

# FLUID POWER FORMULAS



## General fluid power guidelines

**Horsepower for driving a pump:** For every 1 hp of drive, the equivalent of 1 gpm @ 1,500 psi can be produced.

**Horsepower for idling a pump:** To idle a pump when it is unloaded will require about 5% of its full rated power.

**Wattage for heating hydraulic oil:** Each watt will raise the temperature of 1 gallon of oil by 1° F per hour.

**Flow velocity in hydraulic lines:** Pump suction lines 2 to 4 feet per second, pressure lines up to 500 psi - 10 to 15 ft./sec., pressure lines 500 to 3,000 psi - 15 to 20 ft./sec.; all oil lines in air-over-oil systems; 4 ft./sec.

## Basis formulas

Formula for:	Word formula:	Letter formula:
FLUID PRESSURE In Pounds/Square Inch	Pressure = $\frac{\text{Force (Pounds)}}{\text{Unit Area (Square Inches)}}$	$P = F/A$ or $\text{psi} = F/A$
FLUID FLOW RATE In Gallons/Minute	Flow Rate = $\frac{\text{Volume (Gallons)}}{\text{Unit Time (Minute)}}$	$Q = V/T$
FLUID POWER In Horsepower	Horsepower = $\frac{\text{Pressure (psi)} \times \text{Flow (GPM)}}{1714}$	$\text{hp} = PQ/1714$

## Fluid formulas

Formula for:	Word formula:	Letter formula:
VELOCITY THROUGH PIPING In Feet/Second Velocity	Velocity = $\frac{.3208 \times \text{Flow Rate through I.D. (GPM)}}{\text{Internal Area (Square Inches)}}$	$V = .3208Q/A$
COMPRESSIBILITY OF OIL In Additional Required Oil to Reach Pressure	Additional Volume = $\frac{\text{Pressure (psi)} \times \text{Volume of Oil under Pressure}}{250,000 \text{ (approx.)}}$	$V_A = PV/250,000 \text{ (approx.)}$
COMPRESSIBILITY OF A FLUID	Compressibility = $\frac{1}{\text{Bulk Modulus of the Fluid}}$	$C(\beta) = 1/BM$
SPECIFIC GRAVITY OF A FLUID	Specific Gravity = $\frac{\text{Weight of One Cubic Foot of Fluid}}{\text{Weight of One Cubic Foot of Water}}$	$SG = W/62.4283$
VALVE (Cv) FLOW FACTOR	Valve Factor = $\frac{\text{Flow Rate (GPM)} \sqrt{\text{Specific Gravity}}}{\sqrt{\text{Pressure Drop (psi)}}$	$C_v = (Q\sqrt{SG})/(\sqrt{\Delta p})$
VISCOSITY IN CENTISTOKES	For Viscosities of 32 to 100 Saybolt Universal Seconds:  Centistokes = $.2253 \times \text{SUS} - \left( \frac{194.4}{\text{SUS}} \right)$	$CS = .2253 \text{ SUS} - (194.4/\text{SUS})$
	For Viscosities of 100 to 240 Saybolt Universal Seconds:  Centistokes = $.2193 \times \text{SUS} - \left( \frac{134.6}{\text{SUS}} \right)$	$CS = .2193 \text{ SUS} - (134.6/\text{SUS})$
	For Viscosities greater than 240 Saybolt Universal Seconds:  Centistokes = $\left( \frac{\text{SUS}}{4.635} \right)$	$CS = \text{SUS}/4.635$

**Note:** Saybolt Universal Seconds can also be abbreviated as SSU.

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## Pump formulas

Formula for:	Word formula:	Letter formula:
PUMP OUTLET FLOW In Gallons/Minute	Flow = $\frac{\text{rpm} \times \text{Pump Displacement (Cu. In./Ref.)}}{231}$	$Q = nd/231$
PUMP INPUT POWER In Horsepower Required	Horsepower Input = $\frac{\text{Flow Rate Output (GPM)} \times \text{Pressure (psi)}}{1714 \text{ Efficiency (Overall)}}$	$HP_{in} = QP/1714\text{Eff.}$ or $(\text{GPM} \times \text{psi})/1714\text{Eff.}$
PUMP EFFICIENCY Overall in Percent	Overall Efficiency = $\left( \frac{\text{Output Horsepower}}{\text{Input Horsepower}} \right) \times 100$	$\text{Eff}_{ov} = (HP_{out} / HP_{in}) \times 100$
	Overall Efficiency = Volumetric Eff. x Mechanical Eff.	$\text{Eff}_{ov} = \text{Eff}_{vol} \times \text{Eff}_{mech}$
PUMP EFFICIENCY Volumetric in Percent	Volumetric Efficiency = $\frac{\text{Actual Flow Rate Output (GPM)}}{\text{Theoretical Flow Rate Output (GPM)}} \times 100$	$\text{Eff}_{vol} = (Q_{act} / Q_{theo}) \times 100$
PUMP EFFICIENCY Mechanical in Percent	Mechanical Efficiency = $\frac{\text{Actual Torque to Drive}}{\text{Theoretical Torque to Drive}} \times 100$	$\text{Eff}_{mech} = (T_{act} / T_{theo}) \times 100$

## Actuator formulas

Formula for:	Word formula:	Letter formula:
CYLINDER AREA In Square Inches	Area = $\pi \times \text{Radius}^2$ (Inches)	$A = \pi r^2$
	Area = $(P/4) \times \text{Diameter}^2$ (Inches)	$A = (\pi D^2)/4$ or $A = .785D^2$
CYLINDER FORCE In Pounds, Push or Pull	Area = Pressure (psi) x Net Area (sq in.)	$F = \text{psi} \times A$ or $F = PA$
CYLINDER VELOCITY or SPEED In Feet/Second	Velocity = $\frac{231 \times \text{Flow Rate (GPM)}}{12 \times 60 \times \text{Net Area (sq in.)}}$	$v = 231Q/720A$ or $v = .3208Q/A$
CYLINDER VOLUME CAPACITY In Gallons of Fluid	Volume = $\frac{\pi \times \text{Radius}^2 \text{ (in.)} \times \text{Stroke (in.)}}{231}$	$V = (\pi r^2 L)/231$
	Volume = $\frac{\text{Net Area (sq. in.)} \times \text{Stroke (in.)}}{231}$	$V = (A L)/231$
CYLINDER FLOW RATE In Gallons/Minute	Flow Rate = $\frac{12 \times 60 \times \text{Velocity (Ft/Sec)} \times \text{Net Area (sq. in.)}}{231}$	$Q = (720vA)/231$ or $Q = 3.117vA$
FLUID MOTOR TORQUE In Inch Pounds	Torque = $\frac{\text{Pressure (psi)} \times \text{F.M. Displacement (Cu. In./Rev.)}}{2\pi}$	$T = \text{psi} d/2\pi$ or $T = Pd/2\pi$
	Torque = $\frac{\text{Horsepower} \times 63025}{\text{rpm}}$	$T = 63025 \text{ hp/n}$
	Torque = $\frac{\text{Flow Rate (GPM)} \times \text{Pressure (psi)} \times 36.77}{\text{rpm}}$	$T = 36.77QP/n$ or $T = 36.77Q\text{psi}/n$
FLUID MOTOR TORQUE/100 psi In Inch Pounds	$\frac{\text{Torque}}{100} = \frac{\text{F.M. Displacement (Cu. In./Rev.)}}{.0628}$	$T_{100\text{psi}} = d/.0628$
FLUID MOTOR SPEED In Revolutions/Minute	Speed = $\frac{231 \text{ Flow Rate (GPM)}}{\text{F.M. Displacement (Cu. In./Rev.)}}$	$n = 231 Q/d$
FLUID MOTOR POWER In Horsepower Output	Horsepower = $\frac{\text{Torque Output (Inch Pounds)} \times \text{rpm}}{63025}$	$hp = Tn/63025$

## Thermal formulas

Formula for:	Word formula:	Letter formula:
RESERVOIR COOLING CAPACITY Based on Adequate Air Circulation	Heat (BTU/Hr) = 2 x Temperature Difference Between Reservoir Walls and Air (F) x Area of Reservoir (Sq. Ft.)	BTU/Hr = 2.0 x DT x A
HEAT IN HYDRAULIC OIL Due to System Inefficiency (SG=.89-.92)	Heat (BTU/Hr) = Flow Rate (GPM) x 210 x Temp. Difference (F)	BTU/Hr = Q x 210 x DT
HEAT IN FRESH WATER	Heat (BTU/Hr) = Flow Rate (GPM) x 500 x Temp. Difference (F)	BTU/Hr = Q x 500 x DT

**Note:** One British Thermal Unit (BTU) is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.  
One Horsepower = 2545 BTU/Hr.

## Accumulator formulas

Formula for:	Word formula:	Letter formula:
PRESSURE OR VOLUME With Constant T (Temperature)	Original Pressure x Original Volume = Final Pressure x Final Volume	$P_1V_1 = P_2V_2$ Isothermic
PRESSURE OR TEMPERATURE With Constant V (Volume)	Original Pressure x Final Temp. = Final Pressure x Original Temp.	$P_1T_2 = P_2T_1$ Isochoric
VOLUME OR TEMPERATURE With Constant P (Pressure)	Original Volume x Final Temp. = Final Volume x Original Temp.	$V_1T_2 = V_2T_1$ Isobaric
PRESSURE OR VOLUME With Temp. Change Due to Heat of Compression	Original Press. x Original Volume <sup>n</sup> = Final Press. x Final Volume <sup>n</sup>	$P_1V_1^n = P_2V_2^n$
	Final Temp./Orig. Temp. = (Orig. Vol./Final Vol.) <sup>n-1</sup> = (Final Press./Orig. Press.) <sup>(n-1)/n</sup>	$T_2/T_1 = (V_1/V_2)^{n-1} = (P_2/P_1)^{(n-1)/n}$

## Volume and capacity equivalents

	Cubic inches	Cubic feet	Cubic centimeters	Liters	U.S. gallons	Imperial gallons	Water at max density	
							Pounds of water	Kilograms of water
<b>Cubic inches</b>	1	0.0005787	16.384	0.016384	0.004329	0.0036065	0.361275	0.0163872
<b>Cubic feet</b>	1728	1	0.037037	28.317	7.48052	6.23210	62.4283	28.3170
<b>Cubic centimeters</b>	0.0610	0.0000353	1	0.001	0.000264	0.000220	0.002205	0.0001
<b>Liters</b>	61.0234	0.0353145	0.001308	1	0.264170	0.220083	2.20462	1
<b>U.S. gallons</b>	231	0.133681	0.004951	3.78543	1	0.833111	8.34545	3.78543
<b>Imperial gallons</b>	277.274	0.160459	0.0059429	4.54374	1.20032	1	10.0172	4.54373
<b>Pounds of water</b>	27.6798	0.0160184	0.0005929	0.453592	0.119825	0.0998281	1	0.453593