FLUID POWER
Design Data Sheet

Womack Machine Supply Co.

Revised Sheet 21 - Womack Design Data File

U.S. CUSTOMARY UNITS COMPARED TO ISO INTERNATIONAL STANDARD UNITS

Preliminary work was started on an international system of units prior to 1954, and some European countries have adopted their own version of a metric system which could be used internationally. However, there are many duplicate metric units which could be used for the same function. At this writing the basic units which we believe will be adopted are shown in the second column of the chart, and will form the SI (International Standard) set of units which will eventually be used all over the world. Some of the units (like the meter) are unhandy for fluid power use and a variation (like the centimeter) may be used instead. These are shown in the third column of the chart. Correct abbreviations for each unit are shown in the table under the chart. There is still controversy over the use of the "bar" for pressure.

Function	Basic SI Unit	Suggested Variation, Fluid Power	Other Metric Equivalents	Conversion To/ From U.S. Units
Length	m	cm	1 m = 10 dm = 100 cm = 1,000 mm	1 m = 39.37 in; or, 1 in = 2.54 cm
Area	m^2	cm^2	1 m^2 = 100 dm^2 = 10,000 cm^2	1 m^2 = 1,550 in^2 = 10.76 ft^2
Volume	m^3	dm^3	1 m^3 = 1,000 dm^3 = 1,000 liters	1 m^3 = 61,023 in^3 = 35.3 ft^3
Accel. of Gravity	m/s^2	Same	Actual value = 9.806 m/s^2	Actual value = 32.17 ft/s^2
Mass	kg	Same	1 kg = 9.807N (joules/meter)	1 kg = 2.2046 lbs (mass) = 70.92 poundals
Force (Weight)	N	Same	1N = 0.102 kg = 1 x 10^5 dynes	1N = 0.225 lbs
Torque	Nm	Same	- - - -	1 Nm = 8.85 in. lb = 0.74 ft. lb
Stress	N/m^2	Same	1 N/m^2 = 1 x 10^{-5} bar	1 N/m^2 = 1.45 x 10^{-4} lbs/in^2 = 0.021 lbs/ft^2
Pressure (Fluid)	N/m^2	bar	1 bar = 100,000 N/m^2	1 bar = 14.5 PSI; or, 1 PSI = 0.069 bar
Power	w	kw	1 kw = 1,000w	1 kw = 1.34 HP; or, 1 HP = 746w = 0.746 kw
Velocity	m/s	dm/min	1 m/s = 600 dm/min	1 dm/min = 3.937 in/min

cm = centimeter	in. lb = inch pound	min = minute
dm = decimeter	in/min = inches per minute	m/s = meters per second
dm/min = decimeters per minute	kg = kilogram	m/s^2 = meters per sec. per sec.
ft = foot	kw = kilowatt	N = newton
ft. lb = foot pound	lb = pound	Nm = newton meters
ft/s^2 = feet per second per second	lb/in^2 = pound per square inch	N/m^2 = newtons per square meter
g = gram	lb/ft^2 = pounds per square foot	PSI = pounds per square inch
HP = horsepower	m = meter	s = second
in = inch	mm = millimeter	w = watt

Familiar Formula in Customary U.S. Units	*Same Formula in the New SI Standard Units*
Torque, Power, and Speed Relations in Hydraulic Pumps and Motors	
T = HP × 5,252 ÷ RPM **HP = T × RPM ÷ 5,252** **RPM = HP × 5,252 ÷ T**	**T = kw × 9,543 ÷ RPM** **kw = T × RPM ÷ 9,543** **RPM = kw × 9,543 ÷ T**
T is torque in foot lbs. **RPM** is speed in revolutions per minute **HP** is horsepower (33,000 ft. lbs/min.)	**T** is torque in Nm (newton meters) **RPM** is speed in revolutions per minute **kw** is power in kilowatts
Hydraulic Power Flowing in the System	
HP = PSI x GPM ÷ 1,714	**Kw = Bars × dm^3/min ÷ 600**
HP is horsepower (33,000 ft. lbs. per min.) **PSI** is gauge pressure, lbs. per square inch **GPM** is flow in gallons per minute	**Kw** is system power in kilowatts **Bars** is system pressure **dm^3/min** is flow in cubic decimeters per minute

(Additional formula on opposite side of this sheet)

Familiar Formula in Customary U.S. Units	*Same Formula in the New SI Standard Units*
Force Developed by Air or Hydraulic Cylinder	
T = A × PSI	**N = A × Bars × 10**
T is force or thrust, in pounds **A** is piston area in square inches **PSI** is gauge pressure, lbs. per sq. in.	**N** is cylinder force or thrust in newtons **A** is piston area in square centimeters **Bars** is gauge pressure
Travel Speed of a Hydraulic Cylinder	
S = V ÷ A	**S = V ÷ 6A**
S is travel speed in inches per minute **V** is volume of oil into cylinder, cu. ins. per min. **A** is piston area in square inches	**S** is travel speed in meters per second **V** is oil flow in cubic decimeters per minute **A** is piston area in square centimeters
Barlow's Formula for Calculating Burst Pressure of Tubing and Pipe	
P = 2t × S ÷ O	**P = 2t × S ÷ O**
P is burst pressure in PSI **t** is wall thickness of pipe in inches **S** is tensile strength of pipe material in PSI **O** is outside diameter of pipe in inches	**P** is burst pressure in bars **t** is wall thickness of pipe in millimeters **S** is tensile strength of pipe material in bars **O** is outside diameter of pipe in millimeters
Velocity of Oil Flow in Hydraulic Lines	
V = GPM × 0.3208 ÷ A	**V = dm^3/min ÷ 6A**
V is velocity in feet per second **GM** is oil flow in gallons per minute **A** is inside area of pipe in square inches	**V** is oil velocity in meters per second **dm^3/min** is flow in cubic decimeters per second **A** is inside area of pipe in square centimeters
Recommended Maximum Oil Velocity in Hydraulic Lines	
Pump suction lines - 2 to 4 per sec. Pressure lines up to 500 PSI - 10 to 15 ft/sec. Pressure lines 500 to 3,000 PSI - 15 to 20 ft/sec. Pressure lines over 3,000 PSI - 25 ft/sec. Oil lines in air/oil system - 4 feet per sec.	Pump suction lines - 0.6 to 1.2 m/s (meters/sec) Pressure lines up to 35 bar - 3.0 to 4.5 m/s Pressure lines 35 to 200 bar - 4.5 to 6.0 m/s Pressure lines over 200 bar - 7.5 m/s Oil lines in air/oil system - 1.2 m/s

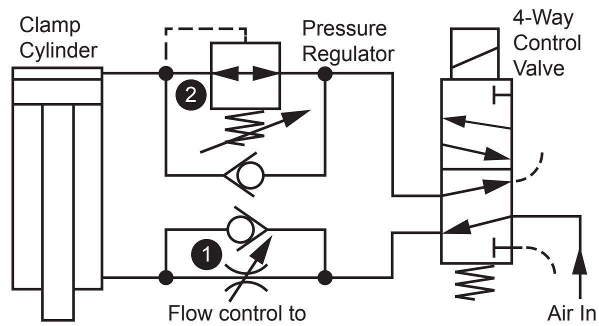
See **Design Data Sheet 25** for many other conversions between U.S. customary and ISO units

CLAMPING DELICATE PARTS

When an air cylinder is used for clamping delicate parts, the parts may be distorted, crushed, or suffer other damage for either or both of two possible reasons:

1. Too high a travel speed of the clamp cylinder may cause damage from impact, especially when the clamp is carrying a significant weight (mass) attached to its piston rod. This type of damage can be avoided by using a speed control and reducing travel speed. A flow control valve, 1, connected in a meter-out circuit will solve this problem.
2. Even though speed is reduced, the part can be crushed from too much steady force after the clamp has closed. When the clamp stalls against the part to be clamped, it will, if given a second or so, come up to full force developed by system PSI working against full piston area. A speed control system, by itself, cannot prevent full force from being exerted against the clamped part. To reduce the force, a pressure regulator, 2, should be installed in the air line to the clamp, and by-passed with a check valve so the clamp can be released fast and retracted under full pressure.

To adjust this circuit, first set the pressure regulator to a pressure which will not damage the part when clamping force is constantly applied. Then adjust the speed control to a speed which will not produce a damaging impact.



Both a speed and a pressure control may be required to avoid a damaging a delicate part which is being clamped.

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