Fixed Displacement Pumps (ISO System of Units):

$$Qpt = \frac{Dp \times np}{1000}$$

$$Evp = [1 - \frac{Pp}{pevpd}\frac{nevpd}{np}(1 - Evpd)] \times 100$$

$$Qpa = Qpt \times Evp / 100$$

$$QpL = Qpt - Qpa$$

$$Npout = Pp \times Qpa / 600$$

$$Etp = Evp \times Emp / 100$$

$$Npin = 100 \times Npout / Etp$$

$$NpL = Npin - Npout$$

$$Tshp = (Npin \times 60 \times 1000) / (2 \times 3.14 \times np)$$

Operating Conditions:

np	Pump speed	rpm
Pp	Pump pressure	bar

Design Parameter:

Dp	Pump displacement	cc/rev
Emp	Pump hydro-mechanical efficiency at the operating conditions	%
Evpd	Pump volumetric efficiency at specified operating conditions	%
nevpd	Pump speed at which efv is defined	rpm
pevpd	Pump pressure at which efv is defined	bar

Output Data:

Evp	Pump volumetric efficiency at new operating conditions	%
Qpt	Pump theoretical flow rate	L/min
Qpa	Pump actual flow rate	L/min
QpL	Pump leakage flow rate	L/min
Etp	Pump total efficiency	%
Npout	Pump output power	kW
NpL	Pump power losses	kW
Npin	Pump drive motor power	kW
Tshp	Torque on the pump shaft	N.m

Fixed Displacement Motors (ISO System of Units):

$$Qmt = \frac{Dm \times nm}{1000}$$

$$Qma = Qpt \times 100 / Evm$$

$$QmL = Qma - Qpt$$

$$Pinm = \frac{2 \times 3.14 \times 1000 \times Tshm}{Emm \times Dm} + Poutm$$

$$Etm = Evm \times Emm / 100$$

$$Ninm = (Pinm - Poutm) \times Qma / 600$$

$$Noutm = Ninm \times Etm / 100$$

$$NmL = Ninm - Noutm$$

Operating Conditions:

nm	Motor speed	rpm
Poutm	Motor outlet pressure	bar
Tshm	Torque on the motor shaft	N.m

Design Parameter:

Dm	Motor displacement	cc/rev
Emm	Motor hydro-mechanical efficiency at the operating conditions	%
Evm	Motor volumetric efficiency at the operating conditions	%

Output Data:

Qmt	Motor theoretical flow rate	L/min
Qma	Motor actual flow rate	L/min
QmL	Motor leakage flow rate	L/min
Pinm	Motor inlet pressure	bar
Etm	Total motor efficiency	%
Noutm	Motor output power	kW
NmL	Motor power losses	kW
Ninm	Motor input power	kW

Double-Acting Hydraulic Cylinder, Static Solution (ISO System of Units):

$$Acap = \pi \times Dcap^2 / 4$$

$$AreaRatio = \frac{Acap}{Arod} = \frac{Dcap^2}{Dcap^2 - Drod^2} \Rightarrow Drod = Dcap\sqrt{\frac{AreaRatio - 1}{AreaRatio}}$$

Extension Stroke Solution: (resistive force applied):

$$Pcap = \frac{Prod \times Arod}{Acap} + \frac{9.81 \times Fcyl}{10 \times Acap} + \frac{kvf \times Vcyl}{10 \times Acap} = \frac{Prod}{AreaRatio} + \frac{9.81 \times Fcyl}{10 \times Acap} + \frac{kvf \times Vcyl}{10 \times Acap}$$

$$Vcyl = [Qcap \times 1000] / [Acap \times 60]$$

$$Stime = Scyl / [Vcyl \times 10]$$

$$Qrod = Qcap / AreaRatio$$

Retraction Stroke Solution: (resistive force applied):

$$Prod = [(10 \times Pcap \times Acap) + (9.81 \times Fcyl) + (kvf \times Vcyl)] / [10 \times Arod]$$

$$Vcyl = [Qrod \times 1000] / [Arod \times 60]$$

$$Stime = Scyl / [Vcyl \times 10]$$

$$Qcap = Qrod \times AreaRatio$$

Cylinder Dimensions:

Dcap	Cylinder bore	mm
Drod	Rod diameter	mm
Acap	Effective area at the cap side	cm^2
Arod	Effective area at the rod side	cm^2
Scyl	Cylinder stroke	mm

Cylinder Hydraulics:

Pcap	Working pressure at the cap side	bar
Prod	Working pressure at the rod side	bar
Qcap	Flow rate at cap side	L/min
Qrod	Flow rate at rod side	Lmin

Cylinder Dynamics:

Fcyl	Equivalent resistive force acts on the cylinder rod	kgf
Vcyl	Cylinder speed	cm/s
kvf	Viscous friction coefficient	N/(cm/s)
Stime	Time required to reach end of the cylinder stroke	s

Hydraulic Cylinder Buckling Calculations, (ISO System of Units):

$$Jrod = \frac{\pi \times Drod^4}{64 \times 1000^4}$$

$$SRatio = 4 \times Elength / Drod$$

$$CSRatio = \pi \sqrt{\frac{Erod}{0.8 \times YMrod}}$$

Euler's Equation (long cylinder strokes - elastic deformation period)

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if SRatio > CSRatio:

$$Bload = \frac{\pi^2 \times Erod \times 10^6 \times Jrod \times 100^2}{Elength^2 \times 9.81 \times 1000}$$

$$Aload = Bload / SF$$

Input Data:

Drod	Rod diameter	mm
Erod	Modulus of elasticity of cylinder rod	MPa
YMrod	Yield Strength of cylinder rod	MPa
SF	Safety Factor	-
Alength	Actual compressed length	cm
-	Load attachment to the cylinder rod	-

Output Data:

Elength	Effective length	cm
Jrod	Second moment of area	m^4
Bload	Critical buckling load	Ton
Aload	Allowable compressive load	Ton
SRatio	Slenderness Ratio	-
CSRatio	Critical slenderness ratio	-

Assumptions:

Load acting axially and cylinder rod is not subjected to side loads

Hydraulic Smooth Lines (Pipes/Tubes/Hoses) (ISO System of Units):

$$\text{Aline} = (\pi \times \text{Dline}^2)/(4 \times 100)$$

$$\text{Vline} = (1000 \times \text{Qline})/(\text{Aline} \times 60 \times 100)$$

$$\text{Re} = \frac{1000 \times \text{Vline} \times \text{Dline}}{\text{Viscosity}}$$

$$\text{Flow is Laminar} \rightarrow \text{FCline} = 64/\text{Re}$$

$$\text{Flow is Turbulent} \rightarrow \text{FCline} = 0.316/\text{Re}^{0.25}$$

$$\text{DPline} = \text{FCline} \times \frac{\text{Density}}{2} \times \frac{\text{Lline} \times 1000}{\text{Dline}} \times \frac{\text{Vline}^2}{10^5}$$

Operating Conditions:

Qline	Flow rate in the hydraulic line	L/min
Vicscosity	Fluid viscosity	cSt = 1mm/s
Density	Fluid density	kg/m^3

Design Parameter:

Dline	Hydraulic line diameter	mm
Lline	Hydraulic line length	m

Output Data:

Aline	Hydraulic line sectional area	cm^2
Vline	Flow speed	m/s
Re	Reynolds number	-
FCline	Friction coefficient	-
DPline	Pressure drop across the hydraulic line length	bar
-	Flow Status	-

Accumulator (ISO System of Units):

Piston Accumulator $\rightarrow$ P0 = P1 - 5

Bladder/Diaphragm accumulator $\rightarrow$ P0 = 0.85$\times$P1

If gas themrmal process is isothermal then

$$V1 = V0\left[\frac{P0}{P1}\right] \quad \text{and} \quad V2 = V0\left[\frac{P0}{P2}\right]$$

If gas themrmal process is adiabatic then

$$V1 = V0\left[\frac{P0}{P1}\right]^{\frac{1}{AE}} \quad \text{and} \quad V2 = V0\left[\frac{P0}{P2}\right]^{\frac{1}{AE}}$$

DV = V2-V1

$$ACHT = \frac{DV \times 60}{Qpump} \qquad ACHP = \frac{Qpump \times \frac{P1+P2}{2}}{600}$$

Operating Conditions:

P1	Minimum system absolute pressure	bar
P2	Maximum system absolute pressure	bar
AE	Adiabatic exponent	

Design Parameter:

V0	Accumulator nominal volume	Liter
Qpump	Pump flow rate	L/min

Output Data:

P0	Accumulator pre-charge absolute pressure	bar
V1	Gas volume at P1	Liter
V2	Gas volume at P2	Liter
DV	Oil stored volume	Liter
ACHT	Accumulator charging time	**s**
ACHP	Accumulator charging power	kW

Note:

For bladder/diaphragm, maximum pressure ratio P2/P0 should be respected

Conversion Factors:

Distance:

1 mm	=	0.03937008	in
1 cm	=	0.3937008	in
1 m	=	3.28084	ft

Area:

1 cm^2	=	0.1550003	in^2

Volume:

1 Liter	=	61.02374	in^3

Speed:

1 cm/s	=	0.3937008	in/s
1 m/s	=	3.28084	f/s

Force:

1 kgf	=	2.204623	lbf
1 Ton	=	2204.623	lbf

Work/Energy/Torque

1 N.m	=	0.73756	lb.ft

Power:

1 kW	=	1.36	HP

Pressure / Modulus od Elasticity

1 bar	=	14.6	psi
1 MPa	=	145.0377	psi

Pump/Motor Displacement:

1 cc/rev	=	0.06102374	in^3/rev

Flow Rate:

1 L/min	=	0.2641721	gpm

Density:

1 kg/m^3	=	0.06242796	lb/ft^3

Viscous Friction:

1 N/(cm/s)	=	0.571	lbf/(in/s)