System With a Heart

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In my job with the Radiant Panel Association, I get to answer all kinds of questions from the whole spectrum of radiant installers. Sometimes the caller is a highly knowledgeable and experienced heating contractor. Sometimes they are a plumber who is tackling their first closed loop heating system. One thing I have learned is to never assume that an experienced contractor knows the basics of hydronic heating systems. Too many contractors missed class on the day they taught things like "Circulators 101."

"What size pump do I need to push heated water at about 130 ˚F through 300-325 feet of 1/2" PEX? The system pressure varies between 40 and 60 psi. I was thinking about a Taco pump. What model should I use? This installation is between the joists, using aluminum heat distributors." This is the type of question I have encountered from self-appointed radiant heating specialists. In this case, a plumber using an open loop water heater.

What information is missing from this attempt to size a pump? Just about everything. Only two numbers are needed to properly size a pump, flow required in gallons per minute, and head pressure in feet of head. Both these numbers are products of knowledge about the whole system and the space to be heated. Unfortunately, neither of these numbers can be found in the information provided by the aforementioned installer.

Pumps, more properly referred to as "circulators", are probably the least understood and most often misapplied component of a radiant system.

Literally the mechanical heart of the system, the pump keeps the liquid coursing through the veins of pipe and tubing. If the pump fails to do its job, the whole system malfunctions.

FLOW

Flow is what delivers heat to the space, so it is imperative that the amount of heat required is known before selecting a pump. This can be as simple as using 1 gpm per 10,000 BTUs per hour of heat required (figuring a 20˚F

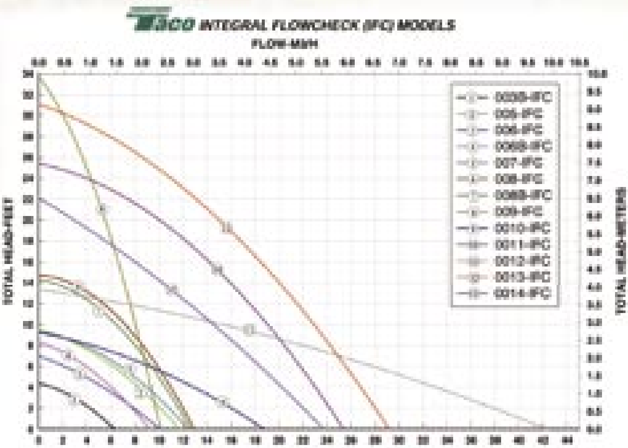

Figure 1

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temperature drop in the water circulating through the system). If you are not a math wiz, there are computer programs available from many sources to do the calculations for you. A lot depends on the complexity of the system and the desired temperature drop of the water from the heated supply side to the return side. The smaller the temperature drop, the greater the flow required.

Some are tempted to simply use the BTU output of the boiler as the determining factor. This approach doesn't confirm whether or not the distribution system can actually disperse the heat or handle the flow. The boiler is only one component in the circuit and is a poor choice as a substitute for performing a load calculation. Granted, a heat load should be performed before the boiler is selected so the boiler can be sized to the load, but what happens if your load is divided. Multiple circulators can be used to do different tasks from the same heat source. Flow in the circuit the pump services must be determined by the heat load in that circuit. If a floor zone requires 20,000 BHUH at design temperatures and you would like to see a 20 °F drop between the supply and return, the formula 40,000 BTUH divided by 10,000 BTUH/1 gpm estimates that you would require a pump that can move 4 gallons per minute through the pipe.

PRESSURE DROP

But flow is only half the equation for sizing a pump. Once flow is determined, pressure drop can be calculated. Pressure drop is a measure of the resistance to movement the water encounters as it travels through the pipes and fittings. It is often expressed in "feet of head" or head pressure. This is actually the amount of mechanical energy added per pound of fluid to overcome this resistance. The pump, when it is running, creates a pressure differential between the supply of the circuit and the return. It is this differential that causes the water to flow. If there is little resistance to flow, the water will flow fast and the pressure differential will be low. If the resistance is great, the water flow will be slow and the pressure differential will be high.

It may help to think of it this way. A 1/4 hp pump will put 1/4 hp of energy into the water. That energy will either be used to move water or build pressure. Whatever energy isn't used for one will be used for the other (except for the energy wasted in heat generated by the motor). Because the pump has a limit to the amount of mechanical energy it can exert, there is also a limit to the amount of pressure differential or flow it can create. Once it reaches its pressure limit it is said to "head out" and no more flow is possible. Figure 1 shows a typical pump chart. By extending a line vertically from the flow until it intersects the pump curve, the maximum head pressure for that pump can be determined. This can be done for any given flow or, visa-versa, for any head pressure within the range of the pump. For example, at a flow of 4 gpm on the attached chart, a line extended vertically intersects the 003B-IFC curve at 2 ft of head and the 006B-IFC curve at 5 ft of head. If I had calculated the system pressure drop at 4 ft of head, I would choose the 006B-IFC because, at 4 ft of head the 003B-IFC can only move about 1 gpm.

The industry supplies charts and graphs that provide the head pressures of various pipes, fittings and devices that are plumbed into the hydronic system. The head pressure of each item that water passes through as it makes its complete circuit around the system must be ADDED to the total for that circuit. If the pump is moving water through several circuits, each circuit is totaled independently and the circuit with the highest head pressure is chosen to represent all circuits. The pump is then sized to overcome the highest head pressure.

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SELECTING A PUMP

This method of determining flow and selecting the circuit with the highest head pressure produces the numbers needed to successfully specify a pump size. It should be noted that flow in the circuits with lower head pressures would increase if the pump services several zones. Flow will increase in the open zones as other zones are closed. This phenomenon can cause flows to exceed limits on valves and fittings resulting in accelerated erosion.

There are several ways of dealing with these challenges. First, balancing valves can be added to circuits and set so that the proper flow is established in each. Second, a pressure bypass valve can be installed downstream from the pump. This valve senses pressure buildup as zones close, and sends some of the flow right back to the system return to keep the flow to the open zones within reason. A third option is to provide each circuit or zone with its own properly sized pump. Figure 2 illustrates the various ways of dealing with multiple circuits.

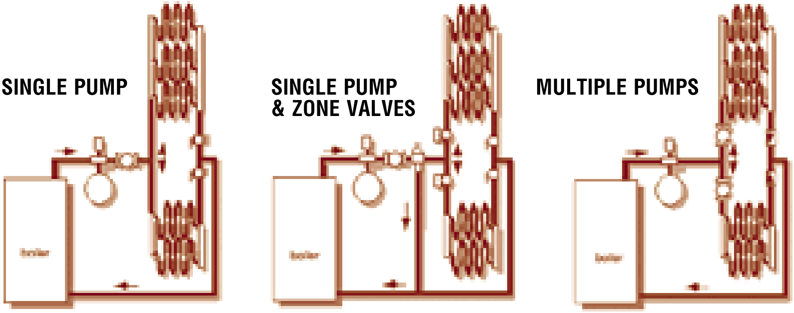

Figure 2

Circulators require a certain amount of system pressure at the inlet to the impeller. System pressure is not to be confused with pump pressure. The entire system is pressurized and held at a given pressure that is typically around 12 psi in residential and light commercial installations. An expansion tank has a compressed gas cushion chamber that absorbs the expansion and contraction of the water as it is heated and cooled. Because this tank maintains the system pressure, it is best to locate the inlet of the pump just downstream from the expansion tank. The pump manufacturer will stipulate how much straight pipe should precede the inlet to the pump. This will insure that, as long as the system is properly filled with water, an adequate amount of pressure will be exerted at the inlet of the pump.

If the pressure at the inlet of the pump drops too low, "cavitation" will occur. This is an actual vapor cavity in the water, not an air bubble. It is formed when the pressure of the liquid is lowered below the vapor pressure. These vapor bubbles collapse with great force as they pass through the volute and, over time, can cause severe damage to the impeller. It sounds like a pinging or knocking in the pump and should be addressed a soon as possible. Often times increasing the system pressure will eliminate the problem. Other systems may require modifying the system piping.

Air passing through the pump can make a similar sound, but is more often a shushing sound. Too much air in the pump and the pump looses its ability to move water or create pressure. When this happens, all the work energy created by the motor is used to generate heat and can result in a burned up pump motor or bearings. An air eliminator upstream from the pump, near the expansion tank, can help reduce the possibility of air getting into the pump.

There are only a few basic rules to pump sizing, but they are extremely important.

1. **Determine flow based on actual heat requirements.**
2. **Calculate head pressure of each circuit**
3. **Select pump that most closely matches the required flow and highest circuit head pressure.**
4. **Install the pump just downstream of the point of no pressure change (the expansion tank)**
5. **Maintain proper system pressure.**
6. **Provide for air elimination upstream from the pump inlet.**

A bigger pump is not always the right solution. You may only be successful in creating a larger pressure drop with little gain in flow. High pressure is not any better in a hydronic system than it is in the body's circulatory system. It makes things work harder and wears things out faster. If you need more flow to carry the BTUs required by the systems heating load, try looking for ways to reduce the head pressure, like shorter circuits, bigger pipe, less fittings, or larger valves. A little time spent with pump curves and pressure drop charts will give your system a longer and healthier life.