APPENDIX (SECTION A)

Flow/Pressure Charts and Conversions

- Flow & Pressure Charts
- Heads and Equivalent Pressure Conversions
- Pressure Conversions
- Flow Rate Conversions

DETERMINING INSIDE DIAMETER OF TUBING

The ID of tubing is set by flow requirements, permissible pressure drop, and maximum allowable velocity. To aid in selecting the proper ID of tubing for liquid flow, Charts 1 through 10 are provided on the following pages. Charts 11 through 20 are provided for sizing tubing for gas flow.

These charts give pressure drop for 100 feet of tubing for both water and air flow. By using the formula provided, it is also possible to obtain the pressure drop of fluids other than water and gas.

To allow for pressure drops in bends and fittings, the equivalent lengths in Table A can be used when obtaining equivalent length of tubing for pressure drop calculations. To obtain equivalent length of tubing, total all straight lengths and then add lengths for each bend, elbow, or tee from Table A.

EQUIVALENT FEET OF STRAIGHT TUBE

Tubing OD (in.)	90° Elbow (ft)	90° Bend (ft)	180° Bend (ft)	45° Bend (ft)	Tee Branch (ft)
1/4	1	1/2	1	1/2	1
3/8	1 1/2	1/2	1	1/2	1 1/2
1/2	2	1/2	1	1/2	2
5/8	2 1/2	1	2	1/2	2 1/2
3/4	3	1	2	1/2	3
1	4 1/2	1	2	1/2	4 1/2
1 1/4	5	2	4	1	5
1 1/2	6	2	4	1	6
2	9	2	4	1	9

Table A

CALCULATIONS FOR LIQUID FLOW

EXAMPLE 1. Water is to flow through 50 feet of tubing at 4 gallons per minute (GPM). Water velocity is not to exceed 5 feet per second. The maximum allowable pressure drop is 5 psig. What diameter of tubing can be used?

Step 1. Pressure drop for 100 feet would be two times the allowable pressure drop for 50 feet, i.e. 10 psi.

Step 2. By looking at Charts 1 through 9, it can be determined that only 3/4 in. or 1 in. OD tubing can be used because the pressure drop would be over 10 psi for a 4 GPM flow in smaller tubing. From Chart 5, for 4 GPM flow rate, the pressure drop per 100 feet of any of the 3/4 in. OD tubes would be satisfactory.

Step 3. The smallest ID on Chart 5 is 0.560 in. An ID of 0.560 in. on Chart 10 shows velocity of 5 feet per second for 4 GPM. Therefore, any of the 3/4 in. tubing can be used, and wall thickness selection would be determined by pressure requirements.

EXAMPLE 2. Suppose the maximum pressure drop of Example 1 was 1 psig. Find the proper size tubing.

Step 1. For 100 feet, maximum pressure drop would be 2 psi.

Step 2. The 3/4 in. tubing is now too small as determined by Chart 5. Looking at Chart 6, it can be seen that 1 in. OD tubing of wall thickness less than 0.100 in. can be used because it will have less than a 2 psi pressure drop.

For liquids with specific gravity near water, the equivalent water flow rate can be calculated and then used to find pressure drop. An example follows:

Equivalent Flow Rate of water = Flow Rate of other liquid times $\sqrt{\text{S.G. Liquid}}$

$$Q_w = Q_2 \sqrt{\text{specific gravity of other liquid}}$$

EXAMPLE 3. Acetone at 1/10 GPM is to flow through 100 feet of tubing with a pressure drop not to exceed 5 psi.

Step 1. $Q_w = Q_2 \sqrt{\text{S.G.L.}}$

$= (1/10) \sqrt{0.792}$ (Specific Gravity Acetone = 0.792)

$= 0.089$ GPM water

Step 2. Chart 2 shows that 1/4 in. OD tubing of wall thickness 0.049 or less will be of sufficient ID to produce less than a 5 psi drop with a water flow of 0.089 GPM.

CALCULATIONS FOR GAS SYSTEMS (CHARTS 11 THROUGH 20)

Pressure drop is directly proportional to length, inversely proportional to absolute pressure, and directly proportional to absolute temperature. Using this information, the pressure drop formula for use with Charts 11 through 20 is:

$$\Delta P_L = \frac{\Delta P}{100} \quad \frac{L}{100} \quad \left(\frac{114.7}{14.7 + P}\right)\left(\frac{460 + t}{530}\right)$$

where ΔP_L — refers to pressure drop (in psi) of air per L feet of tubing at conditions of pressure (P in psig) and temperature (t in °F).

$\frac{\Delta P}{100}$ — refers to pressure drop at 100 psig, 70°F for 100 feet of tubing.

In order to use Charts 11 through 20, it is necessary to obtain equivalent conditions at 100 psig. This is most easily explained by example problems given below.

EXAMPLE 1. What is the pressure drop for 6 CFM of 100 psig air at 70°F for 100 feet of 3/4 in. 0.095 wall tubing?

SOLUTION: From Chart 15 read 7.5 psi pressure drop.

EXAMPLE 2. Same problem as 1 but for 200 feet of tubing.

SOLUTION: Pressure drop is directly proportional to length. Therefore, if 7.5 psi is the pressure drop for 100 feet, $2 \times 7.5 = 15$ psi is drop for 200 feet.

EXAMPLE 3. Same problem as 1 but for 50 feet of tubing.

SOLUTION: Pressure drop is directly proportional to length. Therefore, if 7.5 psi is the pressure drop for 100 feet, $1/2 \times 7.5 = 3.75$ psi is the drop for 50 feet of tubing.

EXAMPLE 4. 10 CFM free air is to pass through 75 feet of tubing at 80 psig inlet pressure and 75°F. The diameter of the proper tubing is to be found knowing the maximum allowable pressure drop is 6 psi.

SOLUTION:

Step 1. Find the pressure drop for 100 feet of tubing at 70°F and 100 psig so that the charts may be used.

$$\Delta P = 6 = \frac{\Delta P}{100} \left(\frac{75}{100}\right)\left(\frac{114.7}{14.7 + 80}\right)\left(\frac{460+75}{530}\right)$$

$$\frac{\Delta P}{100} = 6.55 \text{ psi drop per 100 feet at 100 psig at 70°F.}$$

Step 2. Change flow rate at 80 psig and 75°F to the flow rate at 100 psig and 70°F.

$$Q_{air} \text{ at 100 psig, 70°F} = Q_{air} \text{ at } 80{,}75 \left(\frac{14.7 + 80}{114.7}\right)\left(\frac{530}{460 + 75}\right)$$

$$= 8.18 \text{ CFM}$$

Step 3. On Chart 16, note that all 1 in. tubing will give a pressure drop of less than 6.55 psi at 8.18 CFM flow at 100 psig.

EXAMPLE 5. Helium is to pass through 100 feet of tubing at 25 psig inlet pressure and 70°F. The flow rate of free helium is 8 CFM. What is the pressure drop in 3/8 in. 0.035 in. wall tubing?

SOLUTION:

Step 1. Find the equivalent air flow so that air flow charts may be used.

$$\text{flow rate of air} = \text{flow rate of helium} \sqrt{\text{specific gravity of helium}}$$

$$Q_a = Q_{He} \sqrt{(S.G.)\ He}$$

$$Q_a = 8 \sqrt{0.138} = 3 \text{ CFM free air}$$

Step 2. Change flow rate at 25 psig to the flow rate of air at 100 psig.

$$Q_{air} \text{ at } 100 = Q_{air} \text{ at } 25 \left(\frac{14.7 + 25}{114.7}\right) = 1.0 \text{ CFM}$$

Step 3. See Chart 13 and find that the pressure drop of 100 psig air at 1.0 CFM is 6 psi for 100 feet of tubing.

Step 4. Solve for pressure drop in the problem by using the pressure drop formula.

$$\Delta P = \frac{P}{100} \left(\frac{L}{100}\right)\left(\frac{114.7}{14.7 + P}\right)\left(\frac{460 + t}{530}\right)$$

$$= 6 \left(\frac{100}{100}\right)\left(\frac{114.7}{14.7 + 25}\right)\left(\frac{530}{530}\right)$$

$$= 6\ (2.9) = 17.3 \text{ psi pressure drop.}$$

EXAMPLE 6. 8 CFM of 15 psig, 70°F air is to pass through 10 feet of 1/2 in. OD, 0.049 wall tubing. What is the pressure drop?

SOLUTION:

Step 1. Change flow rate at 15 psig to flow rate at 100 psig.

$$Q_{air} @ 100 = Q_{air} @ 15 \left(\frac{14.7+15}{100 + 14.7}\right) = 8 \left(\frac{29.7}{114.7}\right) = 2.07$$

Step 2. From Chart 14, pressure drop at 100 psig is found to be 6 psi for 100 feet of tubing.

Step 3. Change this pressure drop to the condition of the problem.

$$\Delta P = \frac{\Delta P}{100} \left(\frac{L}{100}\right)\left(\frac{114.7}{14.7 + P}\right)\left(\frac{460 + t}{530}\right)$$

$$= 6 \left(\frac{10}{100}\right)\left(\frac{114.7}{14.7 + 15}\right)\left(\frac{530}{530}\right)$$

$$= 6 \times 1/10 \times 3.86 = 2.3 \text{ psi drop.}$$

OR:

Step 1. Change flow rate to that of free air.

$$Q_{air} @ 14.7 \text{ psia} = Q_{air} @ 15 \text{ psig} \left(\frac{14.7 + 15}{14.7}\right)$$

$$= 8 \times 2.02 =$$

$$= 16.16 \text{ CFM}$$

Step 2. From Chart 14, pressure drop at 14.7 psia for 100 feet of 1/2 in. 0.049 wall tubing and 16.16 CFM free air flow is 6 psi.

Step 3. Same as Step 3 above.

Chart 1: 1/8 in. OD Tubing

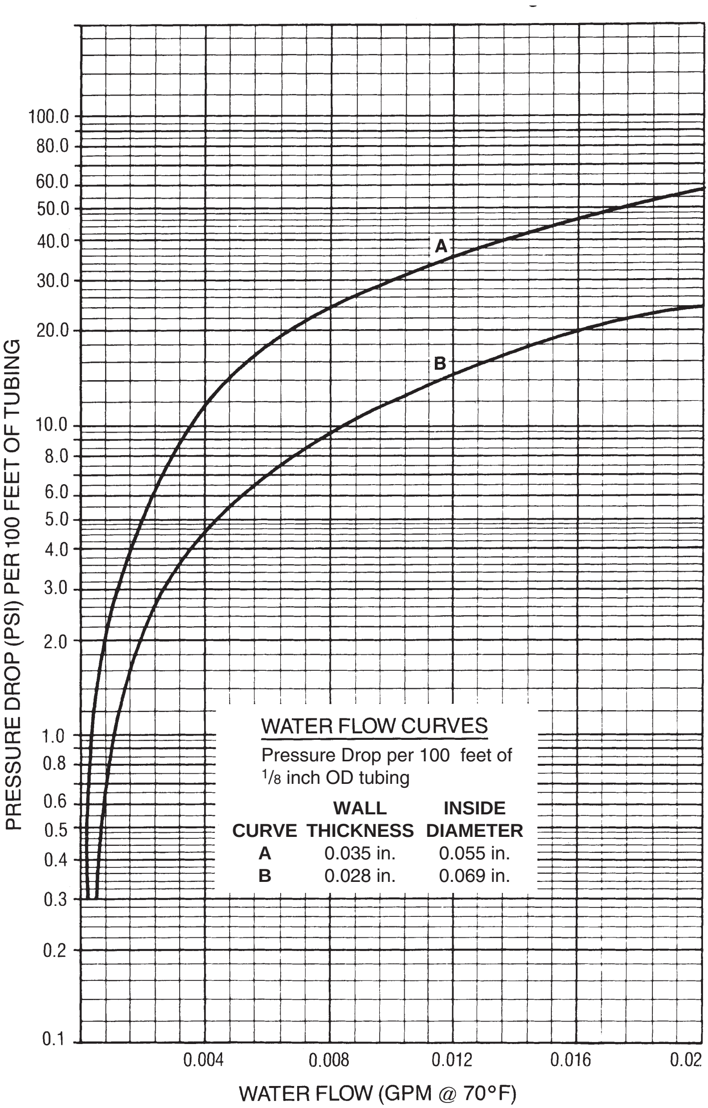
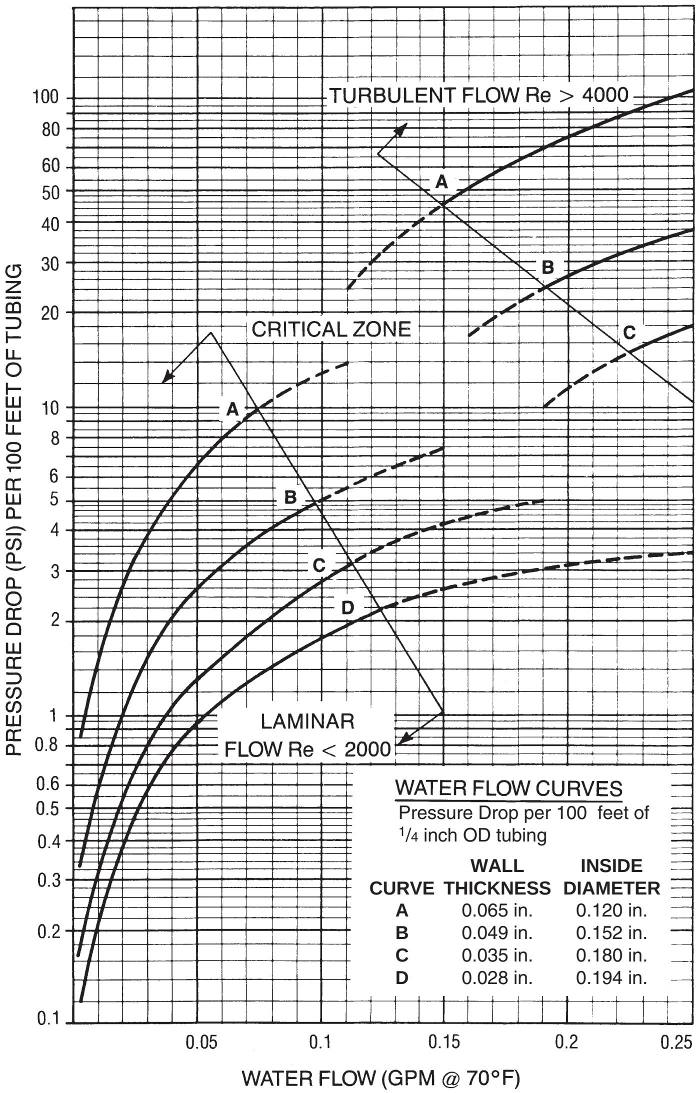


Chart 2: 1/4 in. OD Tubing



WATER FLOW CURVES

Pressure Drop per 100 feet of 1/4 inch OD tubing

CURVE	WALL THICKNESS	INSIDE DIAMETER
A	0.065 in.	0.120 in.
B	0.049 in.	0.152 in.
C	0.035 in.	0.180 in.
D	0.028 in.	0.194 in.

Chart 3: 3/8 in. OD Tubing

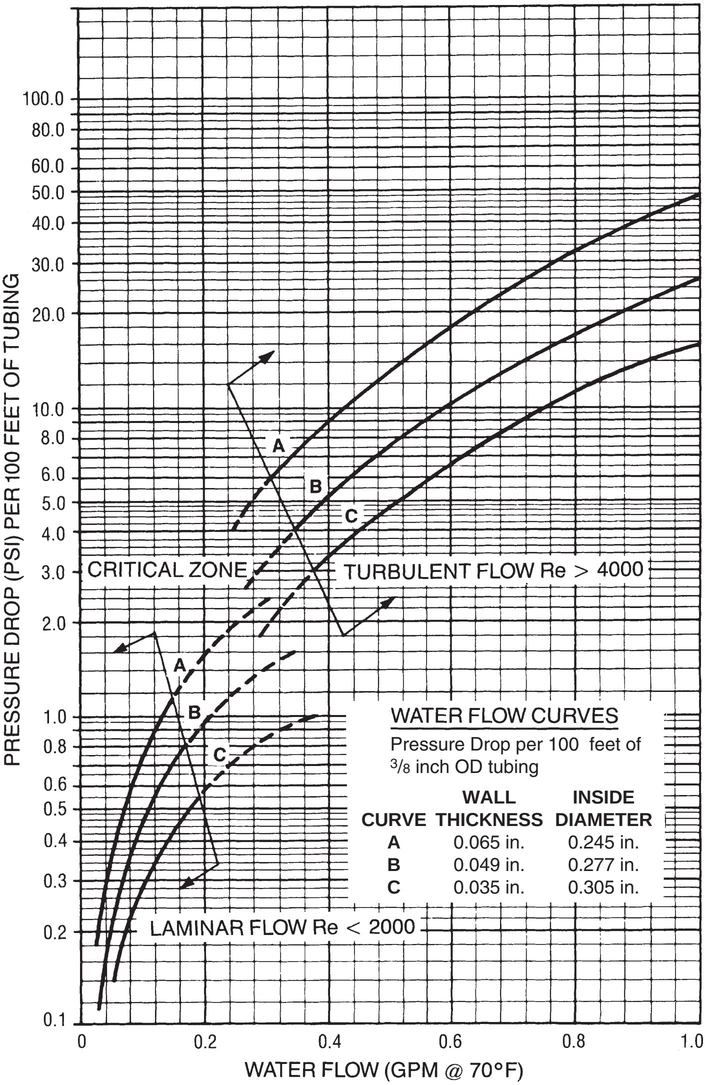


Chart 4: 1/2 in. OD Tubing

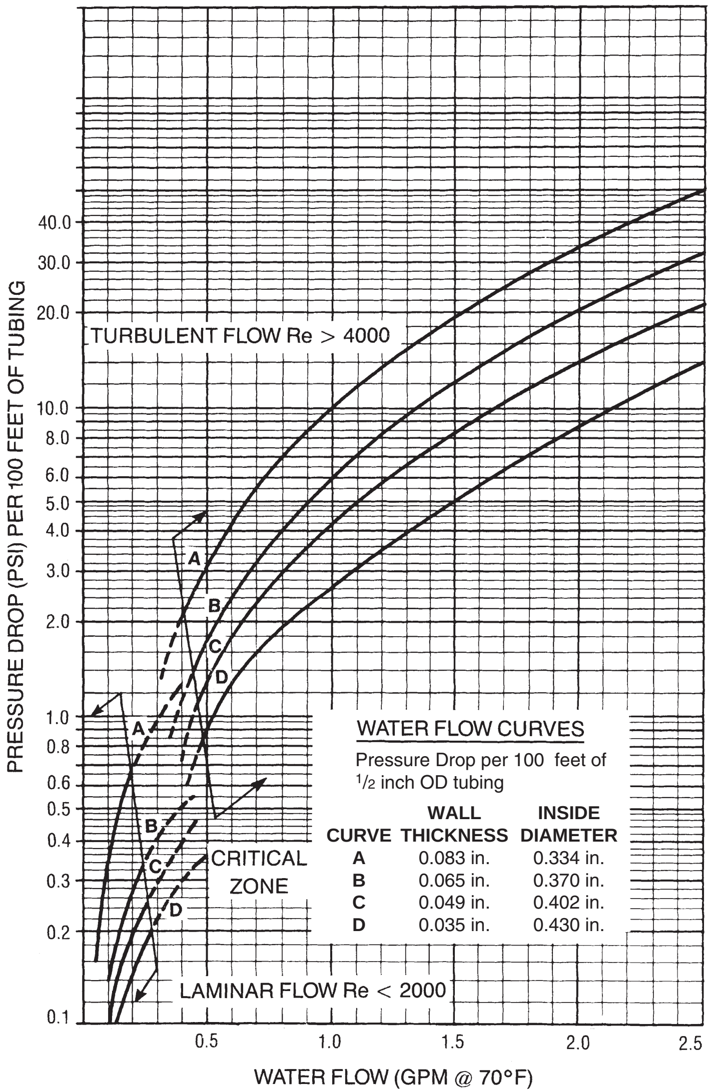
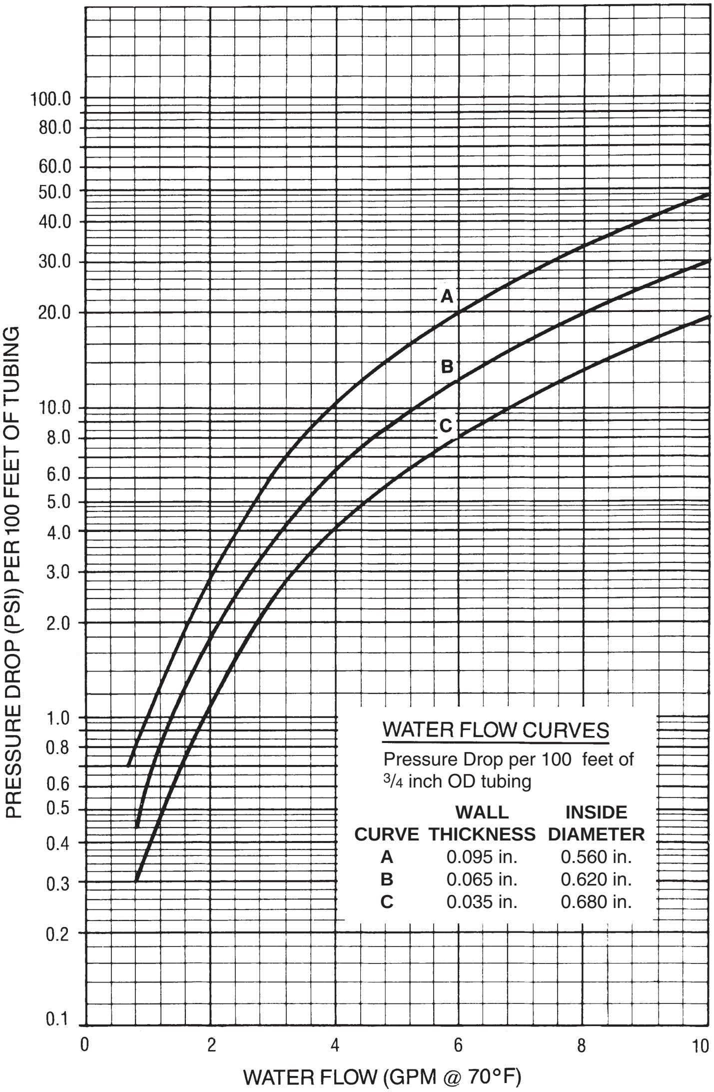


Chart 5: 3/4 in. OD Tubing



CURVE	WALL THICKNESS	INSIDE DIAMETER
A	0.095 in.	0.560 in.
B	0.065 in.	0.620 in.
C	0.035 in.	0.680 in.

Chart 6: 1 in. OD Tubing

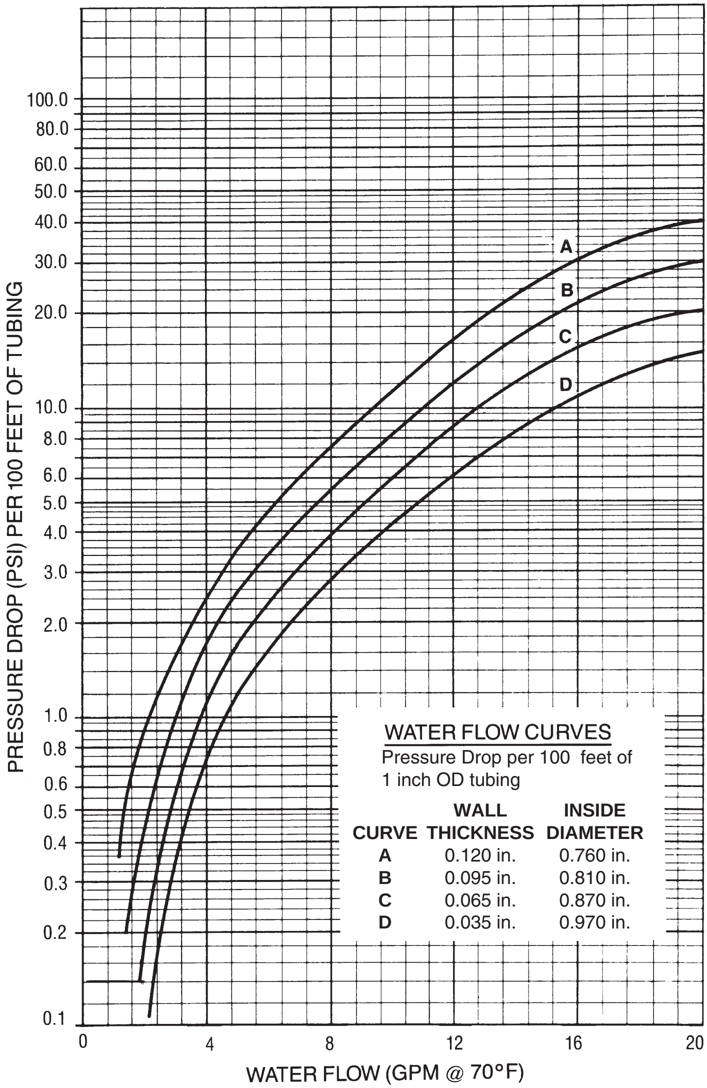


Chart 7: 1 1/4 in. OD Tubing

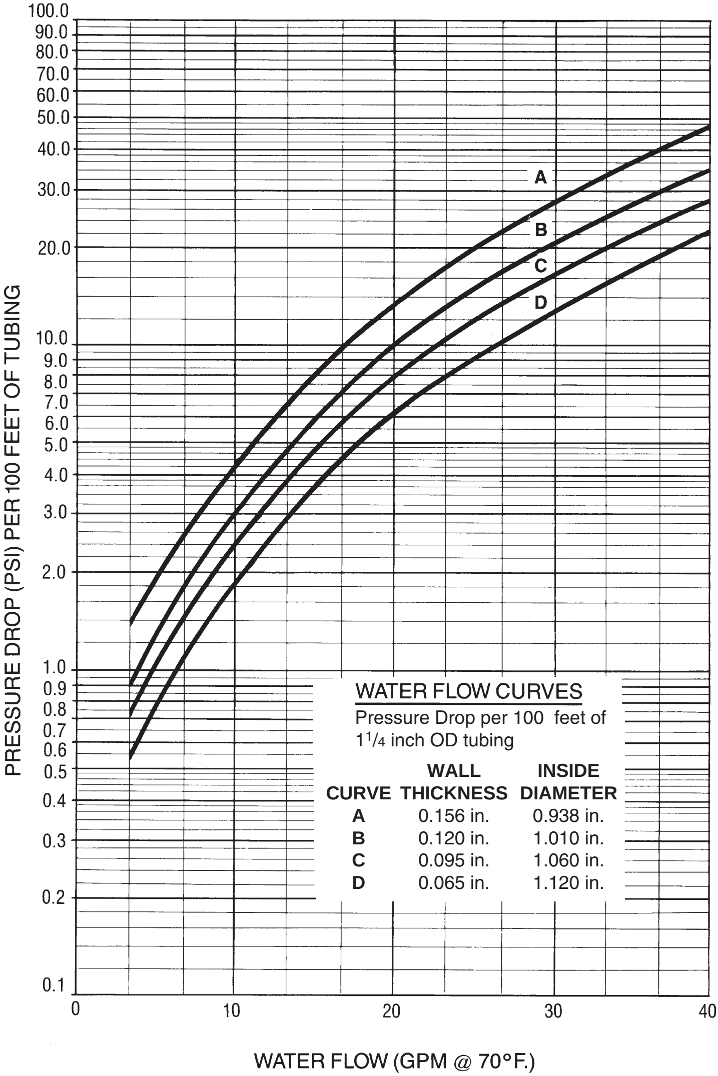


Chart 8: 1 1/2 in. OD Tubing

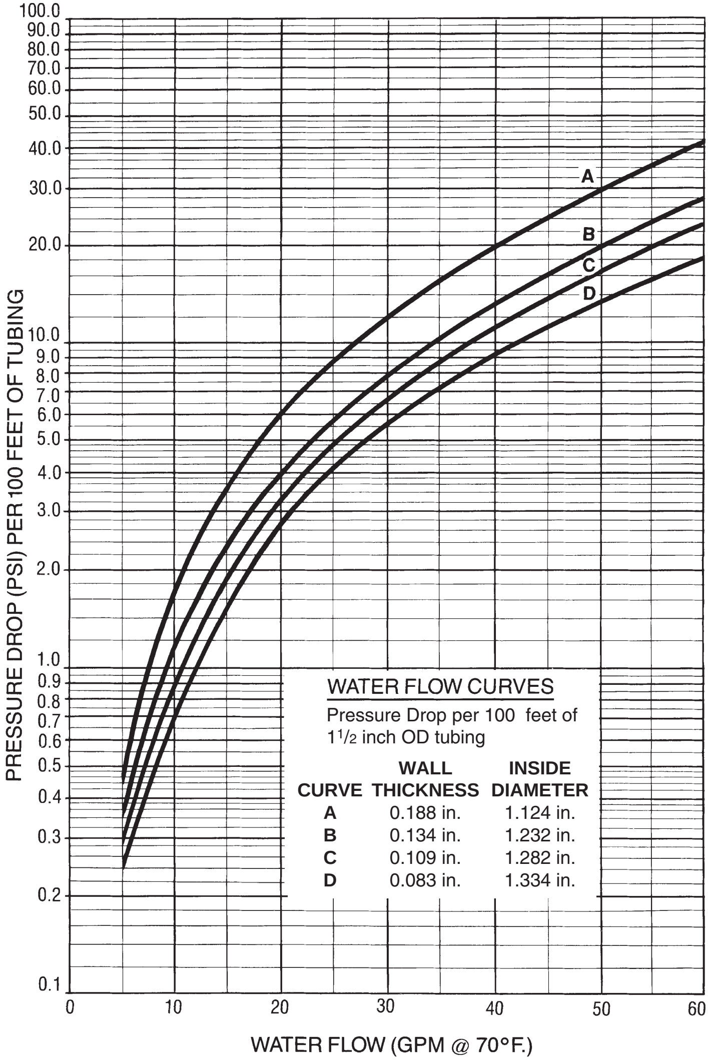


Chart 9: 2 in. OD Tubing

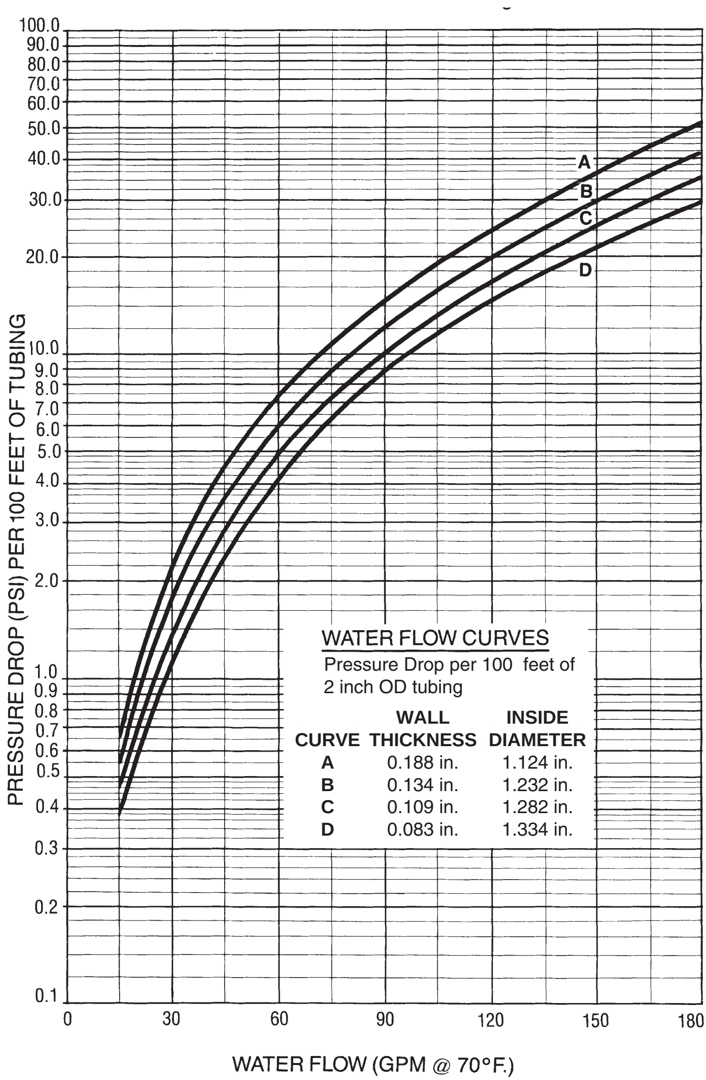


Chart 10:
Mean Velocity versus Tube Inside Diameter for Various Water Flows

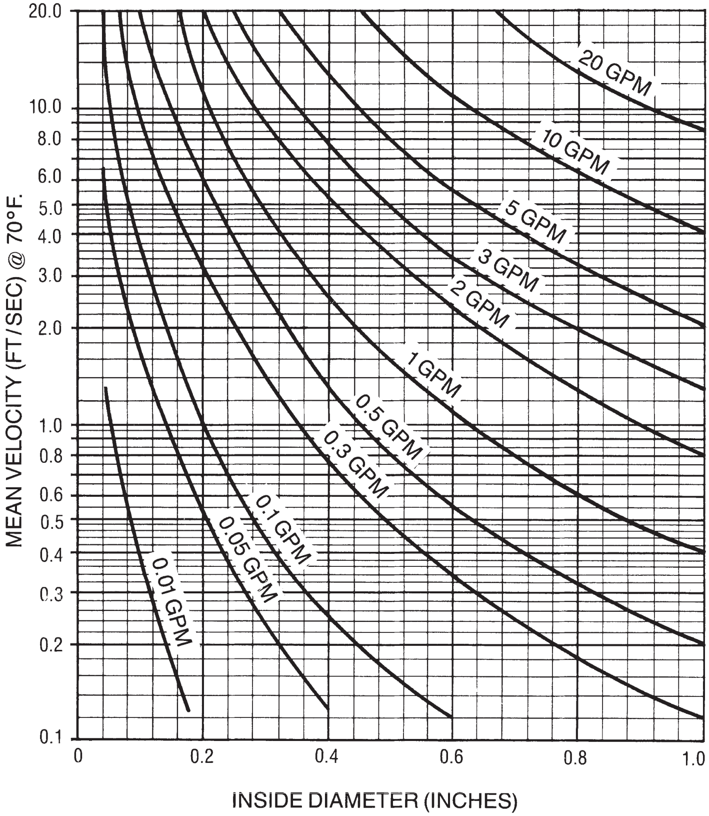


Chart 11: 1/8 in. OD Tubing
CFM Air Standard Temperature and Pressure (14.7 PSIA @ 70° F)

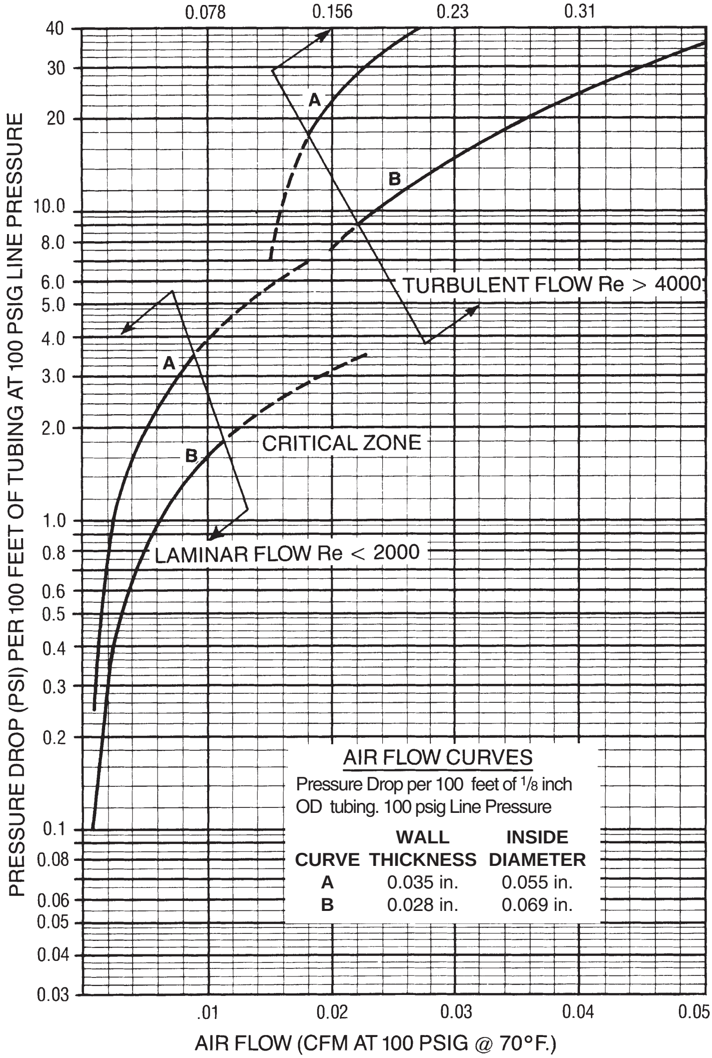
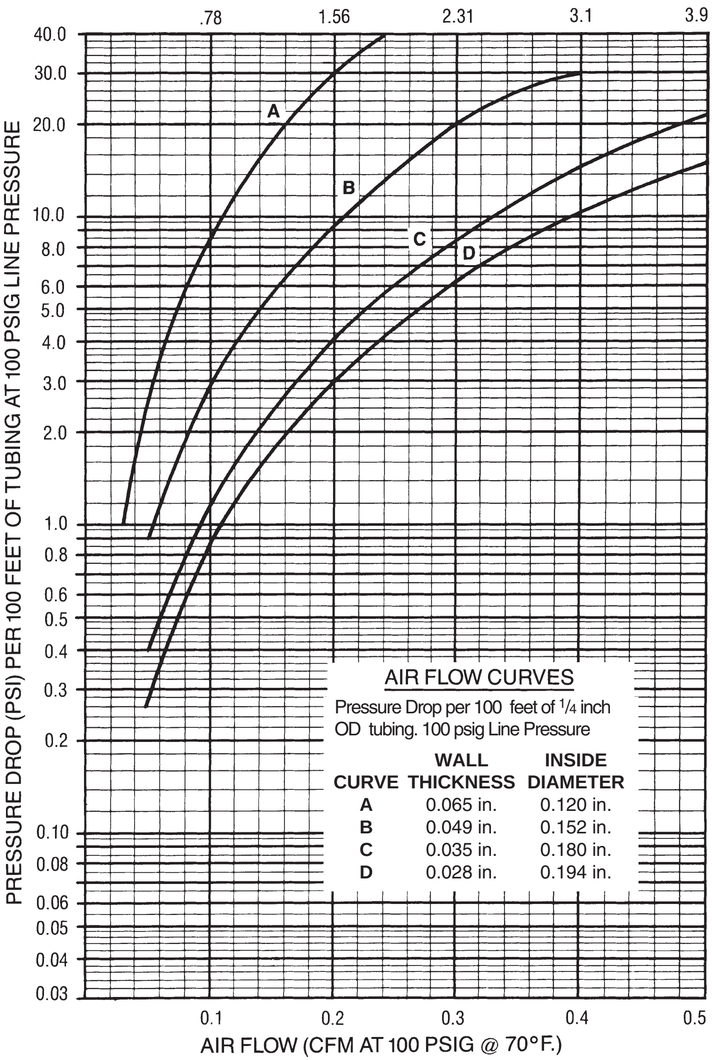


Chart 12: 1/4 in. OD Tubing
CFM Air Standard Temperature and Pressure (14.7 PSIA @ 70° F)



CURVE	WALL THICKNESS	INSIDE DIAMETER
A	0.065 in.	0.120 in.
B	0.049 in.	0.152 in.
C	0.035 in.	0.180 in.
D	0.028 in.	0.194 in.

Chart 13: 3/8 in. OD Tubing
CFM Air Standard Temperature and Pressure (14.7 PSIA @ 70° F)

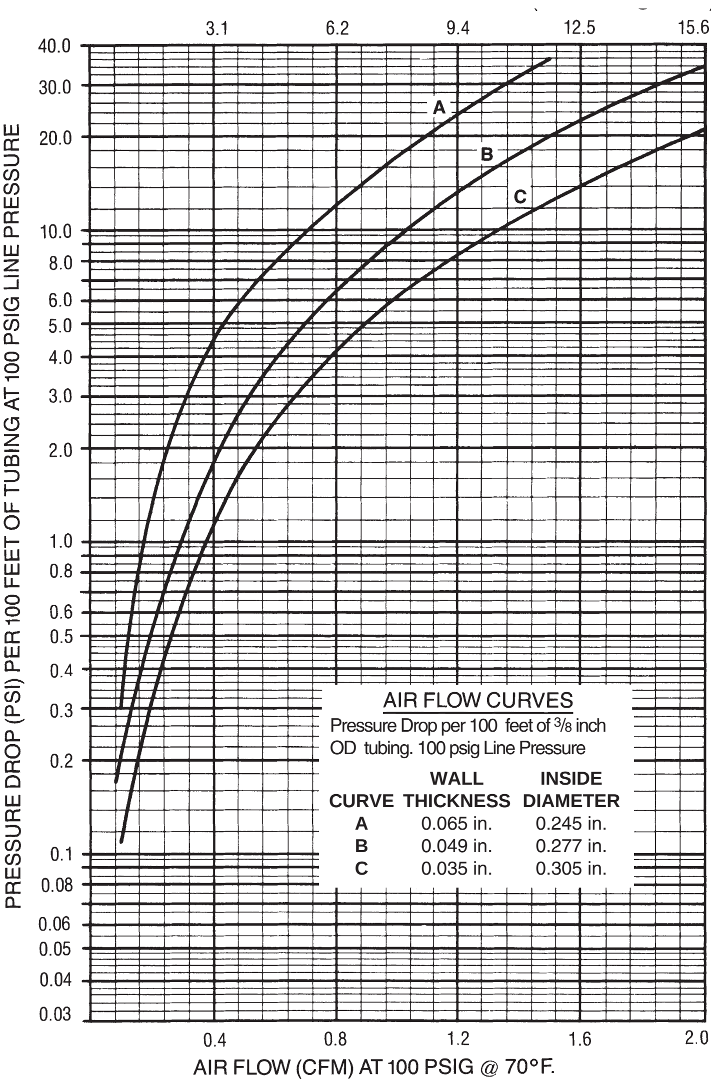


Chart 14: 1/2 in. OD Tubing

CFM Air Standard Temperature and Pressure (14.7 PSIA @ 70° F)

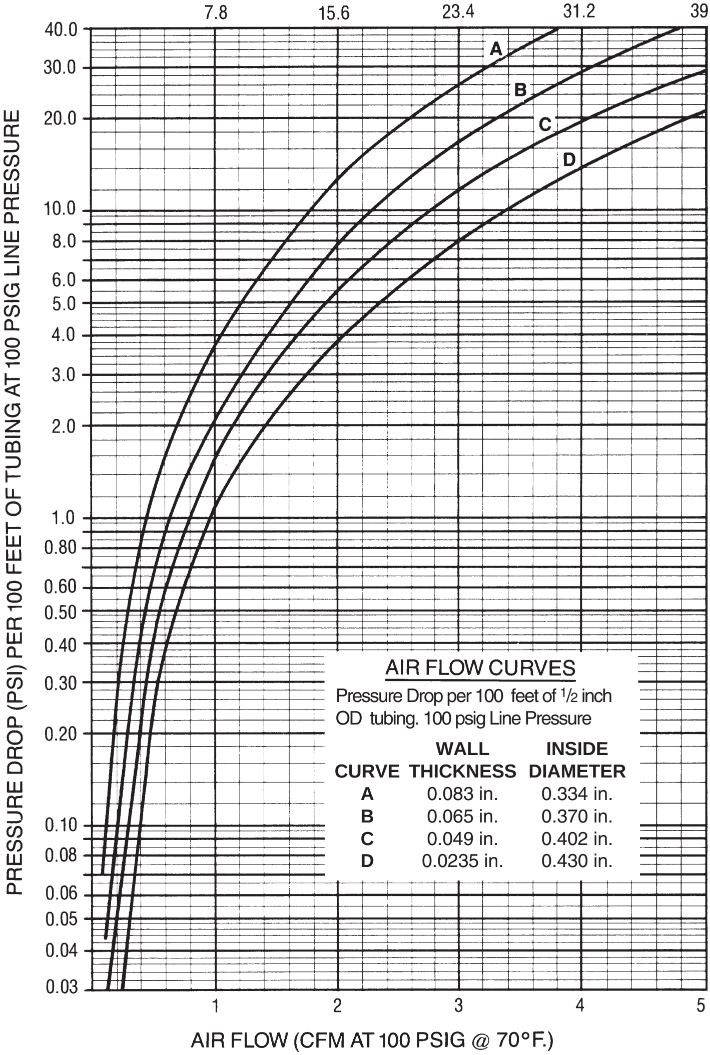


Chart 15: 3/4 in. OD Tubing
CFM Air Standard Temperature and Pressure (14.7 PSIA @ 70° F)

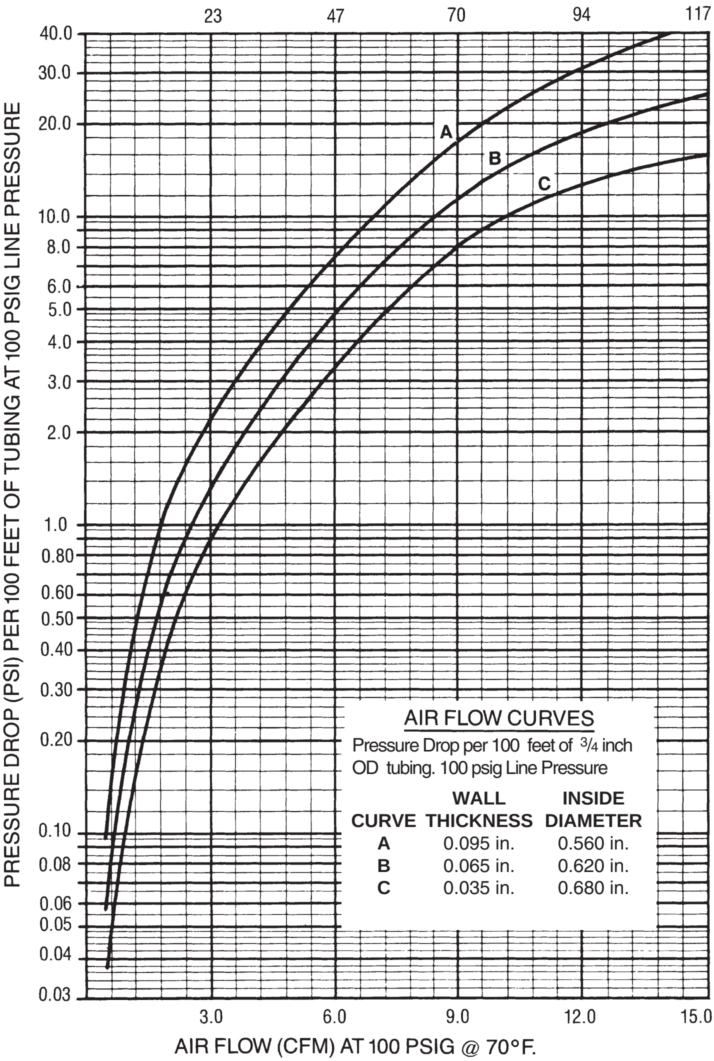


Chart 16: 1 in. OD Tubing
CFM Air Standard Temperature and Pressure (14.7 PSIA @ 70° F)

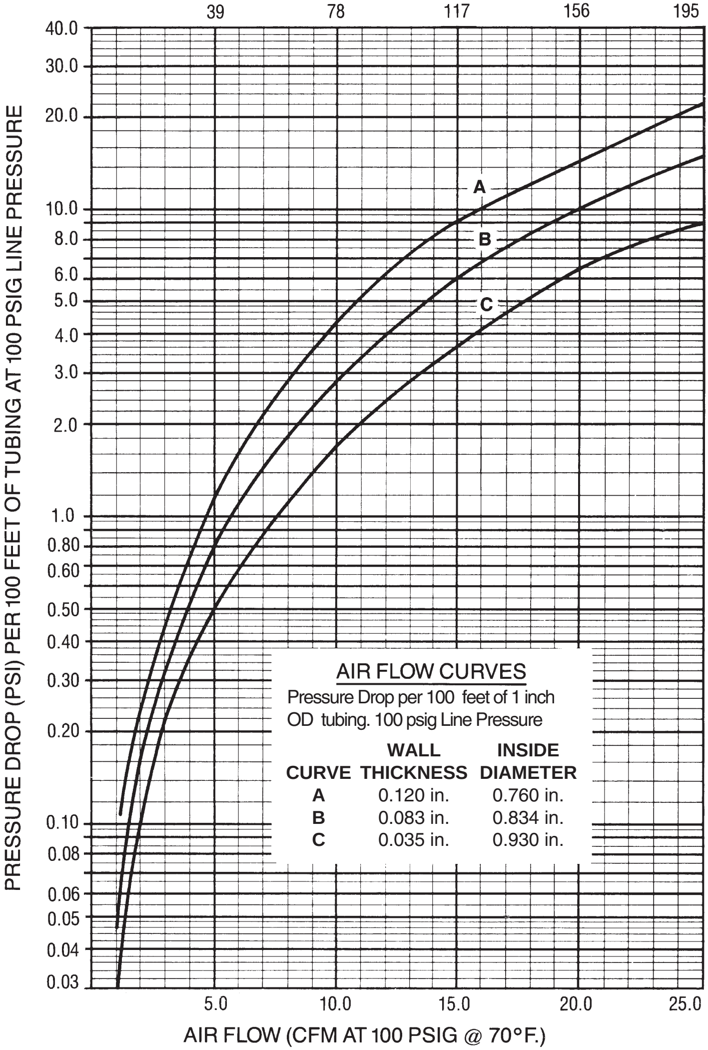


Chart 17: 1 1/4 in. OD Tubing
CFM Air Standard Temperature and Pressure (14.7 PSIA @ 70° F)

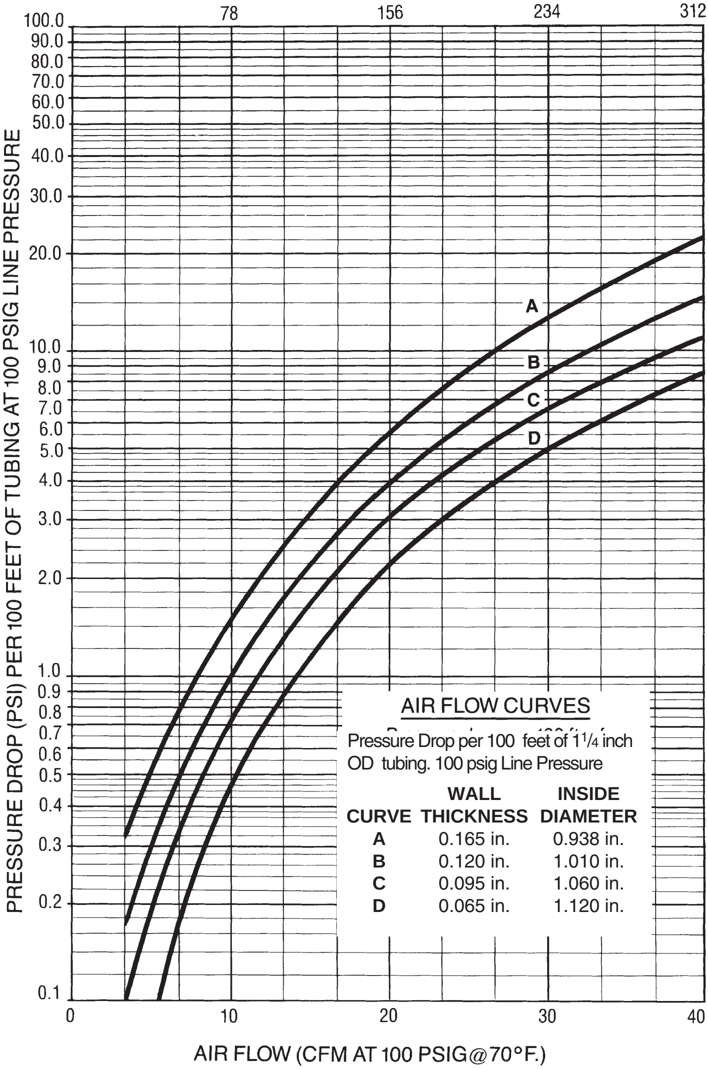


Chart 18: 1 1/2 in. OD Tubing
CFM Air Standard Temperature and Pressure (14.7 PSIA @ 70° F)

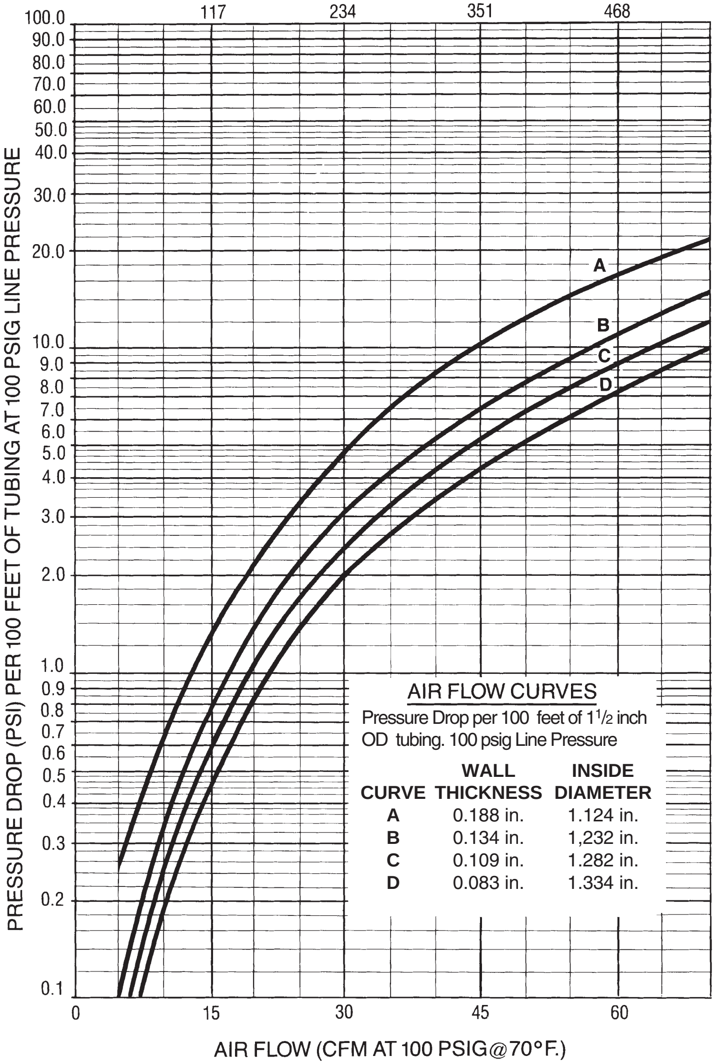
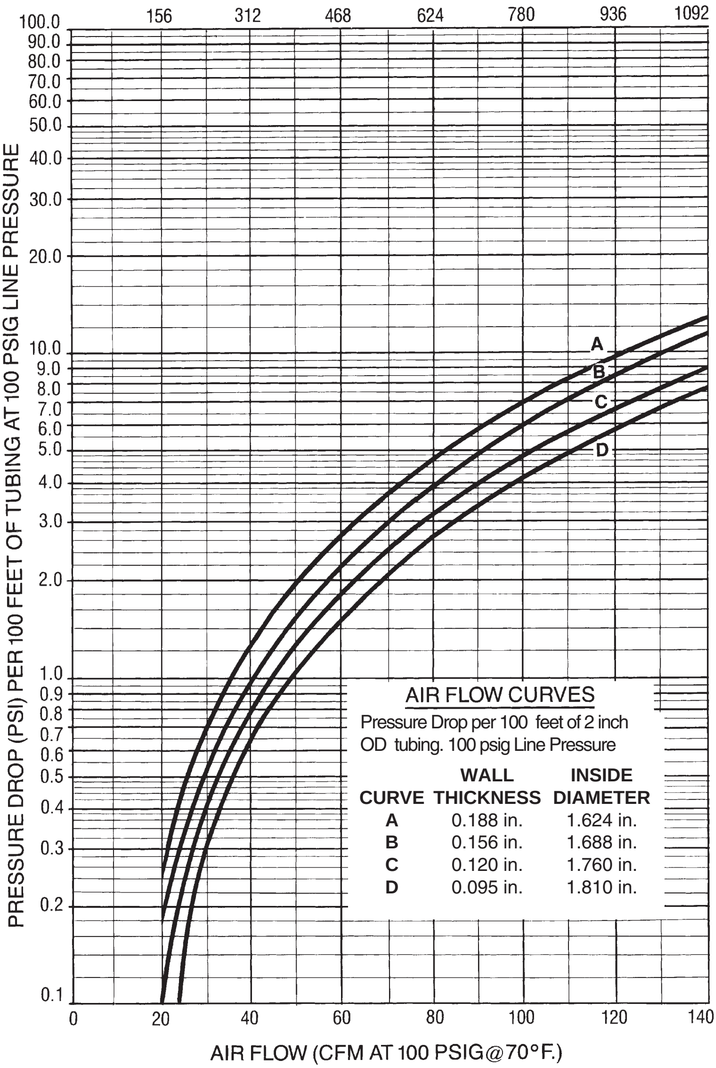


Chart 19: 2 in. OD Tubing
CFM Air Standard Temperature and Pressure (14.7 PSIA @ 70° F)



AIR FLOW CURVES

Pressure Drop per 100 feet of 2 inch OD tubing. 100 psig Line Pressure

CURVE	WALL THICKNESS	INSIDE DIAMETER
A	0.188 in.	1.624 in.
B	0.156 in.	1.688 in.
C	0.120 in.	1.760 in.
D	0.095 in.	1.810 in.

Chart 20:
Air Velocity versus Tubing ID for 100 PSIG Air and 14.7 PSIA Air