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Written By Engineers For Engineers

Sizing Tube to Maximize System Efficiency

Hydraulic systems using properly sized tube will perform more efficiently and cost-effectively. Tube that is too small can increase fluid velocity causing pressure drops and heat generation, and in suction lines, pump cavitation damage. Tube that is too large unnecessarily increases costs and is more difficult to fit in tight spaces.

Here's a simple procedure for optimizing tube size to maximize system performance...

Flow Diameter

The first step in choosing the correct tube size is to determine required flow diameter. Use the following "Recommended flow diameters" table (*Table 1*) for specific flow rates and types of line. *Table 1* is based on the following recommended flow velocities:

- Pressure lines – 25 ft/sec or 7.62 meters/sec
- Return lines – 10 ft/sec or 3.05 meters/sec
- Suction lines – 4 ft/sec or 1.22 meters/sec

If flow velocities differ from those in *Table 1*, calculate the required flow diameter using the following formula:

$$d = 0.64(Q/V)^{0.5}$$

d = tube ID, in.
 Q = flow, gpm
 V = velocity, ft/sec

For metric units: $d_m = 4.61(Q_m/V_m)^{0.5}$

d_m = tube ID, mm
 Q_m = flow, lpm
 V_m = velocity, meters/sec.



Diameter and Thickness

The next step is to determine tube OD and wall thickness. Using the "Pressure ratings" table (*Table 2*), find the diameter and thickness combination that satisfies the following two conditions:

1. Recommended design pressure equals or exceeds maximum operating pressure.
2. Tube ID equals or exceeds the required flow diameter determined earlier.

Another consideration is choosing the right wall thickness for bent tube. If bending without a mandrel, then wall thickness of less than 7% of tube OD is not recommended.

Design pressures in *Table 2* are based on a severity of service rating "A" (design factor of 4) as listed in the "Design and derating factors" table (*Table 3*).

In more severe operating conditions, multiply values in *Table 2* by the

appropriate derating factors before determining the tube OD and wall thickness combination. Contact a Parker expert when in doubt.

Allowable stress levels and the underlying specifications used to arrive at the pressure ratings are given in the "Design stress ratings" chart (*Table 4*). Values are for fully annealed tubing.

Design pressure can also be formulated based on Lame's equation,

$$P = S((D^2 - d^2)/(D^2 + d^2))$$

D = tube OD, in.
 d = tube ID, in. ($D - 2T$)
 P = recommended design pressure, psi
 S = allowable stress for a design factor of 4, psi
 T = tube wall thickness, in.

For thin wall tubes ($D/T \geq 10$) the following equation may be used:

$$P = 2ST/D$$

Maximum flow rate, gpm	Recommended flow diameter, in.			Maximum flow rate, gpm	Recommended flow diameter, in.			Maximum flow rate, gpm	Recommended flow diameter, in.			Maximum flow rate, gpm	Recommended flow diameter, in.			Maximum flow rate, gpm	Recommended flow diameter, in.		
	Pressure Lines	Return Lines	Suction Lines		Pressure Lines	Return Lines	Suction Lines		Pressure Lines	Return Lines	Suction Lines		Pressure Lines	Return Lines	Suction Lines		Pressure Lines	Return Lines	Suction Lines
0.25	0.064	0.101	0.160	5.50	0.300	0.474	0.750	15.00	0.496	0.782	1.239	38.00	0.789	1.278	1.973	90.00	1.214	1.916	3.036
0.50	0.091	0.143	0.226	6.00	0.314	0.495	0.784	16.00	0.512	0.808	1.280	40.00	0.810	1.309	2.024	95.00	1.248	1.969	3.119
0.75	0.111	0.175	0.277	6.50	0.326	0.515	0.816	17.00	0.528	0.833	1.319	42.00	0.830	1.340	2.074	100.00	1.280	2.020	3.200
1.00	0.128	0.202	0.320	7.00	0.339	0.534	0.847	18.00	0.543	0.857	1.358	44.00	0.849	1.370	2.123	110.00	1.342	2.119	3.356
1.25	0.143	0.226	0.358	7.50	0.351	0.553	0.876	19.00	0.558	0.880	1.395	46.00	0.868	1.399	2.170	120.00	1.402	2.213	3.505
1.50	0.157	0.247	0.392	8.00	0.362	0.571	0.905	20.00	0.572	0.903	1.431	48.00	0.887	1.428	2.217	130.00	1.459	2.303	3.649
1.75	0.169	0.267	0.423	8.50	0.373	0.589	0.933	22.00	0.600	0.947	1.501	50.00	0.905	1.428	2.263	140.00	1.515	2.390	3.786
2.00	0.181	0.286	0.453	9.00	0.384	0.606	0.960	24.00	0.627	0.990	1.568	55.00	0.949	1.498	2.373	150.00	1.568	2.474	3.919
2.50	0.202	0.319	0.506	9.50	0.395	0.623	0.986	26.00	0.653	1.030	1.632	60.00	0.991	1.565	2.479	160.00	1.619	2.555	4.048
3.00	0.222	0.350	0.554	10.00	0.405	0.639	1.012	28.00	0.677	1.069	1.693	65.00	1.032	1.629	2.580	170.00	1.669	2.634	4.172
3.50	0.239	0.378	0.599	11.00	0.425	0.670	1.061	30.00	0.701	1.143	1.753	70.00	1.071	1.690	2.677	180.00	1.717	2.710	4.293
4.00	0.256	0.404	0.640	12.00	0.433	0.700	1.109	32.00	0.724	1.178	1.810	75.00	1.109	1.749	2.771	190.00	1.764	2.784	4.411
4.50	0.272	0.429	0.679	13.00	0.462	0.728	1.154	34.00	0.746	1.212	1.866	80.00	1.145	1.807	2.862	200.00	1.810	2.857	4.525
5.00	0.286	0.452	0.716	14.00	0.479	0.756	1.197	36.00	0.768	1.245	1.920	85.00	1.180	1.862	2.950				

Table 1: Recommended Flow Diameters

Tube OD, in.	Wall thickness, in.	Tube ID, in.	Design pressure, psi (4:1 design factor)			
			Steel 1010	Steel 1021	Stainless Steel (304, 316) 4130, HSLA	Cooper
0.250	0.020	0.210	2,150	2,600	3,250	1,050
0.250	0.028	0.194	3,100	3,700	4,650	1,500
0.250	0.035	0.180	3,950	4,750	5,950	1,900
0.250	0.049	0.152	5,750	6,900	8,650	2,750
0.250	0.058	0.134	6,900	8,300	10,400	3,300
0.250	0.065	0.120	7,800	9,350	11,750	3,750
0.250	0.083	0.084	9,950	11,950	15,000	4,800
0.500	0.028	0.444	1,500	1,800	2,200	700
0.500	0.035	0.430	1,850	2,200	2,800	900
0.500	0.049	0.402	2,700	3,250	4,050	1,300
0.500	0.058	0.384	3,250	3,900	4,850	1,550
0.500	0.065	0.370	3,650	4,400	5,500	1,750
0.500	0.072	0.356	4,100	4,900	6,150	1,950
0.500	0.083	0.334	4,800	5,750	7,200	2,300
0.500	0.095	0.310	5,550	6,650	8,350	2,650
0.500	0.109	0.282	6,450	7,750	9,750	3,100
0.500	0.120	0.260	7,200	8,650	10,800	3,450
0.500	0.134	0.232	8,050	9,650	12,150	3,850
0.500	0.148	0.204	8,950	10,750	13,450	4,300
0.500	0.188	0.124	11,050	13,250	16,600	5,300
0.625	0.072	0.481	3,200	3,850	4,800	1,550

Table 2: Pressure Ratings (continued on page 3)

Maximum Working Pressures

The design factor is generally applied to the material's ultimate strength (or tubing burst pressure) to provide a margin of safety against unknowns in material and operating conditions. Apply the derating factors listed in Table 3 directly to values in the pressure ratings table (Table 2) to determine maximum recommended working pressures. That is, multiply values in Table 2 by the derating factors.

Temperature Considerations

Besides severity of service, high operating temperatures also reduce allowable working pressure in tube. Temperature derating factors for various tube materials are given in Table 5. Where applicable, apply derating factors for severity of service and temperature to the design pressure values to calculate the maximum recommended working pressure. For example, the combined derating factor for 316SS tubing for B (severe) service and 500°F operation is 0.67 × 0.9 = 0.60.

If you have questions or comments, please post them and I'll respond if warranted. If you want to talk to me directly, I can be reached at Parker Tube Fittings Division, 614.279.7070.

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Tube OD, in.	Wall thickness, in.	Tube ID, in.	Design pressure, psi (4:1 design factor)			
			Steel 1010	Steel 1021	Stainless Steel (304, 316) 4130, HSLA	Copper
1.000	0.049	0.902	1,300	1,550	1,950	600
1.000	0.058	0.856	1,550	1,850	2,300	750
1.000	0.065	0.870	1,750	2,100	2,600	850
1.000	0.072	0.856	1,950	2,350	2,900	950
1.000	0.083	0.834	2,250	2,700	3,400	1,100
1.000	0.095	0.810	2,600	3,100	3,900	1,250
1.000	0.109	0.782	3,000	3,600	4,550	1,450
1.000	0.120	0.760	3,350	4,000	5,050	1,600
1.000	0.134	0.732	3,800	4,550	5,700	1,800
1.000	0.148	0.704	4,200	5,050	6,350	2,000
1.000	0.156	0.688	4,450	5,350	6,700	2,150
1.000	0.188	0.624	5,500	6,600	8,250	2,650
1.000	0.220	0.560	6,550	7,850	9,800	3,150
1.250	0.049	1.152	1,000	1,200	1,550	500
1.250	0.058	1.134	1,200	1,450	1,850	600
1.250	0.065	1.120	1,350	1,600	2,050	650
1.250	0.072	1.106	1,500	1,800	2,300	700
1.250	0.083	1.084	1,750	2,100	2,650	850
1.250	0.095	1.060	2,050	2,450	3,050	1,000
1.250	0.109	1.032	2,350	2,800	3,550	1,150
1.250	0.120	1.010	2,650	3,200	3,950	1,250
1.250	0.134	0.982	2,950	3,550	4,450	1,400
1.250	0.148	0.954	3,300	3,950	4,950	1,600
1.250	0.156	0.938	3,500	4,200	5,250	1,700
1.250	0.188	0.874	4,300	5,150	6,450	2,050
1.250	0.22	0.810	5,100	6,100	7,700	2,450

Table 2: Pressure Ratings (continued from page 2)

Severity of Service	Description	Design Factor	Derating Factor
A (Normal)	Moderate mechanical and hydraulic shocks	4.00	1.00
B (Severe)	Severe hydraulic shock and mechanical strain	6.00	0.67
C (Hazardous)	Hazardous application with severe service conditions	8.0	0.50

Table 3: Design and Derating Factors

Material and Type	Allowable design stress, psi (Design factor of 4 at 72°F)	Tube Specification
Steel C-1010	12,500	SAE J356, J524, J525
Steel C-1021	15,000	SAE J2435, J2467
Steel, HSLA	18,000	SAE J2613, J2614
Stainless Steel, 304 & 316	18,800	ASTM A213, A449, A279
Alloy Steel C-4130	18,000	ASTM A519
Copper, K or Y	6,000	SAE J528, ASTM B75
Aluminum 606 1-T6	10,500	ASTM B210
Monel, 400	17,500	ASTM B165

Table 4: Design Stress Ratings

Maximum Operating Temp. °F	Steel, C-1010 and C-4130	Stainless Steel		Copper	Aluminum 6061-T6	Monel, Type 400
		304	316			
100	1.00	1.00	1.00	1.00	1.00	1.00
150	1.00	1.91	1.00	0.85	1.00	0.97
200	1.00	0.84	1.00	0.80	1.00	0.94
250	1.00	0.79	1.00	0.80	0.94	0.91
300	1.00	0.75	1.00	0.78	0.80	0.88
350	0.99	0.72	0.99	0.67	0.60	0.86
400	0.98	0.69	0.97	0.50	0.43	0.85
500	0.96	0.65	0.90			0.84
600		0.61	0.85			0.84
700		0.59	0.82			0.84
800		0.57	0.80			0.83
900		0.54	0.78			
1,000		0.52	0.77			
1,100		0.47	0.62			
1,200		0.32	0.37			

Table 5: Temperature Derating Factors

