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Domestic Water System Pipe Sizing

Fixtures require a minimum quantity of water at a minimum pressure, and piping systems are designed to serve these requirements. However, gravity and friction can interfere with that quest, so you must compensate with an appropriate response.

This column provides a basic guide to the sizing and design of domestic water supply systems. It is not intended to cover all possible design scenarios and/or special cases. It addresses domestic water system sizing in two parts: the piping distribution system and the distribution piping.

PART 1: PIPING DISTRIBUTION SYSTEM

Part 1 is typically done first, but it is a little more advanced and requires more experience than Part 2. Always keep your calculations in your file and in the project calculations directory. Keep the fixture units in the drawing file, on a "no plot" layer that can be turned off.

To size the system, you need to determine the following:

- Maximum flow rate of the system
- Maximum and minimum water pressures in the main
- Residual pressure required at the governing fixture or appliance
- Static pressure loss to get to the governing fixture or appliance
- Average pressure drop through the water meter
- Other losses between the meter and the governing fixture or appliance
- Pressure available for friction
- Size of the line from the meter to the governing fixture or appliance
- Size of the branch lines
- Coefficient of friction in the pipe material
- Velocity of the fluid within the piping

Several factors reduce the available pressure:

- Friction from the interior surface of the pipe (An improperly made joint can have a great effect here.)
- Turbulence from every encountered fitting
- Static head from gravity

Step 1: Draw a System Riser Flow Diagram

You need to create a simple map of the system to form the basis of your design (see Figure 1). Then you need to identify the path and account for any factors that affect the design. This should include anything that would have an effect on the flow and/or the pressure characteristics of the water that you want to deliver.

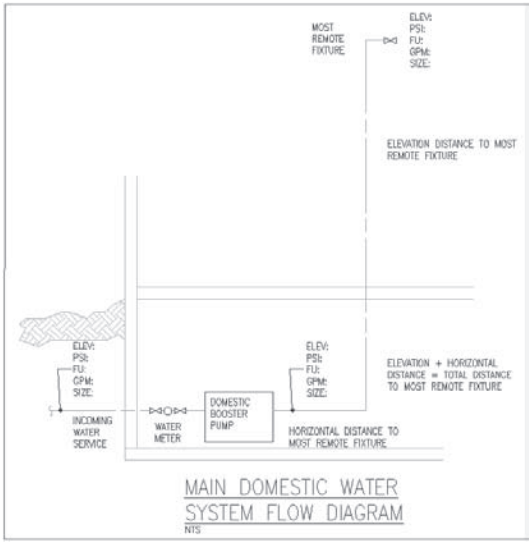

Figure 1 Sample flow diagram

The flow diagram must include the complete water distribution system, but it does not need to include every detail at this level. At this point, you may not even know all of these details.

This diagram should include:

- Incoming water pressure, in pounds per square inch (psi)
- Elevation of the incoming water service where this psi occurs
- Floor-to-floor heights
- Static psi at each floor
- Minimum psi required at the most remote fixture
- Water meter
- Backflow preventer, if required

From this flow diagram, you can now determine:

- Pressure needed at the end of the system
- Pressure required to overcome the static head from gravity
- Available pressure

This flow diagram can be included in your final drawings, even if you are using Revit or other 3D programs. You can use these programs to generate 3D details of sections of the system as they are drawn, but this system flow diagram can be used before the final drawings are complete and even at the very early stages of development, although the design will need to be updated as the project progresses. It also provides a complete overview of the system, which is vital to engineering a complete system. Thus, even when you generate 3D details in Revit, you can use the system flow diagram much as you would use a key plan to see how the pieces fit together in the system.

Step 2: Determine the Pressure Requirement

Use the plans and diagrams to determine the longest run to the highest fixture in the system. Multiply this distance by 0.03 to calculate the pressure required to overcome friction along this distance, based on a 3-psi loss per 100 feet (as a starting point), which allows an acceptable pressure drop of 3 psi per 100 feet of linear pipe run. Multiply this number by 150 percent to allow for fittings and valves. This is the pressure required to overcome friction to the governing fixture.

Add this pressure to the minimum pressure required at that fixture, and then add the pressure required to overcome other losses such as those due to the meter and backflow preventer. This is the pressure needed to serve this fixture, excluding the pressure needed to overcome gravity for the vertical riser.

By adding this to the total static pressure, you will arrive at the total pressure requirement of the system. This is the psi that you need to consider in determining the system pressure requirements.

Here is a step-by-step guide to determining the pressure requirement:

1. Find the static head by multiplying the height from the main to the highest fixture outlet by 0.433 to get psi.
2. Measure the distance to the most remote fixture.
3. Get the discharge pressure of the pumping system, minus the head (in psi) to get to the fixture, minus the psi needed at the fixture. The value is what you have available for friction.
4. Divide the distance (in feet), plus 50–100 percent for fittings, by the psi available for friction to get the psi available per foot. The chart reads in psi per 100 feet, so multiply by 100.

Step 3: Determine the Flow Requirement

While the pressure requirement is based on the most remote (governing) fixture with the highest psi requirement, the flow requirement is based on the anticipated flow of the entire system—not necessarily all of the fixtures and equipment in the system running simultaneously, but still considering the entire system and allowing for reasonable factors for probable simultaneous flow.

To determine the flow requirement, you need to assess all of the risers and branches of the entire system. The flow diagram does not have to show all of the fixtures, but it does need to include the quantities and water supply fixture units (WSFU) for each branch as it connects to the system. This is required to size the water supply service main and the domestic water booster pump system.

Save this information! It will be used to size the domestic booster pump system if needed.

PART 2: DISTRIBUTION PIPING

To size the water piping, take the following steps.

Step 1: Start with the Individual Fixture Requirements

The individual fixture connections are indicated in the plumbing fixture rough-in schedule, so you do not have to go into that level of detail for every individual fixture on the plans or diagrams.

The individual branches must be sized on the diagrams and the plans, except the individual fixture connections that are indicated within the rough-in schedule. The risers should include all of the sizes, but the plans may only include the "major" piping. This is determined based on the layout and complexity of the project, but every pipe must be indicated in one way or another someplace within the documents. Wherever a pipe size changes, the size needs to be noted on both sides of the transition (see Figure 2).

This does not mean that every piece of piping is directly labeled, but that both sides of each size change must be indicated to fully communicate the design intent. However, in the early stages of the project, you are attempting to determine the size of the water service, risers, mains, and booster pumps, so for now you can simply note the WSFU loads on the major branches and totals for the system.

Step 2: Count the Supply Fixture Units

The fixture unit values can be found in code books. Make sure that you are using the correct code and the correct version. It is not always the latest version, but depends on the authority having jurisdiction in the project's location.

Hot water and cold water fixture units are both calculated as 75 percent of the combined WSFU factor. For example, a public lavatory equals 2 DomFU, which breaks down to 1.5 CWFU and 1.5 HWFU.

Step 3: Add the Fixture Units (not the gallons per minute!)

This is true except when dealing with fixtures or equipment with continuous or semi-continuous flow. Most plumbing fixtures only flow when called upon to do so and are not using any water when not in use.

This needs to be done step by step. Each piece of piping must be sized separately.

Step 4: Convert the Fixture Units to Gallons per Minute

You can use the charts provided in most code books, as well as the charts in ASPE's *Plumbing Engineering Design Handbooks*. However, the values in these charts do not always

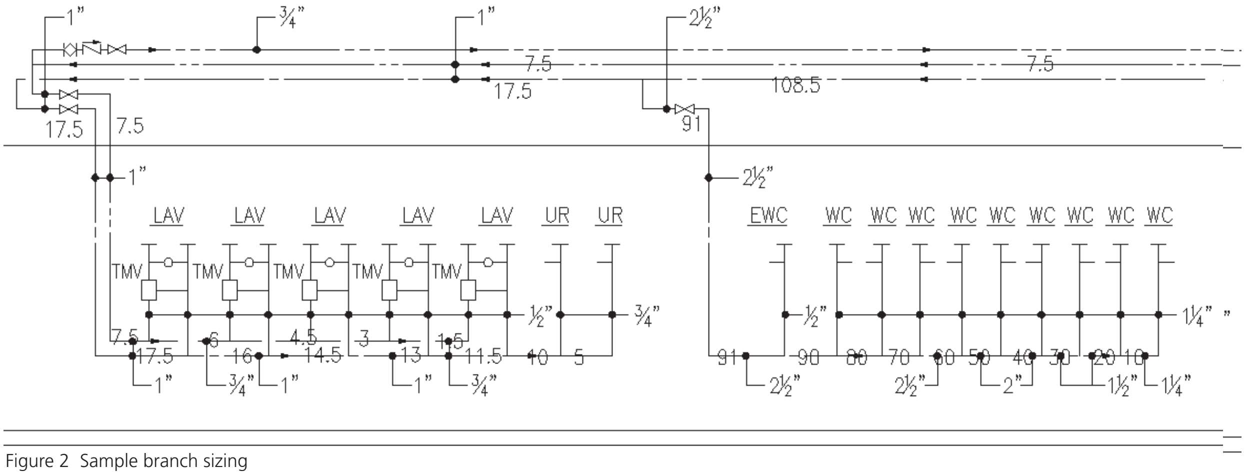

Figure 2 Sample branch sizing

match exactly. Remember that the values listed in any code are either *minimum requirements* or the *maximum allowed*, which does not mean that they will work for each specific application, but that they are the limits by the code for any situation. You cannot design by code alone! If you design by code alone, you will certainly have problems.

There are separate charts, or columns, for systems that are primarily flush valve or primarily flush tank. For domestic water, which includes not only the cold water but also the combined domestic water before it splits off to water heaters, you typically have flush valve toilets and therefore need to reference the flush valve (FV) data. For hot water pipe sizing, you use the flush tank (FT) data.

These values are very different up to a certain level. They are derived from Hunter's curves, which use data collected in studies (decades ago) to account for the probability that a certain percentage of fixtures will be used simultaneously. The accuracy of Hunter's curves has come into question and results utilizing the curves have proven to be as much as 100 percent inflated in some cases. Nonetheless, with more fixtures, it is less probable that they will be used simultaneously. Obviously, if you have only one fixture, the chances are 100 percent that it will be used "simultaneously," so at some point it doesn't really matter if the fixtures are FV or FT.

Depending on your application, you may have to adjust the use of these numbers. For instance, in a stadium application, you could see 25 percent of the fixtures being used at the same moment, but this probably will never happen in an office building.

To sum up:

- Use the flush valve or flush tank values for the cold water piping depending on the type of water closets within the system.
- Use the flush tank values for the hot water piping.
- Use the flush tank values for both the hot and cold water for non-flushing fixtures, regardless of the type of water closets within the overall system.

Step 5: Determine the Velocity

You've determined the gallons per minute, but what about the velocity?

Generally, you should limit the velocity to 5 feet per second (fps) to protect the interior of the piping from erosion, as well as to reduce stress on the fittings, especially with copper piping. If this velocity needs to be exceeded, you may need to switch to galvanized steel or another material such as PVC, which can handle a tremendous flow.

What about the friction loss? This is considered when you are sizing the booster pumps and the domestic water main

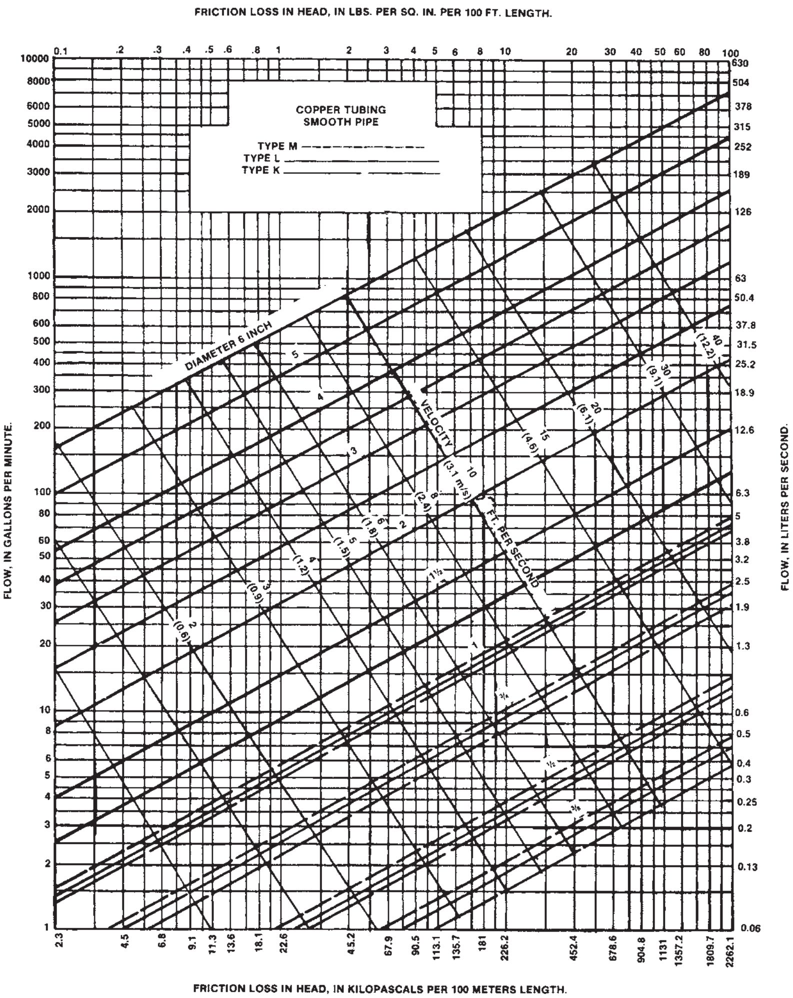

Figure 3 Pipe sizing data chart

and typically will be about 3–5 psi per 100 feet of piping. Since you accounted for friction loss in the previous system calculations, you should already know the value (probably around 3 psi). However, you may encounter issues when working with an existing system if you don't know to what criteria it was designed. Then you should calculate the system to see what you have available for friction loss and size the piping accordingly. (See step 6 below.) If you have 2 psi or less available per 100 feet, the pipe sizes will need to be increased over what they would be if you had more psi available. Remember: Bigger pipes equal less friction. If this is an existing system that is undergoing modifications, additional loads may be added.

Back to velocities: How fast should you go?

Note that erosion increases exponentially as the velocity increases ($E = FV^5$), and smaller pipe is more sensitive to velocity than larger pipe. Some say that galvanized steel can safely handle 10 fps for pipe more than 1½ inches and 8 fps for smaller sizes and that copper can handle up to 8 fps. However, try to keep your velocities down.

- Cold water = 5 fps
- Hot water = 4 fps
- Hot water return = Less than 4 fps

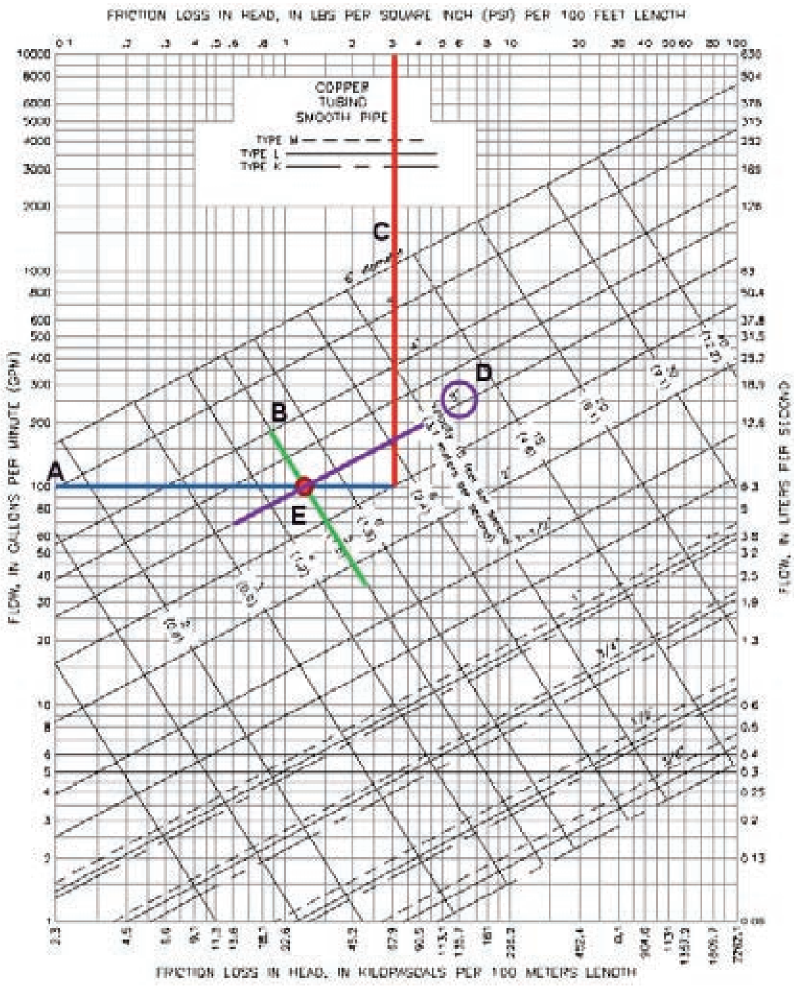

Figure 4 Pipe sizing data chart with example references

Step 6: Size the Piping

Now that you have collected these numbers, how do you size the piping?

1. Reference a pipe sizing data chart that shows demand (in gpm) versus velocity (in fps) and pressure loss due to friction (in psi per 100 feet). The charts differentiate between the types of piping because different materials have different coefficients of friction. Note that the chart in Figure 3 is for copper piping and that it includes separate lines for type L, K, and M copper pipe because each type has a slightly different coefficient of friction.
2. Look for the gpm on the flow side of the chart.
3. Follow that line to the intersection of either the velocity or the allowable friction loss, whichever comes first.
4. Find the diagonal line closest to the intersection. Everything below that line will be that pipe size. (Disregard 3½-inch piping. It isn't used anymore.)

The chart in Figure 3 is from the ASPE *Plumbing Engineering Design Handbook*. Other charts may rotate the data 90 degrees, so make sure that you carefully read the chart and modify this procedure to ensure that you are looking at the correct data points.

This process must be repeated for every piece of piping within the system, from the most remote fixture to the point of the incoming service.

Let's Look at an Example

A system with copper pipe requires 100 gpm and has an allowable pressure drop of 3 psi per 100 feet and a maximum velocity of 5 fps.

On the pipe sizing data chart, look for the gpm on the flow side (reference A in Figure 4). Follow that line to the intersection of either the velocity (reference B) or the allowable friction loss (reference C), whichever comes first. In this case, the maximum velocity comes first.

Use 5 fps for cold water, 4 fps for hot water, and 3 fps or less for hot water return.

At the intersection is a diagonal line with a size over it (reference D). Everything below that line will be that pipe size. Note the design point (reference E). In this case, the pipe size will be 3 inches, but 5 fps is at the upper limit of the capacity of 3-inch pipe. Any additional load will exceed the design parameters for 3-inch pipe, thus requiring 4-inch pipe. (Remember that 3½-inch pipe is no longer used.)

Again, this process must be repeated for every piece of piping within the system, from the most remote fixture to the point of the incoming service. PSD

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