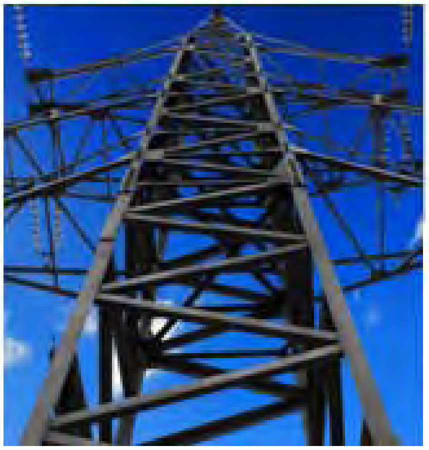

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Hydraulics for Sprinkler Systems with Typical Branch Lines

Occupancy classification

Any hydraulic design of sprinkler systems must begin with an analysis of the commodity being protected. The National Fire Protection Association, Standard No. 13 *“Installation of Sprinkler Systems”* (NFPA-13) defines three basic commodity classification: Light Hazard, Ordinary Hazard and Extra Hazard. These classifications are defined in NFPA-13 and examples are given in that document.

Ordinary Hazard occupancies are divided into two categories: Ordinary Hazard Group 1 and Ordinary Hazard Group 2. Extra Hazard occupancies are also divided into two categories: Extra Hazard Group 1 and Extra Hazard Group 2.

Once a hazard classification is chosen for a known occupancy, the water requirements may be established from NFPA-13, (2007) Figure 11.2.3.1.1

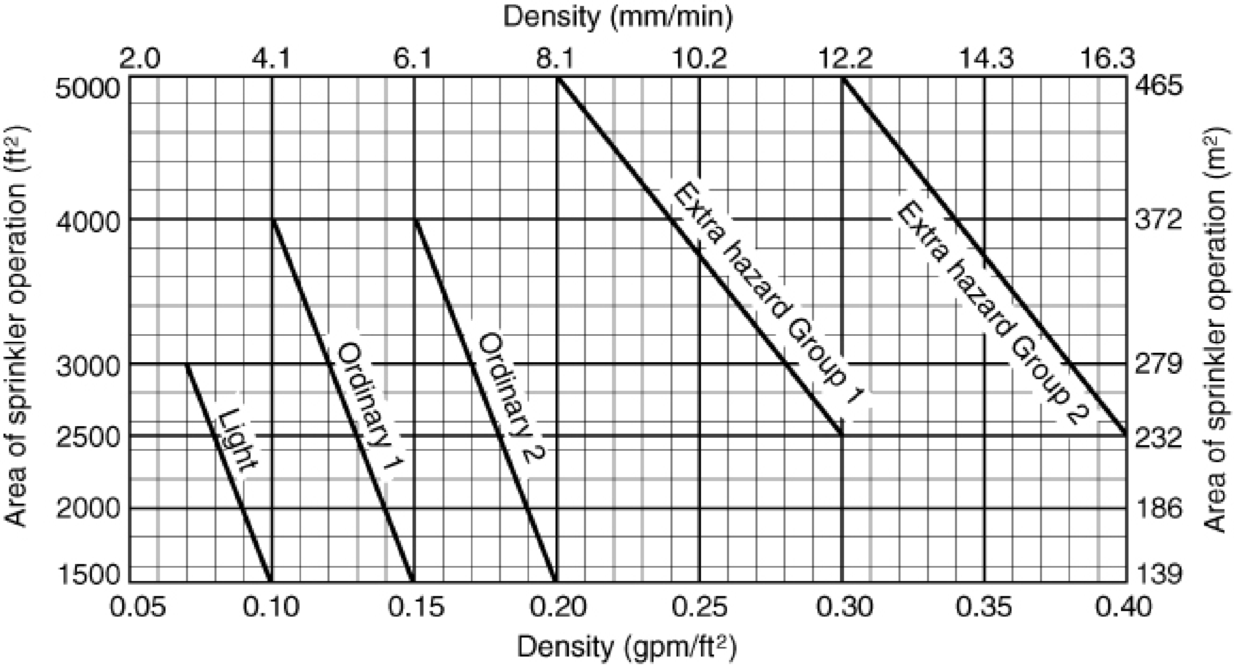

FIGURE 11.2.3.1.1

Density/Area Curves.

[1]

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Densities and Remote Areas

NFPA-13, (2007) Figure 11.2.3.1.1 displays five density/area curves overlain on a graph. These five curves correspond to the previously discussed hazard classifications: Light Hazard, Ordinary Group 1 Hazard, Ordinary Group 2 Hazard, Extra Hazard Group 1 and Extra Hazard Group 2.

These curves stipulate the required minimum densities and remote areas that establish minimum water requirements for sprinkler systems.

Definition:

Density – *the amount of water that must be delivered every minute for every square foot of floor space The English units for density is (gallons per minute per square foot (gpm/sq.ft.) For example, a Light Hazard occupancy could be designed for a density of 0.1-gpm/sq.ft. This means that 0.1-gallons must discharge every minute for every square foot of floor space over a specified area.*

Definition:

Remote Area – *the minimum area of floor space over which the density must discharge.*

As an example, Figure 11.2.3.1.1 indicates that an acceptable design for an Ordinary Hazard Group 1 occupancy is 0.15-gpm/sq.ft. over 1500-sq.ft.

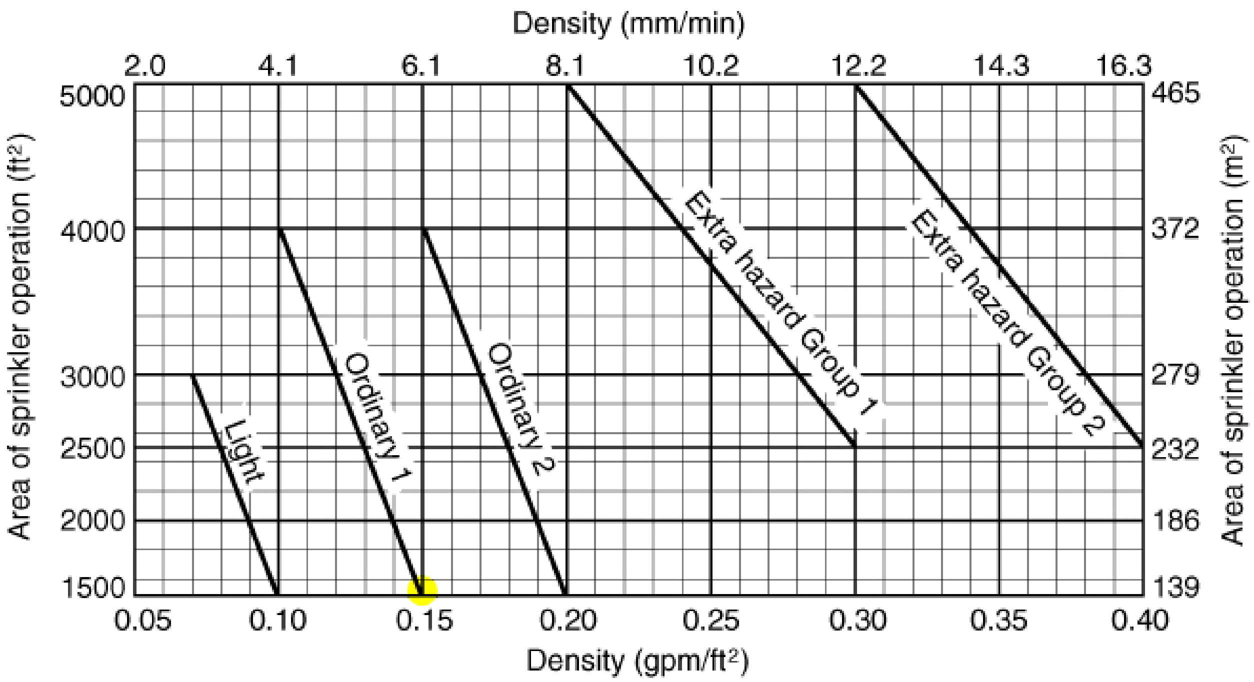

FIGURE 11.2.3.1.1

Density/Area Curves.

[2]

This means the sprinkler system designer will choose the most hydraulically demanding 1500-sq.ft. of the sprinkler system layout and perform a calculation of all sprinklers within that 1500-sq.ft. area. Therefore, only a portion of sprinklers on a sprinkler system are expected to operate during a typical fire, not all. If all sprinklers on a sprinkler system operate the water supply most likely will not be adequate to control the fire.

Below is an example remote area for an Ordinary Group 1 occupancy, which in this example is a 1500-sq.ft. remote area. Note the remote area contains fifteen sprinklers which are numbered 1 – 15. The most hydraulically remote sprinkler is sprinkler #1, since it is physically the mort remote. There are cases when the physically remote sprinkler will not be the hydraulically remote. If the hydraulically remote sprinkler is not evident, additional calculations can be performed to verify.

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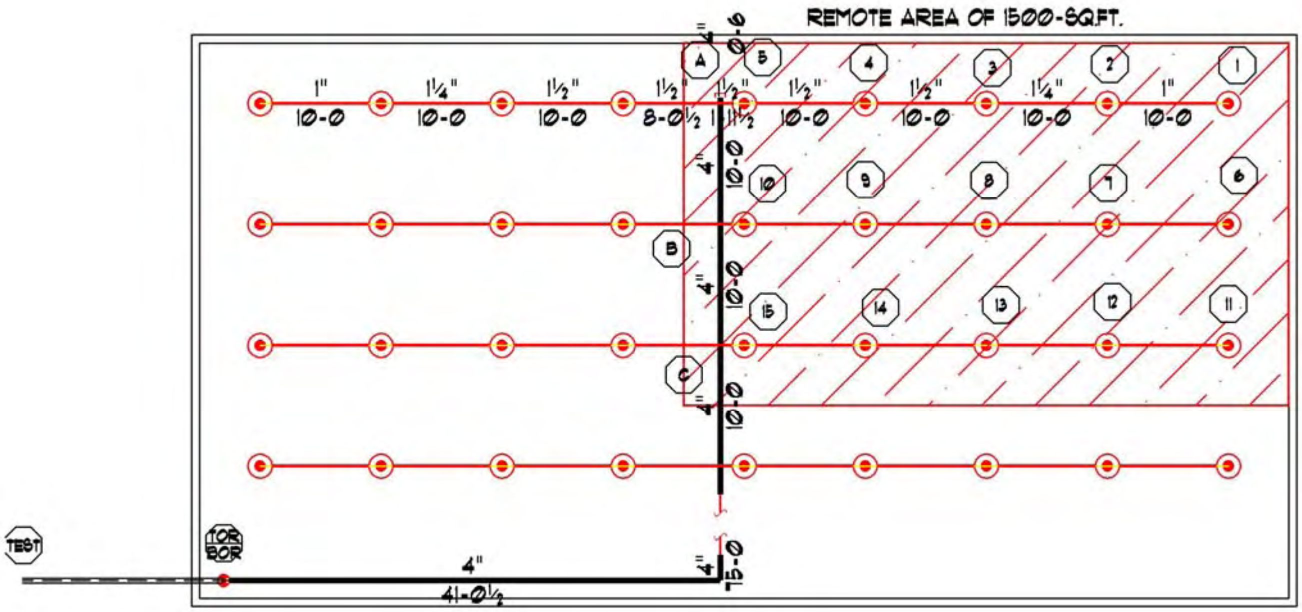

Remote Area #1

End sprinkler start conditions

Once the hydraulic requirements are selected for the occupancy, the hydraulic calculation of the sprinkler system may begin. In modern times sprinkler system hydraulics are performed by computer programs. However, in the early days of sprinkler system hydraulic design all systems were calculated with a calculator as we will do here. A thorough understanding of these principles is not required to perform calculations on a hydraulic calculation program but these are the principles on which the program operates. A better understanding of these principles will allow the designer to better understand how the sprinkler system will function hydraulically.

The density/area curves will tell the designer the starting point of the design. Our example is an Ordinary Hazard Group 1 occupancy and we will choose the point on the density/area curve of 0.15-gpm/sq.ft. over 1500-sq.ft.

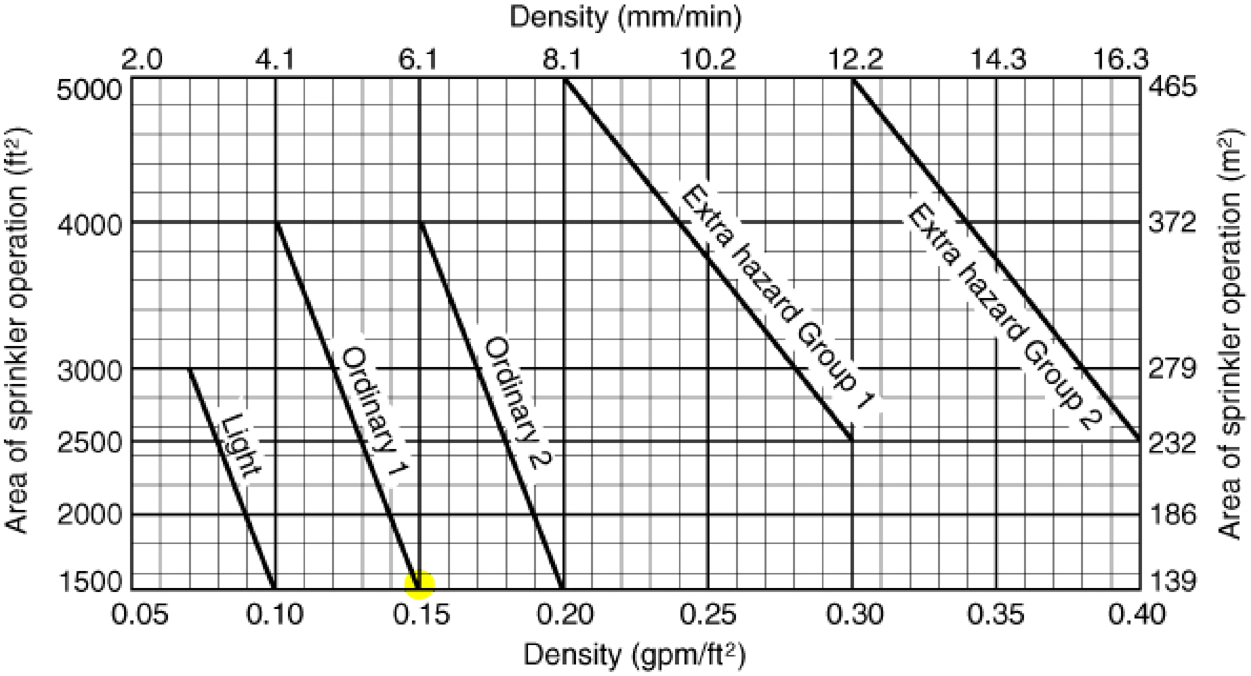

FIGURE 11.2.3.1.1

Density/Area Curves.

[3]

This means that every square foot of the 1500-sq.ft. remote area must be covered with at least 0.15-gpm. By extension, this means that the floor area under each sprinkler, called the Protection Area of

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Coverage, must be provided with 0.15-gpm/sq.ft. In other words, each sprinkler must discharge enough water to provide a minimum of 0.15-gallons per minute for every square foot it protects.

Definition:

Protection Area of Coverage – *the floor area protected by an individual sprinkler.*

$$A_c \text{ x } D = Q_s$$

Where:
Q_s = Flow from individual sprinkler
A_c = Protection Area of Coverage for individual sprinkler
D = Density

Therefore, 130-sq.ft. x $\frac{0.15-gpm}{sq.ft.}$ = 19.5-gpm.

The end sprinkler must discharge 19.5-gallons every minute over the 130-sq.ft. it protects in order to meet the minimum density requirement of NFPA-13. We might start the calculation process at this point, however there is one other item that must be verified. NFPA-13, (2007) section 22.4.4.10.1 states that no sprinkler may operate at less than 7-psi. This means that we must verify that our end sprinkler satisfies this condition. For our example, we have chosen a sprinkler with a k-factor of 8.0. The formula for determining the minimum flow from a sprinkler at a specified pressure is:

$$Q = k\sqrt{p}$$

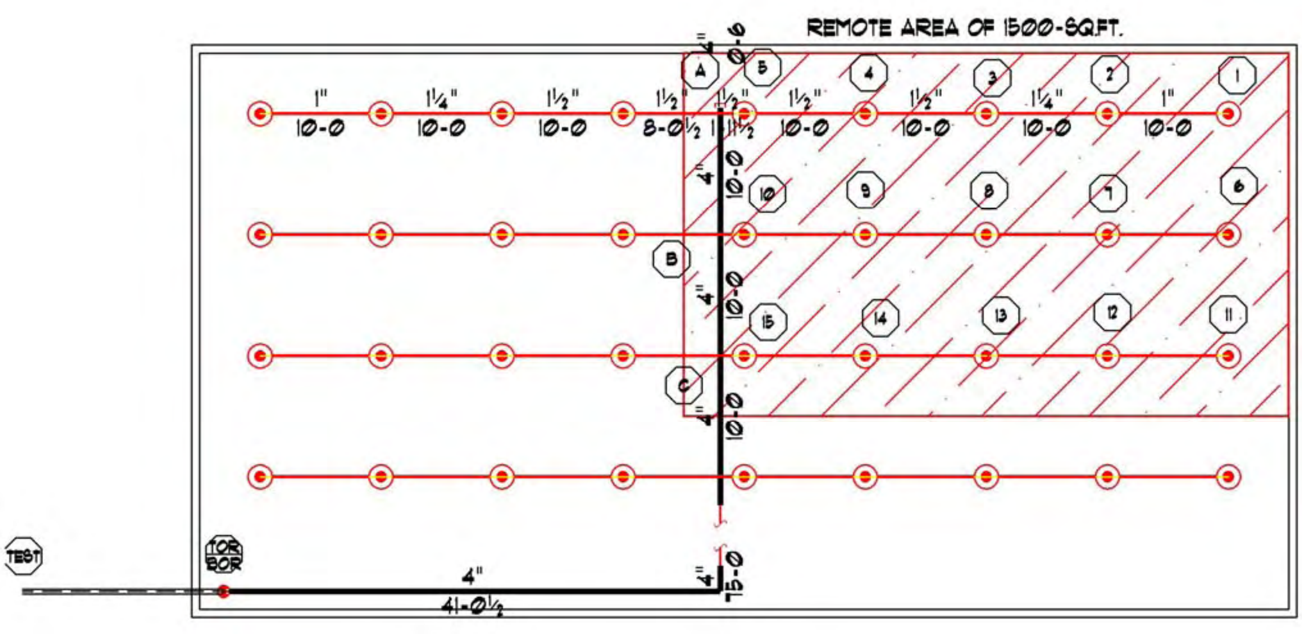
Where,
Q = Flow from individual sprinkler
k = Sprinkler k-factor (see NFPA-13, (2007) Table 6.2.3.1)
p = Pressure from an individual sprinkler.

Therefore, $Q = 8.0\sqrt{7}$ = 21.2-gpm.

Since the sprinkler in our example requires 21.2-gpm to meet the 7-psi requirement and only 19.5-gpm to meet the density requirement, we must start our end sprinkler at 21.2-gpm.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom			lgth				Pt	7	
1	Q	21.2	Act.			ftg				Pf		
						tot				Pe		
2	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
3	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
4	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now that we have our starting conditions entered. We must now calculate the pressure it takes to get our 21.2-gpm through the piece of pipe supplying sprinkler #1. Take a look again at our remote area:



Sprinkler #1 is supplied by a piece if 1-inch pipe that is 10-feet long. In order to calculate friction loss through this pipe, we must learn to use the Hazen-Williams friction loss formula.

Hazen-Williams Friction Loss Formula

You will find the Hazen-Williams friction loss formula in NFPA-13 (2007), section 22.4.2.1.1. It is as follows:

$$P_f = \frac{4.52 \times Q^{1.85} \times L}{C^{1.85} \times D^{4.87}}$$

Where,
P_f = Total friction loss in piece of pipe (psi)
Q = Total flow in pipe (gpm)
L = Length of pipe (feet)
C = C-factor of pipe (from NFPA-13 (2007) Table 22.4.4.7)
D = Diameter of pipe (inches)

These variables are all self-explanatory except for the C-factor. This variable simulates the internal roughness of the piece of pipe and differs depending on sprinkler system type and pipe type. NFPA-13, Table 22.4.4.7 indicates C Values as follows:

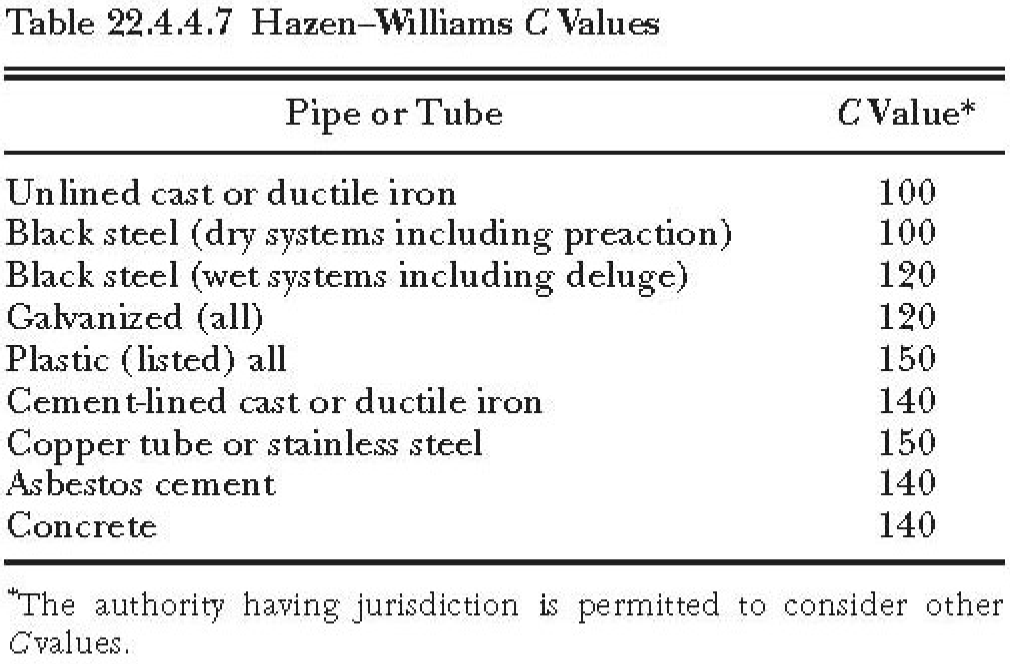


Table 22.4.4.7 Hazen–Williams *C* Values

Pipe or Tube	*C* Value*
Unlined cast or ductile iron	100
Black steel (dry systems including preaction)	100
Black steel (wet systems including deluge)	120
Galvanized (all)	120
Plastic (listed) all	150
Cement-lined cast or ductile iron	140
Copper tube or stainless steel	150
Asbestos cement	140
Concrete	140

*The authority having jurisdiction is permitted to consider other *C* values.

[4]

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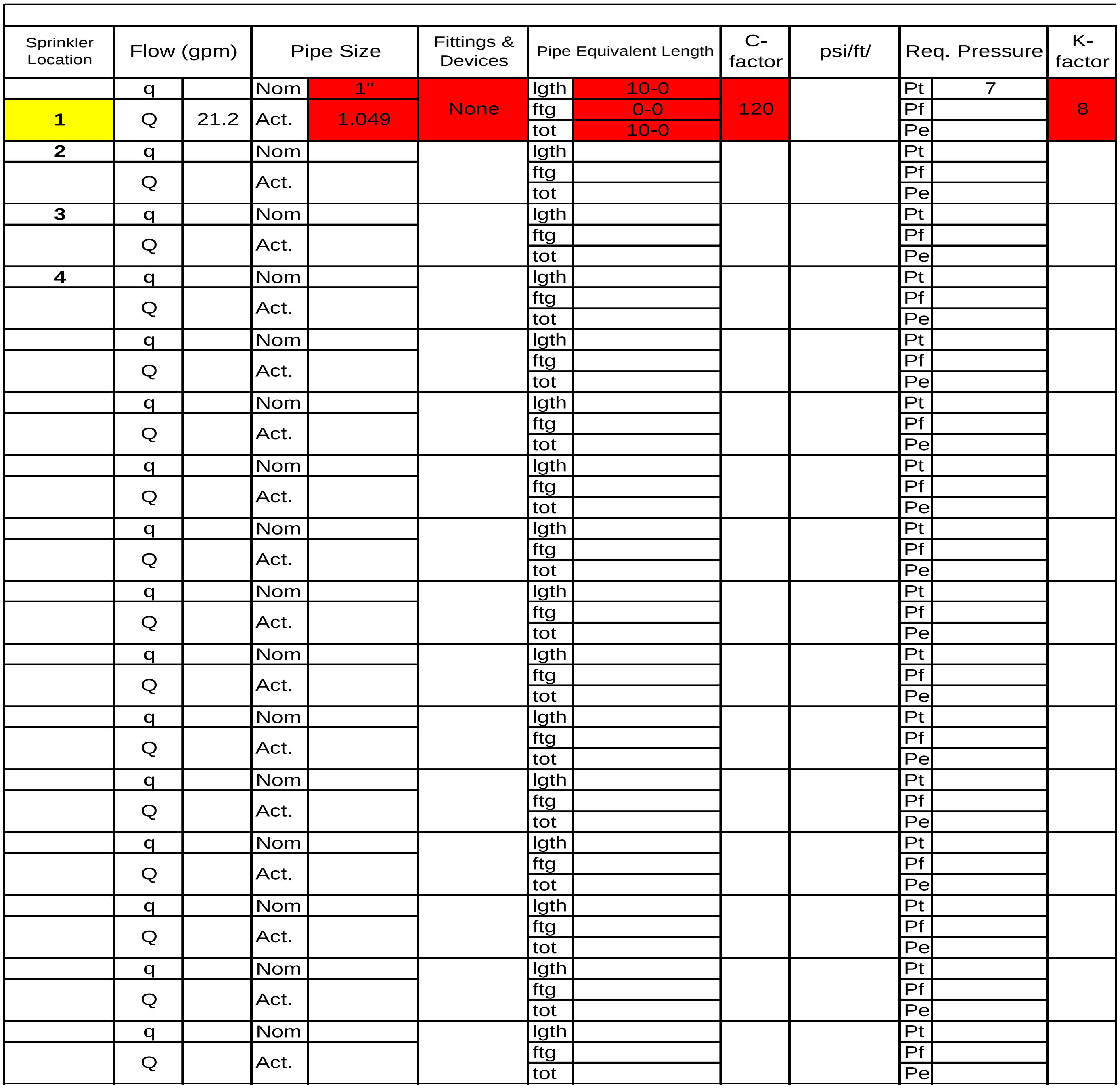
For our sample sprinkler system, will be use Black steel wet system which = C value of 120.

We will enter all of the appropriate information into our calculation formula sheet as follows:



Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf		
						tot	10-0			Pe		
2	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
3	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
4	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Notice the <u>actual</u> pipe diameter is entered in the worksheet and this is the value you will use in your friction loss calculation. Do not use the nominal diameter of 1.0-inches in the Hazen-Williams formula. Actual internal diameters of some pipes can be found in NFPA-13, Table A.6.3.2 or manufacturer's websites.

The pipe length of 10-0 is entered in the appropriate box but the fitting length is 0-0. There are no fittings in this piece of pipe that are required to be considered. A discussion of friction loss for fittings will occur later.

We now have enough information to perform the friction loss calculation in the pipe supplying sprinkler #1. It is as follows:

$$P_f = \frac{4.52 \times 21.2^{1.85} \times 10}{120^{1.85} \times 1.049^{4.87}} = 1.449\text{-psi}$$

This friction loss is now entered in the worksheet:

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
3	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
4	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
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	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Since there is no elevation change in the ends of this pipe, the pressure loss due to elevation is 0 and is also entered in the worksheet. Pressure loss due to elevation will be discussed later.

Now that we have the starting pressure at sprinkler #1 and the friction pressure required to get our 21.2-gpm to sprinkler #1, we can add these two to get the pressure needed at sprinkler #2.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q		Nom			lgth				Pt	8.5	
	Q		Act.			ftg				Pf		
						tot				Pe		
3	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
4	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
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	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
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						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now that we know the pressure at sprinkler #2, we can calculate the actual flow from sprinkler #2 with the increased pressure of 8.5-psi. This is done with the equation:

$Q = k\sqrt{p}$ which yields

$Q = 8.0\sqrt{8.5}$ = 23.3-gpm; this is entered in the appropriate place on the worksheet:

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom			lgth				Pt	8.5	
	Q		Act.			ftg				Pf		
						tot				Pe		
3	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
4	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
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	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
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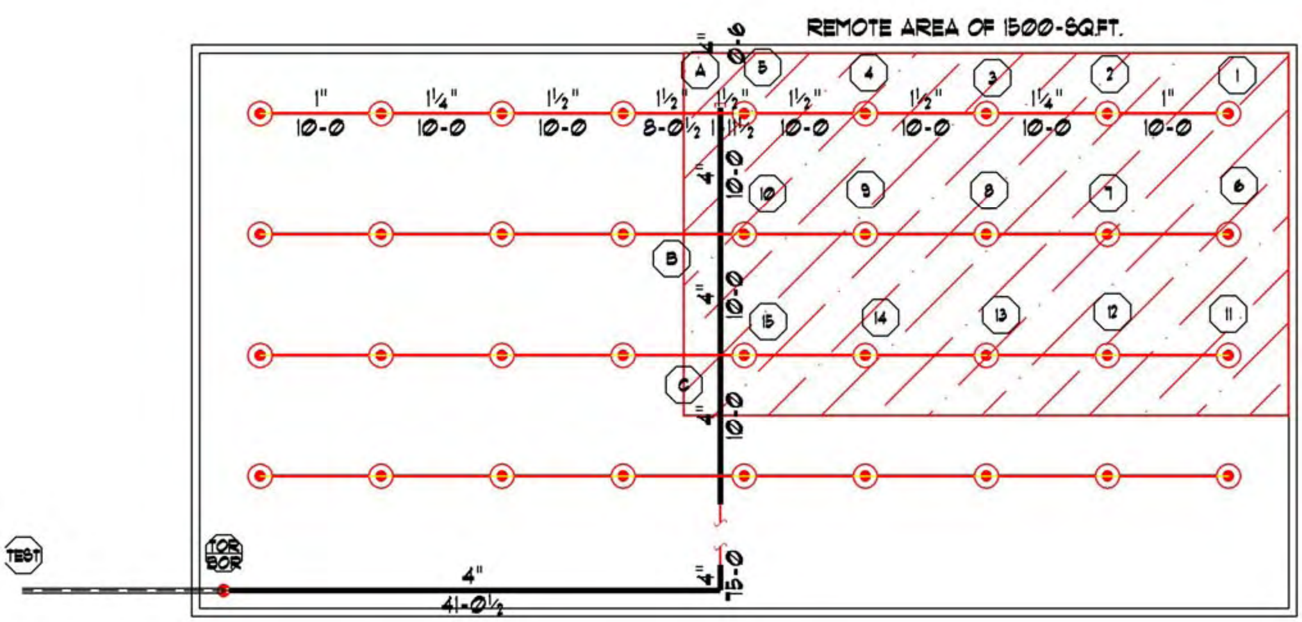
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now we add the flow from sprinkler #1 and sprinkler #2 to get the total flow through the pipe supplying sprinkler #2. Notice that the variable q = the flow from a single sprinkler and the variable Q = the total flow in the system.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom			lgth				Pt	8.5	
	Q	44.5	Act.			ftg				Pf		
						tot				Pe		
3	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
4	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now that we know the total flow in the pipe supplying sprinkler #2, we use the Hazen-Williams formula to calculate the friction loss pressure in the pipe supplying sprinkler #2.



The pipe supplying sprinkler #2 is a piece of 1 ¼-inch schedule 40 10-feet long, which would yield the following friction loss calculation:

$$P_f = \frac{4.52 \times 44.5^{1.85} \times 10}{120^{1.85} \times 1.38^{4.87}} = 1.50\text{-psi}$$

Enter all of the pipe information and friction loss data in the worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
4	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now we add the pressure at sprinkler #2 and the friction loss through the pipe supplying sprinkler #2 to get the pressure at sprinkler #3.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q		Nom			lgth				Pt	10.0	
	Q		Act.			ftg				Pf		
						tot				Pe		
4	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

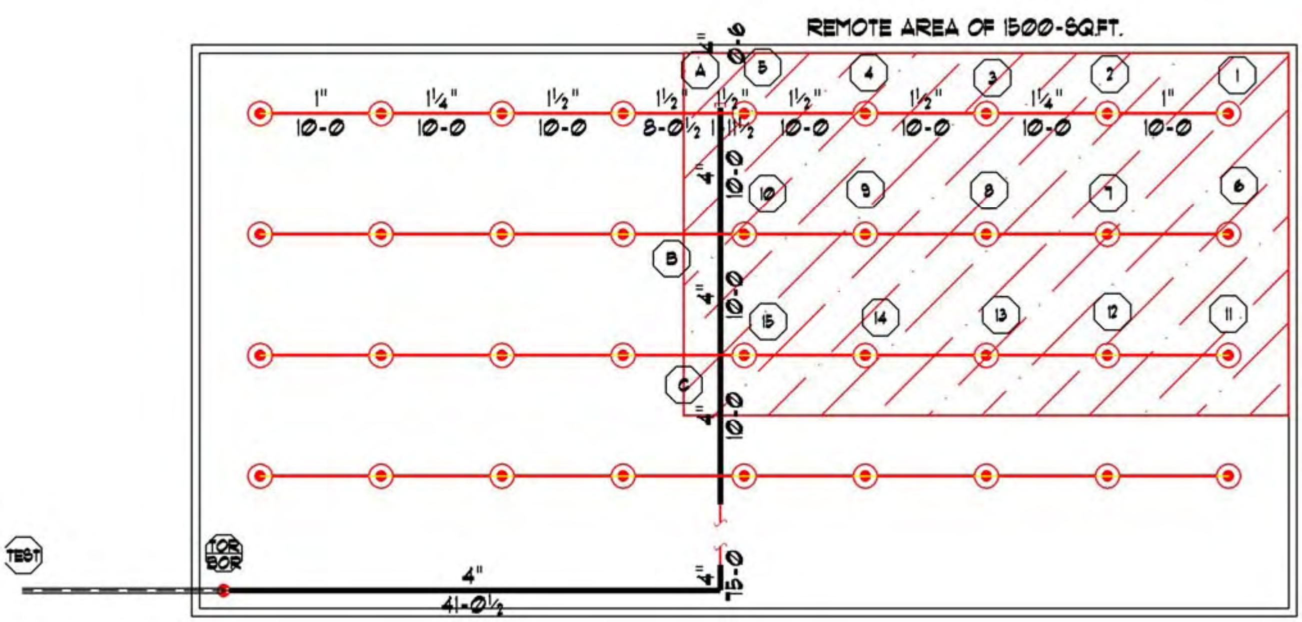
At this point you should begin to notice the back-and-forth process of calculating sprinkler flow and friction loss. Since we last calculated friction loss, this should give a clue that the next step is to calculate sprinkler flow. Indeed, since we now know the actual pressure at sprinkler #3, we can calculate the actual flow from sprinkler #3 which is as follows:

$Q = k\sqrt{p}$ which yields

$Q = 8.0\sqrt{10.0}$ = 25.3-gpm; this is entered in the appropriate place on the worksheet and the total flow also through the pipe supplying sprinkler #3 can be calculated by adding the flow from sprinkler #3 to the flow through the pipe supplying sprinkler #2.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom			lgth				Pt	10.0	
	Q	69.8	Act.			ftg				Pf		
						tot				Pe		
4	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now we will calculate the friction loss pressure in the pipe supplying sprinkler #3.



The pipe supplying sprinkler #3 is a piece of 1 ½-inch schedule 40 10-feet long, which would yield the following friction loss calculation:

$$P_f = \frac{4.52 \times 69.8^{1.85} \times 10}{120^{1.85} \times 1.61^{4.87}} = 1.6\text{-psi}$$

Enter all of the pipe information and friction loss data in the worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now we add the pressure at sprinkler #3 and the friction loss through the pipe supplying sprinkler #3 to get the pressure at sprinkler #4.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q		Nom			lgth				Pt	11.6	
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

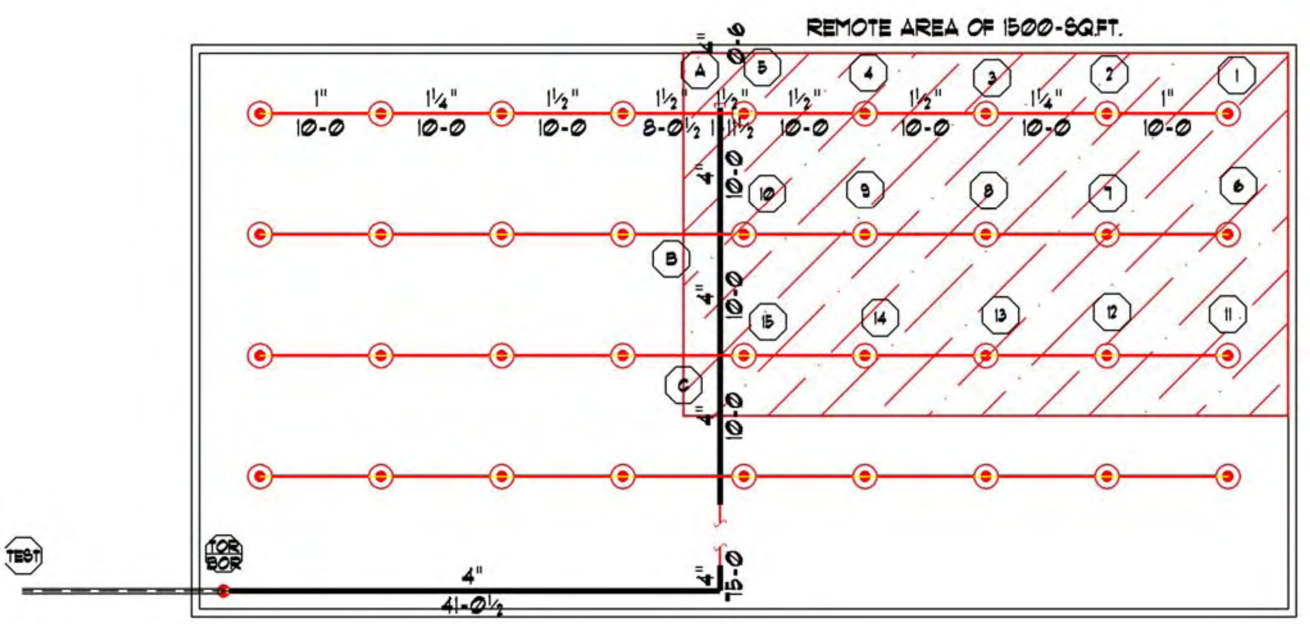
If you've caught on to the process you will expect that since we now know the actual pressure at sprinkler #4, we can calculate the actual flow from sprinkler #4 which is as follows:

$Q = k\sqrt{p}$ which yields

$Q = 8.0\sqrt{11.6}$ = 27.2-gpm; this is entered in the appropriate place on the worksheet and the total flow also through the pipe supplying sprinkler #4 can be calculated by adding the flow from sprinkler #4 to the flow through the pipe supplying sprinkler #3.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom			lgth				Pt	11.6	
	Q	97.0	Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now we will calculate the friction loss pressure in the pipe supplying sprinkler #4.



The pipe supplying sprinkler #4 is a piece of 1 ½-inch schedule 40 10-feet long, which would yield the following friction loss calculation:

$$P_f = \frac{4.52 \times 97.0^{1.85} \times 10}{120^{1.85} \times 1.61^{4.87}} = 3.0\text{-psi}$$

Enter all of the pipe information and friction loss data in the worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now we add the pressure at sprinkler #4 and the friction loss through the pipe supplying sprinkler #4 to get the pressure at sprinkler #5.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q		Nom			lgth				Pt	14.6	
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

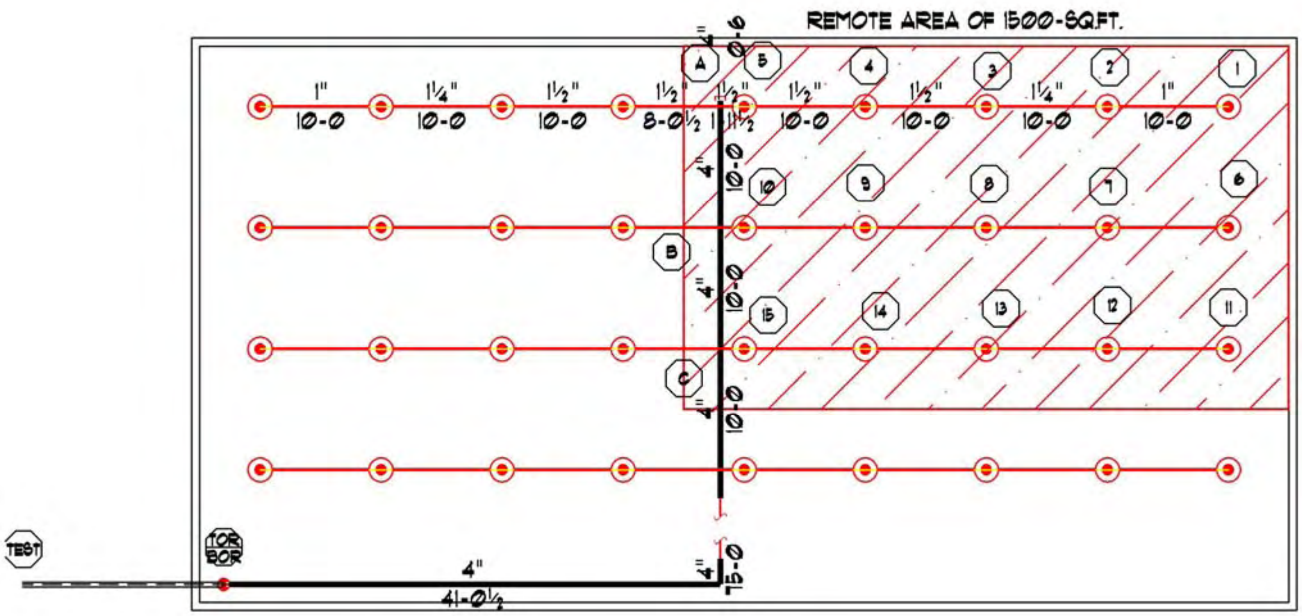
Now that we know the actual pressure at sprinkler #5, we can calculate the actual flow from sprinkler #5 which is as follows:

$Q = k\sqrt{p}$ which yields

$Q = 8.0\sqrt{14.6}$ = 30-6-gpm; this is entered in the appropriate place on the worksheet and the total flow also through the pipe supplying sprinkler #5 can be calculated by adding the flow from sprinkler #5 to the flow through the pipe supplying sprinkler #4.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom			lgth				Pt	14.6	
	Q	127.6	Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now we will calculate the friction loss pressure in the pipe supplying sprinkler #5.



The pipe supplying sprinkler #5 is a piece of 1 ½-inch schedule 40 1’-11 ½-inches long. Also, in this piece of pipe there is a fitting at the connection to the main which must be accounted for in the friction loss calculation.

NFPA-13, section 22.4.4.7 (3) states **“Calculate the loss for a tee or a cross where flow direction change occurs based on the equivalent pipe length of the piping segment in which the fitting is included.”** This tells us when to include a fitting in the friction loss calculation, when flow direction changes.

NFPA-13, section 22.4.4.7 (4) states **“The tee at the top of a riser nipple shall be included in the branch line, the tee at the base of a riser nipple shall be included in the riser nipple, and the tee or cross at a cross main-feed main junction shall be included in the cross main.”** This tells us where to include the fitting, into upstream piece of pipe. This is why the Tee fitting at the cross main at point A on our drawing is added to the branch line friction loss calculation and not the friction loss through the piece of 4-inch main.

If you are wondering about all of those Tee fittings that the sprinklers are threaded into, NFPA-13, section 22.4.4.7 (9) states **“Friction loss shall be excluded for the fitting directly connected to a sprinkler.”** Therefore we ignore the Tee fittings for the sprinklers.

Now we know to include a Tee fitting in our friction loss calculation for the pipe supplying sprinkler #5. This is entered in our worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0			Pt	14.6	
	Q	127.6	Act.	1.61		ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

I’ve also entered the pipe diameter and length. Now that we know there will be one Tee, we must add some equivalent footage of 1 ½-inch pipe to account for the additional friction loss through the Tee. This is found in NFPA-13, Table 22.4.3.1.1. In this table the pipe sizes are across the top and the fittings are along the left side. If you find the intersection of “Tee or cross” and “1 ½ in.”, you will find an equivalent footage for this fitting of “8”. This means that you include an additional 8-feet in the friction loss calculation.

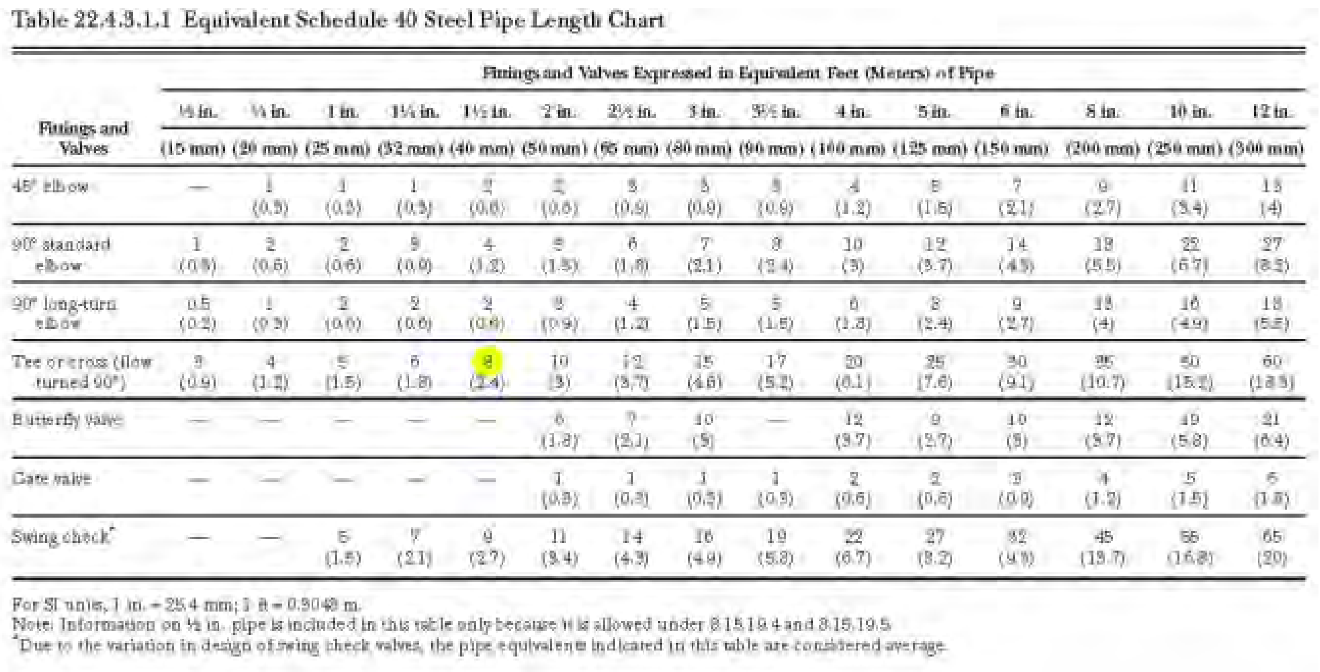


Table 22.4.3.1.1 Equivalent Schedule 40 Steel Pipe Length Chart

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet (Meters) of Pipe														
	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
	(15 mm)	(20 mm)	(25 mm)	(32 mm)	(40 mm)	(50 mm)	(65 mm)	(80 mm)	(90 mm)	(100 mm)	(125 mm)	(150 mm)	(200 mm)	(250 mm)	(300 mm)
45° elbow	—	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	3 (0.9)	3 (0.9)	4 (1.2)	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	13 (4)
90° standard elbow	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	7 (2.1)	8 (2.4)	10 (3)	12 (3.7)	14 (4.3)	18 (5.5)	22 (6.7)	27 (8.2)
90° long-turn elbow	0.5 (0.2)	1 (0.3)	2 (0.6)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	5 (1.5)	6 (1.8)	8 (2.4)	9 (2.7)	13 (4)	16 (4.9)	18 (5.5)
Tee or cross (flow turned 90°)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	8 (2.4)	10 (3)	12 (3.7)	15 (4.6)	17 (5.2)	20 (6.1)	25 (7.6)	30 (9.1)	35 (10.7)	50 (15.2)	60 (18.3)
Butterfly valve	—	—	—	—	—	6 (1.8)	7 (2.1)	10 (3)	—	12 (3.7)	9 (2.7)	10 (3)	12 (3.7)	19 (5.8)	21 (6.4)
Gate valve	—	—	—	—	—	1 (0.3)	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)
Swing check*	—	—	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	14 (4.3)	16 (4.9)	19 (5.8)	22 (6.7)	27 (8.2)	32 (9.8)	45 (13.7)	55 (16.8)	65 (20)

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: Information on ½ in. pipe is included in this table only because it is allowed under 8.15.19.4 and 8.15.19.5.
*Due to the variation in design of swing check valves, the pipe equivalents indicated in this table are considered average.

[5]

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When entered into the worksheet it will appear as follows:

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0			Pt	14.6	
	Q	127.6	Act.	1.61		ftg	8-0			Pf		
						tot	18-0			Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

This makes our total length of pipe in our friction loss calculation = 18-0, which would yield the following friction loss calculation:

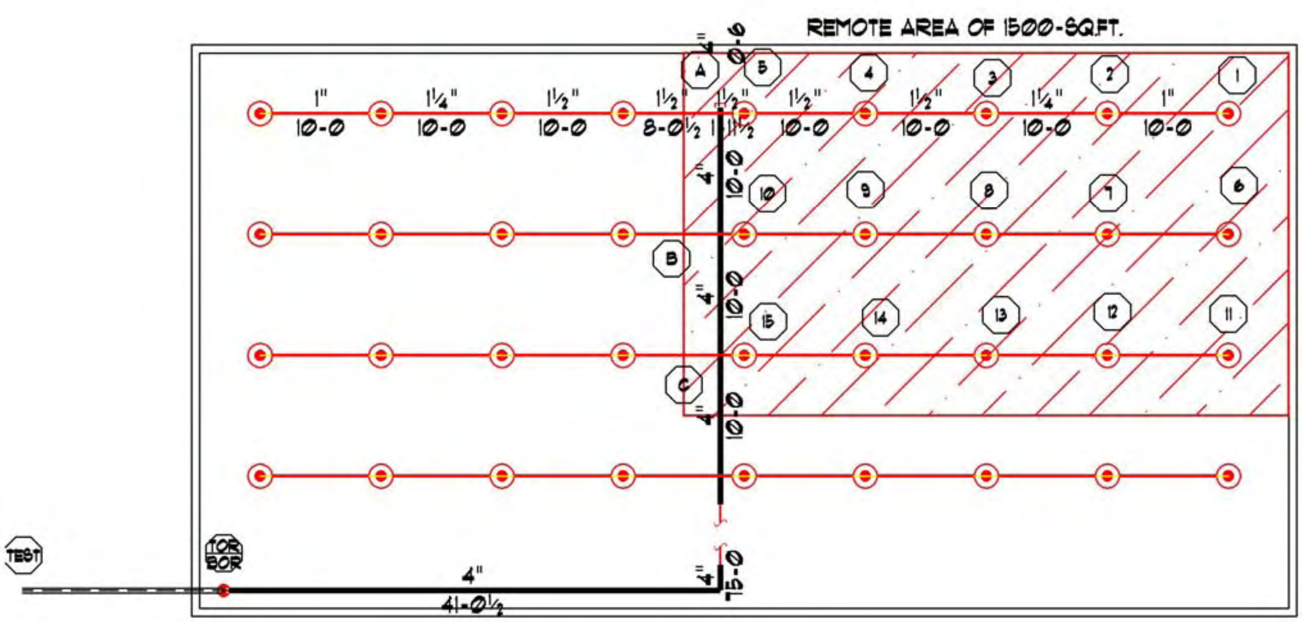
$$P_f = \frac{4.52 \times 127.6^{1.85} \times 18}{120^{1.85} \times 1.61^{4.87}} = 9.0\text{-psi}$$

Enter all of the pipe information and friction loss data in the worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q		Nom			lgth				Pt	23.6	
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Adding the pressure at sprinkler #5 and the friction loss pressure in the pipe supplying sprinkler #5, we have the pressure required at point A in our system. This is 23.6-psi. With this piping arrangement, 23.6-psi is required at point A to get the required minimum amount of water and pressure through sprinklers #1 through #5.

Since there are no more sprinklers to account for on this line, the next step is to simply calculate the friction loss from point A to point B.



This pipe is a piece of 4-inch schedule 10 10-feet long, which would yield the following friction loss calculation:

$$P_f = \frac{4.52 \times 127.6^{1.85} \times 10}{120^{1.85} \times 4.26^{4.87}}$$ = 0.04-psi; I will round this to 0.1-psi.

Enter all of the pipe information and friction loss data in the worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now we add the pressure at point A and the friction loss through the pipe supplying point A to get the pressure at point B.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q		Nom			lgth				Pt	23.7	
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now that we are at point B in the system we must add the flow for sprinklers #6 through #10. Since this branch line is typical to the first, we can use an additional formula to calculate the additional flow through this second branch line due to the increased pressure at point B of 23.7-psi.

Flow Adjustments

Flow adjustments are required to balance two different calculated flows at the same point in a sprinkler system. Obviously, two separate flows and pressure cannot exist at the same point. Notice below that the pressure at point A, where the first branch line connects to the main is 23.6-psi but the pressure at point B, where the second branch line connects to the main is 23.7-psi. Since the pressure is increased at point B, all of the sprinklers will overflow due to the higher pressure. However, in order to continue our calculation we must know how much water will actually flow through the second branch line.

The formula used to calculate this is as follows:

$$Q_{adj} = Q_L \times \sqrt{\frac{P_H}{P_L}}$$

Where:

Q_{adj} = Adjusted Flow
Q_L = Calculated Flow in the Low Pressure Line
P_H = Calculated Pressure in the High Pressure Line
P_L = Calculated Pressure in the Low Pressure Line

Note the two pressures highlighted in the worksheet below:

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q		Nom			lgth				Pt	23.7	
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

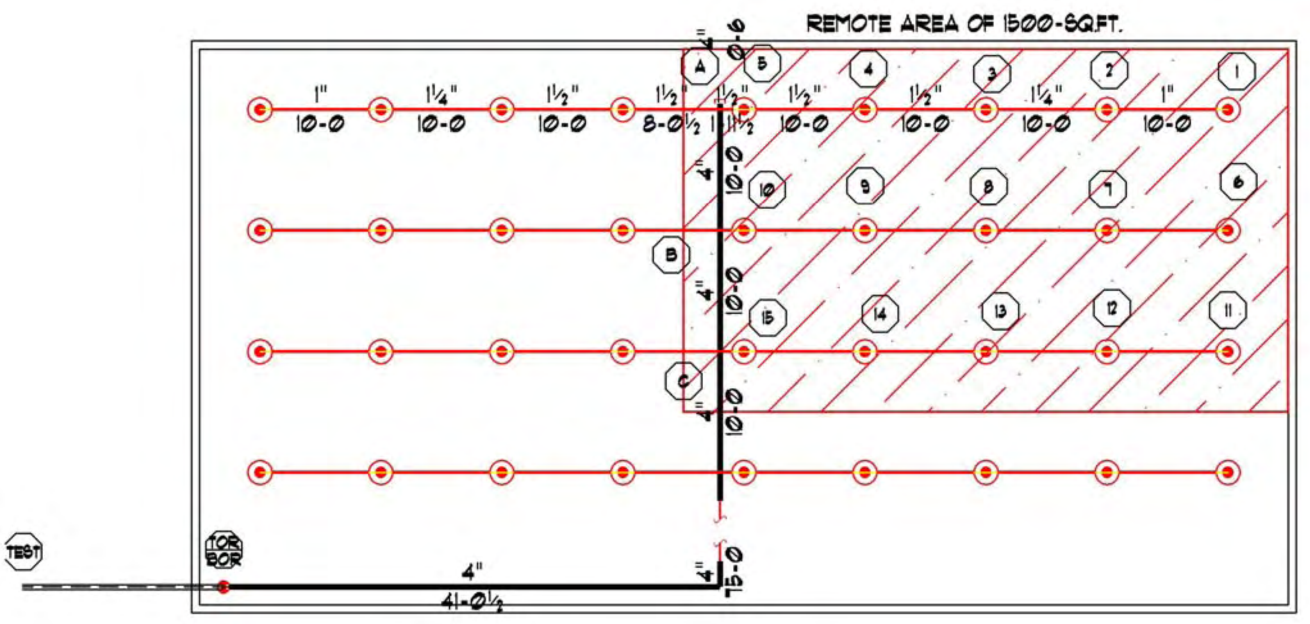
The pressure required to get our minimum end sprinkler conditions down our typical branch line was calculated to be 23.6-psi at point A. But our pressure at point B is 23.7-psi. Our calculated flow for our typical branch line was 127.6-gpm. We can use our formula to calculate the actual flow down our second branch line based on the higher pressure.

$$Q_{adj} = Q_L \times \sqrt{\frac{P_H}{P_L}} = 127.6 \times \sqrt{\frac{23.7}{23.6}} = 127.9\text{-gpm}$$

We now show this flow as the flow through the second branch line and add the two flows to get the total flow through the piece of pipe supplying the second branch line.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom			lgth				Pt	23.7	
	Q	255.5	Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Next comes the friction loss calculation for the flow from point B to point C.



This pipe is a piece of 4-inch schedule 10 10-feet long, which would yield the following friction loss calculation:

$$P_f = \frac{4.52 \times 255.5^{1.85} \times 10}{120^{1.85} \times 4.26^{4.87}} = 0.2\text{-psi}$$

Enter all of the pipe information and friction loss data in the worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now we add the pressure at point B and the friction loss through the pipe supplying point B to get the pressure at point C.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"		lgth	10-0			Pt	7	
1	Q	21.2	Act.	1.049	None	ftg	0-0	120		Pf	1.5	8
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"		lgth	10-0			Pt	8.5	
	Q	44.5	Act.	1.38	None	ftg	0-0	120		Pf	1.5	8
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"		lgth	10-0			Pt	10.0	
	Q	69.8	Act.	1.61	None	ftg	0-0	120		Pf	1.6	8
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"		lgth	10-0			Pt	11.6	
	Q	97.0	Act.	1.61	None	ftg	0-0	120		Pf	3.0	8
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"		lgth	10-0			Pt	14.6	
	Q	127.6	Act.	1.61	T	ftg	8-0	120		Pf	9.0	8
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"		lgth	10-0			Pt	23.6	
	Q	127.6	Act.	4.26	None	ftg	0-0	120		Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"		lgth	10-0			Pt	23.7	
	Q	255.5	Act.	4.26	None	ftg	0-0	120		Pf	0.2	
						tot	10-0			Pe	0	
C	q		Nom			lgth				Pt	23.9	
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

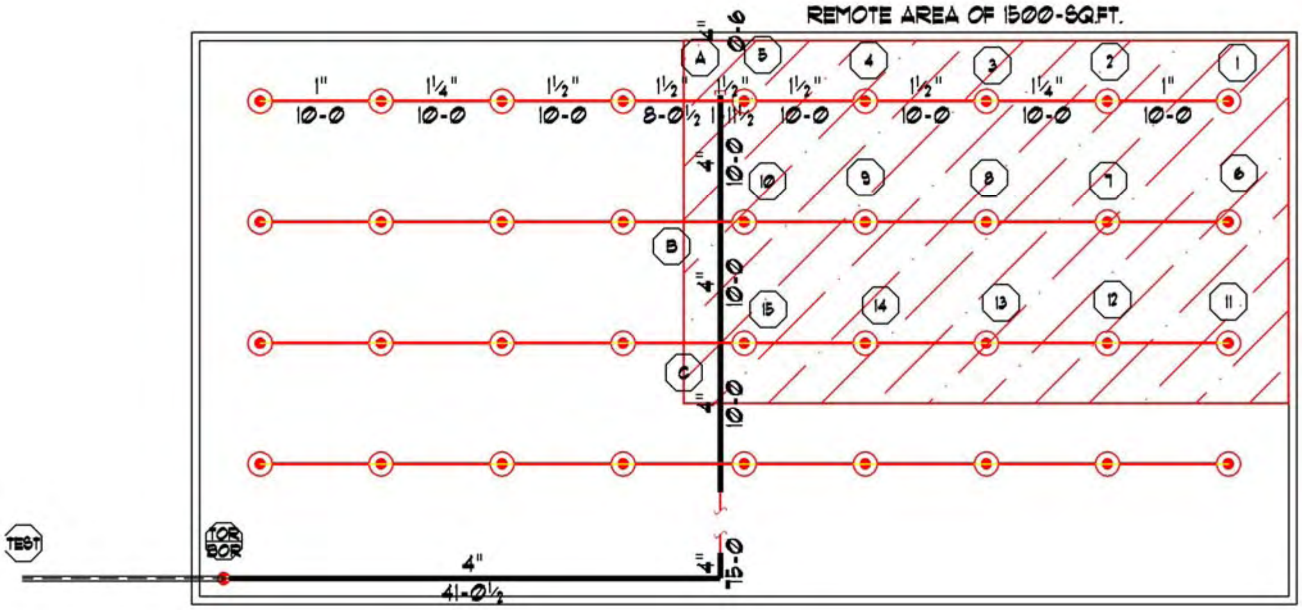
The pressure required to get our minimum end sprinkler conditions down our typical branch line was calculated to be 23.6-psi at point A. But our pressure at point C is 23.9-psi. Our calculated flow for our typical branch line was 127.6-gpm. We can use our formula to calculate the actual flow down our third branch line based on the higher pressure.

$$Q_{adj} = Q_L \times \sqrt{\frac{P_H}{P_L}} = 127.6 \times \sqrt{\frac{23.9}{23.6}} = 128.4\text{-gpm}$$

We now show this flow as the flow through the third branch line and add the two flows to get the total flow through the piece of pipe supplying the third branch line.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom			lgth				Pt	23.9	
	Q	383.9	Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

By looking at our drawing, you will notice that we are past the last flowing sprinkler. There will be no more flow additions for sprinklers. The remainder of the calculation is only for friction loss for a flow of 383.9-gpm through the piping system down the cross main, through the riser and out to the connection to the street.


REMOTE AREA OF 1500-SQ.FT.
A
B
C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1"
10-0
1¼"
10-0
1½"
10-0
1½"
8-0½
1½"
1-1½
1½"
10-0
1½"
10-0
1¼"
10-0
1"
10-0
4"
10-6
4"
10-0
4"
10-0
4"
10-0
4"
15-0
4"
41-0½
TOR
BOR
TEST

Next we will calculate the friction loss from point C to the top of the riser, node TOR.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom	4	2E	lgth	126-0 1/2			Pt	23.9	
	Q	383.9	Act.	4.26		ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
TOR	Q	383.9	Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

The length of 4-inch schedule 10 pipe is 126’-0 ½”, or 126.04’ excluding fitting length. Enter this value in the worksheet. Now we must enter the equivalent footage for the fittings in this run of pipe. From node C to node TOR there are two elbows. In order to get our equivalent footage for these fittings, we again reference Table 22.4.3.1.1. We will see the equivalent footage for one elbow is 10-feet; therefore two elbows will equal 20-feet equivalent footage. However, we are not finished yet because the title of the Table is “Equivalent Schedule 40 Steel Pipe Length Chart. Since we are using schedule 10 pipe for the mains, we must make a modification to our equivalent footage number.

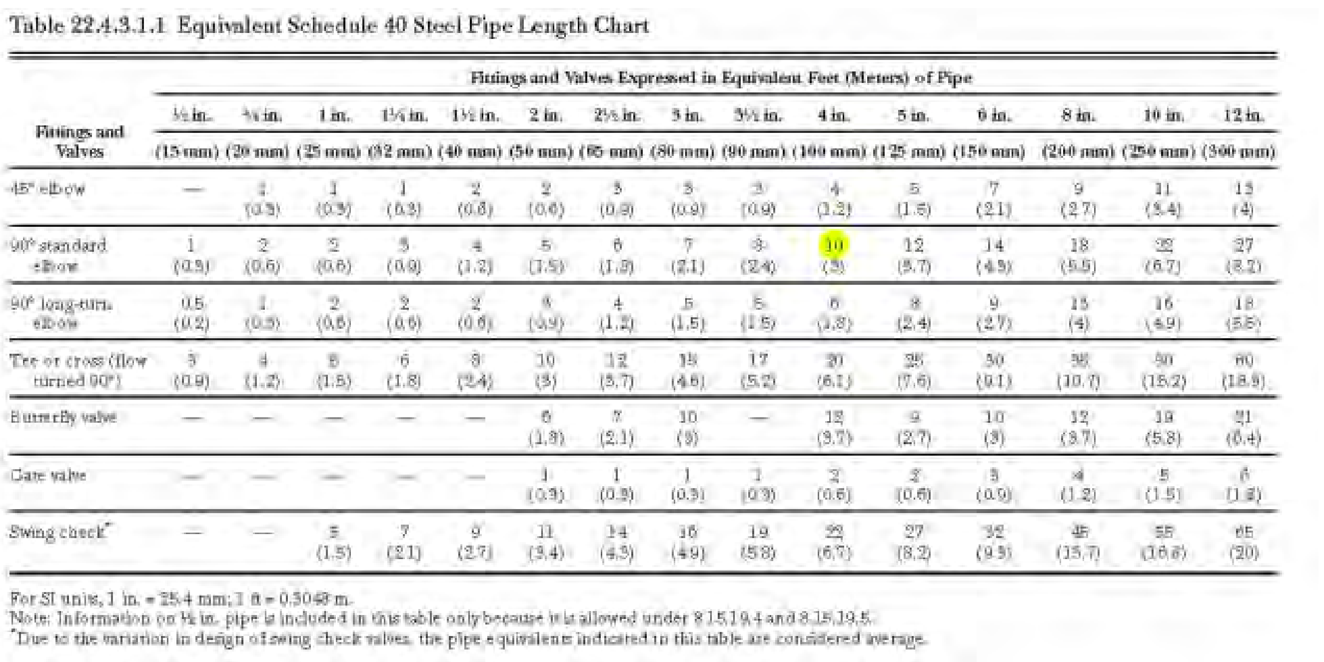


Table 22.4.3.1.1 Equivalent Schedule 40 Steel Pipe Length Chart

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet (Meters) of Pipe														
	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
	(15 mm)	(20 mm)	(25 mm)	(32 mm)	(40 mm)	(50 mm)	(65 mm)	(80 mm)	(90 mm)	(100 mm)	(125 mm)	(150 mm)	(200 mm)	(250 mm)	(300 mm)
45° elbow	—	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	3 (0.9)	3 (0.9)	4 (1.2)	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	13 (4)
90° standard elbow	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	7 (2.1)	8 (2.4)	10 (3)	12 (3.7)	14 (4.3)	18 (5.5)	22 (6.7)	27 (8.2)
90° long-turn elbow	0.5 (0.2)	1 (0.3)	2 (0.6)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	5 (1.5)	6 (1.8)	8 (2.4)	9 (2.7)	13 (4)	16 (4.9)	18 (5.5)
Tee or cross (flow turned 90°)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	8 (2.4)	10 (3)	12 (3.7)	15 (4.6)	17 (5.2)	20 (6.1)	25 (7.6)	30 (9.1)	35 (10.7)	50 (15.2)	60 (18.3)
Butterfly valve	—	—	—	—	—	6 (1.8)	7 (2.1)	10 (3)	—	12 (3.7)	9 (2.7)	10 (3)	12 (3.7)	19 (5.8)	21 (6.4)
Gate valve	—	—	—	—	—	1 (0.3)	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)
Swing check*	—	—	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	14 (4.3)	16 (4.9)	19 (5.8)	22 (6.7)	27 (8.2)	32 (9.3)	45 (13.7)	55 (16.8)	65 (20)

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Note: Information on ½ in. pipe is included in this table only because it is allowed under 8.15.19.4 and 8.15.19.5.

*Due to the variation in design of swing check valves, the pipe equivalents indicated in this table are considered average.

[6]

The formula for equivalent footage modifiers is found in NFPA-13, section 22.4.3.1.3 and is as follows:

$$\text{Factor} = \left(\frac{ActualInsideDiameter}{Schedule40SteelPipeInsideDiameter}\right)^{4.87}$$

Which yields,

$$\text{Factor} = \left(\frac{4.26}{4.026}\right)^{4.87} = 1.32$$

We now take our factor and multiply it times the 20-feet equivalency from the table to get:

20 x 1.32 = 26.3-feet or 26’-4” equivalent

Enter this into our worksheet.

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Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom	4	2E	lgth	126-0 1/2	120		Pt	23.9	
	Q	383.9	Act.	4.26		ftg	26-4			Pf		
						tot	152-4			Pe		
	q		Nom			lgth				Pt		
TOR	Q	383.9	Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

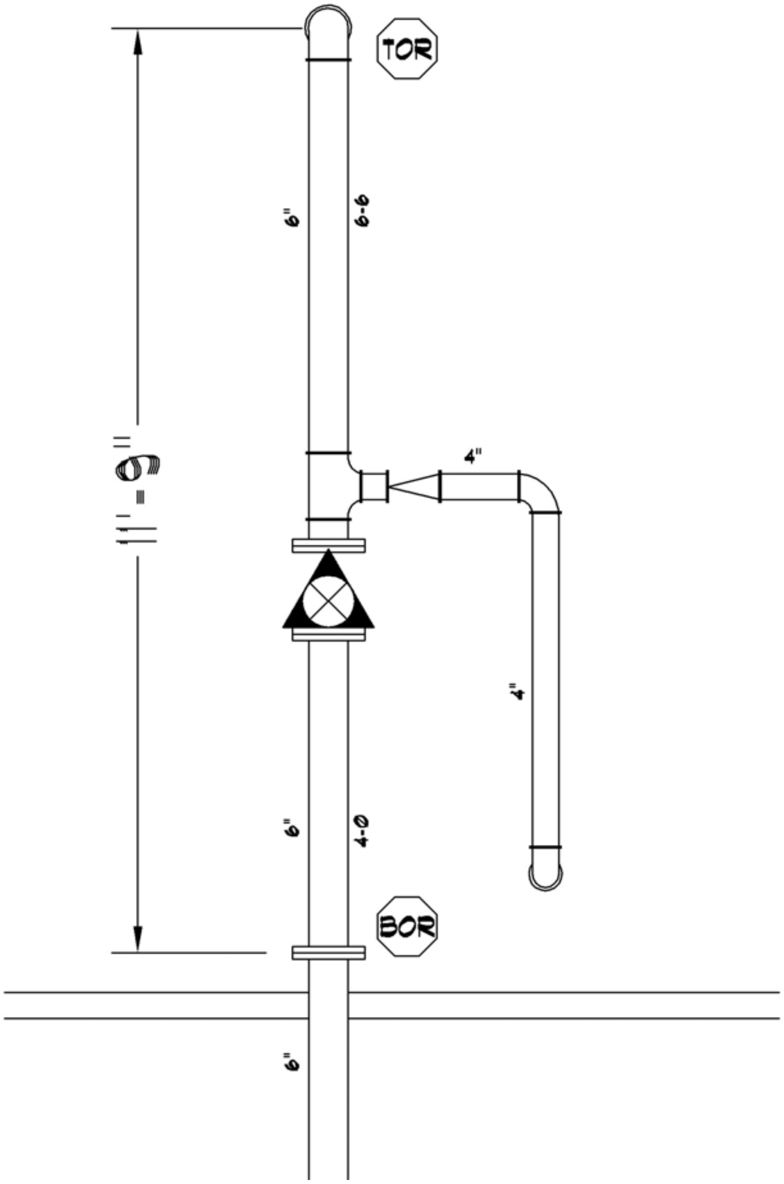
The friction loss equation now becomes,

$$P_f = \frac{4.52 \times 283.9^{1.85} \times 152.3}{120^{1.85} \times 4.26^{4.87}} = 5.1\text{-psi}$$

Enter this in the worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom	4	2E	lgth	126-0 1/2	120		Pt	23.9	
	Q	383.9	Act.	4.26		ftg	26-4			Pf	5.1	
						tot	152-4			Pe	0	
	q		Nom			lgth				Pt	29.0	
TOR	Q	383.9	Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Now we have the sprinkler system demand at the top of the riser. To get to the bottom of the riser we add the pipe and fittings for the riser. The riser detail looks this way,

TOR
6"
6-6
11'-9"
4"
4"
6"
4-0
BOR
6"

From our riser detail we see that from the TOR to the BOR we have 10’-6” of 6-inch schedule 10 pipe and an alarm check valve.

Converting the 6-inch alarm check valve to equivalent feet requires a modifier just like the 4-inch schedule 10. Table 22.4.3.1.1 gives us 32-feet,

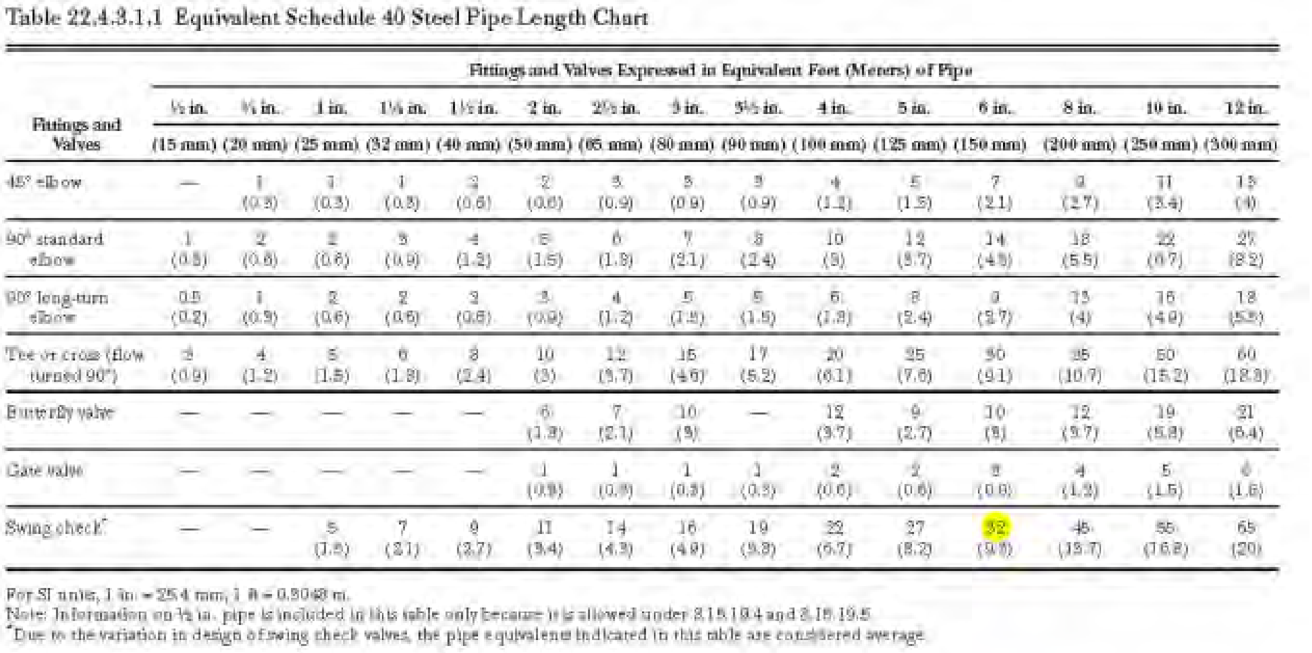


Table 22.4.3.1.1 Equivalent Schedule 40 Steel Pipe Length Chart

Fittings and Valves	Fittings and Valves Expressed in Equivalent Foot (Meters) of Pipe														
	½ in. (15 mm)	¾ in. (20 mm)	1 in. (25 mm)	1¼ in. (32 mm)	1½ in. (40 mm)	2 in. (50 mm)	2½ in. (65 mm)	3 in. (80 mm)	3½ in. (90 mm)	4 in. (100 mm)	5 in. (125 mm)	6 in. (150 mm)	8 in. (200 mm)	10 in. (250 mm)	12 in. (300 mm)
45° elbow	—	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	3 (0.9)	3 (0.9)	4 (1.2)	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	13 (4)
90° standard elbow	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	7 (2.1)	8 (2.4)	10 (3)	12 (3.7)	14 (4.3)	18 (5.5)	22 (6.7)	27 (8.2)
90° long-turn elbow	0.5 (0.2)	1 (0.3)	2 (0.6)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	5 (1.5)	6 (1.8)	8 (2.4)	9 (2.7)	13 (4)	16 (4.9)	18 (5.5)
Tee or cross (flow turned 90°)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	8 (2.4)	10 (3)	12 (3.7)	15 (4.6)	17 (5.2)	20 (6.1)	25 (7.6)	30 (9.1)	35 (10.7)	50 (15.2)	60 (18.3)
Butterfly valve	—	—	—	—	—	6 (1.8)	7 (2.1)	10 (3)	—	12 (3.7)	9 (2.7)	10 (3)	12 (3.7)	19 (5.8)	21 (6.4)
Gate valve	—	—	—	—	—	1 (0.3)	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)
Swing check*	—	—	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	14 (4.3)	16 (4.9)	19 (5.8)	22 (6.7)	27 (8.2)	32 (9.8)	45 (13.7)	55 (16.8)	65 (20)

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: Information on ½ in. pipe is included in this table only because it is allowed under 8.15.19.4 and 8.15.19.5.
*Due to the variation in design of swing check valves, the pipe equivalents indicated in this table are considered average.

[7]

Using the modifier equation we get:

$$\text{Factor} = \left(\frac{6.357}{6.065}\right)^{4.87} = 1.257$$

We now take our factor and multiply it times the 32-feet equivalency from the table to get:

32 x 1.257 = 40.23-feet or 40’-3” equivalent

Enter this into our worksheet.

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Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom	4	2E	lgth	126-0 1/2	120		Pt	23.9	
	Q	383.9	Act.	4.26		ftg	26-4			Pf	5.1	
						tot	152-4			Pe	0	
	q		Nom	6	S	lgth	10-6	120		Pt	29.0	
TOR	Q	383.9	Act.	6.357		ftg	40-3			Pf		
						tot	50-9			Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

The friction loss equation now becomes,

$$P_f = \frac{4.52 \times 383.9^{1.85} \times 50.75}{120^{1.85} \times 6.357^{4.87}} = 0.2\text{-psi}$$

Enter this in the worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom	4	2E	lgth	126-0 1/2	120		Pt	23.9	
	Q	383.9	Act.	4.26		ftg	26-4			Pf	5.1	
						tot	152-4			Pe	0	
	q		Nom	6	S	lgth	10-6	120		Pt	29.0	
TOR	Q	383.9	Act.	6.357		ftg	40-3			Pf	0.2	
						tot	50-9			Pe		
	q		Nom			lgth				Pt		
BOR	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Notice I have not added the friction loss to the total pressure yet. This is because there is one other type of pressure that must be accounted for at this point. This is elevation pressure. You will notice from the riser detail that the elevation difference between the TOR and BOR points is 11’-9”. As water rises, it must overcome gravity. This type of pressure is calculated by an oft-used constant in fire protection:

1-foot of elevation = 0.433-psi/ft of pressure.

For example, if a water tower is 100-feet tall what pressure will be present at the base? Using our constant we get:

100-feet x 0.433-psi/ft = 43.3-psi.

In our example we have 11.75-feet of elevation from point TOR to BOR. This elevation pressure is:

11.75-feet x 0.433-psi/ft = 5.09-psi. Enter this in the worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom	4	2E	lgth	126-0 1/2	120		Pt	23.9	
	Q	383.9	Act.	4.26		ftg	26-4			Pf	5.1	
						tot	152-4			Pe	0	
	q		Nom	6	S	lgth	10-6	120		Pt	29.0	
TOR	Q	383.9	Act.	6.357		ftg	40-3			Pf	0.2	
						tot	50-9			Pe	5.1	
	q		Nom			lgth				Pt	34.3	
BOR	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
TEST	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

The pressure demand at BOR is 34.3-psi. Now we can calculate the friction and elevation loss in the underground piping. For this we will assume the underground is 100-feet long including a 4-foot drop from the BOR point. We will also assume there is one gate valve in the piping and the piping is 6-inch Class 52 ductile iron. With this information, our worksheet looks this way:

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom	4	2E	lgth	126-0 1/2	120		Pt	23.9	
	Q	383.9	Act.	4.26		ftg	26-4			Pf	5.1	
						tot	152-4			Pe	0	
	q		Nom	6	S	lgth	10-6	120		Pt	29.0	
TOR	Q	383.9	Act.	6.357		ftg	40-3			Pf	0.2	
						tot	50-9			Pe	5.1	
	q		Nom	6	E,T,G	lgth	100-0	140		Pt	34.3	
BOR	Q	383.9	Act.	6.275		ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
TEST	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

The internal diameter of 6-inch Class 52 ductile iron is taken from a resource on pipe sizes. The fittings include the elbow at the bottom of the riser, the tee at the city connection and the valve at the city connection. Notice the C-factor of ductile iron is 140. This is taken from NFPA-13, Table 22.4.4.7:

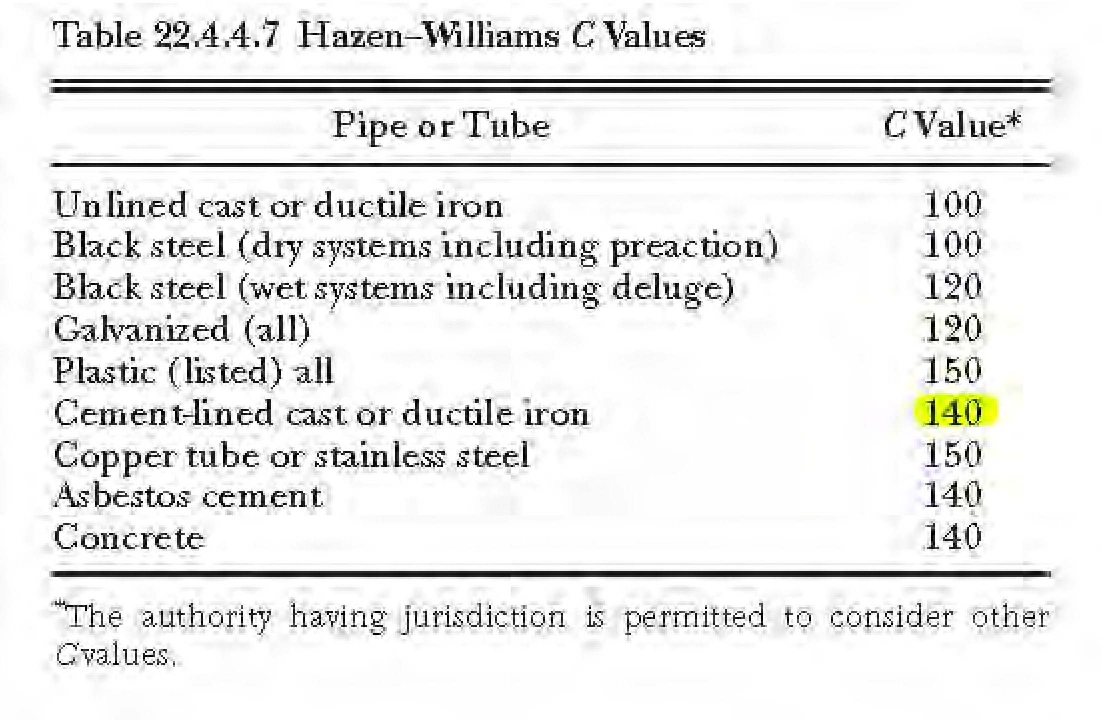

Table 22.4.4.7 Hazen–Williams *C* Values

Pipe or Tube	*C* Value*
Unlined cast or ductile iron	100
Black steel (dry systems including preaction)	100
Black steel (wet systems including deluge)	120
Galvanized (all)	120
Plastic (listed) all	150
Cement-lined cast or ductile iron	140
Copper tube or stainless steel	150
Asbestos cement	140
Concrete	140

*The authority having jurisdiction is permitted to consider other *C* values.

[8]

To get the fitting equivalent footage, we take the values from Table 22.4.3.1.1

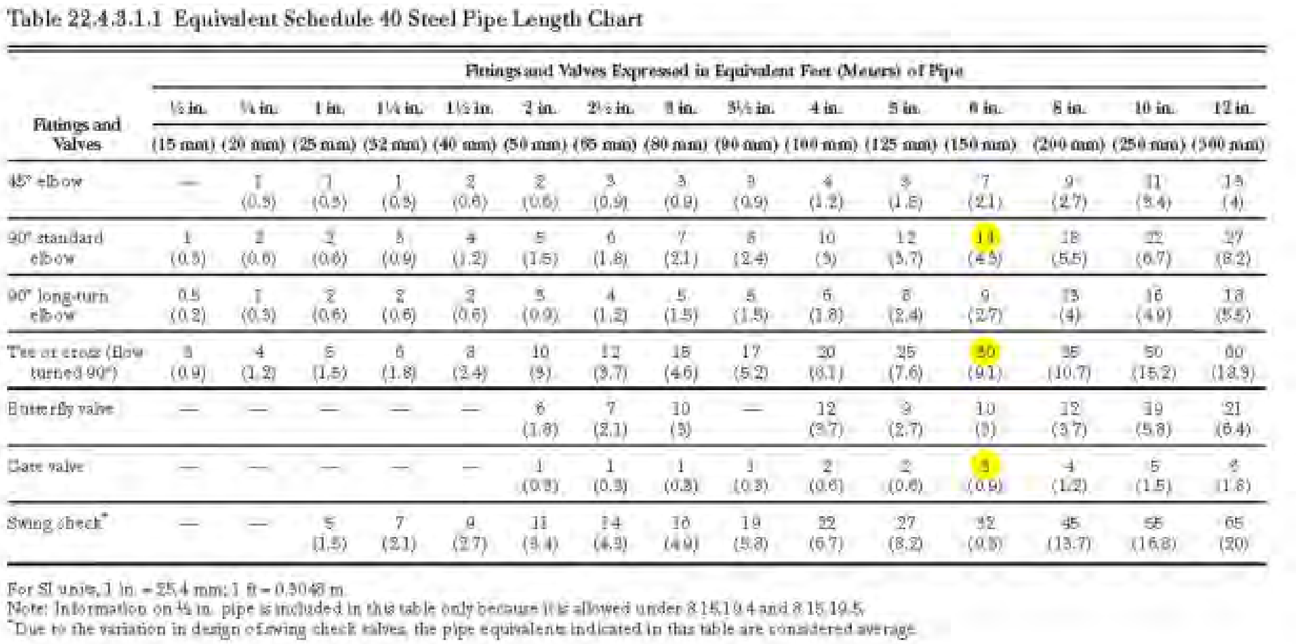

Table 22.4.3.1.1 Equivalent Schedule 40 Steel Pipe Length Chart

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet (Meters) of Pipe														
	½ in. (15 mm)	¾ in. (20 mm)	1 in. (25 mm)	1¼ in. (32 mm)	1½ in. (40 mm)	2 in. (50 mm)	2½ in. (65 mm)	3 in. (80 mm)	3½ in. (90 mm)	4 in. (100 mm)	5 in. (125 mm)	6 in. (150 mm)	8 in. (200 mm)	10 in. (250 mm)	12 in. (300 mm)
45° elbow	—	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	3 (0.9)	3 (0.9)	4 (1.2)	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	13 (4)
90° standard elbow	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	7 (2.1)	8 (2.4)	10 (3)	12 (3.7)	14 (4.3)	18 (5.5)	22 (6.7)	27 (8.2)
90° long-turn elbow	0.5 (0.2)	1 (0.3)	2 (0.6)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	5 (1.5)	6 (1.8)	8 (2.4)	9 (2.7)	13 (4)	16 (4.9)	18 (5.5)
Tee or cross (flow turned 90°)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	8 (2.4)	10 (3)	12 (3.7)	15 (4.6)	17 (5.2)	20 (6.1)	25 (7.6)	30 (9.1)	35 (10.7)	50 (15.2)	60 (18.3)
Butterfly valve	—	—	—	—	—	6 (1.8)	7 (2.1)	10 (3)	—	12 (3.7)	9 (2.7)	10 (3)	12 (3.7)	19 (5.8)	21 (6.4)
Gate valve	—	—	—	—	—	1 (0.3)	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)
Swing check*	—	—	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	14 (4.3)	16 (4.9)	19 (5.8)	22 (6.7)	27 (8.2)	32 (9.8)	45 (13.7)	55 (16.8)	65 (20)

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: Information on ½ in. pipe is included in this table only because it is allowed under 8.15.19.4 and 8.15.19.5.
*Due to the variation in design of swing check valves, the pipe equivalents indicated in this table are considered average.

[9]

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The total equivalent footage will be 14 + 30 + 3 = 47-feet. Again we must apply the diameter modifier:

$$\text{Factor} = \left(\frac{6.275}{6.065}\right)^{4.87} = 1.18$$

47 x 1.18 = 55.46-feet or 55’-6” equivalent. We cannot enter this into the worksheet yet however. For this run of pipe we must make one more modification to the fitting equivalent footage. This will come from NFPA-13, Table 22.4.3.2. Whenever your pipe C-value is other than 120, you must make an adjustment to the equivalent footage you get from Table 22.4.3.1.1. Here is Table 22.4.3.2:

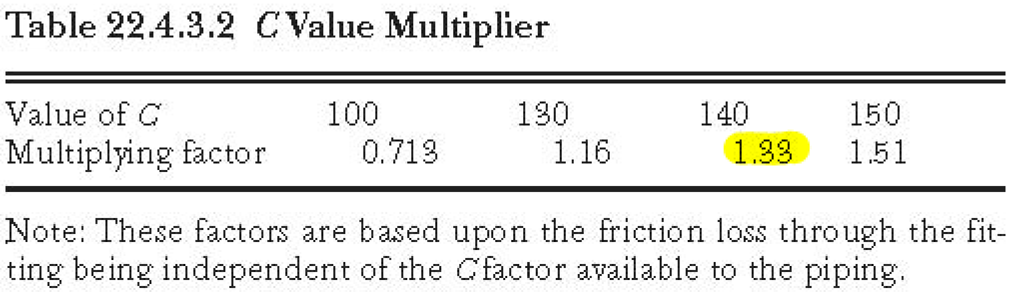

Table 22.4.3.2 *C* Value Multiplier

Value of *C*	100	130	140	150
Multiplying factor	0.713	1.16	1.33	1.51

Note: These factors are based upon the friction loss through the fitting being independent of the *C* factor available to the piping.

[10]

For a C-value of 140, we use multiplier of 1.33. We take our modified equivalent footage for diameter and adjust it for C = 140:

55.46 x 1.33 = 73.76-feet or 73’-9” equivalent. We now enter this into our worksheet.

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Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom	4	2E	lgth	126-0 1/2	120		Pt	23.9	
	Q	383.9	Act.	4.26		ftg	26-4			Pf	5.1	
						tot	152-4			Pe	0	
	q		Nom	6	S	lgth	10-6	120		Pt	29.0	
TOR	Q	383.9	Act.	6.357		ftg	40-3			Pf	0.2	
						tot	50-9			Pe	5.1	
	q		Nom	6	E,T,G	lgth	100-0	140		Pt	34.3	
BOR	Q	383.9	Act.	6.275		ftg	73-9			Pf		
						tot	173-9			Pe		
	q		Nom			lgth				Pt		
TEST	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

We now can calculate our friction loss as

$$P_f = \frac{4.52 \times 383.9^{1.85} \times 173.75}{140^{1.85} \times 6.275^{4.87}} = 0.7\text{-psi}$$

Also, don’t forget to include our estimated 4-foot elevation drop from the BOR to the underground main: 4-feet x 0.433-psi/ft = 1.7-psi.

Enter these two values in the worksheet.

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom	4	2E	lgth	126-0 1/2	120		Pt	23.9	
	Q	383.9	Act.	4.26		ftg	26-4			Pf	5.1	
						tot	152-4			Pe	0	
	q		Nom	6	S	lgth	10-6	120		Pt	29.0	
TOR	Q	383.9	Act.	6.357		ftg	40-3			Pf	0.2	
						tot	50-9			Pe	5.1	
	q		Nom	6	E,T,G	lgth	100-0	140		Pt	34.3	
BOR	Q	383.9	Act.	6.275		ftg	73-9			Pf	0.7	
						tot	173-9			Pe	1.7	
	q		Nom			lgth				Pt	36.7	
TEST	Q	383.9	Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

This gives us our sprinkler demand at the connection to the city main of 383.9-gpm at 36.7-psi. This is not our final flow requirement since NFPA-13, section 11.1.4.2 states **"The minimum water supply requirements for a sprinkler system shall be determined by adding the hose stream allowance to the water supply for sprinklers."** We have calculated the water supply requirements for the sprinkler now we will add our hose allowance. The hose allowance simulates water taken from the water supply by fire department operations in fighting the fire. Remember that our occupancy classification is

Ordinary Hazard Group 2. This will be required to determine our hose stream allowance from Table 11.2.3.1.2:

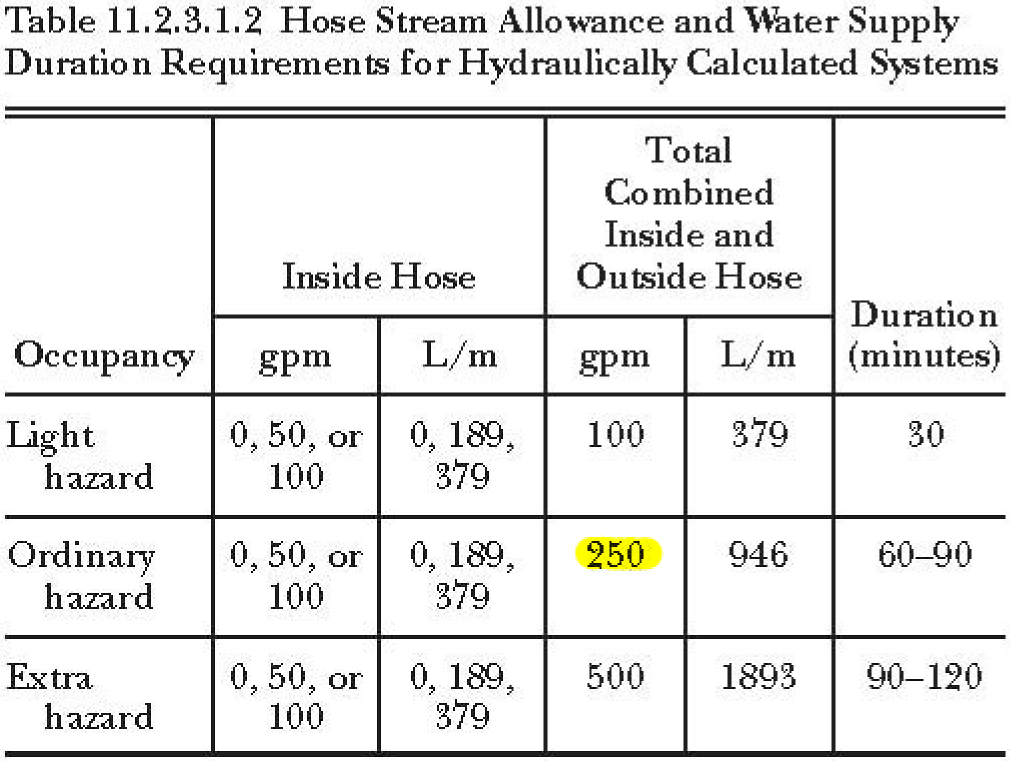

Table 11.2.3.1.2 Hose Stream Allowance and Water Supply Duration Requirements for Hydraulically Calculated Systems

Occupancy	Inside Hose		Total Combined Inside and Outside Hose		Duration (minutes)
	gpm	L/m	gpm	L/m	
Light hazard	0, 50, or 100	0, 189, 379	100	379	30
Ordinary hazard	0, 50, or 100	0, 189, 379	250	946	60–90
Extra hazard	0, 50, or 100	0, 189, 379	500	1893	90–120

[11]

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This makes our final demand requirements as follows:

Sprinkler Location	Flow (gpm)		Pipe Size		Fittings & Devices	Pipe Equivalent Length		C-factor	psi/ft/	Req. Pressure		K-factor
	q		Nom	1"	None	lgth	10-0	120		Pt	7	8
1	Q	21.2	Act.	1.049		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
2	q	23.3	Nom	1 1/4"	None	lgth	10-0	120		Pt	8.5	8
	Q	44.5	Act.	1.38		ftg	0-0			Pf	1.5	
						tot	10-0			Pe	0	
3	q	25.3	Nom	1 1/2"	None	lgth	10-0	120		Pt	10.0	8
	Q	69.8	Act.	1.61		ftg	0-0			Pf	1.6	
						tot	10-0			Pe	0	
4	q	27.2	Nom	1 1/2"	None	lgth	10-0	120		Pt	11.6	8
	Q	97.0	Act.	1.61		ftg	0-0			Pf	3.0	
						tot	10-0			Pe	0	
5	q	30.6	Nom	1 1/2"	T	lgth	10-0	120		Pt	14.6	8
	Q	127.6	Act.	1.61		ftg	8-0			Pf	9.0	
						tot	18-0			Pe	0	
A	q	0.0	Nom	4"	None	lgth	10-0	120		Pt	23.6	
	Q	127.6	Act.	4.26		ftg	0-0			Pf	0.1	
						tot	10-0			Pe	0	
B	q	127.9	Nom	4"	None	lgth	10-0	120		Pt	23.7	
	Q	255.5	Act.	4.26		ftg	0-0			Pf	0.2	
						tot	10-0			Pe	0	
C	q	128.4	Nom	4	2E	lgth	126-0 1/2	120		Pt	23.9	
	Q	383.9	Act.	4.26		ftg	26-4			Pf	5.1	
						tot	152-4			Pe	0	
	q		Nom	6	S	lgth	10-6	120		Pt	29.0	
TOR	Q	383.9	Act.	6.357		ftg	40-3			Pf	0.2	
						tot	50-9			Pe	5.1	
	q		Nom	6	E,T,G	lgth	100-0	140		Pt	34.3	
BOR	Q	383.9	Act.	6.275		ftg	73-9			Pf	0.7	
						tot	173-9			Pe	1.7	
	q		Nom			lgth				Pt	36.7	
TEST	Q	383.9	Act.			ftg				Pf		
						tot				Pe		
HOSE	q	250.0	Nom			lgth				Pt	36.7	
	Q	633.9	Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		
	q		Nom			lgth				Pt		
	Q		Act.			ftg				Pf		
						tot				Pe		

Notice there is no additional pressure required for the hose allowance. It is simply added as flow since the fire department will use the pump on the pumper truck to produce the pressure needed. The final sprinkler demand requirements are:

633.9-gpm at 36.7-psi.
CONGRATULATIONS! YOU HAVE JUST COMPLETED MANUALLY CALCULATING THIS FIRE SPRINKLER SYSTEM.

Summary

In this course you have learned the five basic types of occupancy classifications outlined in NFPA-13. You have taken a sprinkler system and applied the two ways to determining the end sprinkler start conditions when beginning a hydraulic calculation. You have applied the Hazen-Williams friction loss formula to water flowing through a pipe and made flow adjustments to calculate the amount a typical branch line will overflow due to higher pressure.