Can water move too fast?

By George Carey

"I think the room is under-heating because the water is moving too fast through the baseboard. If I use a smaller pump or at least throttle down on the pump's flow rate, the baseboard will start heating better." I have heard this statement numerous times from a variety of heating technicians that were having problems with their customer's heating system. I guess you could reason that with the water moving so fast, it doesn't have enough time while inside the baseboard to "give up" its heat. Unfortunately, you are giving the BTUs too much credit…they aren't that smart!

So how do "BTUs" in hot water give off their heat? There are three methods that govern heat transfer: thermal radiant, conduction and convection. Without getting too deep or technical, the mode of heat transfer that we want to focus on with a baseboard system is convection. Most people are aware of the convective nature of the air surrounding a baseboard. The hotter, lighter air wants to rise and float into the room while the colder, heavier air wants to drop to the floor and move along towards the baseboard to replace the hotter air that has just floated up. In the process, the hotter air gives up its BTUs to the cooler surroundings.

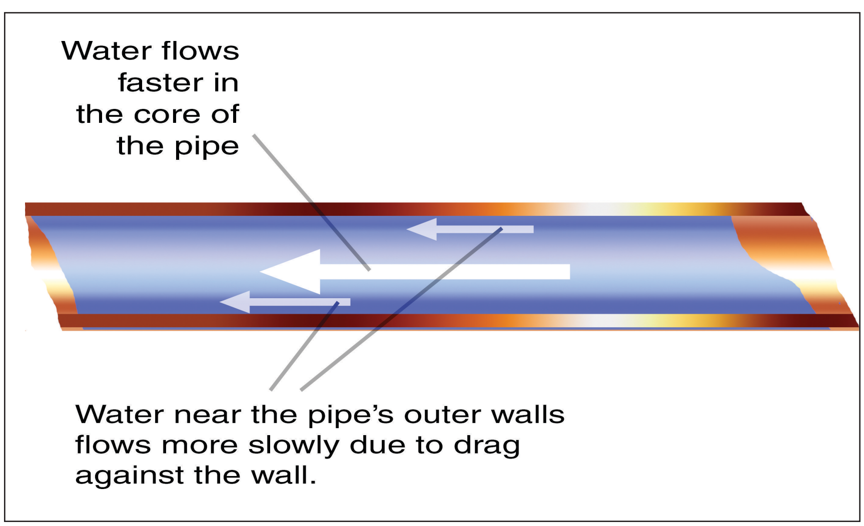
But before this even takes place, there is another convective occurrence that must take place…and that is the hot water (fluid) flowing through the tubing has to give off its heat to the tubing wall. Before the baseboard can emit heat into the space, the heated stream of water must transfer its heat to the baseboard's inner pipe wall by convection.

Now, at the risk of getting too deep, for convection to occur, there are three factors to consider: 1) surface contact area, 2) temperature difference between the water and the inside wall of the tubing, and 3) the convection coefficient which is calculated based upon the properties of the fluid, the surface area's shape and the velocity of the fluid.

Instead of spending too much time with the math formulas, I think if you use your mind's eye, you can visualize the following: as the stream of water flows through the baseboard, the outer edge of this stream is in direct contact with the tube's inner wall. This "rubbing" against the wall creates drag, which means the water that is touching the inner wall of the tubing is moving slower than the "core" or inner stream. Because of this, the temperature of this outer layer of water becomes cooler than the inner stream. This drop in temperature impacts the rate of heat transfer—it slows it down.

Remember, one of the factors that affect convection is temperature difference! In fact, a good visual is to think of this outer layer as an insulator that impacts the rate of heat transfer from the hotter inner stream of water to the tubing's inner wall. This is especially true when the speed of the water approaches laminar flow instead of turbulent flow. So in effect, the faster the water flows through the tubing, the thinner the outer boundary layer or insulator becomes, thus increasing the rate of heat transfer from the hotter inner "core" water to the tubing's inner wall.

You can confirm this by taking a look at any



Can water move too fast?

baseboard manufacturer's literature and check out their capacity charts. They typically will publish their BTU output per linear foot based upon two flow rates: 1gpm and 4gpm. The BTU output is ALWAYS higher in the 4gpm column.

Here is another way of looking at this concept. More speed (faster flow rate) equals more heat transfer (higher output). Consider the size of a hot water coil used in an air handler and the amount of BTUs it can provide. Now think about how much fin-tube baseboard you would need to install to provide the equivalent amount of BTUs. Obviously the difference is the speed at which the fan blows the air across the coil, which is much faster than the air that flows naturally across the baseboard.

Everyone experiences this phenomenon each winter. The weatherman refers to it as the "wind chill" factor. He will tell you what the actual temperature is outside, but because of the wind chill, it will feel X degrees cooler. Why? Because the cold air is moving across our body much faster, which in turn takes heat away from us much faster; so it feels colder than it really is.

A trick of the trade that has been passed on to fellow technicians over the years has been to turn up the aquastat setting on the boiler to increase the water temperature. The reason the guys will do this is if a room or a zone isn't quite heating up to the thermostat's setting, they find that by increasing the water temperature, they can increase the amount of BTUs per linear foot available from the baseboard. (Of course, this will only work if the boiler is big enough to offset the home's actual heat loss.)

Knowing that baseboards can provide more heat with hotter water, follow this next example to see why moving the water faster and not slowing it down will provide more heat. Let's use the average design conditions when sizing for the amount of baseboard you would need to offset a room's heat loss. Typically, we design a hot water heating system for a residential home at a 20°F temperature drop. That means the water would enter the radiation at 180°F and exit 20°F cooler at 160°F. The average water temperature in the radiation would then be considered 170°F.

You would then check the BTU/h rating of the baseboard at this average water temperature and determine how many feet of baseboard the room needs to offset the heat loss.

What happens if we increase the flow rate so that the water only takes a 10°F temperature drop? If it entered the radiation at 180°F and came out at 170°F, then the average water temperature would be 175°F. At this higher average water temperature, the baseboard would be capable of providing more BTU/h. output. Taking it one step further, if the system only took a 5°F temperature drop, the average water temperature would be 177.5°F in the radiation, yielding even more BTU/h output.

So now, you can clearly see that water can ***not*** be moving too fast through your baseboard to prevent the BTUs from jumping off where needed. Of course, to achieve these tighter temperature drops while delivering the right amount of BTU/h, the flow rate has to increase accordingly. And here comes the trade-off…with higher flow rates through a given pipe size, the pressure drop increases quite dramatically. The result can be very large, requiring high headed circulators that cost more and use more electricity. Also the higher flow rates increase the velocity of the water—and at some point the velocity will create noise issues. The point is not to design a system around these high flow rate/small temperature drops, but rather to recognize that the next time someone tells you they think the water is moving too fast and that is why the room is underheating, you'll know that's not the cause of the problem.

If you have any questions or comments please call me at 1-800-423-7187 or email me at gcarey@fiainc.com.