The Importance of Velocity in a Piping System

UNIFORM PLUMBING CODE® CONTINUES DR. HUNTER'S WORK ON EFFECTIVE SIZING OF A SUPPLY AND DISTRIBUTION SYSTEM

By Enrique Gonzalez

Plumbing systems consist of various parameters such as pressure, velocity, flow rates, resistance, and other fluid mechanics. When sizing a water supply and distribution system, it is important to know such parameters and what effect they will have throughout the system. Water supply systems with constant and continuous flow rates will maintain relatively constant pressures and velocities at any given point and predictable results can be established, which can make sizing the water supply system easier. However, the flow rates are generally not constant in plumbing systems, as the use of fixtures and appliances are highly variable. This column will discuss the relationship between the velocity, flow rates, and ways in which the *Uniform Plumbing Code (UPC®)* continues to implement safe and effective methods for sizing a water supply and distribution system.

During the 1930s and 1940s, Dr. Roy B. Hunter, a physicist from the National Bureau of Standards, dedicated his talents to plumbing

TABLE 1.
CALCULATED WATER VELOCITY FROM GIVEN FLOW RATES

FIXTURE	MAXIMUM FLOW RATE, GPM	MINIMUM PIPE DIAMETER (ID), IN	ESTIMATED WATER VELOCITY IN PIPE, FPS
Showerheads	2.5	0.5	4.09
Public Lavatory Faucet	2.2	0.5	3.59
Pre-rinse spray valves	1.6	0.5	2.61

Table 1 – Maximum flow rates and minimum pipe diameters for fixtures from the *2015 UPC*. The velocity was determined using Equation 1.

TABLE GRAPHIC DEVELOPED BY ENRIQUE GONZALEZ

in an effort to standardize plumbing systems in the United States. The intent was to protect the public health and welfare by applying standardized design methods to water supply, distribution, and drainage plumbing systems of all sizes. During the 1940s, Dr. Hunter developed and published the BMS66 document, which contains methods for sizing a water supply system for fixtures by assigning fixture-loading factors. The BMS66 document correlates with the degree at which a system will be loaded by that fixture at a presumed peak demand. Today, these water supply units are known as water supply fixture units (WSFU).

The first edition of the *UPC*, officially published in 1946, contains a section titled "Size of Water Pipe and Fittings" that indicates "The following fixture Unit Tables are based on BMS66 (Plumbing Manual) and have been designed as a simple method of determining the sizes of the meter, house supply, and branches of the average water piping system." Over time, the *UPC* fixture unit table has evolved to what is now known as the "Water Supply Fixture Units (WSFU) and minimum fixture branch pipe sizes," which is Table 610.3 of the 2015 *UPC*. Table 610.3 lists the WSFU values for various appliances, appurtenances, and fixtures that are required for sizing the water supply and distribution piping system.

The BMS66 document indicates that, "in general, a velocity greater than 15 feet per second in the building main should not be employed, as objectionable line noise is likely to result." This limit established a firm foundation as to what is a considered a high velocity for water supply. Appendix A of the 2015 *UPC* specifies "velocities shall not exceed 10 feet per second, except as otherwise approved by the Authority Having Jurisdiction." Furthermore, the 2015 *UPC* indicates "velocities within the water supply piping systems should be limited to 8 feet per second for the cold supply and 5 feet per second for hot water supply using copper piping or tubing, including other piping or tubing materials using copper fittings."

There have been many studies with data supporting the damaging effects, such as corrosion and erosion of copper pipe and fittings, due to high water velocities. Furthermore, higher water temperatures can accelerate the process of corrosion and erosion. The Copper Development Association recommends a velocity of not more than 5-8 feet per second for cold water and 4-5 feet per second for hot water at temperatures up to 140 degrees Fahrenheit.

Under normal conditions, the WSFU values obtained from Table 610.3 or Table A 103.1 of the 2015 *UPC* and their corresponding minimum pipe diameters keep the velocities within the requirements of the *UPC*. However, the *UPC* does not indicate how a velocity can be determined in order to justify the velocities are within the required limits. Regardless of the method used to size the piping systems, it is important to limit velocities, as excessive velocities are the single most destructive condition in a piping system. Let's take a look at a few ways to estimate the velocity within the water supply system by obtaining a flow rate and the pipe diameter in question.

Chapter 4 of the 2015 *UPC* contains maximum flow rates for some fixtures. For example, public lavatory faucets are limited to 2.2 gallons per minute. Table 610.3 of the *UPC* indicates that the minimum nominal (I.D.) pipe size supplying a public lavatory faucet shall be not less than ½-inch in diameter. Table A 103.1 will contain similar information. If the flow rate and the pipe diameter are known, you can determine the velocity by using simple algebra. Equation 1 shows the relationship between flow rate, velocity, and the inside diameter of the pipe (cross sectional flow area).

$V=QA$ Equation 1

Where:
V = Velocity
Q = Flow rate
A = Cross Sectional Area of Internal Diameter (I.D.)

As indicated, public lavatory faucets are limited to 2.2 gallons per minute and it was determined the minimum nominal pipe diameter is half an inch. Given the pipe size inner diameter and the flow rate, the velocity can be calculated as follows:

$$\text{Flow Rate} = Q = 2.2\left(\frac{\text{gal}}{\text{min}}\right)\left(\frac{\text{ft}^3}{7.48052\ \text{gal}}\right)\left(\frac{\text{min}}{60\ \text{sec}}\right) = 0.00490\ \frac{\text{ft}^3}{\text{sec}}$$

$$\text{Cross Sectional Area of Pipe} = A = \pi r^2 = \pi\left[\left(\frac{0.5\ \text{in}}{2}\right)\left(\frac{\text{ft}}{12\ \text{in}}\right)\right]^2 = 0.00136\ \text{ft}^2$$

$$\text{Velocity} = \frac{Q}{A} = \left(\frac{0.00490\ \frac{\text{ft}^3}{\text{sec}}}{0.00136\ \text{ft}^2}\right) = 3.59\ \frac{\text{ft}}{\text{sec}}$$

Note: The units selected for the example were based on the common units used in the 2015 *UPC.*

This example demonstrates that a public lavatory faucet at the maximum flow rate and minimum pipe diameter will contain a velocity well within the requirements of the *UPC.* Table 1 shows other fixtures that also require limited flow rates with their corresponding pipe diameters and calculated velocities that fall well within range of the *UPC* velocity limits.

Furthermore, the total WSFU for the system can be obtained from Table 610.3 or Table A 301.1 and can be used to size for the meter and main supply. The total WSFU can be used to determine the estimated required demand load, as a flow rate, by using Chart A 103.1(1) or Chart A 103.1(2). These estimated demand load curves, also known as Hunter's Curve, can be used to estimate the flow rate demand (gpm) for a given water supply fixture unit (WSFU) value.

The pipe diameter for the meter or main water supply can be determined by using the total WSFU values, the known minimum pressure, and the most remote distance of the plumbing system with Table 610.4 of the 2015 *UPC.* In larger systems, the pipe diameter for the meter or main water supply can be determined using Appendix A, where friction factors and pressure loss is accounted for in more detail. Regardless of the method used, when the flow rate and pipe diameters are known, the velocity at the given pipe diameter can be estimated to verify that velocities are within the required limits.

The limits on water supply and distribution system velocities have changed throughout the years and are now more stringent. However, the intent of the limits on velocity still assists the end user in designing a safe and effective water supply system. The years bring improvements in the design of fixtures and appliances and the fixture units introduced by Dr. Hunter need to be refined, as many of today's fixtures use less water. IAPMO has been working with ASPE to revise Hunter's curves and fixture unit tables in an effort to keep the *UPC* up to date with the latest fixtures, appliances, and the effort to conserve water required by today's standards. While the study is still active, we can look forward to what modifications and methods will be proposed.

It seems safe to say that Hunter had successfully demonstrated a valid procedure to keep systems safe and effective. The examples above indicate that using the recommended tables and minimum nominal pipe size diameters given for each plumbing fixture will keep you well within the velocity limits required in the *UPC* for water distribution piping, which at the end will help establish a safe and reliable plumbing supply system for many years to come.

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