APPENDIX F
SIZING OF WATER PIPING SYSTEM

(APPENDIX F IS FOR INFORMATIONAL PURPOSES ONLY)

F101 GENERAL

F101.1 Scope

F101.1.1 This appendix outlines a procedure for sizing a water piping system. This design procedure is based on the minimum static pressure available from the supply source, the head charges in the system due to friction and elevation, and the rates of flow necessary for operation of various fixtures.

F101.1.2 Because of the variable conditions encountered in hydraulic design, it is impractical to specify definite and detailed rules for sizing of the water piping system. Accordingly, other sizing or design methods conforming to good engineering practice standards are acceptable alternates to that presented herein.

F102 INFORMATION REQUIRED

F102.1 Preliminary

Obtain the necessary information regarding the minimum daily static service pressure in the area where the building is to be located. If the building supply is to be metered, obtain information regarding friction loss relative to the rate of flow for meters in the range of sizes likely to be used. Friction loss data can be obtained from most manufacturers of water meters.

F 102.2 Demand Load

F102.2.1 Estimate the supply demand of the building main and the principal branches and risers of the system by totaling the corresponding demand from the applicable part of Table F102.

F102.2.2 Estimate continuous supply demands in gallons per minute for lawn sprinklers, air conditioners, etc., and add the sum to the total demand for fixtures. The result is the estimated supply demand for the building supply.

F103 SELECTION OF PIPE SIZE

F103.1 General

Decide what is the desirable minimum residual pressure that should be maintained at the highest fixture in the supply system. If the highest group of fixtures contains flush valves, the pressure for the group should be not less than 15 psi (103.4 kPa) flowing. For flush tank supplies, the available pressure may not be less than 8 psi (55.2 kPa) flowing, except blowout action fixtures may not be less than 25 psi (172.4 kPa) flowing.

F103.2 Pipe Sizing

F103.2.1 Pipe sizes may be selected according to the following procedure, except that the sizes selected shall be not less than the minimum required by the Standard Plumbing Code.

F103.2.2 This water pipe sizing procedure is based on a system of pressure requirements and losses, the sum of which must not exceed the minimum pressure available at the supply source. These pressures are as follows:

1. Pressure required at fixture to produce required flow. See 607.3 and 607.4.
2. Static pressure loss or gain (due to head) is computed at 0.433 psi per foot (9.8 kPa/m) of elevation change. Example: Assume that the highest fixture supply outlet is 20 ft (6.1 m) above or below the supply source. This produces a static pressure differential of 20 ft x 0.433 psi/ft (6.1 m x 9.8 kPa/m) and an 8.66 psi (59.8 kPa) loss.
3. Loss through water meter. The friction or pressure loss can be obtained from meter manufacturers.
4. Loss through taps in water main. See Table F103A.
5. Losses through special devices such as filters, softeners, backflow preventers, and pressure regulators. These values must be obtained from the manufacturers.
6. Loss through valves and fittings, see Tables F103B and F103C. Losses for these items are calculated by converting to equivalent length of piping and adding to the total pipe length.
7. Loss due to pipe friction can be calculated when the pipe size, the pipe length and the flow through the pipe are known. With these three items, the friction loss can be determined using Figures F103A through F103D. When using charts, use pipe inside diameter. For piping flow charts not included, use manufacturers' tables and velocity recommendations.

F103.3 Example

Note: For the purposes of this example the following metric conversions are applicable:

1 cfm = 0.4719 Us	1 ft^2 = 0.0929 m^2
1 degree = 0.0175 rad	1 psi = 6.895 kPa
1 in = 25.4 mm	1 gpm = 0.0631 Us

Problem: What size copper water pipe, service and distribution will be required to serve a two story factory building having on each floor, back-to-back, two toilet rooms each equipped with hot and cold water? The highest fixture is 21 ft above the street main which is tapped with a 2-inch corporation cock at which point the minimum pressure is 55 psi. In the building basement a 2-inch meter and 3-inch reduced pressure zone backflow preventer with a maximum pressure drop of 9 psi are to be installed. The system is shown by the Example Diagram. To be determined are the pipe sizes for the service main and the cold and hot water distribution pipes.

Solution: A Tabular Arrangement such as shown in Table F101A should first be constructed. The steps to be followed in solving the problem are indicated by the Tabular Arrangement itself as they are in sequence, columns 1 through 10 and lines a through 1.

Step 1, Column 1: Divide the system into sections breaking at major changes in elevation or where branches lead to fixture groups. After point B (see figure F103) separate consideration will be given to the hot and cold water piping. Enter the sections to be considered in the service and cold water piping in Column 1 of the Tabular Arrangement. Column 3: According to the method given in F102.2, determine the gpm of flow to be expected in each section of the system. These flows range from 28.6 to 108 gpm.

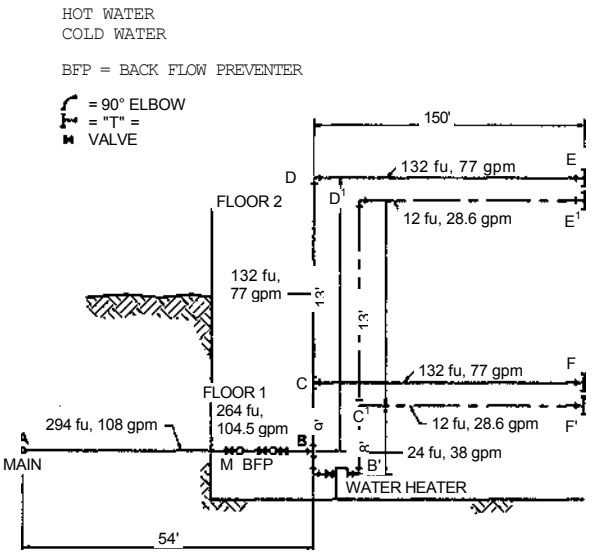

Figure F103
Example — Sizing

Step 2, Line a: Enter the minimum pressure available at the main source of supply in Column 2. This is 55 psi.
Line b: Determine from 607.4 the highest pressure required for the fixtures on system, which is 15 psi, to operate a flushometer valve.
Line c: Determine the pressure loss for the meter size given or assumed. The total water flow from the main through the service as determined in step 1 will serve to aid in the meter selected.
Line d: Select from Table F103A and enter the pressure loss for the tap size given or assumed.
Line e: Determine the difference in elevation between the main or source of supply and the highest fixture on the system and multiply this figure, expressed in feet, by 0.43 psi. Enter the resulting psi product on Line e.
Line f, g, h: The pressure losses through filters, backflow preventers or other special fixtures must be obtained from the manufacturer or estimated and entered on these lines.

Step 3, Line i: The sum of (lines b through h) the pressure requirements and losses which affect the overall system is entered on this line.

Step 4, Line j: Subtract line i from line a. This gives the pressure which remains available from overcoming friction losses in the system. This figure is a guide to the pipe size which is chosen for each section, as the total friction losses through the longest run of pipe.

> **EXCEPTION:** When the main is above the highest fixture, the resulting psi must be considered a pressure gain (static head gain) and omitted from the sums of lines b through h and added to line j.

Step 5, Column 4: Enter the length of each section from the main to the end of the longest run (at Point E).

Step 6, Column 5: Select a trial pipe size. A rule of thumb is that size will become progressively smaller as the system extends farther from the main source of supply. (Trial pipe size may be arrived at by the following formula:) PSI = j x 100/Total pipe length

> **EXAMPLE**: PSI = 9.36 x 100/254 = 3.69
> From main to most remote outlet-Check applicable graph for size for this PSI and GPM

Step 7, Column 6: Select from Table F103B or F103C the equivalent lengths for the trial pipe size of fittings and valves on the section. Enter the sum for each section in Column 6. (The number of fittings to be used in the installation of this piping must be an estimate.)

Step 8, Column 7: Add the figures from Column 4 and Column 6, and enter in Column 7. Express the sum in 100s of feet.

Step 9, Column 8: Select from the applicable figure (F103A through F103D) the friction loss per 100 feet of pipe for the gpm flow in a section (Column 3) and trial pipe size (Column 5).

Step 10, Column 9: Multiply the figures in Columns 7 and 8 for each section and enter in Column 9.

Step 11, Line k: Enter the sum of the values in Column 9.
Step 12, Line 1: Subtract Line k from Line j and enter in Column 10.
The result should always be a positive or plus figure. If it is not, it is necessary to repeat the operation utilizing Columns, 5, 6, 8 and 9 until a balance or near balance is obtained. If the difference between lines j and k is positive and large, it is an indication that the pipe sizes are too large and may, therefore, be reduced thus saving materials. In such a case, the operations utilizing Columns 5, 6, 8 and 9 should again be repeated.

Answer: The final figures entered in Column 5 become the

design pipe size for the respective sections. Repeating this operation a second time using the same sketch but considering the demand for hot water, it is possible to size the hot water distribution piping. This has been worked up as a part of the overall problem in the Tabular Arrangement used for sizing the service and cold water distribution piping. It should be noted that consideration must be given the pressure losses from the street main to the water heater (section AB) in determining the hot water pipe sizes.

Table F101A Recommended Tabular Arrangement for Use in Solving Pipe Sizing Problems

Column		1	2	3	4	5	6	7	8	9	10
Line		Description	Lbs. Per square inch (psi)	Gal. Per min. through section	Length of section (ft)	Trial pipe size (in)	Equivalent length of fittings and valves (ft)	Total equivalent length col. 4 and col. 6 (100 ft)	Friction loss per 100' of trial size pipe (psi)	Friction loss in equivalent length col. 8 x col. 7 (psi)	Excess pressure over friction losses (psi)
a		Minimum pressure available at main……	55.00								
b		Highest pressure required at a fixture (Section 607.4)……	15.00								
c		Meter loss 2" meter……	11.00								
d		Tap in main loss 2" tap (Table F103A)….	1.61								
e	Service and cold water distribution piping (Note 1)	Static head loss 21x0.43 psi……..	9.03								
f		Special fixture loss backflow preventer…	9.00								
g		Special fixture loss – Filter……	0.00								
h		Special fixture loss – Other……	0.00								
i		Total overall losses and requirements (sum of lines b through h)……..	45.64								
j		Pressure available to overcome pipe friction (line a minus lines b to h)……..	9.36								
	Designation Pipe section (from diagram) Cold water distribution piping		FU								
		AB……	294	108.0	54	2 ½	12	0.66	3.3	2.38	
		BC……	264	108.0	8	2 ½	2.5	0.105	3.2	0.34	
		CD……	132	77.0	13	2 ½	8	0.21	1.9	0.40	
		CF……	132	77.0	150	2 ½	12	1.62	1.9	3.08	
		DE……	132	77.0	150	2 ½	14.5	1.645	1.9	3.12	
k	Total pipe friction losses (cold)								6.24		
l	Difference (line j minus line k)						9.36	6.24			3.12
	Pipe section (from diagram) Hot water Distribution Piping										
		A' B'……	294	108.0	54	2 ½	9.6	0.64	3.3	2.1	
		B' C'……	24	38.0	8	2	9.0	0.17	1.4	0.24	
		C' D'……	12	28.6	13	1 ½	5	0.18	3.2	0.58	
		C' F' (Note 2)……	12	28.6	150	1 ½	14	1.64	3.2	5.25	
		D' E' (Note 2)……	12	28.6	150	1 ½	7	1.57	3.2	5.02	
k	Total pipe friction losses (hot)								7.94		
l	Difference (line j minus line k)						9.36	7.94			1.42

1 psi = 6.895 kPa
1 gpm = 0.0631 L/s
1 ft = 305 mm
1 in = 25.4 mm

Notes:

1. To be considered as pressure gain for fixtures below main (consider separately omit from "i" and add to "j").
2. Consider separately, in k use C-F only if greater loss than above

Table F101B Load Values
Assigned to Fixtures[1]

Fixture	Occupancy	Type of Supply Control	Load Values, in Water Supply Fixture Units		
			Cold	Hot	Total
Bathroom group	Private	Flush tank	2.7	1.5	3.6
Bathroom group	Private	Flush valve	6.0	3.0	8.0
Bathtub	Private	Faucet	1.0	1.0	1.4
Bathtub	Public	Faucet	3.0	3.0	4.0
Bidet	Private	Faucet	1.5	1.5	2.0
Combination fixture	Private	Faucet	2.25	2.25	3.0
Dishwashing machine	Private	Automatic		1.4	1.4
Drinking fountain	Offices, etc.	3/8" valve	0.25		0.25
Kitchen sink	Private	Faucet	1.0	1.0	1.4
Kitchen sink	Hotel, Restaurant	Faucet	3.0	3.0	4.0
Laundry trays (1 to 3)	Private	Faucet	1.0	1.0	1.4
Lavatory	Private	Faucet	0.5	0.5	0.7
Lavatory	Public	Faucet	1.5	1.5	2.0
Service sink	Offices. etc.	Faucet	2.25	2.25	3.0
Shower head	Public	Mixing valve	3.0	3.0	4.0
Shower head	Private	Mixing valve	1.0	1.0	1.4
Urinal	Public	1" flush valve	10.0		10.0
Urinal	Public	3/4" flush valve	5.0		5.0
Urinal	Public	Flush tank	3.0		3.0
Washing machine (8 lbs.)	Private	Automatic	1.0	1.0	1.4
Washing machine (8 lbs.)	Public	Automatic	2.25	2.25	3.0
Washing machine (15 lbs.)	Public	Automatic	3.0	3.0	4.0
Water closet	Private	Flush valve	6.0		6.0
Water closet	Private	Flush tank	2.2		2.2
Water closet	Public	Flush valve	10.0		10.0
Water closet	Public	Flush valve	5.0		5.0
Water closet	Public or Private	FlushometerTank	2.0		2.0

Note:

1. For fixtures not listed, loads should be assumed by comparing the fixture to one listed using water in similar quantities and at similar rates. The assigned loads for fixtures with both hot and cold water supplies are given for separate hot and cold water loads and for total load, the separate hot and cold water loads being three-fourths of the total load for the fixture in each case.

Table F102 Table for Estimating Demand

Supply Systems Predominantly for Flush Tanks			Supply Systems Predominantly for Flush Valves		
Load	Demand		Load	Demand	
(Water Supply Fixture Units)	(Gallons per Minute)	(Cubic Feet per Minute)	(Water Supply Fixture Units)	(Gallons per Minute)	(Cubic Feet per Minute)
1	3.0	0.04104			
2	5.0	0.0684			
3	6.5	0.86892			
4	8.0	1.06944			
5	9.4	1.256592	5	15.0	2.0052
6	10.7	1.430376	6	17.4	2.326032
7	11.8	1.577424	7	19.8	2.646364
8	12.8	1.711104	8	22.2	2.967696
9	13.7	1.831416	9	24.6	3.288528
10	14.6	1.951728	10	27.0	3.60936
11	15.4	2.058672	11	27.8	3.716304
12	16.0	2.13888	12	28.6	3.823248
13	16.5	2.20572	13	29.4	3.930192
14	17.0	2.27256	14	30.2	4.037136
15	17.5	2.3394	15	31.0	4.14408
16	18.0	2.90624	16	31.8	4.241024
17	18.4	2.459712	17	32.6	4.357968
18	18.8	2.513184	18	33.4	4.464912
19	19.2	2.566656	19	34.2	4.571856
20	19.6	2.620128	20	35.0	4.6788
25	21.5	2.87412	25	38.0	5.07984
30	23.3	3.114744	30	42.0	5.61356
35	24.9	3.328632	35	44.0	5.88192
40	26.3	3.515784	40	46.0	6.14928
45	27.7	3.702936	45	48.0	6.41664
50	29.1	3.890088	50	50.0	6.684
60	32.0	4.27776	60	54.0	7.21872
70	35.0	4.6788	70	58.0	7.75344
80	38.0	5.07984	80	61.2	8.181216
90	41.0	5.48088	90	64.3	8.595624
100	43.5	5.81508	100	67.5	9.0234
120	48.0	6.41664	120	73.0	9.75864
140	52.5	7.0182	140	77.0	10.29336
160	57.0	7.61976	160	81.0	10.82808
180	61.0	8.15448	180	85.5	11.42964
200	65.0	8.6892	200	90.0	12.0312
225	70.0	9.3576	225	95.5	12.76644
250	75.0	10.0260	250	101.0	13.50168
275	80.0	10.6944	275	104.5	13.96956
300	85.0	11.3628	300	108.0	14.43744
400	105.0	14.0364	400	127.0	16.97736
500	124.0	16.57632	500	143.0	19.11624
750	170.0	22.7256	750	177.0	23.66136
1000	208.0	27.80544	1000	208.0	27.80544
1250	239.0	31.94952	1250	239.0 -	31.94952
1500	269.0	35.95992	1500	269.0	35.95992
1750	297.0	39.70296	1750	297.0	39.70296
2000	325.0	43.446	2000	325.0	43.446
2500	380.0	50.7984	2500	380.0	50.7984
3000	433.0	57.88344	3000	433.0	57.88344
4000	535.0	70.182	4000	525.0	70.182
5000	593.0	79.27224	5000	593.0	79.27224

1 gpm « 0.0631 L/s

1 cfm = 0.4719Us

Table F103A
Loss of Pressure Through Taps and Tees In Pounds Per Square Inch (psi)

Gallons per Minute	Size of tap or tee (in)						
	5/8	3/4	1	1 1/4	1 1/2	2	3
10	1.35	0.64	0.18	0.08			
20	5.38	2.54	0.77	0.31	0.14		
30	12.1	5.72	1.62	0.69	0.33	0.10	
40		10.2	3.07	1.23	0.58	0.18	
50		15.9	4.49	1.92	0.91	0.28	
60			6.46	2.76	1.31	0.40	
70			8.79	3.76	1.78	0.55	0.10
80			11.5	4.90	2.32	0.72	0.13
90			14.5	6.21	2.94	0.91	0.16
100			17.94	7.67	3.63	1.12	0.21
120			25.8	11.0	5.23	1.16	0.30
140			35.2	15.0	7.12	2.20	0.41
150				17.2	8.16	2.52	0.47
160				19.6	9.30	2.92	0.54
180				24.8	11.8	3.62	0.68
200				30.7	14.5	4.48	0.84
225				38.8	18.4	5.6	1.06
250				47.9	22.7	7.00	1.31
275					27.4	7.70	1.59
300					32.6	10.1	1.88

1 in = 25.4 mm
1 psi = 6.895 kPa

Table F103B
Allowance in Equivalent Length of Pipe for Friction Loss in Values and Threaded Fittings (ft)

Fitting or valve	Pipe Sizes (in)							
	1/2	3/4	1	1 1/4	1 1/2	2	21/2	3
45° elbow	1.2	1.5	1.8	2.4	3.0	4.0	5.0	6.0
90° elbow	2.0	2.5	3.0	4.0	5.0	7.0	8.0	10.0
Tee, run	0.6	0.8	0.9	1.2	1.5	2.0	2.5	3.0
Tee, branch	3.0	4.0	5.0	6.0	7.0	10.0	12.0	15.0
Gate valve	0.4	0.5	0.6	0.8	1.0	1.3	1.6	2.0
Balancing valve	0.8	1.1	1.5	1.9	2.2	3.0	3.7	4.5
Plug-type cock	0.8	1.1	1.5	1.9	2.2	3.0	3.7	4.5
Check valve, swing	5.6	8.4	11.2	14.0	16.8	22.4	28.0	33.6
Globe valve	15.0	20.0	25.0	35.0	45.0	55.0	65.0	80.0
Angle valve	8.0	12.0	15.0	18.0	22.0	28.0	34.0	40.0

1 in = 25.4 mm
1 psi = 6.895 kPa
1 degree = 0.01 75 rad

Table F103C
Allowance in Equivalent Length of Tube for Friction Loss in Valves and Fittings[1] (ft)
(Copper Water Tube)

Fitting or valve	Tube Sizes (in)							
	1/2	3/4	1	1 1/4	1 1/2	2	21/2	3
45° elbow (wrought)	0.5	0.5	1.0	1.0	2.0	2.0	3.0	4.0
90° elbow (wrought)	0.5	1.0	1.0	2.0	2.0	2.0	2.0	3.0
Tee, run (wrought)	0.5	0.5	0.5	0.5	1.0	1.0	2.0	-
Tee, branch (wrought)	1.0	2.0	3.0	4.0	5.0	7.0	9.0	-
45° elbow (cast)	0.5	1.0	2.0	2.0	3.0	5.0	8.0	1.0
90° elbow (cast)	1.0	2.0	4.0	5.0	8.0	11.0	14.0	18.0
Tee, run (cast)	0.5	0.5	0.5	1.0	1.0	2.0	2.0	2.0
Tee, branch (cast)	2.0	3.0	5.0	7.0	9.0	12.0	16.0	20.0
Compression Stop	13.0	21.0	30.0	-	-	-	-	-
Globe valve	7.5	10.0	12.5	53.0	66.0	90.0	33	40
Gate valve	0.5	0.25	1.0	1.0	2.0	2.0	2.0	2.0

Note:
1. From "Copper Tube Handbook" by Copper Development Association, Inc.

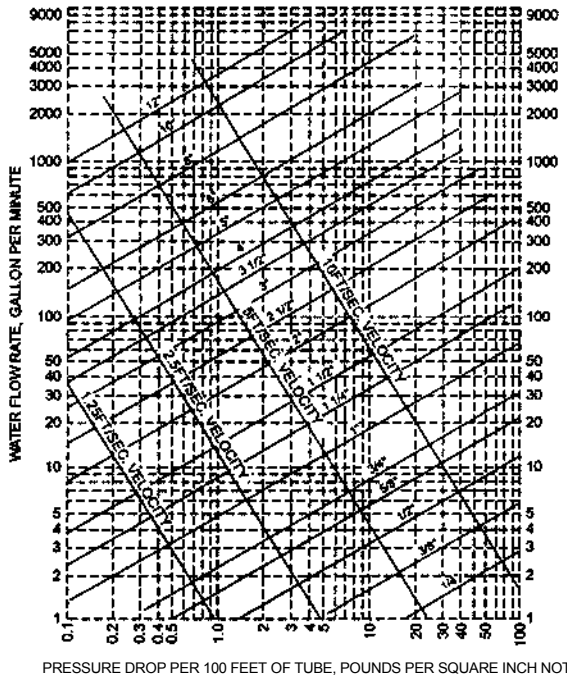

Figure F103A. 1 Friction Loss in Smooth Pipe[1]

(Type K, ASTM B88 Copper Tubing)

Note:
1. This chart applies to smooth new copper tubing with recessed (Streamline) soldered joints and to the actual sizes of types indicated on the diagram.

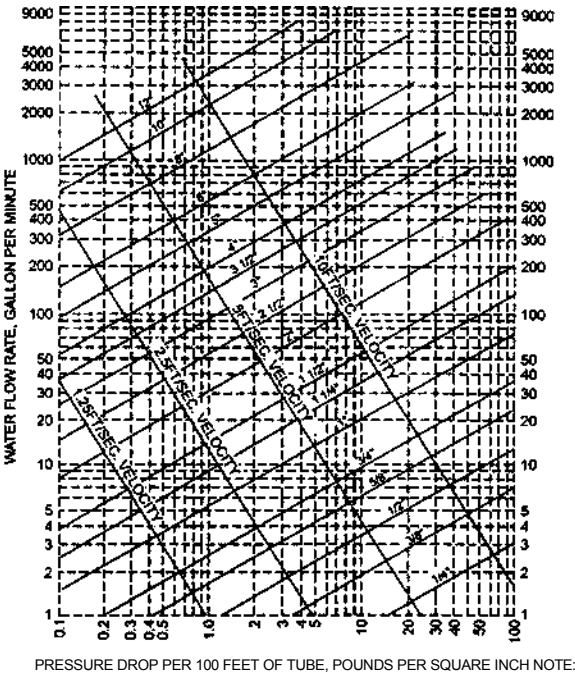

Figure F103A. 2 Friction Loss in Smooth Pipe[1]

(Type L, ASTM B88 Copper Tubing)

Note:
1. This chart applies to smooth new copper tubing with recessed (Streamline) soldered joints and to the actual sizes of types indicated on the diagram.

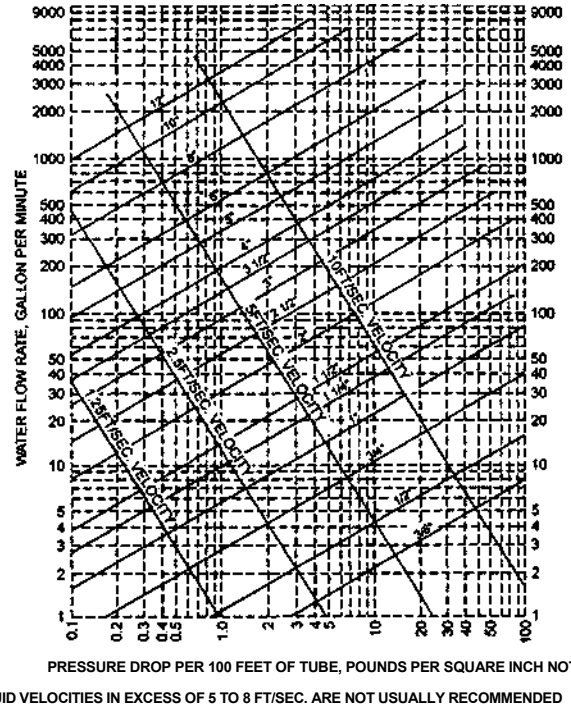

Figure F103A. 3 Friction Loss in Smooth Pipe[1]

(Type M, ASTM B88 Copper Tubing)

Note:
1. This chart applies to smooth new copper tubing with recessed (Streamline) soldered joints and to the actual sizes of types indicated on the diagram.

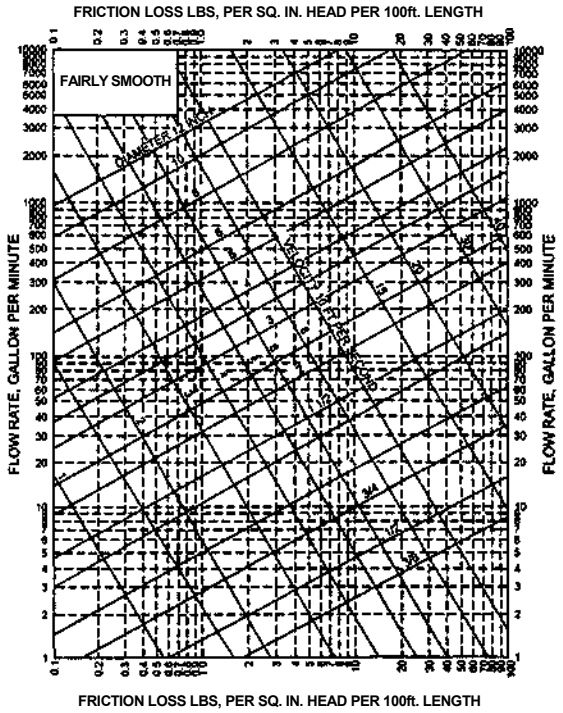

Figure F103B
Friction Loss in Fairly Smooth Pipe[1]

Note:
1. This chart applies to new steel (fairly smooth) pipe and to actual diameters of standard-weight pipe.

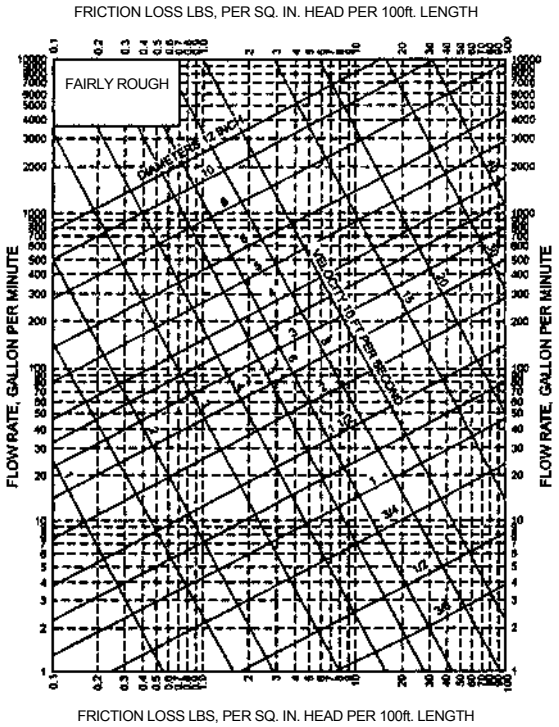

Figure F103C
Friction Loss in Fairly Rough Pipe[1]

Note:
1. This chart applies to fairly rough pipe and to actual diameters which in general will be less than the actual diameters of the new pipe of the same kind.

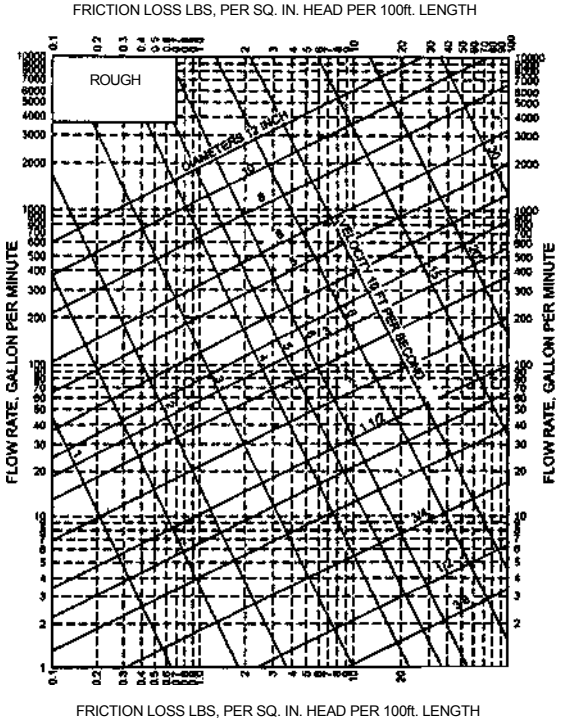

Figure F103D Friction Loss
in Rough Pipe[1]

Note:
1. This chart applies to very rough pipe and existing pipe and to their actual diameters.