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Designing Domestic Hot Water Recirculation Systems: Part 1 Determining the Flow Rate

Monday Morning Minutes | by Norm Hall, December 18, 2017

This R. L. Deppmann Monday Morning Minutes series will focus on the design of domestic hot water recirculation systems in the plumbing portion of the commercial and institutional building. This series will be of value to engineers and designers who are new to our industry. The seasoned plumbing engineer will also pick up a few new ideas. Let's start by offering a process to determine the flow rate of domestic hot water recirculation systems. (Photo credit : 59th Medical Wing)

Why Domestic Water Recirculation is Needed

A waste of **time**, **health**, **money** and **resources**. Every one of us has experienced the frustration of running a shower or lav for many seconds to many minutes while we wait for the hot water. *"A waste of time."*

If a lavatory in your client's office runs cold water for 45 seconds before turning hot, do employees wait? If they don't wait, do they properly wash their hands? *"An issue of health."*

If a shower takes a couple minutes before getting warm, think of the water going down the drain. *"A waste of money and resources."*

For these reasons, plumbing codes and engineering office standards require some form of domestic water recirculating systems. The whole idea of a "recirc" system is to provide hot water quickly to the person at the fixture. When water moves through the hot water piping system, it loses heat to the space through the insulation or pipe wall if no insulation. If there is no demand or flow rate in the piping system, the water will eventually drop to the ambient temperature. All of that cold water has to leave the faucet or shower, down the drain, before hot water makes it from the water heater to the fixture.

The goal of the recirculation flow rate is to keep the temperature drop in the supply piping to a reasonable amount. So how much flow rate do we need?

How Much BTUH Loss?

The total heat loss of the pipe is a function of the insulation rating, the temperature difference between the supply water and the ambient air, and the length of the pipe. ASHRAE addresses the insulation rating in the standard 90.1-2013. Their table 6.8.3-1 indicates that water supply temperatures of 140°F or less should have a conductivity rating between 0.22 and 0.28 BTU-IN/(h-ft2-°F). The chart suggests 1” insulation for 1” pipe or less and 1-1/2” over 1”. There are many notes to this chart.

The American Society of Plumbing Engineers (ASPE) has an insulation publication with charts and explanations about the heat loss from pipes.

I use a quick estimate formula that tends to be safe. The actual differences in flow rates with and without a safety factor can amount to just 1 or 2 GPM so this estimate will get you in the ballpark. If the pipe size is less than 2”, I use 10 BTUH loss/ft. and when 2” to 4”, I use 20 BTUH loss/ft.. Any pipe size over 4”, I use 5 times the pipe size for the BTUH loss per ft. This gets you in the neighborhood and may oversize a bit.

Let’s try an example. Suppose you have a 4 story commercial building. Let’s assume the hot water mains are 4” in the basement and about 300 feet long. Let’s say there are four 2” hot water risers at 80 feet each and each riser at each floor has about 100 feet of run out using pipe less than 1”. The specification will meet the ASHRAE 90.1 standard. What is the BTUH loss?

- Mains: 300 X 20 = 6000 BTUH
- Risers: 4 X 80 X 10 = 3200 BTUH
- Floors: 4 X 4 X 100 X 10 = 16000 BTUH

The total heat loss in this example is 25,200 BTUH. We want the temperature at the last fixture to be no less than 10°F cooler than the supply temperature so the BTUH formula will be:

GPM = BTUH/(∆T X 500) so GPM = 25,200/(10 X 500) = 5.04 GPM

If we did the actual math using the exact figures from the ASPE article, the loss would be 22,700 BTUH.

We only use the supply pipe because the goal is to get the correct water temperature to the last fixture. There will be some drop in the return piping to the water heater. That would be important if you were trying to keep the minimum temperature ANYWHERE above a certain value. If that is the case, then use a different ΔT and also include the return pipe BTUH loss.

Minimum Flow Rate of Each Balanced Return

In some systems, it is possible to have an extremely low flow rate on each balanced return. In our example, there are 16 returns and the total flow rate is 5 GPM. The average flow rate per balance valve, in this example, would be 5 divided by 16 or 1/3 of a GPM per valve. The engineer could take the time to calculate the exact flow rate that each balance valve would need but two things would happen. First, some of the flow rates would be less than 1/10 of a GPM. Second, the engineer would go out of business because of the time required.

There are two problems with low flow rates. The ability of the valve to be accurate at such a low flow rate and the issue of dirt or calcium buildup in this open plumbing system. Assuming the contractor can accurately set such a low flow rate, the valve opening would be so small that any debris could clog it up.

I suggest the minimum flow rate through any manual or automatic balance valve should be ½ GPM. It is a nice round number and a combination balance and flow measuring valve like the lead free B&G model RS-1/2S LF circuit setter can easily handle that low flow rate accurately. So, in our example, the flow rate would be the greater of the calculated flow rate or the number of balance valves times ½ GPM.

GPM = 16 X ½ = 8 GPM

What is an Acceptable Temperature Drop in Domestic Hot Water Recirculation Design?

Using the suggestions above, our example will require a pump for 8 GPM. Since the BTUH loss of the system remains at 25,200 BTUH, the temperature drop at the end of the farthest fixture would be 6.3°F rather than 10°F. This means the water will be warmer for the first person to open the faucet. There is no magic to the temperature drop. An engineer may want to keep the lowest system temperature in the mains and branches above 124°F for legionella concerns. She could do the math and determine the required ΔT based on the pipe lengths and then adjust the GPM required. The generally accepted ΔT is 10 but it could be changed if the engineer wants a different supply temperature.

Obviously, the engineer would use code approved point of use temperature control at the fixtures to avoid scalding if the supply temperature is too hot.

Domestic Hot Water Recirculation Steps: Part 1 - Find the Pump GPM

1. Determine the heat loss of the total supply pipe using tables or rules of thumb.
2. Calculate the GPM required using a 10°F ΔT or other value as determined by the engineer.
3. Compare that to ½ GPM times the number of balance valves and choose the larger value.

The next R. L. Deppmann Monday Morning Minutes will look at the pump head and how steep the pump curve should be.