## Appendix D

# Pipe Sizes For Water Distribution System Design

D-1. This appendix contains information to help determine pipe sizes when designing a water distribution system. Use *Table D-1 and Tables D-2 through D-4, pages D-3 through D-6* to determine pipe sizes.

**Table D-1. Capacities of Galvanized-Steel/Iron Pipe (in GPM)**

| Length of Pipe (in Feet) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pressure at Source (psi)** | **20** | **40** | **60** | **80** | **100** | **120** | **140** | **160** | **180** | **200** |
| **3/8 Inch** | | | | | | | | | | |
| 10 | 5 | 3 | 3 | 2 | 2 | 2 | | | | |
| 20 | 9 | 5 | 4 | 3 | 3 | 3 | 2 | 2 | 2 | 2 |
| 30 | 10 | 6 | 5 | 4 | 4 | 3 | 3 | 3 | 3 | 2 |
| 40 | | 8 | 6 | 5 | 4 | 4 | 4 | 3 | 3 | 3 |
| 50 | | 9 | 7 | 6 | 5 | 4 | 4 | 3 | 3 | 3 |
| 60 | | 9 | 7 | 6 | 6 | 5 | 5 | 4 | 4 | 4 |
| 70 | | 10 | 8 | 7 | 6 | 6 | 5 | 5 | 4 | 4 |
| 80 | | | 8 | 7 | 7 | 6 | 5 | 5 | 5 | 4 |
| **1/2 Inch** | | | | | | | | | | |
| 10 | 10 | 8 | 5 | 5 | 4 | 3 | 3 | 3 | 3 | 3 |
| 20 | 14 | 10 | 8 | 6 | 6 | 5 | 5 | 4 | 4 | 4 |
| 30 | 18 | 12 | 10 | 8 | 8 | 7 | 6 | 6 | 5 | 5 |
| 40 | 20 | 14 | 11 | 10 | 10 | 8 | 7 | 7 | 6 | 6 |
| 50 | | 16 | 13 | 11 | 11 | 9 | 8 | 7 | 7 | 7 |
| 60 | | 18 | 14 | 12 | 12 | 10 | 9 | 9 | 8 | 7 |
| 70 | | | 15 | 13 | 12 | 11 | 10 | 9 | 8 | 8 |
| 80 | | | | | | | | | | |
| **3/4 Inch** | | | | | | | | | | |
| 10 | 22 | 14 | 12 | 10 | 8 | 8 | 7 | 6 | 6 | 6 |
| 20 | 30 | 22 | 18 | 14 | 12 | 12 | 11 | 10 | 10 | 8 |
| 30 | 38 | 26 | 22 | 18 | 16 | 14 | 13 | 12 | 12 | 10 |
| 40 | | 30 | 24 | 21 | 19 | 17 | 16 | 16 | 15 | 13 |
| 50 | | 34 | 28 | 24 | 21 | 19 | 18 | 17 | 16 | 15 |
| 60 | | 38 | 31 | 26 | 23 | 21 | 20 | 19 | 18 | 17 |
| 70 | | | 34 | 29 | 25 | 23 | 22 | 21 | 19 | 18 |
| 80 | | | 36 | 30 | 27 | 24 | 23 | 22 | 21 | 20 |

**Table D-1. Capacities of Galvanized-Steel/Iron Pipe (in GPM) (Continued)**

| | Length of Pipe (in Feet) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pressure at Source (psi)** | **20** | **40** | **60** | **80** | **100** | **120** | **140** | **160** | **180** | **200** |
| **1 Inch** | | | | | | | | | | |
| 10 | 40 | 28 | 22 | 18 | 16 | 15 | 14 | 13 | 12 | 11 |
| 20 | 55 | 40 | 32 | 27 | 24 | 22 | 20 | 19 | 18 | 16 |
| 30 | 70 | 50 | 40 | 34 | 30 | 27 | 25 | 23 | 22 | 20 |
| 40 | 80 | 58 | 45 | 40 | 35 | 32 | 29 | 27 | 25 | 24 |
| 50 | | 65 | 57 | 45 | 40 | 36 | 33 | 31 | 29 | 27 |
| 60 | | 70 | 58 | 50 | 44 | 40 | 36 | 34 | 32 | 30 |
| 70 | | 76 | 63 | 54 | 45 | 42 | 40 | 37 | 34 | 32 |
| 80 | | | 65 | 57 | 47 | 43 | 39 | 37 | 35 | 33 |
| **1 1/4 Inch** | | | | | | | | | | |
| 10 | 80 | 55 | 45 | 37 | 35 | 30 | 27 | 25 | 26 | 24 |
| 20 | 110 | 80 | 65 | 55 | 50 | 45 | 41 | 38 | 36 | 34 |
| 30 | | 100 | 80 | 70 | 60 | 56 | 51 | 47 | 45 | 42 |
| 40 | | | 95 | 80 | 72 | 65 | 60 | 56 | 52 | 50 |
| 50 | | | 107 | 92 | 82 | 74 | 68 | 63 | 60 | 55 |
| 60 | | | | 102 | 90 | 81 | 75 | 70 | 65 | 62 |
| 70 | | | | | 97 | 88 | 82 | 74 | 69 | 67 |
| 80 | | | | | 105 | 95 | 87 | 79 | 74 | 72 |
| **1 1/2 Inch** | | | | | | | | | | |
| 10 | 120 | 90 | 70 | 60 | 55 | 50 | 45 | 40 | 40 | 35 |
| 20 | 170 | 130 | 100 | 90 | 75 | 70 | 65 | 60 | 55 | 55 |
| 30 | | 160 | 130 | 110 | 100 | 90 | 80 | 75 | 70 | 65 |
| 40 | | 170 | 150 | 130 | 110 | 100 | 90 | 90 | 80 | 80 |
| 50 | | | 170 | 140 | 130 | 120 | 110 | 100 | 90 | 90 |
| 60 | | | | 160 | 140 | 130 | 120 | 110 | 100 | 100 |
| 70 | | | | 170 | 150 | 140 | 130 | 120 | 110 | 100 |
| 80 | | | | | 160 | 150 | 140 | 130 | 120 | 110 |
| **2 Inch** | | | | | | | | | | |
| 10 | 240 | 160 | 130 | 110 | 100 | 90 | 90 | 80 | 80 | 70 |
| 20 | 300 | 240 | 200 | 160 | 150 | 140 | 130 | 120 | 110 | 100 |
| 30 | | 300 | 240 | 200 | 180 | 160 | 150 | 140 | 140 | 130 |
| 40 | | | 380 | 240 | 220 | 200 | 180 | 160 | 160 | 150 |
| 50 | | | | 280 | 240 | 220 | 200 | 200 | 180 | 160 |
| 60 | | | | | 280 | 240 | 220 | 200 | 200 | 180 |
| 70 | | | | | 300 | 260 | 240 | 220 | 220 | 200 |
| 80 | | | | | | 280 | 260 | 240 | 220 | 220 |

**Table D-2. Capacities of Copper Tubing and Plastic Pipe (in GPM)**

| | Length of Pipe (in Feet) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pressure at Source (psi)** | **20** | **40** | **60** | **80** | **100** | **120** | **140** | **160** | **180** | **200** |
| **1/2 Inch** | | | | | | | | | | |
| 10 | 8 | 5 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| 20 | 12 | 8 | 6 | 5 | 5 | 4 | 4 | 3 | 3 | 3 |
| 30 | 15 | 10 | 8 | 7 | 6 | 5 | 5 | 4 | 4 | 4 |
| 40 | 17 | 12 | 9 | 8 | 7 | 6 | 6 | 5 | 5 | 4 |
| 50 | | 14 | 10 | 9 | 8 | 7 | 6 | 6 | 5 | 5 |
| 60 | | 15 | 12 | 10 | 9 | 8 | 7 | 7 | 6 | 6 |
| 70 | | | 13 | 11 | 10 | 9 | 8 | 7 | 7 | 6 |
| 80 | | | 14 | 12 | 10 | 10 | 8 | 8 | 7 | 7 |
| **5/8 Inch** | | | | | | | | | | |
| 10 | 12 | 8 | 7 | 6 | 5 | 5 | 4 | 4 | 3 | 3 |
| 20 | 18 | 12 | 10 | 9 | 7 | 6 | 6 | 5 | 5 | 5 |
| 30 | 22 | 16 | 12 | 10 | 9 | 9 | 8 | 7 | 6 | 6 |
| 40 | 26 | 18 | 14 | 12 | 10 | 10 | 9 | 8 | 8 | 7 |
| 50 | | 22 | 16 | 14 | 12 | 11 | 10 | 9 | 9 | 8 |
| 60 | | 24 | 18 | 16 | 14 | 13 | 12 | 11 | 10 | 9 |
| 70 | | | 20 | 18 | 15 | 14 | 13 | 12 | 11 | 10 |
| 80 | | | 22 | 19 | 16 | 15 | 14 | 13 | 12 | 11 |
| **3/4 Inch** | | | | | | | | | | |
| 10 | 20 | 14 | 10 | 10 | 8 | 8 | 6 | 6 | 6 | 5 |
| 20 | 30 | 20 | 16 | 14 | 12 | 10 | 10 | 10 | 8 | 8 |
| 30 | 36 | 26 | 20 | 17 | 15 | 14 | 13 | 11 | 10 | 8 |
| 40 | | 30 | 24 | 20 | 18 | 16 | 15 | 14 | 13 | 12 |
| 50 | | 34 | 28 | 24 | 20 | 18 | 16 | 16 | 14 | 14 |
| 60 | | 36 | 30 | 26 | 22 | 20 | 18 | 18 | 16 | 16 |
| 70 | | | 32 | 28 | 24 | 22 | 20 | 18 | 18 | 16 |
| 80 | | | 36 | 30 | 26 | 24 | 22 | 20 | 18 | 18 |
| **1 Inch** | | | | | | | | | | |
| 10 | 50 | 30 | 24 | 20 | 18 | 16 | 14 | 14 | 12 | 12 |
| 20 | 70 | 45 | 36 | 30 | 26 | 24 | 22 | 20 | 18 | 18 |
| 30 | 80 | 55 | 45 | 38 | 34 | 30 | 28 | 26 | 24 | 22 |
| 40 | | 65 | 55 | 45 | 40 | 36 | 32 | 30 | 28 | 26 |
| 50 | | 75 | 60 | 50 | 45 | 40 | 36 | 34 | 32 | 30 |
| 60 | | 80 | 66 | 55 | 50 | 45 | 40 | 38 | 36 | 34 |
| 70 | | | 70 | 60 | 55 | 50 | 45 | 40 | 38 | 36 |
| 80 | | | 80 | 65 | 60 | 50 | 50 | 45 | 40 | 40 |

**Table D-2. Capacities of Copper Tubing and Plastic Pipe (in GPM) (Continued)**

| Length of Pipe (in Feet) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pressure at Source (psi)** | **20** | **40** | **60** | **80** | **100** | **120** | **140** | **160** | **180** | **200** |
| **1 1/4 Inch** | | | | | | | | | | |
| 10 | 80 | 55 | 42 | 37 | 32 | 30 | 27 | 25 | 22 | 22 |
| 20 | 110 | 80 | 65 | 55 | 47 | 42 | 40 | 35 | 35 | 32 |
| 30 | | 105 | 80 | 70 | 60 | 55 | 50 | 45 | 44 | 40 |
| 40 | | 110 | 95 | 80 | 70 | 65 | 60 | 55 | 50 | 47 |
| 50 | | | 110 | 90 | 80 | 70 | 65 | 60 | 57 | 55 |
| 60 | | | | 105 | 90 | 80 | 75 | 70 | 65 | 60 |
| 70 | | | | 110 | 100 | 90 | 80 | 75 | 70 | 65 |
| 80 | | | | | 105 | 95 | 85 | 80 | 75 | 70 |
| **1 1/2 Inch** | | | | | | | | | | |
| 10 | 130 | 90 | 70 | 60 | 50 | 45 | 40 | 40 | 35 | 35 |
| 20 | 170 | 130 | 100 | 90 | 75 | 70 | 65 | 60 | 55 | 50 |
| 30 | | 170 | 130 | 110 | 100 | 90 | 80 | 75 | 70 | 65 |
| 40 | | | 155 | 130 | 115 | 105 | 95 | 88 | 80 | 77 |
| 50 | | | 170 | 150 | 130 | 120 | 108 | 100 | 90 | 88 |
| 60 | | | | 165 | 145 | 130 | 120 | 110 | 105 | 98 |
| 70 | | | | 170 | 160 | 142 | 130 | 122 | 113 | 106 |
| 80 | | | | | 170 | 155 | 140 | 130 | 122 | 115 |
| **2 Inch** | | | | | | | | | | |
| 10 | 280 | 180 | 150 | 145 | 110 | 100 | 90 | 85 | 80 | 70 |
| 20 | 320 | 280 | 220 | 190 | 165 | 160 | 140 | 125 | 120 | 110 |
| 30 | | 320 | 280 | 240 | 210 | 180 | 170 | 160 | 150 | 140 |
| 40 | | | 320 | 280 | 240 | 220 | 200 | 190 | 175 | 160 |
| 50 | | | | 320 | 280 | 250 | 230 | 210 | 200 | 190 |
| 60 | | | | | 300 | 280 | 260 | 240 | 220 | 200 |
| 70 | | | | | 320 | 300 | 280 | 260 | 240 | 230 |
| 80 | | | | | | 320 | 300 | 280 | 260 | 240 |

## Table D-3. Allowance for Equivalent Length of Pipe for Friction Loss (Valve and Threaded Fittings)

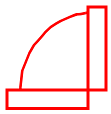
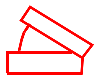
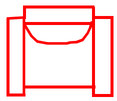
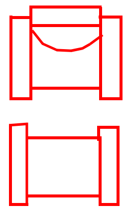
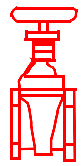
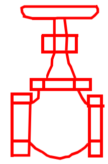
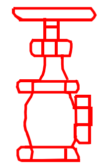
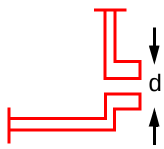
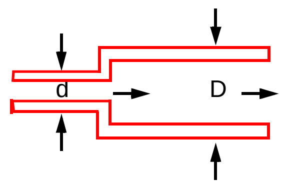
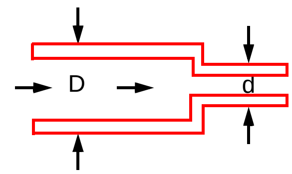
| Diameter of Fitting (in Inches) | 90° Standard Elbow, Foot | 45° Standard Elbow, Foot | 90° Side T, Foot | Coupling of Straight Run of T, Foot | Gate Valve, Foot | Globe Valve, Foot | Angle Valve, Foot |
|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |
| 3/8 | 1.0 | 0.6 | 1.5 | 0.3 | 0.2 | 8 | 4 |
| 1/2 | 2.0 | 1.2 | 3.0 | 0.6 | 0.4 | 15 | 8 |
| 3/4 | 2.5 | 1.5 | 4.0 | 0.8 | 0.5 | 20 | 12 |
| 1 | 3.0 | 1.8 | 5.0 | 0.9 | 0.6 | 25 | 15 |
| 1 1/4 | 4.0 | 2.4 | 6.0 | 1.2 | 0.8 | 35 | 18 |
| 1 1/2 | 5.0 | 3.0 | 7.0 | 1.5 | 1.0 | 45 | 22 |
| 2 | 7.0 | 4.0 | 10.0 | 2.0 | 1.3 | 55 | 28 |
| 2 1/2 | 8.0 | 5.0 | 12.0 | 2.5 | 1.6 | 65 | 34 |
| 3 | 10.0 | 6.0 | 15.0 | 3.0 | 2.0 | 80 | 40 |
| 3 1/2 | 12.0 | 7.0 | 18.0 | 3.6 | 2.4 | 100 | 50 |
| 4 | 14.0 | 8.0 | 21.0 | 4.0 | 2.7 | 125 | 55 |
| 5 | 17.0 | 10.0 | 25.0 | 5.0 | 3.3 | 140 | 70 |
| 6 | 20.0 | 12.0 | 30.0 | 6.0 | 4.0 | 165 | 80 |

**Table D-4. Head Loss, Equivalent Length of Pipe (in Feet)**

| | Ordinary Entrance | Sudden Enlargement | | | Sudden Contraction | | |
|---|---|---|---|---|---|---|---|
| | | d1 D4 | d1 D2 | d3 D4 | d1 D4 | d1 D2 | d3 D4 |
| Size of Pipe d (in inches) |   |   | | |   | | |
| 1/2 | 0.90 | 1.50 | 1.10 | 1.00 | 0.77 | 0.59 | 0.35 |
| 3/4 | 1.20 | 2.20 | 1.40 | 1.30 | 1.00 | 0.79 | 0.47 |
| 1 | 1.50 | 2.70 | 1.70 | 1.60 | 1.30 | 0.99 | 0.60 |
| 1 1/4 | 2.00 | 3.70 | 2.40 | 2.20 | 1.60 | 1.30 | 0.80 |
| 1 1/2 | 2.40 | 4.30 | 2.80 | 2.60 | 2.00 | 1.50 | 0.95 |
| 2 | 3.00 | 5.50 | 3.50 | 3.20 | 2.50 | 1.90 | 1.20 |
| 2 1/2 | 3.60 | 6.50 | 4.20 | 3.90 | 3.00 | 2.30 | 1.40 |
| 3 | 4.50 | 8.10 | 5.10 | 4.90 | 3.80 | 2.80 | 1.70 |
| 3 1/2 | 5.10 | 9.50 | 6.00 | 5.60 | 4.40 | 3.30 | 2.00 |
| 4 | 6.00 | 11.00 | 7.00 | 6.50 | 5.00 | 3.80 | 2.30 |
| 4 1/2 | 6.60 | 12.00 | 7.90 | 7.10 | 5.50 | 4.30 | 2.60 |
| 5 | 7.50 | 14.00 | 8.90 | 8.10 | 6.10 | 4.80 | 2.90 |
| 6 | 9.00 | 16.00 | 11.00 | 10.00 | 7.70 | 5.70 | 3.50 |
| 8 | 12.00 | 21.00 | 14.00 | 13.00 | 10.00 | 7.60 | 4.50 |
| 10 | 15.00 | 26.00 | 17.00 | 16.00 | 13.00 | 9.70 | 5.70 |
| 12 | 18.00 | 32.00 | 20.00 | 19.00 | 15.00 | 11.00 | 6.70 |

D-2. Refer to *Figures D-1 through D-5, pages D-7 through D-11*, to design and draw a water service line. These figures can also be used to determine pipe sizes.

D-3. Use the following steps and *Figure D-1* to determine the size of the pipe, the velocity, and the friction loss from Point A to Point B:

***Step 1.*** Locate the number along the bottom of the chart.

***Step 2.*** Locate the flow rate in GPM demand along the left side of the chart, using the GPM demand from Step 1.

***Step 3.*** Proceed to the right from the GPM scale and up from the bottom.

***Step 4.*** Locate the point at which these two values intersect. From this point, read left and stop at the first pipe size selection line. This is the size of pipe needed.

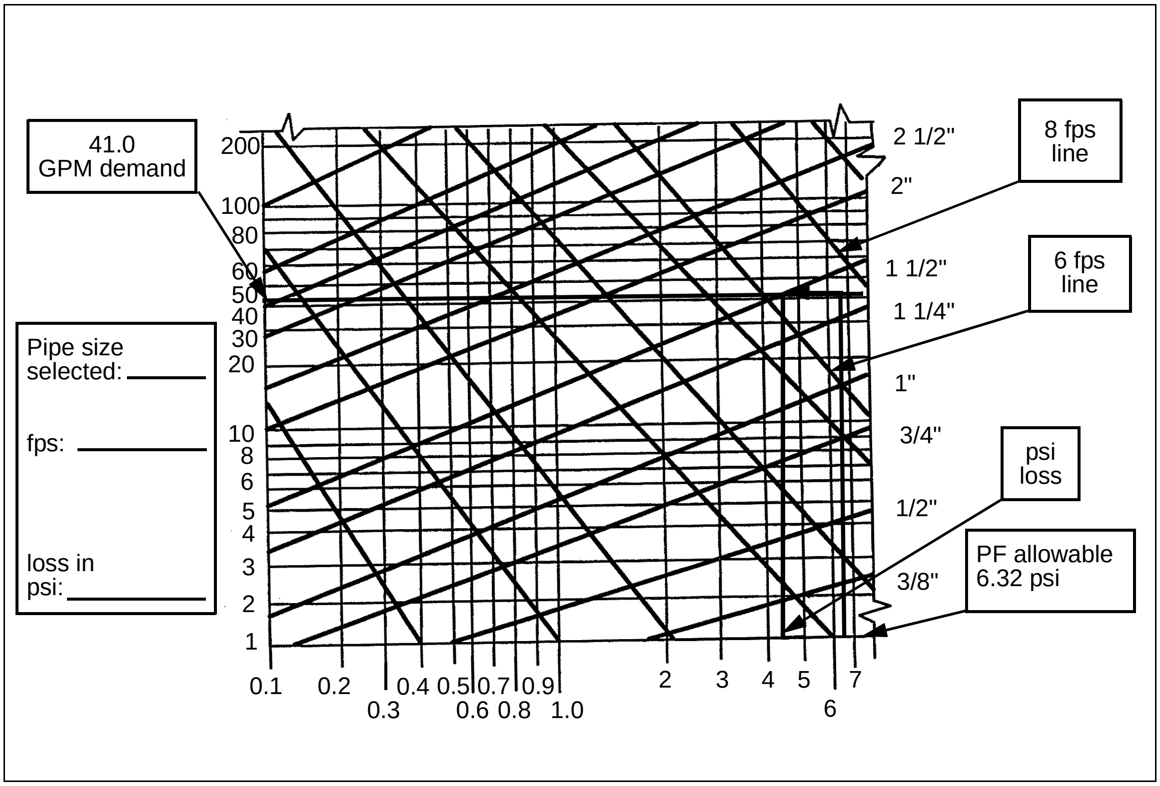



**Figure D-1. Friction Loss Using a Fairly Smooth Pipe**

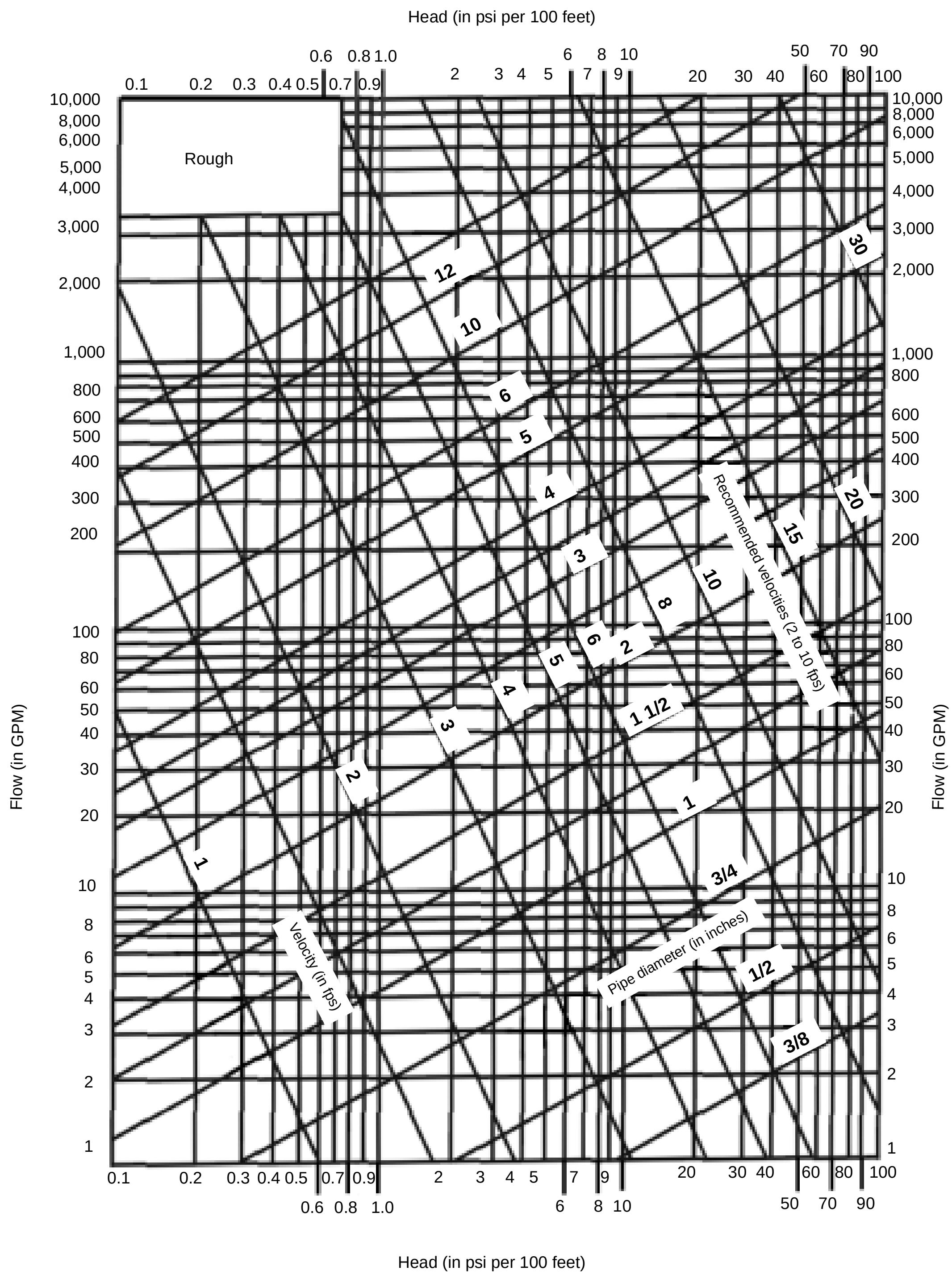



**Figure D-2. Friction Loss, Rough Pipe**

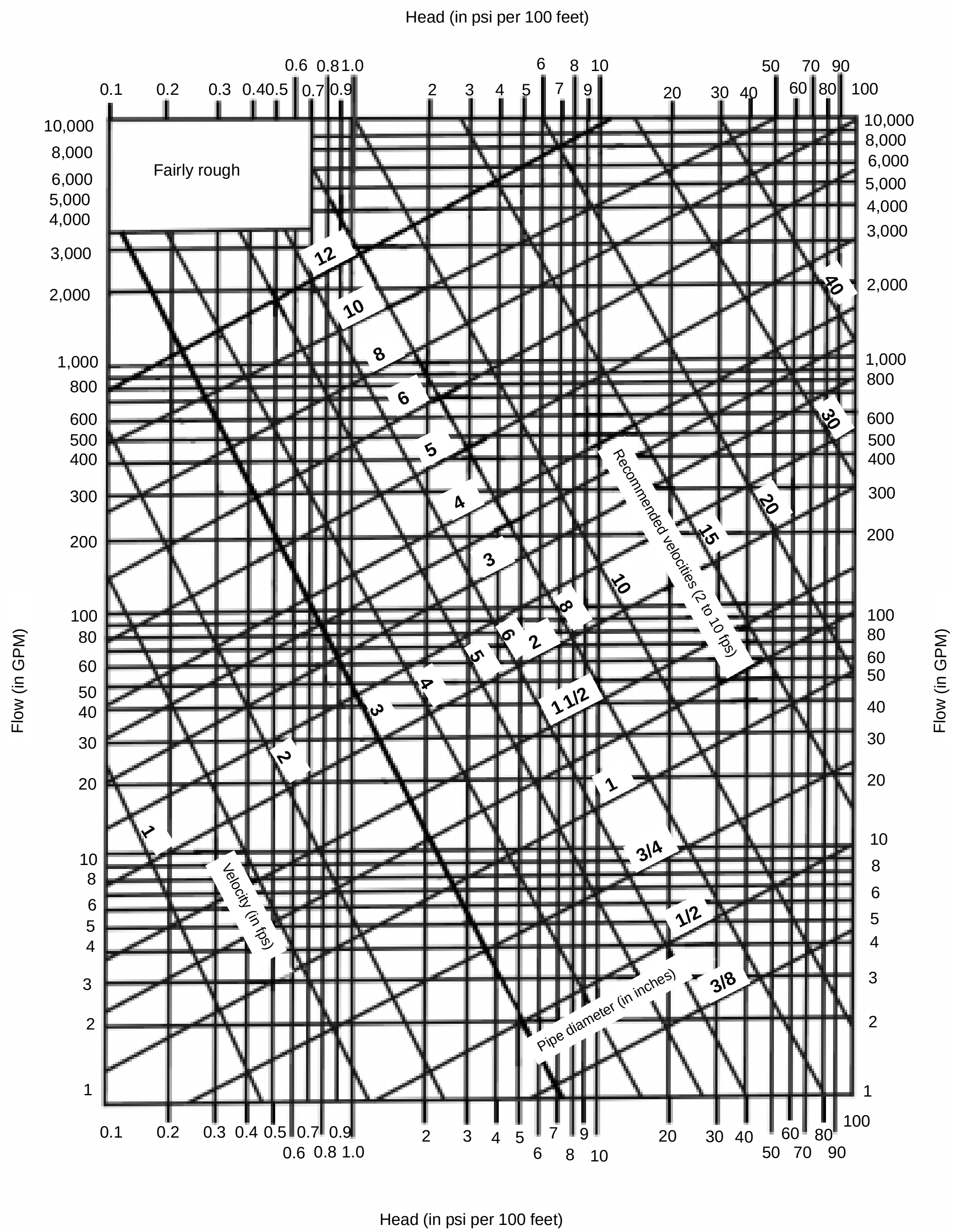



**Figure D-3. Friction Loss, Fairly Rough Pipe**

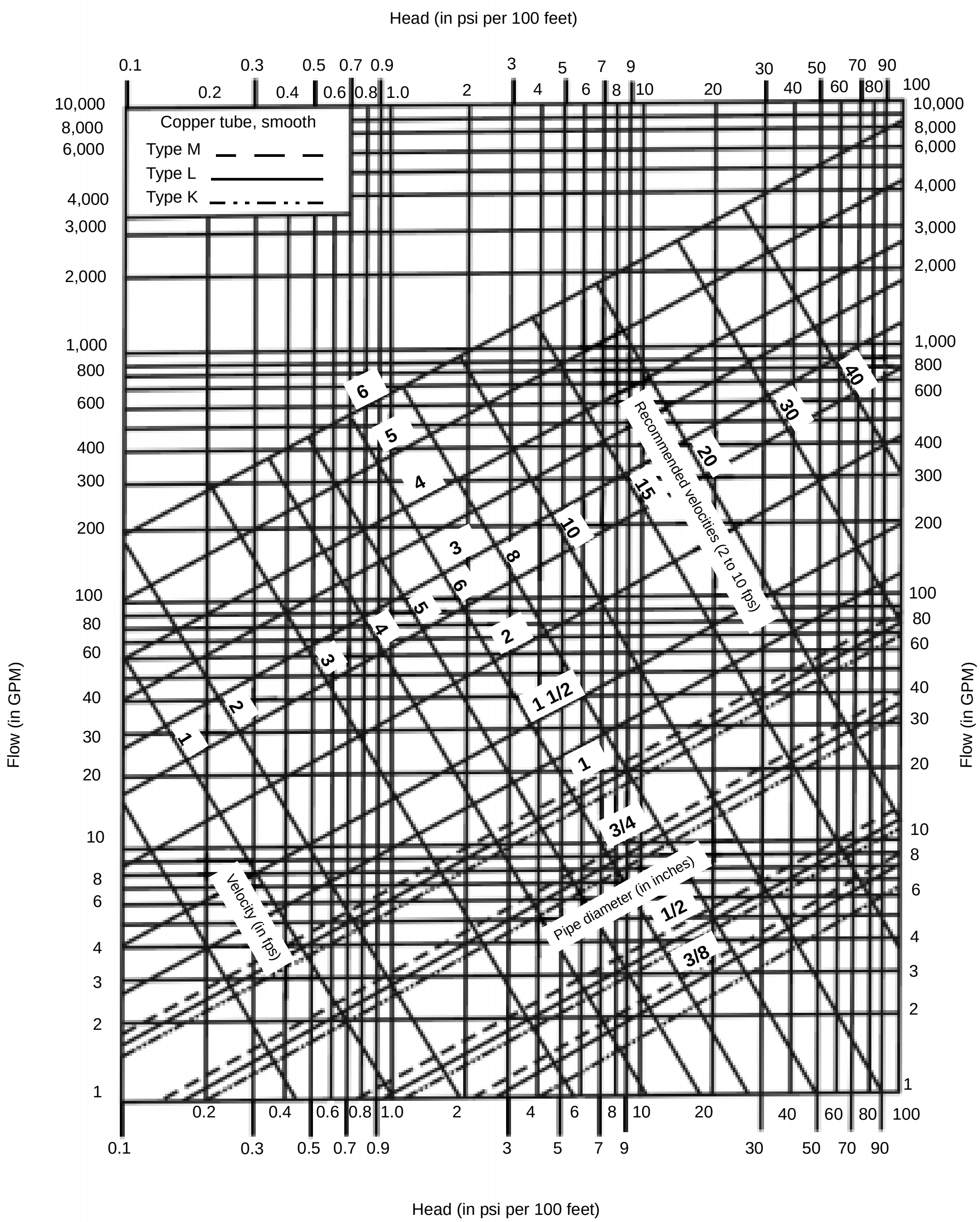



**Figure D-4. Friction Loss, Smooth Pipe**

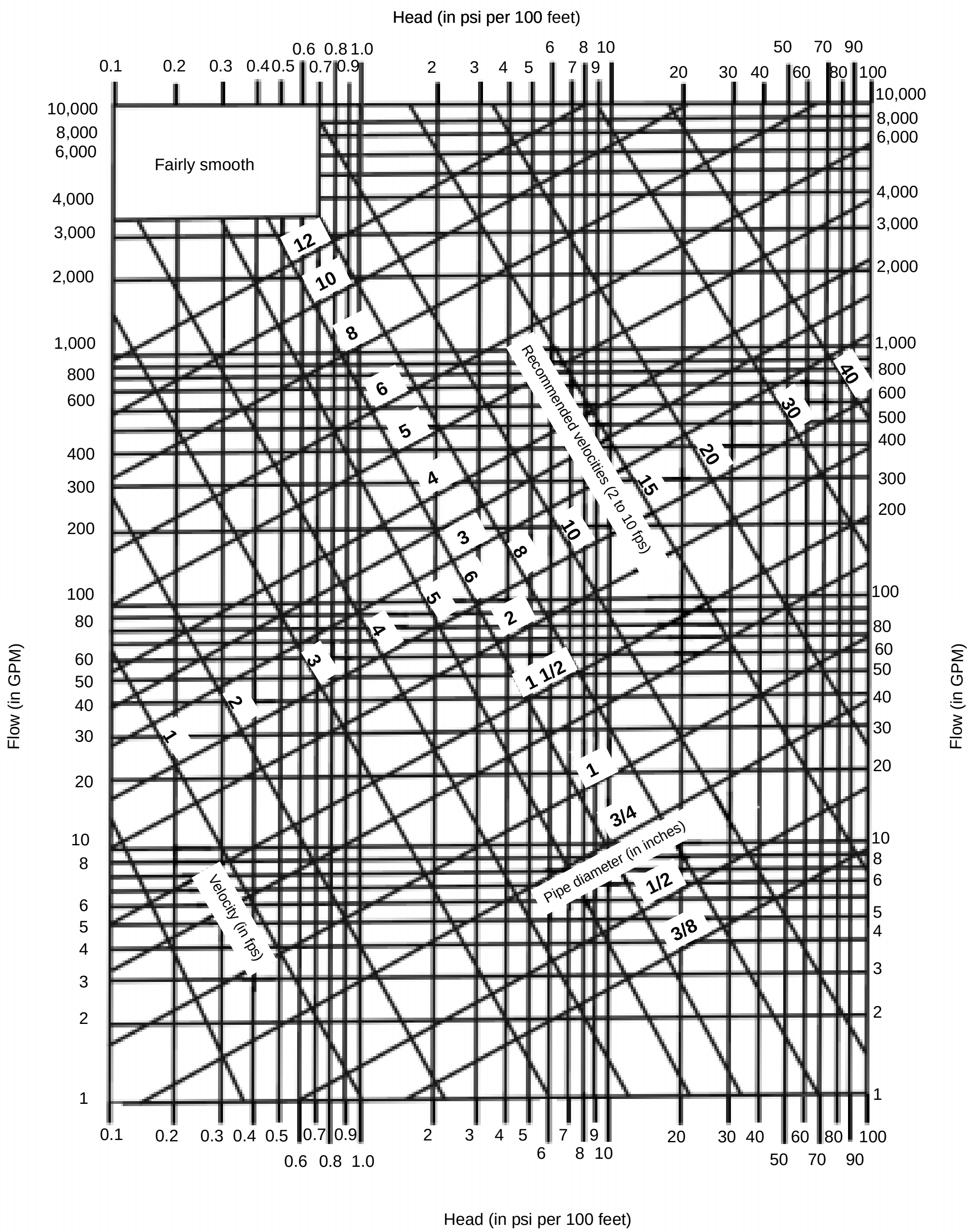



**Figure D-5. Friction Loss, Fairly Smooth Pipe**

# Appendix E

# Distribution Systems Design Procedures

## DESIGN PROCEDURES

### BASIC CONCEPTS

E-1. Water weighs 62.4 pounds per cubic ft ($lb/ft^3$)

#### Pressure

E-2. Pressure (P) is an expression, in psi ($lb/in^2$), of the total gravitational force (lb) exerted at the base of an imaginary 1-inch square ($in^2$) column of water—thus psi—of any column height or head (H) in feet (*Figure E-1*).

$$P(lbs/in^2) = \frac{62.4 lb/ft^3}{144 in^2/ft^2} \times H(ft); \quad P = 0.433H$$

So, for example, for a 10-foot column, or head of water (H) the pressure would be:

$$P(lbs/in^2) = \frac{62.4 lb/ft^3}{144 in^2/ft^2} \times 10(ft); \quad P = 0.433(10) = 4.33 \text{ psi}$$

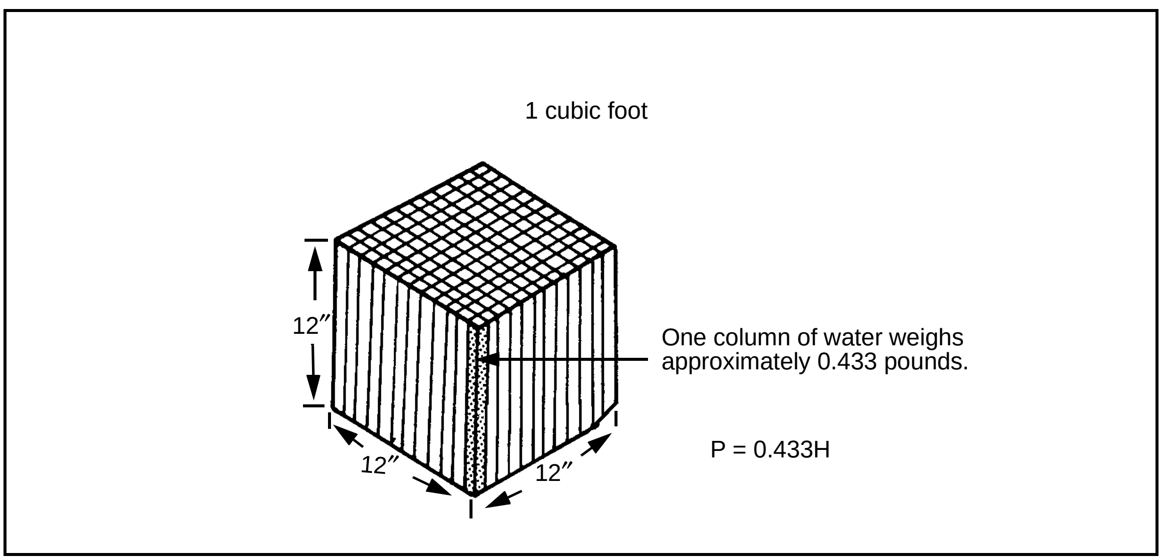



**Figure E-1. Water Pressure**

## Head

E-3. Conversely, "head" is another way to express the same total force exerted by the same column of water, expressed in feet.

From E-2:

$$P(psi) = 0.433H(ft) \quad \text{so}$$

$$H(ft) = \frac{P(psi)}{0.443} \quad or \quad H = 2.31P \qquad where\ P = pressure\ in\ psi$$

(Note: for any other liquid, the constant of 0.443 would change with any change in density).

So, for example, for a pressure of 4.33 psi, the head would be:

$$H = 2.31P \quad or \quad 2.31(4.33) = 10\ foot\ head$$

Another way to express this is "a 10-foot head of pressure" which is actually 4.33 psi.

E-4. **Static Head**. Static head is the height of a fluid at rest (no flow) (*Figure E-2*).

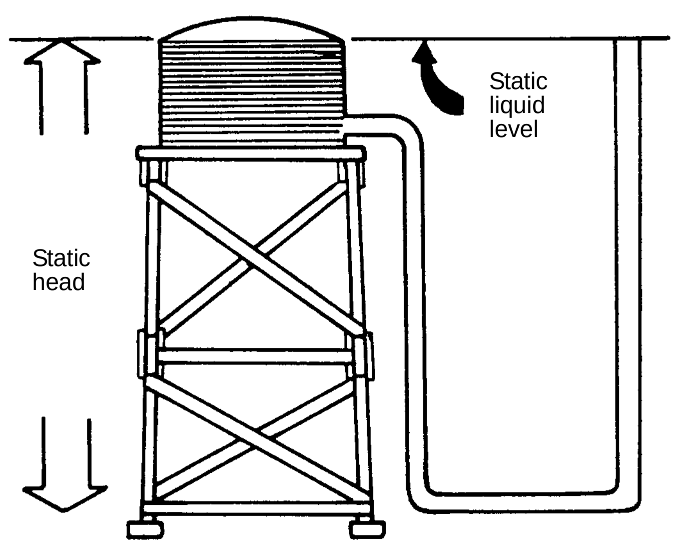



**Figure E-2. Static Head**

E-5. **Dynamic Head**. Dynamic head is static head minus the friction loss of a flowing liquid, expressed in feet (*Figure E-3*). It is also known as free-water surface (FWS) elevation.

*Dynamic head = Static head - Friction loss*

## DEFINITIONS

E-6. Use the following definitions to identify equations:

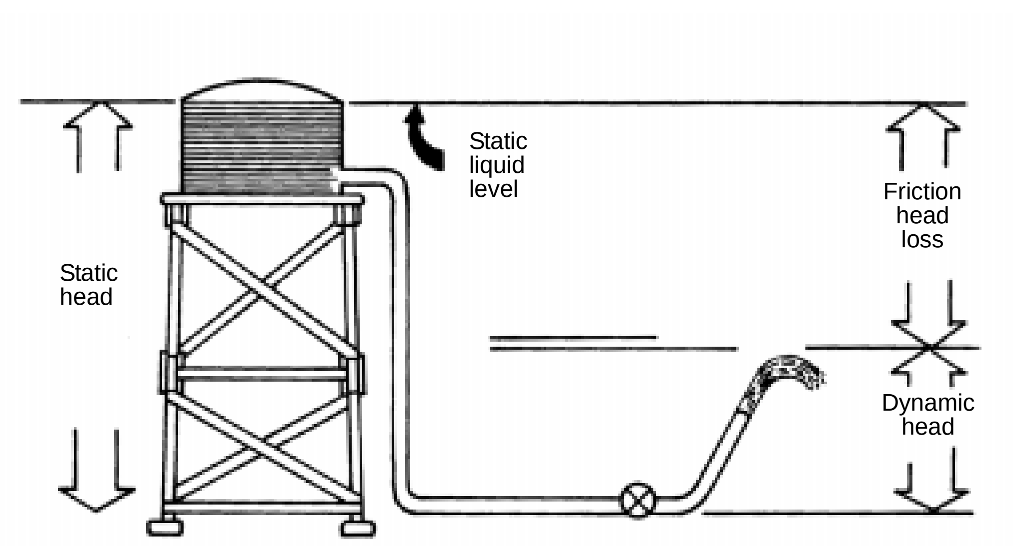



**Figure E-3. Relation of Static and Dynamic Heads**

- $Pf_{allowable}$ The maximum pressure that can be lost from all sources of friction without falling below the required service-connection pressure. (Minimum service-connection pressure in the TO is 20 psi.)
- $Pf_{actual}$ The pressure loss from all sources of friction in a pipe segment.
- $PF_{allowable}$ The allowable pressure loss in a 100-foot section.
- $PF_{actual}$ The actual pressure loss in a 100-foot section.
- *Equivalent Length (EL).* The length of a fitting or valve expressed in feet of straight pipe that produces the same amount of friction loss.
- *Pressure at Service Connection (PSC).* The actual pressure that will be provided to the user (building or facility).

## DYNAMIC WATER DISTRIBUTION SYSTEM DESIGN

E-7. Dynamic water distribution systems are designed using the procedures below. When working the two examples that follow, refer back to the procedures below.

### DESIGN PROCEDURES

E-8. Use the following steps to perform design procedures:

***Step 1.*** Determine the quantity (Q) of the flow rate, in GPM.

***Step 2.*** Determine $Pf_{allowable}$ for each line.

$$Pf_{allowable} = H(E_1 - E_2) - \text{required pressure}$$

*where —*

$Pf_{allowable}$ = *allowable pressure loss, in psi*

H = height (0.433)

*E1 = higher elevation, in feet*

*E2 = lower elevation, in feet*

***Step 3.*** Determine the pipe length (in feet).

***Step 4.*** Determine $PF_{allowable}$ in a 100-foot section of pipe.

$$PF_{allowable} = \frac{Pf_{allowable}}{\text{total system length}} \times 100'$$

*where —*

$PF_{allowable}$ = *allowable pressure loss in a 100-foot pipe section, in psi*

$Pf_{allowable}$ = *allowable pressure loss, in psi*

The total system length is in feet.

Find the fluid's actual velocity, which should be between 2 and 10 fps, and find $PF_{actual}$ (from *Figures D-1 to D-5, pages D-7 through D-11*).

***Step 5.*** Determine the size of the pipe and the velocity, and $PF_{actual}$ (from *Tables D-3 and D-4, pages D-5 through D-6*).

***Step 6.*** Determine $Pf_{actual}$

$$Pf_{actual} = \frac{PF_{actual}}{100'} \times \text{system length}$$

*where —*

$Pf_{actual}$ = actual pressure loss from all sources, in psi

$PF_{actual}$ = actual pressure loss in a 100-foot pipe section, in psi

System length is in feet.

***Step 7.*** Determine the equivalent pipe length (EL) for fittings. Go back to *Step 4* and recalculate $PF_{allowable}$. If the pipe size changes in the appropriate friction loss table (*Figure D-1 through D-5, pages D-7 through D-11*), then find the new velocity and $PF_{actual}$ from *Figures D-1 through D-4*. EL is negligible if there is 1,000 feet or more between fittings.

***Step 8.*** Determine *free-water surface (FWS)* elevation.

$$FWS = E_{BT} - (H \times Pf_{actual})$$

*where —*

$FWS$ = *free water surface, in feet*

$E_{BT}$ = *elevation at bottom of the tank, in feet*

$H$ = *height or head (constant 2.31)*

$Pf_{actual}$ = *actual pressure factor (from Step 6), in psi*

***Step 9.*** Determine the pressure at the service connection.

$$P_{SC} = H(E_{BT} - E_{SC}) - Pf_{actual}$$

*where —*

$P_{SC}$ = *pressure at the servicice connection, in psi*

$H$ = *height (0.433)*

$E_{BT}$ = *elevation at bottom of the tank, in feet*

$E_{SC}$ = *elevation at the service connection, in feet*

## EXAMPLE - WATER LINE DESIGN 1

E-9. Use the following steps as an example to design a water line:

***Step 1.*** Determine the required Q from the tank to A.

$Q = 230$ *GPM (Figure E-4)*

***Step 2.*** Determine $Pf_{allowable}$

$Pf_{allowable} = H(E1 - E2)$ *- required pressure*

$0.433(135 - 70) - 20 = 8.14$ *psi*

***Step 3.*** Determine the pipe length. Pipe length given is 1,300 feet (*Figure E-4*).

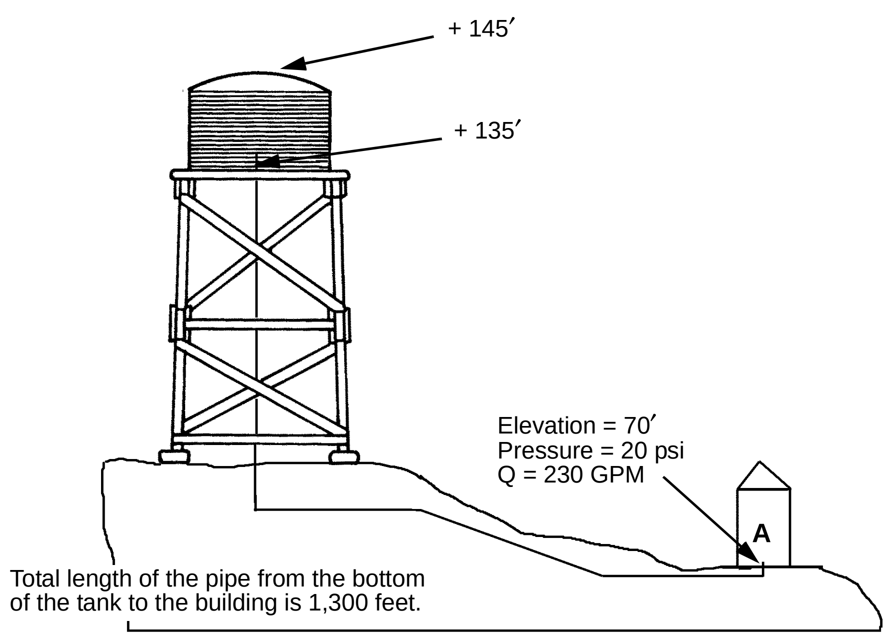



**Figure E-4. Water Line, Design 1**

***Step 4.*** Determine $Pf_{allowable}$ in a 100-foot section.

$$PF_{allowable} = \frac{Pf_{allowable}}{total\ system\ length} \times 100'$$

$$\frac{8.14}{1,300'} \times 100' = 0.63\ psi$$

***Step 5.*** Select a 6-inch diameter pipe and a velocity of 2.6 fps (intersection of selected pipe and Q). See *Figure D-3, page D-9*.

***Step 6.*** Determine $Pf_{actual}$

$$Pf_{actual} = \frac{PF_{actual}}{100'} \times system\ length$$

$$\frac{0.29}{100'} \times 1,530.5' = 4.44\ psi$$

***Step 7.*** Determine the EL. EL is 230.5 feet (refer to *page E-4, Step 7*).

***Step 8.*** Not applicable.

***Step 9.*** Determine the pressure at the service connection.

$$P_{sc} = H(E_{BT} - E_{SC}) - Pf_{actual}$$

$$0.433(135 - 70) - 4.44 = 23.7\ psi$$

## EXAMPLE - WATER LINE DESIGN 2

E-10. Use the following steps as an example to design a water line:

***Step 1.*** Determine Q from Tank to A.

$Q = Q_B + Q_C$ (Use *Table E-1* to find the fixture unit (FU) values and *Table E-2* to find flow rate quantity (Q) demands.)

**Table E-1. Fixture Unit Values**

| Type of Fixture | Fixture Unit Value |
|---|---|
| Water closet (flush valve) | 10.0 |
| Water closet (flush valve) | 5.0 |
| Urinal (1-inch flush valve) | 10.0 |
| Urinal (3/4-inch flush valve) | 5.0 |
| Shower head | 4.0 |
| Kitchen sink | 4.0 |
| Lavatory (bathroom) sink | 2.0 |
| Service (stop) sink | 3.0 |
| Laundry tub (dishwasher) | 3.0 |
| Laundry (wash) machine, 8 pounds | 3.0 |
| Laundry (wash) machine, 16 pounds | 4.0 |
| Water fountain | 0.25 |
| NOTES:<br>1. If the type of water closet is not specified, the TO standard for water closets is with a flush valve (fixture unit valve = 10.0).<br>2. If the type of urinal is not specified, the TO standard for urinals is with a 3/4-inch flush valve (fixture unit valve = 5.0). | |

**Table E-2. Flow Rate Quantity Demands**

| Supply System Predominantly for Flush Tanks | | Supply System Predominantly for Flushometers | |
|---|---|---|---|
| **Load (in Water Supply Fixture Units)** | **Demand (in GPM)** | **Load (in Water Supply Fixture Units)** | **Demand (in GPM)** |
| 6 | 5.0 | | |
| 8 | 6.5 | | |
| 10 | 8.0 | 10 | 27.0 |
| 12 | 9.2 | 12 | 28.6 |
| 14 | 10.4 | 14 | 30.2 |
| 16 | 11.6 | 16 | 31.8 |
| 18 | 12.8 | 18 | 33.4 |
| 20 | 14.0 | 20 | 35.0 |
| 25 | 17.0 | 25 | 38.0 |
| 30 | 20.0 | 30 | 41.0 |
| 35 | 22.5 | 35 | 43.8 |
| 40 | 24.8 | 40 | 46.5 |
| 45 | 27.0 | 45 | 49.0 |
| 50 | 29.0 | 50 | 51.5 |
| 60 | 32.0 | 60 | 55.0 |
| 70 | 35.0 | 70 | 58.5 |
| 80 | 38.0 | 80 | 62.0 |
| 90 | 41.0 | 90 | 64.8 |
| 100 | 43.5 | 100 | 67.5 |
| 120 | 48.0 | 120 | 72.5 |
| 140 | 52.5 | 140 | 77.5 |
| 160 | 57.0 | 160 | 82.5 |
| 180 | 61.0 | 180 | 87.0 |
| 200 | 65.0 | 200 | 91.5 |
| 225 | 70.0 | 225 | 97.0 |
| 250 | 75.0 | 250 | 101.0 |
| 275 | 80.0 | 275 | 105.5 |
| 300 | 85.0 | 300 | 110.0 |
| 400 | 105.0 | 400 | 126.0 |
| 500 | 125.0 | 500 | 142.0 |
| 750 | 170.0 | 750 | 178.0 |
| 1,000 | 208.0 | 1,000 | 208.0 |
| 1,250 | 240.0 | 1,250 | 240.0 |
| 1,500 | 267.0 | 1,500 | 267.0 |
| 1,750 | 294.0 | 1,750 | 294.0 |
| 2,000 | 321.0 | 2,000 | 321.0 |
| 2,250 | 348.0 | 2,250 | 348.0 |
| 2,500 | 375.0 | 2,500 | 375.0 |
| 2,750 | 402.0 | 2,750 | 402.0 |
| 3,000 | 432.0 | 3,000 | 432.0 |
| 4,000 | 525.0 | 4,000 | 525.0 |
| 5,000 | 593.0 | 5,000 | 593.0 |
| 6,000 | 643.0 | 6,000 | 643.0 |
| 7,000 | 685.0 | 7,000 | 685.0 |
| 8,000 | 718.0 | 8,000 | 718.0 |

$$FU = WC(FU) + UR(FU)$$

$$FU_B = 1(10) + 2(10) = 30\ FU;\ therefore,\ Q_B = 41\ GPM$$

$$FU_C = 10(10) + 4(10) = 140FU;\ therefore\ Q_C = 775\ GPM$$

$$Q = 41 + 77.5 = 118.5\ GPM$$

**NOTE: The elevation at the bottom of the tank is used. This corresponds to the minimum (worst-case) operating pressure.**

***Step 2.*** Determine $Pf_{allowable}$

$$Pf_{allowable} = H(E_1 - E_2) - required\ pressure$$

$$Tank\ to\ B{:}\ 0.433(145 - 85) - 20\ psi = 5.98\ psi$$

$$Tank\ to\ C{:}\ 0.433(145 - 70) - 20\ psi = 12.48\ psi$$

***Step 3.*** Determine the pipe length (*Figure E-5*).

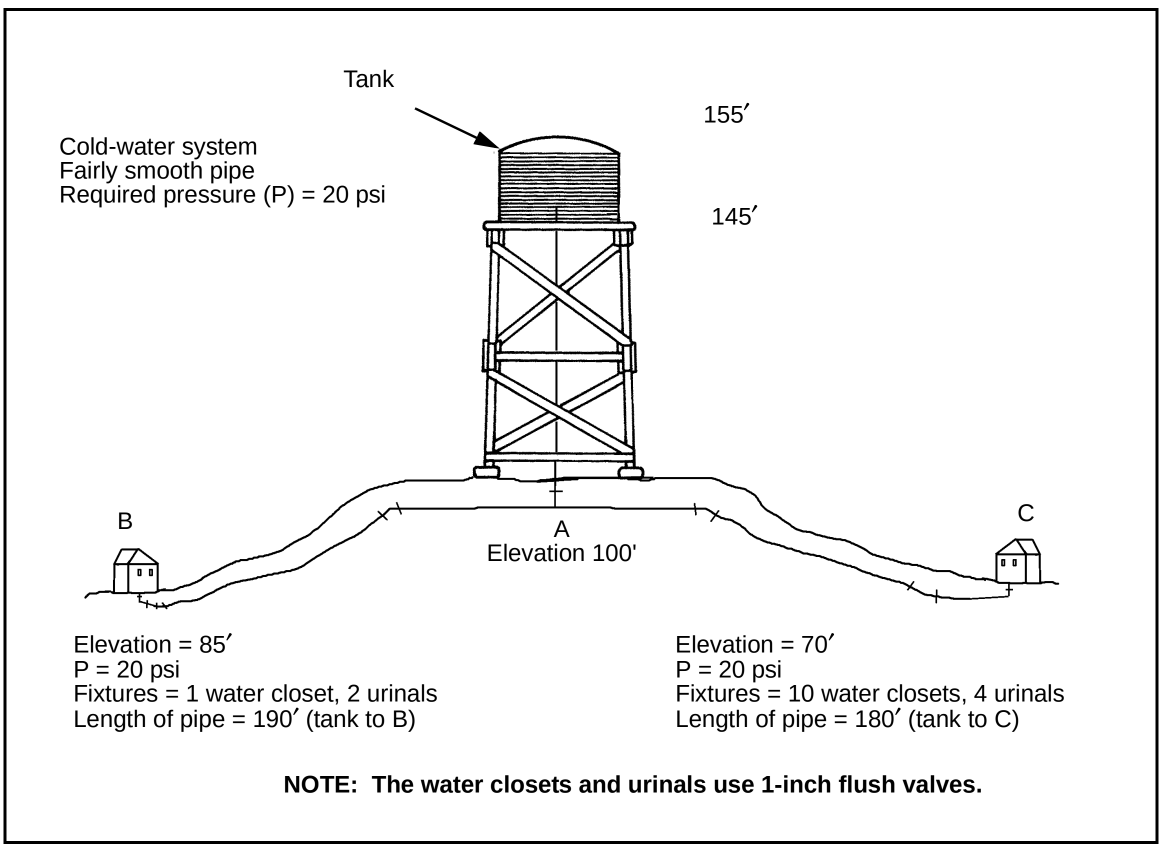



**Figure E-5. Water Line, Design 2**

***Step 4.*** Determine $PF_{allowable}$ in a 100-foot section.

$$PF_{allowable} = \frac{Pf_{allowable}}{total\ system\ length} \times 100'$$

$$Tank\ to\ B: \frac{5.98}{190} \times 100' = 3.14\ psi$$

$$Tank\ to\ C: \frac{12.48}{180} \times 100' = 6.93\ psi$$

Select that portion of the water line that allows for the least amount of pressure loss ($PF_{allowable}$). In this example, Tank to B is the smallest.

$PF_{actual}$ for Tank to C is 1.7 psi (*Figure D-4, page D-6*).

***Step 5.*** Select a 3-inch diameter pipe and a velocity of 5.0 fps (intersection of selected pipe and Q) (*Figure D-4*).

***Step 6.*** Determine $Pf_{actual}$

$$Pf_{actual} = \frac{PF_{actual}}{100'} \times system\ length$$

$$Tank\ to\ A: \frac{1.7}{100'} \times 45 = 0.77\ psi\ lost$$

***Step 7.*** Not applicable.

***Step 8.*** Determine the FWS elevation for the tank to A.

$$FWS_A = E_{BT} - (H \times PF_{actual})$$

$$145 - (2.31 \times 1.7) = 141\ feet$$

***Step 9.*** Not applicable.

## DESIGN A TO C

E-11. Use the following steps when performing Design A to C:

***Step 1.*** Determine Q from A to C.

$$Q_C = 77.5\ (from\ Step\ 1,\ Example\ Water\ Line\ Design\ 2)$$

***Step 2.*** Determine $Pf_{allowable}$

$$Pf_{allowable} = H(E_1 - E_2) - required\ pressure$$

$$0.433(143 - 70) - 20\ psi = 11.6\ psi$$

***Step 3.*** Determine the length of the pipe (*Figure E-5*).

$$Total\ length = length\ T\ to\ C - length\ T\ to\ A$$

$$180' - 45' = 135'$$

***Step 4.*** Determine $PF_{allowable}$ in a 100-foot section.

$$PF_{allowable} = \frac{Pf_{allowable}}{total\ system\ length} \times 100'$$

$$\frac{11.6}{135'} \times 100' = 8.6\ psi$$

***Step 5.*** Select a 2-inch diameter pipe and a velocity of 7.6 fps (intersection of selected pipe and Q).

***Step 6.*** EL for A to C is 28.4.

***Step 7.*** Determine $PF_{allowable}$ in a 100-foot section.

$$A\ to\ C: \frac{11.6}{135' + 28.4'} \times 100' = 7.09\ psi$$

***Step 8.*** Determine $Pf_{actual}$

$$Pf_{actual} = \frac{PF_{actual}}{100'} \times system\ length$$

$$\frac{5.3}{100'} \times 163.4 = 8.66\ psi$$

***Step 9.*** Determine FWS. $FWS_A$ = 143 feet.

***Step 10.*** Determine pressure service connection at C.

$$P_{SC} = H(E_{BT} - E_{SC}) - PF_{actual}$$

$$0.433(143 - 70) - 8.92 = 22.7\ psi$$

All system parameters are within acceptable limits. No redesign is neccessary.

## DESIGN A TO B

E-12. Use the following steps when performing Design A to B:

***Step 1.*** Determine Q from A to B.

$$Q_B = 41\ (from\ Step\ 1, Example\ Water\ Line\ Design\ 2)$$

***Step 2.*** Determine $Pf_{allowable}$

$$Pf_{allowable} = H(E1 - E2) - required\ pressure$$

$$0.433(143 - 85) - 20\ psi = 5.1\ psi$$

***Step 3.*** Determine the length of the pipe (*Figure E-5, page E-8*).

$$Total\ length = length\ T\ to\ B - length\ T\ to\ A$$

$$190' - 45' = 145'$$

***Step 4.*** Determine $PF_{allowable}$ in a 100-foot section.

$$PF_{allowable} = \frac{Pf_{allowable}}{total\ system\ length} \times 100'$$

$$\frac{5.1}{145} \times 100' = 3.52\ psi$$

***Step 5.*** Select a 2-inch pipe diameter with a velocity of 4.2 fps (intersection of selected pipe and Q). See *Figure D-4, page D-6*.

***Step 6.*** EL for A to B is 28.4.

***Step 7.*** Determine $PF_{allowable}$ in a 100-foot section.

$$A\ to\ B:\ \frac{5.1}{145' + 28.4'} \times 100' = 2.94\ psi$$

***Step 8.*** Determine $Pf_{actual}$

$$Pf_{actual} = \frac{PF_{actual}}{100'} \times system\ length$$

$$\frac{1.9}{100'} \times 178.4' = 3.39\ psi$$

***Step 9.*** Determine the FWS. $FWS_A$ = 143 feet.

***Step 10.*** Determine the pressure at service connection B.

$$P_{SC} = H(E_{BT} - E_{SC}) - Pf_{actual}$$

$$0.433(143 - 85) - 3.39\ psi = 21.7\ psi$$

System parameters are within acceptable limits.