Electric Motor Horsepower

Required to Drive a Hydraulic Pump

This chart is based on the formula:

$$hp = \frac{GPM \times psi}{1714 \times Efficiency}$$

For the purposes of this chart, pump efficiency was assumed to be 85%.

As horsepower varies directly with flow or pressure, multiply proportionately to determine values not shown.
For instance, at 4000 psi, multiply 2000 psi values by 2.

	Pump Pressure psi										
GPM	**100**	**200**	**250**	**300**	**400**	**500**	**750**	**1000**	**1250**	**1500**	**2000**
1/2	0.04	0.07	0.09	0.10	0.14	0.17	0.26	0.34	0.43	0.52	0.69
1	0.07	0.14	0.17	0.21	0.28	0.34	0.52	0.69	0.86	1.03	1.37
1 1/2	0.10	0.21	0.26	0.31	0.41	0.52	0.77	1.03	1.29	1.54	2.06
2	0.14	0.28	0.34	0.41	0.55	0.69	1.03	1.37	1.72	2.06	2.75
2 1/2	0.17	0.34	0.43	0.52	0.69	0.86	1.29	1.72	2.15	2.58	3.43
3	0.21	0.41	0.52	0.62	0.83	1.03	1.54	2.06	2.57	3.09	4.12
3 1/2	0.24	0.48	0.60	0.72	0.96	1.20	1.80	2.40	3.00	3.60	4.81
4	0.28	0.55	0.69	0.82	1.10	1.37	2.06	2.75	3.43	4.12	5.49
5	0.34	0.69	0.86	1.03	1.32	1.72	2.57	3.43	4.29	5.15	6.86
6	0.41	0.82	1.03	1.24	1.65	2.06	3.09	4.12	5.15	6.18	8.24
7	0.48	0.96	1.20	1.44	1.92	2.40	3.60	4.81	6.01	7.21	9.61
8	0.55	1.10	1.37	1.65	2.20	2.75	4.12	5.49	6.86	8.24	11.00
9	0.62	1.24	1.55	1.85	2.47	3.09	4.63	6.18	7.72	9.27	12.40
10	0.69	1.37	1.62	2.06	2.75	3.43	5.15	6.86	8.58	10.30	13.80
11	0.76	1.51	1.89	2.27	3.02	3.78	5.66	7.55	9.44	11.30	15.10
12	0.83	1.65	2.06	2.47	3.30	4.12	6.18	8.24	10.30	12.40	16.50
13	0.89	1.79	2.23	2.68	3.57	4.46	6.69	8.92	11.20	13.40	17.80
14	0.96	1.92	2.40	2.88	3.84	4.81	7.21	9.61	12.00	14.40	19.20
15	1.03	2.06	2.57	3.09	4.12	5.15	7.72	10.30	12.90	15.40	20.60
16	1.10	2.20	2.75	3.30	4.39	5.49	8.24	11.00	13.70	16.50	22.00
17	1.17	2.33	2.92	3.50	4.68	5.83	8.75	11.70	14.60	17.50	23.30
18	1.24	2.47	3.09	3.71	4.94	6.18	9.27	12.40	15.40	18.50	24.70
19	1.30	2.61	3.26	3.91	5.22	6.52	9.78	13.00	16.30	19.60	26.10
20	1.37	2.75	3.43	4.12	5.49	6.86	10.30	13.70	17.20	21.60	27.50
25	1.72	3.43	4.29	5.15	6.86	8.58	12.90	17.20	21.50	25.80	34.30
30	2.06	4.12	5.15	6.18	8.24	10.30	15.40	20.6	25.70	30.90	41.20
35	2.40	4.81	6.01	7.21	9.61	12.00	18.00	24.00	30.00	36.00	48.00
40	2.75	5.49	6.86	8.24	11.00	13.70	20.60	27.50	34.30	41.20	54.90
45	3.09	6.18	7.72	9.27	12.40	15.40	23.20	31.00	38.60	46.30	61.80
50	3.43	6.86	8.58	10.30	13.70	17.20	25.70	34.30	42.90	51.50	68.60
55	3.78	7.55	9.44	11.30	15.10	18.90	28.30	37.80	47.20	56.60	75.50
60	4.12	8.24	10.30	12.40	16.50	20.60	30.90	41.20	51.50	61.80	83.40
65	4.46	8.92	11.20	13.40	17.80	22.30	33.50	44.60	55.80	66.90	89.20
70	4.81	9.61	12.00	14.40	19.20	24.00	36.00	48.00	60.10	72.10	96.10
75	5.15	10.30	12.90	15.40	2.60	25.70	38.60	51.40	64.30	77.20	103.00
80	5.49	11.00	13.70	16.50	22.00	27.50	41.20	54.90	68.60	82.40	109.80
90	6.18	12.40	15.40	18.50	24.70	30.90	46.30	61.80	77.20	92.70	123.60
100	6.86	13.70	17.20	20.60	27.50	34.40	51.50	68.60	85.80	103.00	137.30

How to Determine Proper Air Valve Size

Most manufacturers' catalogs provide flow ratings for valves in Cv, based on National Fluid Power Association (NFPA) standard T3.21.3. The following tables and formulas will enable you to quickly size a valve properly. The traditional, often-used approach of using the valve size equivalent to the port in the cylinder can be very costly. Cylinder speed, not port size, should be the determining factor.

The following Cv calculations are based upon simplified formulas which yield results with acceptable accuracy under the following standard condition:

Air at a temperature of 68 °F (20 °C)

Absolute downstream or secondary pressure must be 53% of absolute inlet or primary pressure or greater. Below 53%, the air velocity may become sonic and the Cv formula does not apply.

Nomenclature:

B	Pressure drop factor	
C	Compression factor	
Cv	Flow factor	
D	Cylinder Diameter	(I N)
F	Cylinder Area	(SQ IN)
L	Cylinder Stroke	(I N)
p1	Inlet or Primary Pressure	(PS I G)
p2	Outlet or Secondary Pressure	(PS I G)
Δp	Pressure differential (p1- p2)	(psiD)
q	Air flow at actual condition	(CFM)
Q	Air flow of free air	(SCFM)
t	Time to complete one cylinder stroke	(SEC)
T	Absolute temperature at operating pressure. Deg R = Deg F + 460	(°R)

Valve Sizing for Cylinder Actuation Direct Formula

$$Cv = \frac{\text{Cylinder Area (F) (Sq. In.) (See Table 1)} \times \text{Cylinder Stroke (L) (In.)} \times \text{Compression (C) Factor (See Table 2)}}{\text{Pressure Drop (B) Factor (See Table 2)} \times \text{Time to Complete Cylinder Stroke (Sec)} \times 28.8}$$

Example: Cylinder size 4" Dia. x 10" stroke. Time to extend: 2 seconds. Inlet pressure 90 psiG. Allowable pressure drop 5 psiD. Determine Cv.

Solution:
F = 12.57 Sq. In. (Table 1)
C = 7.1 (Table 2) B = 21.6

$$Cv = \frac{12.57 \times 10 \times 7.1}{21.6 \times 2 \times 28.8} = 0.7$$

Select a valve that has a Cv factor of .7 or higher. In most cases, a 1/4" valve would be sufficient.

It is considered good engineering practice to limit the pressure drop Dp to approximately 10% of primary pressure P1. The smaller the allowable pressure drop, the larger the required valve will become.

After the minimum required Cv has been calculated, the proper size valve can be selected from the catalog.

Table 1:

Cylinder push bore area F for standard size cylinders			
Bore Size D (In.)	Cylinder Area F (Sq. In)	Bore Size D (In.)	Cylinder Area F (Sq. In)
3/4	0.44	4	12.57
1	0.79	4 1/2	15.90
1 1/8	0.99	5	19.64
1 1/4	1.23	6	28.27
1 1/2	1.77	7	38.48
1 3/4	2.41	8	50.27
2	3.14	10	78.54
2 1/2	4.91	12	113.10
3 1/4	8.30	14	153.94

Table 2:

Compression factor C and pressure drop factor B						
Inlet Pressure (psiG)	Compr. Factor C	Pressure Drop Factor B for Various Pressure Drops Δ p				
		2 psiD	5 psiD	10 psiD	15 psiD	20 psiD
10	1.7	6.5	-	-	-	-
20	2.4	7.8	11.8	-	-	-
30	3.0	8.9	13.6	18.0	-	-
40	3.7	9.9	15.3	20.5	23.6	-
50	4.4	10.8	16.7	22.6	26.4	29.0
60	5.1	11.7	18.1	24.6	29	32.0
70	5.8	12.5	19.3	26.5	31.3	34.8
80	6.4	13.2	20.5	28.2	33.5	37.4
90	7.1	13.9	21.6	29.8	35.5	39.9
100	7.8	14.5	22.7	31.3	37.4	42.1
110	8.5	15.2	23.7	32.8	39.3	44.3
120	9.2	15.8	24.7	34.2	41.0	46.4
130	9.8	16.4	25.6	35.5	42.7	48.4
140	10.5	16.9	26.5	36.8	44.3	50.3
150	11.2	17.5	27.4	38.1	45.9	52.1
160	11.9	18.0	28.2	39.3	47.4	53.9
170	12.6	18.5	29.0	40.5	48.9	55.6
180	13.2	19.0	29.8	41.6	50.3	57.2
190	13.9	19.5	30.6	42.7	51.7	58.9
200	14.6	20.0	31.4	43.8	53.0	60.4
210	15.3	20.4	32.1	44.9	54.3	62.0
220	16.0	20.9	32.8	45.9	55.6	63.5
230	16.7	21.3	33.5	46.9	56.8	64.9
240	17.3	21.8	34.2	47.9	58.1	66.3
250	18.0	22.2	34.9	48.9	59.3	67.7

Fluid Power Formulas

Basic 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 SUS.

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 = Theoretical Torque to Drive / Actual Torque to Drive x 100	$Eff_{mech} = (T_{theo}/T_{act}) \times 100$
PUMP LIFE B_{10} Bearing Life	B_{10} Hrs. Bearing Life = Rated Life Hrs. x Rated Speed (rpm) / New Speed (rpm) x Rated Pressure (psi) / New Pressure (psi)	B_{10} = Rated Hrs x $(RPM_r/RPM_n) \times (P^r/P_n)^3$

Actuator Formulas

Formula For:	Word Formula:	Letter Formula:
CYLINDER AREA In Square Inches	Area = ∏ x Radius² (Inches)	$A = \prod r^2$
	Area = (P/4) x Diameter² (Inches)	$A = (\prod D^2)/4$ or $A = .785D^2$
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	$V = (\prod r^2 L)/231$
	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

Fluid Power Formulas

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	Kilograms of Water
Cubic Inches	1	0.0005787	16.384	0.016384	0.004329	0.0036065	0.361275	0.0163872
Cubic Feet	1,728	1	28,316.8	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	1,000	1	0.264170	0.220083	2.20462	1
U.S. Gallons	231	0.133681	3,785.41	3.78543	1	0.833111	8.34545	3.78543
Imperial Gallons	277.274	0.160459	4,546.09	4.54374	1.20032	1	10.0172	4.54373
Pounds of Water	27.6798	0.0160184	453.59	0.453592	0.119825	0.0998281	1	0.453593