A New Formula to Estimate Peak Water Demand

Next-generation plumbing fixtures require next-generation technology — and next-generation calculations.

By Kay Herbert

When estimating peak water demand in buildings, engineers have been using the same formula since the 1940s — Hunter's Curve. However, just as nearly every facet of life has changed in the past 80 years, so too have plumbing fixtures.

Today's engineers and contractors have a variety of factors to consider, such as green technology, touch-free fixtures, hygiene concerns and more, bringing about a need for a calculation that more accurately predicts peak water demand.

That's why I developed a new formula yielding more accurate water demand estimates to meet the challenges of today's buildings. While my formula can be applied to residential buildings as well, commercial facilities with varying water pressures, high-efficiency fixtures and many different fixture types will benefit from it the most.

Engineers using this formula will be better equipped to save costs, reduce water use and prevent bacteria growth.

Estimating Water Demand is Crucial — and Challenging

Large pipe unnecessarily increases cost and can collect excess water that may breed pathogens, including *Legionella* bacteria, the cause of the extremely dangerous *Legionnaire's* Disease. However, piping that is too small does not allow enough water volume for fixtures to operate properly during peak demand.

The challenge for engineers is specifying the right-sized pipe — not only for the main building intake, but also for every pipe in the building. That specification depends on an accurate estimate of peak water demand; the maximum expected load on the system.

If a building had only one type of fixture, estimating peak water demand would be easy. Instead, estimation is complicated for the following reasons:

- Even small buildings have several faucets and flushometers; large buildings can have thousands.
- Faucets and flushometers do not run continuously; they only run when people use them.
- The number of people in the building may vary widely from one time of day to another or from one day to the next.
- Fixtures in various parts of the building may be set with different flow rates.
- Multistory buildings must employ mechanical pumps to overcome the loss of water pressure in vertical piping that must reach the higher floor levels within buildings.

Roy Hunter's 1940 approach, Hunter's Curve, took most of these variables into account and became the standard for generations of engineers estimating plumbing system loads. But while Hunter's system has greatly contributed to plumbing applications, it leaves some gaps for modern plumbing systems. For example, an increased number of fixture types means more water-saving devices and flow rates.

If not relying on Hunter's curve, engineers use the International Association of Plumbing and Mechanical Officials (IAPMO) calculator for commercial and residential buildings — based on other approximate formulas — which does not account for different water pressures and resulting fixture flow rates.

Think about an office building vs. a sports stadium — peak water demand is much different for these two usage

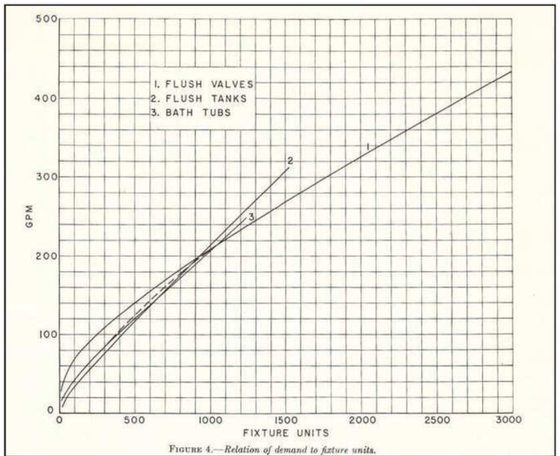

Figure 1. Hunter's Curve

scenarios. In addition, pressure often varies with elevation in multistory buildings, and estimation errors often occur in large buildings with smaller numbers of fixtures.

The Facts on Hunter's Curve

Hunter's Curve assumes that every plumbing fixture has an expected on-time, during which it draws water at a specific flow rate for a specific duration of time. Every fixture also has a minimum expected time between uses, impacted by the number of people in the building, their behavior and the properties of the fixtures. Estimating peak demand takes into account the following variables:

- Fixtures;
- Flow rate;
- Duration;
- Time between uses;
- Number of people in the building;
- Fixture characteristics.

Due to the fact that several of these variables change drastically over time, estimating peak demand becomes a probability problem. To create his probability curve, Hunter proposed using the 99th percentile of each fixture's likelihood of being in use; in other words, the most fixtures running at the same time.

However, Hunter had to assign arbitrary values to each fixture to account for multiple fixture types with different flow rates. It's why Hunter's method can be off by more than 20% in estimating peak demand with modern fixtures.

Lightening the Load

When all the probabilities for each variable are considered, the complexity of accurately estimating peak water demand is truly staggering. For instance, as water is pumped higher in a tall building, water pressure varies from one floor to the next. A flush valve set to a given flush volume will open for a shorter duration at higher pressure, translating to a lower probability that the valve is open, which impacts the demand calculation. You can have a different calculation for every floor in the building.

Exact enumeration of all the variables in play requires 2^n (2 to the power of n) calculations, with n being the total number of fixtures in the building. A building with 100 fixtures would require 1.27 x 1,030 calculations, which would take 4 x 1,018 centuries, even on the fastest NASA-level supercomputer. Other more approximate methods are more accurate for large buildings but less accurate for smaller buildings.

My formula is as accurate as an exact enumeration for any type of fixture and incorporates different pressure and usage scenarios. The formula involves convolution, a mathematical operation on two functions expressing how the shape of one is modified by the other. For nonmathematicians, convolution is, essentially, a fancy type of multiplication.

With convolution, the number of calculations required to account for all the probabilities in a peak demand estimate is only n^2 (n square), where n is the total number of fixtures in the building. In a building with 1,000 fixtures, that's 1 million operations or calculations, which is a much lighter computational load.

How much lighter? I'm able to run it on a spreadsheet from my laptop in a fraction of a second.

Innovation around the new formula is still taking place. The convolution calculator is only a software program right now, as it still needs to be accepted by the appropriate regulatory bodies — IAPMO and the *International Plumbing Code*.

To optimize water demand calculations, accurate flow rates and probabilities need to be obtained and estimated at known pressures in different types of buildings. In addition, the flow rate and pressure dependence for each fixture must be discovered.

Why Use My Formula?

More accurate peak water demand estimates are important for three reasons:

1. Cost. Most engineers specify larger piping than needed, knowing their estimates can be off by as much as 20%. They reason it's better to spend too much than to risk the piping system failing to deliver enough water during peak demand.

2. Hygiene. Too-large pipe is more likely to retain standing water, which can breed *Legionella* bacteria, which cause *Legionnaire's* Disease, and other pathogens.

3. Sustainability. To estimate peak water demand more accurately, engineers need more precise flow rates. When set to an accurate flow rate, modern faucets and flushometers deliver optimal water-saving performance.

Next-generation plumbing fixtures require next-generation technology. This new formula is a step in the right direction for peak water demand estimation and pipe specification for engineers. ●

Kay Herbert, Ph.D., is chief scientist at Sloan and has been with the company since 2000. In his role, Kay aids in the research and development of new technologies and products, specializing in fluid mechanics and acoustics, as well as the design and analysis of hydraulic, electronic and mechanical systems. For more information, visit www.sloan.com.