

When Zone Valves Close – TD01

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Zone valves are one of the most common control components in residential and light commercial hydronic systems. A rack of zone valves is often installed downstream of the system circulator as shown in Figure 1.

Under design load conditions, all space heating zones will theoretically need heat, and thus all zone valves will be open. When this happens, the distribution system exhibits its lowest flow resistance. You can think of the distribution system as a multiple lane bridge with all lanes open.

As the zone thermostats reach their setpoint temperatures, and the associated zone valves close, the distribution system as a whole develops increasing flow resistance. The overall system flow rate decreases, while the flow rate through each open zone circuit increases. Some of the lanes on the bridge are now blocked off, and it's simply not possible to get the same amount of traffic across, even though traffic moves slightly faster along each open lane.

The system head loss curve of the distribution system gets steeper each time a zone valve closes. Figure 2 shows this effect for a system having several identical floor heating circuits each controlled by its own zone valve.

All hydronic systems constantly seek equilibrium between the mechanical energy (head) input from their circulator and the head loss due to fluid friction in the piping. When represented on a graph, the system always operates at the point where the system head loss curve crosses over the pump curve as shown in Figure 3.

To find the flow rate through the circulator draw a line straight down from the intersection of the curves to the lower axis of the graph. To determine the differential pressure across the circulator draw a horizontal line from the operating point to the vertical axis and read the head added to the fluid as it passes through the circulator. Then convert that head number to a corresponding differential pressure using Formula 1.

$$\text{Formula 1: } \Delta P = \frac{\text{head} \times d}{144}$$

Where:

P = pressure differential across pump

head = head added by circulator (in ft. of head)

d = density of fluid being pumped (in lb/cubic ft.)
(for water at 140 °F d= 61.3 lb / ft³)

Anything that changes the flow resistance of the distribution system causes the system head loss curve to either steepen, (for increasing flow resistance), or flatten (for decreasing flow resistance). As the system curve shifts so does the point where it intersects the pump curve.

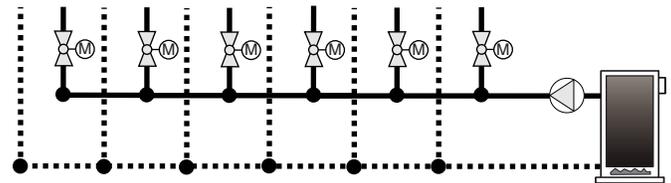


Figure 1

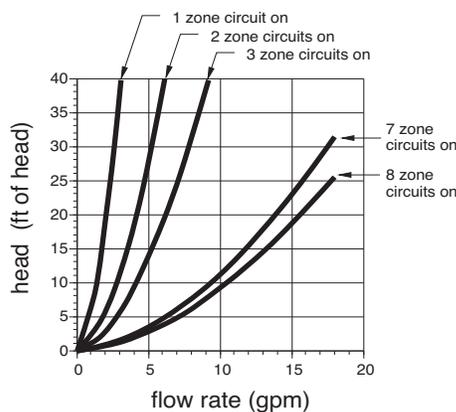


Figure 2

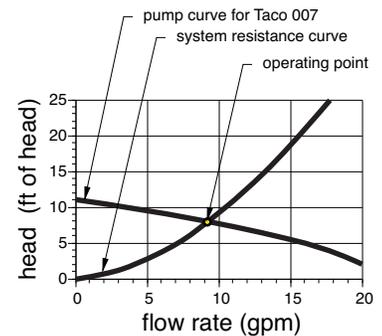


Figure 3

Product & Application Documents:

PA05 - Variable Speed Setpoint "00" Circulator (00-VS)

PA08 - Variable Speed Variable Voltage "00" Circulator (00-VV)

PA11 - Differential By-Pass Valve (Model 3196)

Taco Product Catalogs:

100-3 - Heat Motor Zone Valves

100-7.7 - ESP Zone Valve

100-8.5 - "00" Series Cartridge Circulators

Operating Mode Documents:

OM05 - Setpoint Temperature: Variable Speed Injection Circulators

OM07 - Delta T (Temperature) & Setpoint with Delta T Max

OM08 - Delta P (Pressure)

When a zone valve closes the system head loss curve gets steeper forcing the operating point to slide upward along the pump curve. This increases the pressure differential imposed on the zones that remain open. The increased pressure differential increases the flow rate through these zones. At some point the increased flow velocity will probably cause noise in either the zone valve or the piping.

In some systems, the increased differential pressure generated by several inactive zones can partially open what are supposed to be closed zone valves. This can cause heat input to zones that are supposed to be off. Note that the Taco ESP Zone Valve with its ball valve design and 125 psi shut-off pressure eliminates this possibility.

Imagine a system having several space heating circuits and a separate circuit supplying an indirect water heater. All the circuits are controlled by zone valves. In warm weather, the domestic water heater is likely to be the only zone operating. It's entirely possible that a high differential pressure across the circulator when the DHW tank is the only operating zone could allow hot water to "ooze" through the closed zone valves on the space heating circuits. This situation is sure to result in a call back.

FLATTER IS BETTER

One way to minimize changes in differential pressure as zone valves open and close is to select a circulator with a relatively "flat" pump curve such as the Taco 007 curve shown in Figure 4. For comparison, the pump curve of a "high head" circulator such as the Taco 009 is also shown.

Compare the changes in differential pressure as the operating point shifts upward along the "flat" pump curve of the 007 circulator to those that would occur along the pump curve of the high head 009 circulator. In both cases, zone circuits that remain on "feel" increased differential pressure as the other zones close, but much less in the system using the 007 circulator with its relatively flat pump curve.

If flatter is better, the ideal pump curve for a circulator in a system using zone valves would be a straight horizontal line at some fixed value of differential pressure. A circulator with this pump curve could deliver constant differential pressure regardless of the flow rate passing through it. As a given zone valve opened or closed, the other operating circuit would "feel" absolutely no change in differential pressure and thus not experience any change in flow rate. Unfortunately, no fixed speed centrifugal pump can yield this ideal pump curve.

Using a circulator with a flat pump curve in zone valve systems is not a new concept. It's been described in many references over several decades. Still, some installers have the mistaken impression that using a high head circulator is a "safer bet" when they think about pushing flow through several zone circuits. This is not correct, and in fact can create problems such as velocity noise, and pipe erosion.

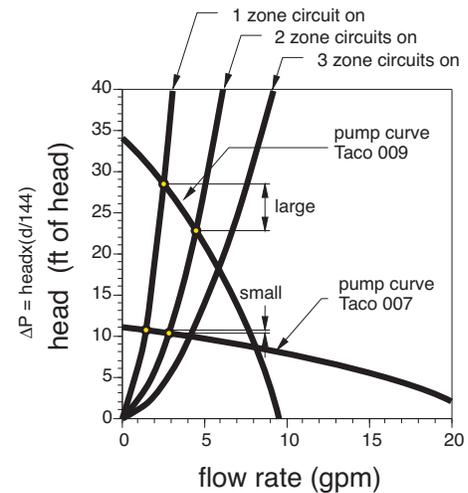


Figure 4

PROVIDING A DETOUR

Another technique for limiting the differential pressure across the circulator is to install a differential pressure bypass valve such as the Taco 3196.

As zone valves close the differential pressure bypass valve shuttles increasing amounts of flow through a piping detour rather than forcing the pump to operate at higher pressure differentials trying to push flow through a more restrictive distribution system.

When you adjust a differential pressure bypass valve, set the knob so the disc just starts to lift away from its seat when all zone valves are open, then increase the differential pressure setting just a bit. This will provide full flow for conditions when all zones are open, but quickly start to regulate differential pressure as zone valves start to close off.

You can estimate the differential pressure across the distribution system when all zones are operating by finding the head at the operating point and converting it to a differential pressure using Formula 1.

For the quiet performance, a differential pressure bypass valve should be installed in any zone valve system or sub-system. They should also be used to prevent "dead heading" the circulator in systems where several parallel-piped heat emitters are controlled by thermostatic radiator valves.

THE ULTIMATE SOLUTION

An even more elegant solution to controlling differential pressure as zone valves close is to reduce the speed of the circulator. As the speed decreases the pump curves shift to the left and downward on the graph as shown in Figure 6.

As various zone valves open and close and the system curve changes its “steepness”, the pump curve of a variable speed circulator can be shifted as necessary to maintain the same differential pressure across the operating zones. The operating zone circuits don’t sense that other circuits have opened or closed. All active zones operate at the same flow rate and differential pressure regardless of which zones are on or off. Properly controlled, the variable circulator can operate as a constant differential pressure device regardless of the flow passing through it. Its behavior mimics the ideal pump curve discussed earlier.

Currently available variable speed circulators such as the Taco 00-VV can be used to prevent changes in differential pressure and reduce electrical energy use in the process. This circulator varies its speed using a 2-10 volt DC or 4-20 milliamp control signal provided by a differential pressure transducer or by a DDC building automation system.

The current cost of accurate differential pressure sensing does not make this approach practical in typical residential applications. However, emerging technologies should make this possible in the near future. Taco has been using this variable speed technology in commercial LoadMatch systems. In a LoadMatch design a circulator replaces the flow control and balancing valves at each terminal unit so that the design loads required for each unit is matched by the flow capabilities of the circulator.

Another possibility is to vary a circulator’s speed based on a temperature setpoint or temperature differential setting. For example, the Taco 00-VS circulator can be operated in a “differential temperature mode” to maintain a constant temperature drop (5°-50°F) across the distribution system as shown in Figure 6. When a zone valve closes less heat is released by the distribution system and hence the temperature drop between the supply to return header drops. The temperature sensor associated with the 00-VS circulator senses this change as it develops and reduces the speed of the pump accordingly to maintain a set temperature drop.

The Taco 00-VS circulator can also be programmed to maintain a temperature setpoint condition. One example is protecting a conventional boiler from sustained flue gas condensation as depicted in Figure 7. Additional applications for this circulator are discussed in other articles.

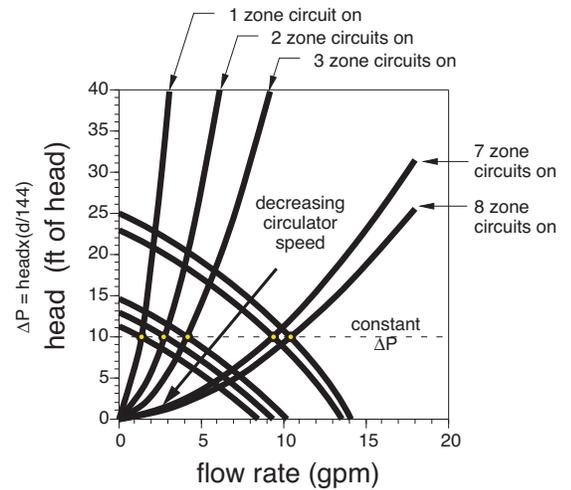
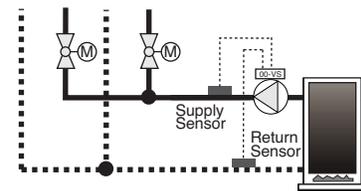


Figure 5



Differential Temperature Mode

Figure 6

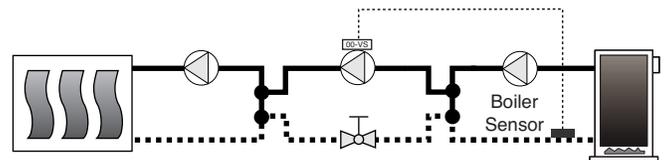


Figure 7

SUMMARY

On your next zone valve system use one of these differential pressure control strategies (bypass valve or variable speed circulator) to keep your system quiet and your customers happy.

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