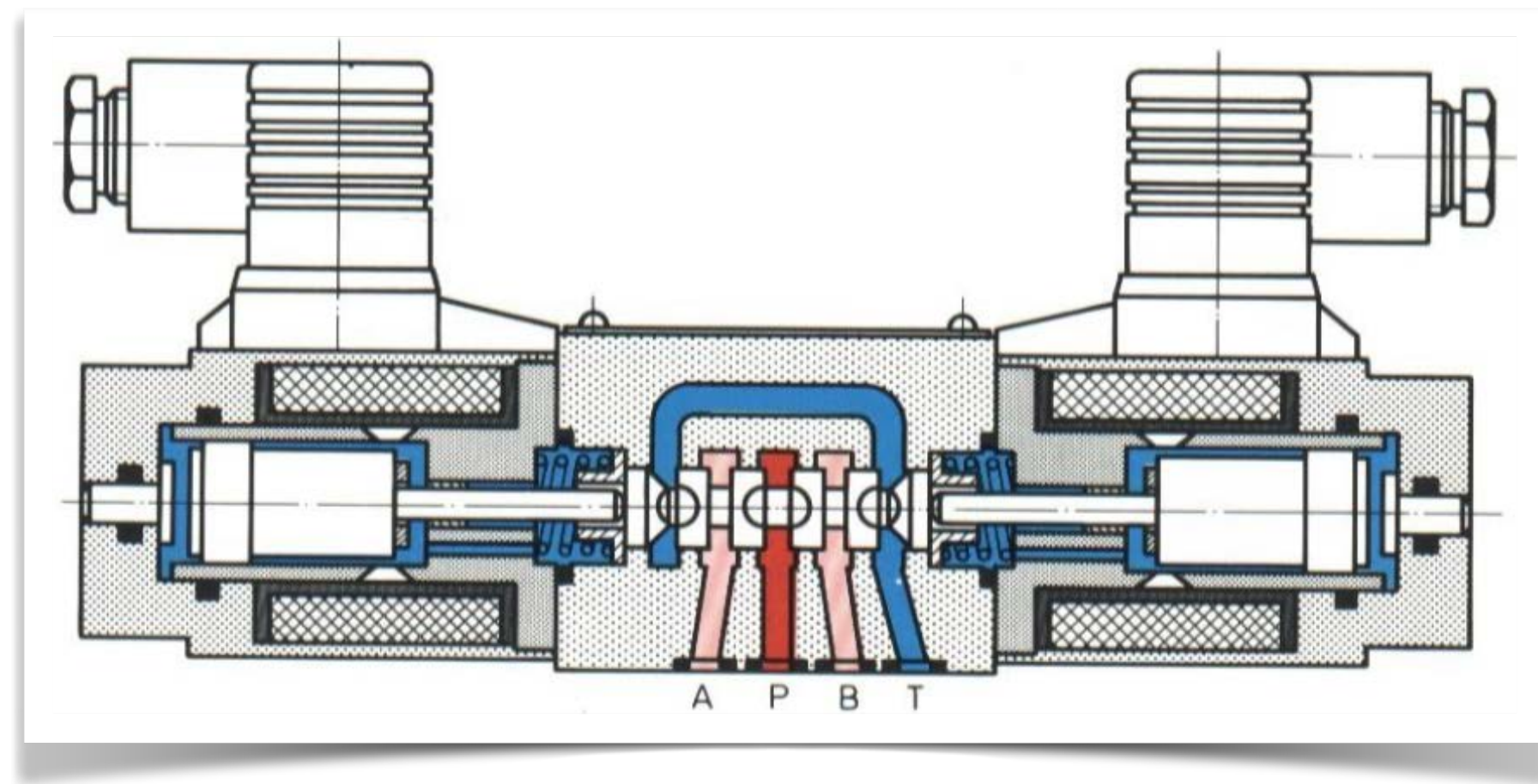
Baixo rendimento

Conclusão

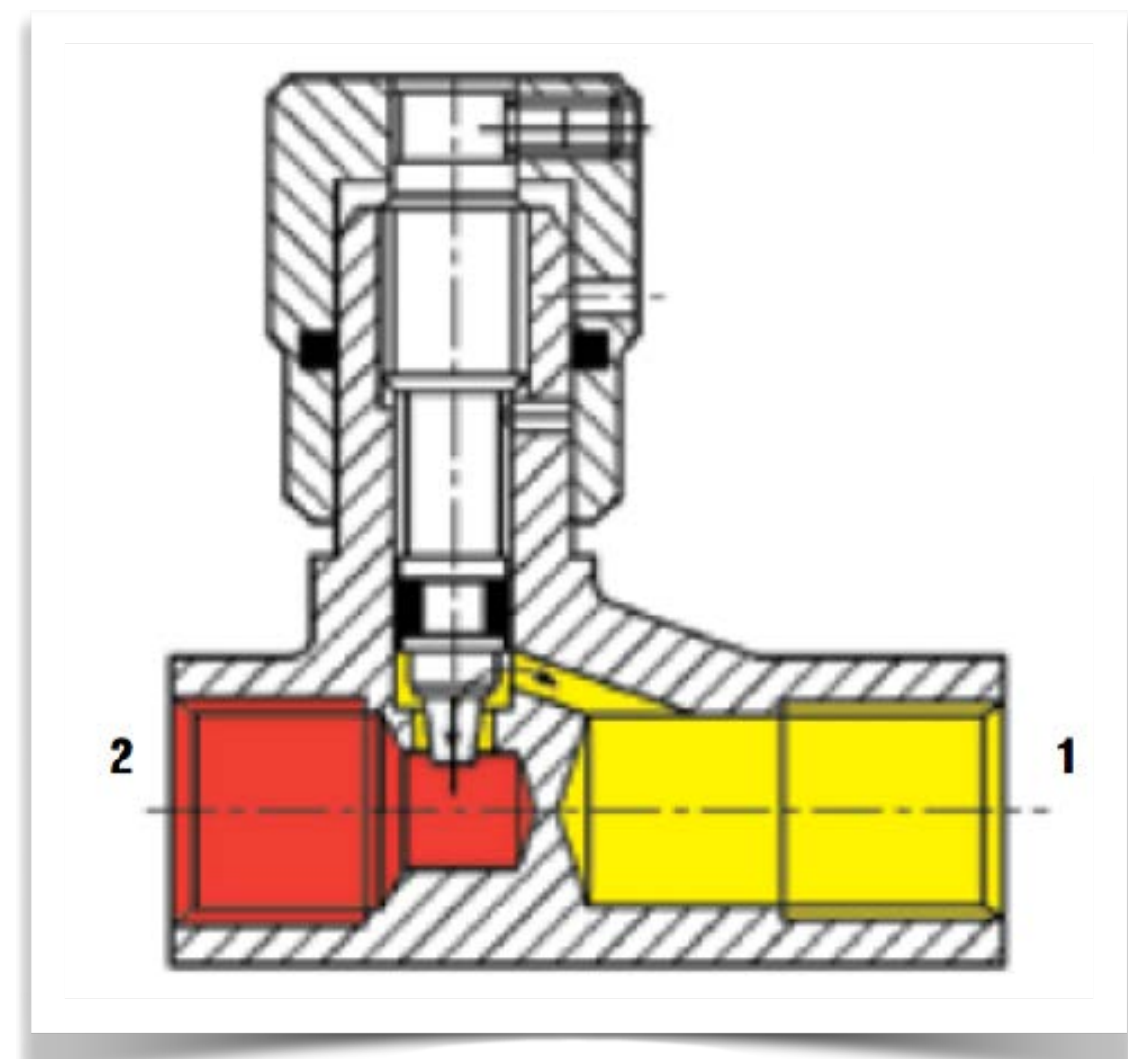
“Take-home messages”



Válvulas de controle direcional

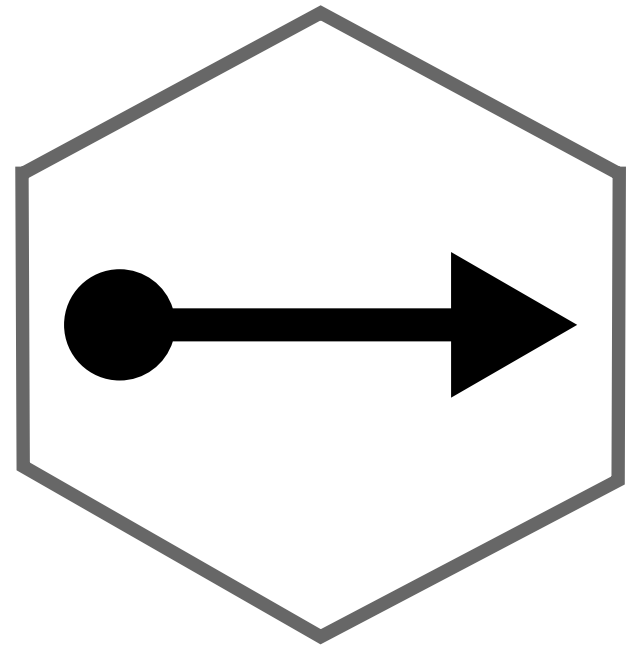


Válvulas auxiliares

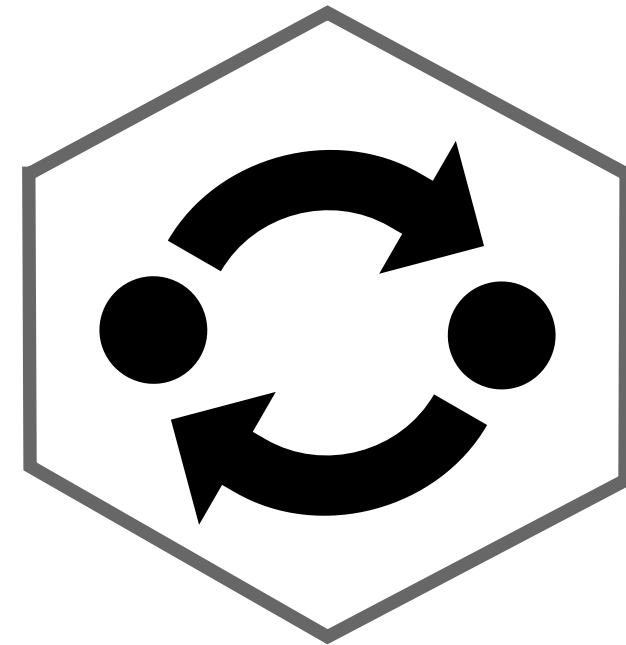


“Take-home messages”

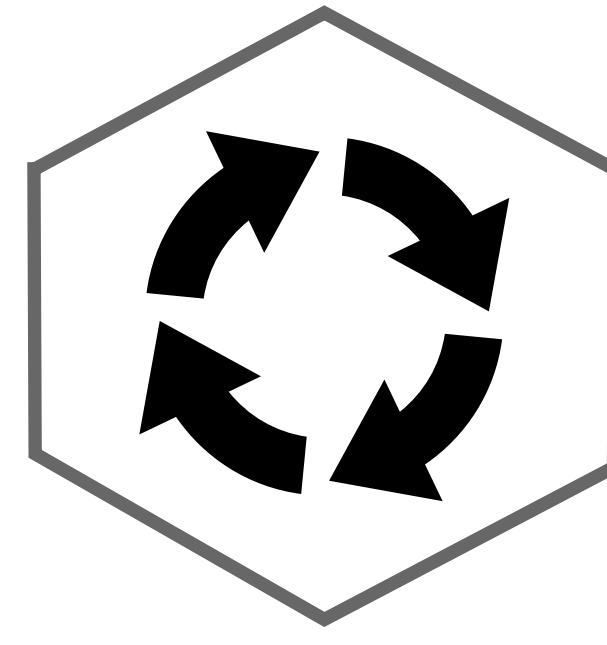
Hidráulica



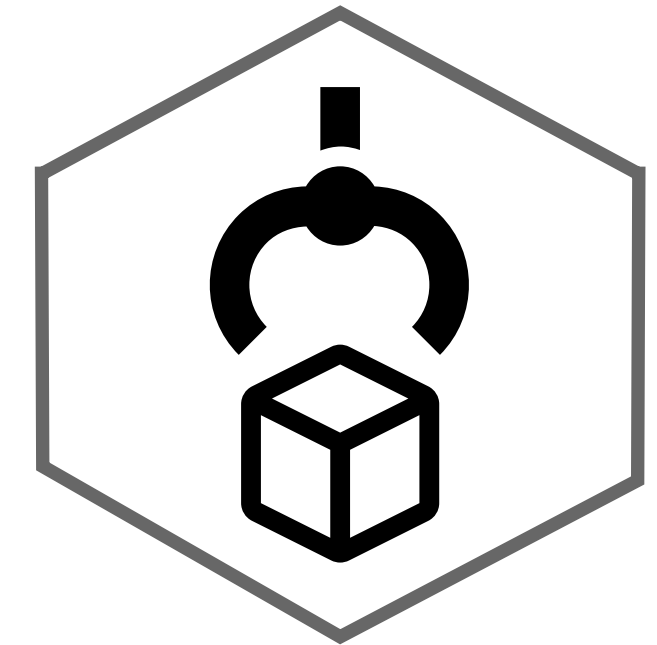
Lineares



Oscilantes



Rotativos



Especiais

Conclusão

Referência bibliográfica

“

Apostila “Painel simulador de Hidráulica Industrial e Eletro-hidráulica”.

Festo Didactic

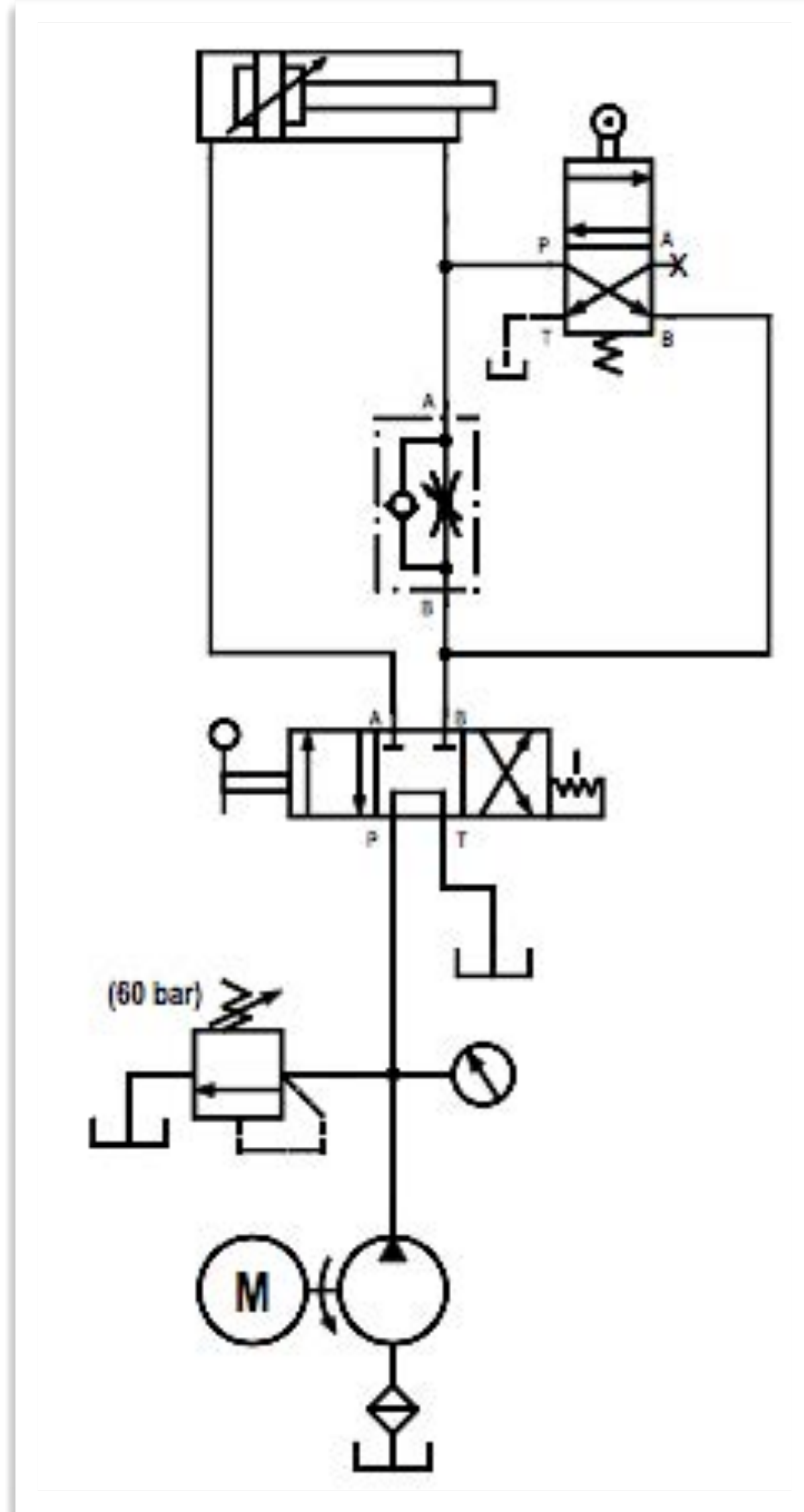
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FIALHO, A. B. Automação hidráulica: Projetos, dimensionamento e análise de circuitos. São Paulo, 2019.

Próxima aula

Hidráulica

Conclusão



Circuitos Hidráulicos



That's all Folks!