Appendix B

Sizing the Building Water Supply System

B.1 GENERAL

Note that there are two questions regarding water supply to a building: first, total consumption of water (hot or cold or both) over a period of time, or second, peak flow at any instant of time. This appendix considers only the second question.

Proper design of the water-distributing system in a building is necessary to avoid excessive installed cost and in order that the various fixtures may function properly under normal conditions. The instantaneous flow of either hot or cold water in any building is variable, depending on the type of structure, usage, occupancy, and time of day. The correct design results in piping, water heating, and storage facilities of sufficient capacity to meet the probable peak demand without wasteful excess in either piping or maintenance cost.
For additional information on this subject, the reader is referred to:

National Bureau of Standards Building Materials and Structures Report BMS 65 (1940), Methods of Estimating Loads in Plumbing Systems, by R. B. Hunter

National Bureau of Standards Building Materials and Structures Report BMS 79 (1941), Water-Distributing Systems for Buildings, by R. B. Hunter

New York State Division of Housing and Community Renewal Building Codes Bureau Technical Report No. 1, (1964), A Simplified Method for Checking Sizes of Building Water Supply Systems, by Louis S. Nielsen.

B.2 PRELIMINARY INFORMATION

B.2.1 General

The information necessary for sizing the building water supply system is described in B.2.2 through B.2.9. Correct sizing is contingent upon accuracy and reliability of the information applied. Thus, such information should be obtained from responsible parties and appropriate local authorities recognized as sources of the necessary information.

B.2.2 Materials for System

Determine what kind or kinds of piping materials are to be installed in the system. This is a matter of selection by the owner of the building or his authorized representative, who may be the architect, engineer, or contractor, as the case may be.

B.2.3 Characteristics of the Water Supply

The corrosivity and the scale-forming tendency of a given water supply with respect to various kinds of piping materials is information that most officials, architects, engineers, and contractors in a water district normally have at their fingertips, as a result of years of experience. For anyone without such experience and knowledge, significant characteristics of the water supply, such as its pH value, CO_2 content, dissolved air content, carbonate hardness, Langelier Index, and Ryznar Index, may be applied to indicate its corrosivity and scale-forming tendency. The most appropriate source of such information is the local water authority having jurisdiction over the system supplying the water, or over the wells from which water is pumped from the underground water table.

B.2.4 Location and Size of Water Supply Source

Location and size of the public water main, where available, should be obtained from the local water authority. Where a private water supply source, such as a private well system, is to be used, the location and size as designed for the premises should be determined.

B.2.5 Developed Length of System

Information should be obtained regarding the developed length of the piping run from the source of water supply to the service control valve of the building (i.e., the developed length of the water service pipe as shown on site plans). Also, determine the developed length of the piping run from the service control valve to the highest and/or the most remote water outlet on the system. This may be established by measurement of the piping run on the plans of the system.

B.2.6 Pressure Data Relative to Source of Supply

Maximum and minimum pressures available in the public main at all times should be obtained from the water authority, as it is the best source of accurate and reliable information on this subject.
Where a private well water supply system is to be used, the maximum and minimum pressures at which it will be adjusted to operate may be applied as appropriate in such cases.

B.2.7 Elevations

The relative elevations of the source of water supply and the highest water supply outlets to be supplied in the building must be determined. In the case of a public main, the elevation of the point where the water service connection is to be made to the public main should be obtained from the local water authority. It has the most authoritative record of elevations of the various parts of the public system, and such elevations are generally referred to a datum as the reference level, usually related to curb levels established for streets.

Elevation of the curb level directly in front of the building should be obtained from building plans, as such information is required to be shown on the building site plans. Elevations of each floor on which fixtures are to be supplied also may be determined from the building plans.

B.2.8 Minimum Pressure Required at Water Outlets

Information regarding the minimum flowing pressure required at water outlets for adequate, normal flow conditions consistent with satisfactory fixture usage and equipment function may be deemed to be as follows: 15 psig flowing for all water supply outlets at common plumbing fixtures, except 20 psig for flushometer valves on siphon jet water closets and 25 psig for flushometer valves for blowout water closets and blowout urinals. Flushometer tank (pressure assisted) water closets require a minimum of 25 psig static pressure. For other types of water supplied equipment, the minimum flow pressure required should be obtained from the manufacturer.

B.2.9 Provision of Necessary Information on Plans

The basis for designing sizes of water supply piping should be provided on plans of the water supply system when submitted to plumbing plan examiners for proposed installations. Provision of such information permits the examiner to quickly and efficiently check the adequacy of sizes proposed for the various parts of the building water supply system.

B.3 DEMAND AT INDIVIDUAL OUTLETS

Maximum possible flow rates at individual fixtures and water outlets have become generally accepted as industry practice, which have since become maximum rates set by law. Recognized flow rates at individual water outlets for various types of typical plumbing fixtures and hose connections are given in Table B.3.
For older faucets, if the applied pressure is more than twice the minimum pressure required for satisfactory water supply conditions, an excessively high discharge rate may occur. Such rates may cause the actual flow in the piping to exceed greatly the estimated probable peak demand rate determined in accordance with the standard method discussed in Section B.5. Such excessive velocity of flow and friction loss in piping may adversely affect performance and durability of the system.

More recent faucets, however, are equipped with flow limiting devices that control the discharge rate at a nearly constant value over a large range of pressures.

Where necessary, it is recommended that means to control the rate of supply should be provided in the fixture supply pipe (or otherwise) wherever the available pressure at an outlet is more than twice the minimum pressure required for satisfactory supply. For this purpose, individual regulating valves, variable orifice flow control devices, or fixed orifices may be provided. They should be designed or adjusted to control the rate of supply to be equal to or less than the maximum rates set by law.

Table B.3
MAXIMUM DEMAND AT INDIVIDUAL WATER OUTLETS

Type of Outlet	Maximum Demand, (gpm)
Metering lavatory faucet	0.25 gal/cycle
Public lavatory faucet	0.5 @ 60 psi
Drinking fountain jet	0.75
Private lavatory faucet	2.2 @ 60 psi
Kitchen sink faucet	2.2 @ 60 psi
Shower head	2.5 @ 80 psi
Ballcock in water closet flush tank	3.0
Dishwashing machine (domestic)	4.0
Laundry machine (8 or 16 lbs.)	4.0
Laundry sink faucet	5.0
Service sink faucet	5.0
Bath faucet, 1/2"	5.0
Hose bibb or sillcock (1/2")	5.0
1/2" flush valve (15 psi flow pressure)	15.0
1" flush valve (15 psi flow pressure)	27.0
1" flush valve (25 psi flow pressure)	35.0

NOTES:

1. The "total" WSFU values for fixtures represent their load on the water service. The separate cold water and hot water supply fixture units for fixtures having both hot and cold connections are each taken as 3/4 of the listed total value for the individual fixture.

B.4 RESERVED

B.5 ESTIMATING DEMAND

B.5.1 Standard Method

A standard method for estimating the maximum probable demand in building water supply systems has evolved and become recognized as generally acceptable. In 1923, the fixture unit method of weighting fixtures in accordance with their load-producing effects was proposed by Roy B. Hunter, of the National Bureau of Standards. After studying application of the method in the design of federal buildings over a period of years, the method was revised by Hunter in 1940[1], and then recommended for general application. With appropriate modifications recently made for modern fixtures, the method fills the need for a reliable, rational way to estimate probable peak demand in water supply systems for all types of building occupancy.

Note that the concept of maximum probable demand is one of probability. We are saying, in effect, that the calculated flow rate at any point in a water piping system will not be exceeded more than, say, 0.1% of the time. For most systems designed by the method described herein, the design flow rates are never reached. Therefore, the method gives a conservative approach that still does not result in wasteful oversizing.

B.5.2 Water Supply Fixture Units (WSFU) Assigned to Fixtures

Individual fixture branch piping should be sized to provide the flow rates listed in Table B.3 for the particular fixture. Minimum fixture branch pipe sizes are listed in Table B.5.2.

Peak demand in building water supply systems serving multiple fixtures cannot be determined exactly. The demand imposed on a system by intermittently used fixtures is related to the number, type, time between uses, and probable number of simultaneous uses of the fixtures installed in the building. In the standard method, fixtures using water intermittently under several conditions of service are assigned specific load values in terms of water supply fixture units. The water supply fixture unit (WSFU) is a factor so chosen that the load-producing effects of different kinds of fixtures under their conditions of service can be expressed approximately as multiples of that factor. WSFUs for two or more fixtures can then be added to determine their combined effect on the water supply system.

Values assigned to different kinds of fixtures and different types of occupancies are shown in Table B.5.2. The total WSFUs represent the fixture's demand on the domestic water service to the building. For fixtures having both hot and cold water supplies, the values for separate hot and cold water demands are taken as being three-quarters (3/4) of the total value assigned to the fixture in each case, rounded to the nearest tenth of a WSFU. As an example, since the value assigned to a kitchen sink in an individual dwelling unit is 1.5 WSFU, the separate demands on the hot and cold water piping thereto are taken as being 1.1 WSFU.

Another consideration, added in 1994, is the nature of the application of the plumbing fixture. Table B.5.2 includes columns for Individual Dwelling Units, More Than 3 Dwelling Units, Other Than Dwelling Units, and Heavy-Use Assembly. The concept behind these added classifications is that the maximum probable demand created by plumbing fixtures varies depending on the type of occupancy in which they are installed.

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1. National Bureau of Standards Building Materials and Structures Report BMS 6, Methods of Estimating Loads in Plumbing Systems, by R. B. Hunter.

TABLE B.5.2
WATER SUPPLY FIXTURE UNITS (WSFU) AND MINIMUM FIXTURE BRANCH PIPE SIZE FOR INDIVIDUAL FIXTURES

	Minimum Branch Pipe Size		In Individual Dwelling Units			In 3 or More Dwelling Units			In Other Than Dwelling Units			In Heavy-Use Assembly		
INDIVIDUAL FIXTURES	**Cold**	**Hot**	**Total**	**Cold**	**Hot**	**Total**	**Cold**	**Hot**	**Total**	**Cold**	**Hot**	**Total**	**Cold**	**Hot**
Bar Sink	3/8”	3/8”	1.0	0.8	0.8	0.5	0.4	0.4						
Bathtub or Combination Bath/Shower	1/2”	1/2”	4.0	3.0	3.0	3.5	2.6	2.6						
Bidet	1/2”	1/2”	1.0	0.8	0.8	0.5	0.4	0.4						
Clothes Washer, Domestic	1/2”	1/2”	4.0	3.0	3.0	2.5	1.9	1.9	4.0	3.0	3.0			
Dishwasher, Domestic		1/2”	1.5		1.5	1.0		1.0	1.5		1.5			
Drinking Fountain or Water Cooler	3/8”								0.5	0.5		0.8	0.8	
Hose Bibb (first)	1/2”		2.5	2.5		2.5	2.5		2.5	2.5				
Hose Bibb (each additional)	1/2”		1.0	1.0		1.0	1.0		1.0	1.0				
Kitchen Sink, Domestic	1/2”	1/2”	1.5	1.1	1.1	1.0	0.8	0.8	1.5	1.1	1.1			
Laundry Sink	1/2”	1/2”	2.0	1.5	1.5	1.0	0.8	0.8	2.0	1.5	1.5			
Lavatory	3/8”	3/8”	1.0	0.8	0.8	0.5	0.4	0.4	1.0	0.8	0.8	1.0	0.8	0.8
Service Sink Or Mop Sink	1/2”	1/2”							3.0	2.3	2.3			
Shower	1/2”	1/2”	2.0	1.5	1.5	2.0	1.5	1.5	2.0	1.5	1.5			
Shower, Continuous Use	1/2”	1/2”							5.0	3.8	3.8			
Urinal, 1.0 GPF	3/4”								4.0	4.0		5.0	5.0	
Urinal, Greater Than 1.0 GPF	3/4”								5.0	5.0		6.0	6.0	
Water Closet, 1.6 GPF Gravity Tank	1/2”		2.5	2.5		2.5	2.5		2.5	2.5		4.0	4.0	
Water Closet, 1.6 GPF Flushometer Tank	1/2”		2.5	2.5		2.5	2.5		2.5	2.5		3.5	3.5	
Water Closet, 1.6 GPF Flushometer Valve	1”		5.0	5.0		5.0	5.0		5.0	5.0		8.0	8.0	
Water Closet, 3.5 GPF (or higher) Gravity Tank	1/2”		3.0	3.0		3.0	3.0		5.5	5.5		7.0	7.0	
Water Closet, 3.5 GPF (or higher) Flushometer Valve	1”		7.0	7.0		7.0	7.0		8.0	8.0		10.0	10.0	
Whirlpool Bath or Combination Bath/Shower	1/2”	1/2”	4.0	3.0	3.0	4.0	3.0	3.0						

NOTES:

1. The fixture branch pipe sizes in Table B.5.2 are the minimum allowable. Larger sizes may be necessary if the water supply pressure at the fixture will be too low due to the available building supply pressure or the length of the fixture branch and other pressure losses in the distribution system.
2. Gravity tank water closets include the pump assisted and vacuum assisted types.

B.5.3 Water Supply Fixture Units for Groups of Fixtures

Table B.5.3 lists water supply fixture unit values for typical groups of fixtures in bathrooms, kitchens, and laundries in dwelling units. There is more diversity in the use of the fixtures in these groups than is reflected by WSFU values for the individual fixtures. The "Total WSFU" represents the demand that the group places on the domestic water service to the building. The separate cold and hot WSFU's for the group are each taken as 3/4 of the WSFU values for the individual fixtures in the group according to Table B.5.3, but not greater than the "Total WSFU" for the group. An exception is that the hot WSFU values for bathroom groups having 3.5 GPF (or greater) water closets are the same as those having 1.6 GPF water closets, since the hot WSFU's are not affected by the demand of the water closet.

B.5.4 Demand (GPM) Corresponding to Fixture Load (WSFU)

To determine the maximum probable demand in gallons per minute corresponding to any given load in water supply fixture units, reference should be made to Table B.5.4, in which the values have been arranged for convenient conversion of maximum probable demand from terms of water supply fixture units of load to gallons per minute of flow. Refer to the increased number of WSFU to GPM listings in Appendix M to avoid the need to interpolate between the values in Table B.5.4.

Note in the table that the maximum probable demand corresponding to a given number of water supply fixture units is generally much higher for a system in which water closets are flushed by means of direct-supply flushometer valves than for a system in which the water closets are flushed by other types of flushing devices. The difference in maximum probable demand between the two systems diminishes as the total number of fixture units of load rises. At 1,000 water supply fixture units, the maximum probable demand in both types of systems is the same, 210 gpm.

Where a part of the system does not supply flushometer water closets, such as in the case with hot water supply piping and some cold water supply branches, the maximum probable demand corresponding to a given number of water supply fixture units may be determined from the values given for a system in which water closets are flushed by flush tanks.

B.5.5 Total Demand Including Continuous Flow

To estimate the maximum probable demand in gpm in any given water supply pipe that supplies outlets at which demand is intermittent and also outlets at which demand is continuous, the demand for outlets that pose continuous demand during peak periods should be calculated separately and added to the maximum probable demand for plumbing fixtures used intermittently. Examples of outlets that impose continuous demand are those for watering gardens, washing sidewalks, irrigating lawns, and for air conditioning or refrigeration apparatus.

Note that some continuous-flow outlets may be controlled to be used only during low-flow periods in the system. Such time-controlled loads should not be added to the maximum probable demand for intermittently used fixtures, since they will not occur at the same times. In such cases, it will be necessary to consider both situations and size the piping for the worse case.

Table B.5.3
WATER SUPPLY FIXTURE UNITS (WSFU) FOR GROUPS OF FIXTURES

	In Individual Dwelling Units			In 3 or More Dwelling Units		
BATHROOM GROUPS HAVING 1.6 GPF GRAVITY-TANK WATER CLOSETS	**Total WSFU**	**Cold WSFU**	**Hot WSFU**	**Total WSFU**	**Cold WSFU**	**Hot WSFU**
Half-Bath or Powder Room	3.5	3.3	0.8	2.5	2.5	0.4
1 Bathroom Group	5.0	5.0	3.8	3.5	3.5	3.0
1-1/2 Bathroom Groups	6.0	6.0	4.5	4.0	4.0	4.0
2 Bathroom Groups	7.0	7.0	7.0	4.5	4.5	4.5
2-1/2 Bathroom Groups	8.0	8.0	8.0	5.0	5.0	5.0
3 Bathroom Groups	9.0	9.0	9.0	5.5	5.5	5.5
Each Additional Half-Bath	0.5	0.5	0.5	0.5	0.5	0.5
Each Additional Bathroom Group	1.0	1.0	1.0	1.0	1.0	1.0
BATHROOM GROUPS HAVING 3.5 GPF (or higher) GRAVITY-TANK WATER CLOSETS	**Total WSFU**	**Cold WSFU**	**Hot WSFU**	**Total WSFU**	**Cold WSFU**	**Hot WSFU**
Half-Bath or Powder Room	4.0	3.8	0.8	3.0	3.0	0.4
1 Bathroom Group	6.0	6.0	3.8	5.0	5.0	3.0
1-1/2 Bathroom Groups	8.0	8.0	4.5	5.5	5.5	4.0
2 Bathroom Groups	10.0	10.0	7.0	6.0	6.0	4.5
2- Bathroom Groups	11.0	11.0	8.0	6.5	6.5	5.0
3 Bathroom Groups	12.0	12.0	9.0	7.0	7.0	5.5
Each Additional Half-Bath	0.5	0.5	0.5	0.5	0.5	0.5
Each Additional Bathroom Group	1.0	1.0	1.0	1.0	1.0	1.0
OTHER GROUPS OF FIXTURES	**Total WSFU**	**Cold WSFU**	**Hot WSFU**	**Total WSFU**	**Cold WSFU**	**Hot WSFU**
Bathroom Group with 1.6 GPF Flushometer Valve	6.0	6.0	3.8	4.0	4.0	3.0
Bathroom Group with 3.5 GPF (or higher) Flushometer Valve	8.0	8.0	3.8	6.0	6.0	3.0
Kitchen Group with Sink and Dishwasher	2.0	1.1	2.0	1.5	0.8	1.5
Laundry Group with Sink and Dishwasher	5.0	4.5	4.5	3.0	2.6	2.6

NOTES:

1. The “Total WSFU” values for fixture groups represent their load on the water service. The separate cold and hot water supply fixture units for the group are each taken as 3/4 of the WSFU values for the individual fixtures in the group according to Table B.5.2, but not greater than the “Total WSFU” for the group in Table B.5.3, except that the hot WSFU for groups having 3.5 GPF water closets are the same as those having 1.6 GPF water closets.

2. The WSFU values for tank-type water closets apply to gravity tanks and pressurized tanks, flushometer tanks (pressure assisted), pump assisted tanks, and vacuum assisted tanks.

Table B.5.4
TABLE FOR CONVERTING DEMAND IN WSFU TO GPM[1, 4]

WSFU	GPM Flush Tanks[2]	GPM Flush Valves [3]	WSFU	GPM Flush Tanks[2]	GPM Flush Valves [3]
3	3		120	49	74
4	4		140	53	78
5	4.5	22	160	57	83
6	5	23	180	61	87
7	6	24	200	65	91
8	7	25	225	70	95
9	7.5	26	250	75	100
10	8	27	300	85	110
11	8.5	28	400	105	125
12	9	29	500	125	140
13	10	29.5	750	170	175
14	10.5	30	1000	210	210
15	11	31	1250	240	240
16	12	32	1500	270	270
17	12.5	33	1750	300	300
18	13	33.5	2000	325	325
19	13.5	34	2500	380	380
20	14	35	3000	435	435
25	17	38	4000	525	525
30	20	41	5000	600	600
40	25	47	6000	650	650
50	29	51	7000	700	700
60	33	55	8000	730	730
80	39	62	9000	760	760
100	44	68	10,000	790	790

NOTES:

1. This table converts water supply demands in water supply fixture units (WSFU) to required water flow in gallons per minute (GPM) for the purpose of pipe sizing.
2. This column applies to the following portions of piping systems:
   (a). Hot water piping;
   (b). Cold water piping that serves no water closets; and
   (c). Cold water piping that serves water closets other than flush valve type.
3. This column applies to portions of piping systems where the water closets are the flush valve type.
4. Refer to Appendix M for WSFU to GPM listings between those in Table B.5.4 to avoid the need to interpolate between the values in Table B.5.4.

B.6 LIMITATION OF VELOCITY

B.6.1 Consideration of Velocity in Design

Velocity of flow through water supply piping during periods of peak demand is an important factor that must be considered in the design of building water supply systems. Limitation of water velocity should be observed in order to avoid objectionable noise effects in systems, shock damage to piping, equipment, tanks, coils, and joints, and accelerated deterioration and eventual failure of piping from corrosion. (Also see Section 10.14.1)

B.6.2 Good Engineering Practice

In accordance with good engineering practice, it is recommended generally that maximum velocity at maximum probable demand in supply piping be limited to 8 fps. This is deemed essential in order to avoid such objectionable effects as the production of whistling line noise, the occurrence of cavitation, and associated excessive noise in fittings and valves.

Note that this velocity is too great for systems where the flow is continuous, as in the case of recirculated hot water piping. The continuous flow rate for hot water with modest chemical content should be limited to not more than 2 fps for such continuous systems. That is, verify that the flow rate in the system as a result of the circulation pump only does not exceed 2 fps at any point.

It is also recommended that maximum velocity be limited to 4 fps in water supply piping that supply a quick-closing device, such as a solenoid valve, pneumatic valve, or a quick-closing valve or faucet of the self-closing, push-pull, push-button, or other similar type. This limitation is necessary in order to avoid excessive and damaging shock pressures in the piping and equipment when flow is suddenly shut off. Plumbing equipment and systems are not designed to withstand the very high shock pressures that may occur as the result of sudden cessation of high velocity flow in piping. (Also see Section 10.14.1)

B.6.3 Manufacturers' Recommendations for Avoiding Erosion/Corrosion

Velocity limits recommended by pipe manufacturers to avoid accelerated deterioration of their piping materials due to erosion/corrosion should be observed. Recent research studies have shown that turbulence accompanying even relatively low flow velocities is an important factor in causing erosion/corrosion, and that this is especially likely to occur where the water supply has a high carbon dioxide content (i.e., in excess of 10 ppm), and where it has been softened to zero hardness. Another important factor is elevated water temperature (i.e., in excess of 110°F).

To control erosion/corrosion effects in copper water tube, and copper and brass pipe, pipe manufacturers' recommendations are as follows:

(1) Where the water supply has a pH value higher than 6.9 and a positive scale-forming tendency, such as may be shown by a positive Langelier Index, peak velocity should be limited to 8 fps;

(2) Where the water supply has a pH value lower than 6.9 and may be classified as aggressively corrosive, or where the water supply has been softened to zero hardness by passage through a water softener, peak velocity should be limited to 4 fps; and

(3) The velocity in copper tube conveying hot water at up to 140°F should be limited to 5 fps because of the accelerated corrosion rate with hot water. Velocities should be limited to 2 - 3 fps for temperatures above 140° F.

Note that the above values apply to velocities at maximum probable demand. For continous flow circulating systems, do not exceed 2 fps flow rate for the flow produced by the circulator.

B.7 SIMPLIFIED METHOD FOR SIZING SYSTEMS IN RELATIVELY LOW BUILDINGS

B.7.1 Application

A simplified method for sizing building water supply systems in accordance with the maximum probable demand load, in terms of water supply fixture units, has been found to constitute a complete and proper method for adequately sizing the water supply systems of a specific category of buildings. In this category are all buildings supplied from a source at which the minimum available water pressure is adequate for supplying the highest and most remote fixtures satisfactorily during peak demand. Included are almost all one- and two-family dwellings, most multiple dwellings up to at least three stories in height, and a considerable portion of commercial and industrial buildings of limited height and area, when supplied from a source at which the minimum available pressure is not less than 50 psi. Under such conditions, the available pressure generally is more than enough for overcoming static head and ordinary pipe friction losses, so that pipe friction is not an additional factor to consider in sizing.

B.7.2 Simplified Method Based on Velocity Limitations

This method is based solely on the application of velocity limitations that are:

(1) Recognized as good engineering practice; and

(2) Authoritative recommendations issued by manufacturers of piping materials regarding proper use of their products in order to achieve durable performance and avoid failure in service, especially in water areas where the supply is aggressively corrosive. These limitations have been detailed in Section B.6. (Also see Section 10.14.1.)

B.7.3 Sizing Tables Based on Velocity Limitations

Tables B.7.3.A through G provide a means of sizing water supply piping on the basis of flow velocities ranging from 4 fps to 8 fps. The velocity in copper water tube for hot water up to 140ºF should not exceed 5 fps. The water flow rates, flow velocities, and pressure loss rates are based on Tables B.9.8.1 through B.9.8.7 for the various piping materials. The allowable water supply fixture unit (WSFU) fixture loadings are based on Table B.5.4.

The pressure loss data in the B.7.3 tables is based on friction for straight pipe and tube and does not include allowances for fittings, valves, and appurtenances. The equivalent length of the piping can be determined by adding the equivalent length of fittings and valves in Tables B.9.7.A, B, C, D, and E. If the exact layout of the piping systems cannot be determined, allowances for fittings and valves range up to 50% of the pipe length for smooth bore piping such as copper and solvent cement joint plastic piping and up to 75% of the pipe length for steel and plastic piping with threaded joints.

In Tables B.7.3.A through B.7.3.G, the columns headed "WSFU (tanks)" apply to piping that serves water closets having gravity or pressure-type flush tanks and no fixtures that are flushed by flushometer valves. The columns headed "WSFU (valves)" apply to piping that serves fixtures that are flushed by flushometer valves.

Table B.7.3.A - GALVANIZED STEEL PIPE - STD WT									
PIPE SIZE	4 FPS VELOCITY				8 FPS VELOCITY				PIPE SIZE
	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	
1/2”	4		3.8	7.6	9		7.6	27.3	1/2”
3/4”	8		6.6	5.5	19		13.3	19.7	3/4”
1”	15		10.8	4.1	33	5	21.5	14.9	1”
1-1/4”	28		18.6	3.0	74	24	37.3	10.8	1-1/4”
1-1/2”	41	8	25.4	2.5	129	49	50.8	9.1	1-1/2”
2”	91	31	41.8	1.9	293	163	83.7	6.8	2”
2-1/2”	174	73	59.7	1.5	472	363	119.4	5.5	2-1/2”
3”	336	207	92.2	1.2	840	817	184.4	4.3	3”
4”	687	634	158.7	0.9	1925	1925	317.5	3.1	4”
5”	1329	1329	249.4	0.7	3710	3710	498.9	2.4	5”
6”	2320	2320	360.2	0.5	7681	7681	720.4	1.9	6”

Table B.7.3.B - TYPE K COPPER TUBE													
TUBE SIZE	4 FPS VELOCITY				5 FPS VELOCITY				8 FPS VELOCITY				TUBE SIZE
	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	
3/8”			1.6	8.4			2.0	12.7	3		3.2	30.4	3/8”
1/2”			2.7	6.1	3		3.4	9.3	6		5.4	22.1	1/2”
3/4”	6		5.4	4.1	8		6.8	6.2	15		10.9	14.8	3/4”
1”	13		9.7	2.9	16		12.1	4.4	29		19.4	10.6	1”
1-1/4”	22		15.2	2.3	28		19.0	3.4	53	14	30.4	8.1	1-1/4”
1-1/2”	33	5	21.5	1.8	45	10	26.9	2.8	96	33	43.0	6.7	1-1/2”
2”	75	24	37.6	1.3	112	40	47.0	2.0	251	126	75.2	4.8	2”
2-1/2”	165	69	58.1	1.0	238	115	72.6	1.6	456	341	116.1	3.7	2-1/2”
3”	289	159	82.8	0.8	392	267	103.4	1.3	725	682	165.5	3.0	3”
4”	615	541	145.7	0.6	826	801	182.1	0.9	1678	1678	291.4	2.2	4”
5”	1134	1134	226.1	0.5	1605	1605	282.6	0.7	3191	3191	452.2	1.7	5”
6”	1978	1978	322.8	0.4	2713	2713	403.5	0.6	5910	5910	645.5	1.4	6”

Table B.7.3.C - TYPE L COPPER TUBE														
TUBE SIZE	4 FPS VELOCITY				5 FPS VELOCITY				8 FPS VELOCITY				TUBE SIZE
	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	
3/8”			1.8	7.8	2		2.3	11.7	4		3.6	28.0	3/8”
1/2”	3		2.9	5.9	4		3.6	8.9	7		5.8	21.3	1/2”
3/4”	7		6.0	3.9	9		7.5	5.8	16		12.1	13.9	3/4”
1”	14		10.3	2.8	18		12.9	4.3	31		20.6	10.2	1”
1-1/4”	23		15.7	2.2	29		19.5	3.3	56	15	31.3	8.0	1-1/4”
1-1/2”	34	5	22.2	1.8	47	11	27.7	2.7	101	36	44.4	6.5	1-1/2”
2”	79	26	38.6	1.3	117	43	48.2	2.0	261	136	77.2	4.7	2”
2-1/2”	173	73	59.5	1.0	247	120	74.4	1.5	470	360	119.0	3.7	2-1/2”
3”	300	170	84.9	0.8	406	281	106.2	1.3	749	713	169.9	3.0	3”
4”	635	567	149.3	0.6	854	833	186.7	0.9	1739	1739	298.7	2.2	4”
5”	1189	1189	232.7	0.5	1674	1674	290.9	0.7	3338	3338	465.5	1.7	5”
6”	2087	2087	334.6	0.4	2847	2847	418.2	0.6	6382	6382	669.1	1.4	6”

Table B.7.3.D - TYPE M COPPER TUBE													
TUBE SIZE	4 FPS VELOCITY				5 FPS VELOCITY				8 FPS VELOCITY				TUBE SIZE
	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	
3/8”			2.0	7.3			2.5	11.1	4		4.0	26.6	3/8”
1/2”	3		3.2	5.6	4		4.0	8.5	7		6.3	20.2	1/2”
3/4”	7		6.4	3.7	10		8.1	5.6	18		12.9	13.4	3/4”
1”	15		10.9	2.7	19		13.6	4.1	34	5	21.8	9.9	1”
	24		16.3	2.2	30		20.4	3.3	59	17	32.6	7.8	
	36	6	22.8	1.8	49	12	28.5	2.7	107	38	45.7	6.4	
2”	82	28	39.5	1.3	122	46	49.4	2.0	270	144	79.1	4.7	2”
	180	77	61.0	1.0	256	131	76.2	1.5	485	380	121.9	3.6	
3”	310	180	87.0	0.8	419	294	108.8	1.2	775	743	174.0	3.0	3”
4”	648	583	151.6	0.6	872	854	189.5	0.9	1783	1783	303.3	2.1	4”
5”	1215	1215	235.8	0.5	1706	1706	294.8	0.7	3407	3407	471.6	1.7	5”
6”	2125	2125	338.7	0.4	2894	2894	423.4	0.6	6548	6548	677.4	1.3	6”

Table B.7.3.E - CPVC, PVC, ABS, PE PLASTIC PIPE - SCHEDULE 40									
PIPE SIZE	4 FPS VELOCITY				8 FPS VELOCITY				PIPE SIZE
	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100 ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	
1/2”	4		3.6	5.2	9		7.3	18.7	1/2”
3/4”	7		6.4	3.7	18		12.9	13.4	3/4”
1”	14		10.5	2.8	32	4	20.9	10.1	1”
1-1/4”	27		18.2	2.0	71	22	36.4	7.3	1-1/4”
1-1/2”	40	8	24.9	1.7	124	47	49.7	6.1	1-1/2”
2”	89	30	41.1	1.3	286	157	82.2	4.6	2”
2-1/2”	168	70	58.5	1.0	460	347	117.1	3.7	2-1/2”
3”	328	198	90.6	0.8	820	795	181.2	2.9	3”
4”	675	618	156.5	0.6	1881	1881	313.1	2.1	4”
5”	1303	1303	246.4	0.5	3642	3642	492.8	1.6	5”
6”	2284	2284	356.2	0.4	7413	7413	712.4	1.3	6”

Table B.7.3.F - CPVC, PVC, ABS, PE PLASTIC PIPE - SCHEDULE 80									
PIPE SIZE	4 FPS VELOCITY				8 FPS VELOCITY				PIPE SIZE
	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	
1/2”	3		2.7	6.1	7		5.5	22.1	1/2”
3/4”	6		5.1	4.2	14		10.3	15.3	3/4”
1”	11		8.6	3.1	25		17.2	11.3	1”
1-1/4”	22		15.4	2.2	55	15	30.8	8.1	1-1/4”
1-1/2”	33	4	21.3	1.9	95	33	42.7	6.7	1-1/2”
2”	70	21	35.8	1.4	233	112	71.7	4.9	2”
2-1/2”	132	51	51.4	1.1	389	264	102.7	4.0	2-1/2”
3”	277	149	80.3	0.9	698	648	160.7	3.1	3”
4”	585	503	140.4	0.6	1590	1590	280.7	2.2	4”
5”	1105	1105	222.6	0.5	3114	3114	445.3	1.7	5”
6”	1942	1942	319.2	0.4	5767	5767	638.3	1.4	6”

Table B.7.3.G - CPVC PLASTIC TUBING (Copper Tube Size) - SDR 11									
TUBE SIZE (CTS)	4 FPS VELOCITY				8 FPS VELOCITY				TUBE SIZE (CTS)
	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100ft	
1/2”	2		2.4	6.6	6		4.8	23.9	1/2”
3/4”	6		4.9	4.4	13		9.8	15.8	3/4”
1”	10		8.1	3.3	24		16.2	11.8	1”
1-1/4”	16		12.1	2.6	38	7	24.2	9.3	1-1/4”
1-1/2”	25		16.9	2.1	62	18	33.7	7.7	1-1/2”
2”	50	12	28.9	1.6	164	68	57.8	5.6	2”

Table B.7.3.H - PEX Plastic Tubing (Copper Tube Size) SDR 9									
TUBE SIZE (CTS)					8 FPS VELOCITY				TUBE SIZE (CTS)
					WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100 ft	
3/8”					1		2.4	35.3	3/8”
1/2”					5		4.5	24.8	1/2”
3/4”					11		8.8	16.8	3/4”
1”					21		14.5	12.5	1”
1-1/4”					33		21.6	9.9	1-1/4”
1-1/2”					53	14	30.2	8.2	1-1/2”
2”					134	52	51.7	6.0	2”

Table B.7.3.I - Composite Plastic Pipe (PE-AL-PE and PEX-AL-PEX)									
PIPE SIZE	4 FPS VELOCITY				8 FPS VELOCITY				PIPE SIZE
	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100 ft	WSFU (tanks)	WSFU (valves)	FLOW GPM	PD psi/100 ft	
3/8”	1		1.1	10.3	1		2.2	37.0	3/8”
1/2”	2		2.4	6.6	5		4.7	23.9	1/2”
3/4”	7		6.2	3.8	17		12.4	13.7	3/4”
1”	13		10.1	2.9	31		20.3	10.3	1”
1-1/4”	22		15.5	2.2	55	15	30.9	8.1	1-1/4”
1-1/2”	41	5	25.3	1.7	128	49	50.7	6.0	1-1/2”
2”	81	27	39.2	1.3	267	142	78.4	4.7	2”
2-1/2”	147	58	54.2	1.1	417	292	108.4	3.9	2-1/2”

B.7.4 Step-by-Step Procedure of Simplified Sizing Method

For sizing systems in relatively low buildings, the simplified sizing method consists of the following seven steps:

1. Obtain all information necessary for sizing the system. Such information should be obtained from responsible parties and appropriate local authorities recognized as sources of the necessary information. (See Section B.2.)

2. Provide a schematic elevation of the complete water supply system. Show all piping connections in proper sequence and all fixture supplies. Identify all fixtures and risers by means of appropriate letters, numbers, or combinations thereof. Identify all piping conveying water at a temperature above 150°F, and all branch piping to such water outlets as solenoid valves, pneumatic valves, or quick-closing valves or faucets. Provide on the schematic elevation all the necessary information obtained in Step 1. (See Section B.2.9.)

3. Mark on the schematic elevation, for each section of the complete system, the hot and cold water loads conveyed thereby in terms of water supply fixture units in accordance with Table B.5.2.

4. Mark on the schematic elevation, adjacent to all fixture unit notations, the demand in gallons per minute corresponding to the various fixture unit loads in accordance with Table B.5.3.

5. Mark on the schematic elevation, for appropriate sections of the system, the demand in gallons per minute for outlets at which demand is considered continuous, such as outlets for watering gardens, irrigating lawns, air conditioning apparatus, refrigeration machines, and similar equipment using water at a relatively continuous rate during peak demand periods. Add the continuous demand to the demand for intermittently used fixtures, and show the total demand at those sections where both types of demand occur. (See Section B.5.4.)

6. Size all individual fixture supply pipes to water outlets in accordance with the minimum sizes permitted by regulations. Minimum fixture supply pipe sizes for typical plumbing fixtures are given in Table B.5.2.

7. Size all other parts of the water supply system in accordance with velocity limitations recognized as good engineering practice, and with velocity limitations recommended by pipe manufacturers for avoiding accelerated deterioration and failure of their products under various conditions of service. (Sizing tables based on such velocity limitations and showing permissible loads in terms of water supply fixture units for each size and kind of piping material have been provided and may be applied in this step.) (See Section B.6.)

B.8 ILLUSTRATION OF SIMPLIFIED SIZING METHOD APPLICATION

B.8.1 Example

A three-story, nine-family multiple dwelling fronts on a public street and is supplied by direct street pressure from a public main in which the certified minimum pressure is 50 psi. The building has a full basement and three above-grade stories, each of which is 10’ in height from floor to floor. The first floor is 2’ above the curb level in front of the building. The public water main is located under the street: 5’ out from and 4’ below the curb.

On each of the above-grade stories there are three dwelling units. Each dwelling unit has a sink and dishwasher, tank-type water closet, lavatory, and bathtub/shower combination.
The basement contains two automatic clothes washing machines, two service sinks, and a restroom with a flush-tank water closet and lavatory.

Two lawn faucets are installed, one on the front of the building and one in the rear.
Hot water is to be supplied from a central storage-tank water heater.
The water supply to the building will be metered at the water service entry point to the building.
An isometric drawing of the water piping layout is shown in Figure B.8.1.

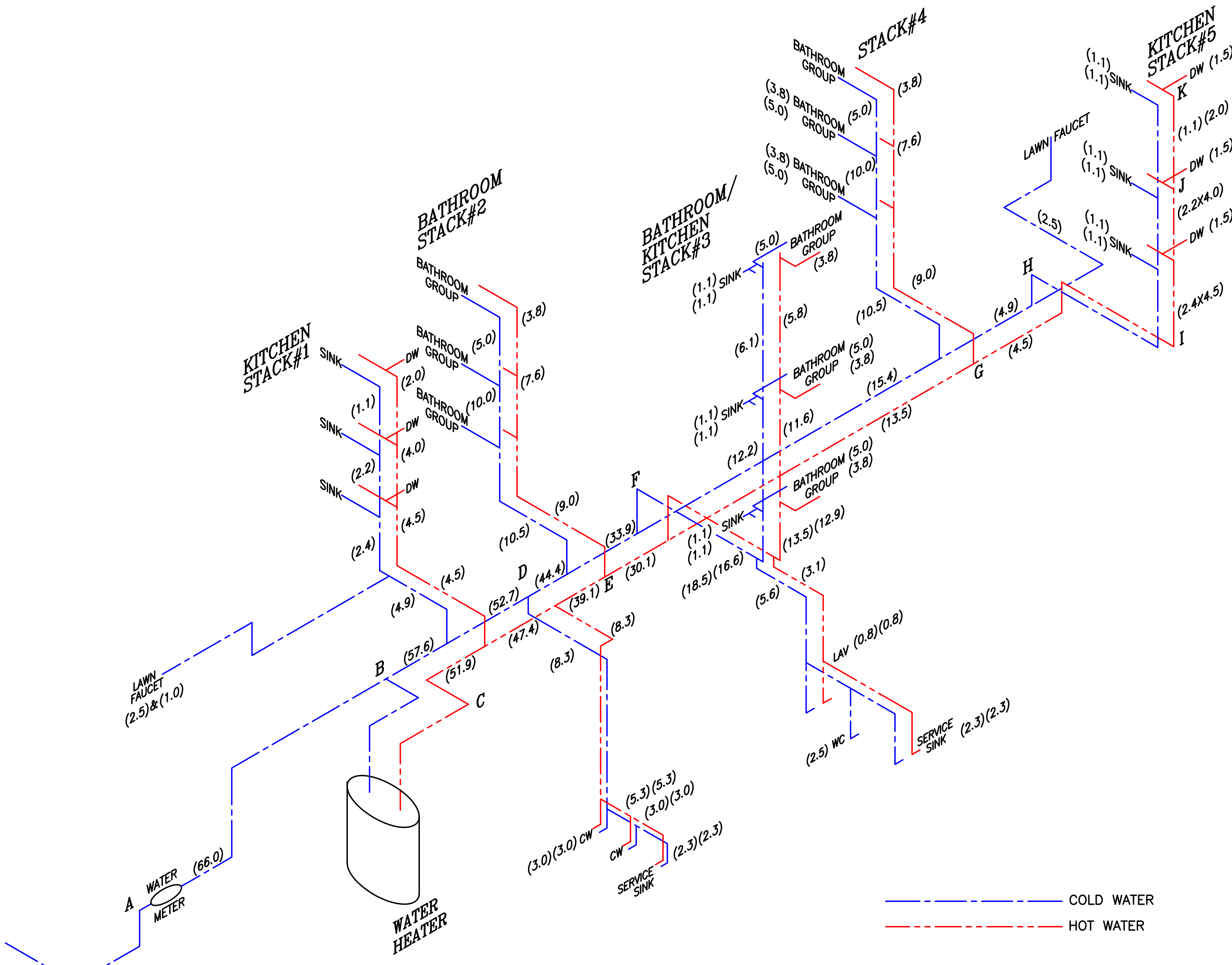


Figure B.8.1

WATER SUPPLY FIXTURE UNITS(WSFU)

DATA for Figure B.8.1 - WATER SUPPLY FIXTURE UNITS (WSFU)

DESIGN BASIS

PIPING
Copper water tube, Type L
wrought fittings and lead-free solder

PUBLIC WATER SUPPLY
10 inch main, 50 psig minimum pressure

WATER CHARACTERISTICS
No significant fouling or corrosive agents

ELEVATIONS

Curb as datum	10.0 ft
Water main	6.0 ft
Basement floor	2.0 ft
First floor	12.0 ft
Second floor	22.0 ft
Third floor	32.0 ft
Highest outlet @ "K"	35.0 ft

MINIMUM OUTLET PRESSURE
15 psig required

VELOCITY LIMITATIONS
8 fps
except 4 fps for branches with quick-closing valves
and 5 fps for hot water up to 140 deg F

LENGTH OF RUN TO FARTHEST OUTLET

Main - A	50 ft
A - B	12 ft
B - C	8 ft
C - D	10 ft
D - E	8 ft
E - F	8 ft
F - G	10 ft
G - H	4 ft
H - I	10 ft
I - J	10 ft
J - K	10 ft

Total = 140 ft plus fitting allowance

Hot water temperature is 140 deg F
controlled by water heater thermosta

WATER SUPPLY FIXTURE UNITS (WSFU)

Fxtures	Piping Serving Fitures in 1 or 2 Dwellings			Piping Serving Fitures in 3 or more Dwellings			Piping Serving Fitures in Other than Dwellings Units		
	Total	Cold	Hot	Total	Cold	Hot	Total	Cold	Hot
Bathroom Group (1.6 GPF tank-type WC)	5.0	5.0	3.8	3.5	3.5	3.0			
Half Bath (1.6 GPF tank-type WC)	3.5	3.3	0.8	2.5	2.5	0.4			
Kitchen Group (sink & dishwasher)	2.0	1.1	2.0	1.5	0.8	1.5			
Clothes Washer							4.0	3.0	3.0
Service Sink							3.0	2.3	2.3
Hose Bibb							2.5	2.5	
Hose Bibb, each additional							1.0	1.0	

WATER SERVICE PIPE SIZING

Fixtures	Qty	WSFU	Total
Bathroom Groups (1.6 tank-type WC) (1)	9	3.5	31.5
Kitchen Groups (sink + dishwasher) (1)	9	1.5	13.5
Clothes Washers (2)	2	4.0	8.0
Service Sinks (2)	2	3.0	6.0
Half Bath (2)	1	3.5	3.5
Hose Bibb (2)	1	2.5	2.5
Hose Bibb (each additional) (2)	1	1.0	1.0
TOTAL WSFU			66.0
DEMAND (GPM)			34.8

1) Fixtures in 3 or more dwellings
(2) Fixtures in other than dwelling units.

B.8.2 Solution

1. All information necessary to develop the design must be obtained from appropriate sources.

2. After the information is known, the isometric drawing (Figure B.8.1) is marked up with general water supply information, and the mains, risers, and branches are suitably identified.

3. The water supply fixture unit loads are marked on the drawing next to each section of the system. These values are obtained from Tables B.5.2 and B.5.3. Many designers use parentheses marks for WSFU to distinguish them from gpm values.

4. The maximum probable demand in gpm is marked on the drawing for each section next to the WSFU values. These values are obtained from Table B.5.4, using the columns for flush-tank systems.

5. Where sections of the piping serve more than one hose bibb, each additional hose bibb adds a demand of 1.0 WSFU to the piping. Wherever a section of piping serves a single hose bibb, it adds a demand of 2.5 WSFU.

6. All individual fixture supply pipes to water outlets are sized in Figure B.8.1 in accordance with the minimum sizes shown in Table B.5.2.

7. All other parts of the system are sized in accordance with the velocity or pressure limitations established for this system as the basis of design. Piping is sized in accordance with the maximum probable demand for each section of the system. Sizing is done using Table B.7.3A through Table B.7.3H, and specifically the tables dealing with Copper Water Tube, Type K for sizing the water service pipe; and with Copper Water Tube, Type L, for sizing piping inside the building since these are the materials of choice as given in the general information on the drawing.

B.8.3 Supplementary Check of Friction Loss in Main Lines and Risers

A supplementary check of the total friction loss in the main lines and risers is made for the longest run of piping from the public water outlet to be sure that the sizes determined were adequate. This run has been shown in heavy lines with letters noted at various points.

The sum of all friction losses due to flow through pipe, valves, and fittings is found to be 17.9 psi, whereas the amount of excess pressure available for such friction loss is 19.4 psi. Thus, the sizes determined on the basis of velocity limitations exclusively are proven adequate. Checking of friction loss in this case is performed following steps 8 through 15 of the Detailed Sizing Method for Building of Any Height presented in Section B.10. The calculations are shown on Figure B.8.2.

B.8.4 Application to Systems in High Buildings

This method of sizing, based upon the velocity limitations that should be observed in design of building water supply systems, has much broader application than just to systems in one-, two-, and three-story buildings where ample excess pressure is available at the source of supply. These velocity limitations should be observed in all building water supply systems. Thus, the sizes determined by this method are the minimum sizes recommended for use in any case. Where pipe friction is an additional factor to be considered in design, larger sizes may be required.

B.9 LIMITATION OF FRICTION

B.9.1 Basic Criterion

The design of a building water supply system must be such that the highest water outlets will have available, during periods of peak demand, at least the minimum pressure required at such outlets for satisfactory water supply conditions at the fixture or equipment.

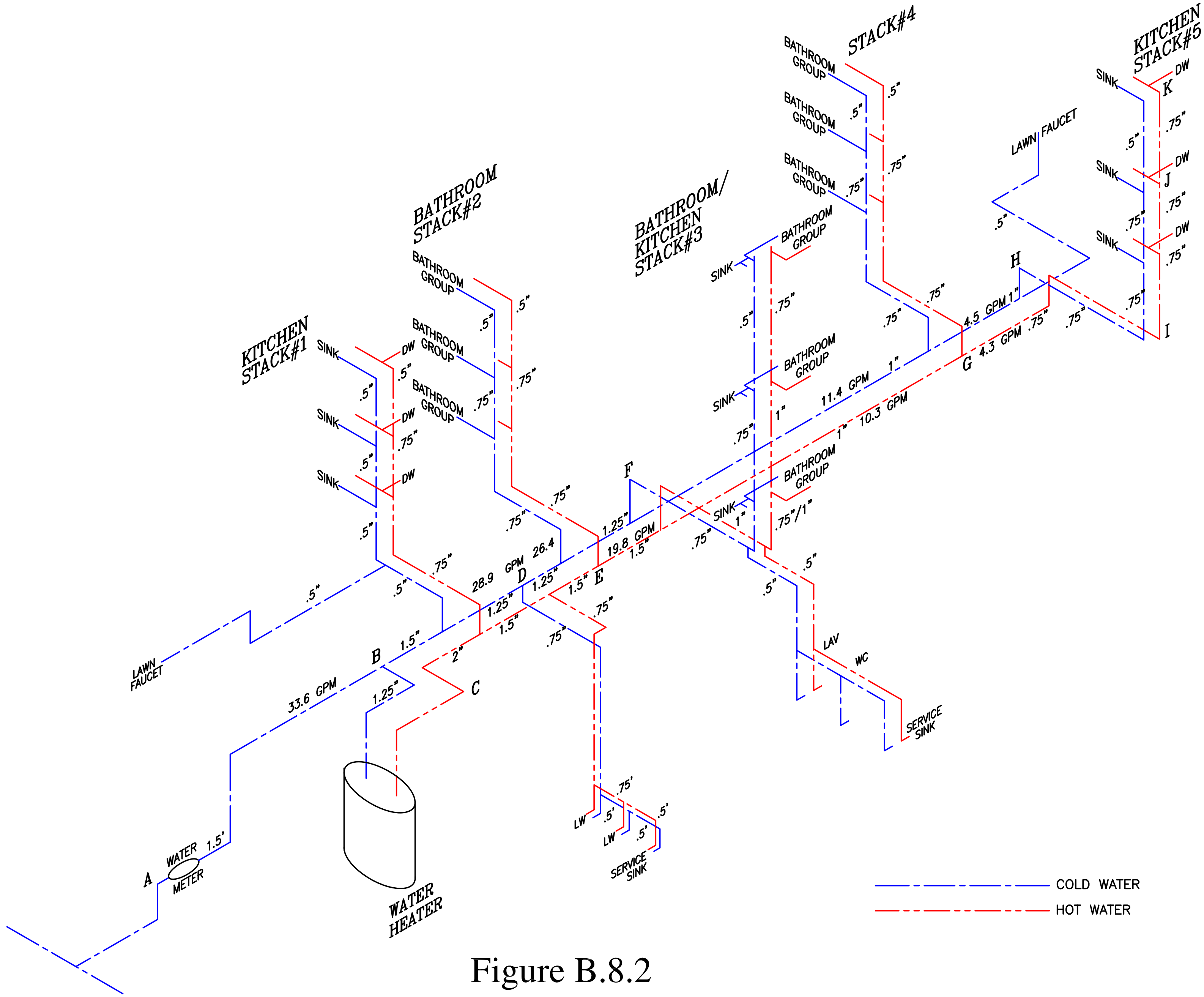


Figure B.8.2

DESIGN FLOW(GPM)AND PIPE SIZES

Table B.8.2
PRESSURE DROPS IN THE BASIC DESIGN CIRCUIT IN FIGURE B.8.2

COLD WATER FRICTION PRESSURE DROP FROM MAIN TO "K"							
SECTION	**WSFU** (1)	**FLOW (gpm)**	**LENGTH (feet)**	**PIPE SIZE**	**VELOCITY (feet/second)**	**PD (psi/100 ft)**	**PRESSURE DROP (psi)**
MAIN - A	66.0	34.8	50	1-1/2"	6.3	4.0	2.0
A - B	66.0	34.8	12	1-1/2"	6.3	4.0	0.5
B - C	57.6	32.0	8	1-1/2"	5.8	3.6	0.3
C - D	52.7	30.1	4	1-1/4"	7.7	8.0	0.3
D - E	44.4	26.8	8	1-1/4"	6.8	6.0	0.5
E - F	33.9	22.0	8	1-1/4"	5.6	4.0	0.3
F - G	15.4	11.4	10	1"	4.4	3.2	0.3
G - H	4.9	10.0 (6)	4	1" (4)	3.9	2.7	0.1
H - I	2.4	5.0 (7)	10	3/4" (4)	3.3	2.7	0.3
I - J	2.2 (2)	5.0 (7)	10	3/4" (4)	3.3	2.7	0.3
J - K	1.1 (2)	2.5 (8)	10	1/2" (4)	3.4	4.3	0.4
Total Pipe Pressure Drop (psig)							5.3
Fitting Allowance (50% of pipe loss, psig)							2.6
Total Pressure Drop Due to Pipe Friction (psig)							7.9
HOT WATER FRICTION PRESSURE DROP FROM MAIN TO "K"							
SECTION	**WSFU** (1)	**FLOW (gpm)**	**LENGTH (feet)**	**PIPE SIZE**	**VELOCITY (feet/second)**	**PD (psi/100 ft)**	**PRESSURE DROP (psi)**
MAIN - A	66.0	34.8	50	1-1/2"	6.3	4.0	2.0
A - B	66.0	34.8	12	1-1/2"	6.3	4.0	0.5
B - HWH	51.9	29.8	4	1-1/4"	7.6	7.5	0.3
HWH - C	51.9	29.8	4	2" (5)	3.1	0.8	0.0
C - D	47.4	28.0	10	1-1/2" (5)	5.0	2.7	0.3
D - E	39.1	24.6	8	1-1/2" (5)	4.4	2.1	0.2
E - F	30.1	20.1	8	1-1/2" (5)	3.6	1.6	0.1
F - G	13.5	10.3	10	1" (5)	4.0	3.0	0.3
G - H	4.5	4.3	4	3/4" (4)	2.9	2.1	0.1
H - I	4.5	4.3	10	3/4" (4)	2.9	2.1	0.2
I - J	4.0 (2)	4.0	10	3/4" (4)	2.7	1.8	0.2
J - K	2.0 (2)	4.0 (3)	10	3/4" (4)	2.7	1.8	0.2
Total Pipe Pressure Drop (psig)							4.3
Fitting Allowance (50% of pipe loss, psig)							2.2
Total Pressure Drop Due to Pipe Friction (psig)							6.5

NOTES FOR PRESSURE DROP CALCULATIONS

(1) Water supply fixture units (WSFU) are for sections of piping serving 3 or more dwelling units except as noted by (2).
(2) Water supply fixture units (WSFU) are for sections of piping serving fixtures in less than 3 dwelling units.
(3) Water flow (gpm) for the dishwasher.
(4) Velocity limited to 4 fps because of dishwashers and quick-closing sink faucets.
(5) Velocity in copper tube with 140 deg F domestic hot water is limited to 5 fps using Chart B.9.8.3.
(6) Allowance of 5 gpm for the hose bibb and two sinks at 2.5 gpm each.
(7) Allowance for two sinks at 2.5 gpm each.
(8) Allowance for one sink at 2.5 gpm.

SUMMARY OF PRESSURE DROP CALCULATIONS
Minimum pressure in water main = 50.0 psig.
Water meter pressure drop = 3.0 psig
Total cold water friction pressure drop from water main to "K" = 7.9 psig
Total hot water friction pressure drop from water main to "K" = 6.5 psig
Elevation pressure drop = (35 ft - 6 ft)(0.433) = 12.6 psig
Cold water pressure available at "K" = 50 - 3 - 7.9 -12.6 = 26.5 psig
Minimum required water pressure at "K" = 15 psig
Therefore, the pipe sizing is satisfactory.

If this calculation had shown that the pressure drop was excessive at "K", it would be necessary to examine the design for sections of the Basic Design Circuit that had the highest pressure drops and then increasse those segment pipe sizes.

B.9.2 Maximum Permissible Friction Loss

The maximum allowable pressure loss due to friction in the water lines and risers to the highest water outlets is the amount of excess static pressure available above the minimum pressure required at such outlets when no-flow conditions exist. This may be calculated as the difference between the static pressure existing at the highest water outlets during no-flow conditions, and the minimum pressure required at such outlets for satisfactory supply conditions.

Where water is supplied by direct pressure from a public main, to calculate the static pressure at the highest outlet, deduct from the certified minimum pressure available in the public main the amount of static pressure loss corresponding to the height at which the outlet is located above the public main (i.e., deduct 0.433 psi pressure for each foot of rise in elevation from the public main to the highest outlet).
Where supplied under pressure from a gravity water supply tank located at an elevation above the highest water outlet, the static pressure at that outlet is calculated as being equal to 0.433 psi pressure for each foot of difference in elevation between the outlet and the water level in the tank. In this case, the minimum static pressure at the outlet should be determined as that corresponding to the level of the lowest water level at which the tank is intended to operate.

B.9.3 Basic Design Circuit

Of all the water outlets on a system, the one at which the least available pressure will prevail during periods of peak demand is the critical outlet that controls the design. Normally, it is the highest outlet that is supplied through the longest run of piping extending from the source of supply.

This circuit is called the Basic Design Circuit (BDC) for sizing the main water lines and risers.

In most systems, the BDC will be found to be the run of cold water supply piping extending from the source of supply to the domestic hot water vessel plus the run of hot water supply piping extending to the highest and most remote hot water outlet on the system. However, in systems supplied directly from the public main and having flushometer-valve water closets at the topmost floor, the BDC may be found to be the run of cold water supply piping extending from the public main to the highest and most remote flushometer valve in the system.

B.9.4 Friction Loss in Equipment

Where a water meter, water filter, water softener, strainer, or instantaneous or tankless water heating coil is located in the BDC, the friction loss corresponding to the maximum probable demand through such equipment must be determined and included in pressure loss calculations. Manufacturers' charts and data sheets on their products provide such information generally, and should be used as a guide in selecting the best type and size of equipment to use with consideration for the limit to which pressure loss due to friction may be permitted to occur in the BDC. The rated pressure loss through such equipment should be deducted from the friction loss limit to establish the amount of pressure that is available to be dissipated by friction in pipe, valves, and fittings of the BDC.

B.9.5 Estimating Pressure Loss in Displacement Type Cold-Water Meters

The American Water Works Association standard for cold-water meters of the displacement type is designated AWWA C 700-64. It covers displacement meters known as nutating- or oscillating-piston or disc meters, which are practically positive in action. The standard establishes maximum capacity or delivery classification for each meter size as follows:

5/8"	20 gpm
3/4"	30 gpm
1"	50 gpm
1-1/2"	100 gpm
2"	160 gpm
3"	300 gpm

Also, the standard establishes the maximum pressure loss corresponding to these maximum capacities as follows:

15 psi for the 5/8", 3/4" and 1" meter sizes
20 psi for the 1-1/2", 2", 3", 4" and 6" sizes.

B.9.6 Uniform Pipe Friction Loss

To facilitate calculation of appropriate pipe sizes corresponding to the permissible friction loss in pipe, valves, and fittings, it is recommended that the BDC be designed in accordance with the principle of uniform pipe friction loss throughout its length. In this way, the friction limit for the piping run may be established in terms of pounds per square inch per 100 feet of piping length. The permissible uniform pipe friction loss in psi/100' is calculated by dividing the permissible friction loss in pipe, valves, and fittings by the total equivalent length of the basic design circuit, and multiplying by 100.

B.9.7 Equivalent Length of Piping

The total equivalent length of piping is its developed length plus the equivalent pipe length corresponding to the frictional resistance of all fittings and valves in the piping. When size of fittings are known, or has been established in accordance with sizes based upon appropriate limitation of velocity, corresponding equivalent lengths may be determined directly from available tables. Five such tables are included herein for various piping materials. See Tables B.9.7.A through B.9.7.E.

As a general finding, it has been shown by experience that the equivalent length to be allowed for fittings and valves as a result of such calculations is approximately fifty percent of the developed length of the BDC in the case of copper water tube systems, and approximately seventy-five percent for standard threaded pipe systems.

Table B.9.7.A
EQUIVALENT LENGTH OF PIPE FOR FRICTION LOSS IN THREADED FITTINGS & VALVES

Fitting or Valve	Equivalent Feet of Pipe for Various Pipe Sizes										
	1/2”	3/4”	1”	1-1/4”	1-1/2”	2”	2-1/2”	3”	4”	5”	6”
45 deg Elbow	0.8	1.1	1.4	1.8	2.2	2.8	3.3	4.1	5.4	6.7	8.1
90 deg Elbow, std	1.6	2.1	2.6	3.5	4.0	5.2	6.2	7.7	10.1	12.6	15.2
Tee, run	1.0	1.4	1.8	2.3	2.7	3.5	4.1	5.1	6.7	8.4	10.1
Tee, Branch	3.1	4.1	5.3	6.9	8.1	10.3	12.3	15.3	20.1	25.2	30.3
Gate Valve	0.4	0.6	0.7	0.9	1.1	1.4	1.7	2.0	2.7	3.4	4.0
Globe Valve	17.6	23.3	29.7	39.1	45.6	58.6	70.0	86.9	114	143	172
Angle Valve	7.8	10.3	13.1	17.3	20.1	25.8	30.9	38.4	50.3	63.1	75.8
Butterfly Valve						7.8	9.3	11.5	15.1	18.9	22.7
Swing Check Valve	5.2	6.9	8.7	11.5	13.4	17.2	20.6	25.5	33.6	42.1	50.5

NOTES FOR TABLE B.9.7.A

1) Equivalent lengths for valves are based on the valves being wide open.

Table B.9.7.B
EQUIVALENT LENGTH OF PIPE FOR FRICTION LOSS IN COPPER TUBE FITTINGS &VALVES

Fitting or Valve	Equivalent Feet of Pipe for Various Tube Sizes										
	1/2”	3/4”	1”	1-1/4”	1-1/2”	2”	2-1/2”	3”	4”	5”	6”
45 deg Elbow	0.5	0.5	1.0	1.0	1.5	2.0	2.5	3.5	5.0	6.0	7.0
90 deg Elbow, std	1.0	2.0	2.5	3.0	4.0	5.5	7.0	9.0	12.5	16.0	19.0
Tee, run	0.0	0.0	0.0	0.5	0.5	0.5	0.5	1.0	1.0	1.5	2.0
Tee, Branch	2.0	3.0	4.5	5.5	7.0	9.0	12.0	15.0	21.0	27.0	34.0
Gate Valve	0.0	0.0	0.0	0.0	0.0	0.5	1.0	1.5	2.0	3.0	3.5
Globe Valve	17.6	23.3	29.7	39.1	45.6	58.6	70.0	86.9	114.0	143.0	
Angle Valve	0.0	0.0	0.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0
Butterfly Valve	7.8	10.3	13.1	17.3	20.1	25.8	30.9	38.4	50.3	63.1	75.8
Swing Check Valve						7.5	10.0	15.5	16.0	11.5	13.5
Fitting or Valve	2.0	3.0	4.5	5.5	6.5	9.0	11.5	14.5	18.5	23.5	26.5

NOTES FOR TABLE B.9.7.B

1) Equivalent lengths for valves are based on the valves being wide open.
2) Data based in part on the 2004 Copper Tube Handbook by the Copper Development Association.

Table B.9.7.C
EQUIVALENT LENGTH OF PIPE FOR FRICTION LOSS IN SCHEDULE 40 CPVC FITTINGS

Fitting	Equivalent Feet of Pipe for Various Pipe Sizes										
	1/2”	3/4”	1”	1-1/4”	1-1/2”	2”	2-1/2”	3”	4”	5”	6”
45 deg Elbow	0.8	1.1	1.4	1.8	2.1	2.7	3.3	4.1	5.3	6.7	8.0
90 deg Elbow	1.5	2.0	2.6	3.4	4.0	5.1	6.1	7.6		12.5	15.1
Tee, Run	1.0	1.4	1.7	2.3	2.7	3.4	4.1	5.1	6.7	8.4	10.1
Tee, Branch	3.0	4.1	5.2	6.8	8.0	10.2	12.2	15.2		25.1	30.2

Table B.9.7.D EQUIVALENT LENGTH OF PIPE FOR FRICTION LOSS IN SCHEDULE 80 CPVC FITTINGS											
Fitting	**Equivalent Feet of Pipe for Various Pipe Sizes**										
	1/2”	**3/4”**	**1”**	**1-1/4”**	**1-1/2”**	**2”**	**2-1/2”**	**3”**	**4”**	**5”**	**6”**
45 deg Elbow	0.7	1.0	1.2	1.7	2.0	2.6	3.1	3.8	5.0	6.4	7.6
90 deg Elbow	1.3	1.8	2.3	3.1	3.7	4.8	5.7	7.2	9.5	11.9	14.3
Tee, Run	0.9	1.2	1.6	2.1	2.5	3.2	3.8	4.8	6.3	7.9	9.5
Tee, Branch	2.6	3.6	4.7	6.3	7.4	9.6	11.5	14.3	18.9	23.8	28.5

Table B.9.7.E EQUIVALENT LENGTH OF PIPE FOR FRICTION LOSS IN CPVC SDR 11 CTS TUBING FITTINGS						
Fitting	**Equivalent Feet of Pipe for Various Pipe Sizes**					
	1/2” CTS	**3/4” CTS**	**1” CTS**	**1-1/4” CTS**	**1-1/2” CTS**	**2” CTS**
45 deg Elbow	0.8	1.1	1.4	1.8	2.2	2.8
90 deg Elbow	1.6	2.1	2.6	3.5	4.0	5.2
Tee, Run	1.0	1.4	1.8	2.3	2.7	3.5
Tee, Branch	3.1	4.1	5.3	6.9	8.1	10.3

B.9.8 Determination of Flow Rates Corresponding to Uniform Pipe Friction Loss

Flow rates corresponding to any given uniform pipe friction loss may be determined readily for each nominal size of the kind of pipe selected for the system. Pipe friction charts (B.9.8.1 through B.9.8.7) are presented herewith for each of the standard piping materials used for water supply systems in buildings. The appropriate chart to apply in any given case depends upon the kind of piping to be used and the effect the water to be conveyed will produce within the piping after extended service.

These charts are based on piping in average service. If piping is used in adverse service or in retrofit applications, conservative practice suggests selecting lower flow rates for a given pipe, or larger pipe for a given required flow rate.

For new work, with the range of materials now available, select a piping material that will not be affected by the water characteristics at the site.

CHART B.9.8.1
GALVANIZED STEEL - ASTM A53

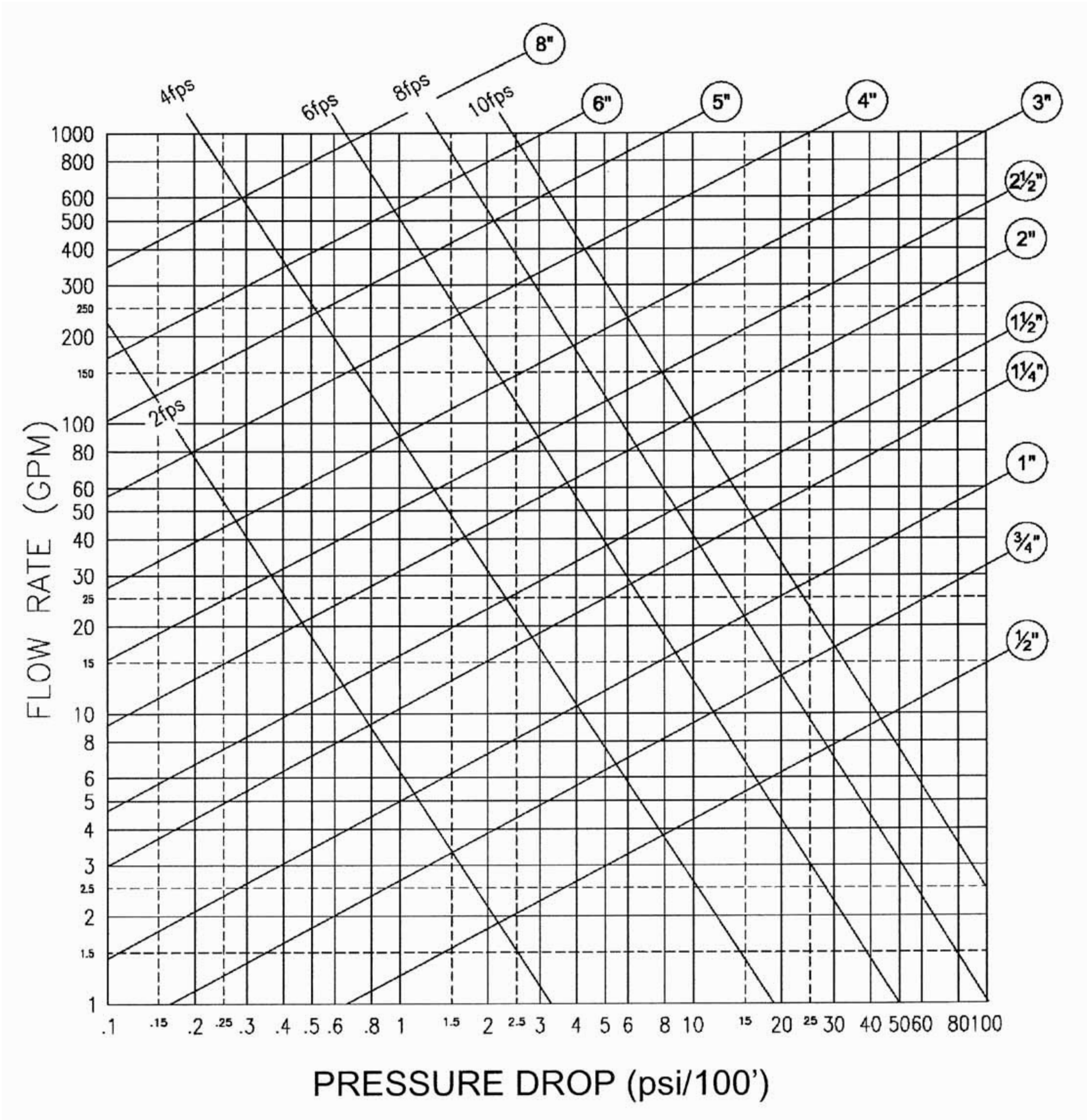


CHART B.9.8.2
TYPE K COPPER TUBE

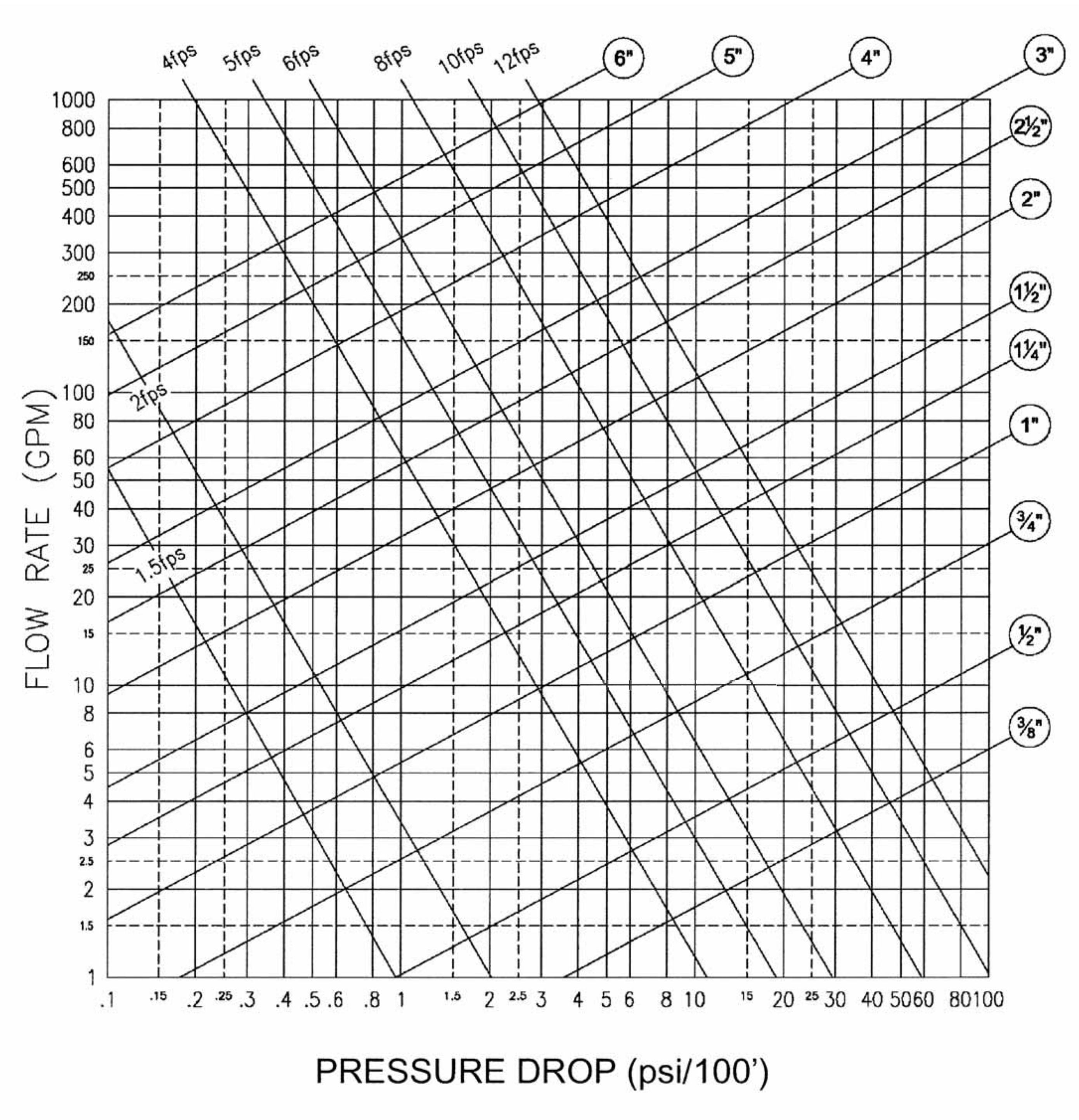


CHART B.9.8.3
TYPE L COPPER TUBE

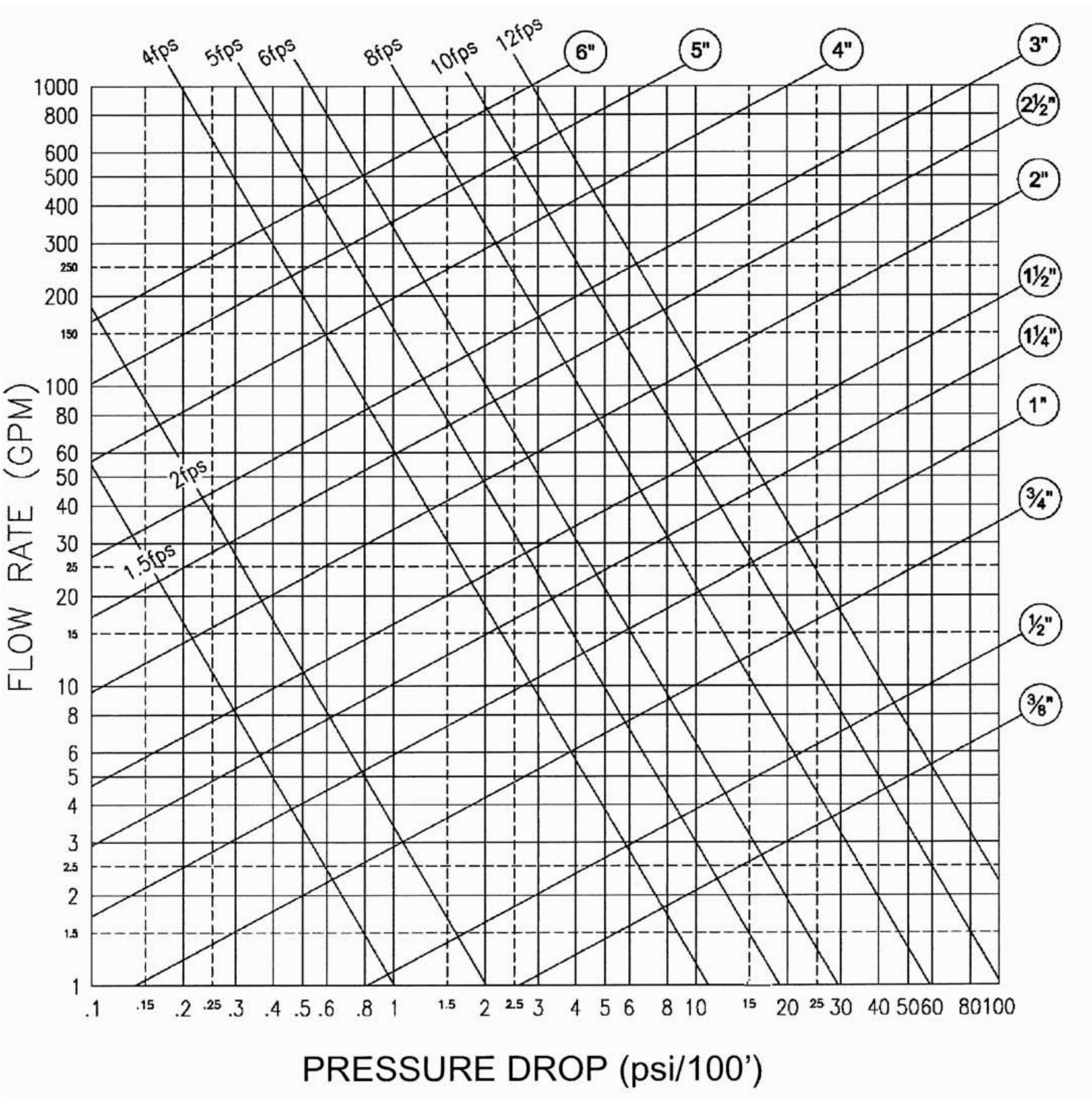


CHART B.9.8.4
TYPE M COPPER TUBE

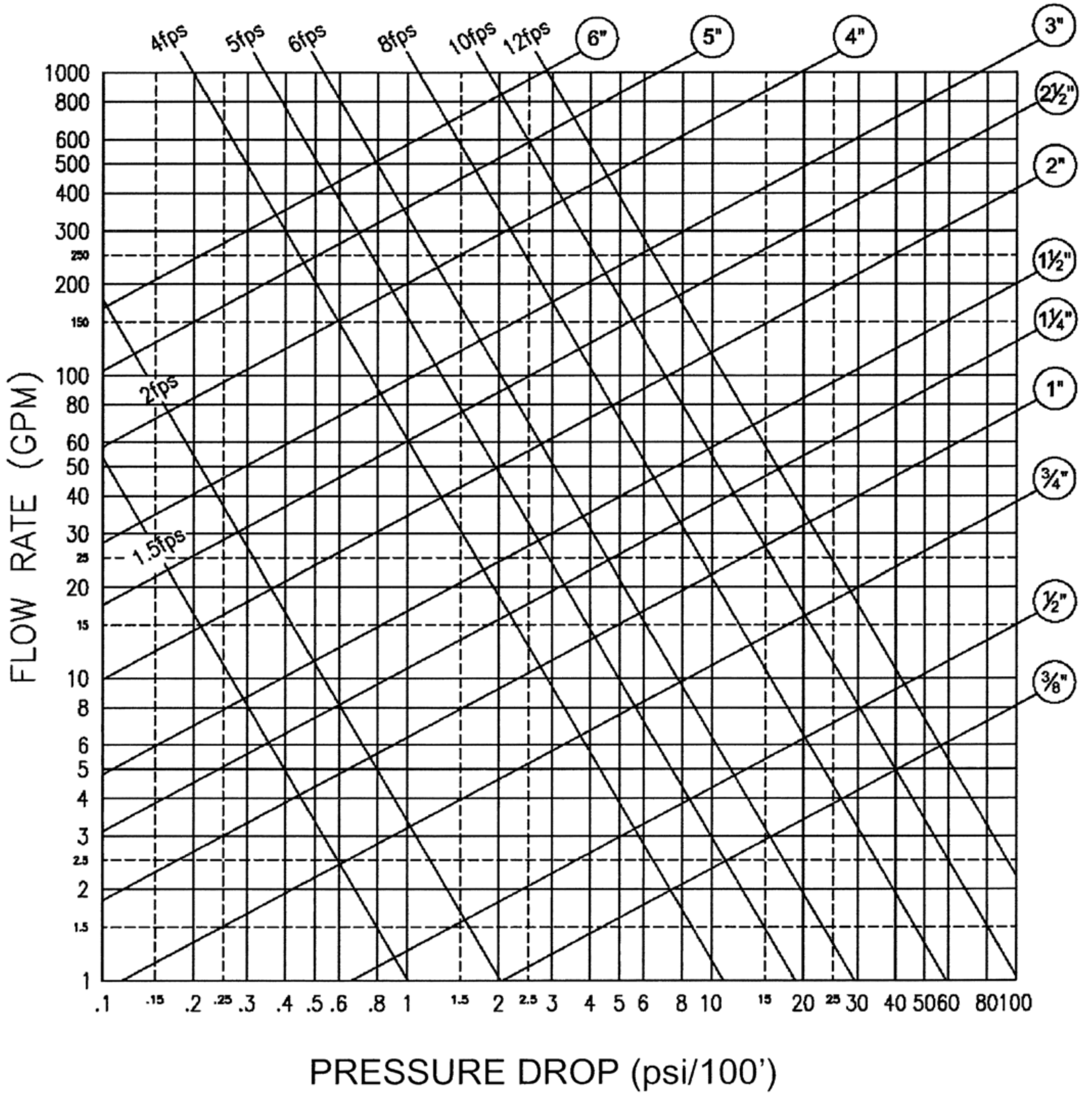


CHART B.9.8.5
CPVC, PVC, ABS, PE SCHEDULE 40 PIPE

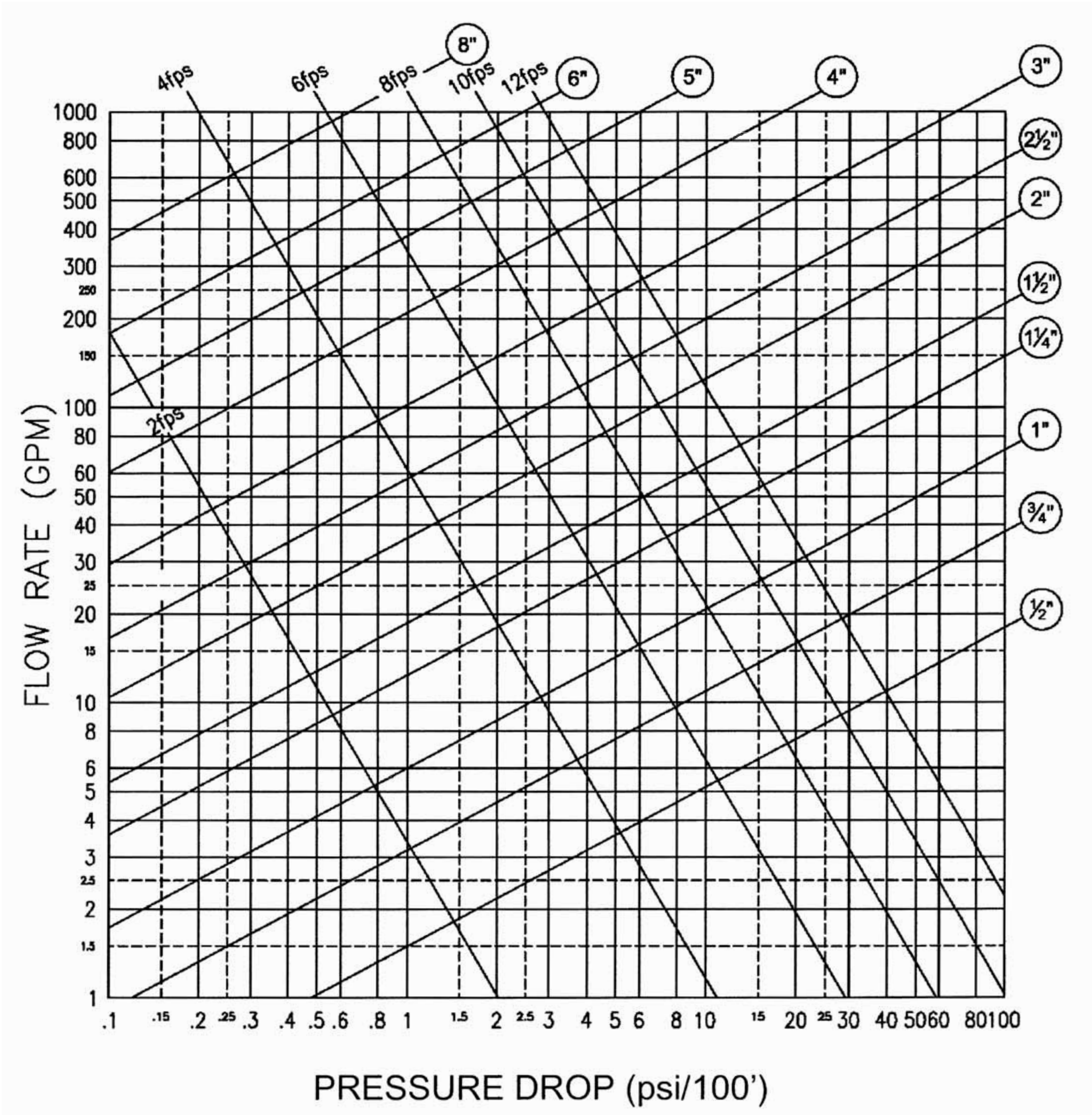


CHART B.9.8.6
CPVC, PVC, ASB, PE SCHEDULE 80 PIPE

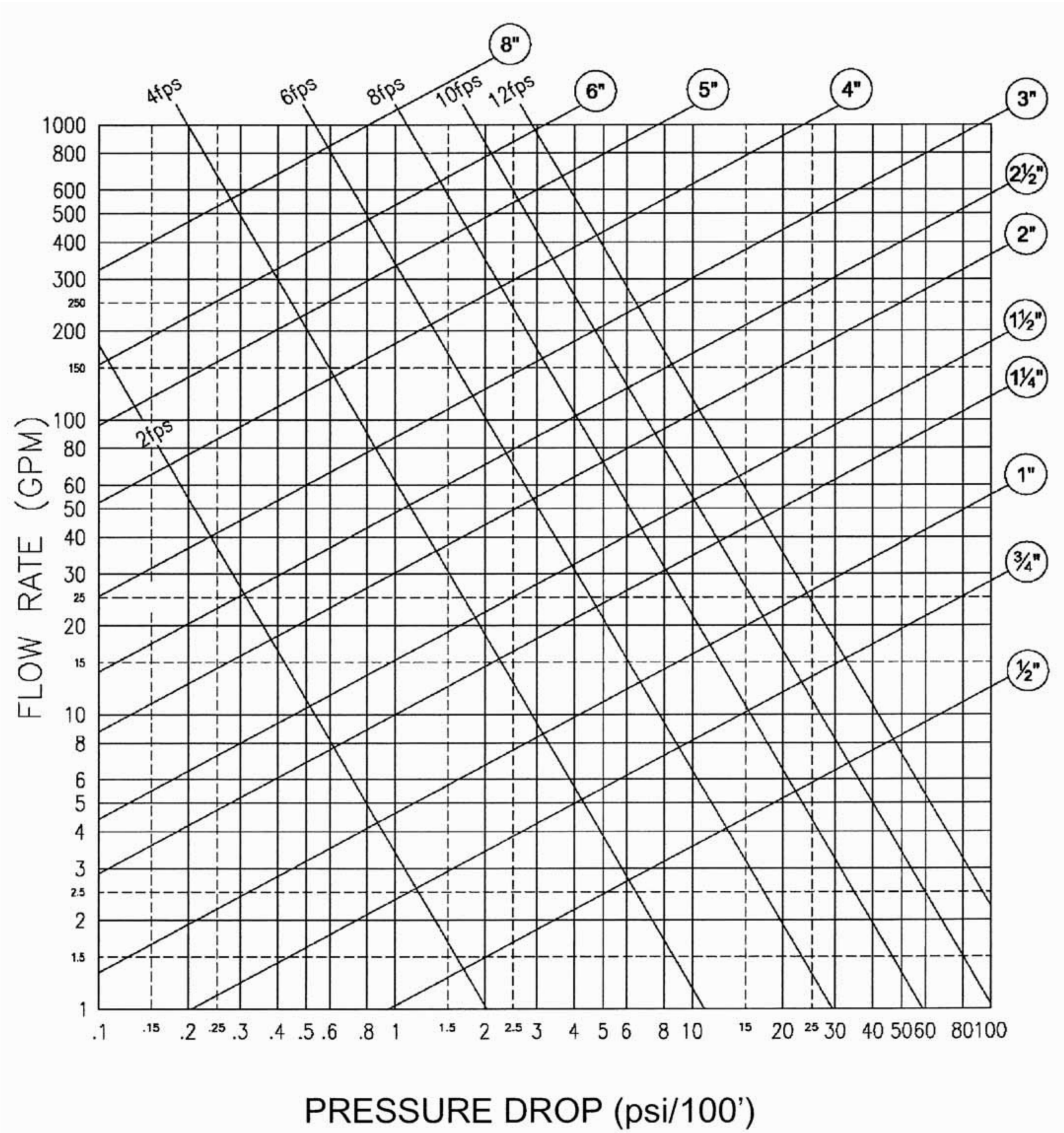
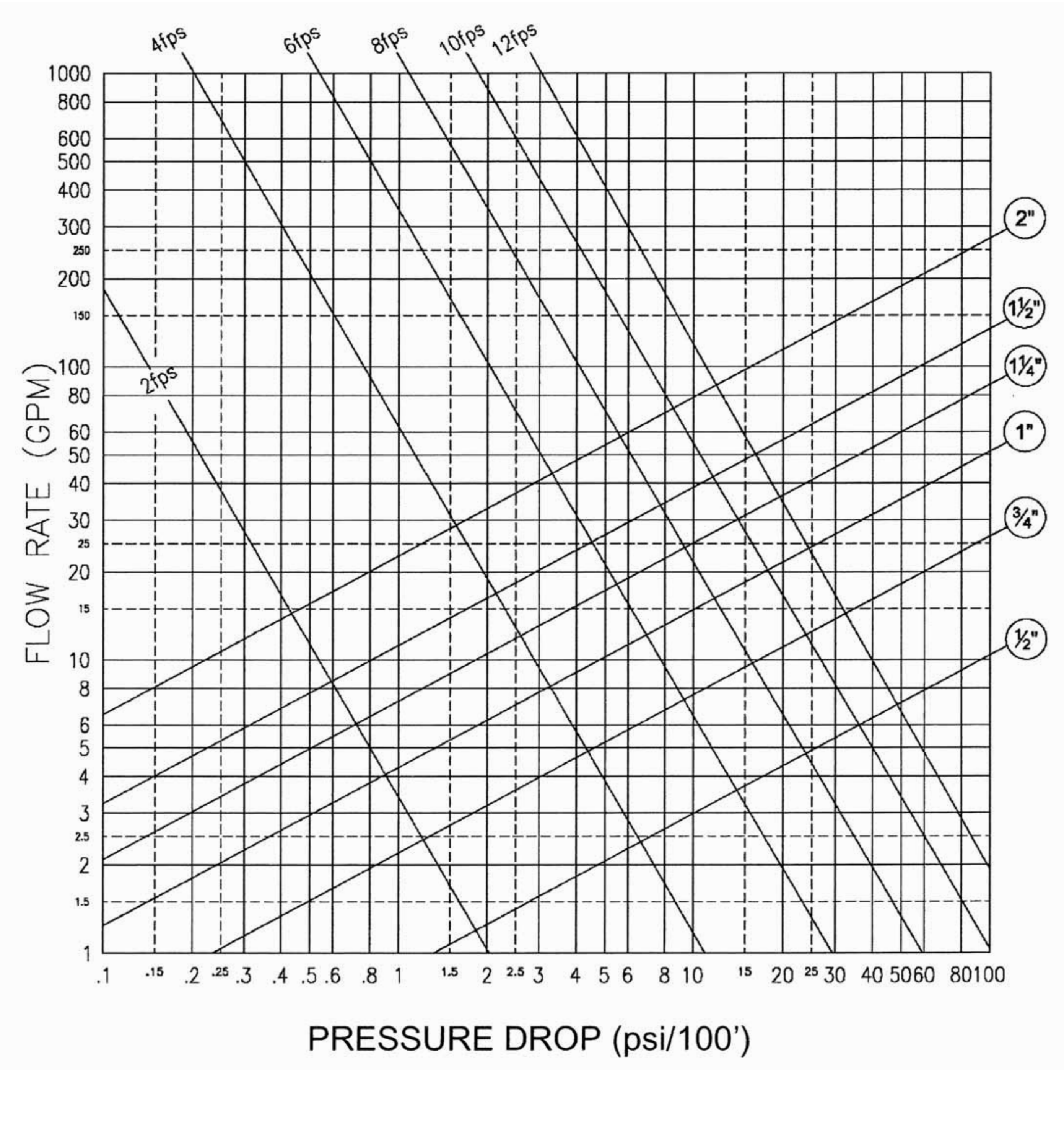


CHART B.9.8.7
CPVC TUBING (Copper Tube Size) SDR 11



B.10 DETAILED SIZING METHOD FOR SYSTEMS IN BUILDINGS OF ANY HEIGHT

For sizing water supply systems in buildings of any height, a detailed method may be applied in the design of modern buildings. The procedure consists of sixteen steps, as follows:

1. Obtain all information necessary for sizing the system. Such information shall be obtained from responsible parties and appropriate local authorities recognized as sources of the necessary information. (See Section B.2.)

2. Provide a schematic elevation of the complete water supply system. Show all piping connections in proper sequence and all fixture supplies. Identify all fixtures and risers by means of appropriate letters, numbers, or combinations thereof. Identify all piping conveying water at a temperature above 150°F, and all branch piping to such water outlets as solenoid valves, pneumatic valves, or quick-closing valves or faucets. Provide on the schematic elevation all the general information obtained per step 1. (See Section B.2.9.)

3. Mark on the schematic elevation, for each section of the complete system, the hot and cold water loads served in terms of water supply fixture units in accordance with Table B.5.2.

4. Mark on the schematic elevation, adjacent to all fixture unit notations, the probable maximum demand in gallons per minute corresponding to the various fixture unit loads in accordance with Table B.5.4.

5. Mark on the schematic elevation, for appropriate sections of the system, the demand in gallons per minute for outlets at which demand is considered continuous, such as outlets for watering gardens, irrigating lawns, air-conditioning apparatus, refrigeration machines, and similar equipment. Add the continuous demand to the demand for intermittently used fixtures, and show the total demand at those sections where both types of demand occur. (See Section B.5.4.)

6. Size all individual fixture supply pipes to water outlets in accordance with the minimum sizes permitted by regulations. Minimum fixture supply pipe sizes for typical plumbing are given in Table B.5.2.

7. Size all other parts of the water supply system in accordance with velocity limitations recognized as good engineering practice, and with velocity limitations recommended by pipe manufacturers for avoiding accelerated deterioration and failure of their products under various conditions of service. Sizing tables based on such velocity limitations and showing permissible loads in terms of water supply fixture units for each size and kind of piping material have been provided and may be applied as a convenient and simplified method of sizing in this step. (See Section B.6)

   Note: These sizes are tentative until verified in Steps 12, 13, 14, 15.

8. Assuming conditions of no-flow in the system, calculate the amount of pressure available at the topmost fixture in excess of the minimum pressure required at such fixtures for satisfactory supply conditions. This excess pressure is the limit for friction losses for peak demand in the system (1 foot of water column = 0.433 psi pressure). (See Section B.9.2.)

9. Determine which piping circuit of the system is the basic one for which pipe sizes in main lines and riser should be designed in accordance with friction loss limits. This circuit is the most extreme run of piping through which water flows from the public main, or other source of supply, to the highest and most distant water outlet. This basic design circuit (BDC) should be specifically identified on the schematic elevation of the system. (See Section B.9.3.)

10. Mark on the schematic elevation the pressure loss due to friction corresponding to the maximum probable demand through any water meter, water softener, or instantaneous or tankless water heating coil that may be provided in the BDC. (See Sections B.9.4 and B.9.5.)

11. Calculate the amount of pressure remaining and available for dissipation as friction loss during peak demand through pipe, valves, and fittings in the BDC. Deduct from the excess static pressure available at the topmost fixtures (determined in step 8), the friction losses for any water meters, softeners, and water heating coils provided in the BDC determined in step 10. (See Section B.9.4.)

12. Calculate the total equivalent length of the BDC. Pipe sizes established on the basis of velocity limitation in step 7 for main lines and risers must be considered just tentative at this stage, but may be deemed appropriate for determining corresponding equivalent lengths of fittings and valves in this step. (See Section B.9.7.)

13. Calculate the permissible uniform pressure loss for friction in piping of the BDC. The amount of pressure available in the circuit for dissipation as friction loss due to pipe, fittings, and valves (determined in step 11), is divided by the total equivalent length of the circuit (determined in step 12). This establishes the pipe friction limit

for the circuit in terms of pressure loss in psi per foot of total equivalent pipe length. Multiply this value by 100 in order to express the pipe friction limit in terms of psi per 100 feet of length. (See Section B.9.6.)

14. Set up a sizing table showing the rates of flow for various sizes of the kind of piping to be used, corresponding to the permissible uniform pressure loss for pipe friction calculated for the BDC (determined in step 13). Such rates may be determined from a pipe friction chart appropriate for the piping to be used and for the effects upon the piping of the quality of the water to be conveyed thereby for extended service. (See Sections B.9.8 and B.2.3.)

15. Check the sizes of all parts of the BDC, and all other main lines and risers that supply water upward to the highest water outlets on the system, in accordance with the sizing table set up in step 14. Where sizes determined in this step are larger than those previously established in step 7 (based on velocity limitation), the increased sizes are applicable for limitation of friction.

16. Due consideration must be given to the action of the water on the interior of the piping, and proper allowance must be made where necessary as a design consideration, such as, where the kind of piping selected and the characteristics of the water conveyed are such that an appreciable buildup of corrosion products or hard-water scale may be anticipated to cause a significant reduction in bore of the piping system and inadequate capacity for satisfactory supply conditions during the normal service life of the system. A reasonable allowance in such cases is to select at least one standard pipe size larger than the sizes determined in the preceding steps. Where the water supply is treated in such manner as to avoid buildup of corrosion products or hard-water scale, no allowance need be made in sizing piping conveying such treated water. (See Sections B.2.3 and B.9.8.)

B.11 ILLUSTRATION OF DETAILED SIZING METHOD APPLICATION

B.11.1 Example

A seven-story building is supplied by direct street pressure from a public water main in which the minimum available pressure is 60 psi. The highest fixture supplied is 64'-8" above the public main, and requires 12 psi flow pressure at the fixture for satisfactory supply conditions.

The water supply is to be metered by a meter through which flow at the maximum probable demand rate will produce a pressure drop of 5.6 psi. Copper tubing, Type L, is to be used for the entire system. Quality of the water supply is known to be noncorrosive to copper tubing in the water district, and is recognized as being non-scaling in characteristic.

The entire system has been initially sized in accordance with the simplified method based solely on velocity limitations. Applying these sizes, the total equivalent length of piping from the public main to the highest and most remote fixture outlet has been calculated to be 600'.

B.11.2 Solution

Steps 1-7. The first seven steps of the detailed sizing method have already been performed. These steps constitute the simplified sizing method based solely on velocity limitations established as the design basis. All that remains is to perform steps 8 through 15 of the detailed sizing method which relate to sizing in accordance with the frictional limitation which must be observed for this particular system, and with allowances which may be necessary in view of the water characteristics.

Step 8. Assuming conditions of no-flow in the system, the amount of excess pressure available at the topmost fixture in excess of the minimum required at the fixture for satisfactory supply conditions is determined as follows:

Excess pressure available = 60 psi - 12 psi - (64.67 x 0.4333 psi/ft) = 20 psi

Step 9. The BDC should be specifically identified on the schematic elevation provided as per step 2.

Step 10. The pressure loss through the water meter selected for this system for flow at maximum probable demand is given in the example as being 5.6 psi. No other items of equipment through which significant friction losses may occur have been noted in the example.

Step 11. The amount of pressure remaining for dissipation as friction loss during peak demand through pipes, valves, and fittings in the basic design circuit is determined as follows:

Pressure available for friction in piping = 20 psi - 5.6 psi = 14.4 psi

Step 12. The total equivalent length of the basic design circuit has been given in the example as being 600 feet, based on the sizes determined in accordance with velocity limitations as per step 7.

Step 13. The permissible uniform pressure loss for friction in piping of the basic design circuit is determined as follows:

Permissible uniform pipe friction loss = 14.4 psi x (100 ft/600 ft)
= 2.4 psi per 100 ft pipe length

Step 14. A sizing table showing the rates of flow through various sizes of copper tubing corresponding to a pipe friction loss rate of 2.4 psi per 100 feet of pipe length is given in Table B.11.2. These flow rates were determined from the chart applicable to such pipe with a "fairly smooth" surface condition after extended service conveying water having the effect stated in the example.

Step 15. All parts of the BDC should be selected in accordance with the flow rates shown in the table established in step 14. Usually, all other parts of the system are sized using the same pressure drop limitation.

Table B.11.2
TYPE L COPPER TUBING, FOR "FAIRLY SMOOTH" CONDITION

Nominal Pipe Size (in)	Flow Rate Corresponding to Friction Loss of 2-4 psi/100' (gpm)
1/2	1.4
3/4	3.9
1	7.5
1-1/4	14.0
1-1/2	21.0
2	47.0
2-1/2	78.0
3	130.0
4	270.0

B.12 MANIFOLD TYPE PARALLEL WATER DISTRIBUTION SYSTEMS

B.12.1 Manifolds

The total water supply demand for the dwelling shall be determined in accordance with Section 10.14 and Appendix B.5. Manifolds shall be sized according to Table B.12.1 based on the total supply demand.

Table B.12.1
MANIFOLD SIZING[1]

Nominal Size Inches	Maximum GPM Available @ Velocity		
	@ 4 fps	@ 8 fps	@ 10 fps
1/2	2	5	6
3/4	6	11	14
1	10	20	25
1-1/4	15	31	38
1-1/2	22	44	55

[1] Refer to Section 10.14 for maximum velocity permitted.

B.12.2 Distribution Lines

a. The water pressure available for distribution pipe friction shall be determined from the minimum supply pressure available at the source, the developed length and size of the water service, the pressure drop through the water meter (if provided), the pressure drop through the manifold, the pressure drop through any other equipment or appurtenances in the system, the elevation of each distribution line, and the minimum pressure required at each fixture.

b. The water flow required at each fixture shall be in accordance with Section 10.14.2a for both hot and cold water. Distribution line sizes shall be in accordance with the system manufacturer's line sizing procedure.

c. The system manufacturer shall provide sizing data for the individual runs of tubing to each fixture based on the water pressure available for pipe friction and static elevation, the GPM required at each fixture, the tubing material, the tube size, and its maximum allowable length from the manifold to the fixture. Tube sizes for parallel water distribution systems include 3/8" nominal, 1/2" nominal, and 3/4" nominal.