FLUID POWER FORMULAS

Certified Power SOLUTIONS

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	$\text{Pressure} = \dfrac{\text{Force (Pounds)}}{\text{Unit Area (Square Inches)}}$	P = F/A or psi = F/A
FLUID FLOW RATE In Gallons/Minute	$\text{Flow Rate} = \dfrac{\text{Volume (Gallons)}}{\text{Unit Time (Minute)}}$	Q = V/T
FLUID POWER In Horsepower	$\text{Horsepower} = \dfrac{\text{Pressure (psi) x Flow (GPM)}}{1714}$	hp = PQ/1714

Fluid formulas

Formula for:	Word formula:	Letter formula:
VELOCITY THROUGH PIPING In Feet/Second Velocity	$\text{Velocity} = \dfrac{\text{.3208 x Flow Rate through I.D. (GPM)}}{\text{Internal Area (Square Inches)}}$	V = .3208Q/A
COMPRESSIBILITY OF OIL In Additional Required Oil to Reach Pressure	$\text{Additional Volume} = \dfrac{\text{Pressure (psi) x Volume of Oil under Pressure}}{\text{250,000 (approx.)}}$	V_A = PV/250,000 (approx.)
COMPRESSIBILITY OF A FLUID	$\text{Compressibility} = \dfrac{1}{\text{Bulk Modulus of the Fluid}}$	C(ß) = 1/BM
SPECIFIC GRAVITY OF A FLUID	$\text{Specific Gravity} = \dfrac{\text{Weight of One Cubic Foot of Fluid}}{\text{Weight of One Cubic Foot of Water}}$	SG = W/62.4283
VALVE (Cv) FLOW FACTOR	$\text{Valve Factor} = \dfrac{\text{Flow Rate (GPM)}\sqrt{\text{Specific Gravity}}}{\sqrt{\text{Pressure Drop (psi)}}}$	$Cv = (Q\sqrt{SG})/(\sqrt{\Delta p})$
VISCOSITY IN CENTISTOKES	For Viscosities of 32 to 100 Saybolt Universal Seconds: $\text{Centistokes} = .2253 \times \text{SUS} - \left(\dfrac{194.4}{\text{SUS}}\right)$	CS = .2253 SUS - (194.4/SUS)
	For Viscosities of 100 to 240 Saybolt Universal Seconds: $\text{Centistokes} = .2193 \times \text{SUS} - \left(\dfrac{134.6}{\text{SUS}}\right)$	CS = .2193 SUS - (134.6/SUS)
	For Viscosities greater than 240 Saybolt Universal Seconds: $\text{Centistokes} = \left(\dfrac{\text{SUS}}{4.635}\right)$	CS = 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 = rpm x Pump Displacement (Cu. In./Ref.) / 231	Q = nd/231
PUMP INPUT POWER In Horsepower Required	Horsepower Input = Flow Rate Output (GPM) x Pressure (psi) / 1714 Efficiency (Overall)	HP_{in} = QP/1714Eff. or (GPM x psi)/1714Eff.
PUMP EFFICIENCY Overall in Percent	Overall Efficiency = (Output Horsepower / Input Horsepower) x 100	$Eff_{OV} = (HP_{out} / HP_{in}) \times 100$
	Overall Efficiency = Volumetric Eff. x Mechanical Eff.	$Eff_{ov} = Eff_{vol} \times Eff_{mech}$
PUMP EFFICIENCY Volumetric in Percent	Volumetric Efficiency = Actual Flow Rate Output (GPM) / Theoretical Flow Rate Output (GPM) x 100	$Eff_{vol} = (Q_{act} / Q_{theo}) \times 100$
PUMP EFFICIENCY Mechanical in Percent	Mechanical Efficiency = Actual Torque to Drive / Theoretical Torque to Drive x 100	$Eff_{mech} = (T_{act} / T_{theo}) \times 100$

Actuator formulas

Formula for:	Word formula:	Letter formula:
CYLINDER AREA In Square Inches	Area = ∏ x Radius² (Inches)	A = ∏r²
	Area = (P/4) x Diameter² (Inches)	A = (∏D²)/4 or A = .785D²
CYLINDER FORCE In Pounds, Push or Pull	Area = Pressure (psi) x Net Area (sq in.)	F = psi x A or F = PA
CYLINDER VELOCITY or SPEED In Feet/Second	Velocity = 231 x Flow Rate (GPM) / 12 x 60 x Net Area (sq in.)	v = 231Q/720A or v = .3208Q/A
CYLINDER VOLUME CAPACITY In Gallons of Fluid	Volume = ∏ x Radius² (in.) x Stroke (in.) / 231	V = (∏r²L)/231
	Volume = Net Area (sq. in.) x Stroke (in.) / 231	V= (A L)/231
CYLINDER FLOW RATE In Gallons/Minute	Flow Rate = 12 x 60 x Velocity (Ft/Sec) x Net Area (sq. in.) / 231	Q = (720vA)231 or Q = 3.117vA
FLUID MOTOR TORQUE In Inch Pounds	Torque = Pressure (psi) x F.M. Displacement (Cu. In./Rev.) / 2∏	T = psi d/2∏ or T = Pd/2∏
	Torque = Horsepower x 63025 / rpm	T = 63025 hp/n
	Torque = Flow Rate (GPM) x Pressure (psi) x 36.77 / rpm	T = 36.77QP/n or T = 36.77Qpsi/n
FLUID MOTOR TORQUE/100 psi In Inch Pounds	Torque / 100 = F.M. Displacement (Cu. In./Rev.) / .0628	T_{100psi} = d/.0628
FLUID MOTOR SPEED In Revolutions/Minute	Speed = 231 Flow Rate (GPM) / F.M. Displacement (Cu. In./Rev.)	n = 231 Q/d
FLUID MOTOR POWER In Horsepower Output	Horsepower = Torque Output (Inch Pounds) x rpm / 63025	hp = Tn/63025

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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^n = Final Press. x Final Volume^n	$P_1V_1^n=P_2V_2^n$
	Final Temp./Orig. Temp. = (Orig. Vol./Final Vol.)$^{n-1}$ = (Final Press./Orig. Press.)$^{(n-1)/n}$	$T_2/T_1=(V_1/V_2)^{n-1} = (P_2/P_1)^{(n-1)/n}$

Volume and capacity equivalents

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