FLUID POWER
Design Data Sheet

Revised Sheet 32 – Womack Design Data File

PRESSURE RATING OF STEEL CYLINDER TUBING

The chart on this page shows the fluid pressure rating of mild steel tubing used for cylinder barrels. Tubing inside diameter (bore) is shown in the first column, and wall thickness along the top of the chart.

The chart includes an ample safety factor to take care of variations in composition or wall thickness of production tubing, pressure spikes generated in the hydraulic system, and metal fatigue caused by high cycle rates. More complete information is given on the opposite side of this sheet.

Safe Working Pressure

The calculation of safe working pressure on steel tubing used for construction of hydraulic cylinders is not an exact science because there are possible variations in the tubing material plus many other variables such as these:

a. SAE grade and hardness of he tubing steel.

b. Yield point of the tubing steel, largely determined by the specifications of Item a. (Continued on next page).

Working Pressure of Steel Tubing for Cylinder Barrels

Bore (Inside Diameter)	Wall Thick., 1/8″ 0.125	Wall Thick., 3/16″ 0.1875	Wall Thick., 1/4″ 0.250	Wall Thick., 3/8″ 0.375	Wall Thick., 1/2″ 0.500	Wall Thick., 5/8″ 0.625	Wall Thick., 3/4″ 0.750	Wall Thick., 7/8″ 0.875	Wall Thick., 1″ 1.000	Wall Thick., 1-1/4″ 1.250	Wall Thick., 1-1/2″ 1.500	Wall Thick., 1-3/4″ 1.750
1.50	1600	2195	2800	3845	4705	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
1.75	1380	2045	2460	3425	4235	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
2.00	1250	1790	2350	3080	3845	4505	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
2.25	1110	1510	2100	2800	3520	4150	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
2.50	1000	1445	1905	2565	3245	3935	4380	- - - -	- - - -	- - - -	- - - -	- - - -
2.75	910	1365	1740	2545	3005	3580	4095	- - - -	- - - -	- - - -	- - - -	- - - -
3.00	835	1250	1600	2350	2800	3350	3845	4295	- - - -	- - - -	- - - -	- - - -
3.25	770	1155	1480	2175	2620	3110	3620	4060	- - - -	- - - -	- - - -	- - - -
3.50	715	1070	1380	2035	2460	2935	3425	3845	4235	- - - -	- - - -	- - - -
4.00	625	940	1250	1790	2350	2655	3080	3480	3845	- - - -	- - - -	- - - -
4.50	555	835	1110	1600	2100	2405	2800	3170	3520	4150	- - - -	- - - -
5.00	500	750	1000	1445	1905	2195	2565	2915	3245	3845		- - - -
5.50	455	680	910	1365	1740	2495	2365	2695	3005	3580	4100	- - - -
6.00	415	625	835	1250	1600	1980	2195	2505	2800	3350	3845	- - - -
6.50	385	575	770	1155	1480	1835	2175	2340	2620	3145	3625	4060
7.00	355	535	715	1070	1380	1710	2030	2195	2460	2960	3425	3845
7.50	335	500	665	1000	1335	1600	1905	2065	2320	2800	3245	3655
8.00	310	470	625	935	1250	1500	1790	2070	2195	2655	3080	3480
8.50	295	440	590	880	1175	1420	1690	1955	2080	2525	2935	3320
9.00	275	415	555	839	1110	1345	1600	1855	2100	2405	2800	3170
9.50	265	395	525	790	1050	1395	1520	1760	1995	2295	2675	3040
10.0	250	375	500	750	1000	1250	1445	1675	1905	2195	2565	2915
10.5	240	355	475	715	950	1190	1380	1600	1835	2245	2460	2800
11.0	225	340	455	680	910	1135	1365	1415	1740	2145	2365	2695
11.5	215	325	435	650	870	1085	1305	1465	1665	2060	2275	2595
12.0	210	310	415	625	835	1040	1250	1410	1600	1980	2195	2505
12.5	200	300	400	600	800	1000	1200	1355	1540	1905	2120	2420
13.0	190	290	385	575	770	960	1155	1345	1480	1835	2175	2340
13.5	185	275	370	555	740	925	1110	1295	1430	1770	2145	2265
14.0	180	270	355	535	715	895	1070	1250	1380	1710	2035	2195

Pressures to the left of the shaded area were calculated by Barlow's formula. Those to the right of shaded area by Lame's formula. Pressures in shaded area are average values from calculations by both formula. See explanation on reverse side.

c. Whether the tubing steel is ductile or brittle.
d. Whether the cylinder will be constructed with "floating" ends or with confined (welded) ends.
e. Ratio of wall thickness to inside diameter of tubing.
f. Operating temperature (if extremely high).
g. Cycle rate. (High cycle rate tends to fatigue tubing).

Formula for Calculating Pressure Rating

Several formula may be used to calculate wall thickness for a desired hydraulic working pressure, but two of them seem to be used more than the others for ductile steel tubing. Lame's formula is used for thick wall tubing. This includes tubing with a wall thickness greater than 10% of its inside diameter. If the wall thickness is less than 10% of the I.D., the tubing is considered as "thin wall", and Barlow's formula gives more accurate results. Most of the tubing used to plumb a hydraulic system is "thin wall", and its pressure rating can be calculated with the same formula given here for cylinder barrel thin wall tubing.

Material for Cylinder Barrels

The most common material for hydraulic cylinder barrels seems to be low carbon steel, such as SAE 1020, finish annealed, or plain low carbon cold drawn seamless steel tubing, with a hardness of about 84 Rockwell B, and having a tensile yield point of 60,000 PSI (mechanical). This material has been used to build cylinders rated at 6,000 PSI working and up to 5-inch bore. To build cylinders with higher pressure rating or larger bore, a ductile steel with higher yield point should be used. Cast iron (a brittle material) should never be used for pressure ratings over 2,000 PSI regardless of wall thickness.

Explanation of Chart (Opposite Side of Sheet)

Working Pressure: The chart is based on a mechanical stress, S, of 10,000 PSI in the tubing material. This is fairly conservative, and gives a safety factor of 5:1 for steel tubing rated for 50,000 PSI yield, or a safety factor of 6:1 for steel tubing rated for 60,000 PSI yield strength. While it may, on some applications, be permissible to use a lower safety factor, under no circumstances would we recommend a safety factor less than 2.5 because of pressure spikes in the hydraulic system, and variations in composition or wall thickness of the tubing. Using a safety factor of 2.5, tubing of dimensions shown in the chart could be used at pressures about twice those shown.

Thin Wall Tubing. Fluid pressure values to the left of the shaded area were calculated by Barlow's formula as explained in the box on this page. These are for tubing sizes where wall thickness is less than 7% of the tubing I.D.

Thick Wall Tubing. Fluid pressure values to the right of the shaded area were calculated by Lame's formula:

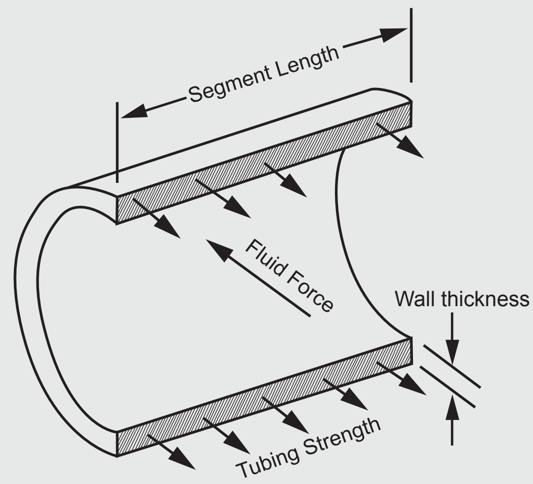
PSI = S × (OR² - IR²) + (OR² + IR²), where:

PSI is fluid pressure;
S is rated yield strength of the material, in PSI;
OR is the outside radius, in inches;
IR is the inside radius, in inches.

This area of the chart includes tubing with wall thickness greater than 10% of the tubing I.D. All areas of the chart are based on the design stress noted above, 10,000 PSI (mechanical), also including the safety factors noted above.

Intermediate Wall Thickness. The shaded area of the chart on the opposite side of this sheet includes tubing with wall thickness between 7% and 10% of tubing I.D. In an attempt to obtain more realistic results, pressure values were calculated with both the thin wall and thick wall formula and the two results were averaged.

Derivation of Barlow's Formula



Barlow's formula for thin wall tubing was derived by taking a section of any length longitudinally through the tubing as shown in the figure, and equating the mechanical holding power of the tubing to the hydraulic force tending to pull it apart.

Mechanical holding power is calculated from the square inches of metal (shaded area) times its yield strength (in mechanical PSI).

Hydraulic force is calculated from the length of the section times its inside diameter (ID) times the hydraulic PSI:

L × 2T × S = L × ID × PSI, where:

L is the length of section (cancels out in the equation);
T is the wall thickness, in inches;
S is the rated yield strength of the material, in PSI;
ID is the inside diameter of the tubing, in inches;
PSI is the internal fluid pressure.

The equation simplifies:

PSI = 2T × S ÷ ID

This calculation is accurate only for tubing of very thin wall. As the wall becomes thicker, the metal near the inside is stressed more than the metal near the outside, and the tubing will burst at a lower internal fluid pressure than calculated by the formula. To give a better approximation to actual burst PSI, the OD rather than the tubing ID is often used in the formula.

On tubing with wall thickness greater than 10% of the ID, other formulae, such as Lame's, is used to give more realistic results.

Tubing Sizes Not Shown in Chart

The formula and general rules given above may be used to determine working pressure of other tubing sizes, or tubing of other material which is ductile, if its tensile yield strength is known.

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Womack Machine Supply Co.
13835 Senlac Dr.
Farmers Branch, TX 75234
Tel: 800-859-9801 Fax: 214-630-5314
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