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Tool & Service Equipment Roundup

Variable Speed Circulation

John Barba and Bill Riley explain some simple facts of life

BY JOHN VASTYAN

THE TOPIC OF VARIABLE SPEED HYDRONIC CIRCULATION HAS been something of a mystery for many in the industry. In 2004, Taco introduced the world to a full line of residential variable speed circulators. Even though that was five years ago, some are still grappling with this “new” technology.

Taking a closer look at the concept of variable-speed pumping, Taco trainer John Barba and professional contractor Bill Riley 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 (ΔT)** is the designed temperature drop across the piping circuit. In a baseboard zone, the design ΔT 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 ΔT is usually about 10 degrees, meaning water would enter a radiant loop at 130°F and return at 120°F.

This 10 degree ΔT is important because it ensures an even, comfortable floor surface temperature throughout a room. A wider ΔT 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

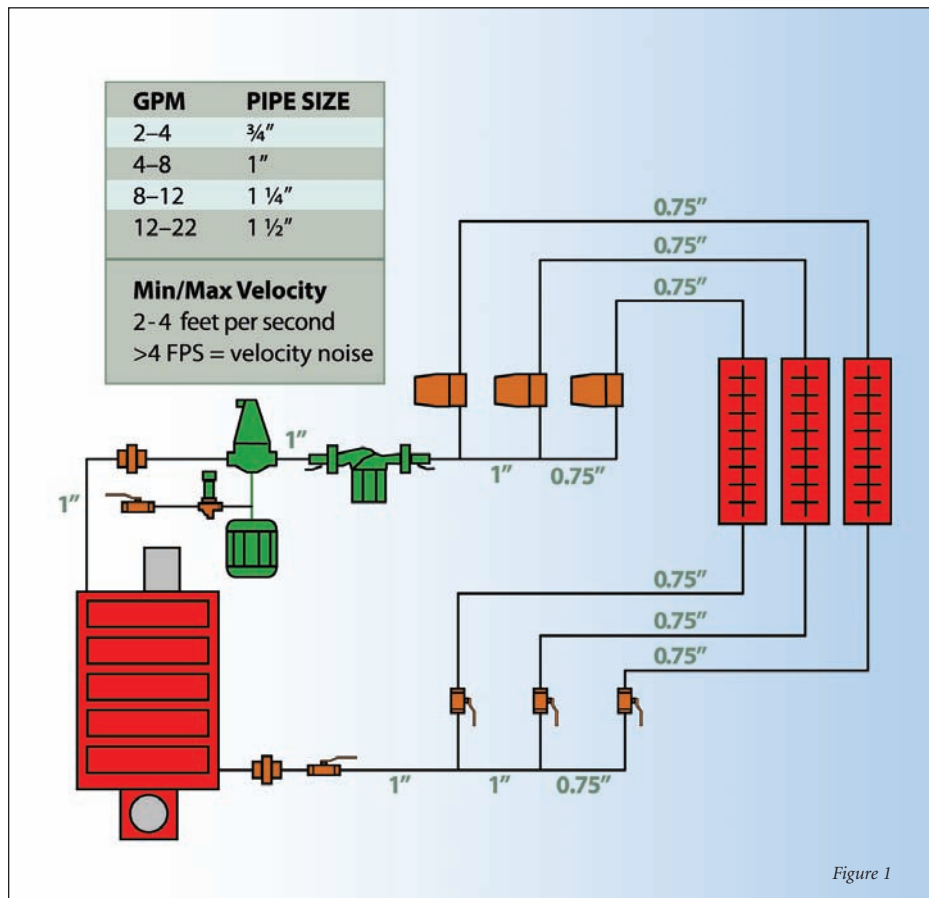


Figure 1

pounds) multiplied by 60 minutes in an hour, again multiplied by a specific heat characteristic of the fluid, which is “1” for 100 percent water. After all, it takes one BTU to raise the temperature of one pound of water one degree Fahrenheit in one hour. $8.33 \times 60 \times 1 = 499.8 \dots$ 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 fin-tube baseboard; each zone has a 25,000 BTU-per-hour heating level. Each zone will be designed to a 20-degree ΔT .”

“Now, let’s plug the numbers into our formula,” he said. “Remember that GPM equals BTUH divided by ΔT times 500. In this case, $GPM = 75,000 \div 20 \times 500$, or $[75,000/20 \times 500] = 10,000$. So, $75,000 \div 10,000$ 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 $[25,000/20 \times 500]$ 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.

In Fig. 1, 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, RI-based WJ Riley Plumbing and Heating, an admitted hydronics junkie. “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

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VARIABLE SPEED CIRCULATION

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 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.

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 $\Delta T = 75,000 \div 9 \div 500$. “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 differ-

ence. With only two zones calling, the delta-T drops to about 15 degrees (a 25 percent difference), and with only one zone calling, the delta-T drops again to 12 degrees . . . a whopping 40 percent 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 percent differences to design, can quickly lead to inefficient boiler short-cycling and plenty of velocity noise.”

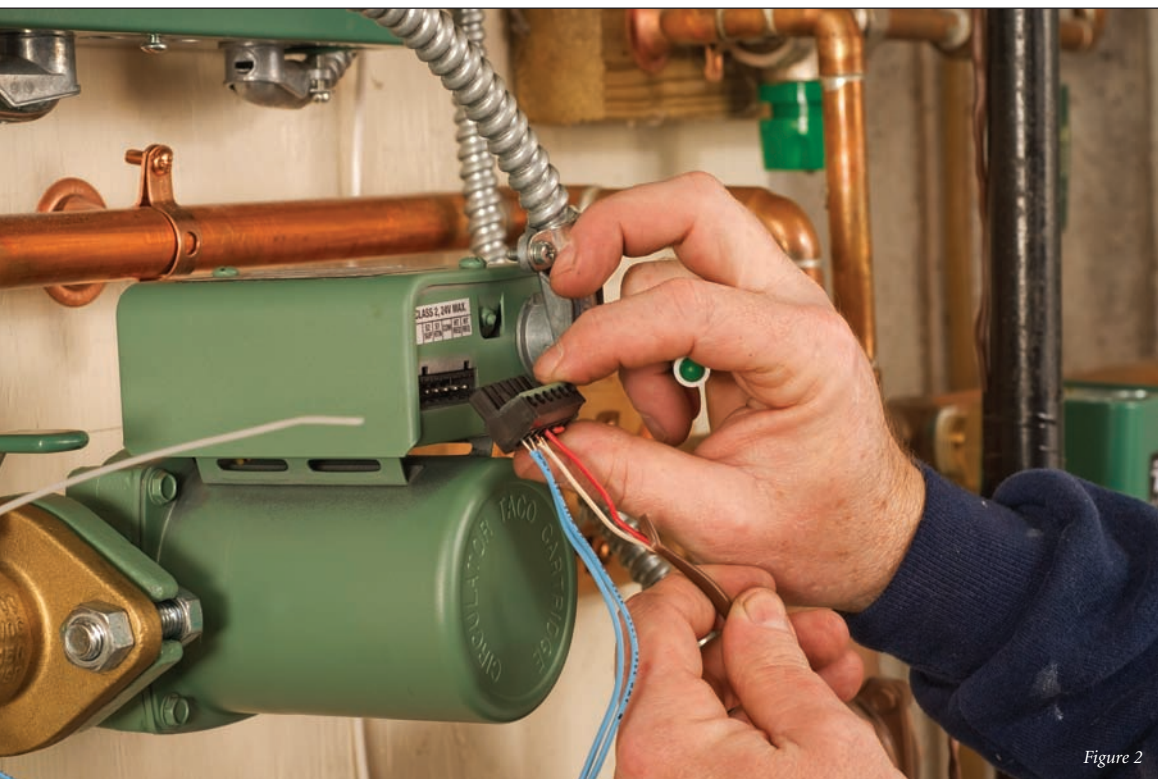


Figure 2

“Solve the dilemma of dropping Delta-Ts by using a fixed ΔT , variable-speed circ,” Barba said.

Looking back at the universal hydronics formula, we know that if we fix the ΔT 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 ΔT , 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 ΔT , 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 ΔT control is built in. They’re simple to install and easy to program. There are no surprises during installation (see Fig 2 – photo of pump wiring). 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 ΔT you want. Just remember that the ΔT is directly related to flow rate. It’s part of the universal hydronics formula: $GPM = BTUH \div \text{the } \Delta T \times 500$.

Another pump control concept on the streets is delta-P (ΔP), or pressure differential. But where is ΔP 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 ΔT (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 ΔP is always on, always drawing power, 24/7/365.

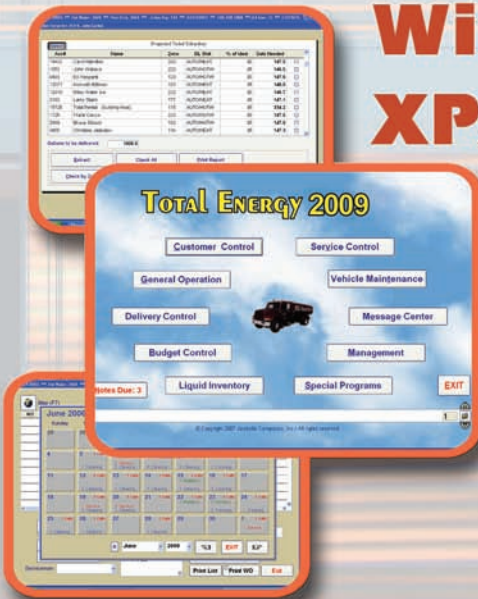
One final thing about ΔT : it doesn’t flat-line. A ΔP circ is not only always on, always drawing power, 24/7/365 but it will always maintain a constant delta-P in the system regardless of what the system actually requires. If the programmed-in ΔP isn’t accurate, actual system flow rates may be much higher than required, and that will

mean a smaller ΔT than designed leading to much less efficient system operation. A ΔT pump, on the other hand, will always run at the lowest possible speed, maximizing system performance and efficiency. | **FON**

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