

Hot Water and How Best to Get It

A SERIES ON HIGH PERFORMANCE HOT WATER SYSTEMS PART TWO: DISTRIBUTION

Story by Gary Klein



About the Author:

Gary Klein has been intimately involved in energy efficiency and renewable energy since 1973. One fourth of his career was spent in the Kingdom of Lesotho, the rest in the United States. He has a passion for hot water: getting into it, getting out of it and efficiently delivering it to meet customer's needs. Recently completing 19 years with the California Energy Commission, his new firm, Affiliated International Management LLC, provides consulting on sustainability through their international team of affiliates. Klein received a BA from Cornell University in 1975 with an Independent Major in Technology and Society with an emphasis on energy conservation and renewable energy.



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Before we talk about hot water distribution systems, we need a few definitions.

A **twig line** serves one faucet, shower or appliance, either hot or cold water; the hot and cold water outlets. The diameter of the twig should be determined by the flow rate of the device it serves. For instance, a garden tub with a 10-gpm flow rate should have a larger diameter twig than a 0.5-gpm lavatory sink. By definition, there can be no simultaneity on a twig, as it serves only one device. (I have begun using “twig” to follow the tree analogy. My friend and colleague, Phil Campbell reminds me that the *Uniform Plumbing Code*® refers to these sections of pipe as fixture branches. Thank you, Phil!)

A **branch line** serves two or more twigs, a trunk line serves a combination of twigs and branches and the main line serves the building. The diameter of the branch, trunk and main lines should also be determined by the flow rate of the devices that they serve, coupled with an estimate of the likelihood of how many devices on the branch, trunk or main line would be operated simultaneously for any significant period of time.

In the previous paragraphs, I used the words “should be determined” when referring to the selection of pipe diameters. Flow rate isn’t the only parameter, but it is a very important characteristic that should be more readily apparent when looking at pipes serving devices with widely varying flow rates. At the present

time, the underlying mathematics behind Water Service Fixture Units (WSFU) and their implementation in various plumbing codes are being revisited to take into account the changes to flow rates that have occurred in the past 20 years and that are expected in the next 20. We will go into more detail on WSFU later in this series.

The ideal hot water distribution system would minimize the time-to-tap. To do this, it would have the smallest volume of water in the pipe from the source of hot water to the fixture. Sometimes the source of hot water is the water heater; sometimes it’s a trunk line. In the ideal hot water distribution system, all the hot water outlets would be close to the water heater that serves them, and there might well be more than one water heater per building. For a given layout of hot water locations, the system will have the shortest buildable trunk line, few or no branches, the shortest buildable twigs and the fewest plumbing restrictions.

Whether the hot water pipes should be insulated and with how much insulation depends on several factors, including the location and length of the piping and the time between hot water events. Insulation makes a significant difference in reducing the time-to-tap when the time between hot water events on the same twig, branch or trunk is between 10 and 60 minutes for pipes from 3/8 to 1 inch in diameter. The time delay gets longer as the diameter of the pipe increases.

The need for insulation is understood when the pipe is installed in adverse environmental conditions, such as in the ground, under a slab or in a cold crawl space. But I would remind



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that normal room temperatures of roughly 70-degrees F are more than 35 degrees from a minimum acceptable hot water temperature. We insulate buildings for this temperature difference; we should do the same for our hot water piping. Oh, yes, all hot water piping, regardless of material (e.g. copper, steel or plastic), needs to be insulated.

High Performance Hot Water Systems

Now we’re ready to talk about high performance hot water systems. Here’s the challenge: Deliver hot water to every fixture or appliance, wasting no more than one cup waiting for the hot water to arrive and wasting no more energy than we currently waste running water down the drain while we wait.

Okay, you’ve thought about it a bit — how would you do it? Well, it turns out we have found five different ways to do this. I’ll discuss them momentarily, but they all revolve around the answer to the following question: If you want to waste no more than one cup waiting for the hot water to arrive, what is the *maximum* amount of water that can be in the pipe that is not usefully hot? The *maximum* is one cup. In fact, it must be less than a cup because you do have to heat the pipe and there are some losses while you do it. If you want to ensure that hot water will arrive before more than one cup runs down the drain, there can only be about 2/3 of a cup in the pipe.

The energy part of the challenge is perhaps less obvious. For this, we need to understand

how much energy is wasted in typical hot water distribution systems while waiting for the hot water to arrive. It turns out there are two kinds of waste in the delivery phase. Structural waste is due to the volume of water between the source of hot water and the hot water outlets. Behavioral waste is what we do with it. The more volume, the longer it takes for hot water to arrive. The longer it takes, the more likely we are to give up (think waiting for hot water at a sink in a public restroom) or to leave and go do something else (Do you know anyone who, while waiting for the hot water to arrive at their shower, goes to the kitchen to make coffee, checks their email or texts their friends and returns when there is steam billowing out of the shower compartment?)

The actual wastefulness of a hot water distribution system is hard to determine since it is a combination of structural and behavioral considerations and you probably won’t let me put a camera in the shower to let me know when you actually get in! The magnitude of this waste will be covered in the next article.

More volume in the piping also means more energy that will be lost when the water in the pipes eventually cools down. In practice, this means that we need to make sure that the hot water piping is “right sized” taking into consideration flow rates, pressure drop, velocity, noise, water hammer and simultaneous uses on branch and trunk lines. Structural waste also includes the energy losses of the water heater, as well as letting the energy in hot water you have used run down the drain. These topics will be covered in future articles in this series.

Without further ado, here are the five possible solutions:

1. You could build every building with central core plumbing, such that all hot water fixtures in that building are within one cup of one water heater. It’s technically possible to do, but it’s not likely to be done in many buildings given the way our floor plans are laid out.
2. You could have one water heater for every hot water fixture. It’s more expensive to bring energy to the water heaters than it is to bring plumbing, so that’s one reason it’s not done very often. You also have the additional costs for the water heaters, the

flues (if the water heaters are fossil fired) and the space, not to mention future maintenance. So, you want to be careful about putting in lots and lots of water heaters, but that's another way of getting the volume down to less than one cup of waste.

This method of improving the delivery phase of a hot water event is often called point-of-use. In most peoples' minds, point-of-use means a small water heater such as the ones found under the sink in a dentist's office. However, each point-of-use water heater needs to be sized for the intended use: a 0.5 gpm lavatory faucet needs a different water heater than a 2.5 gpm shower, a 70 gallon garden tub or a commercial dish machine. Point-of-use is really about location, not the capacity of the water heater.

3. You could put two to three water heaters per building or home. Implementing this solution depends on the clustering of hot water outlets, such as back-to-back or stacked bathrooms, or other hot water locations. It's the same idea as one water heater for every hot water fixture, but you're going to space them out a little bit farther apart. You still have some issues with the running of the power for the water heater, the power or the energy supply for the water heater, but nonetheless it makes sense, particularly as buildings get bigger. Our estimates are that you ought to be putting in a second water heater when the distance between fixture groupings gets to be on the order of 75 feet.

A good example of using distributed water heating for clustered hot water outlets is for the supply of hot water to the sinks in public restrooms at hotels and airports. There are usually several sinks, all of which could be served by one water heater located under the sinks or elsewhere in or nearby the bathroom. Since the faucets all have 0.5 gpm aerators (federal law since the 1990s), the trunk line from the water heater only needs to be 1/2 inch diameter and the twigs need to be no larger than 3/8 inch. The short, small diameter, pipes will be insulated and once the first person draws hot water, everyone else will have hot water quickly throughout the day. You can make sure the trunk line is filled with hot water before anyone turns on the tap by using an on-demand pump to prime the line



with hot water triggered by a motion sensor when someone walks through the doorway to the restroom.

4. You could put heat trace on the pipes. Heat trace is electrical resistance heating elements that are strapped to the pipe and then insulation is wrapped around the entire combination. The electric resistance elements are self-regulating cables. It's a very sophisticated technology and you can have as many feet of heat trace pipe as you would like to have. Since you can run the heat trace very close to each hot water outlet, it can easily meet the water waste portion of the challenge. However, it is not clear that it will use less energy than is currently wasted while waiting for the hot water to arrive. Sometimes heat trace is used in combination with a circulation loop; the heat trace is used to maintain the temperature in the branches and twigs, and a pump is used to maintain the temperature in the trunk line. We're still investigating where it makes the most sense, but it looks competitive in certain applications, particularly where there would normally be very long return line runs found in large commercial buildings or multistory buildings.
5. And then finally you could put a circulation loop one cup from every hot water fixture. We have found this to be the most buildable option, and all circulations systems, however their operation is controlled, can save water if the volume from the circulation loop to the hot water outlets are minimized. Only one that we have found can actually save energy.

In the next article, we will examine each of these hot water distribution strategies in detail. 📄