Variable speed circulation – the simple facts

BY JOHN VASTYAN

Renowned Taco trainer John Barba opened a recent webcast this way: "I'm John Barba, and today's topic is variable speed pumping. It's not a new concept and it's not very hard to do."

Well, I'm not John Barba, and that's why the topic of variable speed hydronic circulation has been something of a mystery for me. But being the talented educator that he is, I've come to learn a lot more about the technology. I'm eager to share it with you.

Harry Grattage, technician for Riley Plumbing, installs a variable speed circulator.

John goes on to point out that 2004 was the year Britney Spears got married and broke his heart, twice. Also in 2004, America's domestic engineer, Martha Stewart, was sent up the river for crimes against humanity. And, 2004 was also the year that Taco introduced the world to a full line of residential variable speed circulators. That was five years ago, but we're still grappling with this "new" technology.

> Remember that virtually everything in hydronics – from pipe sizing to circulator selection – is tied to the universal hydronics formula which, states that GPM = BTUH ÷ △T and multiplied by 500.

Let's take a closer at the concept of variable-speed pumping. I've asked Barba and professional contractor Bill Riley (www.rileyplumbing.com) to explain when it's best to apply the technology, where you'd use it, and what the key benefits are.

The universal hydronics formula

The purpose of a variable speed circulator is to automatically adjust its speed based on heating load demands, or how many BTUs are needed in a structure. To understand how it does that, let's take a quick look at the universal hydronics formula which states that GPM is equal to BTUH divided by delta-T, multiplied by 500.

Let's define the terms.

GPM is gallons per minute. That's the flow rate needed to deliver the required amount of BTUs.

BTUH or BTUs per hour, or the required amount of heat for a house, or zone, at any given point in time. We all know that outdoor temps or the number of people in a home will alter the BTU load.

Delta-T (△T) is the designed temperature drop across the piping circuit. In a baseboard zone, the design △T is usually best at 20 degrees, meaning the water might enter the baseboard zone at 180°F and return to the boiler 20 degrees cooler, at say, 160°F. In most residential radiant floor heating systems however, the design △T is usually about 10 degrees, meaning water would enter a radiant loop at 130°F and return at 120°F.

This 10-degree △T is important because it ensures an even, comfortable floor surface temperature throughout a room. A wider △T would likely create greater variation in floor surface temperatures; not a good thing.

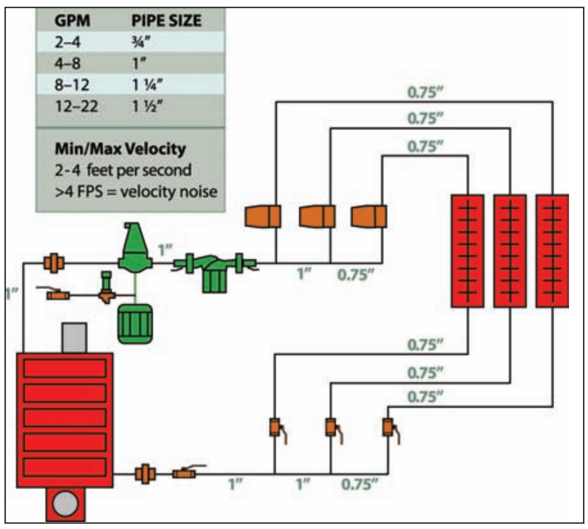
The final element of this equation is 500. That's a shortcut that represents the weight of one gallon of water (8.33 pounds) multiplied by 60 minutes in an hour, again multiplied by a specific heat characteristic of the fluid, which is "1" for 100% water. After all, it takes one BTU to raise the temperature of one pound of water one degree Fahrenheit in one hour. 8.33 × 60 × 1 = 499.8 . . . so we'll just call it an even 500.

Sample project

"Let's say we have a house with a heat loss of 75,000 BTUH with an outdoor design temp of 0°F," said Barba. "We need three zones of fintube baseboard; each zone has a 25,000 BTU-per-hour heating level. Each zone will be designed to a 20-degree △T.

"Now, let's plug the numbers into our formula," he continued. "Remember that GPM equals BTUH divided by △T times 500. In this case, GPM = 75,000 ÷ 20 × 500, or [75,000/20 × 500] = 10,000. So, 75,000 ÷ 10,000 gives us a flow rate for the job of 7.5 gallons per minute (remember 7.5 GPM for later). Each zone has a heating load of 25,000 BTUH. If we plug this information into our formula, we would divide the load, 25,000, by 20 times 500 [25,000/20 × 500] or 10,000, for a flow rate per zone of 2.5 gallons/minute."

Knowing this, said Barba, we can now size the pipe. Using the following guidelines, the proper pipe size for the boiler supply pipe and the boiler return pipe, the distribution header, and the zone piping can be determined.



Pipe sizing guidelines are all based on minimum and maximum flow velocities, a minimum of two feet per second (FPS) and a maximum of four FPS. If we exceed the maximum of four FPS, flow velocity noise will occur.

"The piping arrangement would be next," added Bill Riley, president of Warwick, R.I.-based WJ Riley Plumbing and Heating, an admitted hydronics junkie. According to Riley, "this hydronic recipe calls for 1-inch pipe and 7.5 gallons per minute. At the header, I'd branch off into 3/4-inch lines for each baseboard zone, then doing the same thing, only backwards, for the return side of the system."

Next up, said Barba: estimate the head loss of the piping system so that circulator(s) can be selected. To do this, measure the longest zone from the discharge side of the circulator all the way around the system, through the boiler, and back to the suction side of the circ. Let's just say that for this application the longest run is going to be 150 feet of pipe, including the baseboard element.

"To estimate head loss, we're going to take the length of the longest run (150 feet) and multiply it by 1.5 to allow for the additional pressure drop through the fittings, the valves and all the other stuff that gets in the way," added Riley. "If we take that 150 and multiply it by 1.5, we're going to find that we have a total equivalent length of 225 feet. Next, we multiply that number by .04 (representing 4 feet of head loss per 100 feet of straight, properly-sized pipe, based on the maximum flow velocity of four FPS).

"Now if we 'math that out,'" said Barba, "225 multiplied by .04 equals nine feet of head loss. Remember, the circulator must be sized to provide 7.5 GPM while overcoming a head loss of nine feet."

To size the pump for the total flow rate needed for the job, we know the need is for 7.5 GPM at nine feet of head to deliver 75,000 BTUs. Size for the worst-case head loss zone. If the circ can overcome the head loss of the worst-case baseboard zone, it can certainly overcome the head loss of all the others.

System curve

According to Barba, we already know how to locate two points on the system curve. At 7.5 GPM we have a head loss of nine feet and, for clarity, at 0 GPM we have a head loss of 0 feet of head. "Using a formula, we can calculate other head-loss points at other flow rates, and then plot them on the pump curve graph against a pump performance curve. Once we do that, we can

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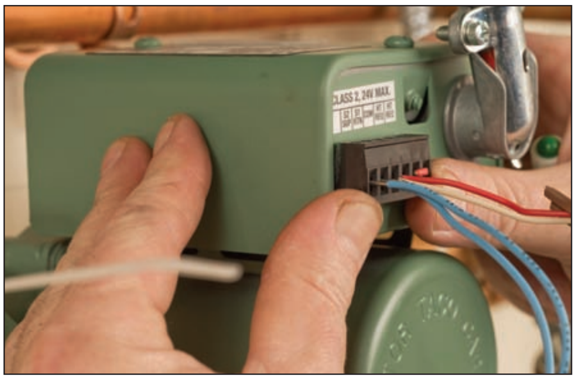
see that the actual operating point of the system will be where the system curve intersects a pump curve. Aha!, but the system requires 7.5 GPM only when all zones are calling, and only when it's zero degrees outside," added Barba with a wild variety of facial expressions and the waving of hands.

"The building will need fewer BTUs when the zone valves begin to close," continued Riley. "If just two zones are calling, we drop to 50,000 BTUs. If only one zone calls, we're down to a need for only 25,000 BTUs — meaning progressively higher flow than we want or need."

Through experience, many of you know this soon translates to boiler short-cycling, possible even in the dead of winter — and this will substantially impact overall system efficiency.


Making the final connection to the variable speed circ.

The perfect hydronic storm: dropping Delta-Ts

Another concern is pressure differential within the system. As zone valves close, the system curve intersects the pump curve at higher and higher pressure differentials. This greater pressure differential can cause higher flow velocities within the system, and that can quickly lead to velocity noise. It's the perfect hydronic storm: with a fixed-speed circulator, it's easy to have poor heat transfer and inefficient, noisy operation, all at once.

One way to deal with the noise would be to install a pressure differential bypass valve, like the Taco 3196, which prevents flow when all of the heating zones are calling. But as those zone valves close, increasing pressure differential within the system, the 3196 bypass valve opens to allow excess pressure and flow to pass through back to the suction (inlet) side of the circulator.

A better solution for noise would be to use a mid-flow, low head, flat-curve circulator like the Taco 007. With such a pump, system pressure rises minimally, nixing the need for a bypass valve. But — if the job has higher head requirements than the 007 can deliver, we may need another solution: a variable speed pump.

With all of the zones calling, we know that △T = 75,000 ÷ 9 ÷ 500. "So, we find that the actual system delta-T at this point may be closer to 16 degrees, not the 20 we designed for," said Barba. "Doesn't sound like much, right? But that also equates to about a 20 percent difference. With only two zones calling the delta-T drops to about 15 degrees (a 25% difference), and with only one zone calling, the delta-T drops again to 12 degrees . . . a whopping 40% difference."

"All of this can happen, even when it's zero degrees outside," asserted Riley. "What if it's, say, 35 degrees outside and the heating load at that temperature is only 38,000 BTUs with all zones calling? As you can see, the potential for smaller and smaller delta-T's, over 60% differences to design, can quickly lead to inefficient boiler short-cycling and plenty of velocity noise."

Barba's waving his arms again to emphasize his point: "Solve the dilemma of dropping Delta-Ts by using a fixed △T, variable-speed circ," he said.

Looking back at the universal hydronics formula, we know that if we fix the △T at 20, and divided the total load of 75,000 by 20 times 500 or 10,000, we find that the flow rate has to be 7.5 GPM. With two zones calling, a load of 50,000 BTUs, and a fixed 20-degree △T, we find that the flow rate has to be 5 GPM. And with one zone calling, the flow rate has to be 2.5 GPM. Clearly, with a fixed △T, flow will vary automatically to the zones, it has to. You'll never have to worry again about over-sizing a circ.

So, rather than searching for the point where the system curve intersects the pump curve, we know that the pump curve will self-adjust every moment and every day of the heating season.

In a variable speed circulator, the △T control is built in. They're simple to install and easy to program. There're no surprises during installation. The only difference is the need to wire the sensors on the supply and return.

Variable speed circs, by design, are also easy to set up. You simply dial-in the pump to meet the △T you want. Just remember that the △T is directly related to flow rate. It's part of the universal hydronics formula: GPM = BTUH ÷ the △T x 500.

Another pump control concept on the streets is Delta-P (△P), or pressure differential. But where is P in the universal hydronic formula? What we're trying to do here is to satisfy the heat loss of the structure in the most efficient way. The best way to do that is to allow the circulator to adjust its speed to deliver the required BTUs. By maintaining a consistent △T (10 for radiant, 20 for baseboard, higher for panel radiator systems, etc.), we can vary the flow as needed to ensure optimal performance and heat transfer. And, the △P is always on, always drawing power, 24/7/365.

One final thing about △T: it doesn't flat-line. A △P circ is not only always on, always drawing power, 24/7/365 but it will always maintain a constant delta-P in the system regardless of what the system actually requires. If the programmed-in △P isn't accurate, actual system flow rates may be much higher than required, and that will mean a smaller △T than designed leading to much less efficient system operation. A △T pump, on the other hand, will always run at the lowest possible speed, maximizing system performance and efficiency.

Now, that's a hydronic recipe Barba says is better than Martha Stewart's best, and a thing of even greater beauty than Britney Spears. ■

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