

# FLUID POWER Design Data Sheet



Revised Sheet 58 - Womack Design Data File

## AIR CONSUMPTION OF CYLINDERS

To calculate the HP load to be placed on an air compressor by a reciprocating air cylinder, the power to operate the cylinder with its circuit losses should first be calculated. Then, the additional HP needed for compression losses caused by compressing to too high a pressure and reducing through a pressure regulator should be estimated and added.

Air consumption for the cylinder and its circuit can be calculated from **Table 1** below. Then the air consumption can be converted to compressor HP. Finally, any additional losses can be estimated and added.

The procedure described in this sheet involves a certain amount of estimation of flow losses because an accurate calculation which includes all pertinent data is difficult.

### How To Use Table 1

First, calculate the pressure behind the cylinder piston to just balance the load resistance. Then add the estimated pressure loss due to flow resistance in the circuit, through valves and plumbing. For most air circuits, unless the application is highly special, an additional 25% of pressure, above the load balance pressure will be sufficient, and the pressure regulator should be set for this pressure. This extra pressure is quite necessary. It pushes the volume of air required for the cylinder cycle rate through the flow resistance of valves and plumbing. It is consumed in the circuit and is not effective against the load while the cylinder is in motion, but does add to the HP load on the compressor.

Pressures along the top of the table represent the outlet setting of the pressure regulator. By using the regulator outlet pressure instead of load balance pressure, all circuit flow losses are included in the HP calculation.

Calculate load balance pressure, then add 25%. Use this pressure column in the table. With a specified cylinder bore diameter, take the figure in the table which is air consumption

for a 1-inch stroke. Multiply times the number of inches stroke and by the number of cycles, forward and return which the cylinder will make in one minute. This gives the SCFM air consumption for this application.

**Table 1** was calculated using compression ratios in the table on the back side of this sheet.

Consumption is given for cylinders with standard diameter piston rods. The saving of air for cylinders with larger rods is negligible for most calculations.

Air consumption is calculated assuming the cylinder piston will be allowed to stall, at least momentarily, at each end of its stroke, giving it time to fill with air up to the pressure regulator setting. If reversed at either end before full stall occurs, air consumption will be less than shown.

### Calculating Cylinder Horsepower

After the SCFM air consumption has been calculated, convert into horsepower using the condensed table on the back side of this sheet, or for other than a 2-stage, piston-type compressor, see table on **Data Sheet 72**.

### System Losses

Flow losses downstream of the pressure regulator outlet have already been included. There are several small additional losses which should be considered.

Compression of air is an inefficient process because a substantial part of the energy is lost as the heat of compression is radiated to atmosphere. By over-compressing the air and then reducing its pressure through a pressure regulator, these compression losses are increased. Also there is a small flow loss through the pressure regulator. Calculation of these losses is very difficult and we suggest the addition of an extra 5 to 10% HP above the calculated level to take care of these losses.

**Table 1.** Cylinder air consumption per 1-inch stroke, forward and return.

Cylinder Bore Inches	PSI on Pressure Regulator Outlet													
	40 PSI	50 PSI	60 PSI	70 PSI	80 PSI	90 PSI	100 PSI	110 PSI	120 PSI	130 PSI	140 PSI	150 PSI	160 PSI	
1.50	0.007	0.008	0.010	0.011	0.012	0.013	0.015	0.016	0.017	0.018	0.020	0.021	0.022	
2.00	0.013	0.015	0.018	0.020	0.022	0.025	0.027	0.029	0.032	0.034	0.036	0.039	0.041	
2.50	0.021	0.024	0.028	0.032	0.035	0.039	0.043	0.047	0.050	0.054	0.058	0.062	0.065	
3.00	0.030	0.035	0.040	0.046	0.051	0.056	0.062	0.067	0.071	0.076	0.081	0.087	0.092	
3.25	0.034	0.040	0.047	0.053	0.059	0.065	0.071	0.077	0.084	0.090	0.096	0.102	0.109	
4.00	0.052	0.062	0.072	0.081	0.091	0.100	0.110	0.120	0.129	0.139	0.148	0.158	0.168	
5.00	0.083	0.098	0.113	0.128	0.143	0.159	0.174	0.189	0.204	0.219	0.233	0.249	0.265	
6.00	0.119	0.140	0.162	0.184	0.205	0.227	0.249	0.270	0.292	0.313	0.334	0.357	0.379	
8.00	0.213	0.252	0.291	0.330	0.369	0.408	0.447	0.486	0.525	0.564	0.602	0.642	0.682	
10.00	0.334	0.394	0.455	0.516	0.576	0.637	0.698	0.759	0.820	0.881	0.940	1.00	1.07	
12.00	0.480	0.568	0.656	0.744	0.831	0.919	1.01	1.09	1.18	1.27	1.36	1.45	1.54	
14.00	0.652	0.771	0.891	1.01	1.13	1.25	1.37	1.49	1.61	1.74	1.85	1.98	2.10	

**Calculation Example**

Estimate the compressor HP capacity to cycle an air cylinder having a 4-inch bore and 28-inch stroke, 11 cycles per minute. Assume the load against the cylinder is 800 lbs., and that a 2-stage piston-type air compressor is used.

**Solution:** Calculate the pressure to balance the load:

**800 lbs. ÷ 12.57 sq. in. (on a 4-in. bore cylinder) = 64 PSI**

Add 25% more pressure to cause air to flow:

**64 + (0.25 × 64) = 64 + 16 = 80 PSI**

This is the suggested setting of the pressure regulator. Use the 80 PSI column in **Table 1**. The table shows a requirement of 0.091 SCF per inch of stroke. Calculate the total air requirement:

**SCFM = 0.091 × 28 × 11 = 17.9**

Use **Table 2** below to convert this into compressor HP. The table shows a figure of 0.148 HP for each SCFM. The total HP then is:

**HP = 0.748 × 17.9 = 2.65**

To take care of the extra losses due to over-compression and flow, add 10%:

**2.65 + (0.1 × 2.65) = 2.92 or approximately 3 HP total**

*Table 2. HP required to compress air.*

PSI	HP*	PSI	HP*	PSI	HP*	PSI	HP*
50	0.116	80	0.148	110	0.171	140	0.190
60	0.128	90	0.155	120	0.178	150	0.196
70	0.138	100	0.164	130	0.185	160	0.201

\*HP to compress 1 SCFM from 0 PSI to the values shown. Compression between adiabatic and isothermal is assumed, with a 2-stage piston-type compressor working at 85% efficiency. For a more complete chart, see **Data Sheet 72**.

**Power Losses in a Pressure Regulator**

Power supplied to the inlet of a pressure regulator is delivered through to the outlet at a similar power level. Outlet power is at a lower pressure level but at a higher flow rate. The inlet would produce a higher force on a cylinder piston but with a slower movement. The outlet pressure would produce less force on the same cylinder but at a higher travel speed. The result would be the same HP except for certain energy losses or gains which occur inside the regulator.

Air expanding inside the regulator will absorb energy from the atmosphere if its temperature drops below ambient. On the other hand, flow loss produces heat which is an energy loss to atmosphere. Calculation of energy gains and losses through the regulator is impractical. As previously stated, we resort to approximations and rules-of-thumb which we have found give satisfactory practical results.

**Increasing the Efficiency of an Air System**

Any change which will put more of the available pressure across the cylinder ports while the cylinder is moving, and less across the regulator, piping, speed control valves, 4-way valve, and other restrictions, will increase efficiency.

- a. Increase the diameter of all plumbing lines.
- b. Increase the flow size of the 4-way valve.
- c. Set the cut-out pressure of the compressor as low as practical.

- d. Use the smallest bore cylinder which will produce the desired results. It will use more of the available pressure, leaving less to be wasted in flow losses.
- e. Use a second regulator to reduce return pressure to just sufficient for return speed and force desired. Remove the return speed control valve.

**Pressure Conversion Chart**

Air volume calculations must be based on absolute zero pressure, PSIA. "Free Air" is defined as air at standard conditions of atmospheric pressure and temperature, and for the chart is taken as 14.7 PSIA or 0 PSIG. Compression ratio in the third column of the chart, is the number of times the pressure is greater than normal atmospheric pressure, again taken as 14.7 PSIA.

**Pressure Conversions**

*Calculated from formula shown underneath the chart.*

Pressure PSIG	Pressure PSIA	No. of Atmos.*	No. of Bars
0	14.7	1.00	1.01
5	19.7	1.34	1.36
10	24.7	1.68	1.70
15	29.7	2.02	2.01
20	34.7	2.36	2.40
25	39.7	2.70	2.74
30	44.7	3.04	3.08
35	49.7	3.38	3.43
40	54.7	3.72	3.77
45	59.7	4.06	4.12
50	64.7	4.40	4.46
55	69.7	4.74	4.81
60	74.7	5.08	5.15
65	79.7	5.42	5.50
70	84.7	5.76	5.84
75	89.7	6.10	6.19
80	94.7	6.44	6.53
85	99.7	6.78	6.88
90	104.7	7.12	7.22
95	109.7	7.46	7.57
100	114.7	7.80	7.91
105	119.7	8.14	8.26
110	124.7	8.48	8.60
115	129.7	8.82	8.94
120	134.7	9.16	9.29
125	139.7	9.50	9.63
130	144.7	9.84	9.98
135	149.7	10.2	10.3
140	154.7	10.5	10.7
145	159.7	10.9	11.0
150	164.7	11.2	11.4
155	169.7	11.5	11.7
160	174.7	11.9	12.0
165	179.7	12.2	12.4
170	184.7	12.6	12.7
175	189.7	12.9	13.1

\*This is also the compression ratio used to convert a given volume of compressed air (cubic feet, or CF) to an equivalent volume of free air (standard cubic feet, or SCF).

For values of gauge pressure not shown, calculate as follows:

**PSIA = PSIG**

**Atmos. = (PSIG + 14.7) ÷ 14.7**

**Bars = (PSIG + 14.7) ÷ 14.5**

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