Connectors & Conductors

Fluid conductors is a broad term that encompasses any methods of connecting components within a hydraulic or pneumatic system. Pneumatic and hydraulic systems today use principally three types of conducting lines: pipe, tubing, and flexible hose. Depending on the application and the sizes needed, pipe may be the cheapest, but its use often presents serious leakage problems, especially at higher operation pressures. Pipe is still widely in use in many installations especially for very large flow rates, and tubing of all types and materials may be found depending upon the application requirements. Flexible hose is widely used for hydraulics and pneumatics applications.

Pipe Specifications

Pipe Schedule is the term used to describe the thickness of a pipe and is used in the selection process by evaluating pressure ratings and flow velocity ratings.

The most important dimension for a steel pipe is the inside diameter (ID), which indicates the approximate fluid conveyance capacity of the tube. The ID is expressed in "NPS" or "DN" (nominal pipe size in inches or metric).

The pipe outside diameter (OD) does not match the nominal size for pipes blow NPS 14 in (a 2-in pipe, for instance, has an internal flow capacity of approximately 2 inc, but has an outside diameter of 2.375 in).

For pipes of a given NPS, the pipe outside diameter is fixed, whereas the pipe inside diameter decreases by increasing schedule values as the pipe wall thickness increases.

The most important mechanical parameters for pipes are the pressure rating, the yield strength, and the ductility.

The standard combinations of pipe nominal diameter and wall thickness (schedule) are covered by the ASME B36.10 and ASME B36.19 specifications (respectively, carbon and alloy pipes, and stainless steel pipes). There are eleven schedule numbers typically used: 5, 10, 20, 30, 40, 60, 80, 100, 120, 140, & 160.

The most popular schedule, by far, is schedule 40. For pipe 8 inches and under, Schedule 40 and Standard Weight pipe wall thicknesses are the same. Schedules 5, 60, 100, 120, & 140 are infrequently used.

The schedule number is calculated as the approximate value of the formula:

$$Schedule_{Number} = 1000 \bullet \frac{P}{S}$$

P = the working pressure, psig

S = the allowable stress (psi) for the material of construction

For example, the schedule number of ordinary steel pipe having an allowable stress of 10,000 psi for use at a working pressure of 800 psig would be

Schedule Number = (1,000)•(800/10,000) = 80

All of the charts and information are for reference only and represent some typical values. The actual manufacturer should be consulted as to the actual specifications of a chosen product for an application.

Pressure Ratings of Pipe

Pipes are most commonly classified based on their pressure and temperature rating or commonly known as P-T Rating. Shown below is a table for A106 Grade B Carbon Steel. Different alloys and types of steel will have different P-T ratings. Consult the manufacturer when selecting.

Pipe Size	Pipe Schedule	100°F	200°	300°	400°	500°	600°	650°	700°	750°
1"	40	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,743	2,476
1"	80	3,950	3,950	3,950	3,950	3,950	3,950	3,950	3,792	3,423
1"	160	5,757	5,757	5,757	5,757	5,757	5,757	5,757	5,526	4,989
1.5"	40	2,116	2,116	2,116	2,116	2,116	2,116	2,116	2,032	1,834
1.5"	80	2,983	2,983	2,983	2,983	2,983	2,983	2,983	2,864	2,585
1.5"	160	4,331	4,331	4,331	4,331	4,331	4,331	4,331	4,157	3,753
2"	40	1,783	1,783	1,783	1,783	1,783	1,783	1,783	1,712	1,545
2"	80	2,575	2,575	2,575	2,575	2,575	2,575	2,575	2,472	2,232
2"	160	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,049	3,655
3"	40	1,693	1,693	1,693	1,693	1,693	1,693	1,693	1,625	1,467
3"	80	2,394	2,394	2,394	2,394	2,394	2,394	2,394	2,298	2,074
3"	160	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,456	3,120
4"	40	1,435	1,435	1,435	1,435	1,435	1,435	1,435	1,378	1,244
4"	80	2,075	2,075	2,075	2,075	2,075	2,075	2,075	1,992	1,798
4"	160	3,376	3,376	3,376	3,376	3,376	3,376	3,376	3,241	2,926
5"	40	1,258	1,258	1,258	1,258	1,258	1,258	1,258	1,208	1,090
5"	80	1,857	1,857	1,857	1,857	1,857	1,857	1,857	1,783	1,610
5"	160	3,201	3,201	3,201	3,201	3,201	3,201	3,201	3,073	2,774
6"	40	1,143	1,143	1,143	1,143	1,143	1,143	1,143	1,098	991
6"	80	1,794	1,794	1,794	1,794	1,794	1,794	1,794	1,722	1,554
6"	160	3,083	3,083	3,083	3,083	3,083	3,083	3,083	2,960	2,672
8"	40	1,006	1,006	1,006	1,006	1,006	1,006	1,006	966	872
8"	80	1,586	1,586	1,586	1,586	1,586	1,586	1,586	1,523	1,375
8"	160	2,976	2,976	2,976	2,976	2,976	2,976	2,976	2,857	2,579
10"	40	913	913	913	913	913	913	913	876	791
10"	80	1,509	1,509	1,509	1,509	1,509	1,509	1,509	1,448	1,308
10"	160	2,950	2,950	2,950	2,950	2,950	2,950	2,950	2,832	2,557

Below is another representative of a typical chart showing schedule numbers and nominal sizes with their respective maximum pressures.

Pipe Pressure Rating Chart by Schedule

Maximum Allowable Pressure *(psi) kPa*

Nominal Pipe Size (in)	Outside Diameter (in) (mm)	Schedule												
		10	20	30	STD	40	60	XS	80	100	120	140	160	XXS
1/4	0.54				7985	7985		10798	10798					
	13.7				55057	55057		74452	74452					
3/8	0.675				6606	6606		9147	9147					
	17.1				45548	45548		63069	63069					
1/2	0.84				6358	6358		8575	8575				10908	17150
	21.3				43838	43838		59125	59125				75211	118249
3/4	1.05				5273	5273		7187	7187				10,220	14373
	26.7				36357	36357		49554	49554				70467	99102
1	1.315				4956	4956		6670	6670				9316	13340
	33.4				34172	34172		45990	45990				64234	91979
1 1/4	1.66				4133	4133		5638	5638				7380	11276
	42.2				28497	28497		38874	38874				50885	77748
1 1/2	1.9				3739	3739		5158	5158				7247	10316
	48.3				25780	25780		35564	35564				49968	71129
2	2.375				3177	3177		4498	4498				7097	8995
	60.3				21905	21905		31014	31014				48934	62021
2 1/2	2.875				3460	3460		4704	4704				6391	9408
	73				23857	23857		32434	32434				44066	64868
3	3.5				3024	3024		4200	4200				6132	8400
	88.9				20850	20850		28959	28959				42280	57918
3 1/2	4				2769	2769		3896	3896					
	102				19092	19092		26863	26863					
4	4.5				2581	2581		3670	3670		4769		5782	7339
	114				17796	17796		25305	25305		32882		39867	50602
5	5.563				2273	2273		3303	3303		4404		5505	6606
	141				15672	15672		22774	22774		30366		37957	45548
6	6.625				2071	2071		3195	3195		4157		5318	6390
	168				14280	14280		22030	22030		28663		36668	44059
8	8.625		1420	1574	1829	1829	2307	2841	2841	3375	4085	4613	5147	4971
	219		9791	10853	12611	12611	15907	19589	19589	23271	28166	31807	35489	34275
10	10.75		1140	1399	1664	1664	2279	2279	2708	3277	3847	4558	5128	4558
	273		7860	9646	11473	11473	15714	15714	18672	22595	26525	31427	35358	31427
12	12.75		961	1268	1441	1560	2160	1922	2644	3244	3843	4324	5042	3843
	324		6626	8743	9936	10756	14893	13252	18230	22367	26497	29814	34765	26497
14	14	875	1092	1313	1313	1533	2079	1750	2625	3283	3829	4375	4921	
	356	6033	7529	9053	9053	10570	14335	12066	18099	22636	26401	30166	33930	
16	16	766	956	1148	1148	1531	2009	1531	2585	3157	3733	4404	4882	
	406	5282	6592	7915	7915	10556	13852	10556	17824	21768	25739	30366	33661	
18	18	681	849	1192	1021	1530	2042	1361	2553	3147	3743	4252	4848	
	457	4695	5854	8219	7040	10549	14080	9384	17603	21699	25808	29318	33427	
20	20	613	919	1225	919	1455	1989	1225	2526	3138	3675	4288	4824	
	508	4227	6337	8446	6337	10032	13714	8446	17417	21637	25339	29566	33261	
22	22	557	835	1114	835		1949	1114	2506	3063	3619	4176	4733	
	559	3841	5757	7681	5757		13438	7681	17279	21119	24953	28794	32634	
24	24	510	766	1147	766	1405	1978	1021	2489	3126	3700	4210	4786	
	610	3516	5282	7909	5282	9687	13638	7040	17162	21554	25512	29028	32999	
30	30	510	817	1021	613			817						
	762	3516	5633	7040	4227			5633						
32	32	478	766	957	574	1054								
	813	3296	5282	6599	3958	7267								
34	34	450	721	901	540	992								
	864	3103	4971	6212	3723	6840								
36	36	425	681	851	510	1021								
	914	2930	4695	5868	3516	7040								
42	42		583	729	438	875								
	1067		4020	5026	3020	6033								

The dimensions - outside pipe diameters and wall thicknesses are according ANSI B36.10.

1 in (inch) = 25.4 mm

1 psi (lb/in^2) = 6,894.8 Pa (N/m^2) = 6.895x10^{-2} bar

Flow Velocity Ratings

There are a number of ways to solve for fluid velocity or conductor size.

Sizing of the fluid conductor is based on
1. Flow rate (gpm)
2. Flow velocity (ft/sec)
3. Pressure
4. External corrosion/environmental issues

The flow velocity is based on the gallons per minute (gpm) flowing through the inner diameter of pipe, tubing, and hose. This can be calculated or found on charts and in technical references. The following formula is used to calculate a fluid velocity when given a known size fluid conductor and flowrate:

$$Velocity_{flow} = \frac{0.3208 \bullet Q}{A}$$

V = velocity (ft/sec)
A = internal area (in²)
Q = gallons per minute (gpm)

STANDARD PIPE - SCHEDULE 40

Pipe Size	OD	Wall	ID	Int Area	Wt/Ft	gpm @ 2 FPS	gpm @ 5 FPS	gpm @ 10 FPS	gpm @ 15 FPS	gpm @ 20 FPS	gpm @ 25 FPS
1/8	0.405	0.068	0.269	0.057	0.245	0.35	0.89	1.8	2.7	3.5	4.4
1/4	0.540	0.088	0.364	0.104	0.425	0.65	1.6	3.2	4.9	6.5	8.1
3/8	0.675	0.091	0.493	0.191	0.567	1.2	3.0	6.0	9.0	12	15
1/2	0.840	0.109	0.622	0.304	0.852	1.9	4.8	9.5	12	19	23.8
3/4	1.050	0.113	0.824	0.533	1.132	3.3	8.4	16.7	25.1	33.4	41.8
1	1.315	0.133	1.049	0.864	1.679	5.4	13.5	27.0	40.6	54.1	67.7
1 1/4	1.660	0.140	1.380	1.495	2.273	9.4	23.4	46.8	70.3	93.7	117
1 1/2	1.900	0.145	1.610	2.036	2.718	12.7	31.9	63.7	95.6	127	159
2	2.375	0.154	2.067	3.356	3.653	21.0	52.5	105	157	210	263
2 1/2	2.875	0.203	2.469	4.788	5.793	30.0	75	150	225	300	375
3	3.500	0.216	3.068	7.393	7.575	46.3	116	232	347	463	579
3 1/2	4.000	0.226	3.548	9.886	9.109	61.9	155	310	465	619	744
4	4.500	0.237	4.026	12.73	10.79	79.7	199	399	598	797	997
4 1/2	5.000	0.247	4.506	15.95	12.54	99.9	250	499	749	998	1,249
5	5.563	0.258	5.047	20.01	14.62	125	313	627	940	1,253	1,567
6	6.625	0.280	6.065	28.89	18.97	181	452	904	1,357	1,810	2,262
7	7.625	0.301	7.023	38.74	23.54	243	607	1,213	1,820	2,427	3,033
8	8.625	0.322	7.981	50.03	28.55	313	783	1,567	2,350	3,134	3,917
10	10.75	0.365	10.02	78.85	40.48	494	1,235	2,470	3,705	4,940	6,175
12	12.75	0.406	11.94	111.9	53.56	701	1,753	3,506	5,259	7,012	8,765

EXTRA STRONG PIPE - XS - SCHEDULE 80

Pipe Size	OD	Wall	ID	Int Area	Wt/Ft	gpm @ 2 FPS	gpm @ 5 FPS	gpm @ 10 FPS	gpm @ 15 FPS	gpm @ 20 FPS	gpm @ 25 FPS
1/8	0.405	0.095	0.215	0.036	0.314	0.23	0.57	1.1	1.7	2.3	2.8
1/4	0.540	0.119	0.302	0.072	0.535	0.45	1.1	2.2	3.4	4.5	5.6
3/8	0.675	0.126	0.423	0.141	0.738	0.88	2.2	4.4	6.6	8.8	11
1/2	0.840	0.147	0.546	0.234	1.087	1.5	3.7	7.3	11.0	14.7	18.3
3/4	1.050	0.154	0.742	0.433	1.473	2.7	6.8	13.6	20.3	27.1	33.9
1	1.315	0.179	0.957	0.719	2.171	4.5	11.3	22.5	33.8	45.0	56.3
1 1/4	1.660	0.191	1.278	1.283	2.996	8.0	20.0	40.1	60.2	80.3	100
1 1/2	1.900	0.200	1.500	1.767	3.631	11.1	27.7	55.3	83.0	110	138
2	2.375	0.218	1.939	2.953	5.022	18.5	46.2	92.5	139	185	231
2 1/2	2.875	0.276	2.323	4.238	7.661	26.5	66.4	133	199	265	332
3	3.500	0.300	2.900	6.605	10.25	41.4	103	207	310	414	517
3 1/2	4.000	0.318	3.364	8.888	12.5	55.7	139	278	418	557	696
4	4.500	0.337	3.826	11.5	14.98	72.0	180	360	540	720	900
4 1/2	5.000	0.355	4.290	14.45	17.61	90.5	226	453	679	905	1,132
5	5.563	0.375	4.813	18.19	20.78	114	285	570	855	1,140	1,425
6	6.625	0.432	5.761	26.07	28.57	163	408	816	1,225	1,633	2,041
7	7.625	0.500	6.625	34.47	38.05	216	540	1,080	1,620	2,160	2,699
8	8.625	0.500	7.625	45.66	43.39	286	715	1,430	2,145	2,861	3,576
10	10.75	0.594	9.562	71.81	64.40	450	1125	2,249	3,374	4,498	5,623
12	12.75	0.688	11.37	101.6	88.57	636	1591	3,182	4,774	6,365	7,956

SCHEDULE 160 PIPE

Pipe Size	OD	Wall	ID	Int Area	Wt/Ft	gpm @ 2 FPS	gpm @ 5 FPS	gpm @ 10 FPS	gpm @ 15 FPS	gpm @ 20 FPS	gpm @ 25 FPS
1/2	0.840	0.187	0.466	0.171	1.310	1.07	2.67	5.34	8.01	10.7	13.4
3/4	1.050	0.218	0.587	0.271	1.940	1.7	4.24	8.5	12.7	17.0	21.2
1	1.315	0.250	0.815	0.522	2.850	3.27	8.17	16.3	24.5	32.7	40.8
1.25	1.660	0.250	1.160	1.060	3.764	6.62	16.6	33.1	49.7	66.2	82.8
1.5	1.900	0.281	1.338	1.410	4.862	8.81	22	44.0	66.1	88.1	110
2	2.375	0.343	1.689	2.241	7.450	14	35.1	70.20	105	140	175
2.5	2.875	0.375	2.125	3.542	10.01	22.2	55.5	111	167	222	278
3	3.500	0.437	2.626	5.416	14.30	33.9	84.8	170	254	339	424
4	4.500	0.531	3.438	9.283	22.52	58.2	145	291	436	682	727
5	5.563	0.625	4.313	14.61	33.00	91.5	229	458	686	915	1,144
6	6.625	0.718	5.189	21.15	45.30	132	331	662	994	1,325	1,656
8	8.625	0.906	6.813	36.44	74.70	230	571	1,142	1,713	2,384	2,855
10	10.75	1.125	8.500	56.75	115.64	355	889	1,777	2,666	3,555	4,443
12	12.75	1.312	10.126	80.53	160.33	504	1,261	2,523	3,784	5,045	6,306

DOUBLE DUTY EXTRA STRONG PIPE

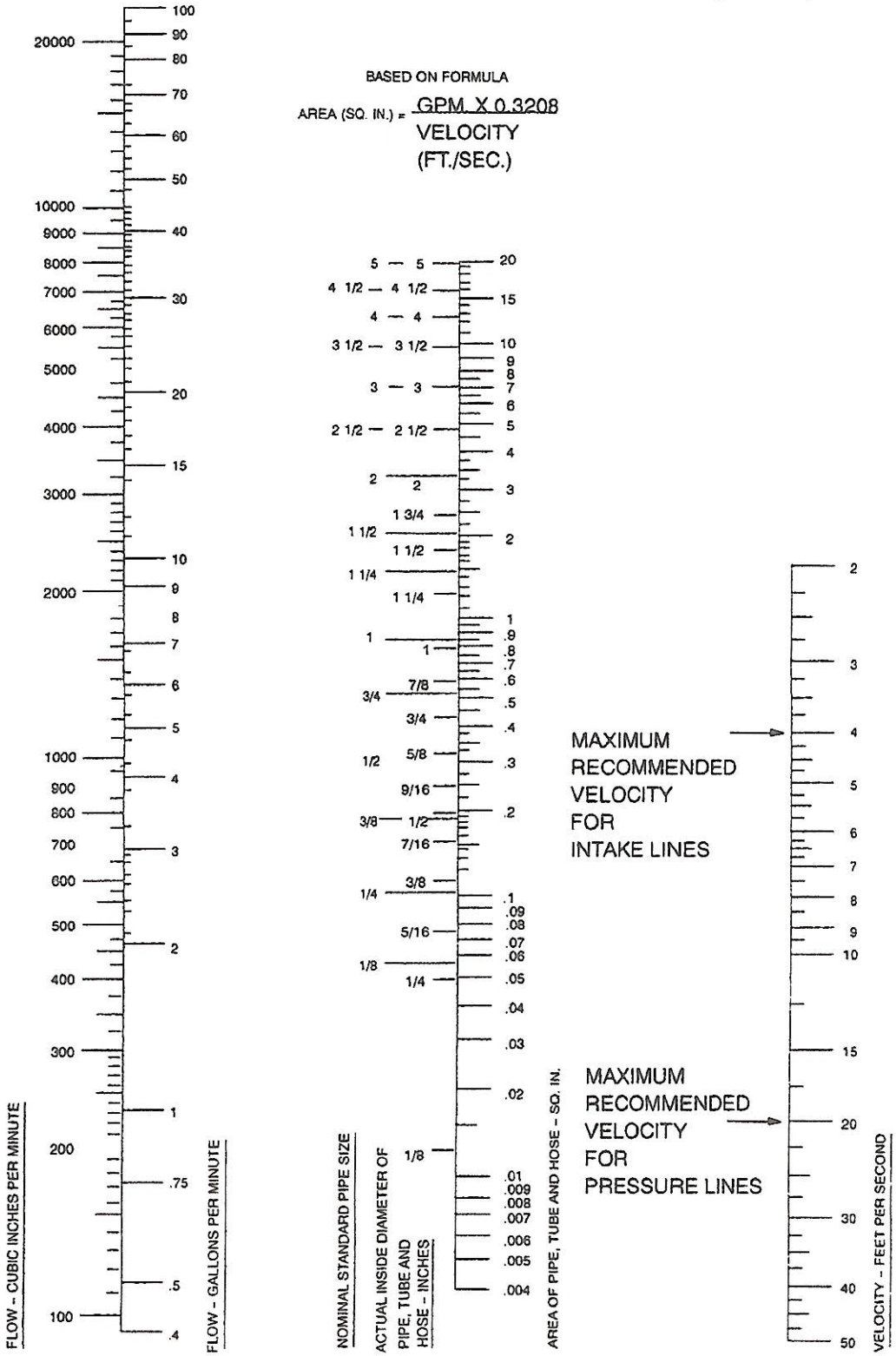
Pipe Size	OD	Wall	ID	Int Area	Wt/Ft	gpm @ 2 FPS	gpm @ 5 FPS	gpm @ 10 FPS	gpm @ 15 FPS	gpm @ 20 FPS	gpm @ 25 FPS
1/2	0.840	0.294	0.252	0.050	1.714	0.32	0.79	1.6	2.4	3.1	3.9
3/4	1.050	0.308	0.434	0.148	2.44	0.93	2.3	4.6	6.9	9.2	11.6
1	1.315	0.358	0.599	0.282	3.659	1.8	4.4	8.8	13.3	17.7	22.1
1.25	1.660	0.382	0.896	0.630	5.214	4.0	9.9	19.8	29.6	39.5	49.4
1.5	1.900	0.400	1.100	0.950	6.408	6.0	14.9	29.8	44.6	59.5	74.4
2	2.375	0.436	1.503	1.774	9.029	11.1	27.9	55.6	83.4	111	139
2.5	2.875	0.552	1.771	2.463	13.7	15.4	38.6	77.1	116	154	193
3	3.500	0.600	2.300	4.154	18.58	26.0	65.1	130	195	260	325
4	4.500	0.674	3.152	7.803	27.54	48.9	122	244	367	488	611
5	5.563	0.750	4.063	12.97	38.55	81.2	203	406	609	812	1,015
6	6.625	0.864	4.897	18.83	53.16	118	295	590	885	1,180	1,475
8	8.625	0.875	6.875	37.12	72.42	233	581	1,163	1,744	2,325	2,907
10	10.75	1.000	8.750	60.13	104.1	377	942	1,883	2,825	3,767	4,709
12	12.75	1.000	10.75	90.76	125.5	569	1,421	2,843	4,264	5,686	7,107

Fluid Conductor Sizing

Some manufacturers provide selection tools such as the nomographs below to assist in determining correct fluid conductor size:

Hydraulic Conductor Inside Diameter Selection Chart (Inch)

Courtesy Eaton Corporation

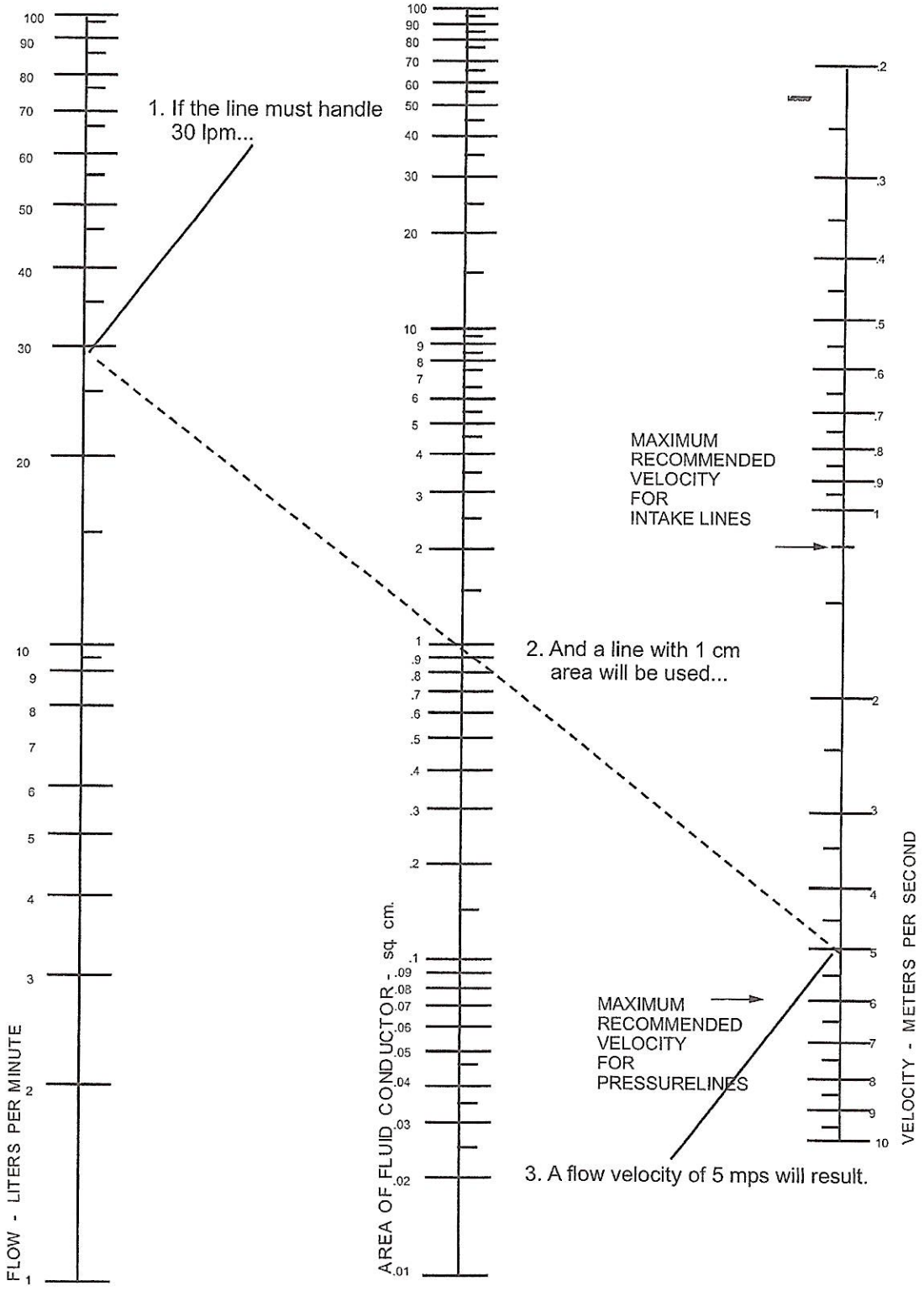


Hydraulic Conductor Inside Diameter Selection Chart (Metric)

Courtesy Eaton Corporation

BASED ON FORMULA

$$\text{AREA (SQ. CM)} = \frac{\text{LPM} \times 0.1667}{\text{VELOCITY (METERS/SEC.)}}$$



Flow velocity for a given fluid conductor ID size significantly impacts the amount of pressure drop experienced within the system. While a smaller size conductor may look inviting due to its lower cost, it is important to remember that pressure drop is wasted energy or power and can cause many issues due to potential heat being generated due to too much friction caused by excessive fluid velocity within the smaller fluid conductor.

Pressure Drops Through Fluid Conductors

Pneumatic:

Air Pressure Drop per 100 Feet of Pipe with Initial Pressure at 114.7 psia

Nominal Pipe Size		1/2		3/4		1		1 1/4		1 1/2		2		2 1/2		3		4	
Inside Diameter		0.622		0.824		1.049		1.380		1.610		2.067		2.469		3.068		4.026	
Flow Rate (Q)																			
scfm	lpm	psi	(kPa)	psi	(kPa)	psi	(kPa)	psi	(kPa)	psi	(kPa)	psi	(kPa)	psi	(kPa)	psi	(kPa)	psi	(kPa)
1	28																		
2	57																		
4	113																		
10	283																		
20	566	1.44	9.95																
30	850	3.06	21.07	0.75	5.16														
50	1,416	7.86	54.21	1.93	13.29	0.58	3.97												
100	2,832			6.94	47.90	2.08	14.32	0.53	3.64										
150	4,248			14.70	101.41	4.40	30.33	1.12	7.70	0.52	3.56								
200	5,664					7.49	51.64	1.90	13.11	0.88	6.06								
250	7,080					11.31	78.03	2.87	19.80	1.33	9.16								
300	8,496							4.02	27.75	1.86	12.84	0.53	3.68						
350	9,912							5.35	36.90	2.48	17.07	0.71	4.90						
400	11,328							6.85	47.24	3.17	21.86	0.91	6.27						
450	12,744							8.52	58.75	3.94	27.18	1.13	7.79						
500	14,160							10.35	71.39	4.79	33.03	1.37	9.47	0.56	3.89				
550	15,576							12.35	85.16	5.71	39.40	1.64	11.30	0.67	4.65				
600	16,992							14.50	100.03	6.71	46.28	1.92	13.27	0.79	5.46				
650	18,408									7.78	53.67	2.23	15.39	0.92	6.33				
700	19,824									8.92	61.55	2.56	17.65	1.05	7.26				
750	21,240									10.14	69.93	2.91	20.05	1.20	8.25				
800	22,656									11.43	78.80	3.28	22.59	1.35	9.29				
850	24,072									12.78	88.15	3.66	25.27	1.51	10.39	0.51	3.51		
900	25,488									14.21	97.98	4.07	28.09	1.68	11.55	0.57	3.90		
950	26,904											4.50	31.05	1.85	12.77	0.62	4.31		
1,000	28,320											4.95	34.14	2.04	14.04	0.69	4.74		
1,050	29,736											5.42	37.36	2.23	15.36	0.75	5.19		
1,250	35,400											7.48	51.58	3.08	21.21	1.04	7.16		
1,500	42,480											10.48	72.28	4.31	29.72	1.45	10.03		
2,000	56,640													7.34	50.61	2.48	17.08	0.64	4.39
2,500	70,800													11.09	76.47	3.74	25.81	0.96	6.63
3,000	84,960															5.24	36.17	1.35	9.29
3,500	99,120															6.98	48.10	1.79	12.36
4,000	113,280															8.93	61.58	2.29	15.83
4,500	127,440															11.10	76.58	2.85	19.68
5,000	141,600															13.49	93.06	3.47	23.91
5,500	155,760																	4.14	28.53
6,000	169,920																	4.86	33.51
6,500	184,080																	5.63	38.86
7,000	198,240																	6.46	44.57
7,500	212,400																	7.34	50.63
8,000	226,560																	8.27	57.05
8,500	240,720																	9.25	63.83
9,000	254,880																	10.29	70.94
9,500	269,040																	11.37	78.41
10,000	283,200																	12.50	86.21
10,500	297,360																	13.68	94.36
11,000	311,520																	14.91	102.84
11,500	325,680																		

The chart above is based on the equation: $\Delta p = K \bullet Q^{1.85} \bullet L / (d^5 \bullet p)$.

Δp = pressure loss $_{psi}$
K = 0.000604
Q = flow $_{scfm}$
L = Length of conductor $_{ft}$
d = inside diameter $_{in}$
p = Initial pressure $_{psia}$

Pressure losses below 0.5 psi may be considered insignificant and pressure losses above 15 psi are greater than would normally be acceptable and so are not shown in the chart. Other pressure losses can be found by using the equation above.

Air Pressure Drop per 30 Meters of Pipe with Initial Pressure at 790 kPa (absolute)

DN mm	15		20		25		32		40		50		65		80		90		100		125	
Inside Diameter mm	9.46		14.26		18.24		24.88		32.64		42.18		54.68		69.02		78.52		87.96		111.90	
Flow Rate (Q)																						
lpm	scfm	kPa	(psi)	kPa	(psi)	kPa	(psi)	kPa	(psi)	kPa	(psi)	kPa	(psi)	kPa	(psi)	kPa	(psi)	kPa	(psi)	kPa	(psi)	kPa	(psi)
10	0.35																						
20	0.71																						
30	1.06																						
50	1.77																						
100	3.53	5.15	0.75																				
200	7.06	18.56	2.69																				
300	11	39.29	5.70	5.05	0.73																		
400	14	66.90	9.70	8.60	1.25																		
500	18	101.08	14.66	12.99	1.88	3.79	0.55																
1,000	35			46.82	6.79	13.67	1.98																
2,000	71					49.30	7.15	10.44	1.51														
3,000	106							22.10	3.21	5.69	0.82												
4,000	141							37.64	5.46	9.69	1.40												
5,000	177							56.87	8.25	14.63	2.12	4.06	0.59										
6,000	212							79.68	11.55	20.51	2.97	5.69	0.83										
7,000	247									27.27	3.95	7.57	1.10										
8,000	282									34.91	5.06	9.69	1.40										
9,000	318									43.42	6.30	12.05	1.75										
10,000	353									52.76	7.65	14.64	2.12	4.00	0.58								
20,000	706											52.77	7.65	14.41	2.09	4.50	0.65						
40,000	1,412													51.96	7.53	16.22	2.35	8.51	1.23	4.82	0.70		
60,000	2,119															34.34	4.98	18.02	2.61	10.21	1.48		
80,000	2,825															58.46	8.48	30.68	4.45	17.39	2.52	5.22	0.76
90,000	3,178															72.70	10.54	38.15	5.53	21.63	3.14	6.49	0.94
100,000	3,531															88.34	12.81	46.36	6.72	26.28	3.81	7.89	1.14
110,000	3,884																	55.30	8.02	31.35	4.55	9.41	1.36
120,000	4,237																	64.96	9.42	36.82	5.34	11.05	1.60
130,000	4,590																	75.32	10.92	42.70	6.19	12.81	1.86
140,000	4,944																	86.39	12.53	48.97	7.10	14.70	2.13
150,000	5,297																	98.15	14.23	55.64	8.07	16.70	2.42
160,000	5,650																			62.70	9.09	18.82	2.73
170,000	6,003																			70.14	10.17	21.05	3.05
180,000	6,356																			77.96	11.30	23.40	3.39
190,000	6,709																			86.16	12.49	25.86	3.75
200,000	7,062																			94.74	13.74	28.43	4.12
210,000	7,415																					31.12	4.51
220,000	7,768																					33.91	4.92
230,000	8,121																					36.82	5.34
240,000	8,475																					39.84	5.78
250,000	8,828																					42.96	6.23
260,000	9,181																					46.19	6.70
270,000	9,534																					49.54	7.18
280,000	9,887																					52.98	7.68
290,000	10,240																					56.54	8.20
300,000	10,593																					60.20	8.73
310,000	10,946																					63.96	9.27
320,000	11,299																					67.83	9.84
330,000	11,653																					71.80	10.41
340,000	12,006																					75.88	11.00
350,000	12,359																					80.06	11.61
360,000	12,712																					84.34	12.23
370,000	13,065																					88.73	12.87
380,000	13,418																					93.22	13.52
390,000	13,771																					97.81	14.18
400,000	14,124																					102.50	14.86
420,000	14,831																						

The chart above is based on the equation: $\Delta p = K \bullet Q^{1.85} \bullet L / (d^5 \bullet p)$.

Δp = pressure loss $_{kPa}$
K = 2049.029
Q = flow $_{Nlm}$
L = Length of conductor $_{meters}$
d = inside diameter $_{mm}$
p = Initial pressure $_{kPa(absolute)}$

Pressure losses below 3.45 kPa may be considered insignificant and pressure losses above 103.45 kPa are greater than would normally be acceptable and so are not shown in the chart. Other pressure losses can be found by using the equation above.

Hydraulic

Limited Detail SAE Size ΔP and Velocity Chart Combined

Pressure Drop and Flow Through Each Foot Length of Inch Tube at Stated Velocity																				Δp Fittings				
Size inch			ft/sec		ft/sec		ft/sec		ft/sec		ft/sec		ft/sec		ft/sec		ft/sec		ft/sec						
			1		2		4		8		10		15		20		25		30						
OD	Wall	ID	psi	gpm	psi	gpm	psi Loss	gpm	psi Loss	gpm	psi Loss	gpm	psi Loss	gpm	psi Loss	gpm	psi	gpm	psi Loss	gpm					
0.125	0.028	0.069	4.621	0.012	9.242	0.023	18.484	0.047	36.968	0.093	46.211	0.117	69.316	0.175	92.421	0.233	115.526	0.291	138.632	0.350	16.411	5.450	17.354	23.796	2.38
0.125	0.035	0.055	7.273	0.007	14.546	0.015	29.092	0.030	58.184	0.059	72.730	0.074	109.095	0.111	145.460	0.148	181.825	0.185	218.190	0.222	16.460	5.450	17.396	23.867	2.39
0.188	0.028	0.132	1.263	0.043	2.525	0.085	5.051	0.171	10.101	0.341	12.627	0.426	18.940	0.640	25.254	0.853	31.567	1.066	37.880	1.279	16.160	5.450	17.164	23.475	2.35
0.188	0.035	0.118	1.580	0.034	3.160	0.068	6.320	0.136	12.641	0.273	15.801	0.341	23.701	0.511	31.601	0.682	39.502	0.852	47.402	1.022	16.229	5.450	17.207	23.547	2.35
0.250	0.028	0.194	0.585	0.092	1.169	0.184	2.338	0.368	4.677	0.737	5.846	0.921	8.769	1.382	11.691	1.842	14.614	2.303	17.537	2.764	15.972	5.450	16.978	23.160	2.32
0.250	0.035	0.180	0.679	0.079	1.358	0.159	2.716	0.317	5.432	0.634	6.790	0.793	10.186	1.190	13.581	1.586	16.976	1.983	20.371	2.379	16.022	5.450	17.020	23.231	2.32
0.250	0.049	0.152	0.952	0.057	1.905	0.113	3.809	0.226	7.618	0.452	9.523	0.566	14.284	0.848	19.045	1.131	23.806	1.414	28.568	1.697	16.120	5.450	17.104	23.374	2.34
0.250	0.065	0.120	1.528	0.035	3.056	0.070	6.111	0.141	12.223	0.282	15.278	0.352	22.918	0.528	30.557	0.705	38.196	0.881	45.835	1.057	16.232	5.450	17.201	23.536	2.35
0.312	0.028	0.256	0.336	0.160	0.671	0.321	1.343	0.642	2.686	1.283	3.357	1.604	5.036	2.406	6.714	3.208	8.393	4.010	10.071	4.813	15.715	5.450	16.702	22.845	2.28
0.312	0.035	0.242	0.376	0.143	0.751	0.287	1.503	0.573	3.005	1.147	3.757	1.434	5.635	2.150	7.513	2.867	9.392	3.584	11.270	4.301	15.804	5.450	16.834	22.916	2.29
0.312	0.049	0.214	0.480	0.112	0.961	0.224	1.922	0.448	3.843	0.897	4.804	1.121	7.206	1.681	9.608	2.242	12.010	2.802	14.412	3.363	15.902	5.450	16.918	23.058	2.31
0.312	0.065	0.182	0.664	0.081	1.328	0.162	2.657	0.324	5.314	0.649	6.642	0.811	9.963	1.216	13.284	1.622	16.605	2.027	19.926	2.432	16.018	5.450	17.014	23.221	2.32
0.375	0.028	0.319	0.216	0.249	0.432	0.498	0.865	0.996	1.730	1.993	2.162	2.491	3.243	3.736	4.324	4.982	5.405	6.227	6.486	7.473	15.534	5.450	16.602	22.524	2.25
0.375	0.035	0.305	0.237	0.228	0.473	0.455	0.946	0.911	1.892	1.822	2.365	2.277	3.548	3.416	4.730	4.554	5.913	5.693	7.095	6.831	15.583	5.450	16.644	22.595	2.26
0.375	0.049	0.277	0.287	0.188	0.573	0.376	1.147	0.751	2.294	1.503	2.867	1.878	4.301	2.817	5.735	3.756	7.168	4.695	8.602	5.634	15.681	5.450	16.728	22.738	2.27
0.375	0.065	0.245	0.367	0.147	0.733	0.294	1.466	0.588	2.932	1.175	3.665	1.469	5.498	2.204	7.331	2.939	9.163	3.673	10.996	4.408	15.794	5.450	16.825	22.901	2.29
0.500	0.035	0.430	0.119	0.453	0.238	0.905	0.476	1.810	0.952	3.621	1.190	4.526	1.785	6.789	2.380	9.052	5.214	11.315	7.174	13.578	15.145	5.450	16.268	21.960	2.20
0.500	0.049	0.402	0.136	0.396	0.272	0.791	0.545	1.582	1.089	3.165	1.361	3.956	2.042	5.934	2.723	7.911	3.404	9.889	7.904	11.867	15.269	5.450	16.353	22.102	2.21
0.500	0.065	0.370	0.161	0.335	0.321	0.670	0.643	1.340	1.286	2.681	1.607	3.351	2.411	5.026	3.214	6.702	4.018	8.377	8.656	10.053	15.393	5.450	16.449	22.265	2.23
0.500	0.083	0.334	0.197	0.273	0.394	0.546	0.789	1.092	1.578	2.185	1.972	2.731	2.958	4.096	3.944	5.461	4.930	6.827	5.917	8.192	15.484	5.450	16.557	22.448	2.24
0.625	0.035	0.555	0.071	0.754	0.143	1.508	0.286	3.016	0.571	6.032	0.714	7.540	1.071	11.310	1.429	15.079	3.790	18.849	5.215	22.619	14.206	5.450	15.893	21.324	2.13
0.625	0.049	0.527	0.079	0.680	0.158	1.360	0.317	2.719	0.634	5.439	0.792	6.798	1.188	10.197	1.584	13.596	4.043	16.995	5.563	20.395	14.804	5.450	15.977	21.466	2.15
0.625	0.065	0.495	0.090	0.600	0.180	1.200	0.359	2.399	0.718	4.798	0.898	5.998	1.347	8.996	1.796	11.995	4.373	14.994	6.016	17.993	14.917	5.450	16.073	21.629	2.16
0.625	0.083	0.459	0.104	0.516	0.209	1.031	0.418	2.063	0.835	4.126	1.044	5.157	1.566	7.735	2.089	10.314	4.806	12.892	6.612	15.471	15.041	5.450	16.181	21.812	2.18
0.750	0.035	0.680	0.048	1.132	0.095	2.264	0.190	4.527	0.381	9.055	0.476	11.318	0.714	16.978	0.952	22.637	2.940	28.296	4.085	33.955	14.218	5.450	15.517	20.688	2.07
0.750	0.049	0.652	0.052	1.041	0.104	2.081	0.207	4.162	0.414	8.324	0.518	10.406	0.776	15.608	1.035	20.811	3.009	26.014	4.264	31.217	14.366	5.450	15.601	20.830	2.08
0.750	0.065	0.620	0.057	0.941	0.114	1.882	0.229	3.764	0.458	7.527	0.572	9.409	0.859	14.114	1.145	18.818	3.300	23.523	4.560	28.228	14.478	5.450	15.697	20.993	2.10
0.750	0.083	0.584	0.065	0.835	0.129	1.670	0.258	3.339	0.516	6.679	0.645	8.348	0.968	12.522	1.290	16.697	3.556	20.871	4.893	25.045	14.604	5.450	15.805	21.176	2.12
0.750	0.109	0.532	0.078	0.693	0.155	1.386	0.311	2.771	0.622	5.542	0.777	6.928	1.166	10.392	1.555	13.856	3.996	17.319	5.498	20.783	14.787	5.450	15.962	21.441	2.14
0.875	0.035	0.805	0.034	1.586	0.068	3.172	0.135	6.345	0.272	12.690	0.340	15.862	0.509	23.793	1.611	31.724	2.381	39.655	3.276	47.586	13.823	5.450	15.141	20.052	2.01
0.875	0.049	0.777	0.036	1.478	0.073	2.956	0.146	5.911	0.292	11.822	0.364	14.778	0.547	22.167	1.694	29.556	2.489	36.945	3.424	44.334	13.927	5.450	15.225	20.194	2.02
0.875	0.065	0.745	0.040	1.359	0.079	2.717	0.159	5.434	0.317	10.869	0.396	13.586	0.595	20.379	1.775	27.171	2.623	33.964	3.609	40.757	14.032	5.450	15.321	20.357	2.04
0.875	0.083	0.709	0.044	1.230	0.088	2.461	0.175	4.922	0.350	9.844	0.438	12.304	0.657	18.457	1.889	24.609	2.791	30.761	3.840	36.913	14.166	5.450	15.429	20.540	2.05
0.875	0.095	0.685	0.047	1.149	0.094	2.297	0.188	4.594	0.375	9.188	0.469	11.486	0.703	17.228	1.572	22.971	2.913	28.714	4.008	34.457	14.250	5.450	15.502	20.662	2.07
0.875	0.109	0.657	0.051	1.057	0.102	2.113	0.204	4.226	0.408	8.453	0.510	10.566	0.765	15.849	2.077	21.132	3.069	26.414	4.223	31.697	14.343	5.450	15.586	20.805	2.08
1.000	0.035	0.930	0.025	2.117	0.051	4.234	0.102	8.468	0.203	16.937	0.254	21.171	0.813	31.756	1.345	42.342	1.988	52.927	2.735	63.512	13.700	5.450	14.765	19.416	1.94
1.000	0.049	0.902	0.027	1.992	0.054	3.983	0.108	7.966	0.216	15.932	0.270	19.915	0.845	29.873	1.398	39.830	2.065	49.788	2.842	59.745	13.809	5.450	14.849	19.559	1.96
1.000	0.065	0.870	0.029	1.853	0.058	3.705	0.116	7.411	0.233	14.822	0.291	18.527	0.884	27.791	1.462	37.054	2.161	46.318	2.978	55.582	13.921	5.450	14.945	19.721	1.97
1.000	0.083	0.834	0.032	1.703	0.063	3.405	0.127	6.810	0.253	13.620	0.316	17.026	0.932	25.538	1.542	34.051	2.278	42.564	3.134	51.077	13.727	5.450	15.054	19.905	1.99
1.000	0.095	0.810	0.034	1.606	0.067	3.212	0.134	6.424	0.268	12.848	0.335	16.060	0.966	24.090	1.599	32.120	2.363	40.150	3.251	48.179	13.811	5.450	15.126	20.027	2.00
1.000	0.109	0.782	0.036	1.497	0.072	2.994	0.144	5.987	0.288	11.975	0.360	14.969	1.010	22.453	1.671	29.937	2.469	37.422	3.397	44.906	13.910	5.450	15.210	20.169	2.02
1.000	0.120	0.760	0.038	1.414	0.076	2.828	0.152	5.655	0.305	11.311	0.381	14.138	1.047	21.207	1.731	28.277	2.559	35.346	3.520	42.415	13.987	5.450	15.276	20.281	2.03
1.125	0.049	1.027	0.021	2.582	0.042	5.163	0.083	10.327	0.167	20.654	0.209	25.817	0.718	38.726	1.188	51.635	1.756	64.543	2.416	77.452	13.059	5.450	14.473	18.923	1.89
1.125	0.065	0.995	0.022	2.423	0.044	4.847	0.089	9.693	0.178	19.387	0.222	24.234	0.747	36.350	1.236	48.467	1.827	60.584	2.514	72.701	13.162	5.450	14.569	19.086	1.91
1.125	0.083	0.959	0.024	2.251	0.048	4.502	0.096	9.005	0.191	18.009	0.239	22.512	0.783	33.768	1.295	45.023	1.913	56.279	2.632	67.535	13.269	5.450	14.678	19.269	1.93
1.125	0.095	0.935	0.025	2.140	0.050	4.280	0.101	8.560	0.201	17.119	0.252	21.399	0.808	32.099	1.336	42.798	1.975	53.498	2.717	64.197	13.373	5.450	14.750	19.391	1.94
1.125	0.109	0.907	0.027	2.014	0.053	4.027	0.107	8.055	0.214	16.109	0.267	20.137	0.839	30.205	1.388	40.273	2.051	50.341	2.822	60.410	13.471	5.450	14.834	19.533	1.95
1.125	0.120	0.885	0.028	1.917	0.056	3.834	0.112	7.669	0.225	15.337	0.281	19.172	0.865	28.757	1.431	38.343	2.115	47.929	2.910	57.515	13.548	5.450	14.900	19.645	1.96
1.250	0.049	1.152	0.017	3.248	0.033	6.497	0.066	12.994	0.133	25.988	0.166	32.484	0.622	48.727	1.029	64.969	1.521	81.211	2.093	97.453	12.612	5.450	14.097	18.287	1.83
1.250	0.065	1.120	0.018	3.070	0.035	6.141	0.070	12.282	0.140	24.564	0.175	30.705	0.645	46.057	1.066	61.410	1.576	76.762	2.168	92.114	12.724	5.450	14.194	18.450	1.84
1.250	0.083	1.084	0.019	2.876	0.037	5.753	0.075	11.505	0.150	23.010	0.187	28.763	0.671	43.144	1.111	57.525	1.641	71.907	2.258	86.288	12.810	5.450	14.302	18.633	1.86
1.250	0.095	1.060	0.020	2.750	0.039	5.501	0.078	11.001	0.157	22.003	0.196	27.503	0.690	41.255	1.142	55.006	1.688	68.758	2.322	82.509	12.884	5.450	14.374	18.755	1.88
1.250	0.109	1.032	0.021	2.607	0.041	5.214	0.083	10.428	0.165	20.855	0.207	26.069	0.714	39.104	1.181	52.139	1.746	65.173	2.402	78.208	13.033	5.450	14.458	18.897	1.89
1.250	0.120	1.010	0.022	2.497	0.043	4.994	0.086	9.988	0.173	19.976	0.216	24.970	0.733	37.455	1.213	49.939	1.793	62.424	2.467	74.909	13.110	5.450	14.524	19.009	1.90
1.500	0.065	1.370	0.012	4.594	0.023	9.188	0.047	18.377	0.094	36.754	0.117	45.942	0.501	68.913	0.829	91.884	1.225	114.855	1.685	137.827	11.547	5.450	13.442	17.178	1.72
1.500	0.083	1.334	0.012	4.356	0.025	8.712	0.049	17.424	0.099	34.848	0.124	43.559	0.518	65.339	0.857	87.119	1.266	108.899	1.742	130.678	11.673	5.450	13.550	17.361	1.74
1.500	0.095	1.310	0.013	4.201	0.026	8.401	0.051	16.802	0.103	33.605	0.128	42.006	0.530	63.009	0.877	84.012	1.295	105.015	1.782	126.019	11.757	5.450	13.622	17.483	1.75
1.500	0.109	1.282	0.013	4.023	0.027	8.046	0.054	16.092	0.107	32.184	0.134	40.230	0.544	60.345	0.901	80.459	1.331	100.574	1.831	120.689	11.856	5.450	13.706	17.626	1.76
1.500	0.120	1.260	0.014	3.886	0.028	7.772	0.055	15.544	0.111	31.089	0.139	38.861	0.556	58.291	0.920	77.722	1.360	97.152	1.871	116.582	12.233	5.450	13.773	17.738	1.77
1.750	0.065	1.620	0.008	6.424	0.017	12.848	0.034	25.696	0.067	51.391	0.084	64.239	0.406	96.359	0.672	128.478	0.993	160.598	1.367	192.718	10.970	5.450	12.690	15.906	1.59
1.750	0.083	1.584	0.009	6.142	0.018	12.283	0.035	24.566	0.070	49.133	0.088	61.416	0.418	92.124	0.691	122.832	1.022	153.540	1.406	184.248	11.096	5.450	12.798	16.089	1.61
1.750	0.095	1.560	0.009	5.957	0.018	11.914	0.036	23.828	0.072	47.655	0.090	59.569	0.426	89.353	0.705	119.138	1.041	148.922	1.433	178.707	11.180	5.450	12.871	16.212	1.62
1.750	0.109	1.532	0.009	5.745	0.019	11.490	0.037	22.980	0.075	45.960	0.094	57.450	0.436	86.175	0.721	114.899	1.065	143.624	1.466	172.349	11.279	5.450	12.955	16.354	1.64
1.750	0.120	1.510	0.010	5.581	0.019	11.162	0.039	22.325	0.077	44.649	0.096	55.812	0.444	83.717	0.734	111.623	1.085	139.529	1.492	167.435	11.356	5.450	13.021	16.466	1.65
2.000	0.065	1.870	0.006	8.560	0.013	17.119	0.025	34.238	0.050	68.477	0.167	85.596	0.340	128.394	0.562	171.192	0.830	213.990	1.142	256.788	10.093	5.450	11.938	14.635	1.46
2.000	0.083	1.834	0.007	8.233	0.013	16.466	0.026	32.933	0.052	65.866	0.171	82.332	0.348	123.498	0.576	164.664	0.851	205.830	1.170	246.996	10.219	5.450	12.047	14.818	1.48
2.000	0.095	1.810	0.007	8.019	0.013	16.038	0.027	32.077	0.054	64.153	0.174	80.191	0.354	120.267	0.585	160.383	0.865	200.478	1.190	240.574	10.303	5.450	12.119	14.940	1.49
2.000	0.109	1.782	0.007	7.773	0.014	15.546	0.028	31.092	0.055	62.184	0.177	77.730	0.361	116.594	0.597	155.459	0.882	194.324	1.213	233.189	10.422	5.450	12.203	15.082	1.51
2.000	0.120	1.760	0.007	7.582	0.014	15.164	0.028	30.329	0.057	60.658	0.180	75.822	0.366	113.733	0.606	151.644	0.896	189.555	1.232	227.466	10.479	5.450	12.269	15.194	1.52
2.250	0.065	2.120	0.005	11.001	0.010	22.003	0.020	44.005	0.039	88.010	0.143	110.013	0.290	165.019	0.480	220.025	0.710	275.031	0.976	330.038	9.216	5.450	11.187	13.363	1.34
2.250	0.083	2.084	0.005	10.631	0.010	21.262	0.020	42.523	0.041	85.046	0.146	106.308	0.297	159.462	0.491	212.616	0.725	265.770	0.998	318.924	9.342	5.450	11.295	13.546	1.35
2.250	0.095	2.060	0.005	10.387	0.010	20.775	0.021	41.549	0.041	83.099	0.148	103.874	0.301	155.810	0.498	207.747	0.736	259.684	1.012	311.621	9.426	5.450	11.367	13.668	1.37
2.250	0.109	2.032	0.005	10.107	0.011	20.214	0.021	40.428	0.043	80.855	0.151	101.069	0.306	151.604	0.506	202.138	0.748	252.673	1.030	303.207	9.525	5.450	11.451	13.811	1.38
2.250	0.120	2.010	0.005	9.889	0.011	19.778	0.022	39.557	0.044	79.114	0.153	98.892	0.310	148.339	0.513	197.785	0.759	247.231	1.044	296.677	9.602	5.450	11.517	13.923	1.39
2.250	0.134	1.982	0.006	9.616	0.011	19.231	0.022	38.463	0.045	76.925	0.155	96.156	0.316	144.235	0.522	192.313	0.772	240.391	1.062	288.469	9.700	5.450	11.602	14.065	1.41

Based on the formula: $\Delta p = .000215 \times f \times p \times x \times Q^2 / d^5$. Δp = psi change, f = friction factor of 64/Re when Re is < 2300 and 0.316/Re.25 when Re > 2300, p = density of 62.4 lb/ft³, Q = flow in gpm, and d = ID of conductor. Re = Renolds # = 3162 x Q / (cs x d).

The information presented here is for estimation only. The data is based on accepted industry formulas using tubing with smooth, circular walls. The default fluid conditions are a viscosity of 33.1 Centistokes (cs), a temperature is 100 °F, and a specific gravity (sg) of 1.0. Other viscosities, temperatures and /or specific gravities will require new calculations. The IFPS makes no claim to the accuracy of the data in the chart. The chart does not provide pressure ratings for the tubing. Be sure tubing with the proper pressure rating is chosen for the specific application.

Numbers in Blue are for Transitional Flow. Numbers in Red are for Turbulent flow.

Metric Detail SAE Size ΔP and Velocity Chart Combined

Pressure Drop in kPa and Flow in lpm Through Each Meter Length of Tube at Stated Velocity																				
			m/sec		m/sec		m/sec		m/sec		m/sec		m/sec		m/sec		m/sec		m/sec	
Size mm			1		2		3		4		5		6		7		8		9	
OD	Wall	ID	kPa Loss	lpm	kPa Loss	lpm	kPa Loss	lpm	kPa Loss	lpm	kPa Loss	lpm	kPa Loss	lpm	kPa Loss	lpm	kPa Loss	lpm	kPa Loss	lpm
4	0.75	2.5	15.37	0.29	30.74	0.59	46.12	0.88		1.18	76.86	1.47	92.23	1.76	107.60	2.06	122.98	2.35	138.35	2.64
4	1.0	2	24.02	0.19	48.04	0.38	72.06	0.56	96.08	0.75	120.09	0.94	144.11	1.13	168.13	1.32	192.15	1.50	216.17	1.69
6	1.0	4	6.00	0.75	12.01	1.50	18.01	2.26	24.02	3.01	30.02	3.76	36.03	4.51	42.03	5.26	48.04	6.02	54.04	6.77
6	1.5	3	10.68	0.42	21.35	0.85	32.03	1.27	42.70	1.69	53.38	2.12	64.05	2.54	74.73	2.96	85.40	3.38	96.08	3.81
6	2.0	2	24.02	0.19	48.04	0.38	72.06	0.56	96.08	0.75	120.09	0.94	144.11	1.13	168.13	1.32	192.15	1.50	216.17	1.69
6	2.5	1	96.08	0.05	192.15	0.09	288.23	0.14	384.30	0.19	480.38	0.24	576.45	0.28	672.53	0.33	768.60	0.38	864.68	0.42
8	1.0	6	2.67	1.69	5.34	3.38	8.01	5.08	10.68	6.77	13.34	8.46	16.01	10.15	18.68	11.84	21.35	13.54	24.02	15.23
8	1.5	5	3.84	1.18	7.69	2.35	11.53	3.53	15.37	4.70	19.22	5.88	23.06	7.05	26.90	8.23	30.74	9.40	34.59	10.58
8	2.0	4	6.00	0.75	12.01	1.50	18.01	2.26	24.02	3.01	30.02	3.76	36.03	4.51	42.03	5.26	48.04	6.02	54.04	6.77
8	2.5	3	10.68	0.42	21.35	0.85	32.03	1.27	42.70	1.69	53.38	2.12	64.05	2.54	74.73	2.96	85.40	3.38	96.08	3.81
10	1.0	8	1.50	3.01	3.00	6.02	4.50	9.02	6.00	12.03	7.51	15.04	9.01	18.05	10.51	21.06	12.01	24.06	13.51	27.07
10	1.5	7	1.96	2.30	3.92	4.61	5.88	6.91	7.84	9.21	9.80	11.52	11.76	13.82	13.73	16.12	15.69	18.42	17.65	20.73
10	2.0	6	2.67	1.69	5.34	3.38	8.01	5.08	10.68	6.77	13.34	8.46	16.01	10.15	18.68	11.84	21.35	13.54	24.02	15.23
10	2.5	5	3.84	1.18	7.69	2.35	11.53	3.53	15.37	4.70	19.22	5.88	23.06	7.05	26.90	8.23	30.74	9.40	34.59	10.58
10	3.0	4	6.00	0.75	12.01	1.50	18.01	2.26	24.02	3.01	30.02	3.76	36.03	4.51	42.03	5.26	48.04	6.02	54.04	6.77
12	1.0	10	0.96	4.70	1.92	9.40	2.88	14.10	3.84	18.80	4.80	23.50	5.76	28.20	6.73	32.90	7.69	37.60	8.65	42.30
12	1.5	9	1.19	3.81	2.37	7.61	3.56	11.42	4.74	15.23	5.93	19.04	7.12	22.84	8.30	26.65	9.49	30.46	10.68	34.26
12	2.0	8	1.50	3.01	3.00	6.02	4.50	9.02	6.00	12.03	7.51	15.04	9.01	18.05	10.51	21.06	12.01	24.06	13.51	27.07
12	2.5	7	1.96	2.30	3.92	4.61	5.88	6.91	7.84	9.21	9.80	11.52	11.76	13.82	13.73	16.12	15.69	18.42	17.65	20.73
12	3.0	6	2.67	1.69	5.34	3.38	8.01	5.08	10.68	6.77	13.34	8.46	16.01	10.15	18.68	11.84	21.35	13.54	24.02	15.23
12	3.5	5	3.84	1.18	7.69	2.35	11.53	3.53	15.37	4.70	19.22	5.88	23.06	7.05	26.90	8.23	30.74	9.40	34.59	10.58
15	1.5	12	0.67	6.77	1.33	13.54	2.00	20.30	2.67	27.07	3.34	33.84	4.00	40.61	4.67	47.38	5.34	54.14	6.00	60.91
15	2.0	11	0.79	5.69	1.59	11.37	2.38	17.06	3.18	22.75	3.97	28.44	4.76	34.12	5.56	39.81	6.35	45.50	7.15	51.18
15	2.5	10	0.96	4.70	1.92	9.40	2.88	14.10	3.84	18.80	4.80	23.50	5.76	28.20	6.73	32.90	7.69	37.60	8.65	42.30
15	3.0	9	1.19	3.81	2.37	7.61	3.56	11.42	4.74	15.23	5.93	19.04	7.12	22.84	8.30	26.65	9.49	30.46	10.68	34.26
16	2.0	12	0.67	6.77	1.33	13.54	2.00	20.30	2.67	27.07	3.34	33.84	4.00	40.61	4.67	47.38	5.34	54.14	6.00	60.91
16	2.5	11	0.79	5.69	1.59	11.37	2.38	17.06	3.18	22.75	3.97	28.44	4.76	34.12	5.56	39.81	6.35	45.50	7.15	51.18
16	3.0	10	0.96	4.70	1.92	9.40	2.88	14.10	3.84	18.80	4.80	23.50	5.76	28.20	6.73	32.90	7.69	37.60	8.65	42.30
18	1.5	15	0.43	10.58	0.85	21.15	1.28	31.73	1.71	42.30	2.14	52.88	2.56	63.45	2.99	74.03	3.42	84.60	3.84	95.18
18	2.0	14	0.49	9.21	0.98	18.42	1.47	27.64	1.96	36.85	2.45	46.06	2.94	55.27	3.43	64.48	3.92	73.70	4.41	82.91
18	2.5	13	0.57	7.94	1.14	15.89	1.71	23.83	2.27	31.77	2.84	39.72	3.41	47.66	3.98	55.60	4.55	63.54	5.12	71.49
18	3.0	12	0.67	6.77	1.33	13.54	2.00	20.30	2.67	27.07	3.34	33.84	4.00	40.61	4.67	47.38	5.34	54.14	6.00	60.91
20	2.5	15	0.43	10.58	0.85	21.15	1.28	31.73	1.71	42.30	2.14	52.88	2.56	63.45	2.99	74.03	3.42	84.60	3.84	95.18
20	3.0	14	0.49	9.21	0.98	18.42	1.47	27.64	1.96	36.85	2.45	46.06	2.94	55.27	3.43	64.48	3.92	73.70	4.41	82.91
20	3.5	13	0.57	7.94	1.14	15.89	1.71	23.83	2.27	31.77	2.84	39.72	3.41	47.66	3.98	55.60	4.55	63.54	5.12	71.49
20	4.0	12	0.67	6.77	1.33	13.54	2.00	20.30	2.67	27.07	3.34	33.84	4.00	40.61	4.67	47.38	5.34	54.14	6.00	60.91
22	2.0	18	0.30	15.23	0.59	30.46	0.89	45.68	1.19	60.91	1.48	76.14	1.78	91.37	2.08	106.60	2.37	121.82	2.67	137.05
22	2.5	17	0.33	13.58	0.66	27.17	1.00	40.75	1.33	54.33	1.66	67.92	1.99	81.50	2.33	95.08	2.66	108.66	2.99	122.25
22	3.0	16	0.38	12.03	0.75	24.06	1.13	36.10	1.50	48.13	1.88	60.16	2.25	72.19	2.63	84.22	3.00	96.26	3.38	108.29
25	2.0	21	0.22	20.73	0.44	41.45	0.65	62.18	0.87	82.91	1.09	103.64	1.31	124.36	1.53	145.09	1.74	165.82	1.96	186.54
25	2.5	20	0.24	18.80	0.48	37.60	0.72	56.40	0.96	75.20	1.20	94.00	1.44	112.80	1.68	131.60	1.92	150.40	2.16	169.20
25	3.0	19	0.27	16.97	0.53	33.93	0.80	50.90	1.06	67.87	1.33	84.84	1.60	101.80	1.86	118.77	2.13	135.74	2.40	152.70
25	4.0	17	0.33	13.58	0.66	27.17	1.00	40.75	1.33	54.33	1.66	67.92	1.99	81.50	2.33	95.08	2.66	108.66	2.99	122.25
25	4.5	16	0.38	12.03	0.75	24.06	1.13	36.10	1.50	48.13	1.88	60.16	2.25	72.19	2.63	84.22	3.00	96.26	3.38	108.29
25	5.0	15	0.43	10.58	0.85	21.15	1.28	31.73	1.71	42.30	2.14	52.88	2.56	63.45	2.99	74.03	3.42	84.60	3.84	95.18
28	2.0	24	0.17	27.07	0.33	54.14	0.50	81.22	0.67	108.29	0.83	135.36	1.00	162.43	1.17	189.50	1.33	216.58	1.50	243.65
28	2.5	23	0.18	24.86	0.36	49.73	0.54	74.59	0.73	99.45	0.91	124.32	1.09	149.18	1.27	174.04	1.45	198.90	1.63	223.77
28	3.0	22	0.20	22.75	0.40	45.50	0.60	68.24	0.79	90.99	0.99	113.74	1.19	136.49	1.39	159.24	1.59	181.98	1.79	204.73
28	4.0	20	0.24	18.80	0.48	37.60	0.72	56.40	0.96	75.20	1.20	94.00	1.44	112.80	1.68	131.60	1.92	150.40	2.16	169.20
28	5.0	18	0.30	15.23	0.59	30.46	0.89	45.68	1.19	60.91	1.48	76.14	1.78	91.37	2.08	106.60	2.37	121.82	2.67	137.05
30	3.0	24	0.17	27.07	0.33	54.14	0.50	81.22	0.67	108.29	0.83	135.36	1.00	162.43	1.17	189.50	1.33	216.58	1.50	243.65
30	4.0	22	0.20	22.75	0.40	45.50	0.60	68.24	0.79	90.99	0.99	113.74	1.19	136.49	1.39	159.24	1.59	181.98	1.79	204.73
30	5.0	20	0.24	18.80	0.48	37.60	0.72	56.40	0.96	75.20	1.20	94.00	1.44	112.80	1.68	131.60	1.92	150.40	2.16	169.20
35	2.0	31	0.10	45.17	0.20	90.33	0.57	135.50	0.40	180.67	0.50	225.84	0.60	271.00	0.70	316.17	0.80	361.34	0.90	406.50
35	2.5	30	0.11	42.30	0.21	84.60	0.60	126.90	0.43	169.20	0.53	211.50	0.64	253.80	0.75	296.10	0.85	338.40	0.96	380.70
35	3.0	29	0.11	39.53	0.23	79.05	0.62	118.58	0.46	158.11	0.57	197.64	0.69	237.16	0.80	276.69	0.91	316.22	1.03	355.74
35	4.0	27	0.13	34.26	0.26	68.53	0.68	102.79	0.53	137.05	0.66	171.32	0.79	205.58	0.92	239.84	1.05	274.10	1.19	308.37
35	5.0	25	0.15	29.38	0.31	58.75	0.46	88.13	0.61	117.50	0.77	146.88	0.92	176.25	1.08	205.63	1.23	235.00	1.38	264.38
35	6.0	23	0.18	24.86	0.36	49.73	0.54	74.59	0.73	99.45	0.91	124.32	1.09	149.18	1.27	174.04	1.45	198.90	1.63	223.77
38	4.0	30	0.11	42.30	0.21	84.60	0.60	126.90	0.43	169.20	0.53	211.50	0.64	253.80	0.75	296.10	0.85	338.40	0.96	380.70
38	5.0	28	0.12	36.85	0.25	73.70	0.65	110.54	0.49	147.39	0.61	184.24	0.74	221.09	0.86	257.94	0.98	294.78	1.10	331.63
38	6.0	26	0.14	31.77	0.28	63.54	0.71	95.32	0.57	127.09	0.71	158.86	0.85	190.63	0.99	222.40	1.14	254.18	1.28	285.95
38	7.0	24	0.17	27.07	0.33	54.14	0.50	81.22	0.67	108.29	0.83	135.36	1.00	162.43	1.17	189.50	1.33	216.58	1.50	243.65
42	3.0	36	0.07	60.91	0.15	121.82	0.47	182.74	0.30	243.65	0.37	304.56	0.44	365.47	0.52	426.38	0.59	487.30	0.67	548.21
42	4.0	34	0.08	54.33	0.17	108.66	0.51	163.00	0.33	217.33	0.42	271.66	0.50	325.99	0.58	380.32	0.66	434.66	0.75	488.99
Numbers in Blue are for Transitional Flow. Numbers in Red are for Turbulent flow.																				

Expanded Detail SAE Size ΔP / ΔP Fittings and Velocity Chart Combined

Pressure Drop and Flow Through Each Foot Length of SAE Tube at Stated Velocity

Size inch			ft/sec 1		Δp Fittings				ft/sec 2		Δp Fittings				ft/sec 3		Δp Fittings			
OD	Wall	ID	psi Loss	gpm	Curved 90°	Through Flow	90° Flow	Sharp 90°	psi Loss	gpm	Curved 90°	Through Flow	90° Flow	Sharp 90°	psi Loss	gpm	Curved 90°	Through Flow	90° Flow	Sharp 90°
0.125	0.028	0.069	4.621	0.012	0.018	0.006	0.019	0.026	9.242	0.023	0.073	0.024	0.077	0.106	13.863	0.035	0.164	0.055	0.174	0.238
0.125	0.035	0.055	7.273	0.007	0.018	0.006	0.019	0.027	14.546	0.015	0.073	0.024	0.077	0.106	21.819	0.022	0.165	0.055	0.174	0.239
0.188	0.028	0.132	1.263	0.043	0.018	0.006	0.019	0.026	2.525	0.085	0.072	0.024	0.076	0.104	3.788	0.128	0.162	0.055	0.172	0.235
0.188	0.035	0.118	1.580	0.034	0.018	0.006	0.019	0.026	3.160	0.068	0.072	0.024	0.076	0.105	4.740	0.102	0.162	0.055	0.172	0.235
0.250	0.028	0.194	0.585	0.092	0.018	0.006	0.019	0.026	1.169	0.184	0.071	0.024	0.075	0.103	1.754	0.276	0.160	0.055	0.170	0.232
0.250	0.035	0.180	0.679	0.079	0.018	0.006	0.019	0.026	1.358	0.159	0.071	0.024	0.076	0.103	2.037	0.238	0.160	0.055	0.170	0.232
0.250	0.049	0.152	0.952	0.057	0.018	0.006	0.019	0.026	1.905	0.113	0.072	0.024	0.076	0.104	2.857	0.170	0.161	0.055	0.171	0.234
0.250	0.065	0.120	1.528	0.035	0.018	0.006	0.019	0.026	3.056	0.070	0.072	0.024	0.076	0.105	4.584	0.106	0.162	0.055	0.172	0.235
0.312	0.028	0.256	0.336	0.160	0.018	0.006	0.019	0.025	0.671	0.321	0.070	0.024	0.074	0.102	1.007	0.481	0.158	0.055	0.167	0.228
0.312	0.035	0.242	0.376	0.143	0.018	0.006	0.019	0.025	0.751	0.287	0.070	0.024	0.075	0.102	1.127	0.430	0.158	0.055	0.168	0.229
0.312	0.049	0.214	0.480	0.112	0.018	0.006	0.019	0.026	0.961	0.224	0.071	0.024	0.075	0.102	1.441	0.336	0.159	0.055	0.169	0.231
0.312	0.065	0.182	0.664	0.081	0.018	0.006	0.019	0.026	1.328	0.162	0.071	0.024	0.076	0.103	1.993	0.243	0.160	0.055	0.170	0.232
0.375	0.028	0.319	0.216	0.249	0.017	0.006	0.018	0.025	0.432	0.498	0.069	0.024	0.074	0.100	0.649	0.747	0.155	0.055	0.166	0.225
0.375	0.035	0.305	0.237	0.228	0.017	0.006	0.018	0.025	0.473	0.455	0.069	0.024	0.074	0.100	0.710	0.683	0.156	0.055	0.166	0.226
0.375	0.049	0.277	0.287	0.188	0.017	0.006	0.019	0.025	0.573	0.376	0.070	0.024	0.074	0.101	0.860	0.563	0.157	0.055	0.167	0.227
0.375	0.065	0.245	0.367	0.147	0.018	0.006	0.019	0.025	0.733	0.294	0.070	0.024	0.075	0.102	1.100	0.441	0.158	0.055	0.168	0.229
0.500	0.035	0.430	0.119	0.453	0.017	0.006	0.018	0.024	0.238	0.905	0.067	0.024	0.072	0.098	0.357	1.358	0.151	0.055	0.163	0.220
0.500	0.049	0.402	0.136	0.396	0.017	0.006	0.018	0.025	0.272	0.791	0.068	0.024	0.073	0.098	0.408	1.187	0.152	0.055	0.164	0.221
0.500	0.065	0.370	0.161	0.335	0.017	0.006	0.018	0.025	0.321	0.670	0.068	0.024	0.073	0.099	0.482	1.005	0.154	0.055	0.164	0.223
0.500	0.083	0.334	0.197	0.273	0.017	0.006	0.018	0.025	0.394	0.546	0.069	0.024	0.074	0.100	0.592	0.819	0.155	0.055	0.166	0.224
0.625	0.035	0.555	0.071	0.754	0.016	0.006	0.018	0.024	0.143	1.508	0.065	0.024	0.071	0.095	0.214	2.262	0.147	0.055	0.159	0.213
0.625	0.049	0.527	0.079	0.680	0.016	0.006	0.018	0.024	0.158	1.360	0.066	0.024	0.071	0.095	0.238	2.039	0.148	0.055	0.160	0.215
0.625	0.065	0.495	0.090	0.600	0.017	0.006	0.018	0.024	0.180	1.200	0.066	0.024	0.071	0.096	0.269	1.799	0.149	0.055	0.161	0.216
0.625	0.083	0.459	0.104	0.516	0.017	0.006	0.018	0.024	0.209	1.031	0.067	0.024	0.072	0.097	0.313	1.547	0.150	0.055	0.162	0.218
0.625	0.095	0.435	0.116	0.463	0.017	0.006	0.018	0.024	0.233	0.926	0.067	0.024	0.072	0.097	0.349	1.390	0.151	0.055	0.163	0.219
0.750	0.035	0.680	0.048	1.132	0.016	0.006	0.017	0.023	0.095	2.264	0.063	0.024	0.069	0.092	0.143	3.396	0.143	0.055	0.155	0.207
0.750	0.049	0.652	0.052	1.041	0.016	0.006	0.017	0.023	0.104	2.081	0.064	0.024	0.069	0.093	0.155	3.122	0.144	0.055	0.156	0.208
0.750	0.065	0.620	0.057	0.941	0.016	0.006	0.017	0.023	0.114	1.882	0.064	0.024	0.070	0.093	0.172	2.823	0.145	0.055	0.157	0.210
0.750	0.083	0.584	0.065	0.835	0.016	0.006	0.018	0.024	0.129	1.670	0.065	0.024	0.070	0.094	0.194	2.504	0.146	0.055	0.158	0.212
0.750	0.095	0.560	0.070	0.768	0.016	0.006	0.018	0.024	0.140	1.535	0.065	0.024	0.071	0.095	0.210	2.303	0.147	0.055	0.159	0.213
0.750	0.109	0.532	0.078	0.693	0.016	0.006	0.018	0.024	0.155	1.386	0.066	0.024	0.071	0.095	0.233	2.078	0.148	0.055	0.160	0.214
0.875	0.035	0.805	0.034	1.586	0.015	0.006	0.017	0.022	0.068	3.172	0.061	0.024	0.067	0.089	0.102	4.759	0.138	0.055	0.151	0.201
0.875	0.049	0.777	0.036	1.478	0.015	0.006	0.017	0.022	0.073	2.956	0.062	0.024	0.068	0.090	0.109	4.433	0.139	0.055	0.152	0.202
0.875	0.065	0.745	0.040	1.359	0.016	0.006	0.017	0.023	0.079	2.717	0.062	0.024	0.068	0.090	0.119	4.076	0.140	0.055	0.153	0.204
0.875	0.083	0.709	0.044	1.230	0.016	0.006	0.017	0.023	0.088	2.461	0.063	0.024	0.069	0.091	0.131	3.691	0.142	0.055	0.154	0.205
0.875	0.095	0.685	0.047	1.149	0.016	0.006	0.017	0.023	0.094	2.297	0.063	0.024	0.069	0.092	0.141	3.446	0.143	0.055	0.155	0.207
0.875	0.109	0.657	0.051	1.057	0.016	0.006	0.017	0.023	0.102	2.113	0.064	0.024	0.069	0.092	0.153	3.170	0.143	0.055	0.156	0.208
1.000	0.035	0.930	0.025	2.117	0.015	0.006	0.016	0.022	0.051	4.234	0.060	0.024	0.066	0.086	0.076	6.351	0.134	0.055	0.148	0.194
1.000	0.049	0.902	0.027	1.992	0.015	0.006	0.016	0.022	0.054	3.983	0.060	0.024	0.066	0.087	0.081	5.975	0.135	0.055	0.148	0.196

Size inch			ft/sec 1		Δp Fittings				ft/sec 2		Δp Fittings				ft/sec 3		Δp Fittings			
OD	Wall	ID	psi Loss	gpm	Curved 90°	Through Flow	90° Flow	Sharp 90°	psi Loss	gpm	Curved 90°	Through Flow	90° Flow	Sharp 90°	psi Loss	gpm	Curved 90°	Through Flow	90° Flow	Sharp 90°
1.000	0.065	0.870	0.029	1.853	0.015	0.006	0.017	0.022	0.058	3.705	0.060	0.024	0.066	0.088	0.087	5.558	0.136	0.055	0.149	0.197
1.000	0.083	0.834	0.032	1.703	0.015	0.006	0.017	0.022	0.063	3.405	0.061	0.024	0.067	0.088	0.095	5.108	0.137	0.055	0.151	0.199
1.000	0.095	0.810	0.034	1.606	0.015	0.006	0.017	0.022	0.067	3.212	0.061	0.024	0.067	0.089	0.101	4.818	0.138	0.055	0.151	0.200
1.000	0.109	0.782	0.036	1.497	0.015	0.006	0.017	0.022	0.072	2.994	0.062	0.024	0.068	0.090	0.108	4.491	0.139	0.055	0.152	0.202
1.000	0.120	0.760	0.038	1.414	0.016	0.006	0.017	0.023	0.076	2.828	0.062	0.024	0.068	0.090	0.114	4.241	0.140	0.055	0.153	0.203
1.125	0.049	1.027	0.021	2.582	0.015	0.006	0.016	0.021	0.042	5.163	0.058	0.024	0.064	0.084	0.063	7.745	0.131	0.055	0.145	0.189
1.125	0.065	0.995	0.022	2.423	0.015	0.006	0.016	0.021	0.044	4.847	0.058	0.024	0.065	0.085	0.067	7.270	0.132	0.055	0.146	0.191
1.125	0.083	0.959	0.024	2.251	0.015	0.006	0.016	0.021	0.048	4.502	0.059	0.024	0.065	0.086	0.072	6.754	0.133	0.055	0.147	0.193
1.125	0.095	0.935	0.025	2.140	0.015	0.006	0.016	0.022	0.050	4.280	0.059	0.024	0.066	0.086	0.075	6.420	0.134	0.055	0.148	0.194
1.125	0.109	0.907	0.027	2.014	0.015	0.006	0.016	0.022	0.053	4.027	0.060	0.024	0.066	0.087	0.080	6.041	0.135	0.055	0.148	0.195
1.125	0.120	0.885	0.028	1.917	0.015	0.006	0.017	0.022	0.056	3.834	0.060	0.024	0.066	0.087	0.084	5.751	0.135	0.055	0.149	0.196
1.250	0.049	1.152	0.017	3.248	0.014	0.006	0.016	0.020	0.033	6.497	0.056	0.024	0.063	0.081	0.050	9.745	0.126	0.055	0.141	0.183
1.250	0.065	1.120	0.018	3.070	0.014	0.006	0.016	0.021	0.035	6.141	0.057	0.024	0.063	0.082	0.053	9.211	0.127	0.055	0.142	0.185
1.250	0.083	1.084	0.019	2.876	0.014	0.006	0.016	0.021	0.037	5.753	0.057	0.024	0.064	0.083	0.056	8.629	0.129	0.055	0.143	0.186
1.250	0.095	1.060	0.020	2.750	0.014	0.006	0.016	0.021	0.039	5.501	0.057	0.024	0.064	0.083	0.059	8.251	0.129	0.055	0.144	0.188
1.250	0.109	1.032	0.021	2.607	0.014	0.006	0.016	0.021	0.041	5.214	0.058	0.024	0.064	0.084	0.062	7.821	0.130	0.055	0.145	0.189
1.250	0.120	1.010	0.022	2.497	0.015	0.006	0.016	0.021	0.043	4.994	0.058	0.024	0.065	0.084	0.065	7.491	0.131	0.055	0.145	0.190
1.500	0.065	1.370	0.012	4.594	0.013	0.006	0.015	0.019	0.023	9.188	0.053	0.024	0.060	0.076	0.035	13.783	0.118	0.055	0.134	0.172
1.500	0.083	1.334	0.012	4.356	0.013	0.006	0.015	0.019	0.025	8.712	0.053	0.024	0.060	0.077	0.037	13.068	0.120	0.055	0.136	0.174
1.500	0.095	1.310	0.013	4.201	0.013	0.006	0.015	0.019	0.026	8.401	0.054	0.024	0.061	0.078	0.038	12.602	0.121	0.055	0.136	0.175
1.500	0.109	1.282	0.013	4.023	0.014	0.006	0.015	0.020	0.027	8.046	0.054	0.024	0.061	0.078	0.040	12.069	0.122	0.055	0.137	0.176
1.500	0.120	1.260	0.014	3.886	0.014	0.006	0.015	0.020	0.028	7.772	0.054	0.024	0.061	0.079	0.042	11.658	0.122	0.055	0.138	0.177
1.750	0.065	1.620	0.008	6.424	0.012	0.006	0.014	0.018	0.017	12.848	0.049	0.024	0.056	0.071	0.025	19.272	0.110	0.055	0.127	0.159
1.750	0.083	1.584	0.009	6.142	0.012	0.006	0.014	0.018	0.018	12.283	0.049	0.024	0.057	0.072	0.026	18.425	0.111	0.055	0.128	0.161
1.750	0.095	1.560	0.009	5.957	0.012	0.006	0.014	0.018	0.018	11.914	0.050	0.024	0.057	0.072	0.027	17.871	0.112	0.055	0.129	0.162
1.750	0.109	1.532	0.009	5.745	0.013	0.006	0.014	0.018	0.019	11.490	0.050	0.024	0.058	0.073	0.028	17.235	0.113	0.055	0.130	0.164
1.750	0.120	1.510	0.010	5.581	0.013	0.006	0.014	0.018	0.019	11.162	0.050	0.024	0.058	0.073	0.029	16.743	0.114	0.055	0.130	0.165
2.000	0.065	1.870	0.006	8.560	0.011	0.006	0.013	0.016	0.013	17.119	0.045	0.024	0.053	0.065	0.019	25.679	0.101	0.055	0.119	0.146
2.000	0.083	1.834	0.007	8.233	0.011	0.006	0.013	0.016	0.013	16.466	0.045	0.024	0.054	0.066	0.020	24.700	0.102	0.055	0.120	0.148
2.000	0.095	1.810	0.007	8.019	0.011	0.006	0.013	0.017	0.013	16.038	0.046	0.024	0.054	0.066	0.020	24.057	0.103	0.055	0.121	0.149
2.000	0.109	1.782	0.007	7.773	0.012	0.006	0.014	0.017	0.014	15.546	0.046	0.024	0.054	0.067	0.021	23.319	0.104	0.055	0.122	0.151
2.000	0.120	1.760	0.007	7.582	0.012	0.006	0.014	0.017	0.014	15.164	0.047	0.024	0.055	0.068	0.021	22.747	0.105	0.055	0.123	0.152
2.000	0.134	1.732	0.007	7.343	0.012	0.006	0.014	0.017	0.015	14.686	0.047	0.024	0.055	0.068	0.022	22.029	0.106	0.055	0.124	0.153
2.250	0.065	2.120	0.005	11.001	0.010	0.006	0.012	0.015	0.010	22.003	0.041	0.024	0.050	0.059	0.015	33.004	0.092	0.055	0.112	0.134
2.250	0.083	2.084	0.005	10.631	0.010	0.006	0.013	0.015	0.010	21.262	0.042	0.024	0.050	0.060	0.015	31.892	0.093	0.055	0.113	0.135
2.250	0.095	2.060	0.005	10.387	0.010	0.006	0.013	0.015	0.010	20.775	0.042	0.024	0.051	0.061	0.016	31.162	0.094	0.055	0.114	0.137
2.250	0.109	2.032	0.005	10.107	0.011	0.006	0.013	0.015	0.011	20.214	0.042	0.024	0.051	0.061	0.016	30.321	0.095	0.055	0.115	0.138
2.250	0.120	2.010	0.005	9.889	0.011	0.006	0.013	0.015	0.011	19.778	0.043	0.024	0.051	0.062	0.016	29.668	0.096	0.055	0.115	0.139
2.250	0.134	1.982	0.006	9.616	0.011	0.006	0.013	0.016	0.011	19.231	0.043	0.024	0.052	0.063	0.017	28.847	0.097	0.055	0.116	0.141

Numbers in blue are for transitional flow

Pressure Drop and Flow Through Each Foot Length of SAE Tube at Stated Velocity

Size inch			ft/sec		Δp Fittings				ft/sec		Δp Fittings			
			4		Curved 90°	Through Flow	90° Flow	Sharp 90°	5		Curved 90°	Through Flow	90° Flow	Sharp 90°
OD	Wall	ID	psi Loss	gpm					psi Loss	gpm				
0.125	0.028	0.069	18.484	0.047	0.292	0.097	0.309	0.423	23.105	0.058	0.456	0.151	0.482	0.661
0.125	0.035	0.055	29.092	0.030	0.293	0.097	0.309	0.424	36.365	0.037	0.457	0.151	0.483	0.663
0.188	0.028	0.132	5.051	0.171	0.288	0.097	0.305	0.417	6.313	0.213	0.450	0.151	0.477	0.652
0.188	0.035	0.118	6.320	0.136	0.289	0.097	0.306	0.419	7.900	0.170	0.451	0.151	0.478	0.654
0.250	0.028	0.194	2.338	0.368	0.284	0.097	0.302	0.412	2.923	0.461	0.444	0.151	0.472	0.643
0.250	0.035	0.180	2.716	0.317	0.285	0.097	0.303	0.413	3.395	0.397	0.445	0.151	0.473	0.645
0.250	0.049	0.152	3.809	0.226	0.287	0.097	0.304	0.416	4.761	0.283	0.448	0.151	0.475	0.649
0.250	0.065	0.120	6.111	0.141	0.289	0.097	0.306	0.418	7.639	0.176	0.451	0.151	0.478	0.654
0.312	0.028	0.256	1.343	0.642	0.280	0.097	0.297	0.406	1.679	0.802	0.438	0.151	0.464	0.635
0.312	0.035	0.242	1.503	0.573	0.281	0.097	0.299	0.407	1.878	0.717	0.439	0.151	0.468	0.637
0.312	0.049	0.214	1.922	0.448	0.283	0.097	0.301	0.410	2.402	0.560	0.442	0.151	0.470	0.641
0.312	0.065	0.182	2.657	0.324	0.285	0.097	0.302	0.413	3.321	0.405	0.445	0.151	0.473	0.645
0.375	0.028	0.319	0.865	0.996	0.276	0.097	0.295	0.400	1.081	1.245	0.432	0.151	0.461	0.626
0.375	0.035	0.305	0.946	0.911	0.277	0.097	0.296	0.402	1.183	1.139	0.433	0.151	0.462	0.628
0.375	0.049	0.277	1.147	0.751	0.279	0.097	0.297	0.404	1.434	0.939	0.436	0.151	0.465	0.632
0.375	0.065	0.245	1.466	0.588	0.281	0.097	0.299	0.407	1.833	0.735	0.439	0.151	0.467	0.636
0.500	0.035	0.430	0.476	1.810	0.269	0.097	0.289	0.390	0.595	2.263	0.421	0.151	0.452	0.610
0.500	0.049	0.402	0.545	1.582	0.271	0.097	0.291	0.393	0.681	1.978	0.423	0.151	0.454	0.614
0.500	0.065	0.370	0.643	1.340	0.273	0.097	0.292	0.396	0.804	1.675	0.427	0.151	0.457	0.618
0.500	0.083	0.334	0.789	1.092	0.275	0.097	0.294	0.399	0.986	1.365	0.430	0.151	0.460	0.624
0.625	0.035	0.555	0.286	3.016	0.261	0.097	0.283	0.379	0.357	3.770	0.409	0.151	0.441	0.592
0.625	0.049	0.527	0.317	2.719	0.263	0.097	0.284	0.382	0.396	3.399	0.411	0.151	0.444	0.596
0.625	0.065	0.495	0.359	2.399	0.265	0.097	0.286	0.385	0.449	2.999	0.414	0.151	0.446	0.601
0.625	0.083	0.459	0.418	2.063	0.267	0.097	0.288	0.388	0.522	2.578	0.418	0.151	0.449	0.606
0.625	0.095	0.435	0.465	1.853	0.269	0.097	0.289	0.390	0.581	2.316	0.420	0.151	0.451	0.609
0.750	0.035	0.680	0.190	4.527	0.254	0.097	0.276	0.368	0.238	5.659	0.396	0.151	0.431	0.575
0.750	0.049	0.652	0.207	4.162	0.255	0.097	0.277	0.370	0.259	5.203	0.399	0.151	0.433	0.579
0.750	0.065	0.620	0.229	3.764	0.257	0.097	0.279	0.373	0.286	4.705	0.402	0.151	0.436	0.583
0.750	0.083	0.584	0.258	3.339	0.260	0.097	0.281	0.376	0.323	4.174	0.406	0.151	0.439	0.588
0.750	0.095	0.560	0.281	3.070	0.261	0.097	0.282	0.379	0.351	3.838	0.408	0.151	0.441	0.592
0.750	0.109	0.532	0.311	2.771	0.263	0.097	0.284	0.381	0.389	3.464	0.411	0.151	0.443	0.596
0.875	0.035	0.805	0.136	6.345	0.246	0.097	0.269	0.356	0.170	7.931	0.384	0.151	0.421	0.557
0.875	0.049	0.777	0.146	5.911	0.248	0.097	0.271	0.359	0.182	7.389	0.387	0.151	0.423	0.561
0.875	0.065	0.745	0.159	5.434	0.250	0.097	0.272	0.362	0.198	6.793	0.390	0.151	0.426	0.565
0.875	0.083	0.709	0.175	4.922	0.252	0.097	0.274	0.365	0.219	6.152	0.394	0.151	0.429	0.571
0.875	0.095	0.685	0.188	4.594	0.253	0.097	0.276	0.367	0.234	5.743	0.396	0.151	0.431	0.574
0.875	0.109	0.657	0.204	4.226	0.255	0.097	0.277	0.370	0.255	5.283	0.399	0.151	0.433	0.578
1.000	0.035	0.930	0.102	8.468	0.238	0.097	0.262	0.345	0.127	10.585	0.372	0.151	0.410	0.539
1.000	0.049	0.902	0.108	7.966	0.240	0.097	0.264	0.348	0.135	9.958	0.375	0.151	0.412	0.543

Size inch			ft/sec		Δp Fittings				ft/sec		Δp Fittings			
			4		Curved 90°	Through Flow	90° Flow	Sharp 90°	5		Curved 90°	Through Flow	90° Flow	Sharp 90°
OD	Wall	ID	psi Loss	gpm					psi Loss	gpm				
1.000	0.065	0.870	0.116	7.411	0.242	0.097	0.266	0.351	0.145	9.264	0.378	0.151	0.415	0.548
1.000	0.083	0.834	0.127	6.810	0.244	0.097	0.268	0.354	0.158	8.513	0.381	0.151	0.418	0.553
1.000	0.095	0.810	0.134	6.424	0.246	0.097	0.269	0.356	0.168	8.030	0.384	0.151	0.420	0.556
1.000	0.109	0.782	0.144	5.987	0.247	0.097	0.270	0.359	0.180	7.484	0.386	0.151	0.423	0.560
1.000	0.120	0.760	0.152	5.655	0.249	0.097	0.272	0.361	0.190	7.069	0.389	0.151	0.424	0.563
1.125	0.049	1.027	0.083	10.327	0.232	0.097	0.257	0.336	0.104	12.909	0.363	0.151	0.402	0.526
1.125	0.065	0.995	0.089	9.693	0.234	0.097	0.259	0.339	0.111	12.117	0.366	0.151	0.405	0.530
1.125	0.083	0.959	0.096	9.005	0.236	0.097	0.261	0.343	0.120	11.256	0.369	0.151	0.408	0.535
1.125	0.095	0.935	0.101	8.560	0.238	0.097	0.262	0.345	0.126	10.700	0.371	0.151	0.410	0.539
1.125	0.109	0.907	0.107	8.055	0.239	0.097	0.264	0.347	0.134	10.068	0.374	0.151	0.412	0.543
1.125	0.120	0.885	0.112	7.669	0.241	0.097	0.265	0.349	0.140	9.586	0.376	0.151	0.414	0.546
1.250	0.049	1.152	0.066	12.994	0.224	0.097	0.251	0.325	0.083	16.242	0.350	0.151	0.392	0.508
1.250	0.065	1.120	0.070	12.282	0.226	0.097	0.252	0.328	0.088	15.352	0.353	0.151	0.394	0.513
1.250	0.083	1.084	0.075	11.505	0.228	0.097	0.254	0.331	0.094	14.381	0.357	0.151	0.397	0.518
1.250	0.095	1.060	0.078	11.001	0.230	0.097	0.256	0.333	0.098	13.752	0.359	0.151	0.399	0.521
1.250	0.109	1.032	0.083	10.428	0.232	0.097	0.257	0.336	0.103	13.035	0.362	0.151	0.402	0.525
1.250	0.120	1.010	0.086	9.988	0.233	0.097	0.258	0.338	0.108	12.485	0.364	0.151	0.403	0.528
1.500	0.065	1.370	0.047	18.377	0.211	0.097	0.239	0.305	0.059	22.971	0.329	0.151	0.373	0.477
1.500	0.083	1.334	0.049	17.424	0.213	0.097	0.241	0.309	0.062	21.780	0.333	0.151	0.376	0.482
1.500	0.095	1.310	0.051	16.802	0.214	0.097	0.242	0.311	0.064	21.003	0.335	0.151	0.378	0.486
1.500	0.109	1.282	0.054	16.092	0.216	0.097	0.244	0.313	0.067	20.115	0.338	0.151	0.381	0.490
1.500	0.120	1.260	0.055	15.544	0.217	0.097	0.245	0.315	0.069	19.430	0.340	0.151	0.383	0.493
1.750	0.065	1.620	0.034	25.696	0.195	0.097	0.226	0.283	0.042	32.120	0.305	0.151	0.353	0.442
1.750	0.083	1.584	0.035	24.566	0.197	0.097	0.228	0.286	0.044	30.708	0.308	0.151	0.356	0.447
1.750	0.095	1.560	0.036	23.828	0.199	0.097	0.229	0.288	0.045	29.784	0.311	0.151	0.358	0.450
1.750	0.109	1.532	0.037	22.980	0.201	0.097	0.230	0.291	0.047	28.725	0.313	0.151	0.360	0.454
1.750	0.120	1.510	0.039	22.325	0.202	0.097	0.231	0.293	0.048	27.906	0.315	0.151	0.362	0.457
2.000	0.065	1.870	0.025	34.238	0.179	0.097	0.212	0.260	0.050	42.798	0.280	0.151	0.332	0.407
2.000	0.083	1.834	0.026	32.933	0.182	0.097	0.214	0.263	0.051	41.166	0.284	0.151	0.335	0.412
2.000	0.095	1.810	0.027	32.077	0.183	0.097	0.215	0.266	0.052	40.096	0.286	0.151	0.337	0.415
2.000	0.109	1.782	0.028	31.092	0.185	0.097	0.217	0.268	0.053	38.865	0.289	0.151	0.339	0.419
2.000	0.120	1.760	0.028	30.329	0.186	0.097	0.218	0.270	0.054	37.911	0.291	0.151	0.341	0.422
2.000	0.134	1.732	0.029	29.372	0.188	0.097	0.220	0.273	0.055	36.714	0.294	0.151	0.343	0.426
2.250	0.065	2.120	0.020	44.005	0.164	0.097	0.199	0.238	0.042	55.006	0.256	0.151	0.311	0.371
2.250	0.083	2.084	0.020	42.523	0.166	0.097	0.201	0.241	0.043	53.154	0.260	0.151	0.314	0.376
2.250	0.095	2.060	0.021	41.549	0.168	0.097	0.202	0.243	0.044	51.937	0.262	0.151	0.316	0.380
2.250	0.109	2.032	0.021	40.428	0.169	0.097	0.204	0.246	0.045	50.535	0.265	0.151	0.318	0.384
2.250	0.120	2.010	0.022	39.557	0.171	0.097	0.205	0.248	0.045	49.446	0.267	0.151	0.320	0.387
2.250	0.134	1.982	0.022	38.463	0.172	0.097	0.206	0.250	0.046	48.078	0.269	0.151	0.322	0.391

Numbers in blue are for transitional flow - Numbers in red are for turbulent flow

Pressure Drop and Flow Through Each Foot Length of SAE Tube at Stated Velocity

Size inch			ft/sec	Δp Fittings				ft/sec	Δp Fittings				ft/sec	Δp Fittings			
			10	Curved 90°	Through Flow	90° Flow	Sharp 90°	15	Curved 90°	Through Flow	90° Flow	Sharp 90°	20	Curved 90°	Through Flow	90° Flow	Sharp 90°
OD	Wall	ID	psi Loss	gpm				psi Loss	gpm					psi Loss	gpm				
0.125	0.028	0.069	46.211	0.117	1.823	0.606	1.928	2.644	69.316	0.175	4.103	1.363	4.339	5.949	92.421	0.233	7.294	2.422	7.713	10.576
0.125	0.035	0.055	72.730	0.074	1.829	0.606	1.933	2.652	109.095	0.111	4.115	1.363	4.349	5.967	145.460	0.148	7.316	2.422	7.732	10.608
0.188	0.028	0.132	12.627	0.426	1.799	0.606	1.907	2.608	18.940	0.640	4.048	1.363	4.291	5.869	25.254	0.853	7.196	2.422	7.628	10.433
0.188	0.035	0.118	15.801	0.341	1.804	0.606	1.912	2.616	23.701	0.511	4.060	1.363	4.302	5.887	31.601	0.682	7.217	2.422	7.648	10.465
0.250	0.028	0.194	5.846	0.921	1.775	0.606	1.886	2.573	8.769	1.382	3.993	1.363	4.245	5.790	11.691	1.842	7.099	2.422	7.546	10.293
0.250	0.035	0.180	6.790	0.793	1.780	0.606	1.891	2.581	10.186	1.190	4.006	1.363	4.255	5.808	13.581	1.586	7.121	2.422	7.564	10.325
0.250	0.049	0.152	9.523	0.566	1.791	0.606	1.900	2.597	14.284	0.848	4.030	1.363	4.276	5.844	19.045	1.131	7.164	2.422	7.602	10.388
0.250	0.065	0.120	15.278	0.352	1.804	0.606	1.911	2.615	22.918	0.529	4.058	1.363	4.300	5.884	30.557	0.705	7.214	2.422	7.645	10.460
0.312	0.028	0.256	3.357	1.604	1.751	0.606	1.856	2.538	5.036	2.406	3.939	1.363	4.176	5.711	6.714	3.208	7.002	2.422	7.423	10.153
0.312	0.035	0.242	3.757	1.434	1.756	0.606	1.870	2.546	5.635	2.150	3.951	1.363	4.209	5.729	7.513	2.867	7.024	2.422	7.482	10.185
0.312	0.049	0.214	4.804	1.121	1.767	0.606	1.880	2.562	7.206	1.681	3.976	1.363	4.230	5.765	9.608	2.242	7.068	2.422	7.519	10.248
0.312	0.065	0.182	6.642	0.811	1.779	0.606	1.890	2.580	9.963	1.216	4.004	1.363	4.254	5.805	13.284	1.622	7.118	2.422	7.562	10.320
0.375	0.028	0.319	2.162	2.491	1.726	0.606	1.845	2.503	3.243	3.736	3.884	1.363	4.151	5.631	4.324	4.982	6.904	2.422	7.379	10.011
0.375	0.035	0.305	2.365	2.277	1.731	0.606	1.849	2.511	3.548	3.416	3.896	1.363	4.161	5.649	4.730	4.554	6.926	2.422	7.397	10.042
0.375	0.049	0.277	2.867	1.878	1.742	0.606	1.859	2.526	4.301	2.817	3.920	1.363	4.182	5.685	5.735	3.756	6.969	2.422	7.435	10.106
0.375	0.065	0.245	3.665	1.469	1.755	0.606	1.869	2.545	5.498	2.204	3.949	1.363	4.206	5.725	7.331	2.939	7.020	2.422	7.478	10.178
0.500	0.035	0.430	1.190	4.526	1.683	0.606	1.808	2.440	1.785	6.789	3.786	1.363	4.067	5.490	3.529	9.052	6.731	2.422	7.230	9.760
0.500	0.049	0.402	1.361	3.956	1.694	0.606	1.817	2.456	2.042	5.934	3.811	1.363	4.088	5.526	2.723	7.911	6.775	2.422	7.268	9.823
0.500	0.065	0.370	1.607	3.351	1.706	0.606	1.828	2.474	2.411	5.026	3.839	1.363	4.112	5.566	3.214	6.702	6.824	2.422	7.311	9.896
0.500	0.083	0.334	1.972	2.731	1.720	0.606	1.840	2.494	2.958	4.096	3.870	1.363	4.139	5.612	3.944	5.461	6.880	2.422	7.359	9.977
0.625	0.035	0.555	0.714	7.540	1.634	0.606	1.766	2.369	1.071	11.310	3.677	1.363	3.973	5.331	2.565	15.079	6.536	2.422	7.064	9.477
0.625	0.049	0.527	0.792	6.798	1.645	0.606	1.775	2.385	1.188	10.197	3.701	1.363	3.994	5.367	2.736	13.596	6.580	2.422	7.101	9.540
0.625	0.065	0.495	0.898	5.998	1.657	0.606	1.786	2.403	1.347	8.996	3.729	1.363	4.018	5.407	2.959	11.995	6.630	2.422	7.144	9.613
0.625	0.083	0.459	1.044	5.157	1.671	0.606	1.798	2.424	1.566	7.735	3.761	1.363	4.045	5.453	3.252	10.314	6.686	2.422	7.192	9.694
0.625	0.095	0.435	1.163	4.632	1.681	0.606	1.805	2.437	1.744	6.948	3.782	1.363	4.063	5.484	3.478	9.264	6.723	2.422	7.224	9.748
0.750	0.035	0.680	0.476	11.318	1.585	0.606	1.724	2.299	0.714	16.978	3.567	1.363	3.879	5.172	1.990	22.637	6.341	2.422	6.896	9.195
0.750	0.049	0.652	0.518	10.406	1.596	0.606	1.733	2.314	0.776	15.608	3.592	1.363	3.900	5.208	2.097	20.811	6.385	2.422	6.934	9.258
0.750	0.065	0.620	0.572	9.409	1.609	0.606	1.744	2.333	0.859	14.114	3.620	1.363	3.924	5.248	2.233	18.818	6.435	2.422	6.976	9.330
0.750	0.083	0.584	0.645	8.348	1.623	0.606	1.756	2.353	0.968	12.522	3.651	1.363	3.951	5.294	2.407	16.697	6.491	2.422	7.024	9.412
0.750	0.095	0.560	0.702	7.676	1.632	0.606	1.764	2.366	1.052	11.514	3.672	1.363	3.969	5.325	2.536	15.352	6.528	2.422	7.056	9.466
0.750	0.109	0.532	0.777	6.928	1.643	0.606	1.774	2.382	1.166	10.392	3.697	1.363	3.991	5.360	2.704	13.856	6.572	2.422	7.094	9.529
0.875	0.035	0.805	0.340	15.862	1.537	0.606	1.682	2.228	0.974	23.793	3.457	1.363	3.785	5.013	1.611	31.724	6.146	2.422	6.729	8.912
0.875	0.049	0.777	0.364	14.778	1.547	0.606	1.692	2.244	1.018	22.167	3.482	1.363	3.806	5.049	1.684	29.556	6.190	2.422	6.767	8.975
0.875	0.065	0.745	0.396	13.586	1.560	0.606	1.702	2.262	1.073	20.379	3.510	1.363	3.830	5.089	1.775	27.171	6.240	2.422	6.809	9.048
0.875	0.083	0.709	0.438	12.304	1.574	0.606	1.714	2.282	1.142	18.457	3.542	1.363	3.857	5.135	1.889	24.609	6.296	2.422	6.857	9.129
0.875	0.095	0.685	0.469	11.486	1.583	0.606	1.722	2.296	1.192	17.228	3.563	1.363	3.876	5.166	1.972	22.971	6.333	2.422	6.890	9.183
0.875	0.109	0.657	0.510	10.566	1.594	0.606	1.732	2.312	1.256	15.849	3.587	1.363	3.897	5.201	2.077	21.132	6.377	2.422	6.927	9.247
1.000	0.035	0.930	0.400	21.171	1.488	0.606	1.641	2.157	0.813	31.756	3.348	1.363	3.691	4.854	1.345	42.342	5.951	2.422	6.562	8.629
1.000	0.049	0.902	0.416	19.915	1.499	0.606	1.650	2.173	0.845	29.873	3.372	1.363	3.712	4.890	1.398	39.830	5.995	2.422	6.600	8.693

Size inch			ft/sec	Δp Fittings				ft/sec	Δp Fittings				ft/sec	Δp Fittings			
			10	Curved 90°	Through Flow	90° Flow	Sharp 90°	15	Curved 90°	Through Flow	90° Flow	Sharp 90°	20	Curved 90°	Through Flow	90° Flow	Sharp 90°
OD	Wall	ID	psi Loss	gpm				psi Loss	gpm					psi Loss	gpm				
1.000	0.065	0.870	0.435	18.527	1.511	0.606	1.661	2.191	0.884	27.791	3.400	1.363	3.736	4.930	1.462	37.054	6.045	2.422	6.642	8.765
1.000	0.083	0.834	0.458	17.026	1.525	0.606	1.673	2.212	0.932	25.538	3.432	1.363	3.764	4.976	1.542	34.051	6.101	2.422	6.691	8.847
1.000	0.095	0.810	0.475	16.060	1.535	0.606	1.681	2.225	0.966	24.090	3.453	1.363	3.782	5.007	1.599	32.120	6.138	2.422	6.723	8.901
1.000	0.109	0.782	0.497	14.969	1.546	0.606	1.690	2.241	1.010	22.453	3.478	1.363	3.803	5.042	1.671	29.937	6.182	2.422	6.760	8.964
1.000	0.120	0.760	0.515	14.138	1.554	0.606	1.697	2.253	1.047	21.207	3.497	1.363	3.819	5.070	1.731	28.277	6.216	2.422	6.789	9.014
1.125	0.049	1.027	0.353	25.817	1.450	0.606	1.608	2.103	0.718	38.726	3.263	1.363	3.618	4.731	1.188	51.635	5.800	2.422	6.432	8.410
1.125	0.065	0.995	0.368	24.234	1.462	0.606	1.619	2.121	0.747	36.350	3.291	1.363	3.642	4.772	1.236	48.467	5.850	2.422	6.475	8.483
1.125	0.083	0.959	0.385	22.512	1.477	0.606	1.631	2.141	0.783	33.768	3.322	1.363	3.670	4.817	1.295	45.023	5.906	2.422	6.524	8.564
1.125	0.095	0.935	0.397	21.399	1.486	0.606	1.639	2.155	0.808	32.099	3.343	1.363	3.688	4.848	1.336	42.798	5.944	2.422	6.556	8.618
1.125	0.109	0.907	0.413	20.137	1.497	0.606	1.648	2.170	0.839	30.205	3.368	1.363	3.709	4.883	1.388	40.273	5.987	2.422	6.593	8.681
1.125	0.120	0.885	0.426	19.172	1.505	0.606	1.656	2.183	0.865	28.757	3.387	1.363	3.725	4.911	1.431	38.343	6.021	2.422	6.622	8.731
1.250	0.049	1.152	0.306	32.484	1.401	0.606	1.566	2.032	0.622	48.727	3.153	1.363	3.524	4.572	1.029	64.969	5.605	2.422	6.265	8.128
1.250	0.065	1.120	0.317	30.705	1.414	0.606	1.577	2.050	0.645	46.057	3.181	1.363	3.549	4.613	1.066	61.410	5.655	2.422	6.308	8.200
1.250	0.083	1.084	0.330	28.763	1.428	0.606	1.589	2.070	0.671	43.144	3.213	1.363	3.576	4.658	1.111	57.525	5.711	2.422	6.356	8.281
1.250	0.095	1.060	0.340	27.503	1.437	0.606	1.597	2.084	0.690	41.255	3.234	1.363	3.594	4.689	1.142	55.006	5.748	2.422	6.388	8.336
1.250	0.109	1.032	0.351	26.069	1.448	0.606	1.606	2.100	0.714	39.104	3.258	1.363	3.615	4.724	1.181	52.139	5.792	2.422	6.426	8.399
1.250	0.120	1.010	0.361	24.970	1.457	0.606	1.614	2.112	0.733	37.455	3.278	1.363	3.631	4.752	1.213	49.939	5.827	2.422	6.455	8.448
1.500	0.065	1.370	0.246	45.942	1.316	0.606	1.494	1.909	0.501	68.913	2.962	1.363	3.361	4.295	0.829	91.884	5.265	2.422	5.974	7.635
1.500	0.083	1.334	0.255	43.559	1.330	0.606	1.506	1.929	0.518	65.339	2.993	1.363	3.388	4.340	0.857	87.119	5.321	2.422	6.022	7.716
1.500	0.095	1.310	0.261	42.006	1.340	0.606	1.514	1.943	0.530	63.009	3.014	1.363	3.406	4.371	0.877	84.012	5.359	2.422	6.054	7.770
1.500	0.109	1.282	0.268	40.230	1.351	0.606	1.523	1.958	0.544	60.345	3.039	1.363	3.427	4.407	0.901	80.459	5.403	2.422	6.092	7.834
1.500	0.120	1.260	0.274	38.861	1.359	0.606	1.530	1.971	0.556	58.291	3.058	1.363	3.443	4.435	0.920	77.722	5.437	2.422	6.121	7.884
1.750	0.065	1.620	0.200	64.239	1.219	0.606	1.410	1.767	0.406	96.359	2.743	1.363	3.173	3.977	0.672	128.479	4.876	2.422	5.640	7.069
1.750	0.083	1.584	0.206	61.416	1.233	0.606	1.422	1.788	0.418	92.124	2.774	1.363	3.200	4.022	0.691	122.832	4.932	2.422	5.688	7.151
1.750	0.095	1.560	0.210	59.569	1.242	0.606	1.430	1.801	0.426	89.353	2.795	1.363	3.218	4.053	0.705	119.138	4.969	2.422	5.720	7.205
1.750	0.109	1.532	0.214	57.450	1.253	0.606	1.439	1.817	0.436	86.175	2.820	1.363	3.239	4.089	0.721	114.899	5.013	2.422	5.758	7.268
1.750	0.120	1.510	0.218	55.812	1.262	0.606	1.447	1.830	0.444	83.717	2.839	1.363	3.255	4.117	0.734	111.623	5.047	2.422	5.787	7.318
2.000	0.065	1.870	0.167	85.596	1.121	0.606	1.326	1.626	0.340	128.394	2.523	1.363	2.985	3.659	0.562	171.192	4.486	2.422	5.306	6.504
2.000	0.083	1.834	0.171	82.332	1.135	0.606	1.339	1.646	0.348	123.498	2.555	1.363	3.012	3.705	0.576	164.664	4.542	2.422	5.354	6.586
2.000	0.095	1.810	0.174	80.191	1.145	0.606	1.347	1.660	0.354	120.287	2.576	1.363	3.030	3.735	0.585	160.383	4.579	2.422	5.386	6.640
2.000	0.109	1.782	0.177	77.730	1.156	0.606	1.356	1.676	0.361	116.594	2.601	1.363	3.051	3.771	0.597	155.459	4.623	2.422	5.424	6.703
2.000	0.120	1.760	0.180	75.822	1.164	0.606	1.363	1.688	0.366	113.733	2.620	1.363	3.067	3.799	0.606	151.644	4.657	2.422	5.453	6.753
2.000	0.134	1.732	0.184	73.429	1.175	0.606	1.373	1.704	0.374	110.143	2.644	1.363	3.088	3.834	0.618	146.858	4.701	2.422	5.490	6.816
2.250	0.065	2.120	0.143	110.013	1.024	0.606	1.243	1.485	0.290	165.019	2.304	1.363	2.797	3.341	0.480	220.025	4.096	2.422	4.972	5.939
2.250	0.083	2.084	0.146	106.308	1.038	0.606	1.255	1.505	0.297	159.462	2.336	1.363	2.824	3.387	0.491	212.616	4.152	2.422	5.020	6.020
2.250	0.095	2.060	0.148	103.874	1.047	0.606	1.263	1.519	0.301	155.810	2.357	1.363	2.842	3.417	0.498	207.747	4.189	2.422	5.052	6.075
2.250	0.109	2.032	0.151	101.069	1.058	0.606	1.272	1.535	0.306	151.604	2.381	1.363	2.863	3.453	0.506	202.138	4.233	2.422	5.089	6.138
2.250	0.120	2.010	0.153	98.892	1.067	0.606	1.280	1.547	0.310	148.339	2.401	1.363	2.879	3.481	0.513	197.785	4.268	2.422	5.119	6.188
2.250	0.134	1.982	0.155	96.156	1.078	0.606	1.289	1.563	0.316	144.235	2.425	1.363	2.901	3.516	0.522	192.313	4.311	2.422	5.156	6.251

Numbers in blue are for transitional flow - Numbers in red are for turbulent flow

Pressure Drop and Flow Through Each Foot Length of SAE Tube at Stated Velocity

Size inch			ft/sec		Δp Fittings				ft/sec		Δp Fittings			
			25		Curved 90°	Through Flow	90° Flow	Sharp 90°	30		Curved 90°	Through Flow	90° Flow	Sharp 90°
OD	Wall	ID	psi Loss	gpm					psi Loss	gpm				
0.125	0.028	0.069	115.526	0.291	11.397	3.785	12.051	16.525	138.632	0.350	16.411	5.450	17.354	23.796
0.125	0.035	0.055	181.825	0.185	11.431	3.785	12.081	16.574	218.190	0.222	16.460	5.450	17.396	23.867
0.188	0.028	0.132	31.567	1.066	11.243	3.785	11.919	16.302	37.880	1.279	16.190	5.450	17.164	23.475
0.188	0.035	0.118	39.502	0.852	11.277	3.785	11.949	16.352	47.402	1.022	16.239	5.450	17.207	23.547
0.250	0.028	0.194	14.614	2.303	11.092	3.785	11.790	16.083	17.537	2.764	15.972	5.450	16.978	23.160
0.250	0.035	0.180	16.976	1.983	11.126	3.785	11.819	16.133	20.371	2.379	16.022	5.450	17.020	23.231
0.250	0.049	0.152	23.806	1.414	11.194	3.785	11.878	16.232	28.568	1.697	16.120	5.450	17.104	23.374
0.250	0.065	0.120	38.196	0.881	11.272	3.785	11.945	16.344	45.835	1.057	16.232	5.450	17.201	23.536
0.312	0.028	0.256	8.393	4.010	10.941	3.785	11.599	15.865	10.071	4.813	15.755	5.450	16.702	22.845
0.312	0.035	0.242	9.392	3.584	10.975	3.785	11.690	15.914	11.270	4.301	15.804	5.450	16.834	22.916
0.312	0.049	0.214	12.010	2.802	11.043	3.785	11.749	16.013	14.412	3.363	15.902	5.450	16.918	23.058
0.312	0.065	0.182	16.605	2.027	11.122	3.785	11.815	16.126	19.926	2.432	16.015	5.450	17.014	23.221
0.375	0.028	0.319	5.405	6.227	10.788	3.785	11.529	15.642	10.420	7.473	15.534	5.450	16.602	22.524
0.375	0.035	0.305	5.913	5.693	10.822	3.785	11.558	15.691	11.021	6.831	15.583	5.450	16.644	22.595
0.375	0.049	0.277	7.168	4.695	10.890	3.785	11.617	15.790	8.602	5.634	15.681	5.450	16.728	22.738
0.375	0.065	0.245	9.163	3.673	10.968	3.785	11.684	15.903	10.996	4.408	15.794	5.450	16.825	22.901
0.500	0.035	0.430	5.214	11.315	10.517	3.785	11.297	15.250	7.174	13.578	15.145	5.450	16.268	21.960
0.500	0.049	0.402	5.672	9.889	10.585	3.785	11.356	15.349	7.804	11.867	15.243	5.450	16.353	22.102
0.500	0.065	0.370	6.292	8.377	10.663	3.785	11.423	15.462	8.656	10.053	15.355	5.450	16.449	22.265
0.500	0.083	0.334	4.930	6.827	10.751	3.785	11.498	15.589	9.838	8.192	15.481	5.450	16.557	22.448
0.625	0.035	0.555	3.790	18.849	10.213	3.785	11.037	14.808	5.215	22.619	14.706	5.450	15.893	21.324
0.625	0.049	0.527	4.043	16.995	10.281	3.785	11.095	14.907	5.563	20.395	14.804	5.450	15.977	21.466
0.625	0.065	0.495	4.373	14.994	10.359	3.785	11.162	15.020	6.016	17.993	14.917	5.450	16.073	21.629
0.625	0.083	0.459	4.806	12.892	10.447	3.785	11.237	15.147	6.612	15.471	15.043	5.450	16.181	21.812
0.625	0.095	0.435	5.139	11.579	10.505	3.785	11.287	15.232	7.071	13.895	15.127	5.450	16.253	21.934
0.750	0.035	0.680	2.940	28.296	9.908	3.785	10.776	14.367	4.045	33.955	14.268	5.450	15.517	20.688
0.750	0.049	0.652	3.099	26.014	9.976	3.785	10.834	14.465	4.264	31.217	14.366	5.450	15.601	20.830
0.750	0.065	0.620	3.300	23.523	10.054	3.785	10.901	14.578	4.540	28.228	14.478	5.450	15.697	20.993
0.750	0.083	0.584	3.556	20.871	10.142	3.785	10.976	14.706	4.893	25.045	14.604	5.450	15.805	21.176
0.750	0.095	0.560	3.748	19.191	10.200	3.785	11.026	14.790	5.156	23.029	14.688	5.450	15.877	21.298
0.750	0.109	0.532	3.996	17.319	10.269	3.785	11.085	14.890	5.498	20.783	14.787	5.450	15.962	21.441
0.875	0.035	0.805	2.381	39.655	9.603	3.785	10.515	13.925	3.276	47.586	13.829	5.450	15.141	20.052
0.875	0.049	0.777	2.489	36.945	9.672	3.785	10.573	14.024	3.424	44.334	13.927	5.450	15.225	20.194
0.875	0.065	0.745	2.623	33.964	9.749	3.785	10.640	14.137	3.609	40.757	14.039	5.450	15.321	20.357
0.875	0.083	0.709	2.791	30.761	9.838	3.785	10.715	14.264	3.840	36.913	14.166	5.450	15.429	20.540
0.875	0.095	0.685	2.913	28.714	9.896	3.785	10.765	14.349	4.008	34.457	14.250	5.450	15.502	20.662
0.875	0.109	0.657	3.059	26.414	9.964	3.785	10.824	14.448	4.223	31.697	14.348	5.450	15.586	20.805
1.000	0.035	0.930	1.988	52.927	9.299	3.785	10.253	13.483	2.735	63.512	13.390	5.450	14.765	19.416
1.000	0.049	0.902	2.065	49.788	9.367	3.785	10.312	13.583	2.842	59.745	13.489	5.450	14.849	19.559
1.000	0.065	0.870	2.161	46.318	9.445	3.785	10.378	13.695	2.973	55.582	13.601	5.450	14.945	19.721
1.000	0.083	0.834	2.278	42.564	9.533	3.785	10.454	13.823	3.134	51.077	13.727	5.450	15.054	19.905
1.000	0.095	0.810	2.363	40.150	9.591	3.785	10.504	13.908	3.251	48.179	13.811	5.450	15.126	20.027
1.000	0.109	0.782	2.469	37.422	9.660	3.785	10.563	14.006	3.397	44.906	13.910	5.450	15.210	20.169
1.000	0.120	0.760	2.559	35.346	9.713	3.785	10.608	14.084	3.520	42.415	13.987	5.450	15.276	20.281
1.125	0.049	1.027	1.756	64.543	9.063	3.785	10.051	13.141	2.416	77.452	13.050	5.450	14.473	18.923
1.125	0.065	0.995	1.827	60.584	9.140	3.785	10.117	13.254	2.514	72.701	13.162	5.450	14.569	19.086
1.125	0.083	0.959	1.913	56.279	9.228	3.785	10.193	13.381	2.632	67.535	13.289	5.450	14.678	19.269
1.125	0.095	0.935	1.975	53.498	9.287	3.785	10.243	13.466	2.717	64.197	13.373	5.450	14.750	19.391
1.125	0.109	0.907	2.051	50.341	9.355	3.785	10.301	13.565	2.822	60.410	13.471	5.450	14.834	19.533
1.125	0.120	0.885	2.115	47.929	9.408	3.785	10.347	13.642	2.910	57.515	13.548	5.450	14.900	19.645
1.250	0.049	1.152	1.521	81.211	8.758	3.785	9.790	12.699	2.093	97.453	12.612	5.450	14.097	18.287
1.250	0.065	1.120	1.576	76.762	8.836	3.785	9.857	12.813	2.168	92.114	12.724	5.450	14.194	18.450
1.250	0.083	1.084	1.641	71.907	8.924	3.785	9.932	12.940	2.258	86.288	12.850	5.450	14.302	18.633
1.250	0.095	1.060	1.688	68.758	8.982	3.785	9.982	13.024	2.322	82.509	12.934	5.450	14.374	18.755
1.250	0.109	1.032	1.746	65.173	9.051	3.785	10.040	13.123	2.402	78.208	13.033	5.450	14.458	18.897
1.250	0.120	1.010	1.793	62.424	9.104	3.785	10.086	13.201	2.467	74.909	13.110	5.450	14.524	19.009
1.500	0.065	1.370	1.225	114.855	8.227	3.785	9.335	11.929	1.685	137.827	11.847	5.450	13.442	17.178
1.500	0.083	1.334	1.266	108.899	8.315	3.785	9.410	12.056	1.742	130.678	11.973	5.450	13.550	17.361
1.500	0.095	1.310	1.295	105.015	8.373	3.785	9.460	12.141	1.782	126.019	12.057	5.450	13.622	17.483
1.500	0.109	1.282	1.331	100.574	8.442	3.785	9.518	12.240	1.831	120.689	12.156	5.450	13.706	17.626
1.500	0.120	1.260	1.360	97.152	8.495	3.785	9.565	12.318	1.871	116.582	12.233	5.450	13.773	17.738
1.750	0.065	1.620	0.993	160.598	7.618	3.785	8.813	11.046	1.367	192.718	10.970	5.450	12.690	15.906
1.750	0.083	1.584	1.022	153.540	7.706	3.785	8.888	11.173	1.406	184.248	11.096	5.450	12.798	16.089
1.750	0.095	1.560	1.041	148.922	7.764	3.785	8.938	11.258	1.433	178.707	11.180	5.450	12.871	16.212
1.750	0.109	1.532	1.065	143.624	7.833	3.785	8.997	11.357	1.466	172.349	11.279	5.450	12.955	16.354
1.750	0.120	1.510	1.085	139.529	7.886	3.785	9.042	11.435	1.492	167.435	11.356	5.450	13.021	16.466
2.000	0.065	1.870	0.830	213.990	7.009	3.785	8.290	10.163	1.142	256.788	10.093	5.450	11.938	14.635
2.000	0.083	1.834	0.851	205.830	7.097	3.785	8.366	10.290	1.170	246.996	10.219	5.450	12.047	14.818
2.000	0.095	1.810	0.865	200.478	7.155	3.785	8.416	10.375	1.190	240.574	10.303	5.450	12.119	14.940
2.000	0.109	1.782	0.882	194.324	7.224	3.785	8.474	10.474	1.213	233.189	10.402	5.450	12.203	15.082
2.000	0.120	1.760	0.896	189.555	7.277	3.785	8.520	10.551	1.232	227.466	10.479	5.450	12.269	15.194
2.000	0.134	1.732	0.914	183.572	7.345	3.785	8.578	10.651	1.257	220.286	10.577	5.450	12.353	15.337
2.250	0.065	2.120	0.710	275.031	6.400	3.785	7.769	9.280	0.976	330.038	9.216	5.450	11.187	13.363
2.250	0.083	2.084	0.725	265.770	6.488	3.785	7.844	9.407	0.998	318.924	9.342	5.450	11.295	13.546
2.250	0.095	2.060	0.736	259.684	6.546	3.785	7.894	9.492	1.012	311.621	9.426	5.450	11.367	13.668
2.250	0.109	2.032	0.748	252.673	6.615	3.785	7.952	9.591	1.030	303.207	9.525	5.450	11.451	13.811
2.250	0.120	2.010	0.759	247.231	6.668	3.785	7.998	9.669	1.044	296.677	9.602	5.450	11.517	13.923
2.250	0.134	1.982	0.772	240.391	6.736	3.785	8.057	9.767	1.062	288.469	9.700	5.450	11.602	14.065

Numbers in blue are for transitional flow - Numbers in red are for turbulent flow

Pipe Used in Pneumatic Systems

Both plastic and steel pipe are commonly used in airline distribution systems. Polyvinyl chloride (PVC) and Acrylonitrile Butadiene Styrene (ABS) are the two plastic pipe materials commonly used in airline distribution systems. An advantage that ABS pipe has over PVC pipe is that when ABS fails, it ruptures but does not shatter. PVC pipe will shatter into small pieces; propelled by rapidly expanding gas, the shards can cause serious personal injury or death to people in the immediate area of the failure, as well as property damage. For this reason, ABS pipe is a much safer choice for use in airline distribution systems. For both ABS and PVC, the pressure rating goes down as the operating temperature increases. Consult pressure/temperature charts to ensure proper selection. PVC pipe is generally seen in inch sizes, while ABS pipe is manufactured in metric sizes in an effort to prevent mixing of the two different types of pipe. Plastic pipe has a greater coefficient of expansion than does metal pipe; make appropriate allowances with adequately designed expansion loops to account for the expected expansion. Expansion loops are "U" shaped sections that allow for thermal expansion and contraction.

Many airline distribution systems are fabricated from Schedule 40 ERW (electrical resistance welded) steel pipe, as this type of pipe is commonly available and is cost effective in comparison to ABS pipe. Steel pipe used in airline distribution systems is generally supplied in twenty-foot lengths. There are several ways to connect these lengths. The cheapest way is to thread the ends of the pipe and screw them together with threaded couplings. All too often, installers begin running pipe and neglect to install pipe unions to allow the piping to be readily disassembled for future maintenance or expansion. If unions aren't installed at appropriate places, it will be virtually impossible to tighten a leaking joint. Another thing often forgotten is the inclusion of expansion loops.

Threaded pipe unions are commonly available in sizes up to 2-1/2 inch. Four-bolt forged steel ANSI flanges are generally used from that point upward in size, though such flanges are manufactured beginning at ½ inch. The interface between these flanges is sealed by a gasket.

In addition to carbon steel pipe, various alloys of stainless-steel pipe are available as well, though it is rare to see a stainless-steel airline distribution system.

An advantage of plastic and stainless-steel pipe over carbon steel pipe is that neither material will rust internally from moisture entrained in the compressed air.

Both PVC and ABS pipe are easily and quickly assembled with adhesives engineered for the respective plastics. Therefore, since plastic pipe tends to be "thread-free," it tends to be "leak-free" as well. Anyone who has had to cut and thread steel pipe knows just what a messy, dirty, and time-consuming job it is, not to mention noisy if a threading machine is used. In contrast, anyone who has worked with plastic pipe knows how quick and easy it is to fabricate.

Manufacturers of PVC and ABS pipe publish tables, similar to the tables shown earlier for carbon steel pipe, that list the plastic pipe dimensions and pressure ratings.

Tubing Specifications

The use of tubing in many applications has displaced the use of pipe as a rigid fluid conductor. Tubing may be constructed of metal, plastic, or hose.

Tubing and pipe used in fluid power systems shall conform to the following:

- Tubing shall comply with SAE 356, SAE J524 (seamless low carbon steel tubing annealed for bending and flaring) or SAE J525 (welded and cold drawn low carbon steel tubing annealed for bending and flaring). Tubing conforming to SAE J525 is preferred.
- For systems designed to operate at 5,000 psi or less, a design (safety) factor of 4:1, based on the minimum tensile strength of the material, should not be exceeded. In systems that do not have repetitive shock, a design factor of 3:1 may be used. Systems subject to repetitive shock should

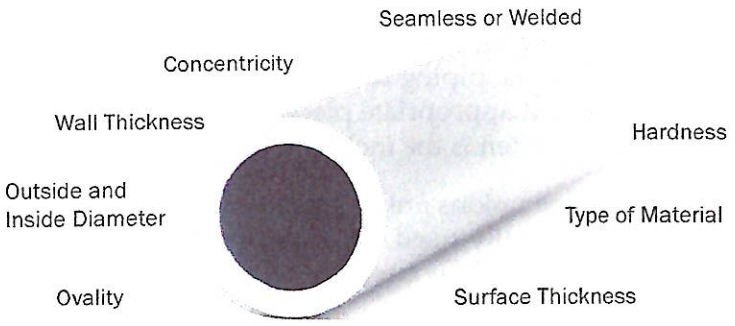
utilize a minimum design factor of 6:1.

- For systems operating higher than 5,000 psi, the design factor shall be agreed upon by the equipment builder and the purchaser.
- To minimize pressure drop, the cross-sectional area should be sized to limit the maximum fluid flow rate to a velocity of 4 ft/sec in inlet (pump suction or intake) lines, 10 ft/sec in return lines, and 20 ft/sec in pressure lines. Fluid conductors shall be capable of meeting the flow and pressure requirements of the components to which they are connected.

Metal

Metal tubing has many advantages over pipe. A bent section of tubing has only two possible leak points – one at each end of the tubing. The time required to fabricate a tube assembly is less than the time required to fabricate a similar assembly using pipe. Finally, for similar flow and pressure capabilities, tubing weighs less than pipe.

Carbon steel tubing is most commonly used, though 304 or 316 stainless steel tubing is used when higher pressures will be encountered or when resistance to corrosion or rusting is required. In order to differentiate between carbon steel and stainless-steel tubing, mechanics and technicians must familiarize themselves with the visual difference between the two types of metal.



Tubing is a cost effective and versatile conductor for sizes up to 1 1/2-in OD. Tubing is measured in 16ths of an inch. Therefore, tubing with an outside diameter of 1/2 in is identified as -8 or -08 tubing. Steel tubing is measured by its outside diameter (OD) and wall thickness. The greater the wall thickness, the greater the pressure capacity of the tubing. Tubing is specified by its nominal OD and wall thickness, which are effectively equal to its actual OD and wall thickness. For example, a -16 (1-in OD) x 0.095-in wall tube may actually measure several thousandths of an inch over or under due to manufacturing tolerances. However, the tube is still called out as a -16 x 0.095 tube.

Careful selecting, specifying, purchasing, and handling of steel tubing are essential to the successful use of tube fittings. Several general rules apply:

- Metal tubing must always be softer than the fitting material.
- When tubing and fittings are made of the same material, the tubing must be fully annealed.
- Mechanical, structural, or ornamental grade tubing should never be used for fluid power systems.
- Extremes in wall thickness should be checked against minimum and maximum wall thickness.
- Understand the limitations and capacity of the fitting selected.
- Tubing surface finish is very important to sealing especially for flareless and flare type fittings.
- Tubing ovality is critical in some fittings. Ferrules may not fit or seal properly.

Ovality is the "out-of-roundness" of the tubing or pipe and is calculated by subtracting the minimum O.D. of the tube or pipe from the maximum OD at a specific location around the diameter of the tube or pipe. Bending a tube or pipe tends to flatten the material, and this causes the tube to lose its roundness and weaken the material where the wall thickness lessens. Generally, ovality should be less than 5%, but ASME allows up to 8%. It is calculated by $\text{Ovality \%} = \frac{(\text{Max OD} - \text{Min OD})}{\text{Nominal OD}} \times 100$

Note: Tubing may be subjected to bending, cold forming, wall thinning, brazing, welding, side loads, shock loads, and extreme vibrations, which can compromise the maximum yield strength causing premature failure of the tube material. Therefore, it is good recommended practice to use tubing that will operate at less than 100% of the calculated reference working pressures.

The table that follows lists the standard wall thicknesses for both carbon steel and stainless-steel tubing. Notice that in the smaller diameters of tubing, the difference between each wall thickness is only about 0.007 inches. A piece of typing paper is about 0.004 inches thick. Also notice how the pressure rating of the tubing increases with small increases in wall thickness. This illustrates the importance of carefully measuring the wall thickness of a piece of tubing. Also shown are the working pressures at design factors of 6:1 and 4:1. The working pressure is calculated by dividing the burst pressure by the design factor. Thus, if the burst pressure is 20,000 psi and a safety factor of 4:1 is being used, the working pressure is 5,000 psi (20,000 psi divided by 4 = 5,000 psi).

The burst pressures in the chart shown were calculated using Barlow's formula which states

$$\text{Burst Pressure}_{psi} = (2 \times \text{Wall Thickness}_{inches} \times \text{Material Strength}_{psi}) / \text{Tube Outside Diameter}_{inches}$$

The maximum material strength for carbon steel is generally given as 50,000 psi while 75,000 psi is typical for 304 and 316 stainless steel.

Tube Dimensions (English)				Carbon Steel			Stainless Steel		
Tube OD	Wall Thickness	Tube ID	ID Area (sq-in)	CS Burst Pressure	WP - 6:1 (psig)	WP - 4:1 (psig)	SS Burst Pressure	WP - 6:1 (psig)	WP - 4:1 (psig)
1/4"	0.035	0.180	0.025	14,000	2,333	3,500	21,000	3,500	5,250
-4	0.042	0.166	0.022	16,800	2,800	4,200	25,200	4,200	6,300
	0.049	0.152	0.018	19,600	3,267	4,900	29,400	4,900	7,350
	0.058	0.134	0.014	23,200	3,867	5,800	34,800	5,800	8,700
	0.065	0.120	0.011	26,000	4,333	6,500	39,000	6,500	9,750
3/8"	0.035	0.305	0.073	9,333	1,556	2,333	14,000	2,333	3,500
-6	0.042	0.291	0.067	11,200	1,867	2,800	16,800	2,800	4,200
	0.049	0.277	0.060	13,067	2,178	3,267	19,600	3,267	4,900
	0.058	0.259	0.053	15,467	2,578	3,867	23,200	3,867	5,800
	0.065	0.245	0.047	17,333	2,889	4,333	26,000	4,333	6,500
1/2"	0.035	0.430	0.145	7,000	1,167	1,750	10,500	1,750	2,625
-8	0.042	0.416	0.136	8,400	1,400	2,100	12,600	2,100	3,150
	0.049	0.402	0.127	9,800	1,633	2,450	14,700	2,450	3,675
	0.058	0.384	0.116	11,600	1,933	2,900	17,400	2,900	4,350
	0.065	0.370	0.108	13,000	2,167	3,250	19,500	3,250	4,875
	0.072	0.356	0.010	14,400	2,400	3,600	21,600	3,600	5,400
	0.083	0.334	0.088	16,600	2,767	4,150	24,900	4,150	6,225
5/8"	0.035	0.555	0.242	5,600	933	1,400	8,400	1,400	2,100
-10	0.042	0.541	0.230	6,720	1,120	1,680	10,080	1,680	2,520
	0.049	0.527	0.218	7,840	1,307	1,960	11,760	1,960	2,940
	0.058	0.509	0.203	9,280	1,547	2,320	13,920	2,320	3,480
	0.065	0.495	0.192	10,400	1,733	2,600	15,600	2,600	3,900
	0.072	0.481	0.182	11,520	1,920	2,880	17,280	2,880	4,320
	0.083	0.459	0.165	13,280	2,213	3,320	19,920	3,320	4,980
	0.095	0.435	0.149	15,200	2,533	3,800	22,800	3,800	5,700
3/4"	0.049	0.652	0.334	6,533	1,089	1,633	9,800	1,633	2,450
-12	0.058	0.634	0.316	7,733	1,289	1,933	11,600	1,933	2,900
	0.065	0.620	0.302	8,667	1,444	2,167	13,000	2,167	3,250
	0.072	0.606	0.288	9,600	1,600	2,400	14,400	2,400	3,600
	0.083	0.584	0.268	11,067	1,844	2,767	16,600	2,767	4,150
	0.095	0.560	0.246	12,667	2,111	3,167	19,000	3,167	4,750
	0.109	0.532	0.222	14,533	2,422	3,633	21,800	3,633	5,450
1"	0.049	0.902	0.639	4,900	817	1,225	7,350	1,225	1,838
-16	0.058	0.884	0.614	5,800	967	1,450	8,700	1,450	2,175
	0.065	0.870	0.594	6,500	1,083	1,625	9,750	1,625	2,438
	0.072	0.856	0.576	7,200	1,200	1,800	10,800	1,800	2,700
	0.083	0.834	0.546	8,300	1,383	2,075	12,450	2,075	3,113
	0.095	0.810	0.515	9,500	1,583	2,375	14,250	2,375	3,563
	0.109	0.782	0.480	10,900	1,817	2,725	16,350	2,725	4,088
	0.120	0.760	0.454	12,000	2,000	3,000	18,000	3,000	4,500
1-1/4"	0.049	1.152	1.042	3,920	653	980	5,880	980	1,470
-20	0.058	1.134	1.010	4,640	773	1,160	6,960	1,160	1,740
	0.065	1.120	0.985	5,200	867	1,300	7,800	1,300	1,950
	0.072	1.106	0.961	5,760	960	1,440	8,640	1,440	2,160
	0.083	1.084	0.923	6,640	1,107	1,660	9,960	1,660	2,490
	0.095	1.060	0.882	7,600	1,267	1,900	11,400	1,900	2,850
	0.109	1.032	0.836	8,720	1,453	2,180	13,080	2,180	3,270
	0.120	1.010	0.801	9,600	1,600	2,400	14,400	2,400	3,600
	0.156	0.938	0.691	12,480	2,080	3,120	18,720	3,120	4,680
	0.188	0.874	0.600	15,040	2,507	3,760	22,560	3,760	5,640

When selecting the tube wall thickness, one must also consider the adapters with which the tubing will be used. In certain cases, a given wall thickness may be too great to be used with a particular style of tube end. For example, when -20 tubing is being used with an SAE 37° flare adapter, the practical wall thickness limit is 0.120 in. If a tube with a thicker wall is used, because of the wall thickness and the thickness of the sleeve, there will not be enough thread engagement between the tube nut and the adapter. However, the O-ring face seal (termed ORS, OFS, or ORFS) style of tube end may be used with -20 x 0.188-in wall tubing as the shoulder is brazed onto the end of the tube. Since the dimensions of the shoulder do not change based on the wall thickness of the tubing, the engagement of the tube nut and the adapter do not change as the wall thickness of the tube varies.

If ORS adapters are being used, the shoulder that is brazed onto the tube must be compatible with the tube material. Stainless steel shoulders must be used with stainless steel tubing, while carbon steel shoulders are used with carbon steel tubing. Appropriate braze rings must be used with each type of material. Black flux should be used when brazing stainless steel materials; white or black flux may be used when brazing carbon steel materials.

Plastic

Plastic tubing is widely used downstream of the airline distribution system to connect components to each other. Nylon, polypropylene, and polyethylene are the three most common materials for this tubing. The size of this tubing ranges from 1/8 in through 1/2 in OD. Equivalent metric sizes are available as well. Plumbing a system with plastic tubing is quick and easy in comparison to using copper or stainless-steel tubing. In comparison to rubber hose, plastic tubing is more rigid (yet still flexible) and there is less OD expansion when it's pressurized, providing better system response.

Unlike copper tubing, plastic tubing is specified based on its actual OD and wall thickness dimensions, with allowance given to tolerances. For example, 3/8" OD x 0.062" wall tubing is specified as such, even though the OD and wall thickness may vary by a few thousandths of an inch.

The burst pressure, and therefore the working pressure, of plastic tubing varies with the operating temperature. As temperature rises, the pressure rating falls.

Nylon is a good choice for general-purpose pneumatic applications. Although nylon is not as flexible as polyurethane, it is much stronger and has a higher pressure rating. Due to its strength, nylon tubing can be manufactured with thinner walls while still maintaining high pressure ratings. This walled tubing allows for a higher flow rating for a given outside diameter.

In addition to its strength, Nylon is heat and light stabilized. Nylon's combination of high-pressure rating, high flow rate, flexibility, and toughness make it the ideal choice for most compressed air systems. Certain grades of nylon are also approved for use in air brake systems under SAE J844. Nylon is also known as Polyamide and was the first engineered thermoplastic. Nylon compounds are classified by the number of carbon molecules that they contain. Common compounds used in tubing are Nylon 11 and Nylon-12.

Nylon is hygroscopic by nature, meaning that it tends to absorb moisture. The compounds used in compressed air tubing generally keep the absorption rate to under 1%. Surge pressure must not exceed the maximum operating pressure. If exceeding that value, fittings may be damaged, and tubing may burst.

Specifications:

- Temp. Range: –4°F to 140°F
- Maximum Operating Pressure: 220 psi (68°F)
- Hardness: Shore D 70

OD Nom In	ID Nom In	Min Bend Radius In
5/32	0.098	0.512
5/16	0.236	1.890
1/8	0.086	0.591
3/16	0.137	0.787
1/4	0.180	1.181
3/8	0.275	2.362
1/2	0.376	2.953

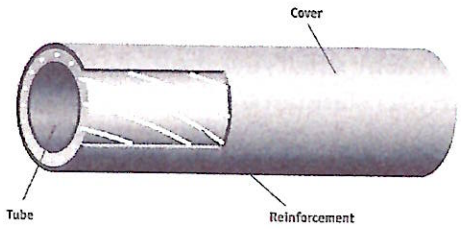
Hose

Hose used in fluid power systems shall conform to the following:

- Hose should comply with SAE J1273-1986, "Selection, Installation, and Maintenance of Hose and Hose Assemblies."
- The maximum operating pressure shall not exceed the manufacturer's rated operating pressure.
- Pressure shocks/surges shall not exceed the manufacturer's recommended rated operating pressure.
- For systems designed to operate at 5,000 psi or less, a design (safety) factor of 4:1, based on the minimum tensile strength of the material, should not be exceeded. In systems that do not have repetitive shock, a design factor of 3:1 may be used. Systems subject to repetitive shock should utilize a minimum design factor of 6:1. For systems operating higher than 5,000 psi, the design factor shall be agreed upon by the equipment builder and the purchaser.
- To minimize pressure drop, the cross-sectional area should be sized to limit the maximum fluid flow rate to a velocity of 4 ft/sec in inlet (pump suction or intake) lines, 10 ft/sec in return lines, and 20 ft/sec in pressure lines. Fluid conductors shall be capable of meeting the flow and pressure requirements of the components to which they are connected.
- The bend radius should not be less than that specified by the manufacturer.
- Hose shall not be applied such that the relative motion between its terminations introduces a twisting motion or causes the bend to be tighter than the recommended minimum bend radius.

Hoses are constructed of three main components: the tube, reinforcement, and the cover.

The inner lining or tube is used to conduct and convey the hydraulic fluid and must be resistant to the fluid being conveyed. Hose manufacturer's catalogs, in their engineering and technical section, have several pages of tables devoted to chemical resistance. These tables have compatibility rating scales for the various chemicals as they apply to the manufacturer's particular hose and fitting materials. The charts can be quite extensive but are vital to safe and practical hose applications.



Hose selection must assure compatibility of the tube, cover, fittings and O-rings with the fluid being used. Additional caution must be exercised in hose selection for gaseous applications where permeation may occur. Permeation, or effusion, is through the hose pores resulting in loss of fluid. This may occur when hose is used with fluids such as (but not limited to)

- Liquid and gas fuels
- Refrigerants
- Helium
- Fuel oil
- Natural gas

One area of compatibility that requires special attention concerns electrostatic discharge. Under certain applications the potential for static discharge must be considered. Be aware that static electricity can be a hazard. Electrocution could occur if hose conducts electricity through a person. Most hoses are conductive. Many contain metal or have metal fittings. Even non-conductive hoses can be conduits for electricity if they carry conductive fluids. Non-conductive hose, SAE J517 100R7, 100R8, and 100R18 hoses, with orange covers marked "non-conductive" are available for this service.

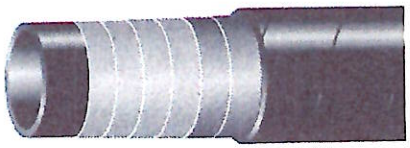
When a liquid contacts a tube that isn't a good conductor for example, a white PTFE tube), the result is a phase separation and the electric charge starts to build. The rate at which static electricity builds up now becomes a function of the flow rate. When the dielectric strength of the PTFE tube is exceeded, the electric charge will puncture the tube wall and ground itself on the wire braid of the hose.

Manufacturers can offset the potential for electrostatic discharge by using a conductive PTFE hose. Carbon is added to the PTFE tube wall during manufacture. The carbon layer directs the charge down the inner diameter of the hose to the metal end fittings. This prevents the charge from building up on the inner wall.

There are many fluids that can generate static electricity. It is recommended to contact the hose manufacturer if there is any concern about electrostatic build-up or potential discharge.

The reinforcement material in the hose construction is the "muscle" to provide the necessary strength to resist internal pressure (or external pressure as in the case of suction/vacuum). The three basic types of reinforcement are

Braided



Spiraled

Helical

SAE Standards

Hydraulic hose construction and performance is covered by various national and international standards including ISO, BSI, SAE, EN/DIN, API, and CETOP. Most hoses conform to one standard or another with many satisfying multiple standards. The SAE standards are the most widely followed in the U.S. as SAE J517 standards provide general, dimensional, and performance specifications for the most common hoses used in hydraulic systems.

SAE J517 has published guidelines for 100R1 through 100R12 series hydraulic hoses. These manufacturer-driven SAE standards have been based on design, construction, and pressure ratings to ensure that hydraulic hoses meet minimum construction requirements. SAE established minimum pressure ratings for various hoses (inside diameters and were later revised to also include constant-pressure hoses, which are hoses that maintain pressure ratings within a group regardless of size). Some common constant-pressure hoses are R13, R15, R17, R18, and R19.

ISO Standards

Hydraulic hose construction and performance is covered by various national and international standards including ISO, BSI, SAE, DIN, API, and CETOP. Most proprietary hoses conform to one standard or another, the SAE standards being the most widely followed in the U.S. SAE standards provide general, dimensional, and performance specifications for the most common hoses used in hydraulic systems on mobile and stationary equipment.

SAE is based on construction technique and material of hydraulic hose. The various application parameters required when selecting hose are size, temperature, fluid type, and pressure, to name a few. Depending on these criteria, the choice of hose construction will change to suit the conditions.

Each of the hydraulic hose styles summarized in the table must meet a set of dimensional and performance characteristics as set forth by SAE, and they are designated as 100R1 through 100R19. However, SAE issues no approval source lists, certification, or letters of approval. Adopting these standards by manufacturers is strictly voluntary. Therefore, SAE standards only ensure a similarity of hoses among different manufacturers, and most manufacturers offer hoses that far exceed SAE standards.

SAE DIMENSIONAL AND SAE DIMENTIONAL AND PERFORMANCE STANDARDS FOR HYDRAULIC HOSE

SAE standard hydraulic hose type / application	Compatible Hydraulic fluids	Temperature range (°F)	Diameter range (I.D. in)	Max. Operating Range (psi)	Proof Pressure Range (psi)	Min. Burst Pressure Range (psi)	Min. Bend Radius (in)
100R1 - Steel wire reinforced, rubber coated	Petroleum & water based	-40 to 212	3/16 to 2	575 to 3,250	1,150 to 6,500	2,300 to 13,000	3.5 to 25
100R2 - High pressure steel wire, reinforced rubber cover	Petroleum & water based	-40 to 212	3/16 to 2	1,150 to 6,000	2,250 to 12,000	4,500 to 24,000	3.5 to 25
100R3 - Double fiber, braid rubber cover – High temp, low pressure	Petroleum & water based	-40 to 212	3/16 to 1-1/4	375 to 1,500	750 to 3,000	1,500 to 6,000	3 to 10
100R4 - Wire inserted, hydraulic suction and return	Petroleum & water based	-40 to 212	3/4 to 4	35 to 300	70 to 600	140 to 1,200	5 to 24
100R5 - Single wire braid, textile cover – Transportation/DOT	Petroleum & water based	-40 to 212	3/16 to 3-1/16	200 to 300	400 to 6,000	800 to 12,000	3 to 33
100R6 - Single fiber braid, rubber cover – Transportation	Petroleum & water based	-40 to 212	3/16 to 3/4	300 to 500	600 to 1,000	1,200 to 2,000	2 to 6
100R7- Single fiber braid, thermoplastic – Hydraulic	Petroleum, water based, & synthetic	40 to +212	1/8 to 1	1,000 to 3,000	2,000 to 6,000	4,000 to 12,000	1 to 12
100R8 - High pressure, thermoplastic Hydraulic	Petroleum, water based & synthetic	40 to 212	1/8 to 1	2,000 to 6,000	4,000 to 12,000	8,000 to 24,000	1 to 12
100R9	This hose has been removed from the SAE standard.						
100R10	This hose has been removed from the SAE standard.						
100R11	This hose has been removed from the SAE standard.						
100R12 - Heavy duty, high impulse, four spiral wire reinforced, rubber cover – Hydraulic	Petroleum & water based	-40 to 250	3/8 to 2	2,500 to 4,000	5,000 to 8,000	10,000 to 16,000	5 to 25
100R13 - Heavy duty, high impulse, four & six spiral steel wire reinforced, rubber cover – Hydraulic	Petroleum & water based	-40 to 250	3/4 to 2	5,000	10,000	20,000	9.5 to 25
100R14 - High temperature, corrosive fluids, Polytetrafluorethylene (PTFE) lined hydraulic hose, single stainless steel braid	Petroleum, water based, & synthetic	-65 to +400	3/16 to 1-1/4	600 to 1,500	1,200 to 6,000	2,500 to 12,000	1.5 to 16
100R15 - Heavy duty, ultrahigh pressure, six spiral steel wire reinforced, rubber cover – Hydraulic	Petroleum based	-40 to 250	3/8 to 1-1/2	6,000	12,000	24,000	6 to 21
100R16 - Compact, high pressure, two-braided wire reinforced rubber cover – Hydraulic hose cover	Petroleum & water based	-40 to 212	1/4 to 1-1/4	1,800 to 5,800	3,600 to 11,600	7,200 to 23,200	2 to 8
100R17 - Compact, maximum operating pressure, one and two steel braided wire reinforced rubber cover – Hydraulic	Petroleum & water based	-40 to 212	3/16 to 1	3,000	6,000	12,000	2 to 6
100R18 - Thermoplastic, synthetic fiber reinforcement, and a hydraulic fluid & weather resistant thermoplastic cover – Hydraulic	Petroleum, water based, synthetic	-40 to 212	1/8 to 1	3,000	6,000	12,000	1 to 10
100R19 - Compact, maximum operating pressure, one and two-braided steel wire, reinforced rubber cover – Hydraulic	Petroleum & water based	-40 to 212	3/16 to 1	4,000	8,000	16,000	2 to 6

In addition to SAE standards, many manufacturers also manufacture hoses that meet the requirements of other industry standards that differ due to geographic origin—such as ISO or EN/DIN.

Difference Between SAE and ISO Standards for Hydraulic Hose

Over the last several years, hydraulic system designers began adopting and designing to conform to ISO specifications. Many large OEMs switched to ISO standards in their design and manufacturing process to ensure the sale and service of their equipment globally. ISO Standard 18752, released in 2006, takes a different approach centered around the design practices of users who typically design hydraulic systems based on performance and pressure requirements.

ISO 18752, released in 2014, specifies the requirements for ten classes, four grades and seven types of wire or textile-reinforced hydraulic hoses and hose assemblies of nominal sizes ranging from 3.5 MPa through 56.0 Mpa. This contrasts with traditional DIN standards, which provide general, dimensional, and performance specifications for the most common hoses used in hydraulic systems based on hose construction.

Each class has a single maximum working pressure for all sizes. Such hoses are suitable for use with hydraulic fluids HH, HL, HM, HR, and HV as defined in ISO 6743-4 at temperatures ranging from -40 °C to +100°C for types AS, AC, BS, and BC and -40 °C to +120 °C for types CS, CC, and DC.

ISO 18752 does not include requirements for the connection ends. It is limited to the performance of hoses and hose assemblies. The hose assembly maximum working pressure is governed by the lowest maximum working pressure of the components.

ISO 18752 Performance Definitions (4.2 Grades and Types)

Grade	Type[a]	Resistance to Impulse		
		Temperature	Impulse Pressure (% of MWP[b])	Minimum Number of Cycles
A	AS	100°C (212°F)	133%	200,000
	AC			
B	BS	100°C (212°F)	133%	500,000
	BC			
C	CS	120°C (250°F)	133% and 120%[c]	500,000
	CC			
D	DC	120°C (250°F)	133%	1,000,000

[a] Standard or compact, e.g. CS is grade C and standard type.
Standard types have larger outside diameters and larger bend radii and compact types have smaller outside diameters and smaller bend radii.

[b] Maximum working pressure.

[c] 120% of the MWP shall be used for classes 350, 420 and 560 instead of 133%

ISO 18752 classifies according to their resistance to impulse into four grades: A, B, C, and D. Each grade is classified by outside diameter indo standard types (AS, BS, and CS) and compact types (AC, BC, CC and DC) as shown in this table.

Regulatory Standards

In addition to the various standards that define performance and operational characteristics of hose, there are also in some cases governmental or industry required standards that mandate certain attributes for a given application.

The following are agency specification requirements that can apply to any application:

SAE: The Society of Automotive Engineers establishes the American standard for most hydraulic hose. SAE guidelines provide general properties of size, tolerances, and minimum performance characteristics of each major hose type. SAE is made up of representatives from the major manufacturers. SAE does not test or certify hose and fitting performance.

Note: SAE rated hoses from different manufacturers are not the same. They are similar. SAE J517 identifies the 100R hose series, which ranges from 100R1 to 100R19. The number designation following the "R" does not identify the number of reinforcement layers, but rather the specific requirement of a type of hose (Refer to SAE J517).

MSHA: Mine Safety and Health Administration specifies flame-resistant properties required of hose used in underground mining applications. It's also the recognized standard for flame resistance for many industries.

DOT/FMVSS: The Department of Transportation Federal Motor Vehicle Safety Standards describe the requirements for hydraulic, air and vacuum brake hose, hose assemblies, and fittings for use on passenger vehicles, trucks, buses, trailers, and motorcycles.

USCG: The United States Coast Guard requirements are met through two SAE specifications for hose and fittings that are used on marine vessels. They are SAE J1475 and J1942.

DOD and MIL: The United States Department of Defense has many specifications that identify dimensional and performance requirements for various hose types. Some specifications require a manufacturer to be listed as an approved source. Many specifications require a low temperature rating to - 65°F.

The following are other industry agencies that have specific requirements:

- ABS – American Bureau of Shipping
- DIN – Deutsches Institut fur Normung (Germany)
- IJS – Industrial Jack Specifications
- ISO – International Organization for Standardization
- Lloyds of London
- DNV – Det Norske Veritas (for North Sea Floating Vessels)

Pressure Ratings

In hose selection, it is important to know the working pressure, including pressure spikes. Published hose working pressures must be equal to or greater than the system pressure. Pressure spikes greater than the published working pressures will shorten hose service life and must be taken under consideration. Hose manufacturers DO NOT recommend using hose on applications having pressure spikes greater than published hose working pressures. Pressure ratings are classified as Operating, Proof, and Burst.

Operating Pressure – the amount of pressure that a hose can experience during normal working operations that is determined by the burst pressure of a hose divided by the safety factor assigned by the manufacturer which, for general applications is a minimum of 4.

Proof Pressure – Proof pressure is the maximum pressure that may be applied to a hose without changing its performance with the specifications. Typically, after the hose is exposed to an overpressure under the proof pressure limit, the hose will return to its original state and operate normally. This pressure is typically twice the max working or operating pressure. It is used to test the integrity of a hose assembly.

Burst Pressure – Burst pressure is the maximum pressure the hose can withstand before failure. Burst pressures are reference pressures intended for destructive testing purposes and design safety factors only.

Selecting a Hose

Proper hose or tubing assembly component selection is critical to a safe hydraulic system. Below is a guideline for proper selection using the acronym **"STAMPED"**:

S = Size of hose – OD, ID, Length.

The inside diameter of the hose must be adequate to keep pressure loss to a minimum and avoid damage to the hose due to heat generation from excessive turbulence. Flow velocity can be determined by calculation, nomograph, charts available from most manufacturers, or reference manuals.

The recommended flow velocities for most systems are based on system conditions. For example, high pressure at high velocity can incur very high shock loads with quick closing valves in the system. Some practical velocities are:

- Pump Intake Less than 1.22 m/s (4ft/sec)
- Return Lines 3.05 m/s (10 ft/sec)
- High Pressure 6.096 m/s (20 ft/sec)

The power transmitted by pressurized fluid varies with pressure and rate of flow. Select hose with adequate size to minimize pressure loss and to avoid hose damage from heat generation or excessive velocity.

Using the general guidelines for line velocities should be done with caution. For example, suction velocities are generally held below 4 ft/sec to prevent cavitation and possible damage to the pumping equipment.

Pressure lines can vary from 10 ft/sec to 25 or even 30 ft/sec. High velocities, however, can be a problem with shock if the circuit has quick closing valves or actuators that stop abruptly. Back pressure in return lines can be a concern with some circuits, so it is wise to consider the application before sizing to the guideline.

T = Temperature of the material conveyed and ambient.

When selecting a new or replacement assembly two, areas of temperature must be considered. These are fluid temperature and ambient temperature. The hose selected must be capable of withstanding the minimum and maximum system temperatures. Care must be taken when routing near hot manifolds and in extreme cases, a heat shield may be advisable.

Caution: To avoid equipment breakdown and possible injury, the fluid manufacturer's recommended maximum operating temperature for any given fluid must not be exceeded. If the fluid's temperature limit is different than the listed hose temperature rating, the lower limit must take precedence. The recommended maximum operating temperature for any given fluid must not be exceeded. If the fluid's temperature limit is different than the listed hose temperature rating, the lower limit must take precedence.

A = Application of use.

Determine where the new or replacement hose assembly is to be used. Most often, only a duplicate of the original will be required, provided the original hose assembly gave acceptable service life.

Hydraulic hose assemblies have a finite life. Some factors that will reduce life include

- External abrasion
- Flexing the hose to less than the specified minimum bend radius
- Twisting, pulling, kinking, or crushing
- Operating above maximum or below minimum temperature range
- Exposing the hose to surge pressures above the maximum working pressure
- Intermixing hose, connectors, or assembly equipment or not following the manufacturer's instructions for fabricating hose assemblies is not recommended by the manufacturer.

Surge pressures referred to above are rapid and transient rises in pressure. Surge pressures will not be indicated on most common pressure gauges and can be best identified on electronic measuring instruments with a high frequency response.

M = Material being conveyed.

Hose selection must assure compatibility of the hose tube, cover, fittings, and O-rings with the fluid to be circulated in the system. Additional caution must be exercised for gaseous applications where permeation may occur. Permeation, or effusion, is through the hose pores resulting in loss of fluid. This may occur when hose is used with fluids such as (but not limited to)

- Air and compressed gases
- Liquid and gaseous fuels
- Refrigerants helium
- Fuel oil
- Natural gas

If fluids permeate through the tube, consider pin-perforated covers to prevent fluid buildup under the cover. Also consider the compatibility of the system fluid not only with the core tube, but also with the braid, cover, fittings, and other components since permeation may expose the entire hose assembly to the system fluid.

Permeation (effusion) is quite complex and can occur with a great many different chemicals and gases. It should be a consideration in every assembly.

O-rings used with fittings must also be considered for chemical compatibility with the fluid to be conveyed. This includes fittings containing internal O-rings, such as pipe swivels and straight thread O-ring fittings. The manufacturer normally lists the O-ring material in their catalog. Prior to installation, O-rings should be lubricated. (Please refer to manufacturer catalog for recommended lubricants.)

P = Pressure that hose will be subjected to – continuous and peak.

It is vital to hose selection to know the working pressure including pressure spikes. Published hose working pressures must be equal to or greater than the system pressure. Pressure spikes greater than the published working pressures will shorten hose service life and must be taken under consideration. Hose manufacturers DO NOT recommend using hose on applications having pressure spikes greater than published hose working pressures.

Burst pressures are reference pressures intended for destructive testing purposes and design safety factors only. Typically, for dynamic hydraulic applications (fluid conductors only), the minimum burst pressure rating is four times that of the maximum working pressure rating.

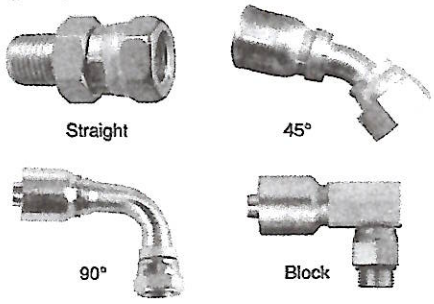
Pressure drop must also be considered. This is the difference between the pressure entering the hose assembly and the pressure at the exit end.

It will be affected by

- Friction: The rubbing of fluid against the inside walls of the hose.
- Type of fluid: Different fluids behave differently under pressure. High viscosity fluids are moved with greater difficulty.
- Temperature of the fluid: Higher temperature will cause the fluid to thin and move more easily through the assembly.
- Length of the assembly: The longer the assembly the more surface area friction to decrease pressure
- Velocity: The higher the velocity the greater the pressure drops.
- Type of fittings and adapters: Any change in flow or direction of flow (such as with a 45° or 90° elbow) can increase the amount of pressure drop.
- Flow rate: Pressure drop increases with increased flow rate for the same size hose.

E = Ends or fittings that will be on the hose assembly.

Identify the end connectors using manufacturers' catalogs – Do not mix hose or fittings from different manufacturers. Different hose ends have different allowable amounts of ovality and still can be considered within tolerance. Ovality of the crimp is checked by subtracting the lowest measured crimp diameter from the highest diameter reading and manufacturers provided acceptable tolerances. Generally ovality in the crimp is due to worn or not properly lubricated dies if not caused by improper assembly techniques.



D = Delivery and refers to packaging, storage, quality, and testing requirements.

Final inspection, special packaging, shipping, and documentation. During this stage, hose assembly is cleaned and sealed, and verifying measurements are taken and recorded into hose assembly documentation