

# Fluid Power Formula

These Formula Cover All Fluid Power Applications  
In This Manual

For Computer Programs To Work Problems  
By Simply Filling In The Blanks

See

Your Local Fluid Power Distributor

Many Companies Web Site Or CD

Also See

The Fluid Power Data Book  
Packaged With This Manual

For Charts and Other Fluid Power Information



# Fluid Power Formula

## Miscellaneous Fluid Power Formula

$$\text{Fluid Pressure} = \frac{\text{Force (Pounds)}}{\text{Unit Area (in}^2\text{)}}$$

$$\text{Velocity Through Pipes in Feet/Second (FPS)} = \frac{0.320833 \times \text{GPM (Flow Through Conduit)}}{\text{Internal Area of Conduit (in}^2\text{)}}$$

$$\text{Extra Hydraulic Oil Required to Fill a Volume (in}^3\text{)} = \frac{\text{PSI} \times \text{Volume (in}^3\text{)}}{250,000} \quad \text{Based on } \frac{1}{2} \text{ of } 1\%/1,000 \text{ PSI}$$

$$\text{Compressibility of a Fluid} = \frac{1}{\text{Bulk Modulus of the Fluid}}$$

$$\text{Specific Gravity of a Fluid} = \frac{\text{Weight of 1 ft}^3 \text{ of the Fluid}}{\text{Weight of 1 ft}^3 \text{ of Water}}$$

### Orifice Flow

$$\text{Pressure Drop } (\Delta P) \text{ Across an Orifice} = \frac{(\text{Flow in GPM (Q)} \times S_G)^2}{29.81 \times d^2 \times \Delta P}$$

$C_d$  = Orifice Coefficient  
From 0.61-0.98 According to  
Orifice Length and Shape.  
0.65 is a Nominal Figure

$$\text{Flow GPM (Q) Across an Orifice} = 29.81 \times C_d \times d^2 \sqrt{\Delta P}$$

$S_G$  = Specific Gravity  
Range .87-.90 For Hyd. Oil  
.88 is a Nominal Figure

$$\text{Diameter of an Orifice } d^2 = \frac{\text{Flow in GPM (Q)} \times S_G}{\sqrt{29.81 \times C_d \times \Delta P}}$$

### Circle Formula:

$$\text{Circumference of a Circle} = \pi D^2 \quad (3.1416 \times \text{Diameter Squared})$$

$$\text{Area of a Circle (in}^2\text{)} = \pi r^2 \quad (3.1416 \times \text{radius}^2) \quad \text{OR} \quad \frac{\pi D^2}{4} \quad \text{OR} \quad .7854 D^2$$

### Volume Formula:

$$\text{Volume (in}^3\text{) of Round Object} = \text{Area (in}^2\text{)} \times \text{Length}$$

$$\text{Volume of Square or Rectangular Object} = \text{Length} \times \text{Width} \times \text{Depth}$$

### Tube Burst Calculations:

$$\text{Barlow Formula} \quad p = \frac{2ST}{D}$$

$p$  = Burst Pressure PSI

$S$  = Ultimate Strength of Tube Material, PSI  
 $T$  = Nominal Wall Thickness, Inches  
 $D$  = Nominal OD of Tubing, Inches

### Boyles Law:

$$P_1 V_1 = P_2 V_2$$

$$P_1 = \frac{P_2 V_2}{V_1}$$

$$P_2 = \frac{P_1 V_1}{V_2}$$

$$V_1 = \frac{P_2 V_2}{P_1}$$

$$V_2 = \frac{P_1 V_1}{P_2}$$

$P_1$  = Pressure 1 Absolute. (Gauge Pressure Plus 14.7)

$P_2$  = Pressure 2 Absolute. (Gauge Pressure Plus 14.7)

$V_1$  = Actual Gas Volume at Pressure 1

$V_2$  = Actual Gas Volume at Pressure 2

# Fluid Power Formula

## Miscellaneous Fluid Power Formula (Cont'd.)

### Charles Law:

$$T_1 V_2 = T_2 V_1$$

$$T_1 = \frac{T_2 V_1}{V_2}$$

$$T_2 = \frac{T_1 V_2}{V_1}$$

$$V_1 = \frac{T_1 V_2}{T_2}$$

$$V_2 = \frac{T_2 V_1}{T_1}$$

$T_1$  = Absolute Temperature of Gas at Volume 1 (Temp. °F + 459.7)

$T_2$  = Absolute Temperature of Gas at Volume 2 (Temp. °F + 459.7)

$V_1$  = Volume of Gas at Temperature 1

$V_2$  = Volume of Gas at Temperature 2

### General Gas Law:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$P_1 = \frac{P_2 V_2 T_1}{T_2 V_1}$$

$$P_2 = \frac{P_1 V_1 T_2}{T_1 V_2}$$

$$V_1 = \frac{P_2 V_2 T_1}{T_2 P_1}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2}$$

$$T_1 = \frac{P_2 V_2}{P_1 V_1 T_2}$$

$$T_2 = \frac{P_1 V_1}{P_2 V_2 T_1}$$

$P_1$  = Pressure 1 Absolute. (Gauge Pressure Plus 14.7)

$P_2$  = Pressure 2 Absolute. (Gauge Pressure Plus 14.7)

$V_1$  = Actual Gas Volume at Pressure 1

$V_2$  = Actual Gas Volume at Pressure 2

$T_1$  = Absolute Temperature of Gas at Volume 1 (Temp. °F + 459.7)

$T_2$  = Absolute Temperature of Gas at Volume 2 (Temp. °F + 459.7)

### Flow Velocity In Hydraulic Lines:

Suction Line	Low Pressure	2-4 Feet/Second
Return Lines	Low Pressure	10-15 Feet/Second
Medium Pressure Lines	500-3,000 PSI	15-20 Feet/Second
High Pressure Lines	3,000 PSI up	25-30 Feet/Second
Air-Oil Systems	All Pressures	2-4 Feet/Second
Work (in-lbs) = Force (Pounds) x Distance (Inches) (Feet)		(Inches) gives Inch Pounds
(ft-lbs)		(Feet) gives Foot Pounds

# Fluid Power Formula

## Cylinder Formula

### **Cylinder Force:**

$$\text{Cap End Area (A)} = \text{Bore Diameter Squared} \times 0.7854 \quad (0.7854D^2)$$

$$\text{Net Rod End Area} = \text{Bore Diameter Squared} \times 0.7854 \text{ Minus Rod Diameter Squared} \times 0.7854 \\ (0.7854 D^2 \text{ Bore} - 0.7854 D^2 \text{ Rod})$$

$$\text{Force Extend} = \text{Cap End Area} \times \text{PSI}$$

$$\text{Force Extend Regeneration} = \text{Rod Area} \times \text{PSI}$$

$$\text{Force Retract} = \text{Net Rod End Area} \times \text{PSI}$$

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:**

$$\text{Gallons per Inch (GPI)} = \frac{\text{A (Area)}}{231 (\text{in}^3/\text{Gallon})}$$

$$\text{Inches per Minute (IPM)} = \frac{\text{Stroke Length} \times 60 (\text{Seconds})}{\text{Stroke Time (Seconds)}}$$

$$\text{Inches per Second (IPS)} = \frac{\text{Stroke Length}}{\text{Stroke Time (Seconds)}}$$

$$\text{Flow at Speed} \quad \text{GPM} = \text{GPI} \times \text{IPM}$$

$$\text{IPM} = \text{GPM}/\text{GPI}$$

$$\text{GPI} = \text{GPM}/\text{IPM}$$

$$\text{Also: GPM} = \frac{\text{A (Area)} \times \text{Stroke Length} \times 60 (\text{Seconds})}{\text{Stroke Time (Seconds)} \times 231 (\text{in}^3/\text{Gallon})}$$

$$\text{A (Area)} = \frac{\text{Stroke Time (Seconds)} \times 231 (\text{in}^3/\text{Gallon}) \times \text{GPM}}{\text{Stroke Length} \times 60 (\text{Seconds})}$$

$$\text{Stroke Length} = \frac{\text{Stroke Time (Seconds)} \times 231 (\text{in}^3/\text{Gallon}) \times \text{GPM}}{\text{A (Area)} \times 60 (\text{Seconds})}$$

$$\text{Stroke Time} = \frac{\text{A (Area)} \times \text{Stroke Length} \times 60 (\text{Seconds})}{\text{GPM} \times 231 (\text{in}^3/\text{Gallon})}$$

### **Cylinder Rod End Intensification:**

$$\text{Single Rod End Cylinders} = \frac{\text{Cylinder Bore A (Area)}}{\text{Cylinder Net Rod End A (Area)}}$$

$$\text{Double Rod End Cylinders} = \frac{\text{Net Rod End A (Area) of Large Rod}}{\text{Net Rod End A (Area) of Small Rod}}$$

### **Cylinder Load Induced Pressure:**

$$\text{Vertical Rod Down Cylinder} = \frac{\text{Load in Pounds}}{\text{Net Rod End A (Area)}}$$

$$\text{Vertical Rod Up Cylinder} = \frac{\text{Load in Pounds}}{\text{Bore A (Area)}}$$

# Fluid Power Formula

## Fluid Motor Formula

### Hydraulic Motors

#### Torque, Horsepower, Speed Relations

$$\text{Torque (lb. in.)} = \frac{\text{HP} \times 63,025}{2\pi} \quad \text{For lb-ft use 5,252 Constant in Place of 63,025}$$

$$\text{Torque (lb. in.)} = \frac{\text{PSI} \times \text{Displacement (in}^3/\text{Revolution)}}{2\pi}$$

$$\text{Torque (lb. in.)} = \frac{\text{GPM} \times \text{PSI} \times 36.77}{\text{RPM}} \quad \text{For more accurate answer use 36.77071 in place of 36.77}$$

$$\text{Torque (lb. in.)} = \frac{\text{Motor Displacement (in}^3/\text{Revolution)}}{0.0628}$$

Rule of Thumb: 1 CIR = 16 lb. In. @ 100 PSI

$$\text{Horsepower} = \frac{\text{Torque (lb-in)} \times \text{RPM}}{63,025} \quad \text{For Newton Meters Divide Answers lb-in by 8.851}$$

$$\text{RPM} = \frac{\text{Horsepower} \times 63,025}{\text{Torque}} \quad \text{lb-ft. by 0.7375}$$

#### Flow Formula:

$$\text{Flow Rate at 100\% Efficiency: } Q \text{ (Flow GPM)} = \frac{\text{RPM} \times \text{CIR (in}^3/\text{Revolution Displacement)}}{231 \text{ (in}^3/\text{Gallon)}}$$

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

#### Efficiency Formula:

$$\text{Mechanical Efficiency } E_M = \frac{\text{Torque Actual}}{\text{Torque Theoretical}}$$

$$\text{Volumetric Efficiency } E_M = \frac{Q \text{ (Flow Actual)}}{Q \text{ (Flow Theoretical)}}$$

$$\text{Overall Efficiency } E_M = \frac{\text{HP Out}}{\text{HP In}}$$

#### 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.

# Fluid Power Formula

## Hydraulic Pump Formula

### Flow Rate:

$$\text{Flow Rate at 100\% Efficiency: } Q \text{ (Flow GPM)} = \frac{\text{RPM} \times \text{CIR (in}^3 \text{ / Re volution Displacement)}}{231 \text{ (in}^3 \text{ / Gallon)}}$$

Take Q times manufacturers Overall Efficiency Rating at a given pressure to get actual output.

$$\text{Pump CIR (in}^3 \text{ / Re volution Displacement)} = \frac{Q \text{ (Flow GPM)} \times 231 \text{ (in}^3 \text{ / Gallon)}}{\text{RPM}}$$

### Horsepower, Torque:

$$\text{Horsepower to drive a pump @ 100\% efficiency} \quad \text{HP} = \text{GPM} \times \text{PSI} \times 0.000583$$

$$\text{Horsepower to drive a pump @ 85\% efficiency} \quad \text{HP} = \text{GPM} \times \text{PSI} \times 0.000686$$

$$\text{Rule of Thumb:} \quad 1 \text{ GPM @ 1,500 PSI} = 1 \text{ HP}$$

$$\text{Torque (lb. in.)} = \frac{\text{PSI} \times \text{CIR (in}^3 \text{ / Re volution Displacement)}}{2\pi} \quad (\text{Replace } 2\pi \text{ with } 24\pi \text{ for lb.ft.)}$$

$$\text{Torque (lb. in.)} = \frac{\text{HP} \times 63,025}{\text{RPM}} \quad (\text{Replace } 63,025 \text{ with } 5,252 \text{ for lb.ft.)}$$

### Efficiency Formula for Pumps:

$$\text{Mechanical Efficiency} \quad E_M = \frac{\text{Torque Actual}}{\text{Torque Theoretical}}$$

$$\text{Volumetric Efficiency} \quad E_V = \frac{Q \text{ (Flow Actual)}}{Q \text{ (Flow Theoretical)}}$$

$$\text{Overall Efficiency} \quad E_{OA} = \frac{\text{HP Out}}{\text{HP In}}$$

### B<sub>10</sub> Bearing Life:

$$B_{10} \text{ Bearing Life (Hours)} = \text{Rated Life (Hours)} \times \left( \frac{\text{Rated Speed (RPM)}}{\text{Actual Speed (RPM)}} \right) \times \left( \frac{\text{Rated Pressure (PSI)}}{\text{Actual Pressure (PSI)}} \right)$$

### Need to Remember Items About Pumps:

Pumps do not make pressure they only make flow. Resistance to flow makes pressure.

Fluid is pushed into a pumps inlet not “sucked.” A pump makes negative pressure at its inlet and Atmospheric pressure pushes fluid in to fill the void of low pressure.

Where possible mount the pump so its inlet is below fluid level. Install a shutoff valve in the inlet line to reduce pump repair or replacement time.

In most catalogs Gear and Vane pumps are rated at 1,200 RPM while Piston pumps are rated at 1,800 RPM. Multiply Gear and Vane pumps rated flow by 1.5 to get flow at 1,800 RPM. Multiply Piston pump flow by 0.6667 to get flow at 1,200 RPM.

For fast priming of a pump in a closed center circuit use an Air Bleed Valve at its outlet. Pipe the return of the Air Bleed Valve so it terminates below fluid level.

Always fill the case of a pressure compensated pump with hydraulic fluid before startup.

Always pipe Case Drain Flow Lines to terminate below fluid level. When the Case Drain Line terminates above fluid level poor sealing of the Cylinder Block to the Valve Plate can suck in bypass fluid faster than it is made and empty the case of lubricating fluid.

# Fluid Power Formula

## Thermal Formulas

### Heat in a Hydraulic System Generated by Wasted Energy:

$$\text{Heat (BTU/Hour)} = \text{Flow Rate (GPM)} \times \text{Pressure Drop (PSI)}$$

$$\text{Flow Rate (GPM)} = \frac{\text{Heat (BTU/Hour)}}{1.485 \times \text{Pressure Drop (PSI)}}$$

$$\text{Pressure Drop (PSI)} = \frac{\text{Heat (BTU/Hour)}}{\text{Flow Rate (GPM)} \times 1.485}$$

### Kilowatts Required to Heat Hydraulic Oil:

$$\text{KW} = \frac{\text{Tank Capacity Gallons} \times (\text{Desired Min. Fluid Temp.}^{\circ}\text{F} - \text{Min. Ambient Temp.}^{\circ}\text{F})}{800 \times \text{Allowable Time in Hours}}$$

Note: Allow at least one hour and up to three hours for heating from minimum temperature.  
To only maintain heat, reduce the KW rating by  $1/2 - 2/3^{\text{rds}}$  in relation to the time in hours allotted.

### Cooling Capacity of a Hydraulic Reservoir at the Poorest Ambient Conditions:

$$\text{HP} = .001 \times (\text{Max. Allowable Fluid Temp.}^{\circ}\text{F} - \text{Max. Ambient Air Temp.}^{\circ}\text{F}) \times \text{Area in Contact W/Fluid (ft}^2\text{)}$$

## Equivalents

One Horsepower Equals:

746 Watts  
42.4 BTU/Minute  
2,545 BTU/Hour  
550 Ft. Lbs/Second  
33,000 Ft. Lb./Minute

1 Bar at Sea Level Equals

14.504 PSI  
0.98692 atmospheres  
33.6 Ft. Water Column  
41 Ft Oil Column

One U.S. Gallon Equals:

Four Quarts, Eight Pints  
128 Ounces (Liquid)  
133.37 Ounces (Weight)  
8.3356 Pounds  
3.785 Liters  
231 Cubic Inches  
0.8333 Imperial Gallons

1 PSI Equals

2.0416" H<sub>g</sub>  
27.771" Water Column  
0.0689 Bar

1 Hg Equals

0.490 PSI  
1.131 Ft. Water Column

One Liter Equals 0.2642 U.S. Gallons

1 Atmosphere at Sea Level Equals

1.013 Bar  
29.291" H<sub>g</sub>  
14.696 PSI  
760 mm H<sub>g</sub>

1 Ft. Water Column Equals

0.432 PSI

1 Ft. Oil Column Equals

0.354 PSI

Atmosphere Decreases Approximately  $1/2$  PSI/1,000 Feet of Elevation

# Fluid Power Formula

## Accumulator Formula

### **General Rules for Sizing and Applying Accumulators:**

Use dry nitrogen to pre-charge an accumulator. Other gasses may have ample pressure but can be a safety or explosion hazard.

Use a pre-charge pressure of 85-90% of minimum system pressure. This keeps some fluid in the accumulator at all times and keeps the bladder or piston from bottoming out during normal operation.

When pre-charge pressure is less than 50-60% of maximum pressure use a piston type accumulator. Bladder type accumulators sustain fast bladder chafing damage below the 50% mark. Piston type accumulators have no problem with low pre-charge pressure as long as the piston is not forced to bottom out as the nitrogen is compressed.

Use a bladder type accumulator for short, rapid high pressure pulses such as shock absorbing. A piston type accumulator in this application can have premature seal failure due to lack of lubrication.

Use the greatest possible difference in maximum system pressure and minimum working pressure to reduce accumulator size and/or number.

Check accumulator pre-charge pressure daily on a new installation or replacement for first week of operation. If pressure is holding, check weekly for three weeks and if pressure is holding check every three to six months. See Chapter 16 Page 16-5 for a simple non-invasive way to check pressure.

Always provide a means of automatically and/or manually dumping stored energy in the accumulator when the system is shut down. Also apply warning signs indicating an accumulator is present and must be checked for stored fluid, at the operating station, control panel and the accumulator.

Always use a check valve between the pump and accumulator inlet to stop back flow to the pump when the circuit is shut down.

# Fluid Power Formula

## Accumulator Formula (Cont'd.)

### Supplementing Pump Flow:

Solving for accumulator size in Gallons

$$V1 = \underline{\hspace{2cm}} \text{ Gallons}$$

Information Required:

Minimum pressure required to satisfy circuit needs:

$$P2 = \underline{\hspace{2cm}} \text{ PSI}$$

Maximum pressure available or allowed:

$$P3 = \underline{\hspace{2cm}} \text{ PSI}$$

Required cycle time of actuator in seconds

$$AC = \underline{\hspace{2cm}} \text{ Seconds}$$

Oil volume capacity to cycle the actuator in Cubic Inches

$$VA = \underline{\hspace{2cm}} \text{ in}^3$$

Dwell time in seconds when no actuators are moving

$$AD = \underline{\hspace{2cm}} \text{ Seconds}$$

Normal system operating temperature in F

$$T = \underline{\hspace{2cm}} \text{ Temp. } ^\circ\text{F}$$

Solve for minimum flow rate (FR) from pump in Cubic Inches/Second

$$FR = \frac{VA}{AD + AC}$$

Solve for minimum pump flow (Q) in Cubic Inches/Second

$$Q = .26 \times FR$$

Solve for total cubic inches of fluid from accumulator  $V_x$

$$V_x = VA - (3.85 \times Q \times AC)$$

Solve for ratio of Minimum to Maximum pressure (a)

$$a = \frac{P3}{P2}$$

From Chart 1, page 10 select (n) using this formula for "Average Pressure" and Normal System Operating Temperature from above.

$$\frac{P2 + P3}{2}$$

Select a figure for (f) from the Charts on pages 11-13 using (a) and (n) above

Solve for (V1) Accumulator Volume in Gallons

$$V1 = \frac{(V_x / 231)}{.807 \times f}$$

Pick out an accumulator or accumulators with an empty capacity equal to or greater than the answer for V1 above. Pre-charge with dry nitrogen at 85% of P2.

### Making up for System Leakage:

Solving for accumulator size in  $\text{in}^3$

$$V1 = \underline{\hspace{2cm}} \text{ in}^3$$

Information Required:

Minimum pressure required to satisfy circuit needs (P2):

$$P2 = \underline{\hspace{2cm}} \text{ PSI}$$

Maximum pressure available or allowed (P3):

$$P3 = \underline{\hspace{2cm}} \text{ PSI}$$

Required cycle time of actuator in seconds (LR)

$$LR = \underline{\hspace{2cm}} \text{ in}^3/\text{Minute}$$

Length in minutes accumulator must hold pressure (TM)

$$TM = \underline{\hspace{2cm}} \text{ Minutes}$$

Solve for:

Solve for ratio of Minimum to Maximum pressure (a)

$$a = \frac{P3}{P2}$$

Since this application is Isothermal, it is not necessary to the reference Charts on pages 11-13. (f) is found by

$$f = 1 - \frac{1}{a}$$

Volume of oil required from accumulator ( $V_x$ )

$$V_x = LR \times TM$$

Solve for Accumulator Volume in  $\text{in}^3$  (V1)

$$V1 = \frac{V_x}{.807 \times f}$$

Pick out an accumulator or accumulators with an empty capacity equal to or greater than the answer for V1 above. Pre-charge with dry nitrogen at 85% of P2.

# Fluid Power Formula

## Accumulator Formula (Cont'd.)

### Emergency Power Supply:

Solving for accumulator size in Gallons

$$V1 = \underline{\hspace{2cm}} \text{ Gallons}$$

Information Required:

Minimum pressure required to satisfy circuit needs:

$$P2 = \underline{\hspace{2cm}} \text{ PSI}$$

Maximum pressure available or allowed:

$$P3 = \underline{\hspace{2cm}} \text{ PSI}$$

Oil volume capacity to cycle the actuators in in<sup>3</sup>

$$VA = \underline{\hspace{2cm}} \text{ in}^3$$

Normal system operating temperature in F

$$T = \underline{\hspace{2cm}} \text{ Temp. } ^\circ\text{F}$$

Solve for ratio of Minimum to Maximum pressure (a)

$$a = \frac{P3}{P2}$$

From Chart 1, page 10 select (n) using this formula for "Average Pressure" and Normal System Operating Temperature from above.

$$\frac{P2 + P3}{2}$$

Select a figure for (f) from the Charts on pages 11-13 using (a) and (n) above

Solve for (V1) Accumulator Volume in Gallons

$$V1 = \frac{(VA / 231)}{.807 \times f}$$

Pick out an accumulator or accumulators with an empty capacity equal to or greater than the answer for V1 above. Pre-charge with dry nitrogen at 85% of P2.

### Hydraulic Line Shock Control:

Solving for accumulator size in in<sup>3</sup>

$$V1 = \underline{\hspace{2cm}} \text{ in}^3$$

Information Required:

Normal system operating pressure (P2):

$$P2 = \underline{\hspace{2cm}} \text{ PSI}$$

Length of pipe generating the shock measured in feet between the pump and valve. (L):

$$L = \underline{\hspace{2cm}} \text{ Feet}$$

Internal area of pipe in in<sup>2</sup> (A)

$$A = \underline{\hspace{2cm}} \text{ in}^2$$

Flow rate of pump in GPM (Q)

$$Q = \underline{\hspace{2cm}} \text{ GPM}$$

Normal system operating temperature in F

$$T = \underline{\hspace{2cm}} \text{ Temp. } ^\circ\text{F}$$

From Chart 1, page 10 select (n) using P2 for "Average Pressure" and Normal System Operating Temperature from above.

$$n = \underline{\hspace{2cm}}$$

Solve for total volume in pipe (TV) in ft<sup>3</sup>

$$TV = \frac{L \times A}{144}$$

Solve for total weight of fluid in pipe in pounds (TW)

$$TW = TV \times 53.04$$

Solve for fluid velocity in feet/second (FPS) (FV)

$$FV = \frac{.3208 \times Q}{A}$$

Pick a figure from Chart 2 page 10 for (C3)

$$C3 = \underline{\hspace{2cm}}$$

Solve for V1 Accumulator volume in in<sup>3</sup>

$$V1 = \frac{FV^2 \times TW \times (n-1) \times .186}{P2 \times C3}$$

Pick out an accumulator or accumulators with an empty capacity equal to or greater than the answer for V1 above. Pre-charge with dry nitrogen at 95-105% of P2

# Fluid Power Formula

## Accumulator Formula (Cont'd.)

### Piston Pump Discharge Shock Control:

Solving for accumulator size in in<sup>3</sup>

$$V1 = \text{_____} \text{ in}^3$$

Information Required:

Normal system operating pressure (P2):

$$P2 = \text{_____} \text{ PSI}$$

Length of piston stroke in inches.(L):

$$L = \text{_____} \text{ Inches}$$

Area of piston bores in the pump in in<sup>2</sup> (A)

$$A = \text{_____} \text{ in}^2$$

Pump constant (K)

$$K = \text{_____}$$

.60 for single piston single acting pumps.

.25 for single piston double acting pumps

.25 for double piston single acting pumps.

.15 for double piston double acting pumps.

.13 for triple piston single acting pumps.

.06 for triple piston double acting pumps.

Normal system operating temperature in F

$$T = \text{_____} \text{ Temp. } ^\circ\text{F}$$

From Chart 1, below, select (n) using P2 for "Average Pressure" and Normal System Operating Temperature from above.

$$n = \text{_____}$$

Pick a figure from Chart 2 below for (C1)

$$C1 = \text{_____}$$

Pick a figure from Chart 2 below for (C2)

$$C2 = \text{_____}$$

Solve for V1 Accumulator volume in in<sup>3</sup>

$$V1 = \frac{L \times A \times K \times C1}{1 - C2}$$

Pick out an accumulator or accumulators with an empty capacity equal to or greater than the answer for V1 above. Pre-charge with dry nitrogen at 95-105% of P2

Chart 1

Average Pressure	Temperature					
	77 F	108 F	140 F	171 F	200 F	220 F
98	1.41					
123	1.42	1.42				
148	1.43	1.42				
172	1.43	1.43	1.43	1.43	1.43	1.43
197	1.44	1.43	1.43	1.43	1.43	1.43
222	1.44	1.44	1.44	1.44	1.44	1.44
246	1.45	1.44	1.44	1.44	1.44	1.44
295	1.46	1.45	1.45	1.45	1.45	1.45
345	1.47	1.47	1.46	1.46	1.45	1.45
395	1.48	1.47	1.46	1.46	1.46	1.46
443	1.49	1.48	1.47	1.47	1.46	1.46
492	1.51	1.49	1.48	1.48	1.47	1.47
590	1.53	1.51	1.50	1.50	1.49	1.48
690	1.55	1.53	1.52	1.52	1.50	1.49
788	1.57	1.54	1.53	1.52	1.51	1.50
886	1.60	1.56	1.56	1.54	1.53	1.52
985	1.62	1.58	1.56	1.55	1.53	1.52
1230	1.65	1.61	1.59	1.58	1.56	1.55
1476	1.70	1.65	1.63	1.61	1.59	1.57
1723	1.74	1.67	1.64	1.62	1.60	1.58
1970	1.78	1.71	1.68	1.66	1.62	1.61
2215	1.82	1.74	1.71	1.68	1.65	1.62
2462	1.86	1.79	1.75	1.71	1.66	1.63
2800	1.92	1.84	1.79	1.75	1.70	1.66
3000	1.94	1.86	1.81	1.76	1.71	1.67

Chart 2

"n"	"c1"	"c2"	"c3"
1.41 Thru 1.45	1.036	.966	.0300
1.46 Thru 1.49	1.035	.967	.0318
1.50 Thru 1.53	1.034	.968	.0336
1.54 Thru 1.57	1.033	.969	.0352
1.58 Thru 1.62	1.032	.970	.0371
1.63 Thru 1.67	1.031	.971	.0389
1.68 Thru 1.73	1.030	.972	.0410
1.74 Thru 1.79	1.029	.973	.0429
1.80 Thru 1.85	1.028	.974	.0447
1.86 Thru 1.91	1.027	.975	.0464
1.92 Thru 1.94	1.026	.976	.0472

# Fluid Power Formula

To use this chart locate “a” in the left hand column and “n” across the top. The correct value for “f” is in the body of the chart where “a” and “n” intersect. When the exact value for “a” is not shown use the next higher figure.

“a”	“n”																			
	1.40	1.41	1.42	1.43	1.44	1.45	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.55	1.56	1.57	1.58	
1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.05	0.0342	0.0340	0.0338	0.0335	0.0333	0.0331	0.0329	0.0328	0.0324	0.0322	0.0320	0.0318	0.0316	0.0314	0.0312	0.0310	0.0308	0.0306	0.0304	0.0304
1.10	0.0658	0.0654	0.0649	0.0645	0.0640	0.0636	0.0632	0.0628	0.0624	0.0620	0.0616	0.0612	0.0608	0.0604	0.0600	0.0596	0.0593	0.0589	0.0585	0.0585
1.15	0.0950	0.0944	0.0937	0.0931	0.0925	0.0919	0.0913	0.0907	0.0901	0.0895	0.0890	0.0884	0.0878	0.0873	0.0868	0.0862	0.0857	0.0852	0.0847	0.0847
1.20	0.1221	0.1213	0.1205	0.1197	0.1189	0.1182	0.1174	0.1166	0.1159	0.1152	0.1145	0.1137	0.1130	0.1123	0.1117	0.1110	0.1109	0.1096	0.1090	0.1090
1.25	0.1473	0.1464	0.1454	0.1445	0.1436	0.1426	0.1417	0.1408	0.1400	0.1391	0.1382	0.1374	0.1365	0.1357	0.1349	0.1341	0.1333	0.1325	0.1317	0.1317
1.30	0.1709	0.1698	0.1687	0.1676	0.1666	0.1655	0.1645	0.1635	0.1624	0.1615	0.1605	0.1595	0.1585	0.1576	0.1566	0.1557	0.1548	0.1539	0.1530	0.1530
1.35	0.1929	0.1917	0.1905	0.1893	0.1881	0.1870	0.1858	0.1847	0.1835	0.1824	0.1813	0.1802	0.1792	0.1781	0.1771	0.1760	0.1750	0.1740	0.1730	0.1730
1.40	0.2136	0.2123	0.2110	0.2097	0.2084	0.2071	0.2058	0.2046	0.2034	0.2021	0.2009	0.1997	0.1986	0.1974	0.1963	0.1951	0.1940	0.1929	0.1918	0.1918
1.45	0.2331	0.2317	0.2302	0.2288	0.2274	0.2261	0.2247	0.2233	0.2220	0.2207	0.2194	0.2181	0.2169	0.2156	0.2144	0.2132	0.2119	0.2107	0.2096	0.2096
1.50	0.2515	0.2499	0.2484	0.2469	0.2454	0.2439	0.2425	0.2411	0.2396	0.2382	0.2369	0.2355	0.2341	0.2328	0.2315	0.2302	0.2289	0.2276	0.2263	0.2263
1.55	0.2688	0.2672	0.2655	0.2640	0.2624	0.2608	0.2593	0.2578	0.2563	0.2548	0.2534	0.2519	0.2505	0.2491	0.2477	0.2463	0.2449	0.2436	0.2422	0.2422
1.60	0.2852	0.2835	0.2818	0.2801	0.2785	0.2769	0.2752	0.2737	0.2721	0.2705	0.2690	0.2675	0.2660	0.2645	0.2630	0.2616	0.2601	0.2587	0.2573	0.2573
1.65	0.3007	0.2989	0.2972	0.2954	0.2937	0.2920	0.2904	0.2887	0.2871	0.2854	0.2838	0.2823	0.2807	0.2791	0.2776	0.2761	0.2746	0.2731	0.2716	0.2716
1.70	0.3155	0.3136	0.3118	0.3100	0.3082	0.3065	0.3047	0.3030	0.3013	0.2995	0.2980	0.2963	0.2947	0.2931	0.2915	0.2899	0.2883	0.2868	0.2853	0.2853
1.75	0.3295	0.3276	0.3257	0.3238	0.3220	0.3202	0.3184	0.3166	0.3149	0.3131	0.3114	0.3097	0.3080	0.3053	0.3047	0.3031	0.3014	0.2998	0.2983	0.2983
1.80	0.3429	0.3409	0.3390	0.3370	0.3351	0.3333	0.3314	0.3298	0.3278	0.3260	0.3242	0.3224	0.3207	0.3190	0.3173	0.3156	0.3139	0.3123	0.3107	0.3107
1.85	0.3556	0.3536	0.3516	0.3496	0.3477	0.3458	0.3438	0.3420	0.3401	0.3383	0.3364	0.3346	0.3328	0.3311	0.3293	0.3276	0.3259	0.3242	0.3225	0.3225
1.90	0.3677	0.3657	0.3637	0.3616	0.3596	0.3577	0.3557	0.3538	0.3519	0.3500	0.3481	0.3463	0.3444	0.3426	0.3408	0.3391	0.3373	0.3356	0.3338	0.3338
1.95	0.3794	0.3773	0.3752	0.3731	0.3711	0.3691	0.3671	0.3651	0.3632	0.3612	0.3593	0.3574	0.3556	0.3537	0.3519	0.3500	0.3483	0.3165	0.3447	0.3447
2.00	0.3905	0.3883	0.3862	0.3841	0.3821	0.3800	0.3780	0.3760	0.3740	0.3720	0.3700	0.3681	0.3662	0.3643	0.3624	0.3606	0.3587	0.3569	0.3551	0.3551
2.05	0.4011	0.3990	0.3968	0.3947	0.3926	0.3905	0.3884	0.3863	0.3843	0.3823	0.3803	0.3784	0.3764	0.3745	0.3726	0.3707	0.3688	0.3670	0.3651	0.3651
2.10	0.4114	0.4092	0.4070	0.4048	0.4026	0.4006	0.3984	0.3963	0.3943	0.3922	0.3902	0.3882	0.3862	0.3843	0.3823	0.3804	0.3785	0.3766	0.3747	0.3747
2.15	0.4212	0.4189	0.4167	0.4145	0.4123	0.4102	0.4080	0.4059	0.4038	0.4017	0.3997	0.3977	0.3956	0.3937	0.3917	0.3897	0.3878	0.3859	0.3840	0.3840
2.20	0.4306	0.4283	0.4261	0.4238	0.4216	0.4194	0.4173	0.4151	0.4130	0.4109	0.4088	0.4068	0.4047	0.4027	0.4007	0.3987	0.3967	0.3948	0.3929	0.3929
2.25	0.4397	0.4374	0.4351	0.4328	0.4306	0.4284	0.4262	0.4240	0.4219	0.4197	0.4176	0.4155	0.4135	0.4114	0.4094	0.4074	0.4054	0.4034	0.4015	0.4015
2.30	0.4484	0.4461	0.4438	0.4415	0.4392	0.4370	0.4347	0.4326	0.4304	0.4282	0.4261	0.4240	0.4219	0.4198	0.4177	0.4157	0.4137	0.4117	0.4097	0.4097
2.35	0.4568	0.4545	0.4521	0.4498	0.4475	0.4453	0.4430	0.4408	0.4386	0.4364	0.4343	0.4321	0.4300	0.4279	0.4258	0.4238	0.4217	0.4197	0.4177	0.4177
2.40	0.4649	0.4625	0.4602	0.4579	0.4655	0.4533	0.4510	0.4487	0.4465	0.4443	0.4421	0.4400	0.4378	0.4357	0.4336	0.4315	0.4295	0.4274	0.4254	0.4254
2.45	0.4727	0.4703	0.4680	0.4656	0.4633	0.4610	0.4587	0.4564	0.4542	0.4520	0.4498	0.4476	0.4454	0.4433	0.4412	0.4390	0.4370	0.4349	0.4329	0.4329
2.50	0.4803	0.4779	0.4755	0.4731	0.4708	0.4684	0.4661	0.4638	0.4616	0.4593	0.4571	0.4549	0.4527	0.4506	0.4484	0.4463	0.4442	0.4421	0.4401	0.4401
2.55	0.4876	0.4852	0.4827	0.4804	0.4780	0.4756	0.4733	0.4710	0.4687	0.4665	0.4642	0.4620	0.4598	0.4576	0.4555	0.4533	0.4512	0.4491	0.4470	0.4470
2.60	0.4927	0.4922	0.4898	0.4874	0.4850	0.4826	0.4803	0.4780	0.4757	0.4734	0.4711	0.4689	0.4667	0.4645	0.4623	0.4601	0.4580	0.4559	0.4538	0.4538
2.65	0.5015	0.4990	0.4966	0.4941	0.4917	0.4894	0.4870	0.4847	0.4824	0.4801	0.4778	0.4755	0.4733	0.4711	0.4689	0.4667	0.4646	0.4625	0.4603	0.4603
2.70	0.5081	0.5056	0.5032	0.5007	0.4983	0.4959	0.4935	0.4912	0.4889	0.4866	0.4843	0.4820	0.4798	0.4775	0.4753	0.4731	0.4710	0.4688	0.4667	0.4667
2.75	0.5145	0.5120	0.5095	0.5071	0.5047	0.5022	0.4999	0.4975	0.4952	0.4928	0.4905	0.4883	0.4860	0.4838	0.4815	0.4793	0.4772	0.4750	0.4728	0.4728
2.80	0.5207	0.5182	0.5157	0.5133	0.5108	0.5084	0.5060	0.5036	0.5013	0.4989	0.4956	0.4943	0.4921	0.4898	0.4876	0.4854	0.4832	0.4810	0.4788	0.4788
2.85	0.5267	0.5242	0.5217	0.5192	0.5168	0.5144	0.5120	0.5096	0.5072	0.5049	0.5026	0.5062	0.4979	0.4957	0.4934	0.4912	0.4890	0.4868	0.4846	0.4846
2.90	0.5326	0.5300	0.5275	0.5251	0.5226	0.5202	0.5177	0.5153	0.5130	0.5106	0.5083	0.5059	0.5036	0.5014	0.4991	0.4969	0.4947	0.4924	0.4903	0.4903
2.95	0.5382	0.5357	0.5332	0.5307	0.5282	0.5258	0.5233	0.5209	0.5185	0.5162	0.5138	0.5115	0.5092	0.5069	0.5046	0.5024	0.5002	0.4979	0.4958	0.4958
3.00	0.5438	0.5412	0.5387	0.5362	0.5337	0.5312	0.5288	0.5264	0.5240	0.5216	0.5193	0.5169	0.5146	0.5123	0.5100	0.5078	0.5055	0.5033	0.5011	0.5011

Continued on Next Page

# Fluid Power Formula

To use this chart locate “a” in the left hand column and “n” across the top. The correct value for “f” is in the body of the chart where “a” and “n” intersect. When the exact value for “a” is not shown use the next higher figure.

“a”	“n”																	
	1.59	1.60	1.61	1.62	1.63	1.64	1.65	1.66	1.67	1.68	1.69	1.70	1.71	1.72	1.73	1.74	1.75	1.76
1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.05	0.0302	0.0300	0.0298	0.0297	0.0295	0.0293	0.0201	0.0290	0.0288	0.0286	0.0285	0.0283	0.0281	0.0280	0.0278	0.0277	0.0275	0.0273
1.10	0.0582	0.0578	0.0575	0.0571	0.0568	0.0565	0.0561	0.0558	0.0555	0.0552	0.0548	0.0545	0.0542	0.0539	0.0536	0.0533	0.0530	0.0527
1.15	0.0841	0.0836	0.0831	0.0827	0.0822	0.0817	0.0812	0.0807	0.0803	0.0798	0.0794	0.0789	0.0785	0.0780	0.0776	0.0772	0.0768	0.0763
1.20	0.1083	0.1077	0.1071	0.1054	0.1058	0.1052	0.1046	0.1040	0.1034	0.1028	0.1023	0.1017	0.1011	0.1006	0.1000	0.0995	0.0989	0.0984
1.25	0.1309	0.1302	0.1294	0.1287	0.1279	0.1272	0.1265	0.1258	0.1251	0.1244	0.1237	0.1230	0.1223	0.1217	0.1210	0.1204	0.1197	0.1191
1.30	0.1521	0.1512	0.1504	0.1495	0.1487	0.1478	0.1470	0.1462	0.1454	0.1446	0.1438	0.1430	0.1422	0.1415	0.1407	0.1400	0.1392	0.1385
1.35	0.1720	0.1710	0.1701	0.1691	0.1682	0.1672	0.1663	0.1654	0.1645	0.1636	0.1627	0.1618	0.1610	0.1601	0.1593	0.1584	0.1576	0.1568
1.40	0.1907	0.1897	0.1886	0.1875	0.1865	0.1855	0.1845	0.1835	0.1825	0.1815	0.1805	0.1796	0.1786	0.1777	0.1767	0.1758	0.1749	0.1740
1.45	0.2084	0.2072	0.2061	0.2050	0.2038	0.2027	0.2016	0.2006	0.1995	0.1984	0.1974	0.1963	0.1953	0.1943	0.1933	0.1923	0.1913	0.1903
1.50	0.2251	0.2239	0.2226	0.2214	0.2202	0.2190	0.2179	0.2167	0.2156	0.2144	0.2133	0.2122	0.2111	0.2100	0.2089	0.2079	0.2068	0.2058
1.55	0.2409	0.2396	0.2383	0.2370	0.2358	0.2345	0.2333	0.2320	0.2308	0.2296	0.2284	0.2272	0.2261	0.2249	0.2238	0.2227	0.2215	0.2204
1.60	0.2559	0.2545	0.2532	0.2518	0.2505	0.2492	0.2479	0.2466	0.2453	0.2440	0.2428	0.2415	0.2403	0.2391	0.2379	0.2367	0.2355	0.2344
1.65	0.2702	0.2687	0.2673	0.2659	0.2645	0.2631	0.2618	0.2604	0.2591	0.2578	0.2564	0.2552	0.2539	0.2526	0.2513	0.2501	0.2489	0.2476
1.70	0.2838	0.2823	0.2808	0.2793	0.2779	0.2764	0.2750	0.2736	0.2722	0.2708	0.2695	0.2681	0.2668	0.2655	0.2641	0.2628	0.2616	0.2603
1.75	0.2967	0.2951	0.2936	0.2921	0.2906	0.2891	0.2876	0.2862	0.2847	0.2833	0.2819	0.2805	0.2791	0.3777	0.3754	0.3750	0.3737	0.2724
1.80	0.3090	0.3074	0.3059	0.3043	0.3027	0.3012	0.2997	0.2982	0.2967	0.2952	0.2938	0.2923	0.2909	0.2895	0.2881	0.2867	0.2853	0.2839
1.85	0.3208	0.3192	0.3176	0.3160	0.3144	0.3128	0.3112	0.3097	0.3081	0.3066	0.3051	0.3036	0.3022	0.3007	0.2992	0.2978	0.2954	0.2950
1.90	0.3321	0.3305	0.3288	0.3271	0.3255	0.3239	0.3223	0.3207	0.3191	0.3175	0.3160	0.3145	0.3130	0.3115	0.3100	0.3085	0.3070	0.3056
1.95	0.3430	0.3412	0.3395	0.3378	0.3362	0.3245	0.3329	0.3312	0.3296	0.3280	0.3264	0.3249	0.3233	0.3218	0.3202	0.3187	0.3172	0.3158
2.00	0.3533	0.3516	0.3498	0.3481	0.3464	0.3447	0.3430	0.3413	0.3397	0.3381	0.3364	0.3346	0.3333	0.3317	0.3301	0.3286	0.3270	0.3255
2.05	0.3633	0.3615	0.3597	0.3580	0.3562	0.3545	0.3528	0.3511	0.3494	0.3477	0.3461	0.3444	0.3428	0.3412	0.3396	0.3380	0.3365	0.3349
2.10	0.3729	0.3711	0.3692	0.3674	0.3657	0.3639	0.3622	0.3604	0.3587	0.3570	0.3553	0.3537	0.3520	0.3504	0.3488	0.3471	0.3456	0.3440
2.15	0.3821	0.3802	0.3784	0.3766	0.3748	0.3730	0.3712	0.3694	0.3677	0.3660	0.3642	0.3625	0.3609	0.3592	0.3576	0.3559	0.3543	0.3527
2.20	0.3910	0.3891	0.3872	0.3853	0.3835	0.3817	0.3799	0.3781	0.3763	0.3746	0.3728	0.3711	0.3694	0.3677	0.3660	0.3644	0.3627	0.3611
2.25	0.3995	0.3976	0.3957	0.3938	0.3920	0.3901	0.3883	0.3865	0.3847	0.3829	0.3811	0.3794	0.3776	0.3759	0.3742	0.3725	0.3709	0.3692
2.30	0.4078	0.4058	0.4039	0.4020	0.4001	0.3982	0.3964	0.3945	0.3927	0.3909	0.3891	0.3873	0.3856	0.3838	0.3821	0.3804	0.3787	0.3770
2.35	0.4157	0.4138	0.4118	0.4099	0.4080	0.4061	0.4042	0.4023	0.4005	0.3987	0.3968	0.3950	0.3933	0.3915	0.3897	0.3880	0.3863	0.3846
2.40	0.4234	0.4214	0.4194	0.4175	0.4156	0.4136	0.4117	0.4099	0.4080	0.4061	0.4043	0.4025	0.4007	0.3989	0.3971	0.3954	0.3936	0.3919
2.45	0.4308	0.4288	0.4268	0.4249	0.4229	0.4210	0.4190	0.4171	0.4153	0.4134	0.4115	0.4097	0.4079	0.4061	0.4043	0.4025	0.4007	0.3990
2.50	0.4380	0.4360	0.4340	0.4320	0.4300	0.4281	0.4261	0.4242	0.4223	0.4204	0.4185	0.4167	0.4148	0.4130	0.4112	0.4094	0.4076	0.4058
2.55	0.4450	0.4429	0.4409	0.4389	0.4369	0.4349	0.4330	0.4310	0.4291	0.4272	0.4253	0.4234	0.4216	0.4197	0.4179	0.4161	0.4143	0.4125
2.60	0.4517	0.4496	0.4476	0.4456	0.4436	0.4416	0.4396	0.4376	0.4357	0.4338	0.4319	0.4300	0.4281	0.4262	0.4244	0.4228	0.4207	0.4189
2.65	0.4582	0.4562	0.4541	0.4521	0.4500	0.4480	0.4460	0.4441	0.4421	0.4402	0.4382	0.4363	0.4344	0.4326	0.4307	0.4288	0.4270	0.4252
2.70	0.4646	0.4625	0.4604	0.4583	0.4563	0.4543	0.4523	0.4503	0.4483	0.4463	0.4444	0.4425	0.4406	0.4387	0.4368	0.4349	0.4331	0.4313
2.75	0.4707	0.4686	0.4665	0.4644	0.4624	0.4603	0.4583	0.4563	0.4543	0.4524	0.4504	0.4485	0.4465	0.4446	0.4427	0.4409	0.4390	0.4372
2.80	0.4767	0.4746	0.4725	0.4704	0.4683	0.4662	0.4642	0.4622	0.4602	0.4582	0.4562	0.4543	0.4523	0.4504	0.4485	0.4466	0.4448	0.4429
2.85	0.4825	0.4803	0.4782	0.4761	0.4740	0.4720	0.4699	0.4579	0.4659	0.4639	0.4619	0.4599	0.4580	0.4561	0.4541	0.4522	0.4503	0.4485
2.90	0.4881	0.4860	0.4838	0.4817	0.4796	0.4775	0.4755	0.4734	0.4714	0.4694	0.4674	0.4654	0.4635	0.4615	0.4596	0.4577	0.4558	0.4539
2.95	0.4936	0.4914	0.4893	0.4872	0.4850	0.4830	0.4809	0.4788	0.4768	0.4748	0.4728	0.4708	0.4688	0.4669	0.4649	0.4630	0.4611	0.4592
3.00	0.4989	0.4967	0.4946	0.4924	0.4903	0.4882	0.4862	0.4841	0.4820	0.4800	0.4780	0.4760	0.4740	0.4720	0.4701	0.4681	0.4662	0.4643

Continued on Next Page

# Fluid Power Formula

To use this chart locate “a” in the left hand column and “n” across the top. The correct value for “f” is in the body of the chart where “a” and “n” intersect. When the exact value for “a” is not shown use the next higher figure.

“a”	“n”																	
	1.77	1.78	1.79	1.80	1.81	1.82	1.83	1.84	1.85	1.86	1.87	1.88	1.89	1.90	1.91	1.92	1.93	1.94
1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.05	0.0272	0.0270	0.0269	0.0267	0.0266	0.0265	0.0263	0.0262	0.0260	0.0259	0.0258	0.0256	0.0255	0.0254	0.0252	0.0251	0.0250	0.0248
1.10	0.0524	0.0521	0.0519	0.0516	0.0513	0.0510	0.0507	0.0505	0.0502	0.0500	0.0497	0.0494	0.0492	0.0489	0.0487	0.0484	0.0482	0.0479
1.15	0.0759	0.0755	0.0751	0.0747	0.0743	0.0739	0.0735	0.0731	0.0728	0.0724	0.0720	0.0716	0.0713	0.0709	0.0706	0.0702	0.0699	0.0695
1.20	0.0979	0.0974	0.0968	0.0963	0.0958	0.0963	0.0948	0.0943	0.0939	0.0934	0.0929	0.0924	0.0920	0.0915	0.0910	0.0906	0.0901	0.0897
1.25	0.1184	0.1178	0.1172	0.1166	0.1160	0.1154	0.1148	0.1142	0.1136	0.1131	0.1125	0.1119	0.1114	0.1108	0.1103	0.1097	0.1092	0.1087
1.30	0.1378	0.1370	0.1363	0.1356	0.1349	0.1342	0.1336	0.1329	0.1322	0.1316	0.1309	0.1303	0.1296	0.1290	0.1283	0.1277	0.1271	0.1265
1.35	0.1560	0.1552	0.1544	0.1536	0.1528	0.1520	0.1513	0.1505	0.1497	0.1490	0.1483	0.1475	0.1468	0.1461	0.1454	0.1447	0.1440	0.1433
1.40	0.1731	0.1722	0.1714	0.1705	0.1696	0.1688	0.1680	0.1671	0.1663	0.1655	0.1647	0.1639	0.1631	0.1623	0.1615	0.1607	0.1600	0.1592
1.45	0.1894	0.1884	0.1874	0.1865	0.1856	0.1847	0.1838	0.1829	0.1820	0.1811	0.1802	0.1793	0.1785	0.1776	0.1768	0.1759	0.1751	0.1743
1.50	0.2047	0.2037	0.2027	0.2017	0.2007	0.1997	0.1987	0.1978	0.1968	0.1959	0.1949	0.1940	0.1931	0.1922	0.1913	0.1904	0.1895	0.1886
1.55	0.2193	0.2182	0.2172	0.2161	0.2150	0.2140	0.2130	0.2119	0.2109	0.2099	0.2089	0.2079	0.2070	0.2060	0.2050	0.2041	0.2031	0.2022
1.60	0.2332	0.2321	0.2309	0.2298	0.2287	0.2276	0.2265	0.2254	0.2244	0.2233	0.2222	0.2212	0.2202	0.2191	0.2181	0.2171	0.2161	0.2152
1.65	0.2464	0.2452	0.2440	0.2429	0.2417	0.2405	0.2394	0.2383	0.2371	0.2360	0.2349	0.2338	0.2328	0.2317	0.2306	0.2296	0.2285	0.2275
1.70	0.2590	0.2578	0.2565	0.2553	0.2541	0.2529	0.2517	0.2505	0.2494	0.2482	0.2471	0.2459	0.2448	0.2437	0.2426	0.2415	0.2404	0.2393
1.75	0.2711	0.2698	0.2685	0.2672	0.2660	0.2647	0.2635	0.2622	0.2610	0.2598	0.2586	0.2575	0.2563	0.2561	0.2540	0.2528	0.2517	0.2506
1.80	0.2926	0.2812	0.2799	0.2786	0.2773	0.2760	0.2747	0.2735	0.2722	0.2710	0.2697	0.2685	0.2673	0.2661	0.2649	0.2637	0.2625	0.2614
1.85	0.2936	0.2922	0.2908	0.2895	0.2881	0.2868	0.2855	0.2842	0.2829	0.2816	0.2803	0.2791	0.2778	0.2766	0.2754	0.2741	0.2729	0.2717
1.90	0.3042	0.3027	0.3013	0.2999	0.2986	0.2972	0.2958	0.2945	0.2932	0.2918	0.2905	0.2892	0.2879	0.2867	0.2854	0.2842	0.2829	0.2817
1.95	0.3143	0.3128	0.3114	0.3100	0.3086	0.3071	0.3058	0.3044	0.3030	0.3017	0.3003	0.2990	0.2977	0.2964	0.2951	0.2938	0.2925	0.2912
2.00	0.3240	0.3225	0.3211	0.3196	0.3182	0.3167	0.3153	0.3139	0.3125	0.3111	0.3097	0.3084	0.3070	0.3057	0.3043	0.3030	0.3017	0.3004
2.05	0.3334	0.3319	0.3304	0.3289	0.3274	0.3259	0.3245	0.3230	0.3216	0.3202	0.3188	0.3174	0.3160	0.3146	0.3133	0.3119	0.3106	0.3093
2.10	0.3424	0.3409	0.3393	0.3378	0.3363	0.3348	0.3333	0.3318	0.3304	0.3289	0.3275	0.3261	0.3247	0.3233	0.3219	0.3205	0.3192	0.3178
2.15	0.3511	0.3495	0.3480	0.3464	0.3449	0.3433	0.3418	0.3403	0.3388	0.3374	0.3359	0.3345	0.3330	0.3315	0.3302	0.3288	0.3274	0.3260
2.20	0.3595	0.3579	0.3563	0.3547	0.3531	0.3516	0.3500	0.3485	0.3470	0.3455	0.3440	0.3426	0.3411	0.3396	0.3382	0.3368	0.3354	0.3340
2.25	0.3675	0.3659	0.3643	0.3627	0.3611	0.3695	0.3580	0.3564	0.3549	0.3534	0.3519	0.3504	0.3489	0.3474	0.3459	0.3445	0.3431	0.3416
2.30	0.3754	0.3737	0.3721	0.3704	0.3688	0.3672	0.3656	0.3641	0.3625	0.3610	0.3594	0.3579	0.3564	0.3549	0.3534	0.3520	0.3505	0.3491
2.35	0.3829	0.3812	0.3796	0.3779	0.3763	0.3747	0.3731	0.3715	0.3699	0.3683	0.3668	0.3652	0.3637	0.3622	0.3607	0.3592	0.3577	0.3562
2.40	0.3902	0.3885	0.3868	0.3851	0.3835	0.3819	0.3802	0.3786	0.3770	0.3754	0.3738	0.3723	0.3707	0.3692	0.3677	0.3662	0.3647	0.3632
2.45	0.3973	0.3955	0.3938	0.3921	0.3905	0.3888	0.3872	0.3855	0.3839	0.3823	0.3807	0.3791	0.3776	0.3760	0.3745	0.3729	0.3714	0.3699
2.50	0.4041	0.4024	0.4006	0.3989	0.3972	0.3956	0.3939	0.3922	0.3906	0.3890	0.3874	0.3858	0.3842	0.3826	0.3811	0.3795	0.3780	0.3764
2.55	0.4107	0.4090	0.4072	0.4055	0.4038	0.4021	0.4004	0.3988	0.3971	0.3955	0.3938	0.3922	0.3906	0.3890	0.3874	0.3859	0.3843	0.3828
2.60	0.4172	0.4154	0.4135	0.4119	0.4102	0.4084	0.4067	0.4051	0.4034	0.4017	0.4001	0.3985	0.3968	0.3952	0.3936	0.3920	0.3905	0.3889
2.65	0.4234	0.4216	0.4198	0.4181	0.4163	0.4146	0.4129	0.4112	0.4095	0.4078	0.4062	0.4045	0.4029	0.4013	0.3996	0.3981	0.3965	0.3949
2.70	0.4295	0.4277	0.4259	0.4241	0.4223	0.4206	0.4189	0.4171	0.4154	0.4137	0.4121	0.4104	0.4088	0.4071	0.4055	0.4039	0.4023	0.4007
2.75	0.4353	0.4335	0.4317	0.4299	0.4282	0.4264	0.4247	0.4229	0.4212	0.4195	0.4178	0.4161	0.4145	0.4128	0.4112	0.4096	0.4079	0.4063
2.80	0.4411	0.4392	0.4374	0.4356	0.4338	0.4321	0.4303	0.4285	0.4268	0.4251	0.4234	0.4217	0.4200	0.4184	0.4167	0.4151	0.4134	0.4118
2.85	0.4466	0.4448	0.4429	0.4411	0.4393	0.4375	0.4358	0.4340	0.4323	0.4305	0.4288	0.4271	0.4254	0.4238	0.4221	0.4204	0.4188	0.4172
2.90	0.4520	0.4502	0.4483	0.4465	0.4447	0.4429	0.4411	0.4393	0.4376	0.4358	0.4341	0.4324	0.4307	0.4290	0.4273	0.4257	0.4240	0.4224
2.95	0.4573	0.4554	0.4536	0.4517	0.4499	0.4481	0.4463	0.4445	0.4428	0.4410	0.4393	0.4375	0.4358	0.4341	0.4324	0.4308	0.4291	0.4274
3.00	0.4624	0.4605	0.4587	0.4568	0.4550	0.4532	0.4514	0.4496	0.4478	0.4460	0.4443	0.4425	0.4408	0.4391	0.4374	0.4357	0.4340	0.4324

# Fluid Power Formula

## SIZING A HYDRAULIC 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. High pressure stroke required-----Usually in inches
4. Total cylinder cycle time-----Usually in seconds
5. Maximum pressure allowed-----Arbitrarily decided by the engineer

### SAMPLE PROBLEM

1. Maximum force required-----50,000 pounds
2. Total stroke required-----42 inches
3. High pressure stroke required----- Total cylinder stroke
4. Total cylinder cycle time-----10 seconds
5. Maximum pressure allowed-----2,000 PSI

A. Minimum Cylinder Bore =  $\sqrt{\frac{\text{Maximum Force Required} \times 1.1 / \text{Maximum PSI Allowed}}{.7854}}$

$$\sqrt{\frac{50,000 \text{ Pounds} \times 1.1 / 2,000 \text{ PSI}}{.7854}} = 5.917'' \text{ diameter or a } \underline{6'' \text{ Bore}}$$

$$\text{GPM} = \frac{\text{Piston Area (in.}^2\text{)} \times \text{Stroke (Inches)} \times 60 \text{ Seconds}}{\text{Cycle Time (Seconds)} \times 231 \text{ (Cubic Inches/Gal.)}}$$

$$\text{GPM} = \frac{28.275 \times 84 \times 60}{10 \times 231} = 61.7 \text{ GPM or a } \underline{65 \text{ GPM pump}}$$

84" is for cylinder extend and retract. Rod displacement is disregarded in this example.

C. Electric motor horse power =  $\text{HP} = \text{GPM} \times \text{PSI} \times .000583$

$$\text{HP} = 65 \times 2,000 \times .000583 = 75.79 \text{ or a } \underline{75 \text{ HP motor}}$$

D. Tank size = 2-3 times pump GPM = 2 x 65 = 130 gallons = 150 gallon tank  
 3 x 65 = 195 gallons = 200 gallon tank

# Fluid Power Formula

## SIZING A HYDRAULIC CIRCUIT

On the facing page is an exercise sizing a simple single cylinder hydraulic circuit with straight forward parameters. The example gives basic requirements for sizing a hydraulic cylinder powered machine.

In the real world of circuit design, experience, knowing the process, the environment, the skill of the user, how long will the machine be in service, and other items affect cylinder and power unit choices. Before designing any circuit it is necessary to know several things.

First is force requirement. Usually, the force to do the work is figured with a formula. In instances where there is no known mathematical way to figure force, use a mock up part on a shop press or on a prototype machine for best results. If all else fails, an educated guess may suffice. The sample problem requires a force of 50,000 pounds.

Second, choose a total cylinder stroke. Stroke length is part of machine function and is necessary to figure pump size. Use a stroke of 42 inches in this problem.

Third, how much of the stroke requires full tonnage? If only a small portion of the stroke needs full force, a HI-LO pump circuit and/or a regeneration circuit could reduce first cost and operating cost. This cylinder requires full tonnage for all 42 inches.

Fourth, what is the total cylinder cycle time? Make sure the time used is for cycling the cylinder. Load, unload and dwell are part of the overall cycle time, but should not be included when figuring pump flow. Use a cylinder cycle time of 10 seconds for this problem.

Finally, choose maximum system pressure. This is often a matter of preference of the circuit designer. Standard hydraulic components operate at 3000 PSI maximum, so choose a system pressure at or below this pressure. If a company has operating and maximum pressure specifications, adhere to them. Remember, lower working pressures require larger pumps and valves at high flow to get the desired speed.

On the facing page part A, taking the square root of the maximum thrust, times 110%, for fast pressure buildup, divided by the maximum system PSI, divided by .7854. This gives a minimum cylinder bore of 5.244". Choose a standard 6" diameter cylinder for this system.

To figure pump capacity, take the cylinder piston area in square inches, times the cylinder stroke in inches, times 60 seconds, divided by the cycle time in seconds, times 231 cubic inches per gallon. This shows a minimum pump flow of 61.7 GPM. A 65 GPM pump is the closest flow available. Never undersize the pump since this formula figures the cylinder is going maximum speed the whole stroke. The cylinder must accelerate and decelerate for smooth operation, so travel speed after acceleration and before deceleration should actually be higher than this formula allows.

Figure horsepower by taking GPM times PSI times a constant of .000583. This comes out to 75.79 HP, and is close to a standard 75 HP motor. This should be sufficient horsepower since the system pressure does not have to go to 2000 PSI with the cylinder size used.

The tank size should be at least two to three times pump flow, which is three times sixty-five, or 195 gallons, so a 200 gallon tank is satisfactory. When using single acting cylinders or unusually large piston rods, size the tank for enough oil to satisfy cylinder volume without starving the pump.

# 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 = 
$$\sqrt{\frac{\text{Maximum Force Required} \times 1.25 \text{ or } 2 / \text{Maximum PSI Allowed}}{.7854}}$$

$$\sqrt{\frac{150 \text{ Pounds} \times 1.25 / 80 \text{ PSI}}{.7854}} = 1.727'' \text{ Diameter or a } \underline{2'' \text{ Bore}}$$

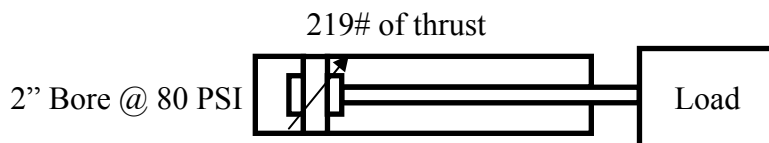
B. 
$$\text{SCFM} = \frac{V(\text{Vol. in.}^3) \times \text{Compression Ratio (PSI} + 14.7 / 14.7)}{\text{Total Cycle Time (Seconds)} \times 28.8}$$

$$\text{SCFM} = \frac{2 \times 2 \times .7854 \times 28 \times (80 + 14.7 / 14.7)}{4 \times 28.8} = \underline{4.92 \text{ SCFM}}$$

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

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

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



Cylinder will move at nominal speed

## 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.

