Circuit balancing: A key to improving HVAC system operation and control

David L. Hudson
Victaulic Company, Inc.
Easton, PA

August 2009

As many building superintendents would agree, the symptoms of indoor climate problems within their buildings usually surface as complaints from tenants. The living or working spaces are too cold in winter, too hot in summer—or some combination of both extremes, year-round.

In response to these temperature variations, building occupants often compensate by using space heaters, opening windows and adjusting thermostat settings. Additional adjustments to the HVAC system may include larger pumps, resizing components, changing night setback and morning startup times, and flow adjustments in mains, branch lines and circuits independent of the impacts on the entire HVAC system.

These types of “fixes” to alleviate cold and hot zones in a building are typically ineffective and costly and usually do not correct the situation.

For example, resetting a workplace HVAC system startup time from 7:30 a.m. to 5:30 a.m. means that the plant operates at capacity two additional hours per day. This works out to a 25 percent increase in energy consumption, which cancels out the energy savings that night setbacks were designed to achieve.

As a result of such actions, building owners realize higher energy and operating costs, additional wear on pumps and HVAC components and reduced control valve authority throughout the system.

System designers may be challenged to defend their design, pipe sizing, operating parameters and adequacy of controls when the HVAC system is simply unbalanced.

Indoor temperature and climate problems typically are not caused by control malfunctions or sizing errors. Often they are traceable to incorrect flow rates in the HVAC system due to improper terminal unit balancing. Engineers typically design HVAC systems with excess capacity for the building they support. Thus, the ability to provide the necessary heat or cooling energy is present. Getting the energy to the terminal unit and air handling unit (AHU) is the real issue.

Therefore, the key to HVAC system effectiveness and efficiency is properly controlling flows throughout the entire system from production and delivery units to terminal units for the comfort of all building occupants.

Balancing for comfort and control

HVAC systems are designed with balancing valves to maintain flow conditions so that control valves may function properly. Proper control valve function provides the correct flow to the heat transfer coil resulting in the correct energy output (BTU) to the building space.

Flow in an HVAC system is dynamic and always changing throughout a typical 24-hour period. Due to heat gain from the sun and changes in building occupancy rates, the demand for heating and cooling output will vary not only throughout the day and night, but by building sector. An effective and efficient HVAC system must provide energy output when required and where required. Proper Hydronic balancing is the key to making your HVAC system perform properly and at the lowest cost.

Proper circuit balancing is essential to ensure that heating and chilled water systems deliver correct flows to all terminal units in the HVAC circuit, as specified by the system's design flow. In an unbalanced system, sectors of a building will have underflow or overflow conditions that impact control valve authority and thus the indoor climate in the building. For example, areas located nearest to the energy production and delivery source could receive excess flows, resulting in excessive heating or cooling. Likewise, areas that are remote (farthest away) may experience inadequate heating or cooling levels because of insufficient flow rates.

In terms of pure economics, each additional degree Fahrenheit increase in thermostat setting can add six percent to a building's heating costs, while every degree Fahrenheit reduction works out to an additional eight percent increase in cooling costs.

A typical HVAC circuit incorporates balancing valves for each terminal unit coil and AHU. To balance a coil using a manual balancing valve, a technician needs to connect a differential pressure gauge or handheld circuit balancing instrument to the valve's two metering/test ports. Based upon the valve size, hand wheel position and the measured differential pressure, the system flow rate through the balancing valve is readily determined with a balancing instrument, balancing flow wheel or the valve's C_v characteristics. The valve hand wheel is then adjusted to obtain the required system flow rate.

Applying this technique to each balancing valve in the system will achieve proper balance throughout the system so that all circuits receive specified design flows for optimal performance. When pumps, chillers and other components operate at the lowest possible load, owners benefit from less wear and tear, longer equipment service life, and savings in energy and maintenance costs.

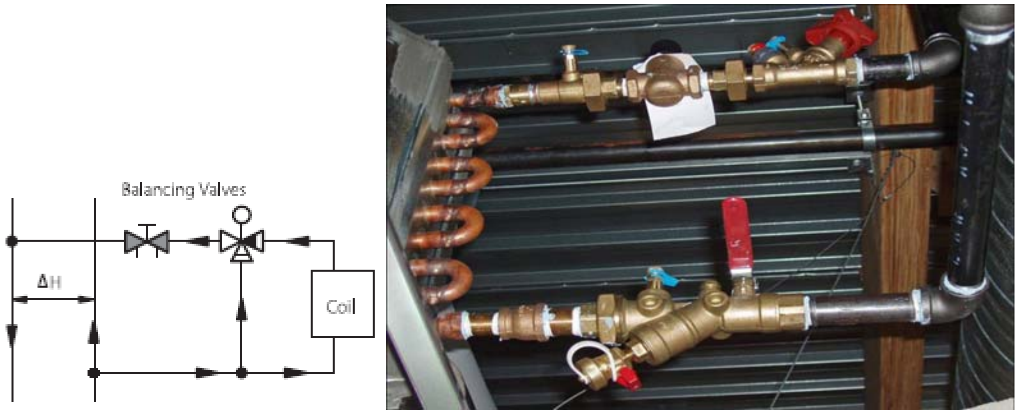

Figure 1: Coil-CW/HW schematic drawing and Tour & Andersson Coil Component

Manual balancing valves

Engineers and contractors have a variety of manual balancing valve configurations to choose from for HVAC circuit balancing and control applications. Throttling characteristics (the relationship between a valve's adjustment range and flow rate) also vary by valve type and are a key determinant in each valve's ability to be set to the desired flow and must be verified using the balancing technique previously described.

For example, a quarter-turn ball valve provides 90 degrees of throttling adjustment range, as compared with the 1,440 degrees of adjustment range available with a four handwheel turn globe valve. As a result, many engineers specify Y-pattern globe valves because of their ability to be set precisely to control flows.

Depending on valve size, globe valves can offer full throttling ranges using 2, 4, 8, 12 or 16 handwheel turns, and enable users to obtain accurate readings of up to one-tenth of a handwheel turn. Some valve manufacturers also provide vernier scales, digital readouts, concealed memory and locking, tamper-proof settings and other features designed to enhance flow rate accuracy and controllability.

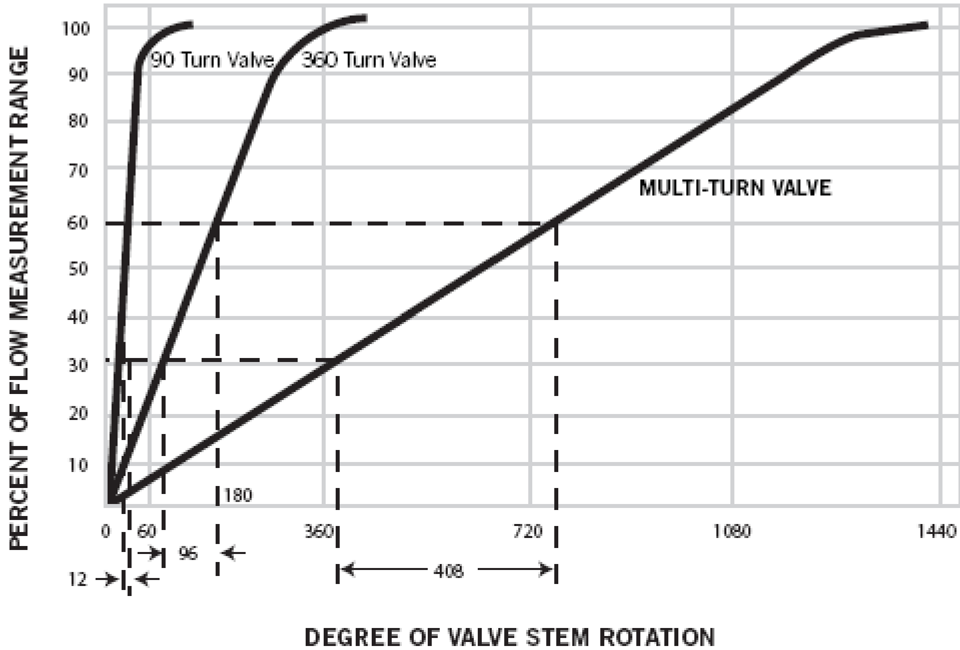

Figure 2: "Comparison of throttling characteristics"

Comparison of throttling characteristics

Generally speaking, a higher number of handwheel rotations equates to more precise flow control. This graph illustrates the throttling characteristics of 90 degrees (1/4 turn), 360 degrees (full turn) and 1,440 degrees (four turn) balancing valves.

- *A 90 degrees fully open-to-closed valve requires just a 12 degree change in adjustment to equal a 30 percent change in flow.*

- *A 360 degrees fully open-to-closed valve would require a 96 degrees change in adjustment to equal the same 30 percent change in flow.*

- *A 1,440 degrees fully open-to-closed valve would require 408 degrees of change in adjustment to equal the same 30 percent change in flow.*

Real-time measurement and control

A variety of optional pressure drop (ΔP) sensors and balancing software programs are available to provide data links to a building's monitoring system. In addition, some handheld circuit balancing instruments integrate ΔP sensors and microprocessors into a portable, lightweight package that enables contractors to perform circuit balancing without the need for flow charts and pressure drop calculations.

Balancing helps isolate system trouble spots
The symptom is typically improper heating or cooling. The cause is an improperly adjusted balancing valve, clogged strainer/coil or other system issue which changes the specified flow rate through a coil or AHU. Diagnostic analysis can be made readily on the suspect coil or AHU by checking the flow rate through the respective balancing valve. Moreover, issues can be identified at a point when they can still be corrected economically during building commissioning and before tenant move-in.

For this reason, circuit balancing valves are integrated as part of a building's commissioning process. In addition to providing engineers with a comprehensive record of specified and actual flows, balancing helps simplify setup and monitoring of control equipment. These advantages reduce capital costs along with commissioning times.

Conclusion
Far too many buildings are unnecessarily plagued by temperature variations that can lead to tenant complaints and high energy and operating expenses for owners. In most cases, these faults can be resolved easily through proper balancing of the heating or cooling system in conformance with original design performance specifications.

In addition to providing occupant comfort and efficient energy and operating costs, effective circuit balancing can aid in troubleshooting the causes for improper heating or cooling. A comprehensive circuit-balancing program should be integrated into new building commissioning as a means of saving time and energy and improving the long-term value of the building.

In the end, everybody wins. Tenants enjoy a comfortable living and working environment, while building owners benefit from faster startup times, savings in energy and operating costs, and enhanced return on their capital investment.

David L. Hudson is a Senior Product Engineer for Victaulic Company, Inc. He is a practicing mechanical engineer with more than 26 years of experience. He can be reached at dhudson@victaulic.com. Victaulic is the world's leading producer of mechanical pipe joining systems and the exclusive U.S. distributor of Tour & Andersson circuit balancing valves.