CALCULATION EXAMPLES

1. Hydraulic motors, scale (1) to (7) and (29) to (32)

a) Given: M=38 Nm (1)
n=1200 rev/mim (7)
Chosen: p=160 bar (2)
Valued: η_{hm} = 95% (3)
η_v = 97% (5)
Searched: V=15,7 cm^3/rev (4)
V=$\boxed{16}$ cm^3/rev (chosen)
Q=20 l/min (6)

b) Given: P=18 kW (32)
n=1450 rev/min (7)
Chosen: p=250 bar (30)
Valued: η_t = 95% (31)
η_v = 97% (5)
Searched: Q=48 l/min (6)(20)
V=32 cm^3/rev (4)

2. Hydraulic pumps scale (4) to (7) and (29) to (32), example 1a.
Given: Q=20 l/min (6)(29)
p=160 bar (30)
Chosen: V=11 cm^3/rev (4)
Valued: η_v = 97% (5)
η_t = 92% (31)
Searched: n=1900 rev/min (7)
P= 5,7 kW (32)

3. Hydraulic cylinders, scale (8) to (17)

a) Given: F=30 kN (11)
H=250 mm (14)
t=1 s (16)
Chosen: p_{th}=200 bar (10)
Searched: d=43,7 mm (8)
d=$\boxed{50}$ mm (chosen)
A=19,6 cm^2 (9)
V=0,49 l (15)
Q=29,5 l/min (17)

b) Given: F=30 kN (11)
v=15 m/min (13)
Chosen: p_{th}=200 bar (10)
Searched: d=43,7 mm (8)
d=$\boxed{50}$ mm (chosen)
A=19,6 cm^2 (9)
Q=29,5 l/min (12)

c) Given: the same as 3a
d_1= 32 mm (piston rod diameter)
Searched (return stroke): d=43,7 mm (8)
d=50 mm (chosen)
A=19,6 cm^2 – 8 cm^2 =11,6 cm^2 (9)
V=0,29 l (15)
t= 0,59 s (16) at Q=29,5 l/min

4. Pressure losses in pipes, scale (18) to (26)

a) Laminar
Given: d=12 mm (18)(24)
ν=36 mm^2/s (19)(21)
Q=20 l/min (20)
Searched: Δp (23)

b) Turbulent
Given: d=20 mm (18)(25)
ν=36 mm^2/s (19)(22)
Q=100 l/min (20)
Searched: Δp (26)

Solution for 4a d=12 mm (18), ν=36 mm^2/s (19), Q=20 l/min (20) "white filed", d.h., the flow is laminar. ν=36 mm^2/s (21), Q=20 l/min (20) results over d=12 (24) Δp=0,21 bar/m (23).
Solution for 4b d=20 mm (18), ν=36 mm^2/s (19), Q=100 l/min (20) "red filed", d.h., the flow is turbulent. ν=36 mm^2/s (22), Q=100 l/min (20) results under d=20 (25) Δp=0,27 bar/m (26).
By taking into account Q (20), then a or b can be expected.

5. Flow velocity in pipes, scale (27) to (29)
Given: d=20 mm (27)
Q=100 l/min (29)
Searched: w=5,3 m/s (28)

Hydraulic pump, motor	(1)	M	Nm	Torque of hydraulic motor
	(2)	p	bar	Operating pressure, motor
	(3)	η_{hm}	%	Mechanic/hydraulic efficiency, motor
	(4)	V	cm^3/rev	Displacement volume pump, inlet volume motor
	(5)	η_v	%	Volumetric efficiency of pump, motor
	(6)	Q	l/min	Flow rate pump, motor
	(7)	n	rev/min	Rotational speed pump, motor
Hydraulic cylinder	(8)	d	mm	Internal diameter of cylinder, piston d, piston rod d_1, nominal size $\boxed{?}$
	(9)	A	cm^2	Piston area, piston/rod area
	(10)	p_{th}	bar	=p* η_{hm} *10^{-2}…operational pressure of cylinder*mechanical-hydraulic efficiency of cylinder
	(11)	F	kN	Piston force
	(12)	Q	l/min	Flow rate of cylinder
	(13)	v	m/min	Cylinder velocity
	(14)	H	mm	Piston diameter, nominal size $\boxed{?}$
	(15)	V	l	Stroke volume of cylinder
	(16)	t	s	Stroke time of cylinder
	(17)	Q	l/min	Flow rate of cylinder
Hydraulic pipes	(18)	*d*	mm	Internal diameter of pipe
	(19)	ν	mm^2/s	Kinematic viscosity of fluid (1cSt=1 mm^2/s)
	(20)	Q	l/min	Flow rate
	(21)	ν	mm^2/s	Kinematic viscosity, laminar flow
	(22)	ν	mm^2/s	Kinematic viscosity, turbulent flow
	(23)	Δp	bar/m	Pressure losses per 1 m pipe length at laminar flow (γ=0,9 g/cm^3)
	(24) (25)	*d*	mm	Internal diameter of pipe
	(26)	Δp	bar/m	Pressure losses per 1 m pipe length at turbulent flow (γ=0,9 g/cm^3)
	(27)	*d*	mm	Internal diameter of pipe
	(28)	*w*	m/s	Flow velocity in pipes
Power	(29)	Q	l/min	Flow rate in pipes, flow rate of pump
	(30)	p	bar	Operating pressure outlet of pump, inlet of motor
	(31)	η_t	%	Overall efficiency of pump, motor
	(32)	P	kW	Power requirement of pump, output power of motor

FORMULAS

Hydraulic motors (1) to (4)

$$M = 1{,}59 \cdot V \cdot p \cdot \eta_{hm\%} \cdot 10^{-4}$$

$$V = 6{,}28 \cdot \frac{M}{p \cdot \eta_{hm\%}} \cdot 10^{3}$$

From (4) to (7)

Pumps
Flow rate Q

$$Q = V \cdot n \cdot \eta_{v\%} \cdot 10^{-5}$$

Displacement volume

$$V = \frac{Q}{n \cdot \eta_{v\%}} \cdot 10^{5}$$

$$n = \frac{Q}{V \cdot \eta_{v\%}} \cdot 10^{5}$$

Motors
Flow rate Q

$$Q = \frac{V \cdot n}{\eta_{v\%}} \cdot 10^{-1}$$

Displacement volume

$$V = \frac{Q \cdot \eta_{v\%}}{n} \cdot 10$$

$$n = \frac{Q \cdot \eta_{v\%}}{V} \cdot 10$$

Form (29) to (32)

Power requirement

$$P = \frac{Q \cdot p}{6 \cdot \eta_{t\%}}\ kW$$

Output power

$$P = \frac{Q \cdot p \cdot \eta_{t\%}}{6} \cdot 10^{-4}\ kW$$

Form (8) to (17) hydraulic cylinders

$$A = \frac{\pi \cdot d^2}{4} \cdot 10^{-2}$$

$$p_{th} = \frac{F}{A} \cdot 10^{2}$$

$$A = \frac{\pi \cdot (d^2 - {d_1}^2)}{4} \cdot 10^{-2}$$

$$p = \frac{p_{th}}{\eta_{hm\%}} \cdot 10^{2}$$

*d_1 – piston rod diameter in mm

$$V = A \cdot H \cdot 10^{-4}$$

$$Q = A \cdot v \cdot 10^{-1}$$

$$Q = \frac{V}{t} \cdot 60$$

From (18) to (26) pressure losses in pipes

$$\Delta p = \lambda \cdot \frac{l \cdot \gamma}{d \cdot 2g} \cdot w^2 \cdot 10^2\ bar$$

γ=0,9 g/cm^3

$$\lambda_{laminar} = \frac{64}{Re} \qquad \lambda_{turbulent} = \frac{0{,}316}{\sqrt[4]{Re}}$$

g=9,81 m/s^2

$$Re = \frac{w \cdot d}{\upsilon} \cdot 10^{3}$$

l (pipe length) in m
ν in mm^2/s

From (27) to (29) Flow velocity in pipes

$$w = \frac{Q}{6 \cdot d^2 \cdot \frac{\pi}{4}} \cdot 10^{2}$$

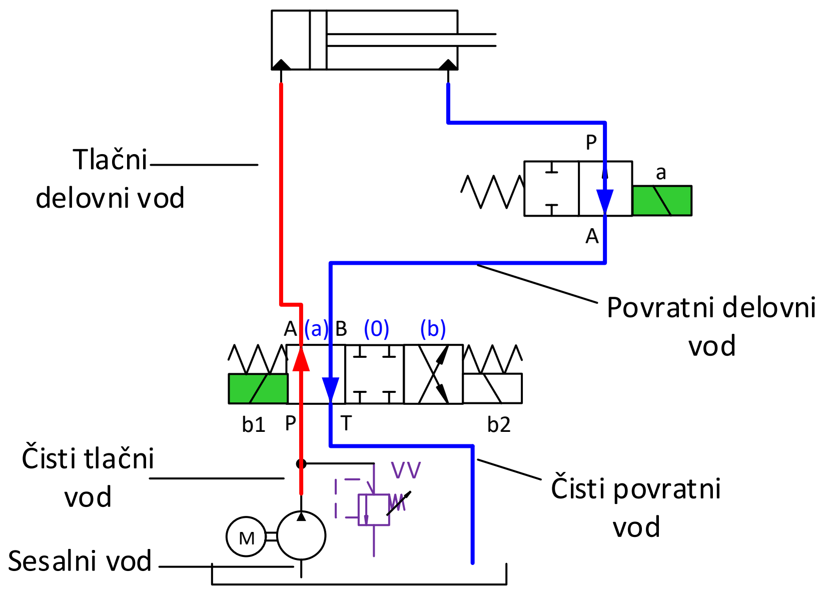
Remark: η in all formulas in %.

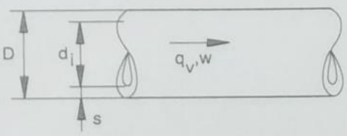
HITROSTI TOKA FLUIDA V CEVEH

Za sprejemljive tlačne izgube ob istočasno ne prevelikih dimenzijah cevovodov je primerno držati se naslednjih priporočil glede hitrosti toka fluida v ceveh:

- sesalni vod	v_S = 0,5 ÷ 1,5 m/s	
- povratni vod	v_T = 2 m/s	
- tlačni vod	p [bar]	v_P [m/s]
	0…10	3
	10…25	3,5
	25…50	4
	50…100	4,5
	100…150	5
	150…200	5,5
	200…300	6

Primer: hitri gib cilindra naprej.





DIN 2445
p_{nom}
$p_{max} = p_{nom} + 45$ bar

$p_{nom} = 100$ bar $p_{max} = 145$ bar		$p_{nom} = 160$ bar $p_{max} = 205$ bar		$p_{nom} = 250$ bar $p_{max} = 295$ bar		$p_{nom} = 320$ bar $p_{max} = 365$ bar		$p_{nom} = 400$ bar $p_{max} = 445$ bar	
D	s	D	s	D	s	D	s	D	s
6	1	6	1	6	1	6	1	6	1,5
8	1	8	1	8	1,5	8	1,5	8	2
10	1	10	1	10	1,5	10	1,5	10	2
12	1	12	1,5	12	2	12	2	12	2,5
16	1,5	16	1,5	16	2	16	2,5	16	3
20	1,5	20	2	20	2,5	20	3	20	4
25	2	25	2,5	25	3	25	4	25	5
30	2,5	30	3	30	4	30	5	30	6
38	3	38	4	38	5	38	6	38	8
50	4	50	5	50	6	50	8	50	10

Nach DIN 2445: $p_{max} = p_{nom} + 45$ bar