TENNCO, INC

EXCELLENCE IN FLUID POWER

Fluid Power Formula

Cylinder Formula

Cylinder Force	
Cap End Area (A)	Bore Diameter Squared x 0.7854 ($0.7854D^2$)
Net Rod End Area	Bore Diameter Squared x 0.7854 Minus Rod Diameter Squared x 0.7854 ($0.7854 D^2$ Bore – $0.7854 D^2$ Rod)
Force Extend	Cap End Area x PSI
Force Extend Regeneration	Rod Area x PSI
Force Retract	Net Rod End Area x PSI

Note: Always size an air cylinder at least 25% above load balance or work force to get nominal speed and/or nominal force buildup time.

For fast speed and fast work force buildup time size them up to 100% above load balance. (More than 100% above load balance gives negligible added cylinder speed.)

Size hydraulic cylinders at least 10% above load balance or work force to get full speed at full force and/or nominal force buildup time.

Cylinder Speed	
Gallons per Inch (GPI)	$\frac{\text{A (Area)}}{\text{231 (in}^3\text{/Gallon)}}$
Inches per Minute (IPM)	$\frac{\text{Stroke Length x 60 (Seconds)}}{\text{Stroke Time (Seconds)}}$
Inches per Second (IPS)	$\frac{\text{Stroke Length}}{\text{Stroke Time (Seconds)}}$
Flow at Speed GPM	GPI x IPM
Flow at Speed IPM	GPM / GPI
Flow at Speed GPI	GPM / IPM
GPM	$\frac{\text{(Area) x Stroke Length x 60 (Seconds)}}{\text{Stroke Time (Seconds) x 231 (in}^3\text{/Gallon)}}$
A (Area)	$\frac{\text{Stroke Time (Seconds) x 231 (in}^3\text{/Gallon) x GPM}}{\text{Stroke Length x 60 (Seconds)}}$
Stroke Length	$\frac{\text{Stroke Time (Seconds) x 231 (in}^3\text{/Gallon) x GPM}}{\text{A (Area) x 60 (Seconds)}}$
Stroke Time	$\frac{\text{A (Area) x Stroke Length x 60 (Seconds)}}{\text{GPM x 231 (in}^3\text{/Gallon)}}$

Cylinder Rod End Intensification	
Single Rod End Cylinders	$\frac{\text{Cylinder Bore A (Area)}}{\text{Cylinder Net Rod End A (Area)}}$
Double Rod End Cylinders	$\frac{\text{Net Rod End A (Area) of Large Rod}}{\text{Net Rod End A (Area) of Small Rod}}$
Cylinder Load Induced Pressure	
Vertical Rod Down Cylinder	$\frac{\text{Load in Pounds}}{\text{Net Rod End A (Area)}}$
Vertical Rod Up Cylinder	$\frac{\text{Load in Pounds}}{\text{Bore A (Area)}}$

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EXCELLENCE IN FLUID POWER

Fluid Power Formula

Fluid Motor Formula

Hydraulic Motors

Torque, Horsepower, Speed Relations		
Torque (lb. in.)	$\frac{\text{HP x 63,025}}{2\varpi}$	*For lb-ft use 5,252 Constant in Place of 63,025*
Torque (lb. in.)	$\frac{\text{PSI x Displacement (in}^3\text{/Revolution)}}{2\varpi}$	
Torque (lb. in.)	$\frac{\text{GPM x PSI x 36.77}}{\text{RPM}}$	*For more accurate answer use 36.77071 in place of 36.77*
Torque (lb. in.)	$\frac{\text{Motor Displacement (in}^3\text{/Revolution)}}{0.0628}$	
Rule of Thumb: 1 CIR	16 lb. In. @ 100 PSI	
Horsepower	$\frac{\text{Torque (lb-in) x RPM}}{\text{63,025}}$	*For Newton Meters Divide Answer lb-in by 8.851 lb-ft by 0.7375*
RPM	$\frac{\text{Horsepower x 63,025}}{\text{Torque}}$	
Flow Formula		
Flow Rate at 100% Efficiency: Q (Flow GPM)	$\frac{\text{RPM x CIR (in}^3\text{/Revolution Displacement)}}{\text{231 (in}^3\text{/Gallon)}}$	

Multiply the answer by the manufacturers published efficiency percent for actual speed of a newmotor.

Efficiency Formula	
Mechanical Efficiency E_M	$\frac{\text{Torque Actual}}{\text{Torque Theoretical}}$
Volumetric Efficiency E_M	$\frac{\text{Q (Flow Actual)}}{\text{Q (Flow Theoretical)}}$

Air Motors

Design for maximum torque at approximately half operating air pressure.

Follow manufacturers recommendations for a given motor type for Starting Torque, Maximum RPM, Maximum Torque and CFM air inlet flow.

Run the air motor only when doing work. Remember an air motor can pull 7-15 compressor HP for each 1 HP output

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EXCELLENCE IN FLUID POWER

Fluid Power Formula

SIZING A PNEUMATIC CIRCUIT

The following information must be known

1. Maximum force required	Usually in pounds or tons of force
2. Total stroke required	Usually in inches
3. Total cylinder cycle time	Usually in seconds
4. System operating pressure	Arbitrarily 80 PSI for most plants

Sample problem

1. Maximum force required	150 pounds
2. Total stroke required	14 inches
3. Total cylinder cycle time	4 seconds
4. System operating pressure	80 PSI

A. Minimum Cylinder Bore = $\sqrt{\dfrac{\text{Maximum Force Required x 1.25 or 2 / Maximum PSI Allowed}}{.7854}}$

$$\sqrt{\frac{\text{150 Pounds x 1.25/80 PSI}}{.7854}} = 1.727 \text{ Diameter or a } \mathbf{2" \text{ Bore}}$$

B. SCFM = $\sqrt{\dfrac{\text{V(Vol. in.}^3\text{) x Compression Ratio (PSI + 14.7 / 14.7)}}{\text{Total Cycle Time Seconds x 28.8}}}$

$$\text{SCFM} = \sqrt{\frac{2 \times 2.7854 \times 28 \times (80 + 14.7 / 14.7)}{4 \times 28.8}} = \mathbf{4.92 \text{ SCFM}}$$

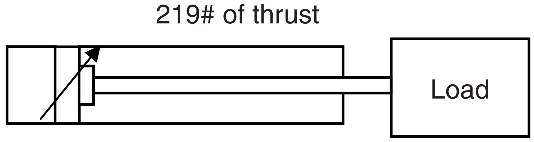
28” is for cylinder extend and retract. Rod displacement is disregarded in this example

C. Min. Valve C_V = $\dfrac{\text{Q (Flow SCFM)}}{\text{22.48 (Constant)}} \sqrt{\dfrac{T_A \text{ (Abs. Temp) x } S_g \text{ (Spec Gravity 1 for air)}}{\Delta P \text{ (Pr. Drop) x (} P_2 \text{ (Outlet Pr.) + } P_A \text{ (Atmos. Pr.))}}}$

$$\text{Min. Valve } C_V = \frac{4.92}{22.48} \sqrt{\frac{460 \times 1}{10 \times (70 + 14.7)}} = .161 = \mathbf{1/8" \text{ ported valve}}$$

219# of thrust

2” Bore @ 80 PSI Load



Cylinder will move at nominal speed

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Fluid Power Formula

SIZING A PNEUMATIC CIRCUIT

Sizing air cylinders is similar to sizing hydraulic cylinders. Most air systems operate around 100 to 120 PSI with approximately 80 PSI readily available at the machine site. This gives little or no option for selecting operating pressure.

Since the compressor is part of plant facilities, the amount of cubic feet per minute (CFM) of air available for the air circuit usually is many times that required. It is good practice though, to check for ample CFM flow capabilities at the machine location.

The only items needed to figure an air circuit is maximum force required, cylinder stroke, and cycle time. With this information, sizing cylinders, valves, and piping is simple.

To figure the cylinder bore required, use the formula given at A. Notice the added multiplier on the force line. For an air cylinder to move at a nominal rate, it needs approximately 25% greater thrust than the force required to offset the load. When the cylinder must move fast, figure a force at up to twice that required to balance the load.

The reason for this added force relates to filling an empty tank from a tank at 100 PSI. When air first starts transferring, a high pressure difference allows fast flow. As the two tanks get closer to the same pressure the rate of transfer slows until the gauges almost stop moving. The last five to ten PSI of transfer takes a long time. As the tanks get close to the same pressure, there is less reason for transfer since pressure difference is so low.

If an air cylinder needs 78 PSI to balance the load, then it has only 2 PSI differential to move fluid into the cylinder at a system pressure of 80 PSI. If it moves at all, it is very slow and intermittent. As pressure differential increases, from higher inlet pressure or less load, the cylinder starts to move smoothly and steadily. The greater the differential the faster the cylinder movement. Once cylinder force is twice the load balance, speed increase is minimal.

Using the 1.25 figure in the formula shows a cylinder bore of 1.72" minimum. Choose a 2" bore cylinder since it is the next size greater than 1.72."

To size the valve use the “flow coefficient,” or C_V rating formula. The C_V factor is an expression of how many gallons of water pass through a valve, from inlet to outlet, at a certain pressure differential. There are many ways of reporting C_V valve efficiency and some may be misleading. Always look at pressure drop allowed when figuring the C_V, to be able to compare different brands intelligently.

The formula shows a valve with 1/8” ports is big enough to cycle the 2" bore cylinder out 14" and back 14" in 4 seconds.

There are many charts in data books as well as valve manufacturers catalogs that take the drudgery out of sizing valves and pipes. There are several computer programs as well to help in proper sizing of components.