ENGINEERING
TOMORROW

Case story

# Rochester Institute of Technology (RIT) puts Pressure Independent Control Valves (PICV) to the Test

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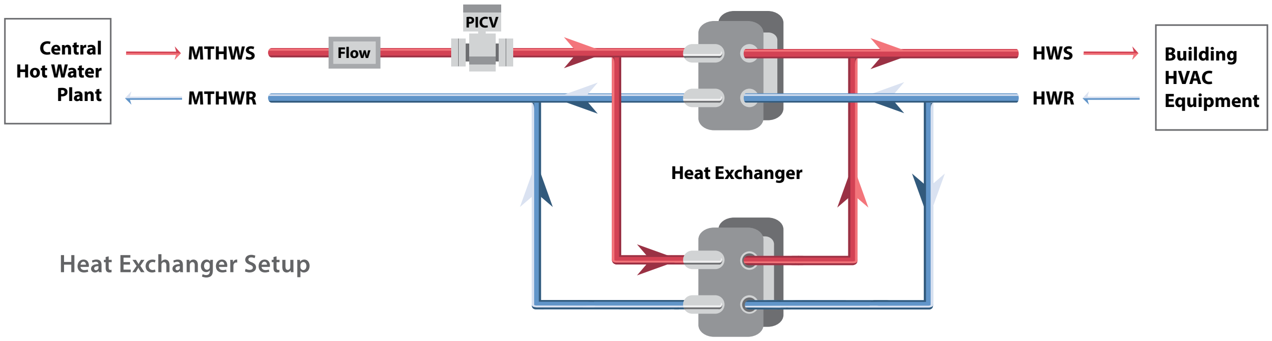
IN HYDRONIC HVAC SYSTEMS MADE UP OF TRADITIONAL BALANCING AND CONTROL VALVES, system pressure is affected every time a valve changes its position. When the system pressure changes, the flow through all of the valves reacts and causes the amount of heat transfer through each device to also change. Assuming that each device was at equilibrium to start, we can deduce that each device is now getting either too much or too little heat transfer. As a result, each device requests that their valve open or close to compensate for the change in flow induced by the change in system pressure.

Due to this chain reaction, HVAC systems with traditional valves can be inherently unstable, which leads to overflows and underflows at the terminal coils. In turn, this leads to wasted energy, suboptimal heat transfer, premature failure of equipment, and a less comfortable space for the building occupants.

At RIT, we wanted to investigate an alternate HVAC design that could improve the stability of our system. Our research suggested a relatively new technology called a pressure independent control valve (PICV), which is able to absorb »




Heat Exchanger Setup

system pressures to maintain a constant desired flow rate at all times. In theory, if a PICV functions properly, then changes in system pressure will not cause flow changes through the valves – thus solving the instability issues.

## PICV testing setup

We set out to test this theory by installing one PICV in our facility and carefully monitoring the results.

We selected a hot water supply line supplying 240°F to two plate and frame heat exchangers that make hot water for a 160,000-square-foot academic building. This line has an existing two-way full port ball valve and a manual balancing valve on the primary side of the heat exchangers. In our previous experience, this line exhibited the classic characteristics of typical HVAC systems in that we experienced instability issues, large swings in temperatures, and valve "hunting."

For the purposes of the test, we replaced both the ball valve and the manual balancing valve with a single Danfoss PICV and actuator. Our complete test setup comprised the following items:

- One 4" Danfoss AB-QM PICV (167 gpm) with a matching Danfoss modulating actuator (2-10V)
- The PICV was installed on the primary side of a plate and frame heat exchanger using Medium Temperature Hot Water (MTHW) at 240°F delivering hot water to the building
- A GE AT868 ultrasonic meter was installed on the pipe to measure flow rates. This meter has a rated accuracy of +/- 2%
- Our Automated Logic Controls WebCTRL System was used to control the valve and record the flow meter measurements

It is important to note that the tests were conducted on a live system, not in a laboratory setting. The test PICV was used to control the temperature of the water to an occupied building under normal operating conditions.

## Flow stability at standard system pressure

The first series of tests was conducted by sending the valve actuator different control signals and measuring the resulting flow on the GE ultrasonic meter using the normal operating system pressure.

We started with the valve completely closed (0%), and then began opening the valve in 5% increments until completely open (100%). Next, we reversed the procedure starting with the valve completely open (100%) and closing in 5% decrements until completely closed (0%). As can be seen in *Figure 2*, we found that, at our standard system pressure, the flow had the desired linear response as the valve was opening or closing. However, since we did not change the system pressure, we had not yet tested the pressure independence feature.

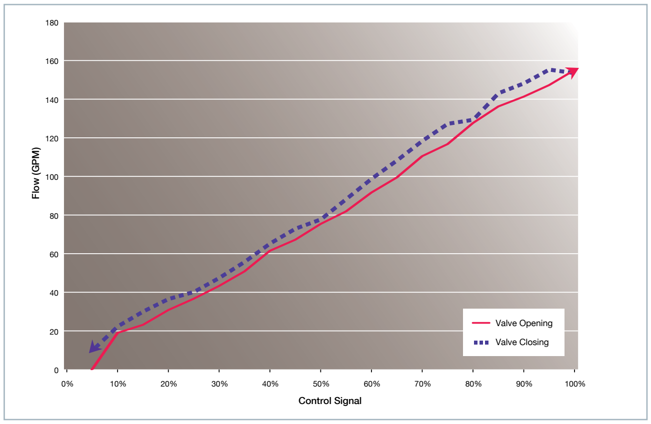



FIGURE 2: Flow vs. Control Signal at Standard System Pressure

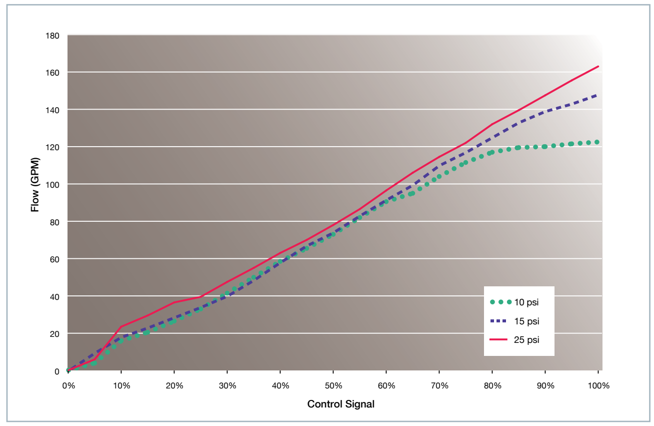



FIGURE 3: Flow vs. Control Signal at Multiple System Pressures

## Flow stability at varied system pressures

In this test, we again opened and closed the valve incrementally, but this time we varied the system pressure at the supply plant. As can be seen in *Figure 3*, we again saw an excellent linear response from the valve at almost all the test points.

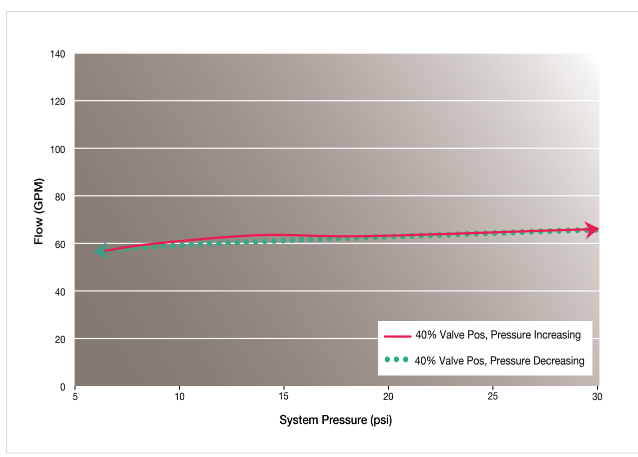
We found that the valve did not always deliver the expected flow when the differential pressure at the valve did not meet the manufacturer's stated minimum pressure rating of 4 psi. For example, when the system pressure was 10 psi and the valve was 85% open, the differential pressure at the valve would fall to between 3.1 and 3.6 psi. This is below minimum requirement for full linear control and caused some loss of valve authority. It is worth noting that this situation of high flow and low system pressure would be unlikely to occur in actual operation. During high demand periods our plant pressure would be at least 15 psi or more. In all test points that reflected actual plant operation, the linearity and control authority were well maintained.

## Constant flow maintained at varied system pressures

In the final test, we kept the valve position constant while varying the plant pressure to see if the valve would compensate for the pressure changes and keep the flow constant. The valve was held at 40% open and the plant system pressure was varied up and then down. As seen in *Figure 4*, the red line indicates the flow as the pressure was increased from 6 psi to 30 psi and the green line indicates flow as the pressure was decreased from 30 psi back down to 6 psi.

This chart shows how well the PICV held the desired flow despite significant changes in system pressure. It is only at the very low end of the system pressure range where the flow starts to slightly drop due to the fact that the pressure at the valve is starting to approach the manufacturer's minimum pressure rating. »

FIGURE 4: Flow vs. System Pressure at 40% Control Signal



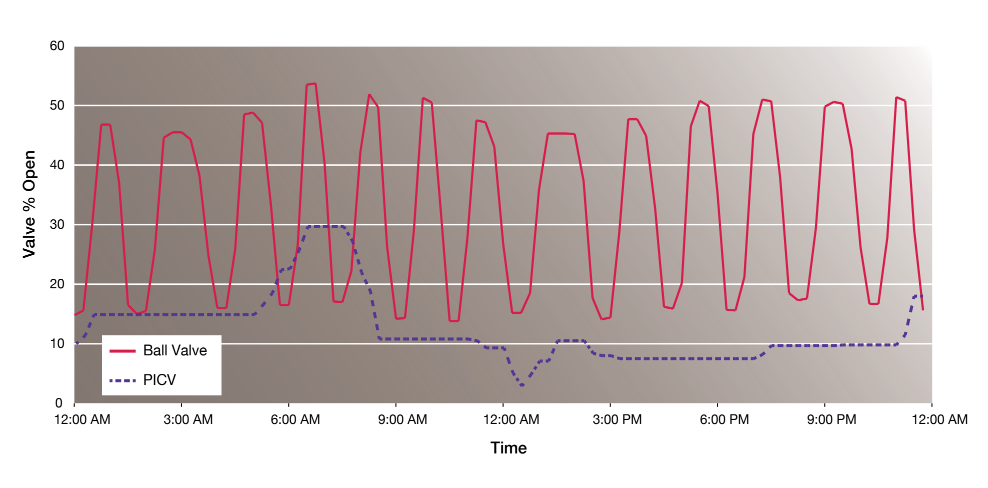



**FIGURE 5: Valve Stability Comparison: PICV vs. Ball Valve**

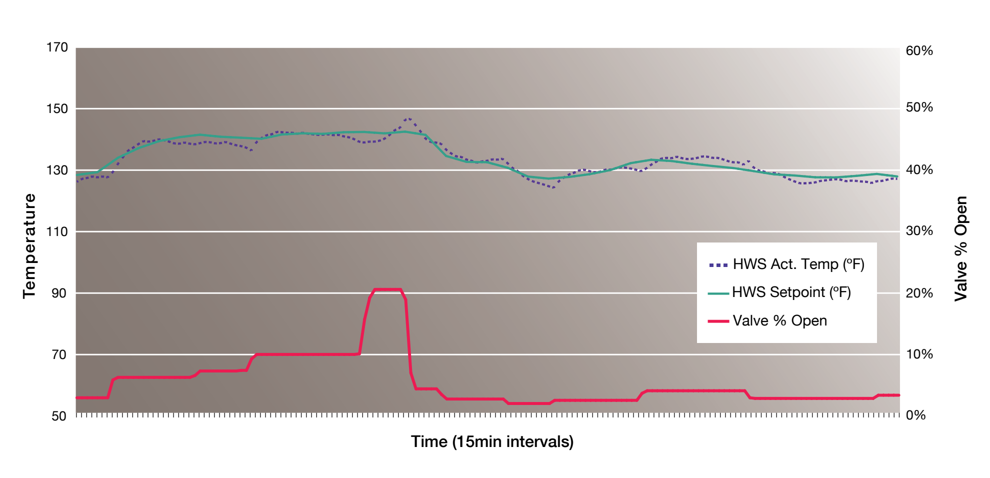



**FIGURE 6: Water Temperature vs. Valve % Opening**

## Conclusion

The results of our analysis showed that, as long as the pressure across the valve body is within the stated pressure range and the valve position is more than 10% open, the flow through the valve is almost perfectly linear regardless of system pressure.

This valve has been installed in our building for several months and the performance has been excellent. The control stability has been outstanding as the valve maintains temperature very well with very little valve movement. Normal changes in the plant system pressure do not affect the valve operation, and this is especially evident at minimal positions where our traditional valves had been particularly unstable. *Figure 5* clearly illustrates the difference in performance between the old ball valve and the new PICV. Furthermore, *Figure 6* shows the actual performance of the PICV in terms of holding set temperature with very little movement of the valve demonstrating the power of a pressure independent valve.

Ultimately, the result of improving the stability of our hydronic system will be energy savings, better temperature stability to our building occupants, and less valve and actuator maintenance as a result of less movement in these components. At RIT, we are planning to make PICVs a standard in all of our future new builds and renovations. ■

**ABOUT THE AUTHOR:**
*Timothy Vann received a BS in Mechanical Engineering from University of Rochester in 1989. Since that time he has been working as a computer programmer, HVAC design engineer and Control System Engineer. Currently he works on the Engineering Team for Rochester Institute of Technology Facilities Management Services. Special thanks to RIT student Taylor Osmonson who assisted in gathering information for this project.*

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