Basic Fluid Power Formulas

Linear Force or Thrust:		
Force (lbs) = Area (in²) x Pressure (psi)	$F_{lb} = AREA\ x\ PSI$	$F_{lb} = Ap$
Force (N) = Area (cm²) x Pressure (bar) x 10	$F_N = (AREA\ x\ BAR)\ x\ 10$	$F_N = 10(Ap)$
Power (hydraulic):		
Power (hp) = Pressure (psi) x Flow (gpm) / 1714	$HP = \frac{PSI\ x\ GPM}{1714}$	$P_{hp} = \frac{pQ}{1714}$
Power (kW) = Pressure (bar) x Flow (lpm) / 600	$kW = \frac{BAR\ x\ LPM}{600}$	$P_{kW} = \frac{pQ}{600}$
***When calculating for sizing a system's prime mover, multiply answer by the pump's efficiency %.**		
Power (pneumatic):		
Power (hp) = Pressure (psi) x Flow (cfm) / 229	$HP = \frac{PSI\ x\ CFM}{229}$	$P_{hp} = \frac{pQ}{229}$
Power (kW) = Pressure (bar) x Flow (dm³/min) / 600	$kW = \frac{BAR\ x\ dm^3/MIN}{600}$	$P_{kW} = \frac{pQ}{600}$
Power (mechanical):		
Power (hp) = Torque (lb-in) x Speed (rpm) / 63025	$HP = \frac{LB.IN\ x\ RPM}{63025}$	$P_{hp} = \frac{Tn}{63025}$
Power (hp) =Torque (lb-ft) x Speed (rpm) / 5252	$HP = \frac{LB.FT\ x\ RPM}{5252}$	$P_{hp} = \frac{Tn}{5252}$
Power (hp) = Torque (Nm) x Speed (rpm) / 7124	$HP = \frac{Nm\ x\ RPM}{7124}$	$P_{hp} = \frac{Tn}{7124}$
Power (kW) = Torque (Nm) x Speed (rpm) / 9543	$kW = \frac{Nm\ x\ RPM}{9543}$	$P_{kW} = \frac{Tn}{9543}$
Fluid Power Motor Torque:		
Torque (lb-in) = Displacement (cir) x Pressure (psi) / 2π	$LB.IN. = \frac{CIR\ x\ PSI}{6.28}$	$T_{lbin} = \frac{Dp}{2\pi}$
Torque (lb-ft) = Displacement (cir) x Pressure (psi) / 24π	$LB.FT. = \frac{CIR\ x\ PSI}{75.40}$	$T_{lbft} = \frac{Dp}{24\pi}$
Torque (Nm) = Displacement (ccr) x Pressure (bar) / 20π	$Nm = \frac{CCR\ x\ BAR}{62.83}$	$T_{Nm} = \frac{Dp}{20\pi}$
Cylinder Travel Speed:		
Speed (in/min) = Flow (cim) / Area (in²)	$IN/MIN = \frac{CIM}{AREA}$	$v_{ipm} = \frac{Q}{A}$
Speed (cm/min) = Flow (ccm) / Area (cm²)	$CM/MIN = \frac{CCM}{AREA}$	$v_{cpm} = \frac{Q}{A}$
Velocity of Oil in Hydraulic Lines:		
Velocity (ft/sec) = Flow (gpm) x 0.3208 / Area (in²)	$FT/SEC = \frac{GPM\ x\ 0.3208}{AREA}$	$v_{fps} = \frac{0.3208Q}{A}$
Velocity (m/sec) = Flow (lpm) / Area (cm²) x 6	$M/SEC = \frac{LPM}{AREA\ x\ 6}$	$v_{mps} = \frac{Q}{6A}$

Pump Flow Required for Hydraulic Cylinder (estimate):		
Flow (gpm) = Area (in²) x 2 x Stroke (in) x Duty Cycle (cycles/min) / 231	$GPM = \frac{2(AREA\ x\ STROKE)\ x\ CPM}{231}$	
Flow (lpm) = Area (cm²) x 2 x Stroke (cm) x Duty Cycle (cycles/min) / 1000	$LPM = \frac{2(AREA\ x\ STROKE) x\ CPM}{1000}$	
Converting Free Air to Compressed Air (standard atm. conditions):		
Compression Ratio = Operating Pressure (psi) + 14.7 / 14.7	$C.R. = \frac{PSI + 14.7}{14.7}$	
Compressed Air (scfm) = Free Air (cfm) x Compression Ratio (C.R.)	$SCFM = CFM\ x\ C.R.$	
Compression Ratio = Operating Pressure (bar) + 1.013 / 1.013	$C.R. = \frac{BAR + 1.013}{1.013}$	
Compressed Air (slpm) = Free Air (lpm) x Compression Ratio (C.R.)	$SLPM = LPM\ x\ C.R.$	
Free air is ambient air at a given temperature and pressure, dependent on environmental conditions. The Compression Ratio is the ratio between the absolute discharge air and the absolute suction pressure. It is used to convert to compressed air delivery at standard atmospheric conditions (14.7 psia, 68°F, 36% relative humidity) at sea level.		
Air Consumption for Pneumatic Cylinder (estimate):		
Flow (scfm) = Area (in²) x 2 x Stroke (in) x Duty Cycle (cycles/min) / 1728 x Compression Ratio (C.R.)	$SCFM = C.R.\left(\frac{2(AREA\ x\ STROKE) x\ CPM}{1728}\right)$	
Sizing an Air Compressor:		
Avergae System Demand (cfm) = Compressor Delivery (scfm) x Duty Cycle (% on) / Compression Ratio (C.R.) x 100	$CFM = \frac{SCFM\ x\ DUTY\ CYCLE\ \%}{C.R. X\ 100}$	
On Time (min) = Tank Volume (in³) x (Max. Pressure (psi) – Min. Pressure (psi)) / 14.7 x Compressed Air Flow (scfm)	$ON\ TIME = \frac{IN^3\ x\ (PSI_{max} - PSI_{\min})}{14.7\ x\ SCFM}$	$T_{\min} = \frac{V(p_1 - p_2)}{14.7\ x\ Q}$
Sizing a Hydraulic Accumulator (isothermal conditions):		
Combined Gas Law: $p_1V_1T_2 = p_2V_2T_1$ (*use absolute values) Where: • p_1 = Precharge Pressure (psia) • p_2 = Minimum System Pressure (psia) • p_3 = Maximum System Pressure (psia)	• V_1 = Empty Accumulator Gas Volume (in³) • V_2 = Accumulator Gas Volume (in³) @ P_2 • V_3 = Accumulator Gas Volume (in³) @ P_3 • ΔV = Oil Outlet Flow (in³)	
$\boldsymbol{\Delta V = \frac{(V_1p_1)(p_3 - p_2)}{(p_3p_2)}}$	$V_1 = \frac{\Delta V(p_3p_2)}{p_1(p_3 - p_2)}$	
Sizing a Valve:		
Hydraulic Valve; Where: • C_v = Velocity Coefficient • Q = Flow (gpm)	• Δp = Differential pressure between inlet & outlet (psi) • SG = Specific Gravity of Liquid Media	
$\boldsymbol{C_v = \frac{Q\sqrt{SG}}{\sqrt{\Delta p}}}$	$Q = C_v\sqrt{\frac{\Delta p}{SG}}$	
The metric equivalent to C_v is flow factor, noted as K_v. The equation is identical, though the units of flow used are cubic meters per hour (m³/hr) and units of pressure used are bar.		

Pneumatic Valve; Where: • C_v = Velocity Coefficient • Q = Flow (scfm) • Δp = Differential pressure between inlet & outlet (psi)	• p_1 = Absolute Inlet Pressure (psia) • p_2 = Absolute Outlet Pressure (psia) • SG = Specific Gravity of Gaseous Media
Subsonic Flow: $$\boldsymbol{C_v = \frac{Q\sqrt{SG}}{\sqrt{p_2 \Delta p}}}$$	$$Q = C_v \sqrt{\frac{p_2 \Delta p}{SG}}$$
Sonic Flow (choked flow): $$\boldsymbol{C_v = \frac{Q\sqrt{SG}}{\left(\frac{p_1}{2}\right)}}$$	• Critical velocity is reached when absolute downstream (outlet) pressure is less than or equal to 53% of absolute upstream (inlet) pressure.
The metric equivalent to C_v is flow factor, noted as K_v. The equations are identical, though the units of flow used are normal cubic meters per hour (m^3/hr) and units of pressure used are bar/bara.	
$$\boldsymbol{C_v = \frac{K_v}{0.86}}$$	$$K_v = 0.86C_v$$

General Information and "Rules of Thumb":

Estimating pump drive horsepower: 1 hp of input drive for each 1 gpm at 1,500 psi pump output

Horsepower when idling a pump: an idle and unloaded pump will require about 5% of its full rate hp

Reservoir capacity (Gallons) = length (in) x width (in) x height (in) x air gap % / 231

Oil compressibility: 1/2% approximate volume reduction for every 1,000 psi of pressure

Wattage to heat hydraulic oil: each 1 watt will raise the temperature of 1 gallon of oil by 1°F per hour

1 HP = 0.746 kW = 2545 BTU/hr = 746 Watts = 44,760 Joules/min

1 bar = 14.5 psi = 100 kPa = 0.987 atm = 29.603"Hg

1 atm = 14.7 psi = 1.013 bar = 29.921"Hg

1"Hg = 0.49 psi = 13.609"H_2O

1 in = 25.4 mm

1 in^2 = 6.45 cm^2

1 in^3 = 16.387 cm^3

1 ft^2 = 144 in^2 = 929 cm^2

1 ft^3 = 1728 in^3 = 28.317 liters = 7.481 gallons

1 gallon = 3.785 liters = 231 in^3 = 0.134 ft^3

1 lb-ft = 12 lb-in = 1.356 Nm

1 meter/sec = 3.28 ft/sec = 39.36 in/sec

°C = 5/9(°F -32); °F = °C x 9/5 + 32

°K = °C + 273.7; °R = °F + 459.7

Guidelines for flow velocity in hydraulic lines:

2 to 4 ft/sec = suction lines

10 to 15 ft/sec = pressure lines up to 500 psi

15 to 20 ft/sec = pressure lines 500 – 3,000 psi

25 ft/sec = pressure lines over 3,000 psi

4 ft/sec = any oil lines in air-over-oil systems