idronics™

JOURNAL OF DESIGN INNOVATION FOR HYDRONIC AND PLUMBING PROFESSIONALS

CALEFFI
Hydronic Solutions

34
Spring 2024

Evolution of Hydronic Balancing

FROM THE CEO

Dear Plumbing and Hydronic Professional,

My name is Tina Gullickson and I am the CEO of Caleffi North America. As I joined the Caleffi team in 2023, one constant was immediately clear: we need to continue to uphold a high standard for the *idronics* journal series.

You can count on *idronics* to keep you abreast of critical energy efficiency concerns and technologies while delivering thermal comfort to your customers through well-designed hydronic systems. As a system component manufacturer, we don't write the policies or building codes. However, together we can identify best practices to develop systems that exceed the expectations defined by policymakers and the building occupants.

Our aim with this release, continuing in the same tradition of Excellence in Education, is to provide a comprehensive background for balancing hydronic systems in a manner that delivers optimal outcomes for our stakeholders. Distribution efficiency doesn't carry an AFUE tag or ENERGY STAR sticker, but it is equally vital for whole-building performance.

The *idronics* journal is one of many ways we help support an essential industry that has the achievable potential to reshape the world in an energy efficient, comfortable way.

We hope you enjoy this issue and encourage you to send us any feedback by emailing us at idronics@caleffi.com. An entire collection of the journal series can be found at idronics.caleffi.com.

Tina Gullickson

CEO, Caleffi North America

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1. INTRODUCTION

Many hydronic heating and cooling systems have multiple branches that serve different heat emitters or cooling coils. The heat emitters or cooling coils can have different flow rate requirements. They can also have very different pressure drop characteristics. The location of the branches within the system relative to the circulator can vary widely, as can the pipe and fitting sizes connecting them to the system. Figure 1-1 shows an example of a heating system with all of the above variations.

In a multi-branch system, the flow rate through each branch depends upon the hydraulic resistance of that branch relative to the others. Branches with lower hydraulic resistance will have higher flow rates relative to branches with higher hydraulic resistance.

Although it is possible to estimate the flow rate that will occur "naturally" in each branch, there is no guarantee that those flow rates would be properly matched to the flow requirements of each heat emitter or cooling coil. Such a system could be described as "unbalanced." In that state, it is unlikely that the amount of thermal energy transferred at each branch will be matched to the thermal load associated with that branch. This will likely result in discomfort, wasted energy, objectionable noise, and even potential damage to components exposed to excessively high flow rates.

A NATURALLY UNBALANCED SYSTEM

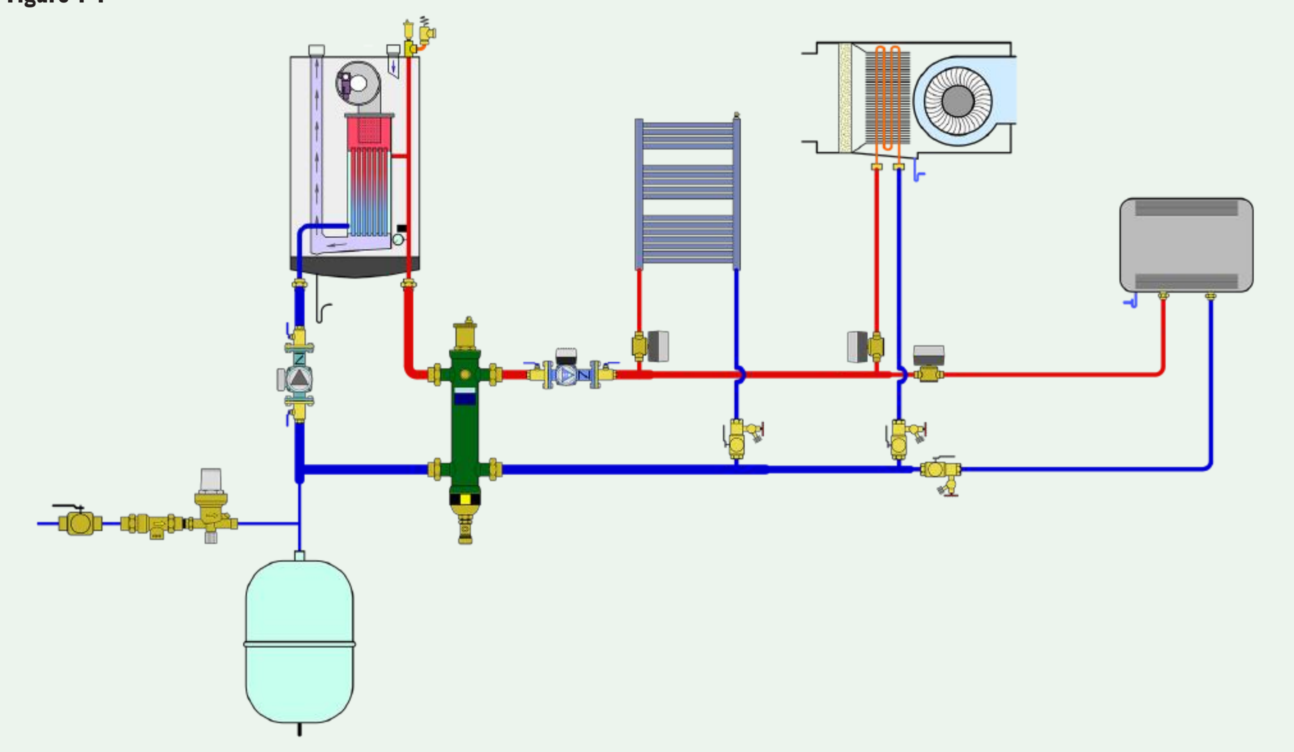
Figure 1-2 shows an example of a multi-branch piping system in which each branch is assumed to have the same piping, fittings and heat emitter.

The arrows adjacent to each branch represent the flow rate through that branch. The hydraulic resistance of the branch closest to the circulator, combined with the resistance through the supply and return mains up to the first branch, is lower than that of the next branch out, and so forth. This allows the flow rate through the first branch to be a higher percentage of the total system flow rate. The farther removed the remaining branches are from the circulator, the lower their flow rate.

Allowing the system to operate in this "natural" state can lead to excessive heating or cooling in some areas of the building, with the other objectionable symptoms of imbalance described in the previous section.

Designers and installers can use balancing valves to adjust the hydraulic resistance of each branch to ensure that the proper rate of heat transfer occurs with each branch.

Figure 1-1



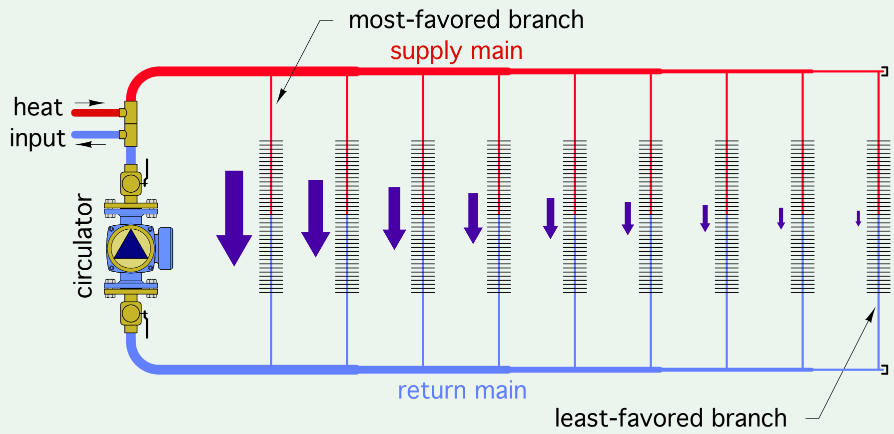


Figure 1-2

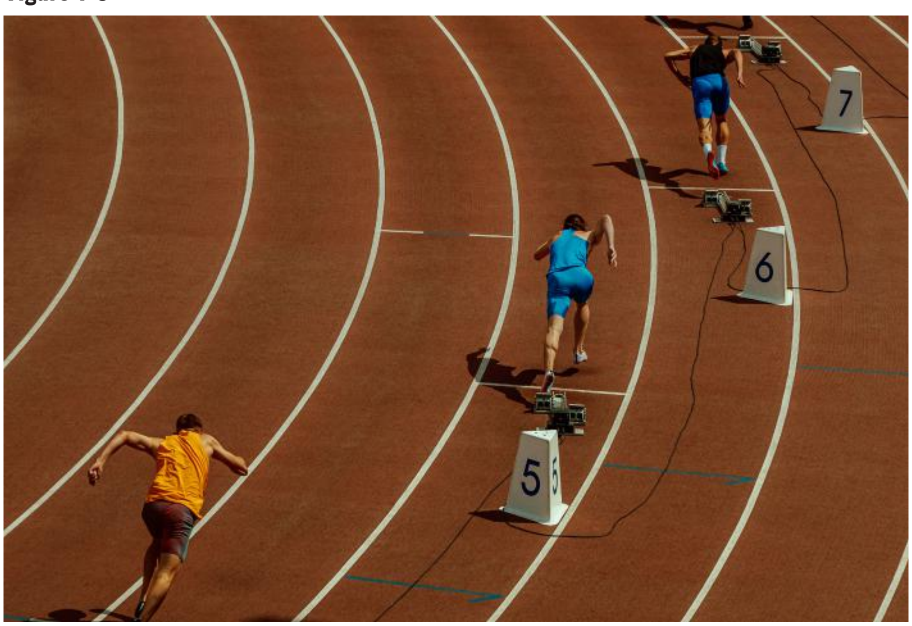
AN ANALOGY

Imagine a track race, in which all runners start on the same line across the width of the track. The runners are told they must stay in their respective lanes during the race. The runner on the innermost lane will have the shortest distance to the finish line. The runner in the next lane out will have the next shortest distance, and so forth. Such a situation is inherently unfair since each runner has a different distance to get to the finish line.

To prevent this inequity, the runners start at staggered points meant to provide the same distance along each lane from the starting point to the finish line. This "balances" the distance, so that runners moving at the exact same speed would reach the finish line at the same time. It removes the inherent unfairness of one runner moving along the inner lane while the other runners have longer paths to the finish line.

This is analogous to a situation in which a hydronic system has several branches of differing lengths, and the designer's intent is to have the same flow rate in each branch.

Figure 1-3



The branches having shorter lengths have the "advantage" of lower hydraulic resistance and will receive a higher percentage of the total system flow rate, relative to the longer branches. Higher flow rates typically result in higher rates of heat transfer. This is a classic "unbalanced" system that needs to be balanced.

The goals of proper hydronic system balancing are:

- To deliver the proper amount of thermal energy required to each branch
- To minimize the electrical energy required to circulate the fluid
- To maintain stability within each active branch as other branches open and close

There are many tools designers, installers and commissioning agents can use to properly balance a hydronic system. These include a range of balancing valves, instruments to read differential pressure and flow rate, and software that simulates flows in complex piping systems.

The devices and methods used for balancing hydronic systems have evolved over several decades.

This issue of *idronics* focusses discussion on the evolution of balancing valves ranging from simple, manually adjusted devices, to state-of-the-art, pressure independent control valves (PICV). The latter offers several advantages in modern hydronic systems and will be discussed in more detail.

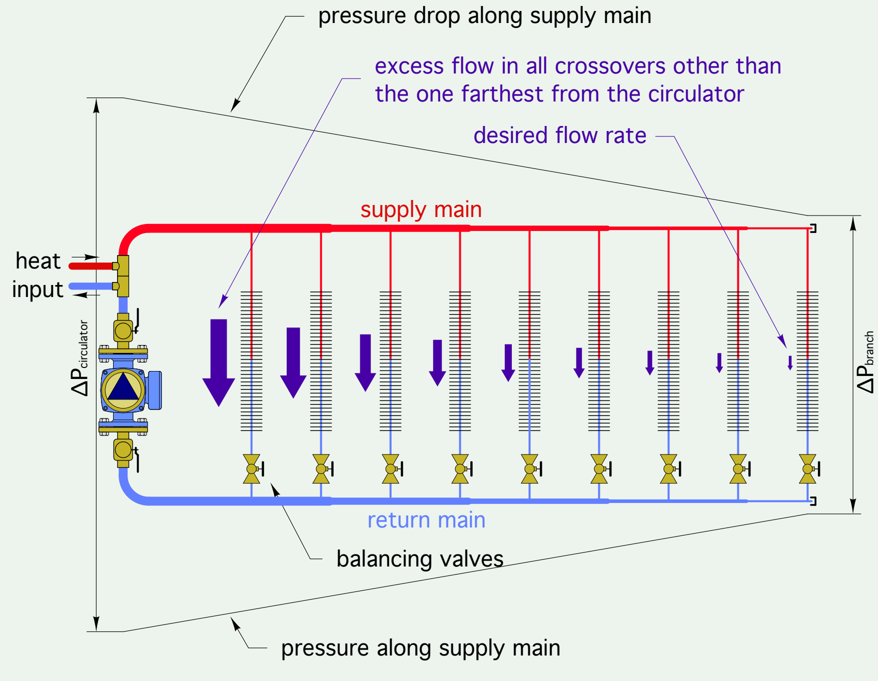
For more background information on the theory of hydronic balancing, see *idronics* #8.

2. BALANCING VALVE FUNDAMENTALS

A properly balanced hydronic system consistently delivers the appropriate rate of heat transfer to each space served by the system. This objective can be achieved even in systems containing branches that have very different lengths, pipe sizes and heat emitters. Doing so requires proper selection, installation and adjustment of balancing valves.

A balancing valve is an adjustable device that has the ability to vary a fluid passageway, manually or automatically, to alter its hydraulic resistance. This resistance combines with the hydraulic resistance of the pipe, fittings or other devices in the branch to determine that branch's overall hydraulic resistance. The greater the total hydraulic resistance of the branch, the lower the flow rate through it.

Figure 2-2



BALANCING BASICS:

Consider the hydronic distribution system shown in Figure 2-1.

This system consists of nine branches connected across common supply and return mains. Circulation is created by a fixed-speed circulator.

This piping arrangement is called a parallel *direct return* system. For simplicity in understanding the function of balancing valves, *assume that all branches have identical piping components, and thus, should (ideally) all operate at the same flow rate.*

The vertical piping near the circulator and the closely spaced tees where heat is added can be considered to have insignificant head loss.

Assume that when this system is first turned on, all the balancing valves are fully open. Because of the head loss along the supply main and return main, the differential pressure exerted across each branch will be different. The "most-favored branch" nearest the circulator will have the highest differential pressure, and thus, the highest flow rate. The "least-favored branch" at the far-right side of the system will have the lowest differential pressure, and thus, the lowest flow rate. This undesirable initial variation in differential pressure across the branches is represented by the sloping lines in Figure 2-2.

The vertical line to the left of the circulator represents the differential pressure established by the circulator. This is the highest differential pressure in the system.

The sloping lines above and below the piping represent pressure drop as flow moves through the supply and return mains. These lines get closer to each other as they progress from left to right. This implies that

Figure 2-1

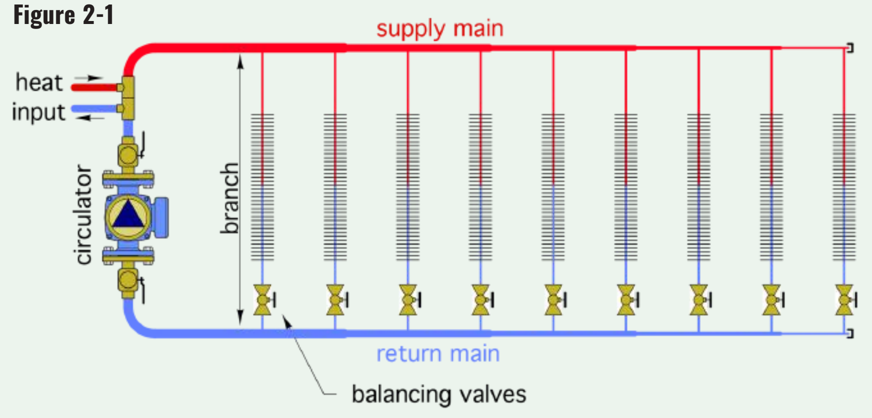


Figure 2-3

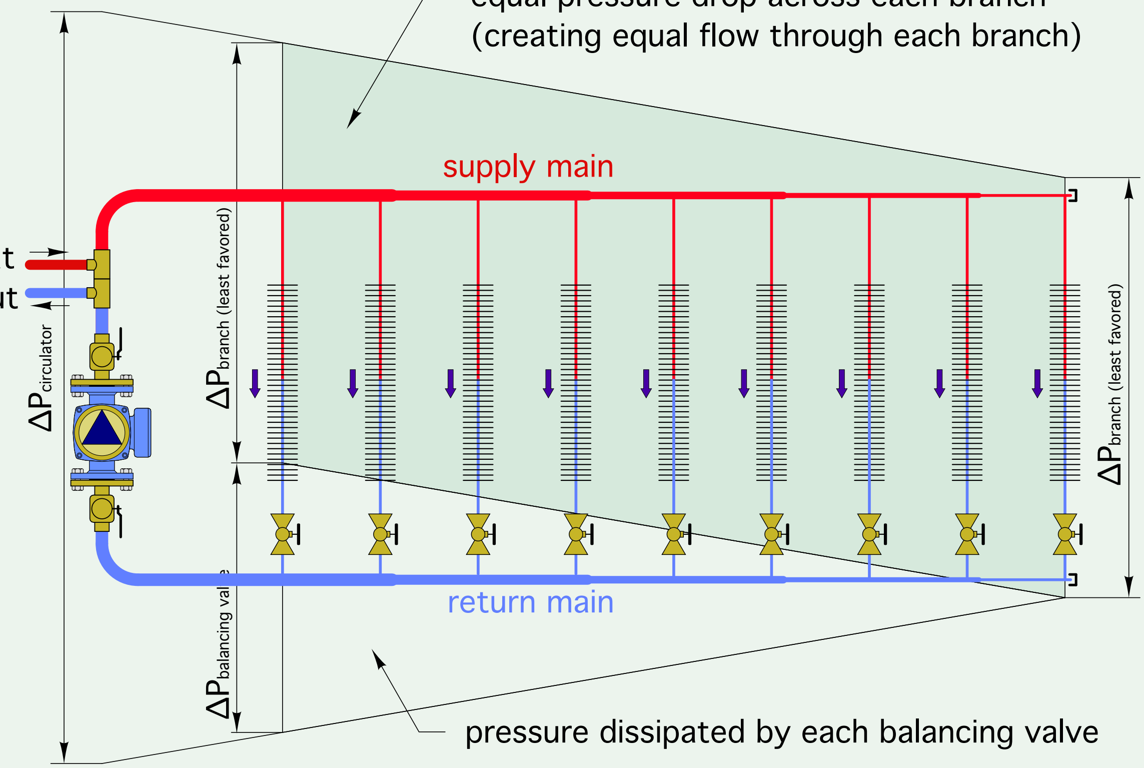


Figure 2-4

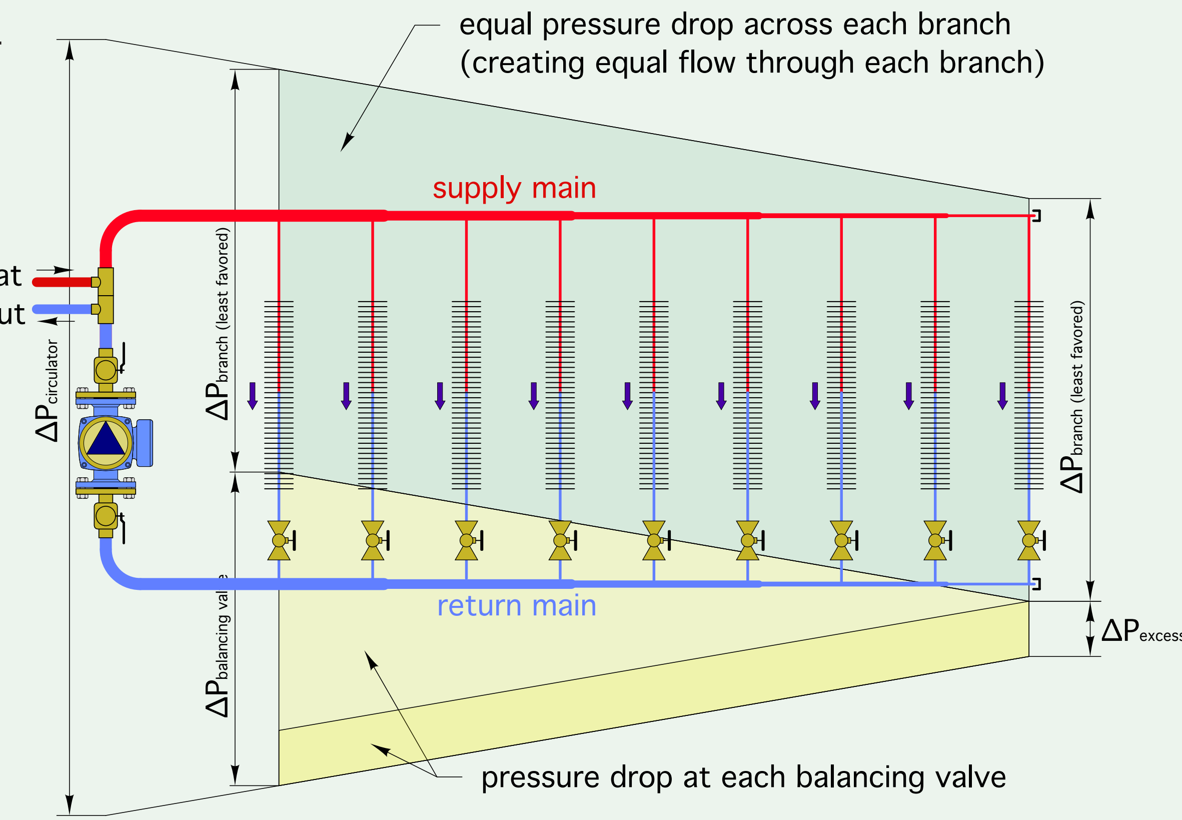
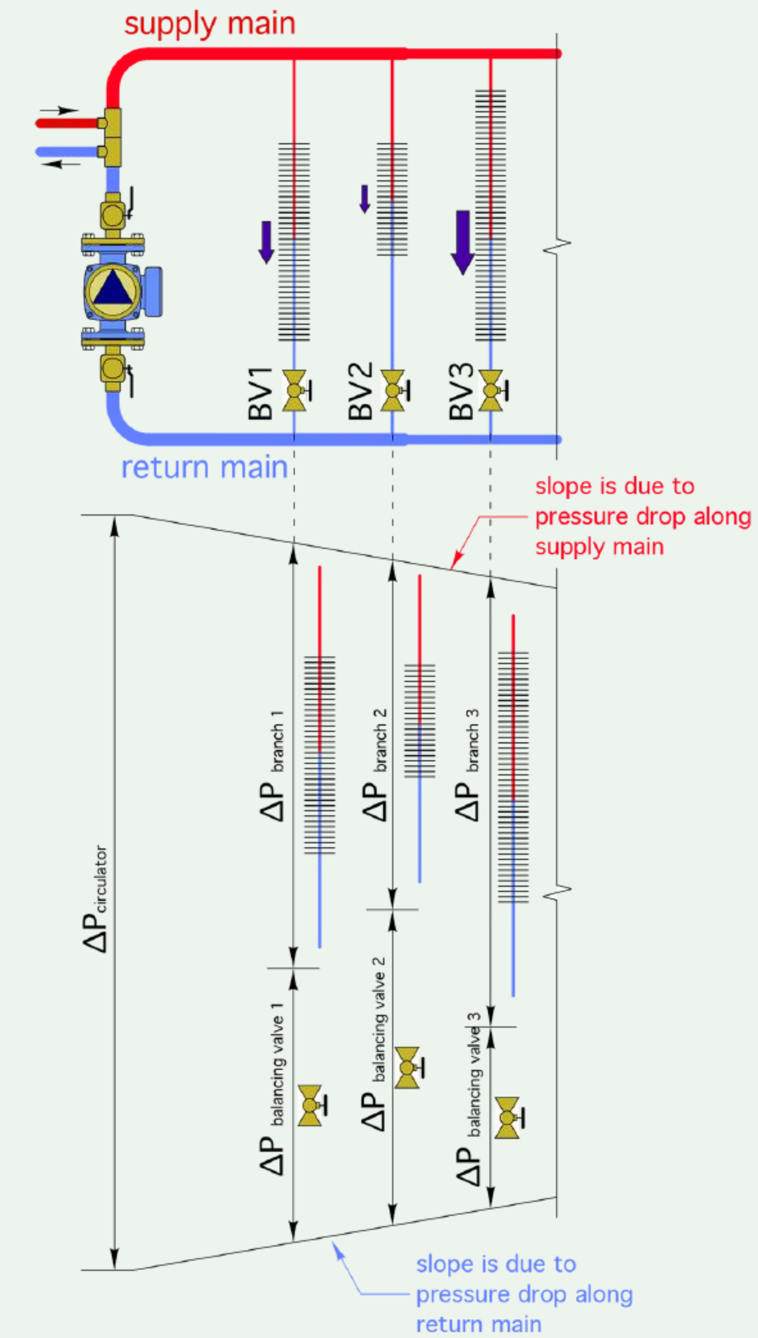


Figure 2-5



each branch has less differential pressure across it compared to the branch to its left, which is due to the pressure drop along the mains. Lower differential pressure results in lower flow rate.

The differential pressure available to the "least-favored branch" at the far right of the system determines the flow rate through that branch. In this system, the circulator is assumed to be sized so that it can provide the necessary differential to drive flow through the least-favored branch, accounting for the head loss along the full length of the supply and return mains.

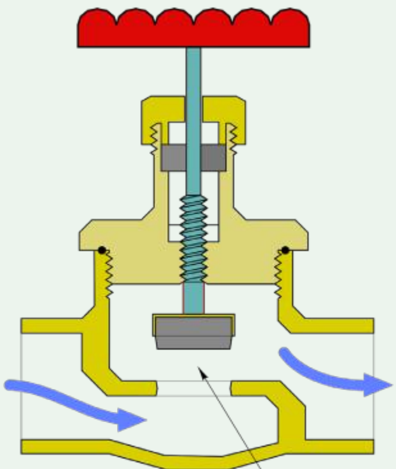
This initial unbalanced condition leads to excess flow in all branches other than the least-favored branch, as represented by the downward arrows. This excessive flow increases the power demand of the circulator, and thus, increases the operating cost of the system. Overflow may also result in unacceptable flow noise and/or corrosion of copper fittings.

To achieve equal flow in each branch, there must be an equal differential pressure across each branch. This requires the balancing valve in each branch to dissipate the *difference* between the differential pressure available between the supply and return mains, and the head dissipated by the other piping components in each branch. This concept is represented in figure 2-3.

The pressure drop that each balancing valve must create is indicated by the vertical height of the yellow shaded area at each branch location. In this system, which assumes identical branch piping, and mains piping that is sized for a consistent pressure drop per unit of length, the required pressure drop of each balancing valve is proportionally less than that of the balancing valve to its left. The balancing valve on the most-favored branch (far left) requires the highest pressure drop, while the balancing valve on the least-favored branch (far right) requires zero pressure drop. The latter case assumes that the circulator is sized to provide exactly the head required by flow along the full length of the mains and through the least-favored branch. If the circulator supplies higher differential pressure than this requirement (which is often the case), the balancing valve in the least-favored branch will also have to be partially closed to absorb some of this excess differential pressure. This scenario is shown in figure 2-4.

In some systems, the hydraulic resistance of a given branch may be significantly different from that of the other branches. The design flow rate requirement may also vary from one branch to another. It is still possible to balance such systems for the desired flow rate in each branch. In each case, a properly adjusted balancing valve will absorb the *difference* between the differential pressure available across the mains at the location of the branch and the differential pressure required to sustain the design flow rate through that branch. The concept is shown in figure 2-5.

Figure 2-6



shaft turns from closed position	Cv
1.5	0.25
2	0.55
2.5	1.0
3	1.7
3.5	2.5
4	3.0
fully open	3.2

VALVE CHARACTERISTICS:

The sections that follow will describe several types of balancing valves. To fully connect how these valves are designed, how they interact with other components, and how they should be sized and selected, it's important to understand several fundamental concepts. These include flow coefficient, valve authority and equal percentage valve characteristics.

FLOW COEFFICIENT (Cv):

All hydronic system components (piping, fittings, valves, heat sources, etc.) that have flow passing through them have hydraulic resistance. That resistance results in a drop in fluid pressure from the inlet to the outlet of the component. The faster the fluid passes through the component, the greater the pressure drop across the component.

There are several methods for estimating the pressure drop of a component based on fluid passing through it at some flow rate. In the case of valves, the relationship between the pressure drop and the flow rate through the valve can be quantified based on Formula 2-1.

Formula 2-1:

$$\Delta P = \left(\frac{D}{62.4}\right)\left(\frac{f}{C_v}\right)^2$$

where:
ΔP = pressure drop across the device (psi)
D = density of the fluid at its operating temperature (lb/ft^3)
62.4 = density of water at 60°F (lb/ft^3)
f = flow rate of fluid through the device (gpm)
C_v = flow coefficient of the valve (gpm)

The C_v value can be thought of as the flow rate (in gpm) of 60ºF water that would produce a pressure drop of 1 psi across the valve.

The "rated" C_v value of a valve is based on the valve being fully open (e.g., when the valve's disc is as far above the valve's seat as possible). As the valve's stem is rotated, and the disc gets closer to the seat, the C_v of the valve decreases. The relationship between valve stem position and C_v is sometimes given as a table such as shown in figure 2-6.

The pressure drop across the valve also depends on the fluid passing through it. Higher density fluids, such as solutions of antifreeze and water, increase the pressure drop across the valve relative to that of water with the same valve stem position valve.

VALVE AUTHORITY

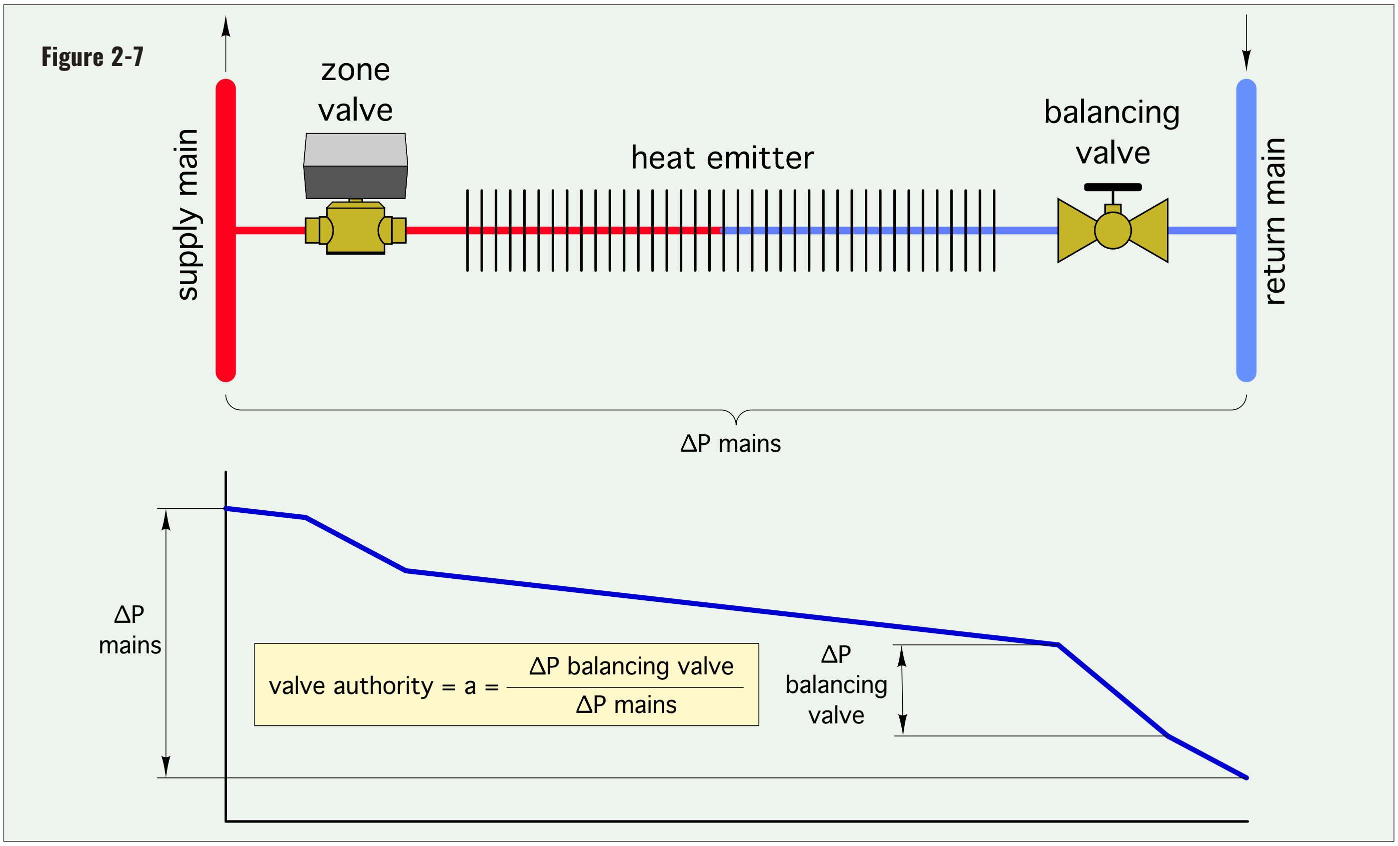
The ability of a manual balancing valve to regulate the branch flow rate depends on the pressure drop across the valve relative to the pressure drop across the entire branch, including the heat emitter, piping, fittings or any other components in the branch. A metric developed to represent this relationship is called valve authority.

Figure 2-7 illustrates the concept of valve authority.

The sloping blue line represents the pressure along the branch from its beginning on the left to its end on the right. The slope of the line changes based on the pressure drop through a component or segment of piping within the branch.

The authority of the balancing valve in the branch is the ratio of the pressure drop across it to the overall pressure drop along the branch.

The higher the authority of the balancing valve, the more accurately it can regulate flow through the branch.



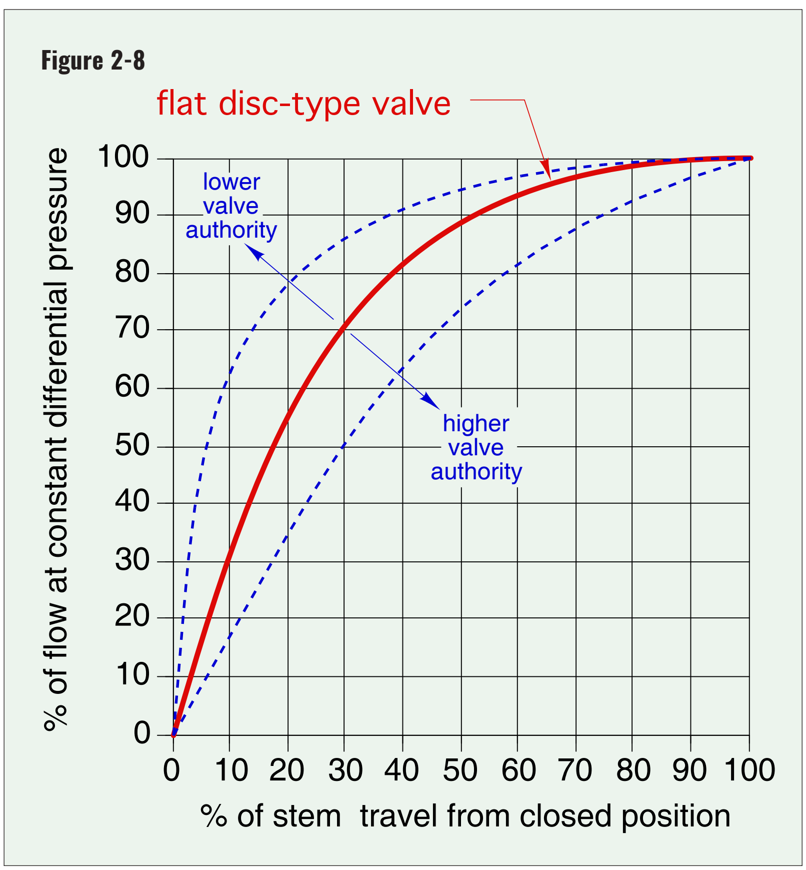


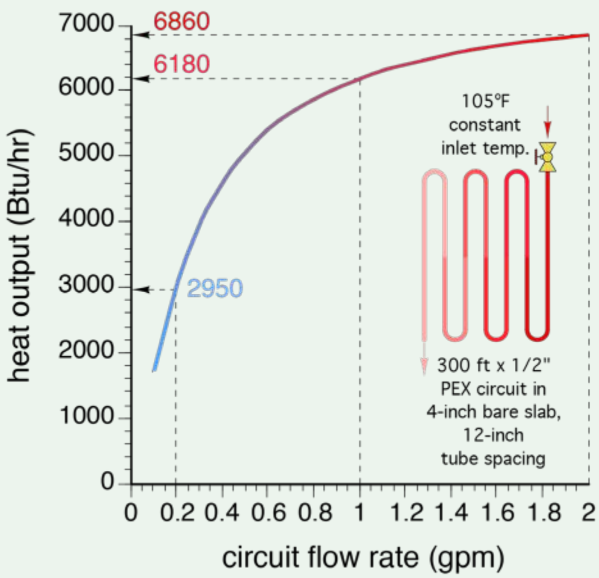
Figure 2-8 shows how valve authority affects the relationship between the stem position of a globe valve and the percentage of flow passing through the valve.

The percent of maximum flow rate versus stem position of a globe valve is not a proportional relationship. As the disc first begins to lift above the set, flow increases rapidly. When the valve stem has reached its 50% open position, the flow rate through the valve, based on the red curve in figure 2-8, has reached approximately 90%.

Manual balancing valves that have higher authority within a given branch reduce the curvature of the flow versus stem position curve in figure 2-8.

A general recommendation in any situation where a balancing valve is used to adjust flow rate through a branch is to select the valve so that its pressure drop at full branch flow is at least 50% of the total pressure drop across the branch. This would make the valve authority 0.5.

Figure 2-9



EQUAL PERCENTAGE VALVES

The flow rate versus stem position of a globe valve with a flat disc could be described as a "quick opening" characteristic. Flow rate increases rapidly as the valve's disc starts to rise above its seat, and flow continues to rise as the disc lifts farther, but at a progressively slower rate. This characteristic is shown in figure 2-8.

Although a valve with a quick opening characteristic can be used to balance flow rates in hydronic systems, it is not ideal. The underlying reason is that heat output from any type of hydronic heat emitter also increases rapidly at lower flow rates, and more slowly as flow rate increases. This characteristic is shown for a typical radiant floor heating circuit in figure 2-9

For more background on heat output from emitters based on flow rate, see *idronics* #8.

The combination of the flow characteristic for a flat disc globe valve, and the heat output versus flow rate relationship for a heat emitter, result in a very "non-linear" and sensitive relationship between the valve's stem adjustment and the resulting heat output from the heat emitter.

To provide a more *proportional* relationship between valve stem position and the heat output of the heat emitter being controlled, designers have created valves with different internal "trim." One of the most common trims gives a valve an "equal percentage characteristic." Flow through this type of valve increases exponentially with upward movement of the stem.

Figure 2-10a shows an example of a manually adjusted equal percentage valve.

Figure 2-10a

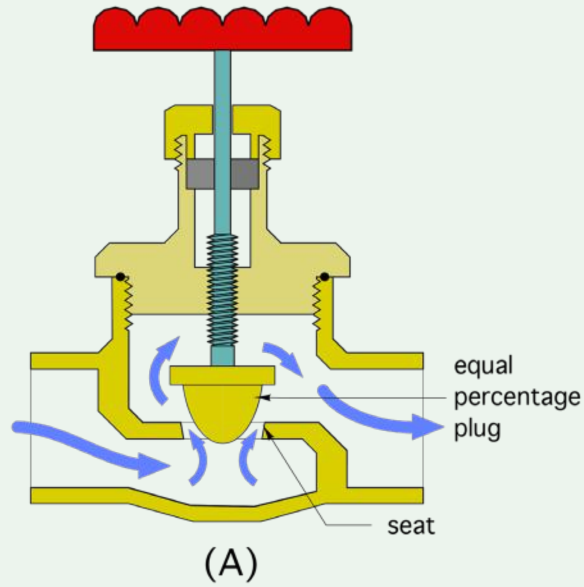
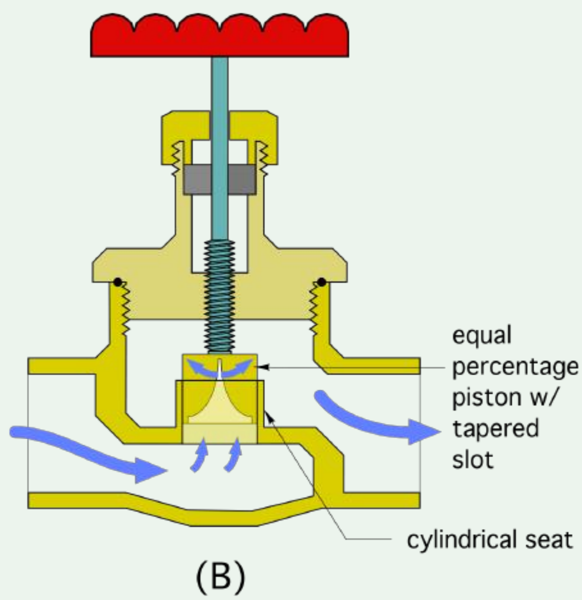


Figure 2-10b



Notice the shape of the valve's plug in comparison to the flat disc used in a standard globe valve. This shape is one way to allow flow to develop slowly as the plug begins to lift above the seat, with progressively high rates of flow rate increasing as the plug lifts higher.

An equal percentage characteristic can also be created using a tapered slot in a piston plug, as shown in figure 2-10b.

The tapered slot concept is also incorporated in some automated control ball valve designs to provide equal percentage throttling control during the 0-90º rotation of the ball.

Assuming that the differential pressure across the valve is held constant, equal increments of stem movement result in an equal percentage change in the current flow through the valve. For example, moving the stem from 40% open to 50% open, (a 10% change), increases flow through the valve by 10% from its value at 40% open. Similarly, opening the valve from 50% to 60% would again increase flow by 10% of its value at the 50% open position.

The overall relationship between flow rate and valve stem position for a valve with an equal percentage characteristic, operated at a constant differential pressure, is shown in figure 2-11.

Figure 2-11

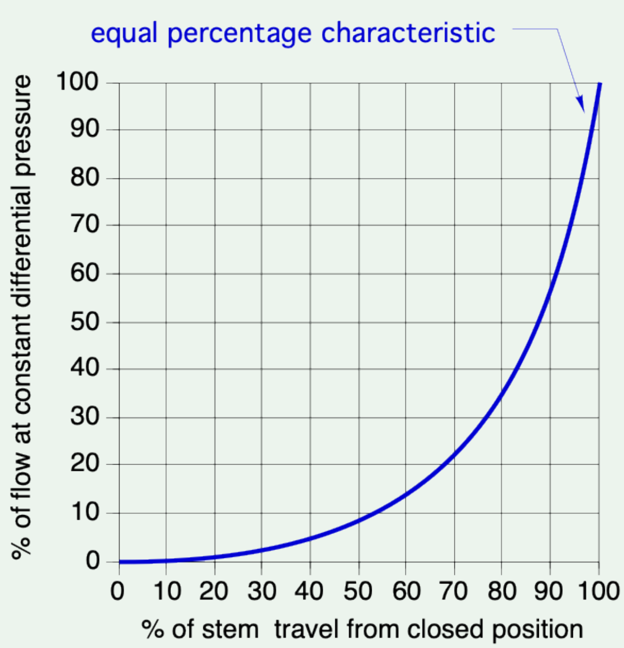
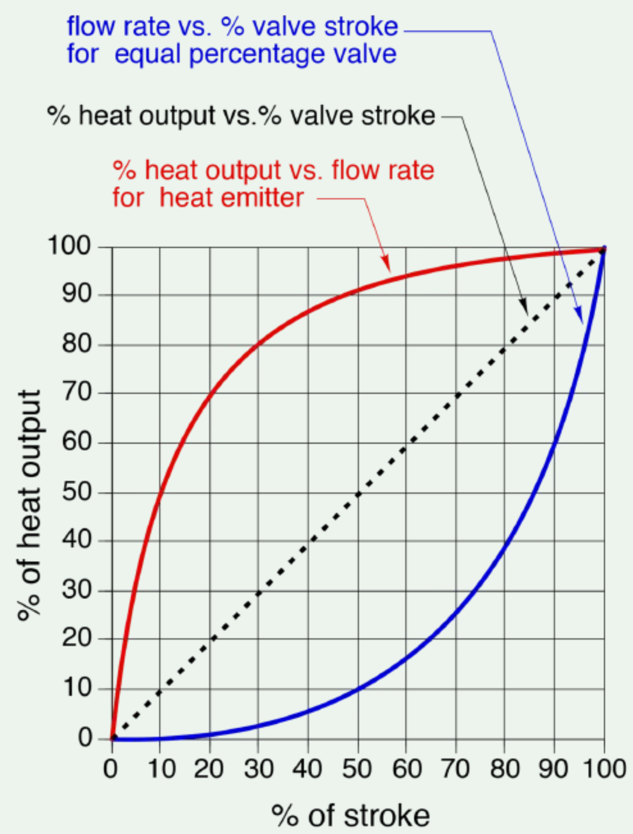


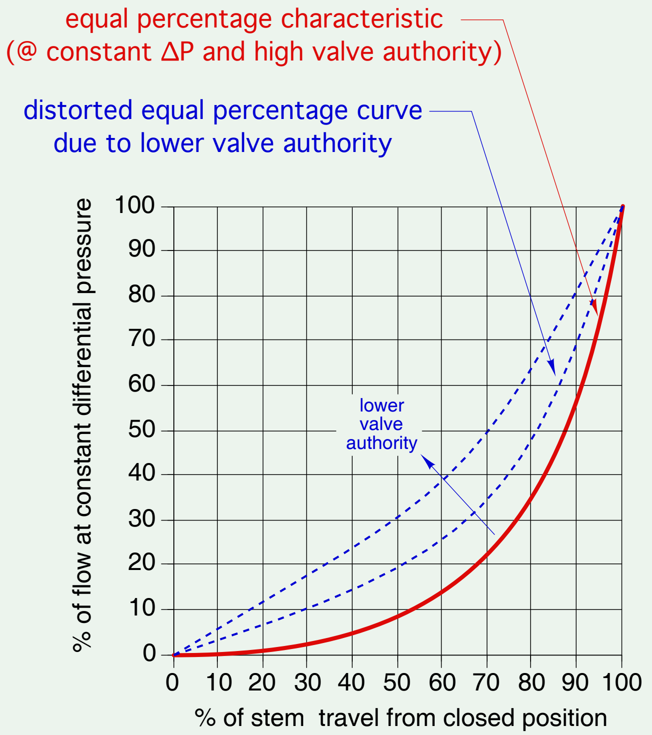
Figure 2-12



When a valve with an equal percentage characteristic regulates flow through a heat emitter, the relationship between stem position and heat output is approximately linear, as shown in figure 2-12. As the valve begins to open, the rapid rise in heat output from the heat emitter is compensated for by the slow increase in flow rate through the equal percentage valve. As the valve approaches fully open, the slow increase in heat output is compensated for by rapid increases in flow rate. This is a desirable response for both manually operated balancing valves and motorized 2-way control valves.

The equal percentage characteristic shown in figure 2-12 only holds true if the differential pressure across the valve remains constant, and if the valve's authority, when installed, is at least 50%. If there are variations in differential pressure across a valve as its stem position changes, or if the valve is applied such that it has low valve authority, the flow versus % stroke curve shown in figure 2-12 will be distorted in an undesirable direction, as shown in figure 2-13.

Figure 2-13



A distorted equal percentage characteristic, although not ideal, is still preferable to a quick-opening characteristic when the valve is used to regulate the heat output of a heat emitter. The overall effect will be a heat output characteristic versus valve stem position curve that is not linear. Heat transfer will increase slightly faster at low flow rates.

The modern electronics used in some motorized valve actuators can create the desirable equal percentage relationship between flow and stem position of the valve being controlled. One example is the Caleffi proportional 145 Series actuator. When its internal switch is set for equal percentage, the C_V of the valve is mapped to the input voltage of the actuator, as shown in figure 2-14.

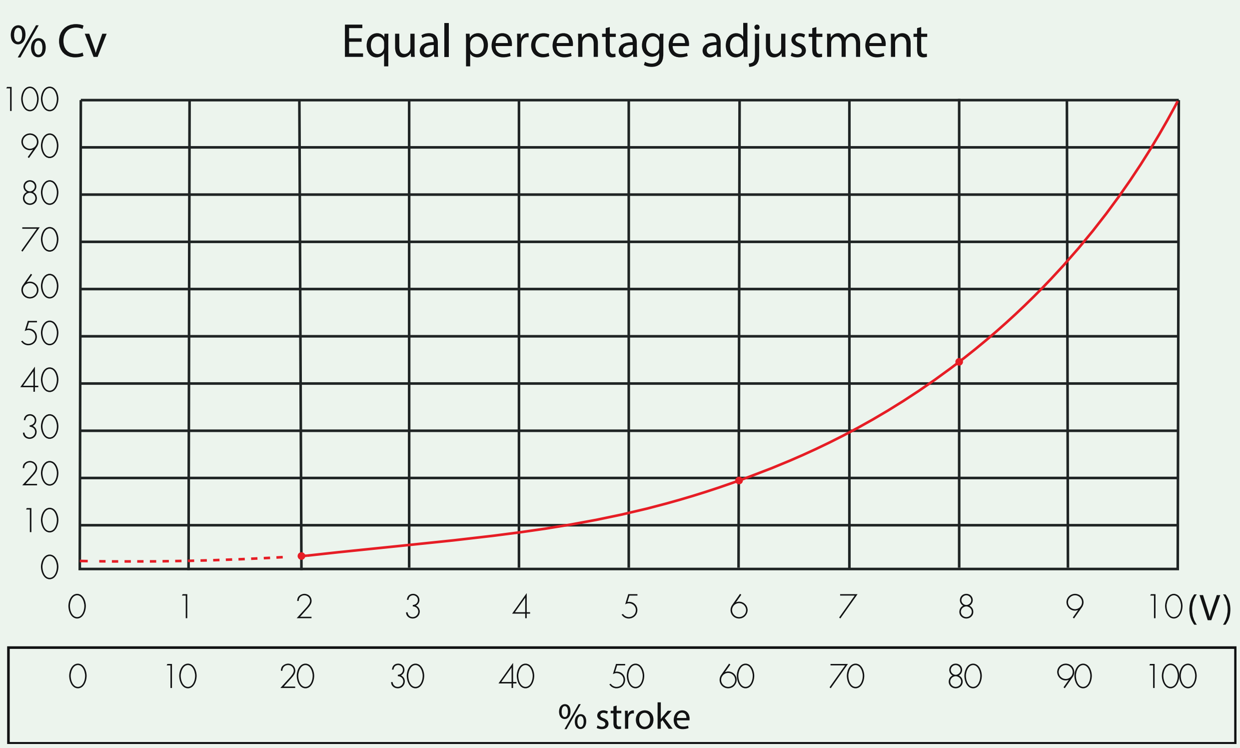
This actuator is one of several that can be fitted to the Caleffi 145 Series pressure-independent control valve, which will be discussed in section 5.

FLOWS IN PARALLEL PIPING SYSTEMS

Consider the parallel piping system shown in figure 2-15.

Assume that (initially) all three zone valves and all balancing valves are open. When the fixed-speed circulator is turned on, the flow that develops through each branch depends upon that branch's hydraulic resistance relative to the

Figure 2-14



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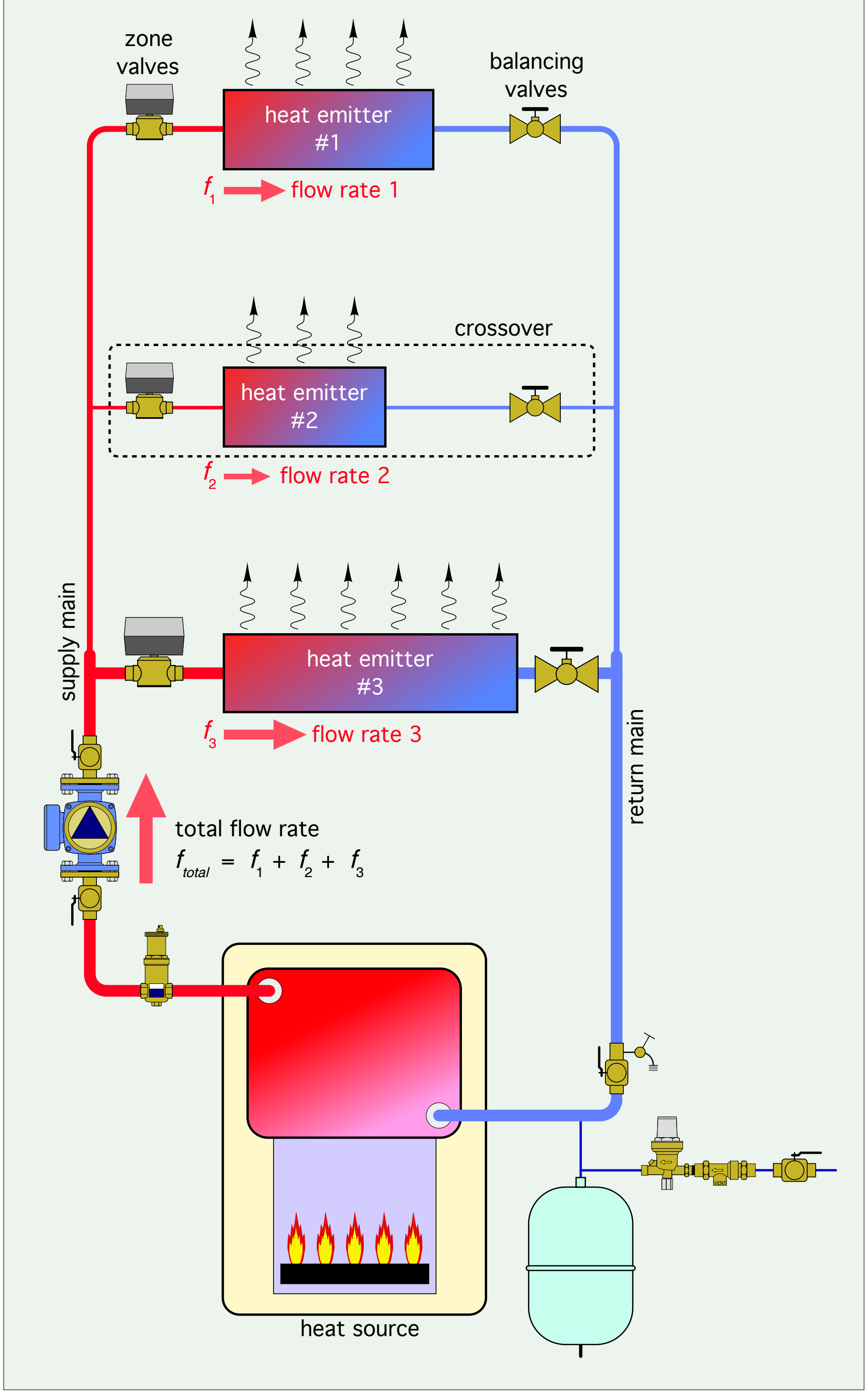
hydraulic resistance of the other branches, as well as the hydraulic resistance of the supply and return mains and the heat source. These flow rates may or may not be appropriate to deliver the desired rate of heat to each branch.

If one zone valve is then closed, the flow rates in the other two operating zones *will change*. It will increase. Likewise, if the setting of any of the three manual balancing valves is changed, the flow rates in any active zone will also change.

Figure 2-15



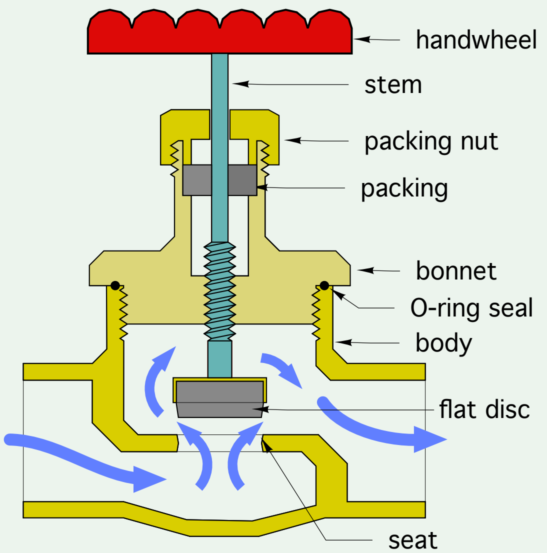
It's possible to calculate the flow rates that will occur in any of the branches based on the status of the zone valves and the settings of the balancing valves. However, those calculations can be complex, especially for larger systems with many branches. Such calculations are typically done using computer models of the piping system.

Regardless of what the branch flow rates are, it's important to understand that any changes to the status of the zone valves or the settings of the balancing valves will have some effect on the flows in *all* the branches. This characteristic is undesirable, especially if the intent of adjusting one of the balancing valves is to change the flow rate in its associated branch *without affecting the flow rates in any other branch.* Still, this is the reality of attempting to establish specific flow rates in each branch that will remain at those specific values as zone valves within the system open and close. This is an inherent limitation of static balancing using any type of manual balancing valve, as it cannot react to changes in other branches of the system, and thus, cannot hold a specific flow rate in any situation other than that which existed when it was last adjusted.

For more information on different types of parallel hydronic distribution systems, see *idronics* #8.

3. MANUAL BALANCING VALVES

Figure 3-1



The simplest type of balancing valve is a globe valve, a cross section of which is shown in figure 3-1.

Flow enters the lower valve chamber, flows upward through the orifice between the seat and the disc, then exits from the upper chamber. The gap between the disc and the seat determines the hydraulic resistance created by the valve. Turning the valve's stem changes the gap between the seat and the disc, which changes the valve's hydraulic resistance. The closer the disc is to the seat, the greater the valve's hydraulic resistance. The greater the valve's hydraulic resistance, the greater the pressure drop across the valve at any given flow rate. Although globe valves were traditionally used for balancing they lack several features that modern balancing valves provide.

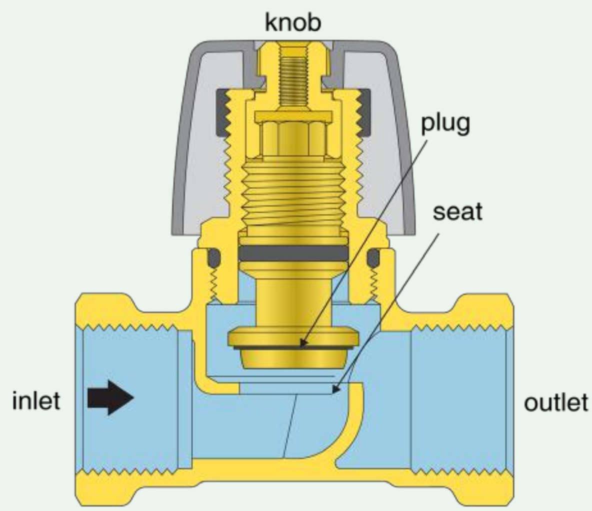
MANUAL BALANCING VALVES WITH DIFFERENTIAL PRESSURE PORTS

There are several other manually-adjusted valve designs that, in addition to flow rate adjustment, provide a way to *measure* the flow rate passing through the valve. Many valves in this category have two small ports on the sides of their bodies that can be used to measure the pressure upstream and downstream of the valve's orifice. The difference in these pressures can then be used to infer the flow rate through the valve. Figure 3-2a shows one example of a balancing valve with differential pressure ports. Figure 3-2b shows the cross section of this valve.

This type of valve is further classified as a *variable orifice* balancing valve. One of the pressure ports connects to the

Figure 3-2a

Figure 3-2b



upstream chamber in the valve, and the other connects to the downstream chamber. The differential pressure is measured across the orifice between these chambers. The knob on the valve controls the position of the valve's plug relative to the seat, and thus, the size of the orifice (e.g., the "gap" between the plug and the seat). Hence the designation "variable orifice."

Another type of manually adjusted balancing valve with pressure ports is shown in figure 3-3a, along with its cross section in figure 3-3b.

The pressure ports on this valve are located on either side of a fixed conical shape known as a venturi. One port provides the pressure at the inlet of the venturi, and the

Figure 3-3a

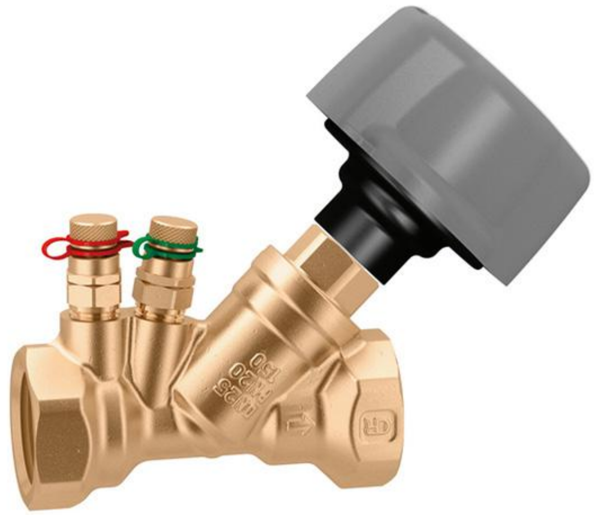
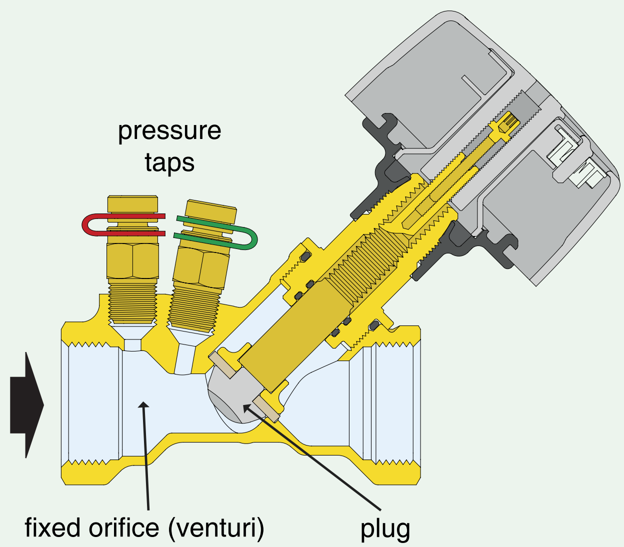


Figure 3-3b



other port provides the pressure at the exit of the venturi. The differential pressure measured across the venturi can be directly correlated to the flow rate through the venturi. The shaft of the valve moves the valve's plug toward or away from its seat. This changes the C_V of the valve and correspondingly changes the flow rate passing through it. Because the pressure ports are located along a fixed surface (e.g., the venturi), this type of valve is often called a *fixed orifice* balancing valve.

Figure 3-4

CORRELATING DIFFERENTIAL PRESSURE TO FLOW RATE

All differential pressure-type balancing valves have a precise relationship between the differential pressure measured at the pressure ports and the corresponding flow rate through the valve. That relationship can be shown as a graph, a table, or automatically determined by specialized instruments called manometers.

Figure 3-4 shows an example of a manometer attached to the pressure ports of a balancing valve using two small-diameter flexible hoses.

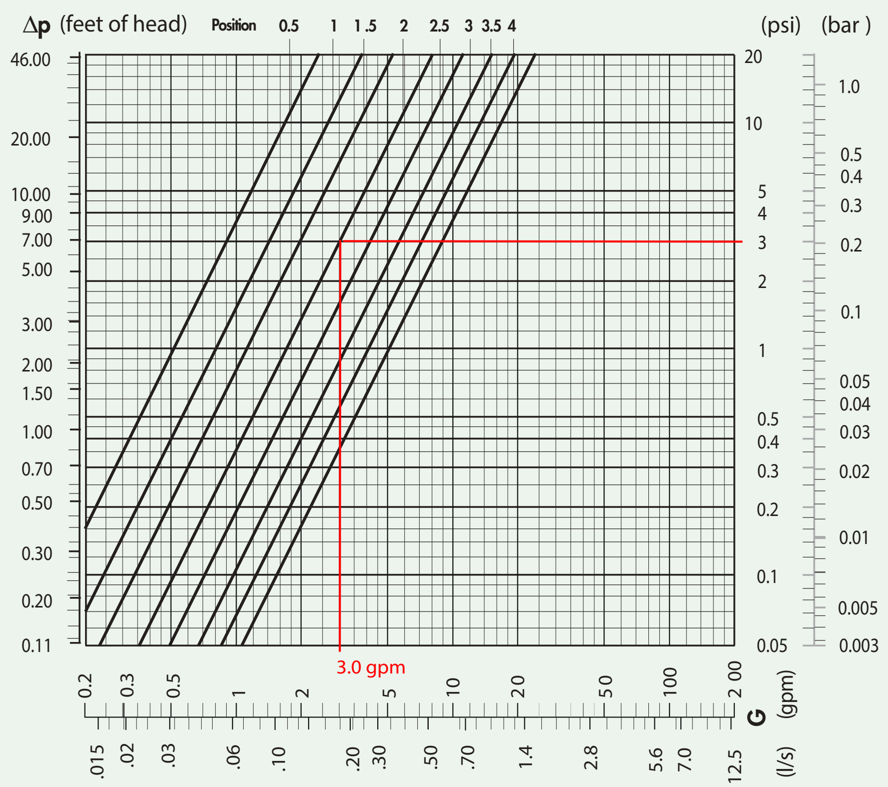
Differential pressure-type balancing valves have fine threads on their stem to allow precise adjustment of the plug relative to its seat. The knobs typically show position numbers that match the number of turns the valve stem has opened from its fully closed position.

Figure 3-5 is an example of a graph that shows the relationship between the differential pressure (ΔP) read by a manometer and the corresponding flow rate through a specific 3/4" variable orifice balancing valve.

To determine the flow rate through the valve, first find the measured differential pressure on the right-side vertical axis. Follow a horizontal line to the left until intersecting a sloping line that corresponds to the valve's knob position number. Then follow a vertical line to the bottom horizontal axis to read the flow rate. In this example, the valve's knob is at position #2, and the differential pressure measured between its pressure ports is 3 psi, which infers a flow rate of 3 gpm through the valve.

When the balancing requirements for a system are provided as a list of branch flow rates *and required pressure drop,* it is possible to preset the balancing valve to the required knob position. This reduces subsequent commissioning time.

Figure 3-5



	Position							Cv Max
Size 3/4"	0.5	1	1.5	2	2.5	3	3.5	4
Cv	0.55	0.8	1.2	1.7	2.4	3.7	4.4	5.0

BALANCING VALVES WITH FLOW INDICATION

Some manually set balancing valves have integrated flow measurement. Figure 3-6 shows an example.

Pulling the ring on the front of the valve allows a small internal magnet to be moved by the fluid flowing through the valve. This magnet lifts a small steel ball inside a transparent chamber. The position of this small ball indicates the flow rate through the valve. This design eliminates the need to have the flow-indicating element in contact with the system fluid, eliminating the possibility of "clouding" the transparent window on the meter over time.

Figure 3-6

SIZING DIFFERENTIAL PRESSURE BALANCING VALVES:

Differential pressure-type balancing valves become more subject to inaccuracies due to limitations of typical manometers when operated at differential pressures below 3 KPa (0.435 psi). It follows that balancing valves should be selected so they will operate at pressure drops higher than 3 KPa (0.435 psi). Using this criterion, along with the definition of C_V, leads to the following formula for the maximum C_V of a differential pressure balancing valve.

Formula 3-1

$$Cv_{BV(\max)} = \frac{f}{\sqrt{\Delta P}} == \frac{f}{\sqrt{.435}} = 1.52 \times f$$

Where:

C_V BV max = maximum C_V of a balancing valve

f = design flow rate through the balancing valve (gpm)

Keep in mind that balancing valves should also be selected to have a minimum valve authority of 0.50, which was discussed in the previous section.

STRENGTHS & LIMITATIONS OF MANUALLY SET BALANCING VALVES:

STRENGTHS:

- Simplicity
- No control system required
- Lower cost relative to other types of balancing valves

LIMITATIONS:

- More labor required for commissioning
- Cannot compensate for changes in differential pressure caused by zone valves opening and closing

SELECTION & INSTALLATION

Balancing valves should be thought of as "instruments." They are precisely made to deliver consistent relationships between differential pressure and flow rate.

4. PRESSURE INDEPENDENT BALANCING VALVES (PIBV)

To ensure long-lasting, accurate performance, adhere to the following installation details.

• Always install the valve in the correct flow direction.
• Provide a minimum of 10 pipe diameters of straight pipe upstream of the valve to reduce turbulence.
• Install a high-performance separator to capture fine dirt and magnetic particles within the system.
• Install a strainer upstream of the balancing valve or use an assembly with an integrated strainer.
• Internally wash the system during commissioning with a hydronic detergent.
• Size the valve based on its C_V rating and valve authority rather than its pipe size.
• Be sure that the pressure ports on the valve are easily accessible.

PIBV valves are also sometimes called “automatic” or “dynamic” balancing valves. They are designed to maintain a constant *preset flow rate*, even when the differential pressure across the valves varies over a wide range. They rely on an internal compensating mechanism to adjust an orifice within the valve so that a calibrated flow rate is maintained within a listed tolerance, typically +/- 10% of the calibrated flow rating. Figure 4-1a shows one body style used for PIBVs.

The internal components in a pressure-independent balancing valve consist of a cylinder, a spring-loaded piston, and a combination of fixed and variable-shaped orifices through which flow passes. The assembly of these components is called the “cartridge” of the PIBV. An example of such a cartridge is seen in figure 4-1b.

Figure 4-1a

Figure 4-1b

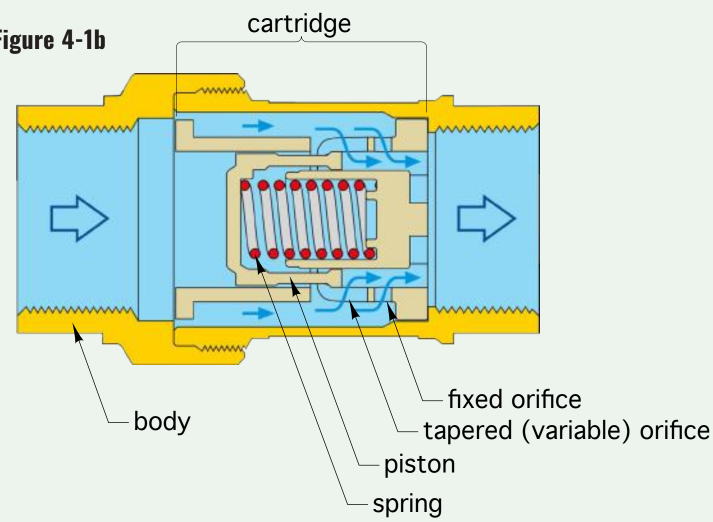


Figure 4-2a

Figure 4-2b

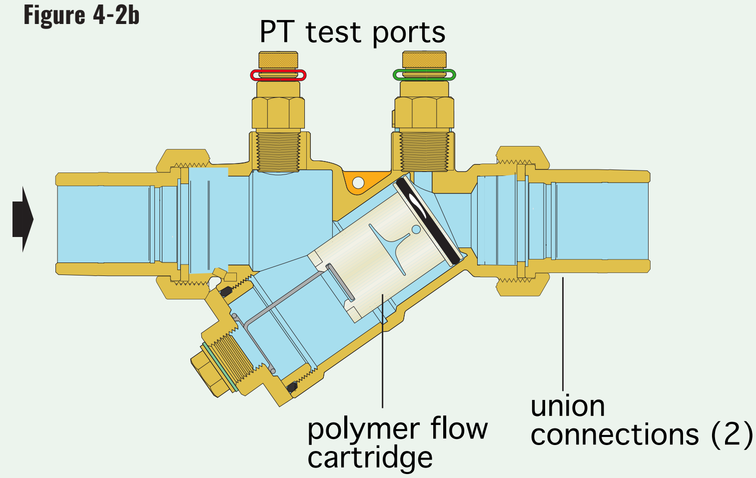


Figure 4-3

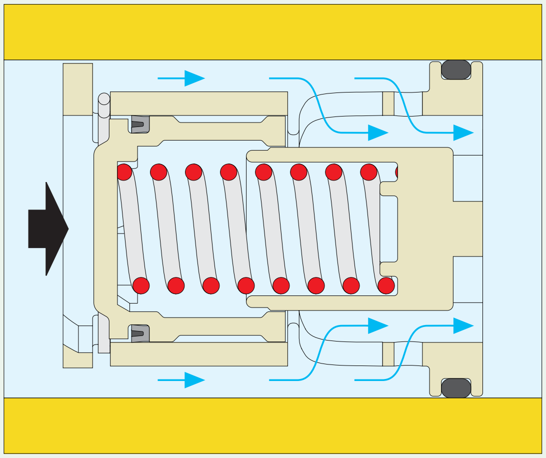


Figure 4-4

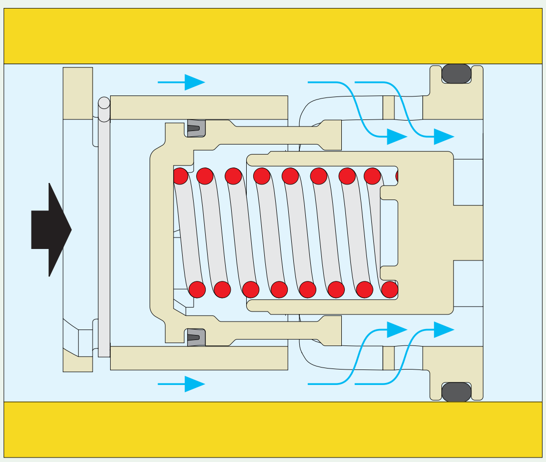


Figure 4-5

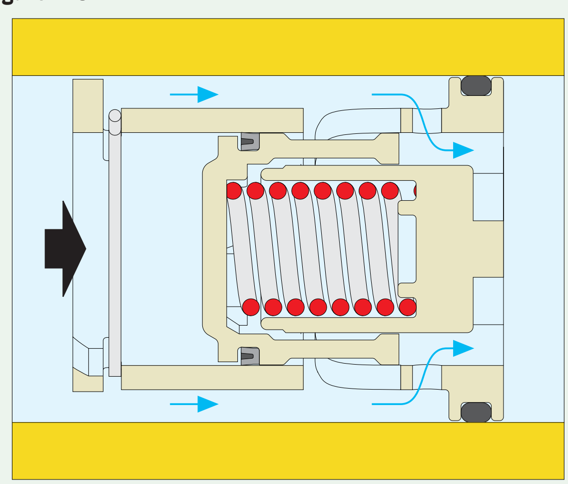
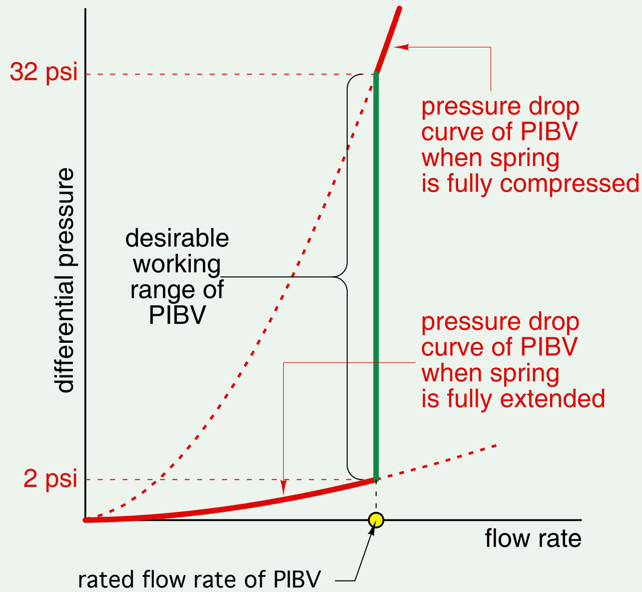


Figure 4-6



A Y-pattern PIBV is shown in figure 4-2a. It uses the same type of pressure-regulating cartridge as the valve shown in figure 4-1a. The Y-pattern valve also allows installers to easily change the cartridge if the design flow rate specification changes. The cartridge can also be removed when the system is being flushed, and then reinstalled.

One example would be a replacement scenario for a hydronic fan coil, wherein the unit being replaced required 2 gpm, but the new unit only requires 1 gpm. Another example would be if panel radiators were retrofitted into a branch circuit to provide heat for a building addition. The original branch flow rate of 2 gpm might not be sufficient, so it could be replaced with a cartridge having a higher flow rate calibration.

The flow cartridge within a PIBV is composed of a cylinder, a spring-loaded piston, and a combination of fixed and variable geometric orifices through which the fluid flows. These variable orifice sizes increase or decrease by the piston movement, contingent on the system's fluid thrust. A specially calibrated spring counteracts this movement to regulate the amount of fluid that will pass through the valve orifices, maintaining a constant flow rate in the circuit.

At low differential pressures (less than 2, 4, or 5 psi, depending on valve model), the internal compensating mechanism does not move. This allows the maximum free flow passage through the valve. Flow passes through both the fixed and variable orifices. *At such low differential pressures, the internal mechanism cannot adjust to* *maintain a fixed flow rate.* Thus, flow rate through the valve will increase as differential pressure increases. The “inactive” position of the internal cartridge is shown in figure 4-3.

If the differential pressure across the PIBV exceeds the minimum threshold pressure of 2, 4 or 5 psi (depending on valve model), the internal piston assembly begins to move in the direction of flow due to thrust against it. An internal spring is partially compressed by this action. Under this condition, the piston partially obstructs the tapered slot through which flow must pass. However, the flow passage is now automatically adjusted so that the valve can maintain its calibrated flow rate at the higher differential pressure.

As the thrust and the differential pressure across the valve continues to increase, the piston moves farther to compress the spring. This movement continues to reduce the flow passage through the tapered orifice, as seen in figure 4-4. The change in the orifice size is such that the valve continues to deliver its calibrated flow rate under the higher differential pressure.

This ability to adjust flow through the tapered orifice remains in effect until the differential pressure across the valve reaches an upper threshold limit of 14, 32, 34 or 35 psi (depending on valve model). Such high differential pressure is relatively uncommon in most well-designed hydronic systems that include some means of differential pressure control.

If the differential pressure across the valve does exceed the upper pressure threshold, the piston and counterbalancing spring can no longer maintain the calibrated flow rate. The piston’s position completely blocks flow through the tapered orifice. All flow must now pass through the fixed orifice. This condition is shown in figure 4-5. The result will be an increase in flow rate if differential pressure increases above the upper pressure threshold.

The overall flow versus differential pressure characteristics of a PIBV is shown in figure 4-6. The desired condition is to maintain the differential pressure across the valve between the lower and upper threshold values, so that the internal cartridge remains active and the valve maintains its calibrated flow rate.

With a PIBV in each branch, and as long as the differential pressure across that valve remains within the regulation range of the valve, the flow rate through each *active* branch remains at the calibrated value of the PIBV, *regardless of the flow status in other branches.* This is a significant benefit of a PIBV valve compared to a manually set balancing valve.

Figure 4-7a,b compares the flow rate changes in two systems that are identical other than the type of balancing valves used.

The system in figure 4-7a uses manual balancing valves that have been adjusted so that the desired flow rates exist in each branch, *provided all branches are active.* However, when a zone valve in one of the branches closes, the flow rates in the other branches increase due to the increased differential pressure created by the fixed-speed circulator. This change in flow rates is undesirable because it increases heat output from the heat emitters.

The system in figure 4-7b uses PIBVs in each branch. Each valve has been configured with a flow cartridge for the design flow rate of its branch. When one of the zone valves closes, the PIBVs in the other branches immediately compensate for the increased differential pressure so that the flow through each active branch remains the same.

The cartridges within each active PIBV absorb the increased head energy from the circulator when the operating point moves to the left and up on the pump curve.

PIBV valves are a significant advancement in balancing technology. They provide a way to hold a stable flow rate in different branches of the system as the hydraulic resistances of other branches change.

The unique polymer cartridges used in all Caleffi PIBVs are specifically designed to prevent potential noise due to low flow.

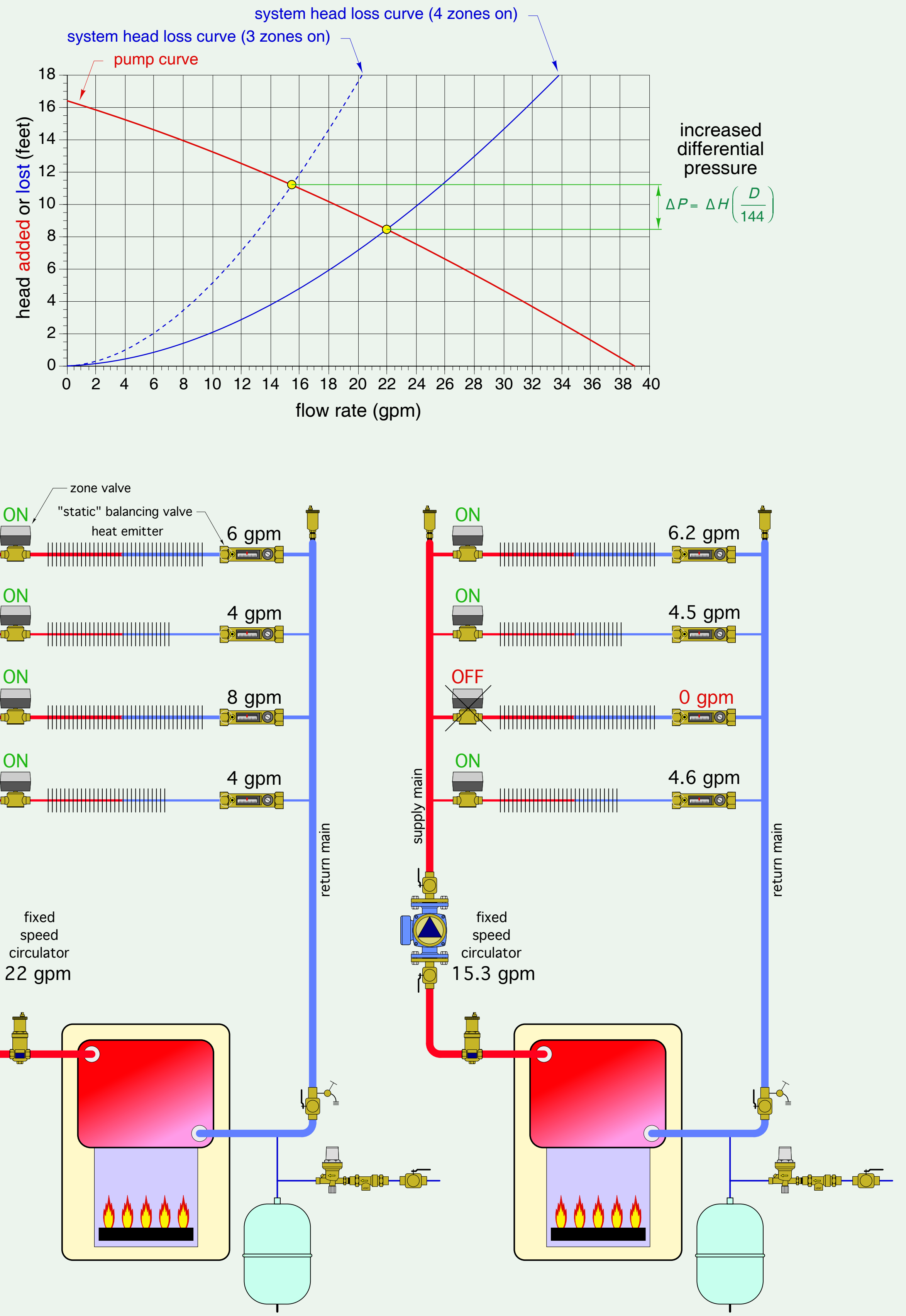
To preserve the performance of PIBVs, the system should be free of small debris that could deposit on the slots used in the calibrated pressure-regulating cartridges. To minimize this possibility, all systems using PIBV should also have a high-efficiency dirt separator, such as a Caleffi DIRTMAG® PRO.

To properly specify a PIBV, the following variables must be determined:

- Required flow rate
- The range of ΔP that could be imposed on the PIBV
- Branch pipe size
- Type of connection (press, sweat, NPT, PEX expansion, PEX crimp, etc.)

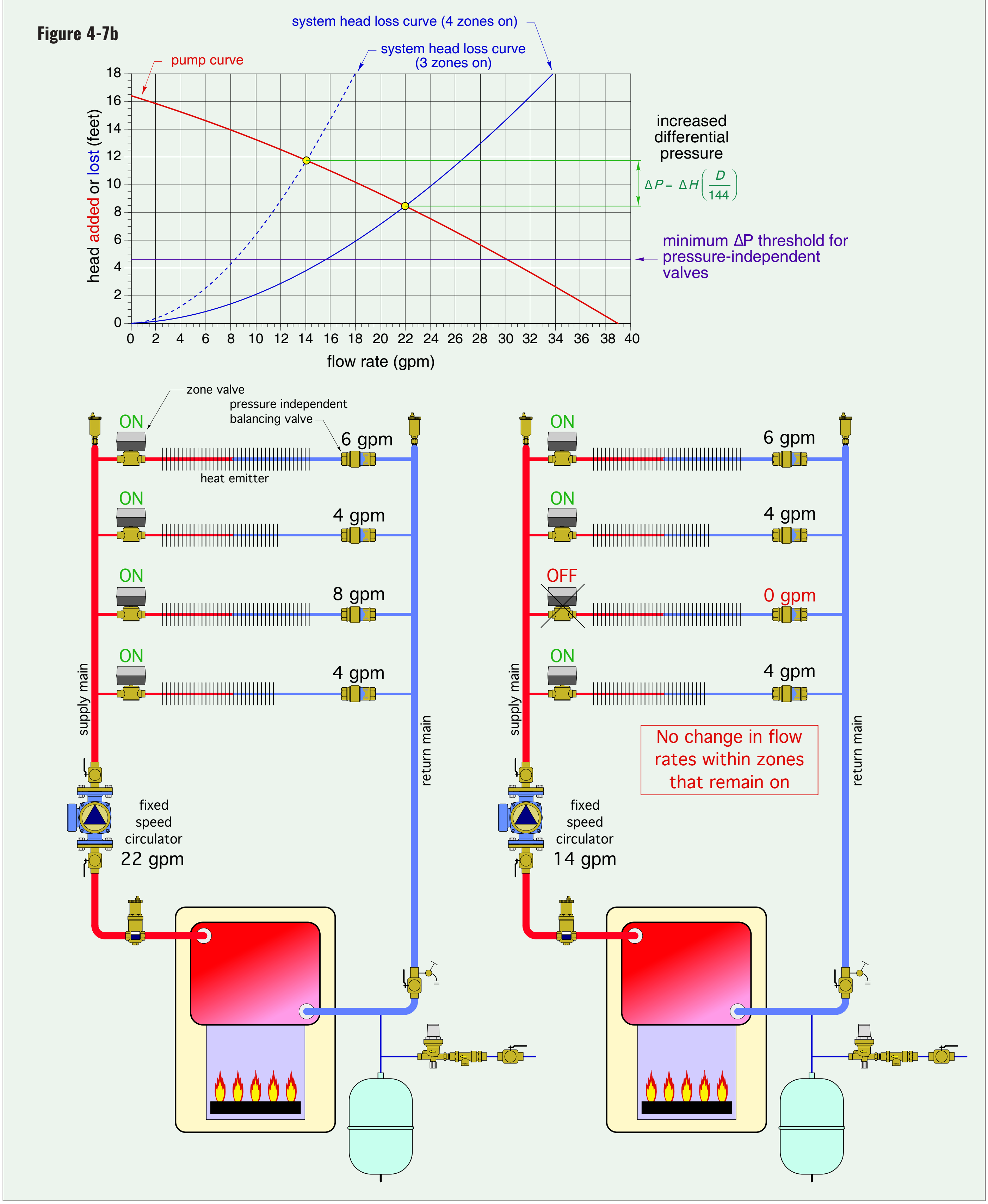
Figure 4-8 shows ratings for Caleffi 128 series PIBVs.

Figure 4-7a



system head loss curve (4 zones on)
system head loss curve (3 zones on)
pump curve
head added or lost (feet)
flow rate (gpm)
increased differential pressure
$\Delta P = \Delta H\left(\frac{D}{144}\right)$
zone valve
"static" balancing valve
heat emitter
ON
6 gpm
ON
4 gpm
ON
8 gpm
ON
4 gpm
supply main
return main
fixed speed circulator
22 gpm
ON
6.2 gpm
ON
4.5 gpm
OFF
0 gpm
ON
4.6 gpm
supply main
return main
fixed speed circulator
15.3 gpm

Figure 4-7b



system head loss curve (4 zones on)
system head loss curve (3 zones on)
pump curve
head added or lost (feet)
flow rate (gpm)
increased differential pressure
$\Delta P = \Delta H\left(\frac{D}{144}\right)$
minimum ΔP threshold for pressure-independent valves
zone valve
pressure independent balancing valve
heat emitter
ON
6 gpm
4 gpm
8 gpm
supply main
return main
fixed speed circulator
22 gpm
OFF
0 gpm
14 gpm
No change in flow rates within zones that remain on

Figure 4-8

Code	Description	Code	Description	Code	Description
128541AF ...	½" NPT male	128551AF ...	¾" NPT male	128561AF ...	1" NPT male, No gauge
128542AF ...	½" PEX expansion	128552AF ...	¾" PEX expansion	128562AF ...	1" PEX exp., No gauge
128544AF ...	½" PEX crimp	128554AF ...	¾" PEX crimp	128564AF ...	1" PEX crimp, No gauge
128546AF ...	½" press	128556AF ...	¾" press	128566AF ...	1" press, No gauge
128549AF ...	½" sweat	128559AF ...	¾" sweat	128569AF ...	1" sweat, No gauge

Flow rate (GPM)	Last 3 digits (AF/AFC___)	ΔP control ranges (psid)
0.35	G35	2 - 14
0.50	G50	
0.75	G75	
1.00	1G0	2 - 32
1.30	1G3	
1.50	1G5	
1.75	1G7	
2.00	2G0	
2.20	2G2	
2.50	2G5	

In this example, a 128556AF 1G5 would denote a ¾" press connection and 1.50 gpm control range with a Δp control range of 2-32 psi.

STRENGTHS & LIMITATIONS OF PRESSURE INDEPENDENT BALANCING VALVES:

STRENGTHS:

• Holds consistent branch flow rates by compensating for changes in differential pressure caused by zone valves opening and closing
• Less labor required for commissioning

LIMITATIONS:

• In the event of a heat emitter changeout/modification, a cartridge replacement might be required.
• Circulator sizing must ensure that the differential pressure across the PIBV stays within the active range of the valve's internal cartridge.
• System fluid needs to be clean to ensure the internal cartridge is not clogged.

5. PRESSURE INDEPENDENT CONTROL VALVES (PICV)

The pressure independent balancing valves (PIBV) discussed in the previous section allow a specific flow rate to be maintained over a wide range of differential pressures. *However, they do not have the ability to start and stop flow, or the ability to vary the flow rate through a heat emitter or cooling coil.*

The latter functions are often desirable to regulate the rate of heat transfer from a heat emitter or from the cooling coil within an air handler or fan-coil.

This functionality can be added to the basic operating characteristic of a pressure independent balancing valve. The result is known as a pressure independent control valve (or PICV).

PICVs are useful when the flow rate to a heat emitter or cooling coil needs to be regulated by a building automation system or other electronic controller in response to changes in the heating or cooling loads.

Figure 5-1

Figure 5-1 shows a Caleffi 145 Series FLOWMATIC® PICV valve. With the green manual adjustment knob as shown, this valve is an *adjustable* PIBV.

Figure 5-2 shows the cross section of this valve.

The lower portion of the valve (within box A) senses the pressure differential between the higher pressure (p2) and the slightly lower pressure (p3). The combined action of the diaphragm and spring in the lower portion of the valve maintain a nearly constant differential pressure (p2-p3) across the flow regulation chamber of the valve. This enables the valve to maintain a set flow rate over a wide range of differential pressure as shown in figure 5-3.

Figure 5-2

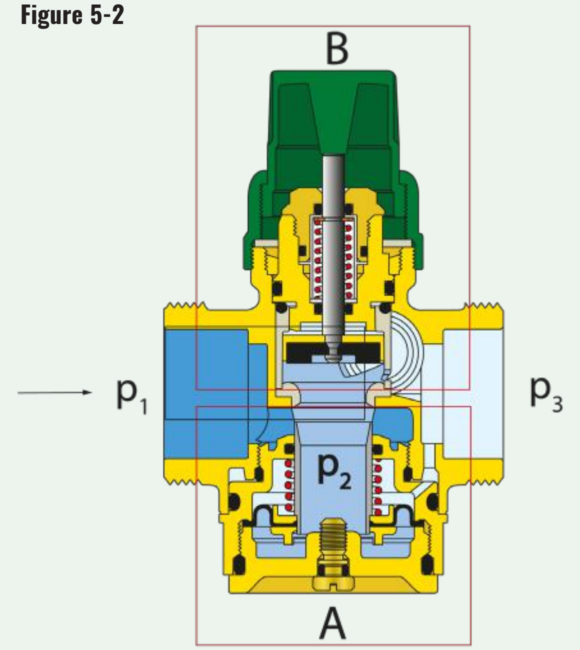
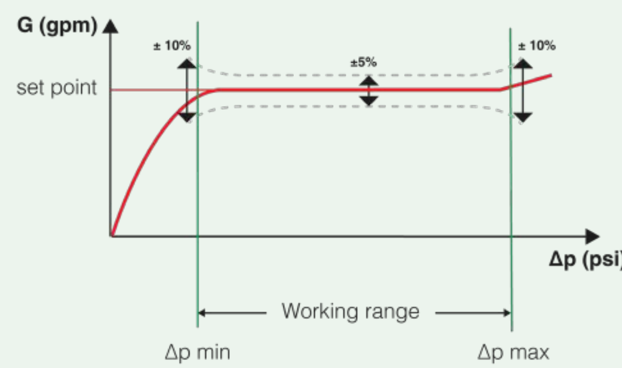


Figure 5-3



The upper portion of the PICV valve (within box B in figure 5-2) combines a disc that moves up and down as the valve stem moves, with a tapered slot through which flow passes. These details are shown in figure 5-4.

As the disc moves up and down, it acts like a “shutter” over the tapered slot, controlling the gap through which flow can pass.

The PICV may be adjusted to match the maximum flow rate (G_{max}) that will pass through the valve. This is easily done by loosening the locknut at the top of the valve and rotating the disc marked with number 1 through

Figure 5-4

10. Doing so rotates the shutter as required by the maximum flow rate. A table that shows how to select the setting number is provided later in this section. This adjustment does not affect the stroke of the stem, only the size of the flow aperture when the valve is fully open. This is an important feature because the proportional control signal to the valve's actuator is always fully utilized for the full stroke of the shaft, even when the maximum flow rate through the valve is reduced.

Once the position of the valve's disc relative to its tapered slot has been set, the valve can function as an automatic balancing device capable of holding a set flow rate over a wide range of differential pressures between its inlet and outlet.

The relationship between the flow rate setting and the differential pressure range across which that setting can be maintained is shown in figure 5-5.

The valve's ability to hold a set flow rate requires that the differential pressure between its inlet and outlet be within the "working range" as shown in figure 5-5. The minimum differential pressure varies from 3.6 to 4.4 psi depending on the flow rate setting of the valve, which is adjusted using the numbered disc on the valve's bonnet. The upper limit of differential pressure at which the valve can maintain a set flow rate is 60 psi.

ADDING AN ACTUATOR

The Caleffi 145 can also be operated automatically rather than manually by replacing the green knob with an actuator. These actuators allow flow through the valve to be regulated by any controller or building automation system (BAS) that can provide a standard 24 VAC on/off or a 0-10 VDC proportional control signal.

Adding an actuator changes the valve from an adjustable pressure-independent balancing device, to a pressure-independent control valve (PICV). Think of the latter as an enhancement that adds control capability to the basic functionality of the PIBVs described in section 4. This combination represents the state-of-the-art in achieving stable heating or cooling capacity control based on varying the flow rate through a heat emitter or cooling coil.

ON/OFF CONTROL OF PICVs

When fitted with a thermo-electric actuator, the upper portion of the valve can operate as an on/off flow control device, much like a zone valve. However, unlike a typical zone valve, the pressure-regulating portion of the valve can maintain a constant flow rate through the valve over a wide range of differential pressures.

Changes in differential pressure across the valve are usually created by other valves in the system opening and closing. This is especially likely when a fixed-speed circulator provides flow in the system. On/off zone valves lack this pressure compensating ability, and as such, can allow significantly different flow rates unless other means of pressure compensation, such as variable-speed circulators, pressure-independent balancing valves, or differential pressure bypass valves, are used in the system.

On/off flow control is often used when the control system is intended to maintain a quasi-steady room temperature based on a setpoint and

Figure 5-5

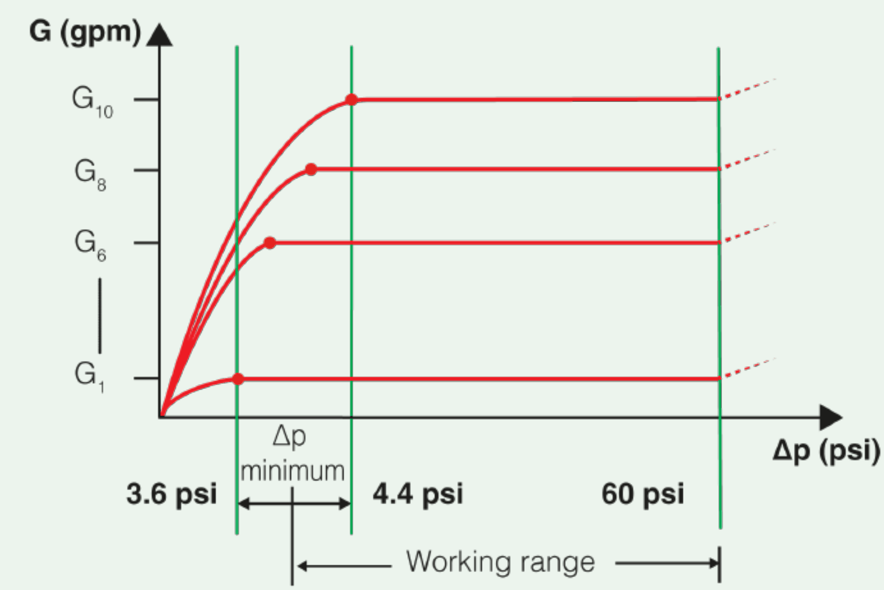
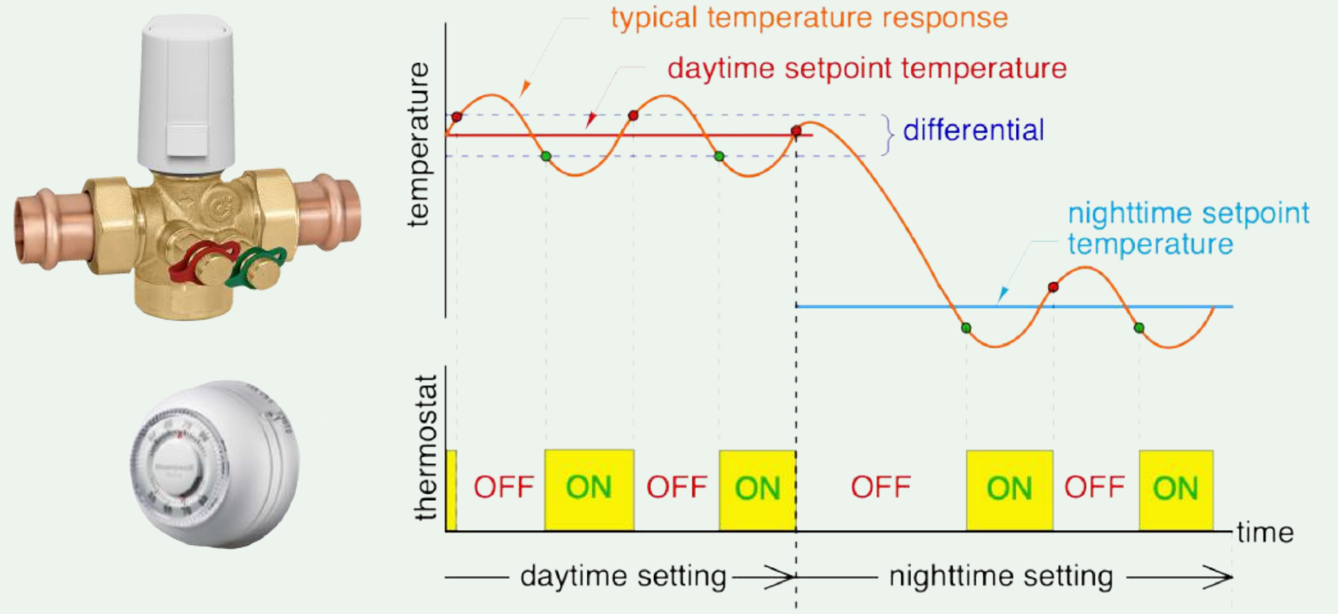


Figure 5-6



differential typically coming from a room thermostat.

A standard room thermostat acts as a "switch" that provides either 0 VAC or nominal 24 VAC voltage to the valve's actuator.

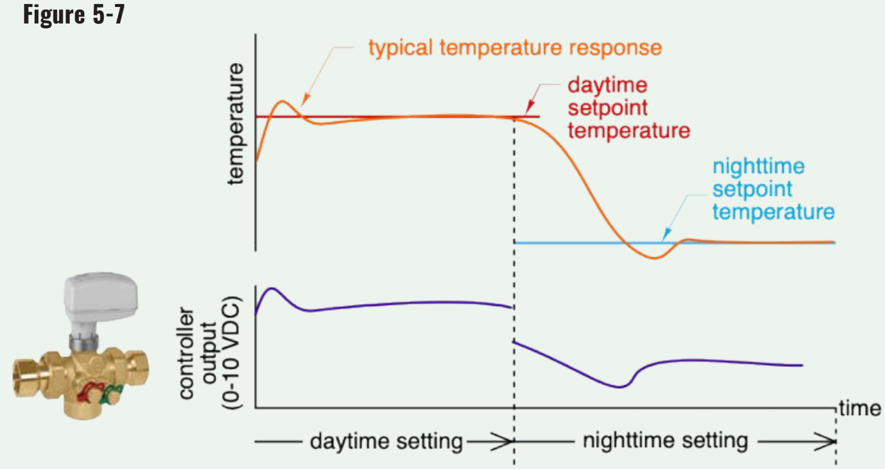
As the thermostat cycles power on and off to the actuator, it fully opens or fully closes the valve. This type of control results in "pulses" of heated water flowing through the room's heat emitter. These pulses create variations in room temperature slightly above and below the "target" setpoint, as shown in figure 5-6.

The on/off status of the valve's actuator is shown at the bottom of the figure. The resulting fluctuations in room temperature above and below the setpoint temperature are shown in the upper portion of the figure. The slight overshoot and undershoot of the temperature are the result of the temperature differential controlling the actuator, as well as the thermal mass of the distribution system and heat emitters. Modern controllers can reduce this differential to limit overshoot and undershoot to nearly undetectable levels. On/off actuators have two advantages compared to proportional actuators; they are silent and they cost less.

PROPORTIONAL CONTROL OF PICVs

The Caleffi PICV valve can also be fitted with an actuator that takes a standard 0-10 VDC proportional signal from any proportional controller, such as a proportional thermostat, or building automation system (BAS). These controllers typically use PID (proportional integral derivative) control algorithms that compare the temperature setpoint to the actual room temperature. The controller's 0-10 VDC output signal then drives the actuator/valve

Figure 5-7



to quickly stabilize room temperature at the desired setpoint with very minimal overshoot or undershoot, as represented in figure 5-7.

A PICV balancing valve equipped with a 0-10 VDC actuator and regulated by a PID temperature controller is analogous to a modulating heat source regulated based on outdoor reset. Both can quickly "zero in" on the target temperature setting and maintain that setting with essentially imperceptible variations.

PICV APPLICATIONS

PICV valves can be used in any application where two or more independently controlled heat emitters, or chilled-water cooling terminal units are connected in a parallel piping arrangement.

One example would be multiple 4-pipe air handlers or fan-coil units, as shown in figure 5-8.

PICV valves can be used in either 2-pipe direct return distribution systems or 2-pipe reverse return distribution systems. They provide the functional equivalent of either a zone valve paired with an automatic balancing valve, or a static balancing valve paired with a modulating flow control valve.

For more information on direct return and reverse return hydronic distribution systems, see *idronics* #8.

PICV SIZING

All PICV valves require a minimum differential pressure (ΔP) to engage their pressure regulation function, as represented in figure 5-3. The circulator driving flow through the system must provide this minimum ΔP in addition to the pressure drop of the piping and other components.

The differential pressure required of the circulator under design load conditions can be determined by adding the pressure drop of all piping and other components *in the flow path of highest resistance* to the ΔP_{min} value in figure 5-9, *which is specific to the Caleffi 145 Series FLOWMATIC PICV valves*.

This table shows the flow setting range of different size 145 Series valves (as numbered 1 through 10 along the top of the table). The minimum and maximum ΔP values, to maintain a constant flow rate, are shown in columns 1

Figure 5-8

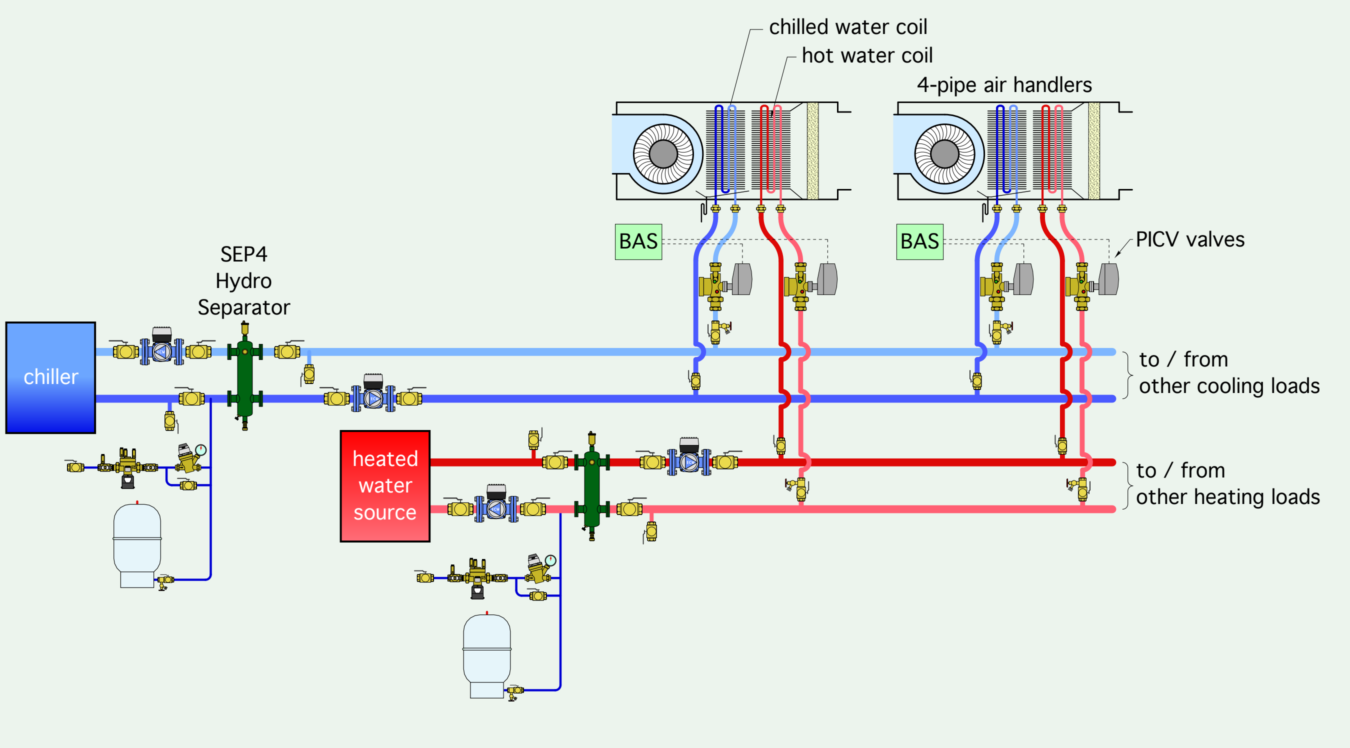


Figure 5-9

Flow rate adjustment table

Code locking nut color	flow range G Δp min		Adjustment position (G_{max}) 1	2	3	4	5	6	7	8	9	10
145... G90 (yellow)	0.34-3.40 (l/min)		0.34	0.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.40
	0.09-0.90 (GPM)		0.09	0.18	0.27	0.36	0.45	0.54	0.63	0.72	0.81	0.90
	Δp min	(kPa)	25	25	25	25	25	25	25,5	25,5	26	26
		(psi)	3.6	3.6	3.6	3.6	3.6	3.6	3.7	3.7	3.8	3.8
145... 1G8 (white)	1.30-6.60 (l/min)		–	1.30	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.60
	0.35-1.75 (GPM)		–	0.35	0.53	0.70	0.88	1.05	1.23	1.40	1.58	1.75
	Δp min	(kPa)	–	25	25,5	26	26	26,5	26,5	27	27	27
		(psi)	–	3.6	3.7	3.8	3.8	3,8	3.8	3.9	3.9	3.9
145... 3G5 (blue)	1.30-13.2 (l/min)		1.30	2.67	4.00	5.33	6.67	8.00	9.33	10.67	12.00	13.20
	0.35-3.50 (GPM)		0.35	0.70	1.05	1.40	1.75	2.10	2.45	2.80	3.15	3.50
	Δp min	(kPa)	25	25	25,5	26	26	27	27,5	28	28,5	29
		(psi)	3.6	3.6	3.7	3.8	3.8	3.9	4.0	4.1	4.1	4.2
145... 5G3 (black)	2.0-20.0 (l/min)		2.00	4.00	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.00
	0.53-5.30 (GPM)		0.53	1.06	1.59	2.12	2.65	3.18	3.71	4.24	4.77	5.30
	Δp min	(kPa)	25	25	25,5	26	26	26,5	26,5	27	27,5	28
		(psi)	3.6	3.6	3.7	3.8	3.8	3.8	3.8	3.9	4.0	4.1
145... 7G9 (red)	3.0-30.30 (l/min)		3.00	6.00	9.00	12.00	15.00	18.00	21.00	24.00	27.00	30.30
	0.79- 7.9 (GPM)		0.80	1.60	2.40	3.20	4.00	4.80	5.60	6.40	7.20	8.00
	Δp min	(kPa)	35	35	35	35	35	28	25	25	25	25
		(psi)	5.1	5.1	5.1	5.1	5.1	4.1	3.6	3.6	3.6	3.6
145... 13G (grey)	5.0-50.0 (l/min)		5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00
	1.30-13 (GPM)		1.30	2.60	3.90	5.20	6.50	7.80	9.10	10.40	11.70	13.00
		(kPa)	35	35	35	35	35	35	35	35	35	35
		(psi)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
145... 16G (white)	6.25-62.50 (l/min)		6.25	12.33	18.5	24.67	30.83	37.00	43.17	49.33	55.50	62.50
	1.6-16 (GPM)		1.65	3.30	4.95	6.60	8.25	9.90	11.55	13.20	14.85	16.50
	Δp min	(kPa)	48	48	48	48	45	45	43	43	43	43
		(psi)	6.96	6.96	6.96	6.96	6.53	6.53	6.24	6.24	6.24	6.24

Minimum differential pressure required

For pump sizing, add the min press difference required by the served emitter to the fixed head losses of the most flow starved circuit. Use this value to find the Δp min shown in the above table to select the 145 series code ($H_{pump} = \Delta p_{circuit} + \Delta p_{min}$).

and 10. The minimum differential pressure across the valve (ΔP_{min}) is listed for each setting position in both metric and IP units.

For example, if the valve is to pass 3 gpm at design conditions, the 145…3G5 valve would be used, its setting number would be 9 (corresponding to 3.15 gpm in the table), and the minimum differential pressure required across the valve would be 4.1 psi.

For more information on sizing variable-speed circulators for systems using PIBV or PICV valves, see *idronics* #8.

COIL KITS

PICVs are ideal for controlling the thermal output from an air handler, fan coil or chilled beam terminal unit in either heating or cooling.

When piping such a terminal unit, several components other than a standard PICV are typically used. These include valves for isolating the terminal unit from the remainder of the system, draining the isolated terminal unit if required, capturing debris that could interfere with operation of the PICV, and verifying the pressure drop across the assembly of these

Figure 5-10

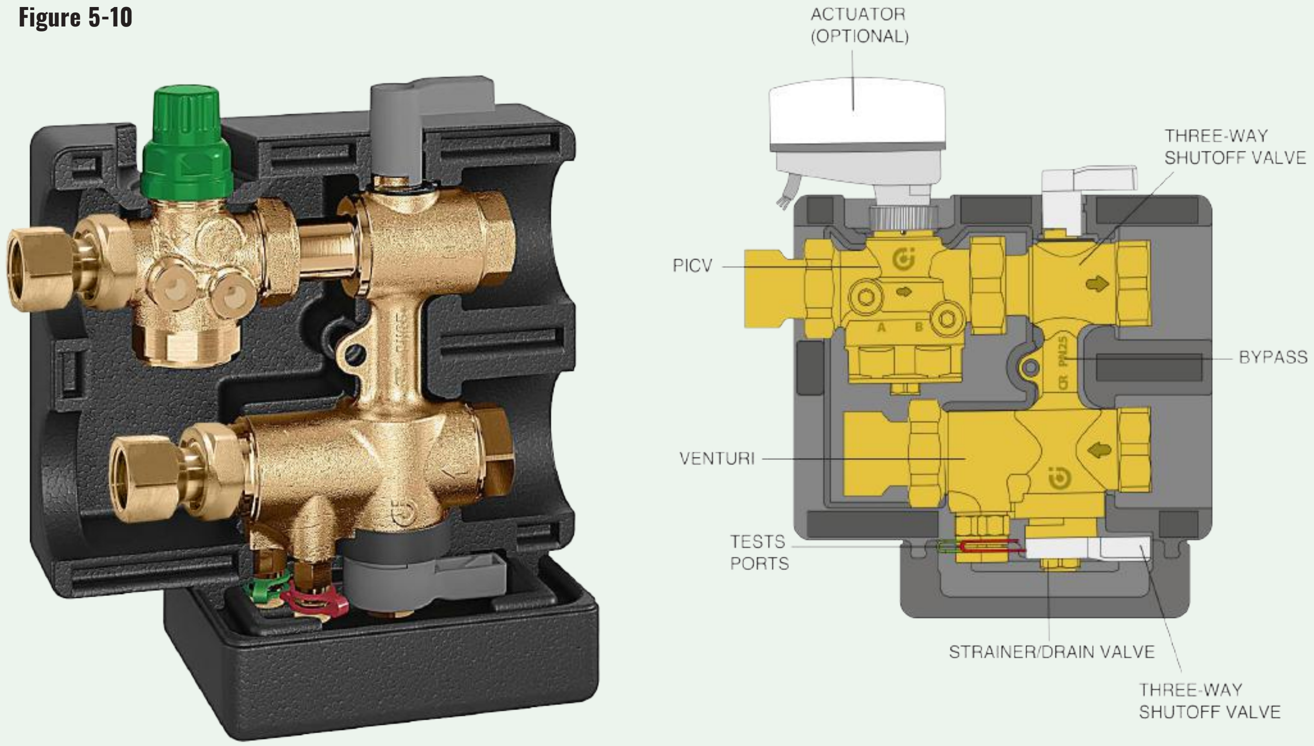
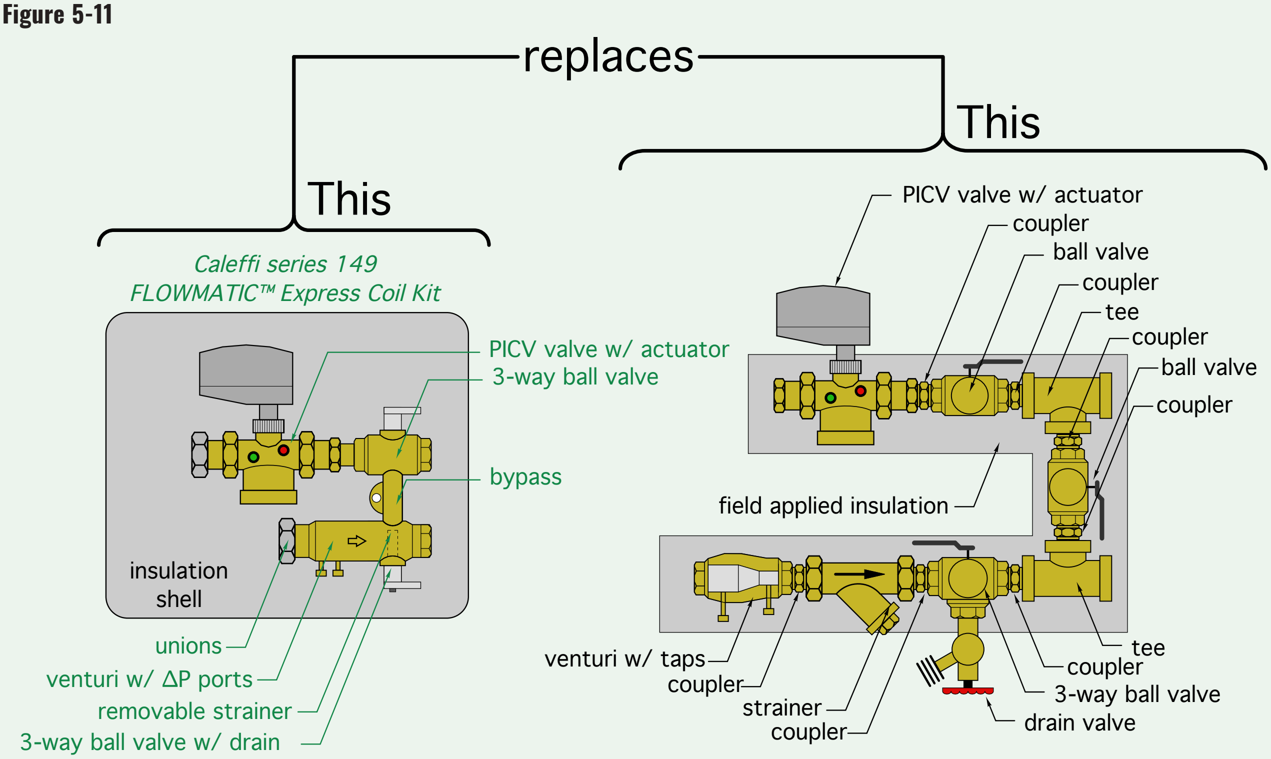


Figure 5-11



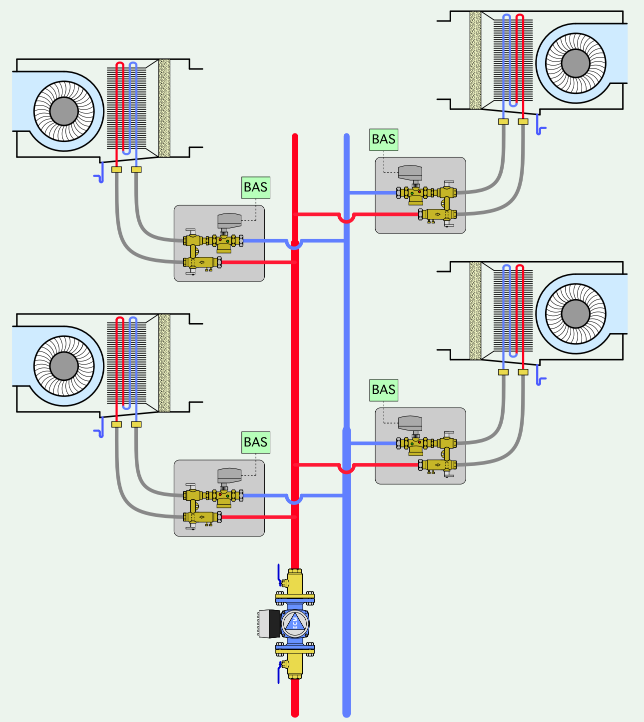


Figure 5-12

components combined with that of the terminal unit.

One approach is to individually specify all the components needed at each terminal unit, and assemble them on site. While this approach can work, it involves additional design, specification, installation and commissioning time. If the terminal unit uses chilled water for cooling, all these separate components must be insulated and vapor sealed to prevent condensation. Several joints are required, increasing the potential for leaks.

Caleffi offers a more efficient approach by combining all the functionality required into a single pre-assembled module called the 149 Series FLOWMATIC Express Coil Kit, which is shown in figure 5-10.

The coil kit, combined with one of the valve actuators available for its PICV, provides all the functionality required to:

1. Control flow through a terminal unit.
2. Isolate that unit from the remainder of the system.
3. Allow flow to bypass the coil during system flushing.
4. Drain the isolated terminal unit.
5. Measure the ΔP across the terminal unit and use it to calculate flow rate.

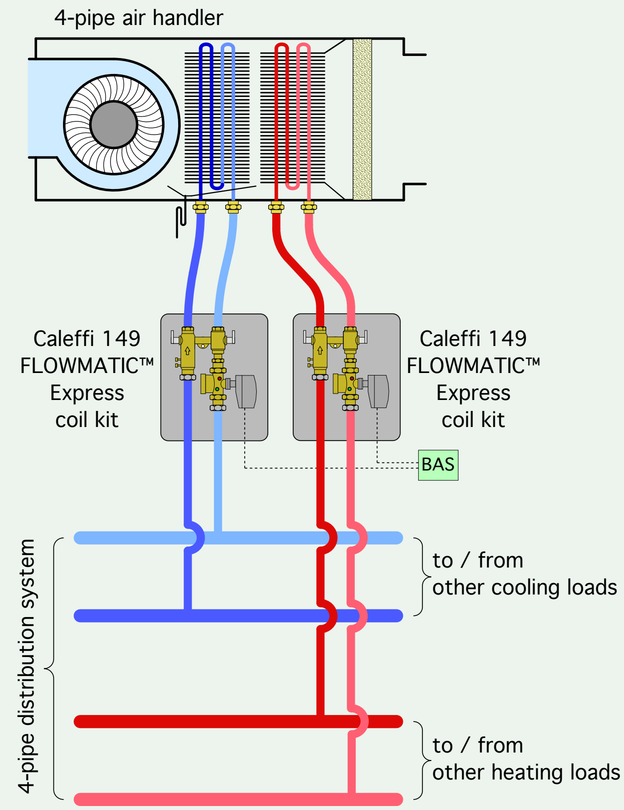


Figure 5-13

6. Collect debris in the flow stream.
7. Protect all components against condensation in chilled-water cooling applications.

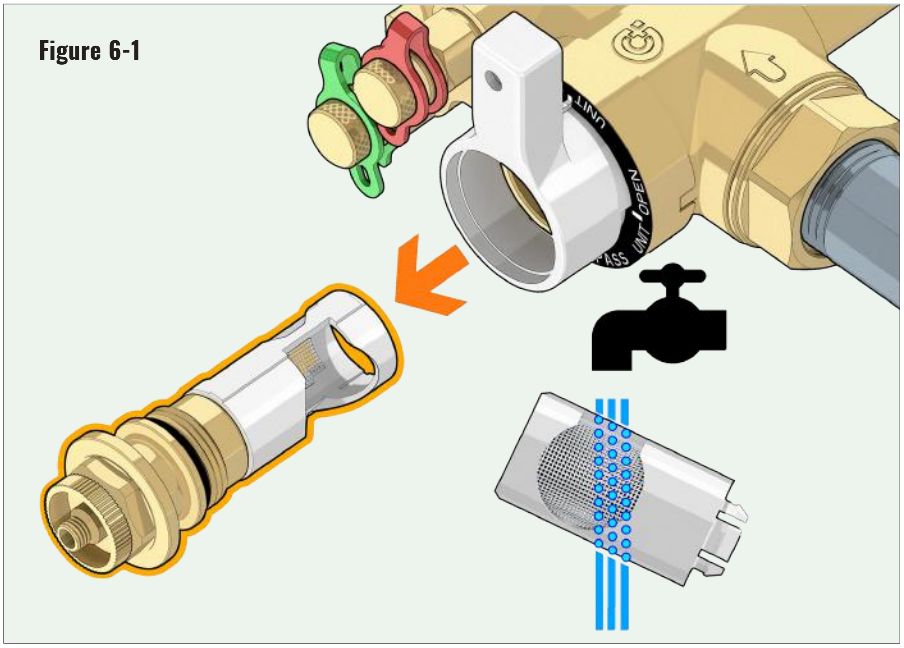
Figure 5-11 shows how the FLOWMATIC coil kit compares to a shop- or field-assembled grouping of components that provides equivalent functionality.

The Caleffi FLOWMATIC coil kit is available in nominal pipe sizes from 1/2-inch to 1-inch. It can be hard-piped to the distribution mains and is connected to the terminal unit using flexible hose connections.

Installation of the coil kit in a 2-pipe distribution system requires two pipes connecting the distribution mains to the coil kit, and two pipes or flexible hoses to connect the coil kit to the terminal unit. Low-voltage wiring connecting the PICV valve actuator to the building's control system is also required. Figure 5-12 shows a typical 2-pipe arrangement of independently-controlled air handlers, operating in heating mode, and supplied with Caleffi FLOWMATIC coil kits.

6. PROTECTION & MAINTENANCE OF BALANCING VALVES

Figure 6-1



In a 4-pipe distribution system supplying air handlers or fan-coils, two coil kits would be used. One connects to the cooling coil, and the other to the heating coil, as shown in figure 5-13.

For a balancing valve to perform well over time, maintenance is required. Balancing valve orifices need to remain clean. If these orifices accumulate debris, the precision operation of the valve is compromised.

A central dirt and magnetic particle separator should be specified in any system containing balancing valves.

The Caleffi FLOWMATIC® Express coil kit contains a removable/washable debris screen, as shown in figure 6-1. This screen supplements the function of a central dirt/magnetic particle separator.

While it may seem redundant to include two dirt separation devices in a system, they serve different purposes. Central dirt separators are best for capturing large amounts of system debris from the flow stream without increasing the pressure drop across the separator as the debris accumulates. A collision media in a dirt separator removes particles down to 5 micrometers in size. Unlike a filter or Y-strainer that traps debris in the flow path, Caleffi dirt separators operate based on slowing the fluid's velocity. When debris collides with the separation media, it falls to the bottom portion of the separator body, out of the flow path. This prevents the differential pressure across the separator from increasing as debris is collected.

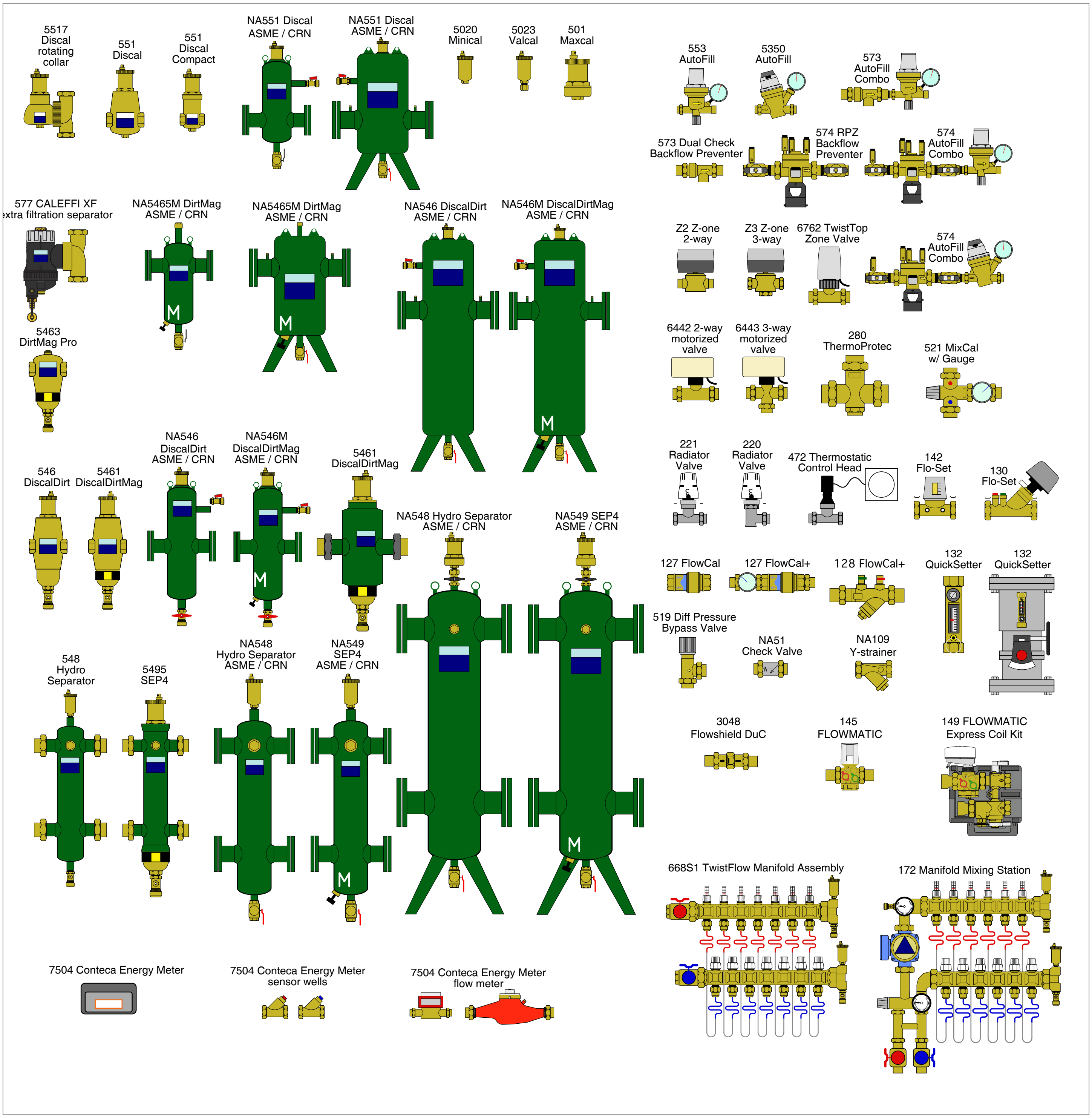
Strainers within components, such as the FLOWMATIC Express coil kit, are best applied as a last defense for small amounts of system debris that may be downstream of the central dirt separator. However, if the central dirt separator was omitted, these small strainers could partially or completely plug and drastically limit flow through the branches. A best practice is to flush a system of as much system debris as is possible before any control valve is commissioned. The Caleffi coil kit includes valves that allow the system fluid to bypass the terminal unit when the system is first flushed. This minimizes the potential of debris becoming lodged in the terminal unit.

For more background on dirt separation strategies in hydronic systems, see idronics #15.

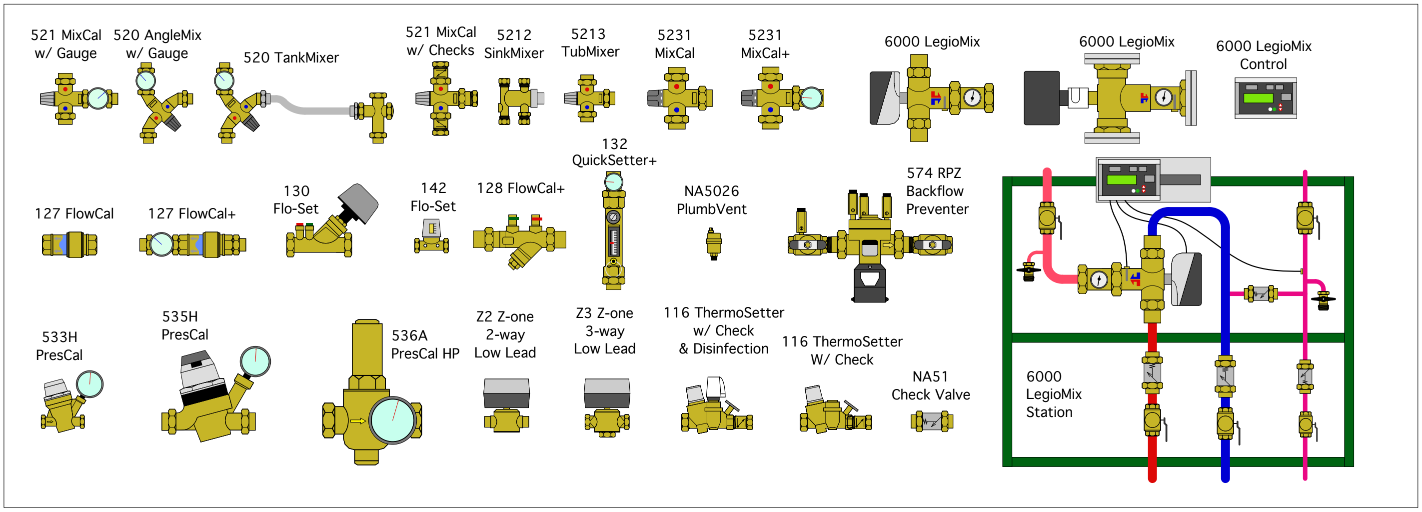
7. SUMMARY

Hydronic balancing has evolved from simple application of globe valves combined with "correcting techniques" that limit variations in differential pressure, to devices that can stabilize both the hydraulic and thermal aspects of controlling heat emitters or cooling terminal units. Caleffi offers a full spectrum of balancing products that enable proper hydraulic and thermal performance in a wide range of system applications. This issue of *idronics* has discussed the refinement of balancing technology. Additional information on balancing procedures can be found in *idronics* #8.

APPENDIX A: CALEFFI HYDRONIC COMPONENTS



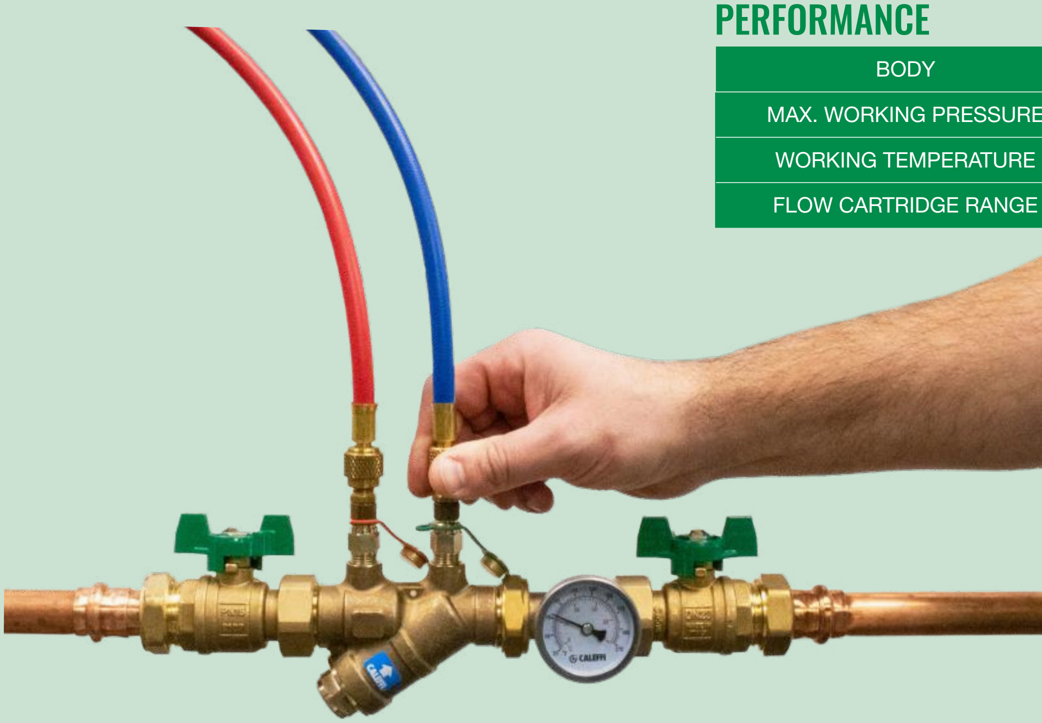
APPENDIX B: CALEFFI PLUMBING COMPONENTS



128 FLOWCAL™
Y-BODY DYNAMIC BALANCING VALVES

HIGH VALUE BALANCING

The low lead FlowCal™ dynamic balancing valve maintains constant flow rates in domestic hot water recirculation and hydronic circuits regardless of pressure fluctuations within the piping system. The patented cartridge is made of a scale-resistant, low-noise polymer which can be removed for system flushing, service or change-out for a different flow rate. Multiple choices of union end connection types make installation flexible and easy. Multi-functional with PT ports, integrated check valve and optional temperature gauge, the Y-body FlowCal™ valve provides quiet operation, ease of commissioning, and simple serviceability.



PERFORMANCE

BODY	DZR Low Lead brass
MAX. WORKING PRESSURE	400 psi (28 bar)
WORKING TEMPERATURE	32° – 212 °F (0° – 100°C)
FLOW CARTRIDGE RANGE	0.35 to 10 GPM

PRODUCT RANGE - FlowCal™ Y-body Dynamic Balancing Valves

UNION CONNECTION STYLE	OUTLET TEMP GUAGE	CODE		
		½ inch	¾ inch	1 inch
SWEAT		128449AFC ***	128459AFC ***	128469AFC ***
	√	128448AFC ***	128458AFC ***	128468AFC ***
NPT Male		128441AFC ***	128451AFC ***	128461AFC ***
	√	128440AFC ***	128450AFC ***	128460AFC ***
PRESS		128446AFC ***	128456AFC ***	128466AFC ***
	√	128447AFC ***	128457AFC ***	128467AFC ***
PEX Crimp (ASTM F1807)		128444AFC ***	128454AFC ***	128464AFC ***
	√	128445AFC ***	128455AFC ***	128465AFC ***
PEX Expansion (ASTM F1960)		128442AFC ***	128452AFC ***	128462AFC ***
	√	128443AFC ***	128453AFC ***	128463AFC ***

***SELECT DESIRED FLOW RATE IN TABLE TO RIGHT TO COMPLETE PART NUMBER. NO RESTRICTIONS.

ICC ES PMG LOW LEAD

GPM	Last 3 digits	Δp control range (psid)
0.35	G35	2-14
0.5	G50	
0.75	G75	
1	1G0	2-32
1.5	1G5	
2	2G0	
2.5	2G5	
3	3G0	
3.5	3G5	
4	4G0	
4.5	4G5	
5	5G0	
6	6G0	4-34
7	7G0	
8	8G0	
9	9G0	5-35
10	10G	

PRODUCT FEATURES

DYNAMIC BALANCING:

When installed in a domestic hot water or hydronic circuit, the valve automatically adjusts to maintain specified flow rates.

COMMISSIONING AND SERVICE SIMPLICITY:

Pressure ports accommodate simple verification of working operation. Self-contained flow cartridge is easily removed from Y-body for inspection, service, upgrade and flushing.

SELECTABLE FLOW RATES:

Factory assembled with patented cartridge ranging from 0.35 GPM to 10 GPM flow capacity for pipe sizes ½", ¾" or 1".

QUIET OPERATION:

The patented anti-scale, low noise polymer FlowCal™ cartridge provides quiet specified flow with **no** field balancing or adjustment requirements and is conveniently replaceable.

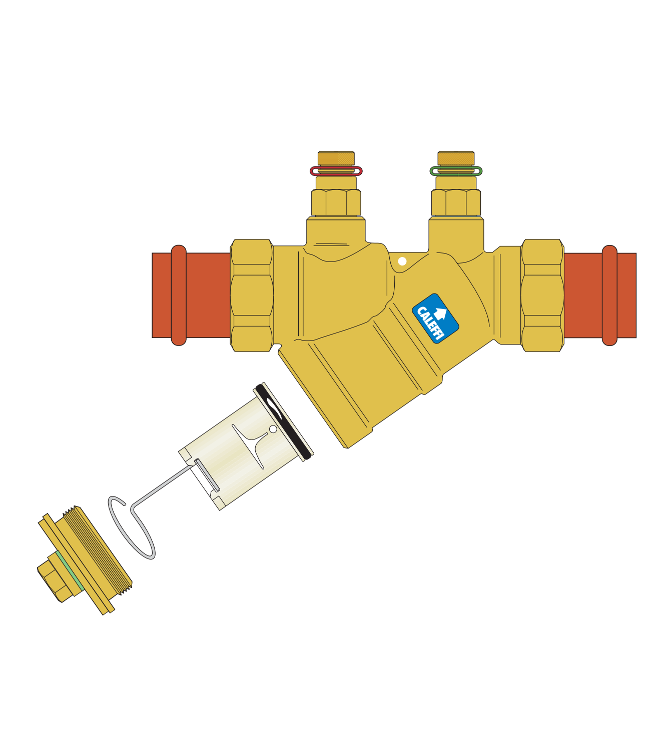
MULTI-FUNCTIONAL:

Integral inlet check valve protects against circuit thermosiphoning. Optional outlet temperature gauge offers local indication.

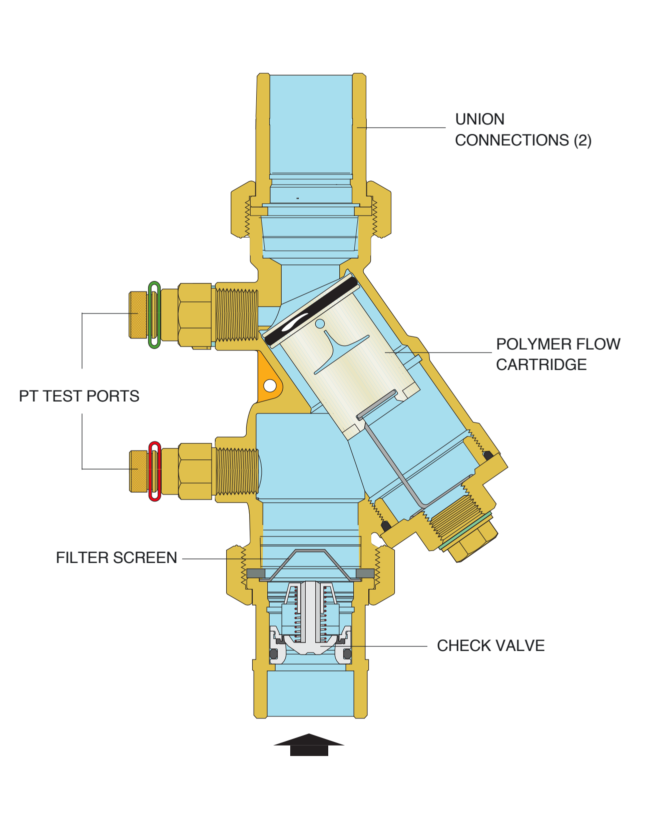
UNION CONNECTIONS:

Dual union end connections with a choice of NPT, Sweat, Press or PEX fittings for ease of installation and maintenance.

CARTRIDGE REMOVAL



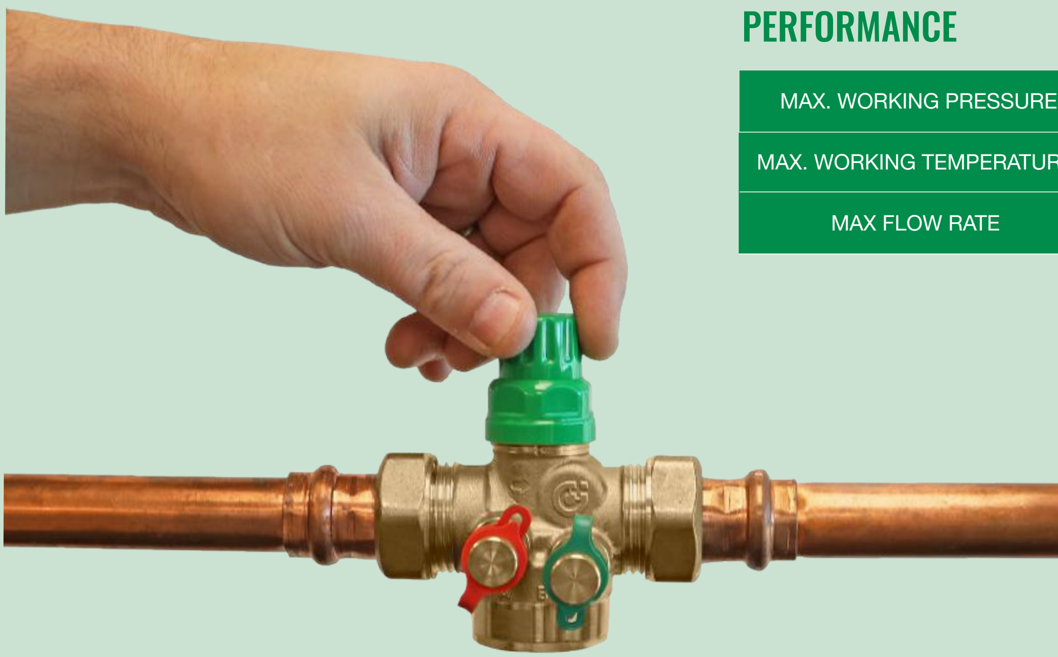
SECTION VIEW (without temp gauge option)



145 FLOWMATIC®
PRESSURE INDEPENDENT CONTROL VALVE

DURABLE CONSTRUCTION FOR LONG LIFE

The FLOWMATIC® pressure independent control valve (PICV) combines an automatic differential pressure regulator and a control valve with optional actuator. With a control signal input, the FLOWMATIC automatically adjusts flow rate and keeps it constant under changing circuit differential pressure conditions.



PERFORMANCE

MAX. WORKING PRESSURE	360 psi (24 bar)
MAX. WORKING TEMPERATURE	4 – 248 °F (-20 – 120 °C)
MAX FLOW RATE	up to 16 GPM

PRODUCT RANGE - FLOWMATIC® Pressure Independent Control Valve (PICV)

SIZES	CODE		
	NPT	SWEAT	PRESS
½"	**145**443 G90	**145**449 G90	**145**446 G90
	145443 1G8	**145**449 1G8	**145**446 1G8
	145443 3G5	**145**449 3G5	**145**446 3G5
¾"	**145**553 G90	**145**559 G90	**145**556 G90
	145553 1G8	**145**559 1G8	**145**556 1G8
	145553 3G5	**145**559 3G5	**145**556 3G5
	145553 5G3	**145**559 5G3	**145**556 5G3
1"	**145**663 7G9	**145**669 7G9	**145**666 7G9
	145663 13G	**145**669 13G	**145**666 13G
	145663 16G	**145**669 16G	**145**666 16G

ICC ES PMG LOW LEAD

PRODUCT FEATURES

DESIGN:

The PICV automatically maintains a constant flow rate even during variable circuit differential pressure conditions.

MANUAL OR AUTOMATIC CONTROL:

The FLOWMATIC® PICV includes a manual control knob which can be easily replaced with optional on/off or proportional control actuator.

EASY INSTALLATION:

Dual union connections allow for fast installation and easy servicing.

PRESSURE TEST PORTS:

The valve features upstream and downstream quick-fit pressure test ports for flow or temperature verification.

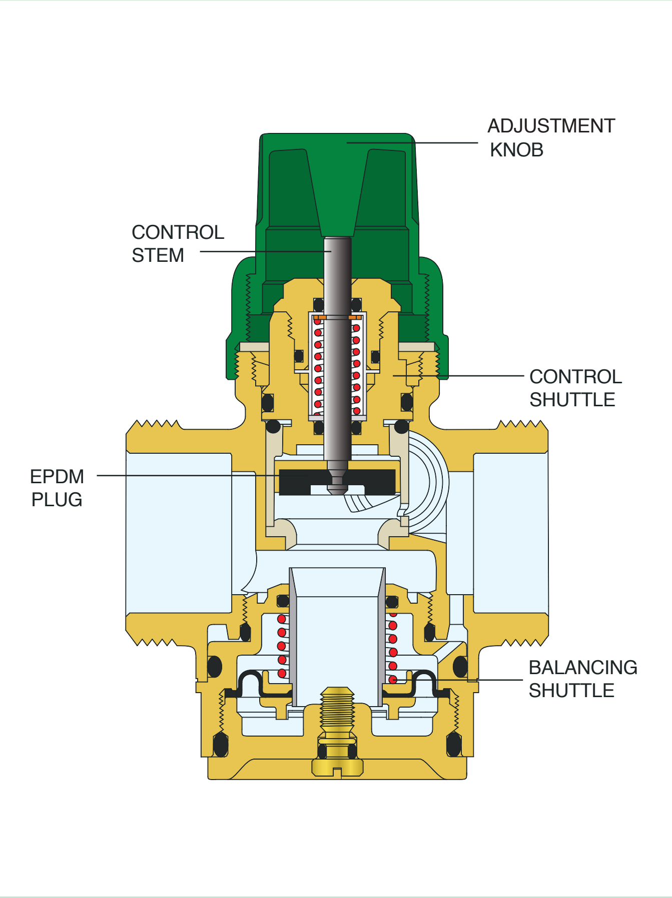
MAXIMUM FLOW RATE ADJUSTMENT:

Flow rate is easily adjusted to match the design requirements of the terminal unit coil.

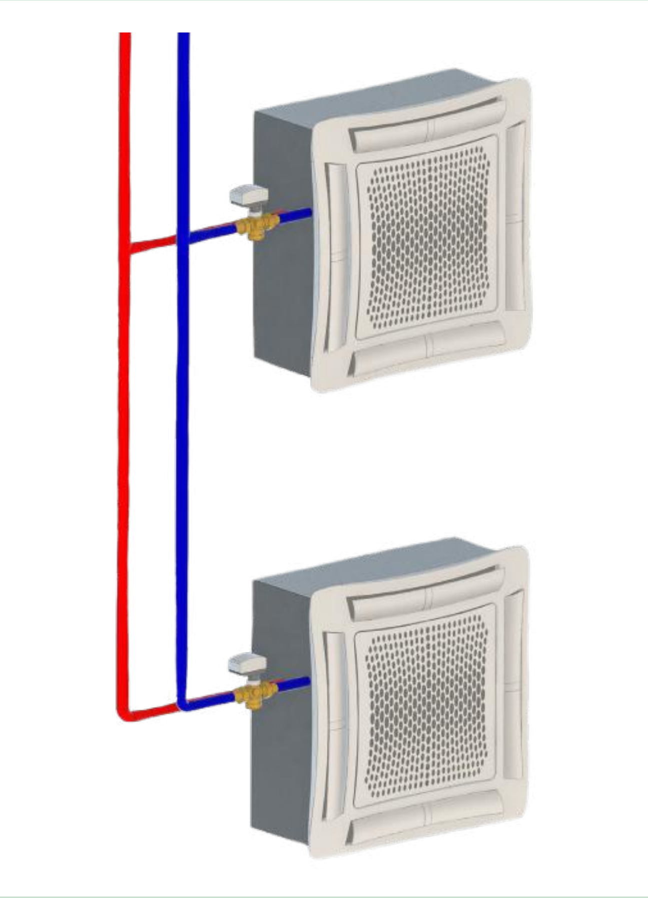
FULL RESOLUTION SIGNAL CONTROL:

The full proportional control signal is never limited or reduced, to optimize comfort control.

CONSTRUCTION



APPLICATION DIAGRAM



CALEFFI Hydronic Solutions

www.caleffi.com

FLOWMATIC®
EXPRESS COIL KIT

Connection and regulation kit for HVAC terminal units. The compact, pre-assembled Kit connects VAV reheat boxes, fan-coils, chilled beams or ceiling-mounted terminal units with the main hydronic distribution system. It provides flow control, balancing, bypass, filtering and isolation functions for maintenance of the terminal unit and flushing of the system. The integral Venturi with PT ports allows the Kit to be sized to match the terminal unit design flow rate. It includes a preformed insulation jacket. Optional on/off or modulating actuators add automatic control for connection to a local controller or BAS. **CALEFFI GUARANTEED.**