FRATELLI PETTINAROLI S.p.A.
CLIMATE SYSTEMS TECHNOLOGY

The Definitive Guide
to Pressure Independent Control Valves

Technical Manual V2

Foreword

This guide addresses commonly posed questions regarding pressure independent control valves (PICVs) and their application in variable flow heating and chilled water systems. The advice provided is based on Pettinaroli products and experience but is generally applicable to all PICVs.

The reason for producing this guide is to explain to designers, installers and commissioning specialists the functions of the valves and their behaviour when installed in real systems. The aim is to ensure that valves are properly selected, and that systems are designed and commissioned so as to achieve the best possible performance from the valves. This will require a different approach than for systems based on more traditional 2, 3 or 4 port control valve solutions. PICVs offer the potential of improved control of thermal comfort and significant energy savings.

Fratelli Pettinaroli is proud to play an important role in improving HVAC systems sustainability, offereing a large range of PICVs for all needs. Thank to 500.000 PICV sold all over the World and more than 10 years of experience, we strongly believe that every player should do his best to make the Earth a better place: Fratelli Pettinaroli took the challenge developing high featured PICVs and helping users to get all the benefits of them. Therefore we support designers, contractors, commissioners and users to deeply understand the operating behaviour of the valves and their key features.

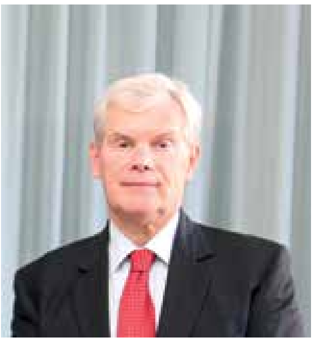
On this Guide we will focus on specific topics which improve building performance and environmental footprint, such as:

- Control characteristic, control valve stroke and DeltaT
- Hysteresis
- Maintenace of a PICV
- Presetting and commissioning
- Start-up pressure
- Actuators
- System layout and design
- Water quality

We hope you can take advantage of the reading.

Ugo Pettinaroli

CEO of Fratelli Pettinaroli S.p.A



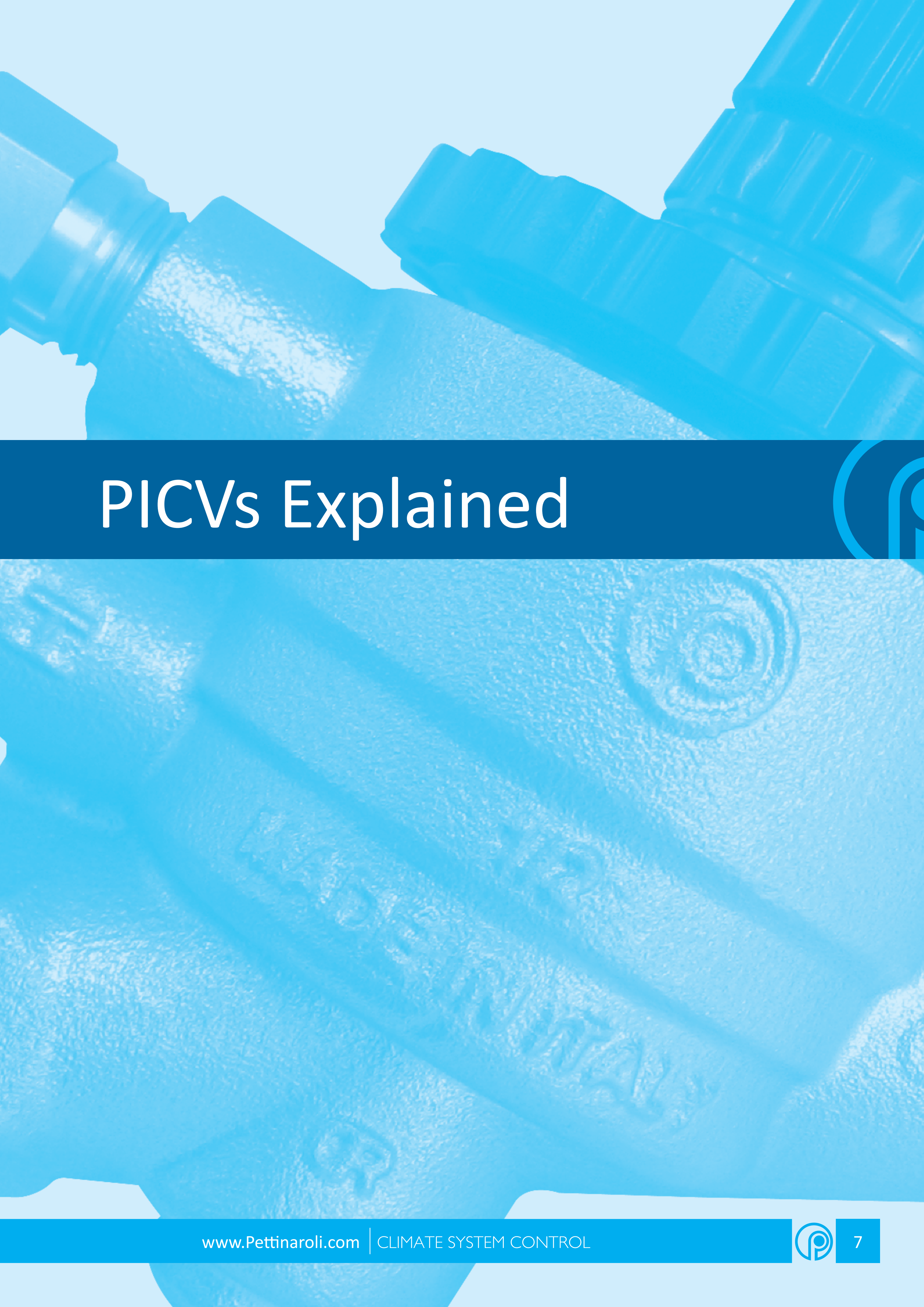
Introduction

This guide describes the design and operation of Pettinaroli pressure independent control valves (PICVs) and pressure independent characterised control valves (PICCVs).

These valves are ideal for use in variable flow re-circulating pipework systems and provide:

- Constant flow regulation under varying pressure conditions
- Protected flow characteristics for optimum control

This guide will explain how the valves work, their operational limits and the control options available. The aim is to educate designers on how to select the appropriate PICV solution for their particular application, and how to design systems to ensure the best performance from the valves.



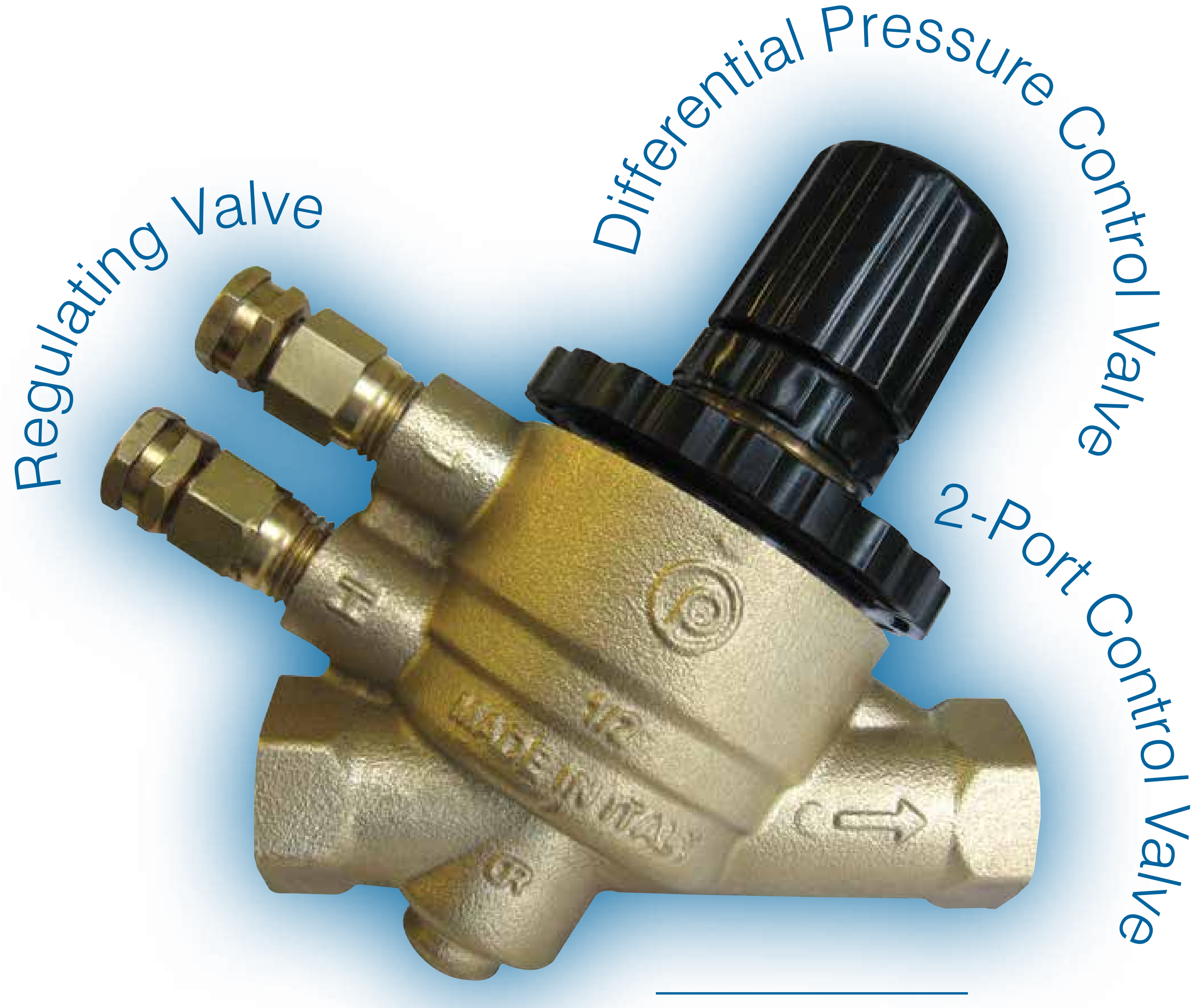
PICVs Explained

What is a PICV?

A PICV is a valve that can be fitted in heating and chilled water systems to provide:

- Flow control - enabling modulating control of heating/cooling outputs
- Flow regulation - enabling flow rates to be set at their specified design values
- Differential pressure control – ensuring a constant differential pressure across control valves regardless of changes in pump speed or valve closures elsewhere in the system

This means that each PICV replaces up to three separate valves that would otherwise be required (i.e.regulating valve, two port control valve, plus a differential pressure control valve).



3 VALVES IN 1

What's the difference between a PICV and PICCV?

A Pressure Independent Control Valve (PICV) is a valve that enables modulating control of flow rate but where the flow characteristic (i.e. the relationship between valve closure and flow rate) may vary depending on the pressure differential across the valve, the flow setting of the valve or the actuator fitted.

A Pressure Independent Characterised Control Valve (PICCV) gives more accurate modulating control of flow rate because the valve itself has a protected characteristic. Hence, the characteristic is unaffected by operating conditions.

Pettinaroli provides both types of valve.

When to use PICVs?

PICVs are the best solution for the control of flows through air handling units, fan coil units and chilled beams fed from variable flow heating and cooling systems. These are systems in which pump speed and, in turn, flow rate varies in response to the heating or cooling demand, thereby saving pump energy.

Before PICVs were introduced, variable flow systems commonly experienced the following problems:

- Valve selection issues - 2 port control valves were difficult to select because their selection depended on the pressure being maintained constant by the nearest upstream differential pressure control valve (DPCV) or system pressure. These pressure settings were not always available until the commissioning stage.
- Valve noise - 2 port control valves sometimes generated noise due to excessive differential pressures. DPCVs are intended to protect 2 port valves from excessive pressures. If located too far away from the 2 port valves, they will be unable to perform this function.
- Poor authority - 2 port control valves often achieved poor modulating control of flows, often achieving little better than crude on/off control. This was again due to poorly located DPCVs that allowed excessive pressures across the control valves.
- Overflow and energy waste – 2 port control valves plus static balancing make the system unbalanced whenever partial load conditions occur. If there is no dynamic balancing, uncontrolled overflow across fully open 2 port control valves significantly waste energy. If the incorrect valve characteristic is used, the design DeltaT cannot be maintained, generating a global decrease of system performances.

PICVs resolve all these problems thereby improving thermal comfort in the building, whilst maximising energy savings from the pump. Advice on how to design systems with PICVs is provided in **CIBSE KNOWLEDGE SERIES GUIDE KS7 VARIABLE FLOW PIPEWORK SYSTEMS**.

PICVs also have the additional benefit of being much easier to commission. The traditional exercise of proportional balancing flow rates through branches is eliminated and instead the task becomes one of merely setting the required flow rate at each PICV. This procedure is explained in **CIBSE COMMISSIONING CODE W, WATER DISTRIBUTION SYSTEMS and BSRIA GUIDE BG2/2010 COMMISSIONING WATER SYSTEMS**.

How does a PICV work?

Figure 1a and 1b shows typical diagrammatic layouts of the two most common types of PICV.

Some valves, as shown in Figure 1a, comprise three distinct sections corresponding to the valve functions i.e. pressure regulation, flow setting and modulating flow control. Alternatively, the flow setting and flow control functions are combined inside the same valve section as shown in Figure 1b.

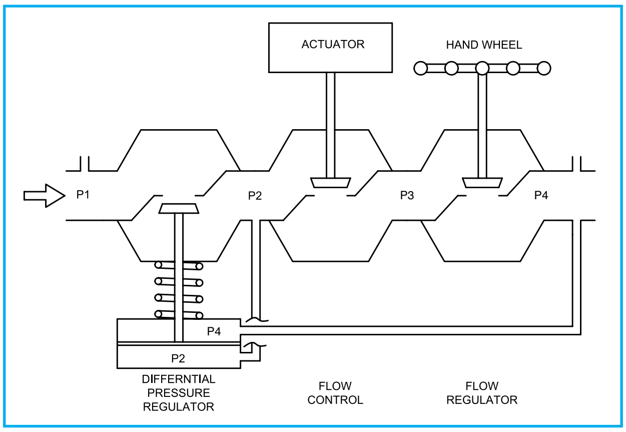


Figure 1a. Three section PICV

Each section of the valve works as follows.

The inlet to the valve houses the differential pressure regulator. This comprises a flexible rubber diaphragm which flexes against a spring simultaneously varying the size of the opening to flow. One side of the diaphragm is in contact with water from the inlet to the valve at a pressure P1, whereas the other side is in contact with water from the outlet to the valve at a pressure P4. This means that if there is any change in the differential pressure P1 to P4, the position of the differential pressure regulator will also change. The result will be that the differential pressure P2 to P4 (i.e. from downstream of the differential pressure regulator to the valve outlet) will always remain constant regardless of changes in the overall differential pressure P1 to P4. Hence the term "pressure independent" – it doesn't matter how external pressures may be varying, the performance and function of the valve will be unaffected providing it's within its working range.

In the central section, there is an actuated 2 port modulating control valve. For example, the opening of the valve can be varied by the actuator depending on a signal from the control system to achieve the required temperature in the occupied space.

At the outlet to the valve body there is a flow setting device. This enables the valve to be adjusted to

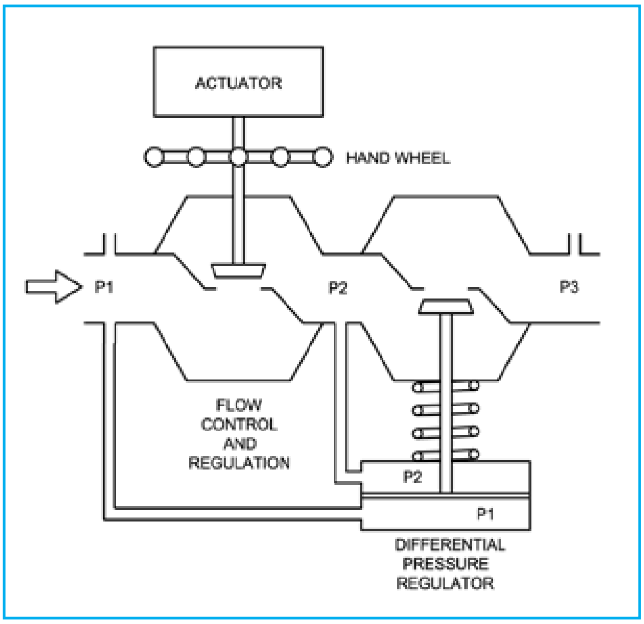


Figure 1b. Two section PICV

achieve the required design flow rate, as specified by the designer. The required flow rate can be set using the flow setting dial incorporated in the valve body. The stroke of the control valve is not affected by the flow setting. A full stroke gives good flow rate control, especially when a modulating actuator is used. The control characteristic of a PICCV is not affected.

If the flow setting device is combined with the modulating control valve (Figure 1b), then as the flow setting is adjusted some of the travel of the control valve is used up in regulating the flow. The reduction in stroke effects the modulating flow control across the remaining travel of the valve, once set. The available control valve stroke for modulation is therefore limited: Limited modulation could affect the performance of the valve resulting in ON-OFF control.

Pressure tapings built into the valve allow the overall pressure differential P1 to P4 (or P3) to be measured to ensure that the valve is operating within the manufacturer's stated pressure differential range.

Static balancing (DRV and Commissioning sets) & PICV (dynamic balancing) require careful consideration to be used together in any system. A System where Terminal units are fitted with Static balancing without dynamic protection will only have full design flow during commissioning and the flow will change in partial load condition. This includes excess flow through DRV's and reduction of system pressure which can affect the PICV performance (low start up). There will be an effect on the complete system performance.

What will a PICV do?

The way PICVs work makes them ideal for use in variable flow systems.

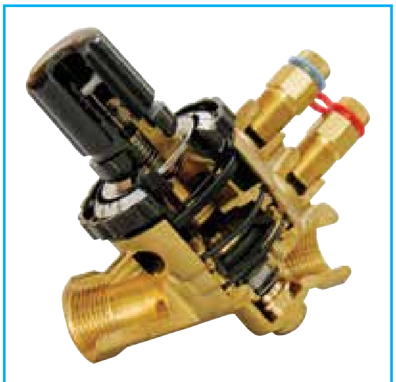
Any changes in the pressure P1 (as might be caused by changes in pump speed or by valve closures in other parts of the system) will automatically be compensated for by the action of the differential pressure regulator. The controller will simply increase the valve's resistance if P1 increases or reduce it if P1 reduces.

Furthermore, the ability of the regulator to maintain a constant pressure differential between P2 and P3 has two important implications.

Firstly, with the control valve fully open and the flow setting device set to its required value, the valve effectively becomes a constant flow regulator (since a constant pressure differential across a constant resistance will result in a constant flow rate). Hence, if installed without the actuator, the valve can be used as a flow limiting valve, to maintain the flow within a fixed pre-settable value, regardless of changes in other parts of the system. This can be useful in by-pass circuits.

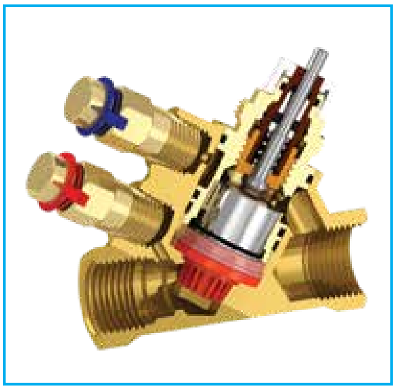
Secondly, by maintaining a constant pressure differential across the control valve and flow setting device, the authority of the control valve is maximised. The authority of a valve is an indication of how accurately the valve will be able to modulate flow as it opens and closes. To achieve good authority, the pressure differential across the valve should be at least 50% of the total pressure differential in the pipe, branch or circuit for which it is controlling flow. Such a valve would be considered as having an authority of 0.5. It is often impossible to size conventional 2 port control valves with such good authority because the controlled circuit may include terminal unit and pipework losses back to a remote pump or DPCV. In many applications, this necessitates 2 port valves with impractically high resistances. Hence, valve authorities as low as 0.2 are common but far from ideal.

In a PICV, authority is improved because the pressure differential P2 to P3 (or P1 to P2) across the control valve and flow setting device is effectively the circuit for which the valve is controlling flow. This means that terminal unit and pipework pressure losses do not need to be considered for valve selection and the valves can be selected purely on flow rate.

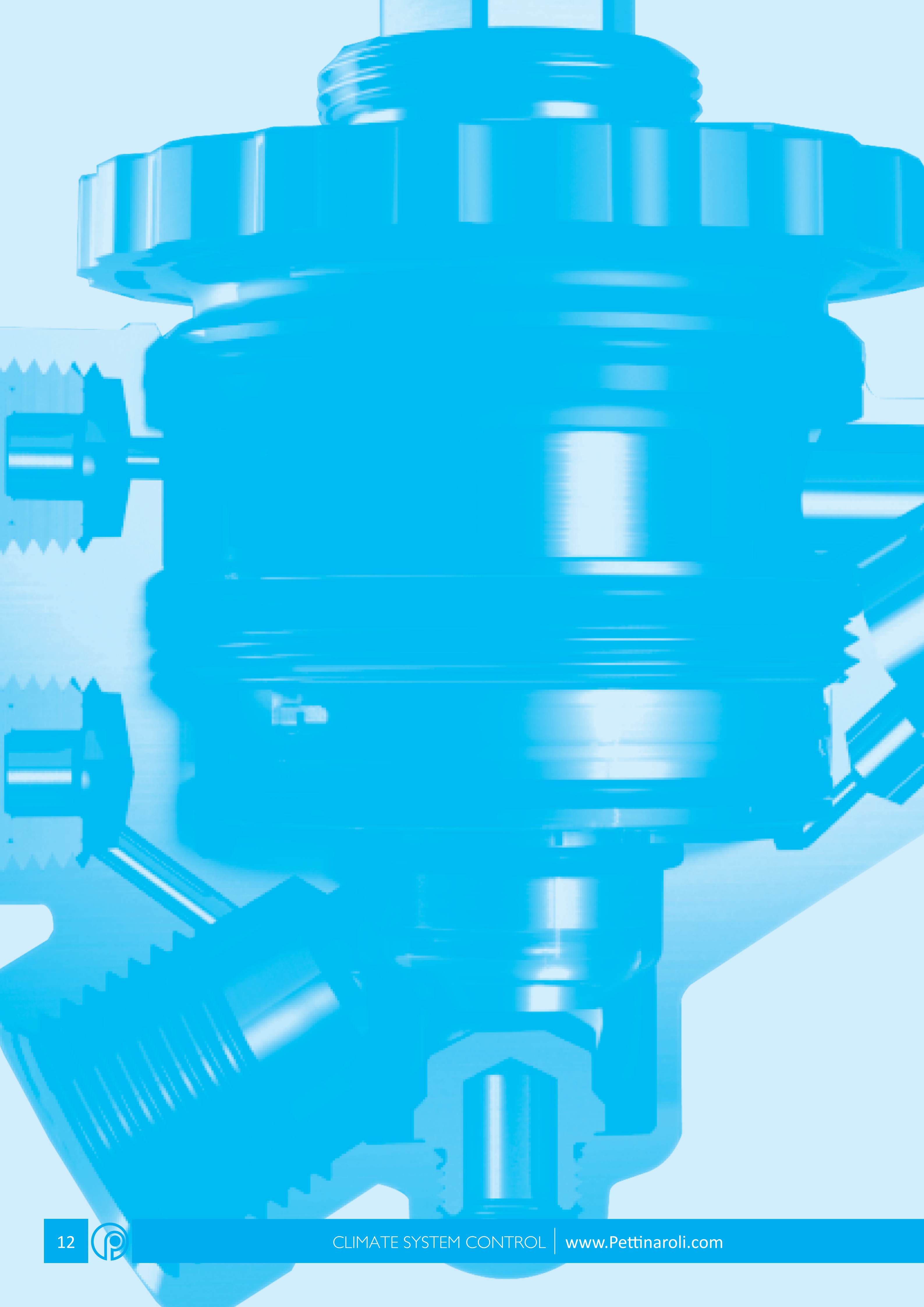


Cut away of 3 section Axial PICV

Cut away of 2 section Rotary PICV



Cut away of 2 section Axial PICV



PICV Control – Essential Considerations

PICVs generally provide better control than most solutions involving separate DPCVs and 2 port control valves. However, the performances of PICVs from alternative suppliers can vary significantly. The following pages explain the main performance issues that should be considered when selecting PICVs.

Equal percentage characteristic

A valve's "characteristic" is the relationship between the flow through the valve relative to its degree of closure. The valve characteristic is a feature of the design of either the valve itself, or the valve and actuator combination. Typical valve control characteristics are described as on/off (quick acting), linear and equal percentage. These are illustrated graphically in Figure 2.

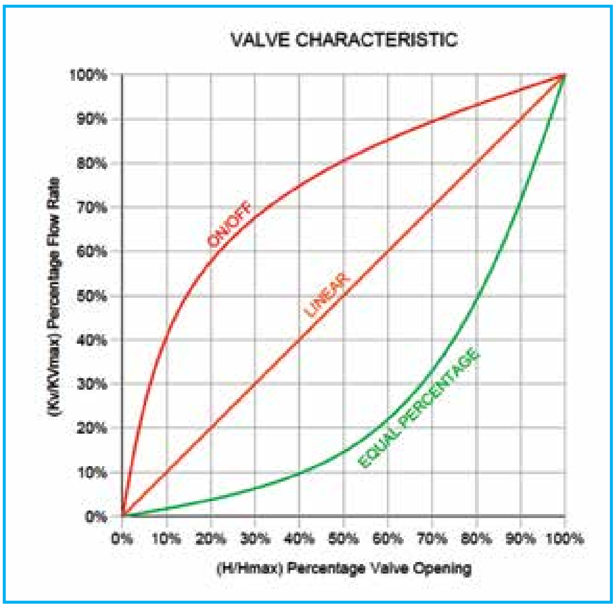


Figure 2. Control valve characteristics

For "forced convection" coils where a fan blows air across the coils, the best solution is an equal percentage characteristic. This is because for these types of coil the heating or cooling output gradually stabilises as water flow increases until a point is reached where the output becomes unresponsive to further increases in flow. This is illustrated in Figure 3.

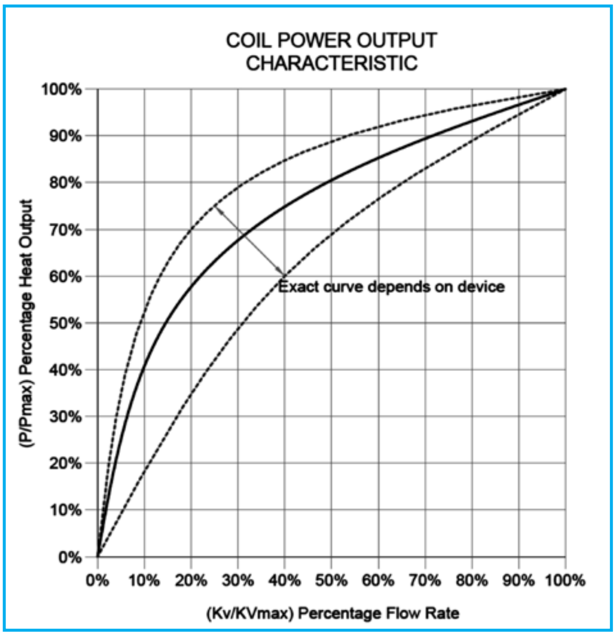


Figure 3. Heat transfer versus percentage design flow rate

For "passive convection" coils where air is naturally drawn across the coil, characterisation is less critical and the level of control will not be improved by fitting an equal percentage control valve. For devices where the power output characteristic is quite linear, such as a plate heat exchanger, a linear control characteristic may be appropriate.

In order to achieve good modulating control of the sensible heating or cooling output from the coil, the control valve needs a characteristic that mirrors the performance of the coil. The equal percentage characteristic does this. Equal percentage valve characteristics are so called because as the valve opens, for each percentage increment in valve travel, the flow increases by an equal percentage. Hence, they produce small changes in flow when the valve is nearly closed, and large changes in flow when the valve is nearly open.

A control valve with full stroke, whose the inherent characteristic of the valve disc is equal percentage, has this characteristic at every pre-setting. Electro-mechanical actuators fitted to linear designed PICV valves can generate an equal percentage characteristic. Equal percentage characteristic accuracy is only achieved in the fully open position.

Figure 4 shows the way that the heat transfer characteristic of the heating or cooling coil is modified by various control valve characteristics. An equal percentage characteristic gives the best control with each change in heat transfer being equal to each change in valve opening. An Equal Percentage characteristic reduces the risk of overflow at partial load conditions, maintaining the Delta T constant (NOTE: delta T can also be affected by external factors such as coil cleaning).

The performance of a terminal unit and its required power output can be of a lowered by a poor Delta T as the water flowing through the coil cannot exchange the whole energy and the Delta T will reduce.
The lower Delta T is proved by:

$P = G * c_p * \Delta T$

Where P is the thermal power, G the mass flow rate, cp the constant (4.186 kJ/kg K) and DeltaT the temperature difference between terminal unit inlet and outlet flow.
To maintaining the same power output, if the Delta T increases, the flow rate must decrease. Every time the Delta T is not maintained, at partial load conditions, energy is wasted, and discomfort is possible. The required energy to pump water increases because of higher flow rate and chiller/boiler efficiency is affected.

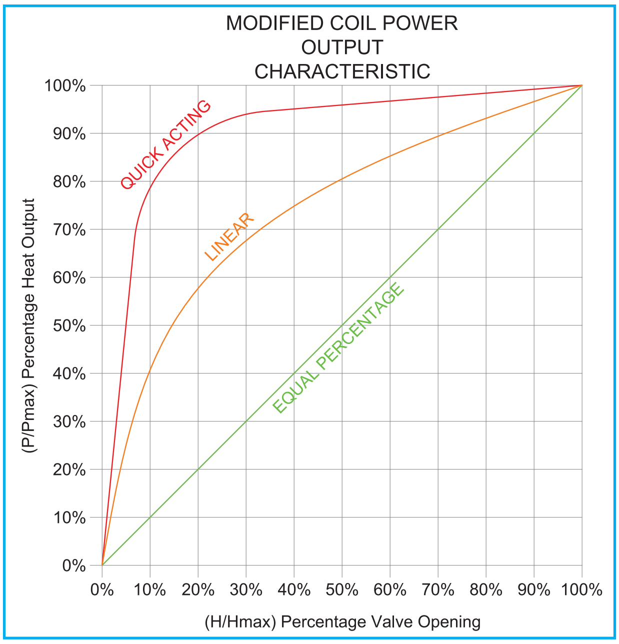


Figure 4. Heat transfer versus valve opening

As shown by the Figure 2, the case of the controller requiring 50% of thermal output, a linear valve provides 50% of nominal flow rate whereas an equal percentage valve just the 15%: as detailed below, pump energy consumption varies cubically with respect the flow rate. A linear valve will potentially consume 37 times more energy than an equal percentage valve in this specific case (see affinity law explanation at page 39).
It can also be seen that a linear characteristic valve with perfect authority is not as good as an equal percentage valve. As previously explained, all PICVs achieve close to perfect authority, but there is a marked difference in the stability of off-coil air temperatures between coils controlled by equal percentage characteristic valves and linear or on-off characteristic valves. Although Equal Percentage Characteristic maximize the Delta T on water to air heat exchangers, the linear characteristic is more suitable for water-to-water heat exchangers, where very quick increases in the secondary water temperature are required to meet design requirements. The ability of a linear PICV valve to open quickly, while still maintaining pressure control, is essential for domestic Hot water in a heat exchanger.

Authority

In the case of a PICV, the authority is calculated by comparing the pressure lost across the flow control element with the controlled pressure diffrential; these two values are nearly equal resulting in an authority close to 1. Depending on the design of the PICV, the authority of the flow control element may change as the valve is regulated. This loss of authority is exhibited as a change in the valve's characteristic curve. Figure 5 shows the effect of loss of authority on an equal percentage valves.

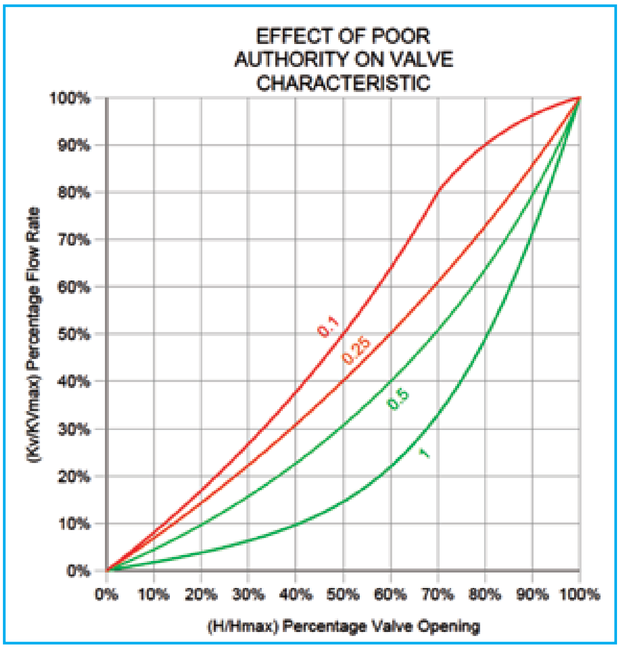


Figure 5. Loss of authority on equal percentage control valve

Actuator selection

Even if a valve has an intrinsically equal percentage characteristic this can be negated through a poor choice of actuator. For example, if the stroke of the actuator does not match the stroke of the valve then the characteristic may be deformed. This is particularly important when the stroke of the valve is being changed in order to regulate the maximum flow rate of the valve. Figure 6 shows how choosing the wrong actuator can affect the intrinsic characteristic of the valve.
If the valve has an inherently linear or on/off characteristic then this can be improved in some cases by using a characterising actuator to change the intrinsic curve to a more acceptable one. However, it is important to match the characterising action of the actuator to the valve to which it is fitted.

The resultant characteristics at different pre-settings (100%, 75%, 50% & 25%), may only result in the desirable characteristics at only one pre-setting.
There are also different types of actuators available: thermal, electrical gear, and fail safe. A brief description of each type of actuator is mentioned below. A selection of an actuator that best suits the application are detailed below.

- Thermal type Fail safe: it is a common economic solution, with the disadvantage of time to open, at least 3 mins or greater. Fail-safe operation can be only closed or open because the wax cartridge inside the actuator heats up to open or close (depending on the model).

- Electrical Gear Fail in place: a preferred actuator solution using electric motor and gears, comparably faster in operation takes from 30sec to 90 sec depending on manufacturer from fully open to close condition. In case of power failure, there is no fail-safe operation on this type of actuator.

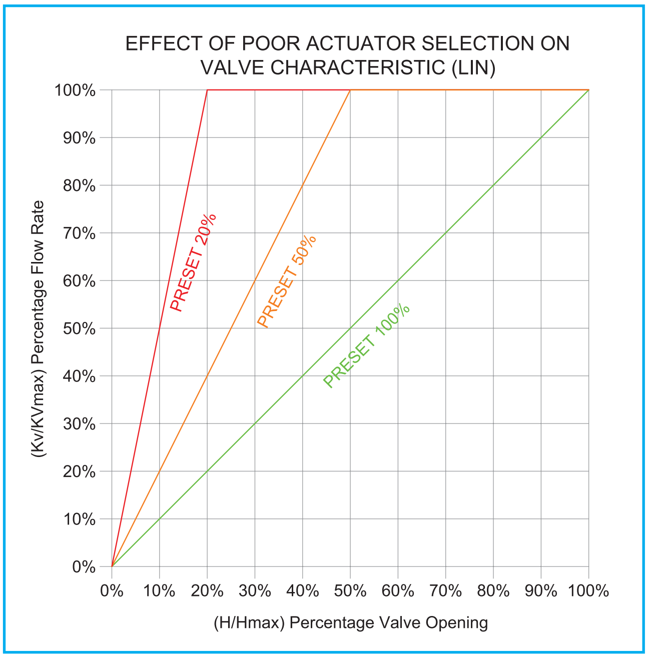


Figure 6. Degradation of valve authority (linear characteristic) by fitting of incorrect actuator to stroke limited valve

- Capacitor type fail safe: a modified electric motor and gears type with an additional feature of fail-safe operation. A capacitor is charged during normal operation. When the power fails the capacitor discharges and the fail-safe operation is achieved. Typical time taken in this operation takes at least 60 sec.

- Spring return Fail safe: an alternative fail-save device is the electric motor, gear type with spring. The addition of this failsafe option provides 100% closure operation and can be provided by a mechanical spring, giving fail-safe closure in 10 sec. The mechanical spring always ensures fails safe operation.

Electromecanic actuator

Electrothermal actuator

Control of supply air temperature

The importance of achieving an accurate equal percentage control characteristic and good valve authority becomes clear when the resulting variations in off-coil supply temperatures are considered.

When in use, the control valve forms the output part of a closed loop controller, changing its opening in response to changes in the measured room or return air temperature. In such systems it is particularly important to ensure effective modulating control of the off-coil temperature, and it is the function of the control valve to achieve this. Inaccurate control will result in hunting whereby the controlled temperature in the occupied space repeatedly over-shoots or under-shoots its set point value. This can make the space uncomfortable for the occupants and wastes energy.

For this reason, it is highly recommended that the PICV and its actuator deliver an accurate equal percentage characteristic.

Figure 7 compares the supply temperature into a space with a poorly characterised valve, performing as on/off, and a correctly performing equal percentage control valve.

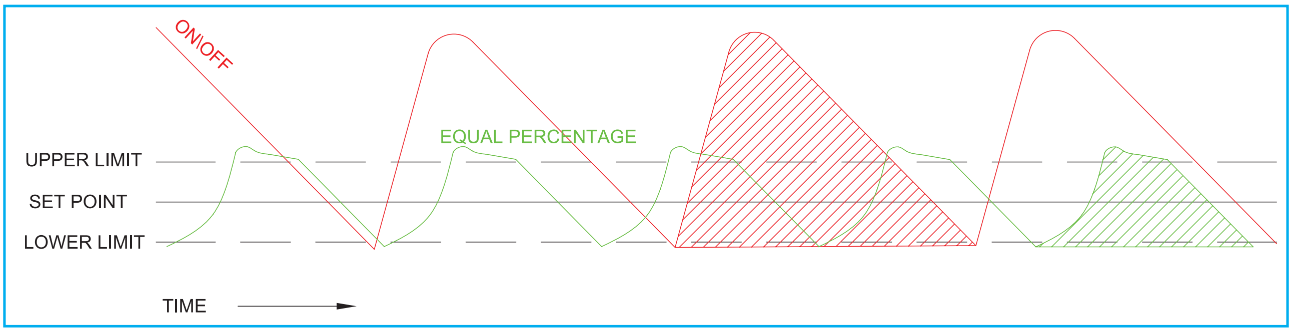


Figure 7. Typical variations in off-coil temperature for heating coils

Flow accuracy and repeatability?

All PICVs will exhibit variations in the accuracy and repeatability of their flow rate settings. The reasons for this can be understood by considering a plot of the valve's flow rate relative to pressure differential. A typical graph is shown in Figure 8.

Each valve has a minimum and maximum pressure differential value below or above which the valve will not control flow. If the pressure differential is less than the minimum value, the spring inside the pressure regulator remains fully extended, whereas at pressure differentials greater than the maximum value, the spring is fully compressed. Under both of these conditions the pressure control element in the valve acts as a fixed resistance; the valve can only control flow when the spring is under some degree of partial compression. The "operating range" of the valve is the range of differential pressures for which control is possible.

Within its operating range, the flow through the valve stabilises, although as can be seen in Figure 8, even in this range the flow rate is not constant. If the pressure across the valve is allowed to vary between its minimum and maximum operating pressures, its flow may vary by up to ±10% from its set point value. The degree of flow variation exhibited by a valve operating within its recommended operating range is sometimes referred to as the valve's "proportional band". The smaller the proportional band the more accurately the valve will maintain its set flow rate.

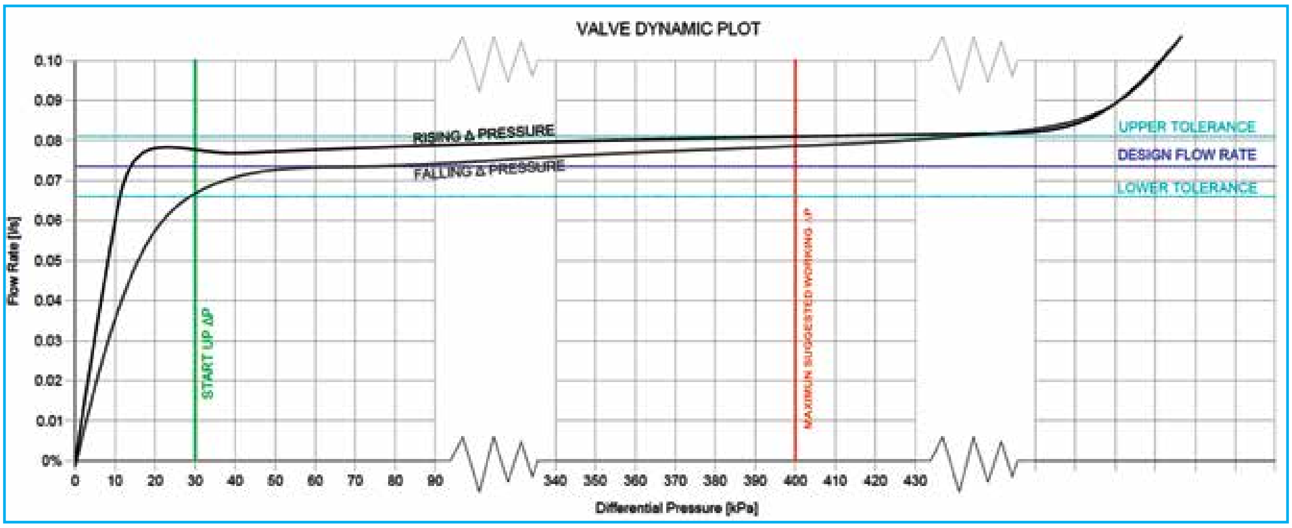
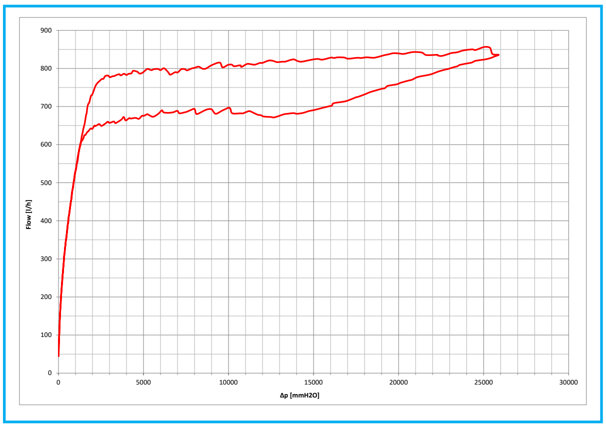
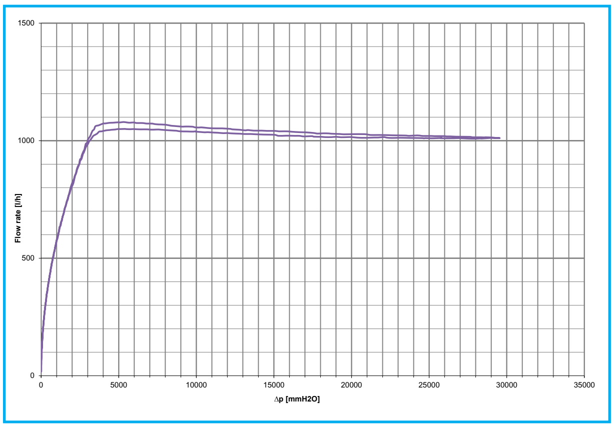


Figure 8. Flow Rate versus Differential Pressure (Typical PICV) – 600 kPa



Example of bad hysteresys



Example of good hysteresys

Hysteresis

To further complicate things, the accuracy with which the flow rate setting is maintained also depends on whether the pressure differential across the valve is rising or falling. It can be seen from Figure 8 that there are distinct rising and falling pressure curves. The difference between the two curves is often referred to as the valve's "hysteresis". The hysteresis effect is caused by the sealing elements in the pressure regulating part of the valve, although the spring and elastic membrane may also have some influence. This hysteresis effect can be seen in all self-acting spring operated PICVs and DPCVs.

Due to hysteresis, two repeatable flow readings can be obtained depending on whether the pressure differential across the valve has risen or fallen to the value when the measurement is taken. Since the valves are factory tested on their rising pressure curves, the flow setting device indicates flows that correspond to a rising rather than decreasing pressure differential.

For the reasons explained, the valve's proportional band and hysteresis may cause flow values to vary from their set values. These effects can be minimised by ensuring that systems are:

- Designed such that when a PICV opens to increase the flow rate to a terminal unit, its pressure differential simultaneously increases rather than decreases.

- Commissioned such that when a PICV is set to its required flow rate, the pressure differential across the valve is as close as possible to its final operating value.

Both objectives can be easily achieved by ensuring that during commissioning and subsequent system operation, pump pressure always reduces as PICVs close. The best way to achieve this is to set the pump speed controller such that a constant pressure differential is maintained at a differential pressure sensor located towards the index PICV i.e. the PICV located furthest from the pump. A single sensor located two thirds of the way along the index branch is satisfactory in systems with a uniform load pattern; alternatively, multiple sensors across the most remote PICV controlled terminal branches can be used in systems with an unpredictable and varying load pattern. Controlling pump speed such that pump pressure is maintained constant should be avoided wherever possible. This solution inevitably results in large increases in pressure differential across PICVs as they close, resulting in the largest possible variations from set flow rate values, much better than standard two ports.

The use of remote sensors for pump speed control will enable PICVs to perform as accurately as possible. This solution also gives the best possible energy savings from the pump as recommended in CIBSE Knowledge Series guide KS7 Variable flow pipework systems and BSRIA BG 12/2011 Energy Efficient Pumping Systems - a design guide.

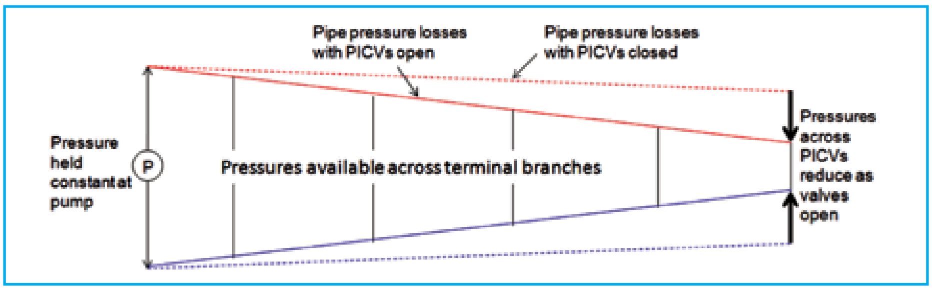


Figure 9. DP sensor fitted at pump

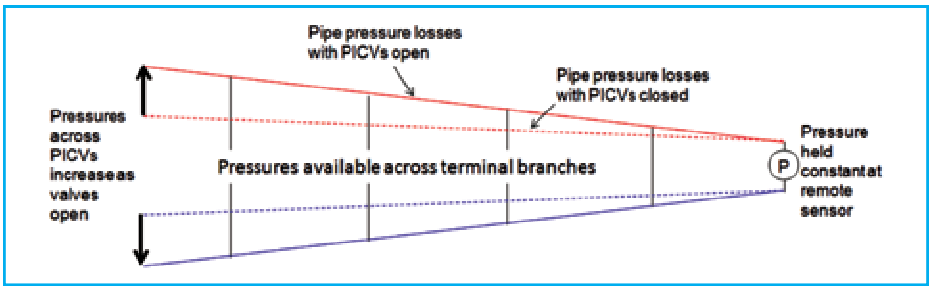


Figure 10. DP sensor fitted at index

Full stroke or stroke limited valves

PICVs where the control and flow setting functions are separated within the valve (Figure 1a) are known as "full stroke" control valves because the full stroke of the control valve is available for control. This type of valve can be fitted with a programmable actuator which can be set to provide an equal percentage characteristic. The actuator always operates over the full stroke of the valve so it never needs to modify its programmed characteristic. The main benefit a full stroke valve offers is that the actuator can be driven through its full range which is of particular importance on valves where the stroke is quite short (e.g. in the 15-25mm size range). Where the control and regulation elements of the valve are separated there is a risk that the control characteristic may change as the valve is regulated although this can be mitigated by the control element having an intrinsic equal percentage characteristic and by proper selection of the actuator.

PICVs where the control valve and flow setting devices are combined in a single component are known as "stroke limited" control valves (Figure 1b). This is because part of the control valve's stroke will be used up in regulating the flow to its required setting. In stroke limited valves a significant proportion of the valve stroke may be taken up during flow regulation. This limitation of stroke is most apparent with linear characteristic valves, since in order to regulate a valve to 50% of its maximum flow, 50% of the control stroke is also lost. It is therefore essential that stroke limited valves have an intrinsic equal percentage characteristic; if an equal percentage valve is similarly regulated to 50% of its maximum flow rate then only around 18% of the stroke of the valve will be lost.

Stroke limited valves can be of the lift and lay type, multi-turn type or characterised ball type. Lift and lay types have a rising stem which the actuator pushes against to close the valve. Multi-turn or characterised ball types have a rotating stem which the actuator must turn to close the valve.

Rotary PICCV with Actuator

In the case of lift and lay valves an actuator which can compensate for the lost stroke as the valve is mechanically regulated must be supplied otherwise the control characteristic of the valve will be adversely affected. Multi-turn valves are usually supplied with a matched actuator so this problem is avoided. In the case of rotary type valves, where the control and regulation device is a characterised slot in a ball valve, the valve can be driven to the regulated position by scaling the output from the controller to the actuator. There are also special actuators available that can be used where the scaling cannot be accomplished by the controller. Generally, stroke limited valves can be usually affected by a lack of control ability: actuators can just partially recover this.

Both full stroke and stroke limited valve solutions can provide effective modulating control of flow rate. Although both types of valve will inevitably exhibit some loss in controllability when flow setting devices are regulated to their minimum flow settings, the level of control achieved is invariably better than that achievable from equivalent 2 port control valves operating against varying pressure differentials.

Shut-off

International standard **IEC 60534-4** defines various classes of shut-off and the methods to test the shut-off capability of a control valve. Most pressure independent control valves are declared as being Class IV which relates to a leakage rate of 0.01% of the valve's nominal maximum flow rate. This is equivalent to traditional control valves.

One of the concerns with any traditional control valve is the maximum shut-off differential pressure, this is the maximum differential pressure that the actuator could close the valve against. The close-off load that the actuator must overcome is the product of the differential pressure acting on the closing element of the valve and the surface area of this closing element (globe, sleeve or ball).

In a pressure independent control valve the differential pressure acting on the closing element of the valve is controlled (P2 in Figure 1a and 1b.) meaning that the close-off pressure of the valve is constant throughout the working range.

Manual Setting

Setting most PICV valves is as simple as turning the setting hand wheel to the specified position. Most often the hand wheel of a PICV will be graduated with a scale showing the set flow rate as a percentage of the valve's maximum flow rate. For furher details, see page 43.

Remote Commissioning

In addition to manual setting, some PICVs can be used in conjunction with a BMS controller to return the valve accurately to a given pre-programmed flow setting. Using a remote BMS controller, this can be achieved without the need to visit each valve and manually set the required flow rates resulting in better use of the available commissioning time.

A standard BMS controller with proprietary strategy can control both heating and cooling outputs for individual terminal units. Each controller can be pre-programmed with the heating and cooling valve references and maximum design flow rate values for each valve.

During commissioning, each control valve is set to a position which will achieve its specified design flow rate. The controller is factory pre-set to the required design flow rates although these can be overridden on site using a commissioning computer. The required setting for each valve is determined based on the known relationship between flow rate and valve setting, as measured on a test rig. A "trim factor" is available in the control software to enable flow settings to be adjusted for greater accuracy. Suitable actuators and controllers must be selected according to the purpose.

This approach provides a flexible method for establishing design flow rates during commissioning. Once set, flows will be maintained within the limits of accuracy dictated by the hysteresis limits of the spring, as explained on page 19.

Setting the valves in this way brings advantages for buildings that are being seasonally commissioned, in other words where commissioning may have to be repeated in an occupied building.

For critical applications, even greater flow accuracy can be achieved by incorporating flow sensors in the pipework feeding terminal units. The controller is then able to adjust its setting until the specified flow rate is achieved at the flow sensor. This solution provides near perfect flow control since it can correct flow variations caused by the hysteresis effect.

Assembled kit for HVAC

Mantaining DeltaT

The design of a chiller or boiler requires a heat exchanger that has been selected to transmit heat between two substance (in chillers a refrigerant gas is used) at various flow rates and temperatures. Once the Chiller or boiler performance has been determined by the manufacturer at design flow rate and temperature difference any further changes in flow and temperature will influence the efficiency of the Chiller or Boiler.

If a Chiller is designed with a return water temperature at 15 °C, but because the system uses a linear valve to control the flow to a Fan Coil Unit and the return water is at 10°C, the heat exchange is strongly affected; the refrigerant within the chiller must compensate for the reduction in Delta T by reducing the heat exchange efficiency. To achieve this performance, the chiller now must work out of best working condition. It is essential that the Delta T is always maintained within a water distribution system.

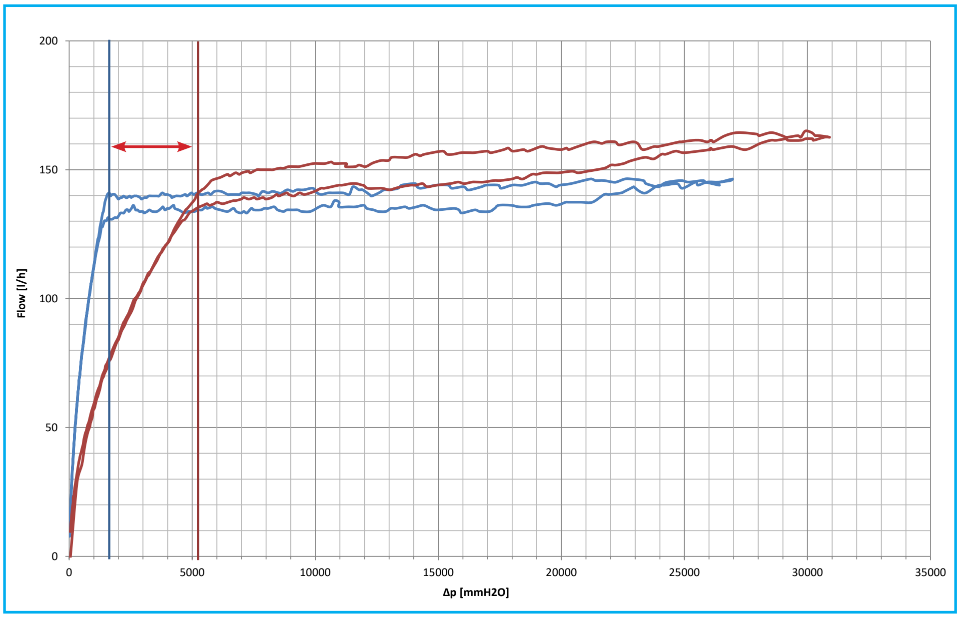
Most of the energy waste related to Low DeltaT is due to overflow and pumping (see dedicated section at page 38).

Pressure losses and start-up

An efficient design of a water distribution system is the one where the pressure generated by the pump is at the minimum required to fully services the terminal units. To ensure the minimum pressure drop in a system is achieved:

1) All manual balancing valves should be removed from branches & risers
2) PICV valves should be selected with minimum start up pressure
3) Flow rates should always be sized as closest as possible to the PICV valves nominal flow rate
4) The system should operate on the rising differential pressure curve
5) The pumps set should achieve 5 -10% more of design flow on the index, on the upward curve
6) The pump should be controlled to ensure the valves are on their upward curve at minimum start up

If care is not taken during the design and commissioning of the water distribution system and many of the above consideration not incorporated in the design and followed during the commissioning process, the performance and efficiency of the system will be compromised. PICV valves with high start-up pressure should be avoided. High start-up requires a higher pump head and increased nominal power. Large amounts of energy are wasted throughout the life of the building. Further information are available at page 40.

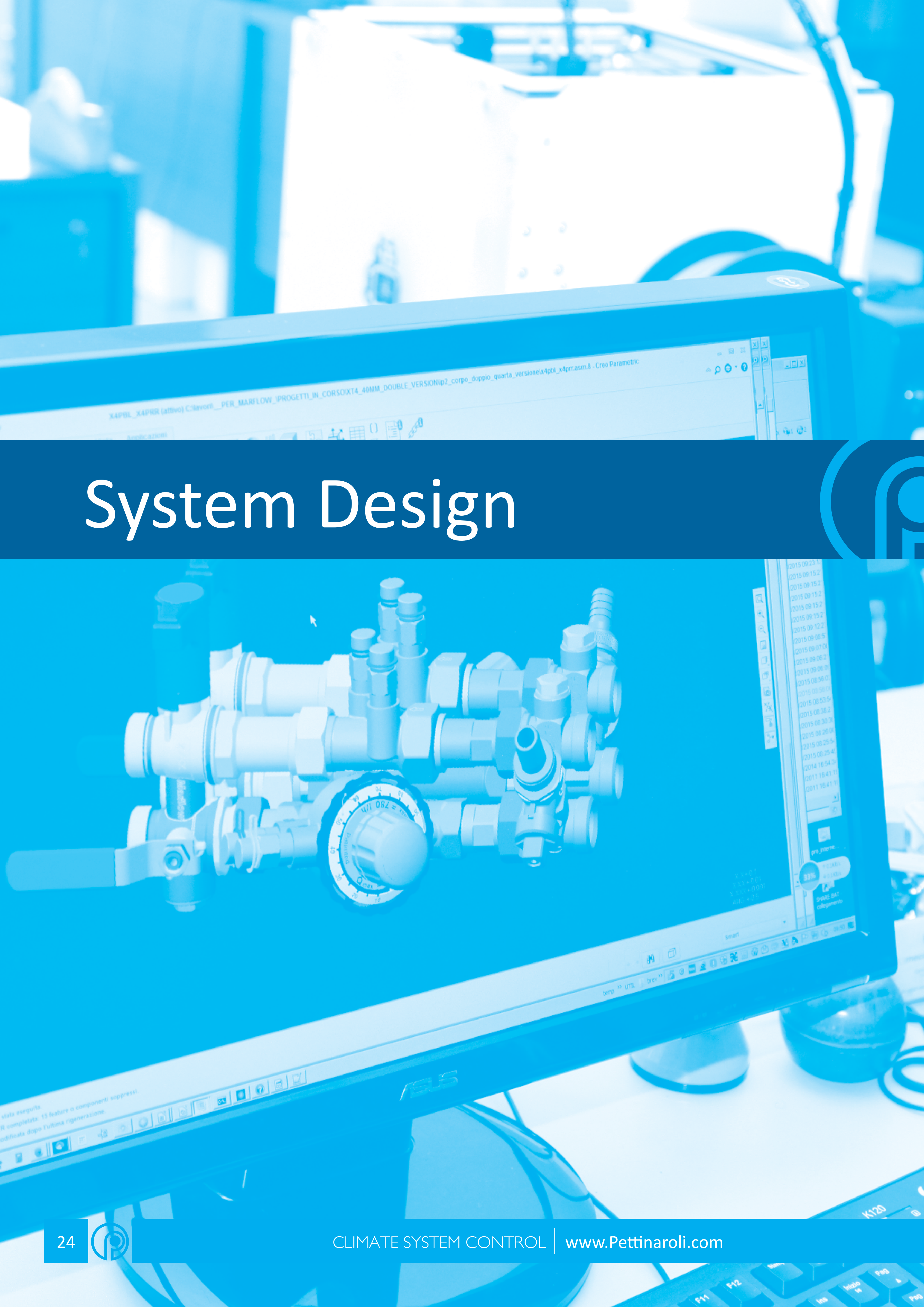


Example of two PICV: same nominal flow rate, different start-up pressure

Materials

It is important that the materials of all valves, pipes and fittings used in a water distribution system are fit for the type system they have to be installed in. Materials should be selected and if required, undergo further specialist process (like specific heat threatments) to ensure the components will not suffer from known stresses such as Stress Corrosion Cracking. Components should be designed to fit together to avoid over stressing and distortion of female threads.

System Design



The design of heating and cooling pipework systems incorporating PICVs is explained in KS7 VARIABLE FLOW PIPEWORK SYSTEMS. Advice on minimising pump energy consumption is provided in BSRIA GUIDE BG 12/2011 ENERGY EFFICIENT PUMPING SYSTEMS - A DESIGN GUIDE.

The main design considerations are summarised as follows:

Isolation

PICVs should not be relied upon as shut off valves for maintenance purposes. Separate isolating valves are required.

Union Joints

As with all control valves, union joints should be included so that the PICV can be easily removed from the system, should they need to be replaced at a later date. For larger PICVs, isolation either side should be considered.

Pump sizing

To allow for variability in the range of final flow measurement results, CIBSE COMMISSIONING CODE W recommends that pumps should be sized with capacity for 110% of the design flow rate. This enables flows to be set in the range -0% to +10%.

In the case of systems incorporating PICVs, for the reasons explained on page 16, final flow measurements may lie in a ±10% band. Hence, pumps should be sized with capacity for 120% of the design flow rate (allowing for any diversity factors) so that flows can be set in the range -0% to +20% if a safety factor or diversity has not already been applied.

When calculating the system pressure loss for pump sizing, include for 1.5 x the start-up pressure of the PICV in the index circuit pressure loss calculation.

PICV locations

PICVs should be located in all terminal unit branches where modulating control of heating or cooling output is required.

Where terminal units controlled by diverting 3 or 4 port control valves are incorporated in the same system as terminal units controlled by PICVs, some form of constant flow limiting valve should be installed in those terminal branches controlled by 3 or 4 port valves. This can take the form of a PICV without an actuator head.

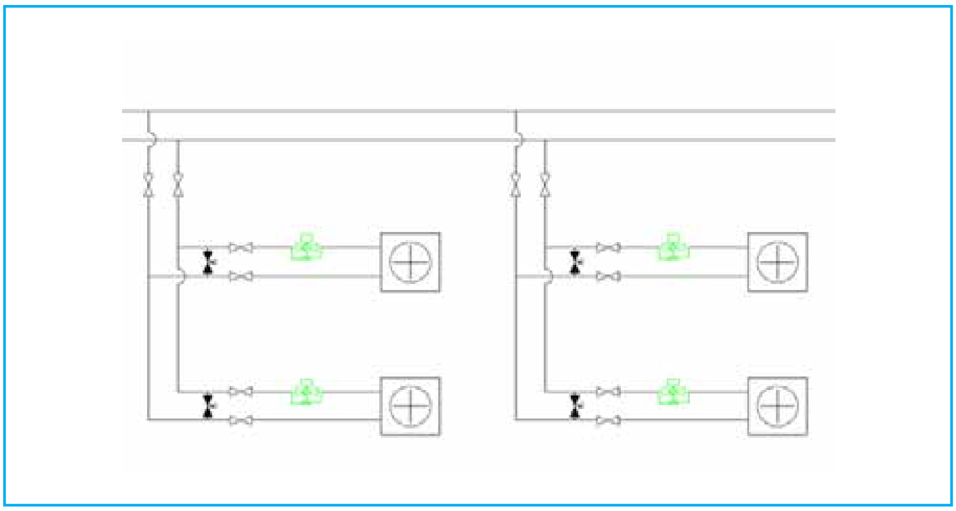


Figure 11. Typical locations for PICVs

Flow or return mounting

PICVs can be mounted in either the flow or return pipework serving terminal units. Consideration should be given to the flushing regime when deciding on the position of the PICV.

PICV selection

PICVs can be selected based on terminal unit design flow rates alone. Always select the smallest valve that can deliver the design flow rate unless it is known in advance that the design flow rate value may increase.

In order to operate satisfactorily, the differential pressure regulator must be able to operate within its specified control range i.e. such that the pressure differential measurable across the tappings on the valve is greater than the minimum "start-up" value and less than the maximum value.

Strainers

PICVs should not be installed in systems where the water quality is known to be poor, where PICVs are to be installed in such systems (retro-fit and re-fit projects for example) works should be carried out to improve the quality of the water. **BSRIA GUIDE BG 29/2012** gives advice on how to achieve acceptable water quality in closed re-circulating pipework systems.

Most of the PICVs can be sensitive to high levels of particulate dirt which causes fouling of the low-pressure areas within the valve, however strainers are not effective at removing this kind dirt from the media as the mesh size usually installed is too large to trap such tiny particles. This kind of fouling can only be prevented, by ensuring the quality of the heating or cooling media is of a high standard by on-going water treatment and filtration.

Strainers should always be installed on the main branch pipework feeding terminals served by PICVs; however strainers protecting each PICV need to be installed if the designer feels there is a risk of large contaminants circulating in the system.

The pre-commission cleaning routine should be designed to mitigate the risk of large contaminants being passed through the PICV.

The use of ball valves with integrated strainer enhance system performance (smaller pressure losses) and make maintenance easier.

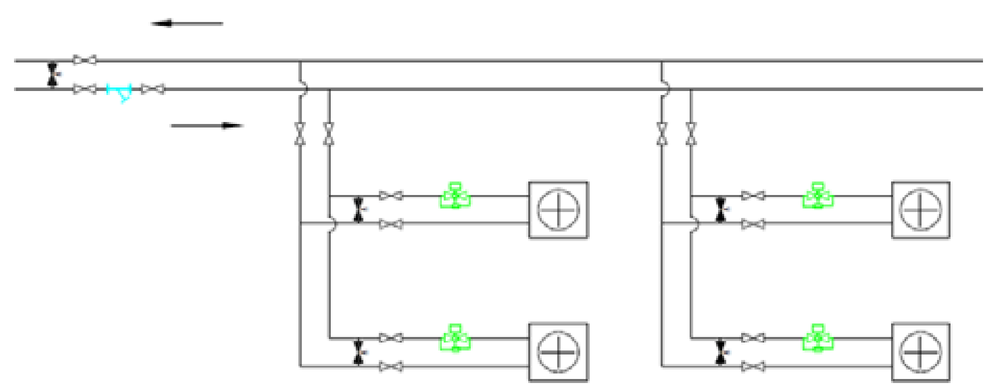


Figure 12. Strainers in main pipe branches

Flushing by-passes and flushing drains

Flushing by-passes should be provided across all branches containing PICVs. These will allow the main branch pipes to be flushed and chemically cleaned without having to circulate dirty water and cleaning chemicals through the PICVs or terminal units.

Each branch should also contain a flushing drain so that (once the main branch pipes are clean) the terminal unit can be flushed through with clean water without having to send the same water through the PICV. To make this possible, the flushing drain should always be situated between the PICV and the terminal unit.

PICV valves can never be forward flushed as their design is to react to increased pressure and maintain a constant flow. Reverse flushing must be avoided because it can also damage the internal workings of the valve. Therefore, a flushing by-pass with a three-way ball valve should be installed to all terminal units to protect the PICV against reverse flushing, if installed in the return. If back flushing of the fan coil is required, the PICV valve should be installed in the flow using a double 3-way ball valve in the flushing by-pass.

PICV valves can never be forward flushed as their design is to react to increased pressure and maintain a constant flow. If the specification asks for the terminal unit to be flushed from the return pipe backwards through the coil to a drain on the flow. The PICV valve should never be installed in the return and only ever installed in the flow with a drain installed between the PICV valve and the terminal unit. The return pipe has no direct connection to the pump flow and the pressure is limited to static pressure giving limited pressure when reversed flushed (this pressure can be significantly higher on multi storey buildings due to a high static head). Trying to back flush through a PICV valve that can have a high resistance and then through a flow measuring device in the return will significantly reduce the pressure available. Also, high static pressures in a system can when back flushed through a PICV valve can cause damage to the internal workings of the valve.

Flow measurement

For checking purposes, flow measurement devices should be located on main branches and sub-branches upstream of the terminals, as deemed appropriate by the designer. Flow measurement devices should also be fitted to the terminal units unless agreed otherwise with the design/validation engineers.

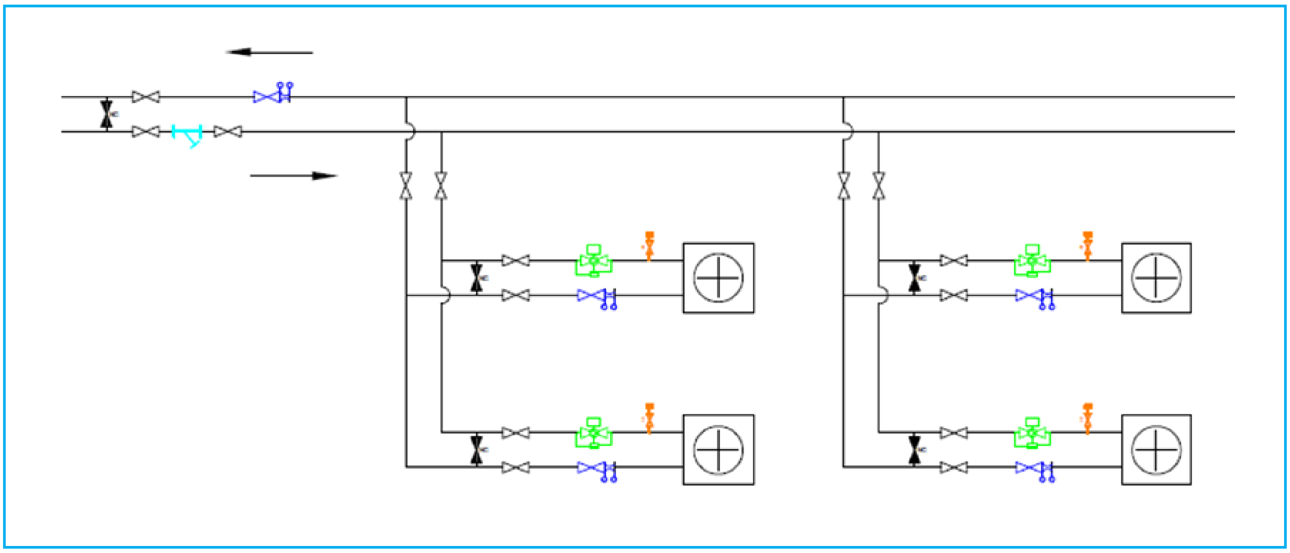


Figure 13. Location of flow measurement devices

Additional regulating valves

All flow regulation is achieved by the PICVs. There is no need for additional regulating valves on any of the main or sub-branches feeding to terminal unit branches containing PICVs.

Systems with Double Regulated Valves and 2-way Control valves mixed with PICV cannot achieve good performances due to the uncontrollable flow through non dynamic valves.

Differential pressure control valves

Since each PICV includes its own differential pressure regulator, separate differential pressure control valves are not required in circuits that contain PICVs. The only exception to this rule would be when the circuit differential pressure exceeds the maximum pressure limit of the PICVs, which is only likely in unusually large systems. A separate DPCV in the circuit feeding to the PICVs could then be used to limit the pressure differential across the PICVs.

Although not required in circuits feeding PICVs, DPCVs might still be required in circuits feeding to terminals with other types of control valve that lack differential pressure control. This might include thermostatic radiator valves and 2 port control valves.

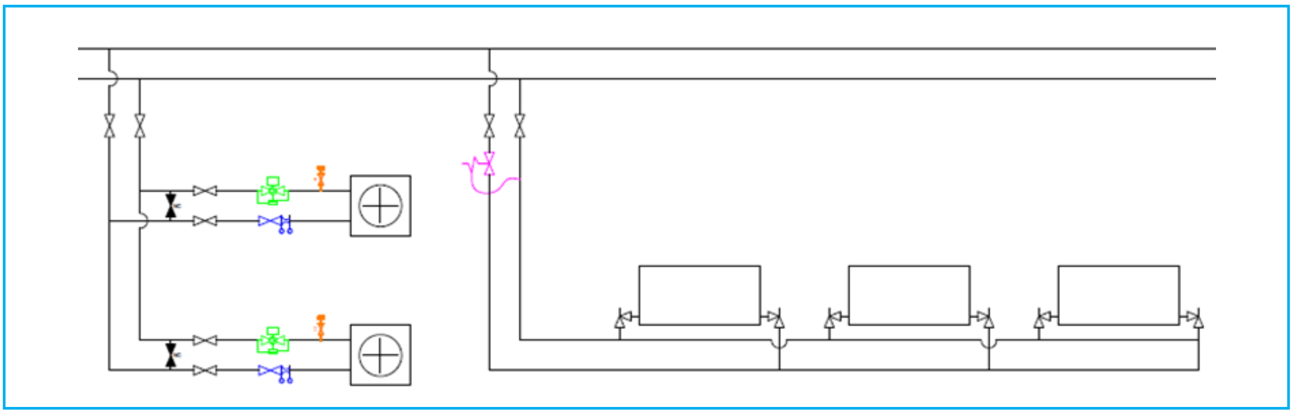


Figure 14. Branches requiring additional differential pressure control valves

System by-passes

When all PICVs are closed, there needs to be some path open to flow to prevent the pump operating against a closed system.

A simple solution is to use non-actuated PICVs as flow limiters in by-passes located at the ends of terminal branches. These will allow a fixed flow of water through them under all operating conditions. Some pump energy can be saved by using the same solution but actuating the by-pass PICVs so that they open only as the pump speed reduces.

Alternatively, by-passes can be integrated within terminal branches by installing 3 or 4 port control valves in end of run terminal branches. Where this solution is adopted, those branches controlled by 3 or 4 port valves also require constant flow limiters so that a constant flow rate is maintained under varying pressure conditions. This can take the form of a non-actuated PICV.

Modern pumps should be able to cope with minimum flows as low as 5% of their full load values. By-passes should be sized to provide an overall flow matching the minimum flow rate of the selected pump (this should be confirmed with the pump manufacturer).

By locating by-passes at system extremities, the flow of water treatment chemicals will be maintained and the pipes will remain “live” ready for a heating or cooling demand. Alternatively, where it is not feasible to locate by-passes at all system extremities, the control system should be configured to “exercise” the valves by ensuring that all valves motor to an open position at least once every 24 hours.

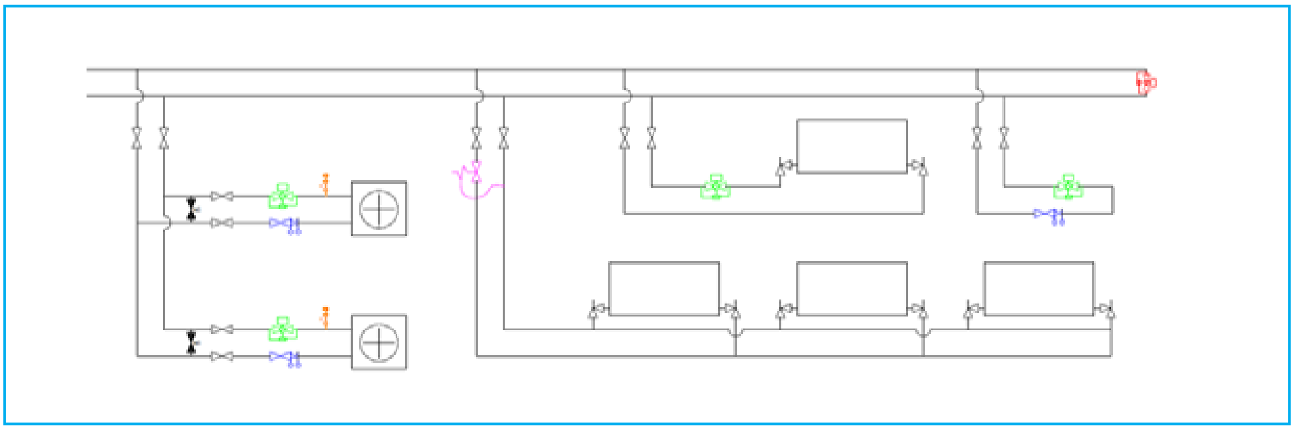


Figure 15. System by-passes

Future use by-pass loops

PICVs without actuators should also be installed on future use by-passes in order to be able to control the additional flow rate without compromising the commissionability of the base build.

Sometimes the combination of DRV and DPCV is preferred than a PICV. Hereunder a comparison of those solutions:

1. Number of joints during installation:
   DRV + DPCV: More, due to use of multiple devices
   PICV: Only 2, as PICV is a combination of DRV +DPCV inbuilt (Less the no of joints, less chances of leaks and Better workmanship)
2. Design:
   DRV + DPCV: More calculation required when Selecting the right DPCV (Flow, pressure etc)
   PICV: Only Flow rate required when selecting PICV is better (with PICV less chances of error as only one parameter involved).
3. Balancing Time:
   DRV + DPCV: Time required is more as requirement to Balance the DRV & DPCV
   PICV: Only Pre-setting on the PICV required
4. Energy Loss after commissioning:
   DRV + DPCV: Once the Flow is set on DRV it cannot be changed as it will cause error when the area is occupied later
   PICV: In case of PICV the pre-setting remains same and the control part can be close to save energy until the area is occupied.
5. Maintenance of ΔT:
   DRV + DPCV: Delta T cannot be maintained as the DRV will be set at required flow and full load condition only
   PICV: Delta T is assured as PICV will only regulate the required flow and more over the flow can be further reduced till the time of non-occupancy (as there is no Diversity in the current system PICV is highly recommended)
6. Accuracy:
   DRV + DPCV: Since 2 components are involved the accuracy of setting at site would be low
   PICV: The accuracy of setting is always better

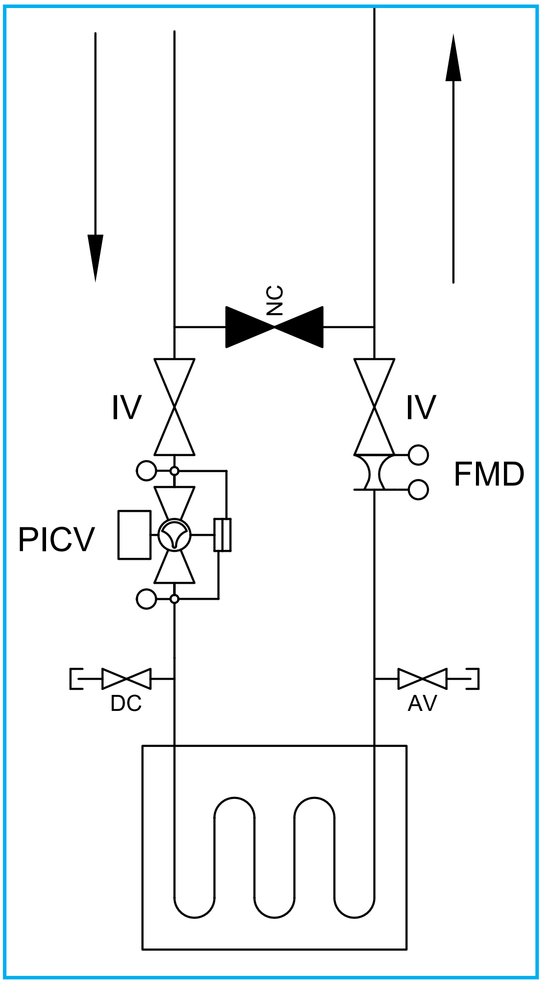
Pump speed control

Pump speed control should be set such that a constant pressure differential is maintained at a differential pressure sensor located towards the index PICV i.e. the PICV located furthest from the pump. A single sensor located two thirds of the way along the index branch is satisfactory in systems with a uniform load pattern; alternatively multiple sensors across the most remote PICV controlled terminal branches can be used in systems with an unpredictable and varying load pattern.

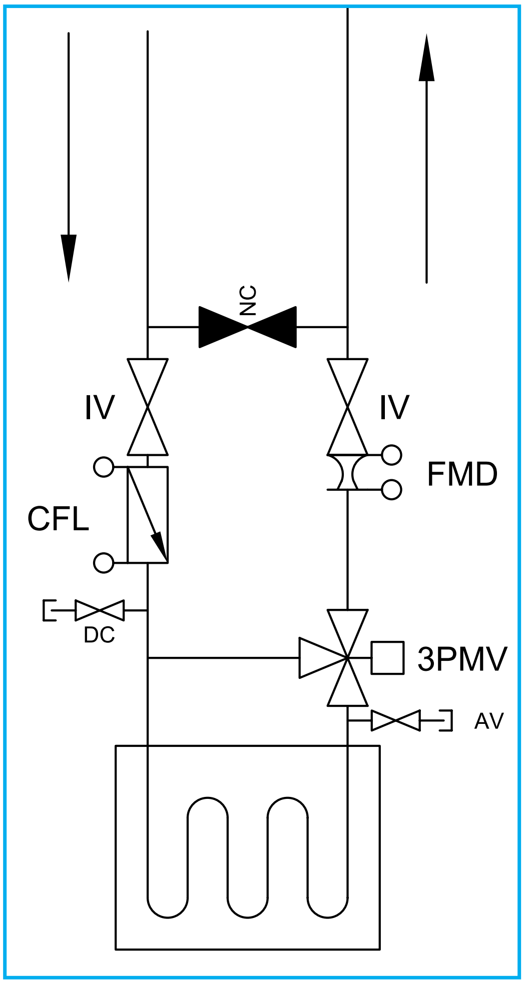
Under no circumstances should pump speed be controlled such that pump pressure is maintained constant. This solution inevitably results in large increases in pressure differential across PICVs as they close, resulting in the significant variations from set flow rate values.

The use of remote sensors for pump speed control will enable PICVs to perform as accurately as possible. This solution also gives the best possible energy savings from the pump as recommended in CIBSE Knowledge Series guide KS7 Variable flow pipework systems and BSRIA BG 12/2011 Energy Efficient Pumping Systems - a design guide.

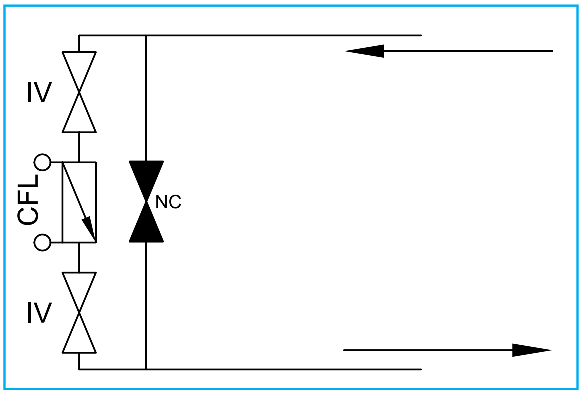
Typical Schematics



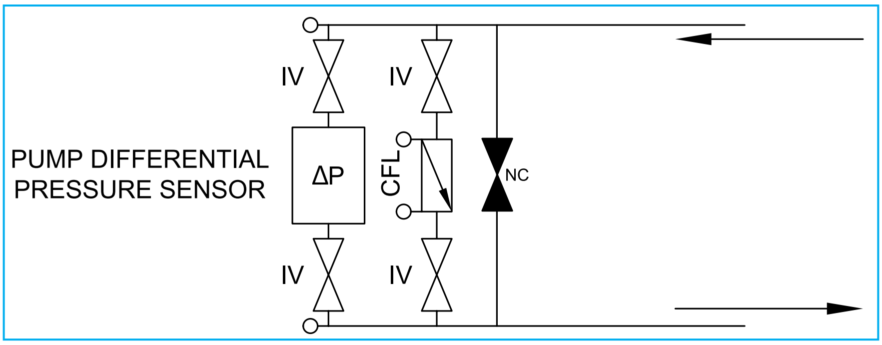
Typical PICV Terminal Schematic



Typical end of branch with 3 port valve



Typical end of branch with CFL



Typical DP sensor Installation

System Commissioning

Section W7.7.3 of CIBSE COMMISSIONING CODE W: 2010 provides a generalised method for commissioning PICV systems. The method statements below provide specific advice relating to Pettinaroli products.

These commissioning methods should ensure repeatable results within acceptable limits but allowing for the inevitable accuracy and repeatability issues described on page 16 of this guide.

It should be noted that commissioning PICV systems is not a "read and record" exercise. In general, two visits to each valve should be allowed for with time allocated for fault finding in between.

Firstly, the start-up pressure must be always checked in all index circuits of the installation. Before any further readings are taken, design flows on the floors (risers) must be measured to ensure design flow is being achieved. If a floor is identified that is lower than design or higher than design, further investigation of that floor is required. An increase in flow could be due to a by-pass left open or to PICV valves have not been regulated to their design position. A reduction in flow could be terminal units isolated. It is important to ensure that design flow is achieved on every floor and the index pressure is slightly above the start-up pressure across the PICV valve before flow readings are taken.
At the flushing and commissioning phase, all the PICV installed in the system should be checked. The checking operation is time demanding, but it is important to ensure the system is properly working, before flow rate readings are taken. Examples of possible problems can vary with some terminal devices generating higher pressure drops or flow deviation due to incomplete or unchecked pipework (i.e. a flushing by-pass left open after flushing). It is always suggested to measure and record the differential pressure across all the PICV fitted into the system (see the draft check list in the appendix). The start-up pressure must be checked and achieved on every PICV. Along with this first check, flow rate through each terminal unit and riser should be checked and recorded. It is suggested to fit a Venturi flow measurement device on every terminal unit and riser to check the flow rate; flow measurement through a variable orifice is always less accurate than a calibrated fixed orifice devices (±20% against ±5%). All this data must be recorded on commissioning sheets , to allow engineers and facility managers to check the system operational every time of system lifetime.
All the PICV should have the tests points allowing total differential pressure measurement across the valve (not just across the control valve) and all the terminal units should have a calibrated Venturi fixed orifice for accurate and repeatable measuring of the flow rate. Although test points add cost to the purchase of the PICV valve, the test proves an insight into the operation of the system and it can explain flow deviations.

Pre-commissioning checks

Before commissioning can commence, pre-commissioning checks should be undertaken in accordance with those outlined in **CIBSE COMMISSIONING CODE W: 2010**.

For the different types of PICV valve the following preparation is also required.

Where the PICVs are to be manually pre-set by means of hand wheel adjustment, the actuator heads, if fitted, should be driven to their fully open position and not repositioned during the commissioning process.

Where the BMS is to be used as a commissioning tool the following pre-requisites should also be completed.

- All controllers to be used for commissioning work must be powered and electrically tested.
- Factory settings must be downloaded to controllers and final flow rates entered.
- Communication cables to each floor or sub section of the building to be commissioned must be installed

and properly terminated.

- Communication to the controls must be established and shown to be stable.
- Actuators should be properly fitted and de-clutched.
- A commissioning computer should have been issued to the commissioning team and training provided in its use.

Systems with pre-settable valves

Methods 1 and 2 relate to the commissioning of pre-settable valves. These are valves in which the flow rate is determined by the position of a hand wheel or programmable actuator.

Method 1 – Setting against flow measurements

This method involves setting the PICVs using measurements obtained from a local flow measurement device. Commissioning can be completed on a floor by floor or sectional basis.

Initial steps

Prior to commencing measurements for each floor or section:

1. Ensure that PICVs are at their factory set 100% open positions.
2. Ensure that all valve actuators, if fitted, are driven fully open.
3. Set the pump to the design speed setting.
4. Turn the pump off and then back on again.
5. Measure the differential pressure across the PICV located furthest from the pump using the pressure tapings incorporated in the PICV. If the measured pressure differential exceeds the start-up value of the PICV, proceed to "measurement and setting" (see over the page).
6. If the start-up pressure cannot be achieved, close down sections of the pipework system or increase the pump speed until the start-up pressure is exceeded at the measurement point. Then turn the pump off and back on before commencing to measurement and setting.

Measurement and setting

Working away from the pump, for each PICV:

1. Connect a manometer to the flow measurement device in the same branch as the PICV.
2. Using the PICV hand-wheel, adjust the setting until the required flow measurement is indicated by the manometer. Aim to set the PICV to 115% of the design flow.
3. Record the pressure drop signal achieved at the flow measuring station and the indicated PICV flow setting.

Method 2 – Pre-set, measure and trim

This method involves by pre-setting the valves to their calculated flow rate values before any flow rate measurements are taken. This pre-setting could be carried out when the flushing works are complete, pre-setting the valve before each terminal is brought on line.

Initial steps

1. Ensure that all PICV valves have been pre-set to their specified flow rate values.
2. Ensure all valve actuators, if fitted, are driven fully open.
3. Set the pump to the design speed setting.
4. Turn the pump off then back on again.
5. Measure the differential pressure across the PICV located furthest from the pump using the pressure tappings incorporated in the PICV. If the measured pressure differential exceeds the start-up value of the PICV, proceed to "measurement and setting" (see below).
6. If the start-up pressure cannot be achieved, close down sections of the pipework system or increase the pump speed until the start-up pressure is exceeded at the measurement point. Then turn the pump off and back on before commencing to measurement and setting.
7. Check the flow rate in the main branch to verify that its value is equal to the sum of the pre-set PICV flow rates fed from the branch.

Measurement and setting

For each PICV, in any order, carry out the following actions:

1. Connect a manometer to the flow measurement device in the same branch as the PICV.
2. Check that the indicated flow measurement is between 105% and 115% of the design value.
3. If required, adjust the setting until a flow reading within these limits is observed on the flow measurement device.
4. Record the pressure drop signal achieved at the flow measuring station and the indicated PICV flow setting.

Remote setting of valves by BMS controller

Methods 3 and 4 relate to the commissioning of valves where the flow rate setting is achieved by the adjustment of the attached actuator using a BMS.

Method 3 – Setting under falling pressure condition

This method involves setting the valves remotely from a BMS using the valve actuator to position the valve to achieve the required flow rate. Setting the valves under falling pressure conditions should ensure that the flows achieved will be as close as possible to those likely to be experienced during normal operating conditions (provided that the advice given in section 3.5 of this guide is followed).

Initial steps

1. Using the commissioning laptop, set all valves into commissioning mode.
2. Set the pump to run at constant speed at the calculated design position.
3. Measure the flow rate at the main branch and compare to design flow rate.
4. Using the commissioning computer close all valves, check flow reading at main branch goes to zero.
5. Return all valves to fully open using commissioning computer.
6. Measure the differential pressure across the PICV located furthest from the pump using the pressure tapings incorporated in the PICV. If the measured pressure differential exceeds the start-up value of the PICV, proceed to “measurement and setting” (see over the page).
7. If the start-up pressure cannot be achieved, close down sections of the pipework system or increase the pump speed until the start-up pressure is exceeded at the measurement point. Then turn the pump off and back on before commencing to measurement and setting.

Measurement and trimming

For each PICV, in any order, carry out the following actions:

1. Connect a manometer to the flow measurement device in the same branch as the PICV.
2. Check that the indicated flow measurement is between 100% and 110% of the design value.
3. If the valve requires adjustment do this by adjusting the trimming factor in the commissioning software.
4. Wait for the valve to re-synchronize.
5. When the pump has restarted record the pressure drop signal at the measuring station and any trim factor applied.

Method 4 – Setting under rising pressure condition

This method involves setting the valves remotely from a BMS using the valve actuator to position the valve to achieve the required flow rate.

Setting the valves under rising pressure conditions should ensure that the flows achieved will be as close as possible to those likely to be experienced during normal operating conditions (provided that the advice in the “PICV Control - Essential Consideration” chapter of this guide is followed).

Prior to commencement of measurements

1. Using the commissioning laptop set all valves into commissioning mode.
2. Set the pump to run under constant speed at the calculated design position.
3. Switch pump on.
4. Measure the flow rate at the main branch and

compare to design flow rate.

5. Using the commissioning computer close all valves, check flow reading at main branch goes to zero.
6. Return all valves to fully open using commissioning computer.
7. Measure the differential pressure across the index PICV using the incorporated test plugs if it exceeds the start-up pressure of the PICV valves proceed to measurement (see verification by reference point to establish known parameters).
8. If the start-up pressure cannot be achieved close down sections of the building or increase the pump speed until the start-up pressure is exceeded at the measurement point. Then turn the pump on and off before commencing to measurement
9. Note down pump set position.

Taking measurements and trimming

In any order, for each PICV,

1. The commissioning team may choose to measure and trim the valves in groups of up to five valves if they have enough measuring instruments.
2. Connect a manometer to the flow measurement device.
3. Check that the indicated reading is between 110% and 115% of the design value.
4. If the valve requires adjustment do this by adjusting the trimming factor in the commissioning software.
5. When the valve has re-synchronised to the new position turn the pump down and then return to set position.

Commissioning incomplete systems

Where commissioning must commence before the water distribution system is complete, the following advice should be applied. The aim is simply to ensure that the final setting and subsequent witnessing of the valve is always done under the same differential pressure conditions. This method also provides a reference point in time of the system conditions and should form part of the commissioning process. This advice also applies where systems have not been designed to the advice given in this chapter and items such as future use by-passes have been installed without pressure control.

Whether it be the flushers opening up part of a system or a commissioning engineer closing a by-pass valve, the problem with attempting to commission a part finished system is that the pressure gradient can change during the commissioning process. This will mean that measured results will be much less repeatable than when compared to a fully finished system. When the system is nearing completion the Index circuit might be more identifiable and therefore the information might have to change to meet the requirements of an almost finished system. This exercise might have to be repeated.

Commissioning by reference points

In order to establish a process for taking repeatable measurements at terminals and branches it's important to first ensure that the circumstance in which each measurement is taken is repeated. To do this differential pressure reference points must be established in the section of the system that is being commissioned. When the readings at the reference points are repeated the terminal measurements should be repeatable. The pump set position should also be noted.

Before initial setting of PICV valves by any method

1. Establish where the reference points for the sub system will be, these should in general be a PICV valve at the index or end of run and optionally a PICV valve near the beginning of the pipework run
2. Turn pump off and on again.
3. Measure differential pressure at index and ensure it is higher than the start-up pressure for the PICV valve. If it is not high enough adjust the pump speed and then turn the pump off and on again.
4. Measure and record the differential pressure at the reference points using the incorporated test plugs.
5. Record pump settings.

On taking repeat readings

1. Before starting to re-measure any flow rates on the sub circuit measure the differential pressure at the reference point.
2. Turn pump off and on again.
3. If the differential pressure readings the reference points are the same as the initial readings then proceed to take the repeated measurements.
4. If the measurements at the reference points are different to the initial readings then adjust the pump speed until the reference values are achieved. Turn pump off and on again and re-check.

Witnessing

Witnessing can take the form of either spot checks or an entire re-measurement depending on the preference of the witnessing authority. In order to ensure high levels of consistency in the witnessed readings ensure the same steps are followed prior to witnessing flow rates as were followed during the commissioning process.

Controls commissioning

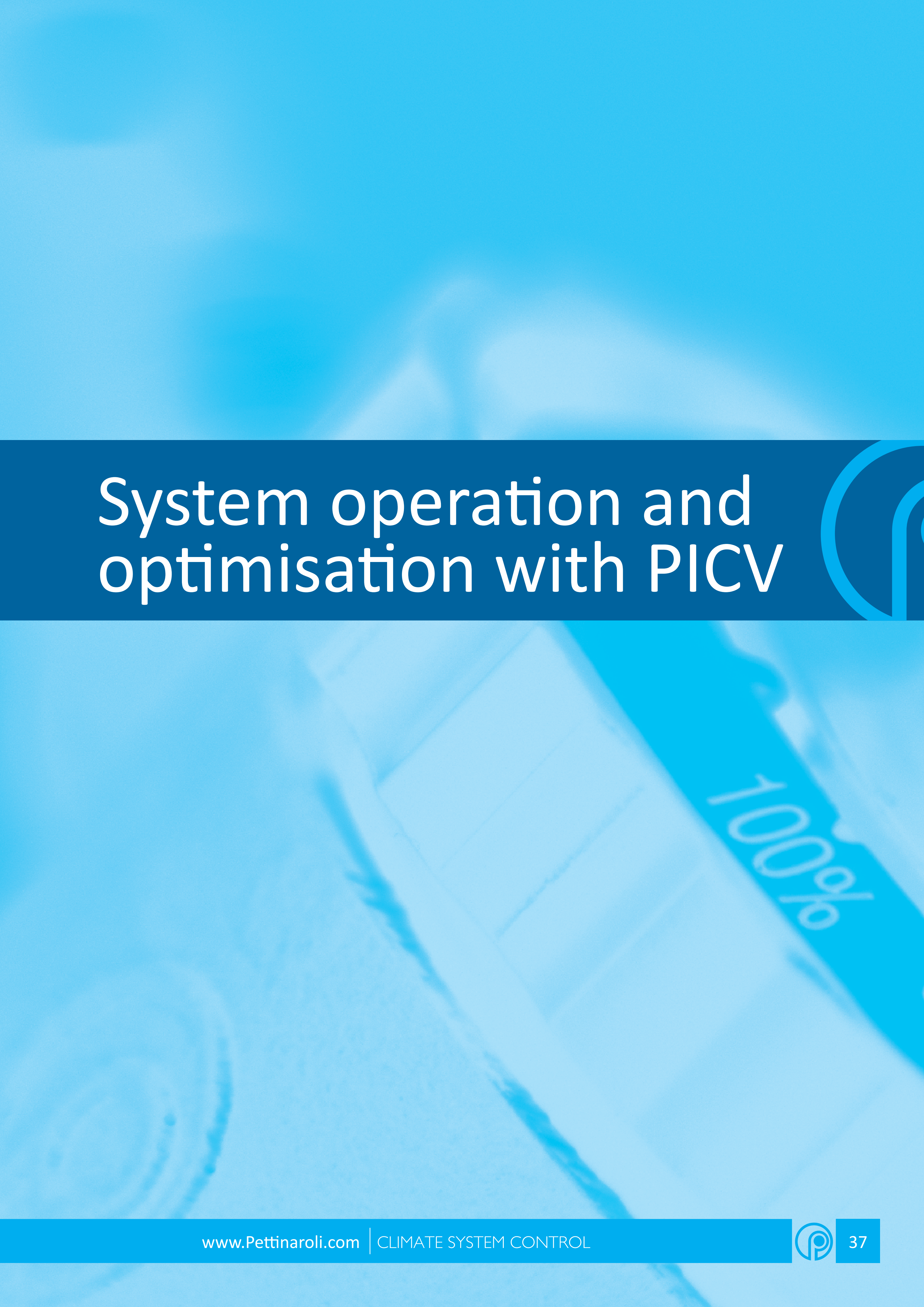
In general there are no additional controls commissioning tasks created by the use of a PICV but it should be ensured that the actuator selection is taken account of by the controls installer.

0-10v Actuators

In general 0-10v proportional actuators require no special commissioning however some models are field configurable by means of dip switches or jumper connections. It should be established with the manufacturer if there are any settings that need to be made in the field.

3 Point Actuators

3 point floating (drive open / drive close, tri-state) actuators require that the drive time (and re-synchronisation time) for the valve and actuator combination be correctly set in the BMS controller.



System operation and optimisation with PICV

Life cycle costs

The Life cycle costs of a building considered strictly from its initial installation cost does not give the total cost from the owner's perspective: owning and operating a facility.

Studies show in general that, a forty-year life cycle of a commercial building, approximates to only 11% of the up-front construction cost. Almost 75% of the costs are going to be accrued as the owner uses and changes the facility to meet their ongoing needs. The costs can be seen in the capital renovation of the facility, as well as the ongoing operations and maintenance of the building.

The owner purchases or leases the building from a developer. The developer is only concerned about construction costs and tries to reduce the initial investment cost by setting price-based equipment only. He takes no account of the costs that occur throughout the building's life cycle and the largest bill will be paid by operation, maintenance and retrofit. The case for quality and efficiency of equipment directly influence the operation costs.

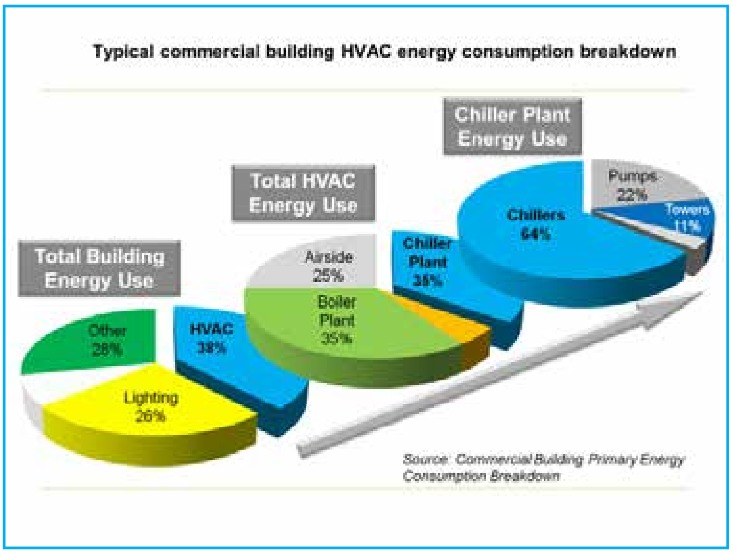
Average HVAC consumption vary from 38 percent (conservative percentage) to as much as 50 percent of the total life cycle costs. Among the various HVAC systems (airside, chillers, boilers), the chiller plant uses the most energy, at around 35%. Within the chiller plant, the chiller uses the most energy, at around 64% with pumping also using a significant portion of the total energy used.

The performance and efficiency of the Chiller is determined by the Delta T effect of terminal units.

Hydronic balancing and flow control are a very important part of maintaining the efficiency to reach good performance in the complete HVAC system.

Although labour are the highest costs during lifetime of the building, the cost of energy is the largest single individual cost that the facility manager can control.

The introduction of an energy saving program that effects the people who work in the building, can have a negative affect (productivity, sick leaves, etc.) if implement that affect the comfort and indoor air quality of the building.



Overflow and DeltaT

Overflow in HVAC systems can cause loss of efficiency and unnecessary expense in many ways.

- Loss of efficiency in chillers due to low Delta T generated by overflow
- Unnecessary spending on pumping energy, moving a larger flow of water than is needed.
- Loss of efficiency in heat exchangers.
- Premature wear of equipment.
- The intrinsic costs generated by the loss of building user productivity caused by improperly functioning or poor performance of air conditioning equipment.

Using PICV with Equal percentage Characteristic reduces overflow and avoids low Delta T phenomena. HVAC system mainly operate at partial load conditions, which means that the Control valves are controlling flow rate to the terminal. The control valve characteristic determines the performance of the system. The equal percentage characteristic in a pressure regulated control valve on a water-to-air heat exchanger is the only characteristic able to ensure good comfort conditions efficiently. Considering the thermal output (P) is driven by the environment thermal requirement (air room temperature), linear valves or ON-OFF valves allow higher mass flow rates (m) at partial load than an equal percentage PICV valve, as shown at page 14. Poor control causes a decrease of design Delta T (ΔT).

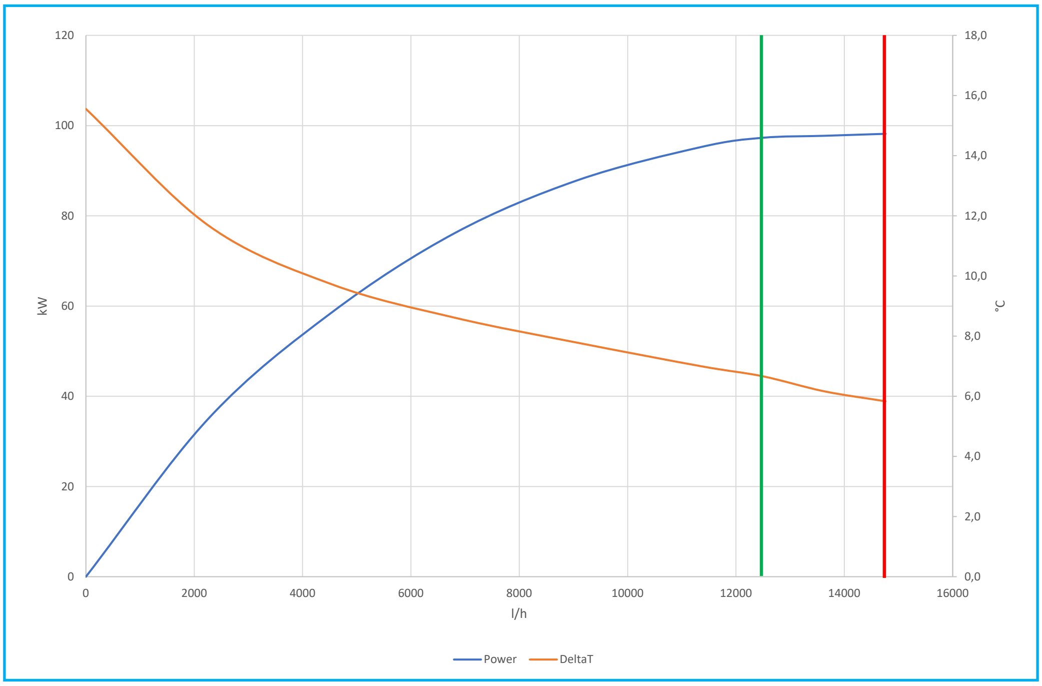
$$P = \dot{m} c_p \Delta T$$

A higher flow rate than required wastes significant energy due to extra pumping: to meet that increase of flow rate in a variable volume system, the pump must therefore increase the pump speed or, alternatively, use more stage pumping. The affinity pump laws and the pump power equation, a higher flow rate requires a higher pump speed (N).

$$\dot{m}_1 = \dot{m}_2 \left(\frac{N_1}{N_2}\right)$$
$$\Delta p_1 = \Delta p_2 \left(\frac{N_1}{N_2}\right)^2$$
$$P_1 = P_2 \left(\frac{N_1}{N_2}\right)^3$$

An increase of pump speed causes a cubic increase of pump power consumption (P). The overflow increases the energy consumption. An unsolved overflow over many years of operation can generate significant energy waste. To prevent the effects of poor Delta T the correct design and selection of flow balancing and control valves is required. Ensuring water-to-air heat exchangers are fitted with equal percentage characterised PICV valves (correctly sized for design flow rate) allows to achieve maximum efficiency.

Compliance of valve features (type of control, authority, quality, material) with all the aspects mentioned in this manual assists designer and managers to make correct valve selection. Moreover the same aspects will help them to correctly evaluate system perfomance.

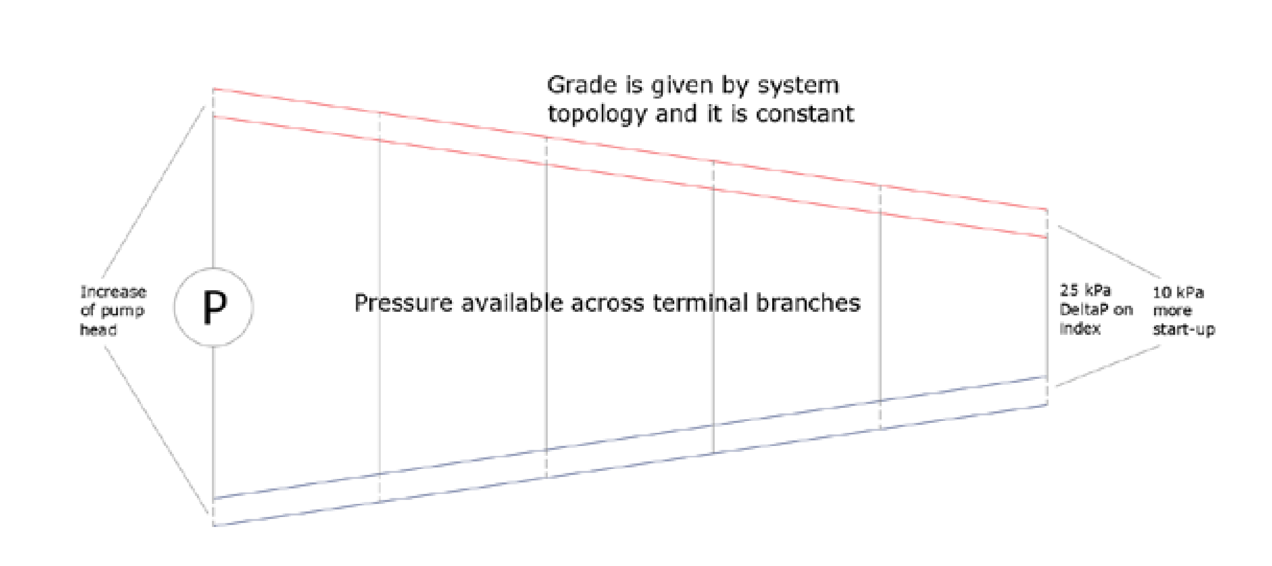


Power output characteristic of a water to air heat exchaner

Effect of high start-up pressure on a PICV valve

Spring operated PICV requires a minimum differential pressure across the valve to start controlling the flow rate. The start-up pressure of the PICV in the index circuit affects the pumping power consumption. The lower the pump head, the lower the pump power required. The pump power equation states that power is proportional to flow rate and pump head, over the pump efficiency. The selected pump to meet system requirements (system pressure drop and mass flow rate) determines the power consumption.

$$P_e = \frac{\dot{m}\Delta p}{\eta_e}$$



Visual explanation of pump head increase due to higher start-up pressure at the index

In large buildings where there is a high flow rate, a small increase of start-up pressure generates a small increase of pump head; however, a small increase leads to higher pump power consumption. It must be noted that the system pressure losses are almost constant throughout the buildings lifetime. A higher start-up pressure (and pressure losses) on the system causes a higher power consumption throughout the buildings lifetime.

Valve maintenance

PICV valves will require maintenance throughout the lifetime of the building. If the water quality is constantly checked and maintained, the PICV valves will operated as designed. If the water quality is not maintained, dirt can gather around moving components (differential pressure regulator, control valve, etc.) and they can become stuck. Maintenance teams must ensure the system is keep clean and operational.

Control valves, that cannot be maintained, might fail and when they do fail, new control valves must be installed to ensure continued operation and performance of the system. Some control valves have been designed to be disassembled, using dedicated tools, and internal components such as differential pressure regulator and control valve can be removed and replaced with new ones. This avoids complete removal of the body. In case the internal components are integrated in a metal body, the insert can be typically unscrewed with a standard spanner and replace with a new internal component. The latest technology allows to disassemble the differential pressure regulator, clean it and reassemble it again.

Maintenance of a PICV with extra tools

Maintenance of a PICV with standard spanner

Water quality: what to do in case it is not maintained

Quality of the water flowing in the HVAC system plays a crucial role ensuring the reliability and the performance of the system. Many devices can be damaged or underperforming because of dirt, aggressive chemicals or other substances contained in the water. Standards of water quality have been issued by different national standard associations. Technicians involved in system commissioning and facility maintenance must be always aware of the national water quality standards.

During system commissioning, contractors must carry out a complete flushing of the pipework and terminal units, ensuring no dirt or contaminant (especially incompatible chemicals) has affected the PICV valve internal components. Then, Facility Managers must ensure the quality is always compliant to those standards throughout the life of the building. As PICV valve performance can be really affected by dirt and contaminates in the water, PICV manufacturers would prefer clean water without any dirt, but accept small amounts of impurities in water which is often more restrictive than standards. Indeed, differential pressure regulators can be blocked or slowed down by extra friction provided by dirt, that gathers around O-Rings and internal surfaces.

Among contaminants, the most common and dangerous is Iron Oxide which can be highly concentrated in system water due to steel pipe corrosion: manufacturers accept very low amount of iron oxide in the water. It tends to be fixed on surfaces: it increases a lot the friction between moving surfaces like differential pressure regulators and their O-Ring. PICV valve performance tests can be carried out.

In case the water quality cannot be maintained or cannot reach the usual standards for PICV, it is recommended that the latest differential pressure regulator technology is used: it can operate in very demanding conditions. This new development allows the new design PICV to work even if very high concentration of iron oxide are in the water. A constant and accurate flow rate is always achieved throughout the lifetime of the PICV. Maintenance of the new design PICV valve is reduced, but ensure good water quality is still recommended.

Example of dirty and clean water

Benefit of external presetting

Contractors, commissioning engineers and facility managers must ensure PICV pre-setting devices can allow fast and accurate operations, which can guarantee quick and optimal working performances. Typically control valves are installed in narrow spaces such as false ceiling and terminal unit enclosures. Pre-setting of the PICV must be accurate and easy to set. There are two types of pre-setting mechanisms: internally adjustable and externally adjustable.

The internal adjustable is small as it fits under the actuator. Internal adjustment PICV valves have small scales and the pre-setting scale is small and hard to read, especially in narrow and dark places. The adjustment can be difficult to see and turn at the same time. The reference scale on the body is usually small and hidden by the setting device. The setting can be only adjusted when the actuator is not fit to the valve. This does avoid any tampering or accidental operation but makes setting operation slower and more expensive. The actuator must be removed and re-assembled by a qualified technician. After the setting is completed, the setting percentage or value is hidden by the actuator. Without removing the actuator there is no way for the facility manager to check the actual setting.

The external adjustment requires a larger valve body but does provide benefits to commissioning engineers and facility managers. The larger scale can be read even in small and dark places; a larger dial makes rotation easier. Larger scales usually have easy identifiable reference points. There are locking or anti-tampering systems to avoid unexpected modification of the pre-setting. A dedicated technician to remove the actuator is not required. The setting dial can be operated even if the actuator is attached. The facility manager can easily check the set position and can modify the setting position if required during the building lifetime.

Internal presetting

External presetting

Tolerances

CIBSE Code W provides commissioning tolerances that are typically in the range -5% to + 10% for most small heating cooling coils, tightening to -0% to + 10% for larger coils.

In practice, these tolerances may prove difficult to achieve using PICVs if the advice provided in the previous 3 sections of this guide have not been followed.

The critical issue is to achieve flow rate values that are greater than the minimum tolerance level. Hence, as described in the commissioning method statements in the previous chapter, it is prudent to set flow rates at values that are in the range +10 to +15% of their design values. This will allow variation of up to -15% before the minimum tolerance limit is exceeded. Similarly, the pump should be sized to cope with a flow of up to 120% of the maximum design value (as recommended on page 23 of this guide) in order to accommodate flow variations upwards from the set design values.

Pettinaroli

PICVs from Pettinaroli

As specialist solution providers for the balancing, controlling and metering of water distribution systems in the HVAC industry, Pettinaroli is dedicated to creating and supplying innovative and efficient products that meet the rapidly changing needs of buildings and users alike.

In addition to a range of PICVs, Pettinaroli supplies an extensive portfolio of products, including the PCS range of valve assemblies for fan coils, chilled beams and other hydronic terminal units, Filterball® Valves, Terminator® Commissioning valves, Ball Valves and Manifold Systems. This is in addition to the ground breaking Remote® Commissioning concept - a system solution that offers all that is required to balance and control water flow to hydronic terminal units in a truly flexible and energy efficient way.

EVOPICV, Axial PICV

The Axial design valve, known as EVOPICV, is selected for several reasons, such as:

- A quick turnaround is required
- The BMS controller is not capable of Remote® Commissioning
- A more traditional commissioning programme is expected
- The construction programme is already set
- Constant flow at the end of the circuit is required
- More compact design
- Intrinsic equal percentage or linear characteristic
- BSP and NPT thread available (threaded valves). DIN and ANSI flange standard available (flanged valves)

Pettinaroli Range of Axial PICV is made split into Equal percentage and linear valves:

- 91 and 93, intrinsic equal percentage characteristic and externally adjustable pre-setting
- 92, intrinsic linear characteristic and dirt-free differential pressure regulator
- 94F, equal percentage and linear characteristic provided by the dedicated actuator

The valve 91/93 has some great features:

- The control valve shutter has an intrinsic equal percentage characteristic, suitable for water-to-air terminal units, such as fan coil units, chilled beams or air handling units
- The rising stem design ensures that valve stroke is maintained even when the valve is pre-set (with no loss of stroke)
- Flow rates can be adjusted and valves locked in position, even with the actuator in place
- It can be maintained by using a dedicated tool and uni-directional; suitable for installation in either the flow or return pipework providing the flow direction arrow is correctly observed
- The valve body is manufactured in dezincification resistant brass (DZR) and is available in 4 sizes (DN15, DN20, DN25 and DN32) and different flow rates
- It has a large, easy to use, black hand-wheel with integrated setting ring and locking facility, used for valve setting and flow rate adjustment
- It is actuated by means of an electromotive actuator, a thermoelectric actuator or a TRV sensor, always providing equal percentage characteristic
- Test points are included in the design of the EVOPICV for measurement of differential pressure in order to verify that the valve is operating correctly

91 Series

93 Series

The valve 92 has some great features:

- The control valve shutter has an intrinsic linear characteristic, suitable for water-to-water terminal units, such as heat exchangers
- The design ensures a smaller body which can fit into narrow spaces
- Flow rates can be adjusted through a graduated knob which can be locked in position once the actuator is in place.
- The presetting reduces the stroke of the control valve: the remote presetting is achievable.
- It can be easily maintained by using a standard spanner; suitable for installation in either the flow or return pipework providing the flow direction arrow is correctly observed
- The valve body is manufactured in dezincification resistant brass (DZR) and is available in different sizes and flow rates.
- The dirt-free design of differential pressure regulator ensures to operate the valve also when quality water cannot be maintained. This makes the valve a very long lasting PICV.
- It is actuated by means of an electromotive actuator, a thermoelectric actuator or a TRV sensor, always providing equal percentage characteristic
- Test points are included in the design of the EVOPICV for measurement of differential pressure in order to verify that the valve is operating correctly

92 Series

The valve 94F has some great features:

- The control valve has an equal percentage and linear characteristic (programmable), provided by the dedicated actuator (specifically developed and set for each valve); suitable for water-to-air terminal units, and water-to-water
- Flow rates can be adjusted through the actuator: the in-built control characteristics ensure perfect linear or equal-percentage characteristics at every presetting.
- Uni-directional; suitable for installation in either the flow or return pipework providing the flow direction arrow is correctly observed
- The valve body is manufactured in dezincification ductile iron
- Large size range and flow rates: from 2” to 10”; from 5.000 l/h to 500.000 l/h
- It is actuated by means of an electromotive smart actuator (included); feedback, fail safe and manual override available
- Test points are included in the design of the EVOPICV for measurement of differential pressure in order to verify that the valve is operating correctly

94F Series

Rotary PICV

The Rotary valve, known as EVOPICVR, is selected for a number of reasons, such as:

- The client requires enhanced flexibility for:
    - Seasonal commissioning
    - Flexibility on room layouts
    - Programmable flushing routines
- Intrinsic equal percentage control is required
- The BMS controller is Remote® Commissioning capable
- A more engineered solution is required
- Shut-off valve

81 Series

The valve has some great features:

- The valve design incorporates a characterised ball, with various profiles available to suit the design flow rate, covering standard flow, low flow and very low flow requirements
- Constant pressure is maintained across the valve by the diaphragm of the differential pressure controller
- The valve has an ISO 5221 F03 and F04 mounting pad for quick and easy installation of actuators
- The valve body is manufactured in dezincification resistant brass (DZR) in sizes DN15, DN20 (81) DN25 and DN32 (83)
- The valve is also available in sizes DN40 and DN50 in ductile iron (83); flushing mode by turning the ball 180°
- It is maintenance free and uni-directional, suitable for installation in either the flow or return pipework providing the flow direction arrow is correctly observed
- There are different models which can be suitable for different actuators.

83 Series

CHECKLIST

Prerequisite

1. Ensure all valves in the complete system are in fully open condition. All bypasses in the systems shall be closed.
2. Ensure all the flushing activities are completed.
3. Ensure all actuators are not installed or the actuators are powered to on condition
4. Set the pump to the design speed setting. Turn the pump off and then back on again. Measure the differential pressure across the PICV using the pressure tapings incorporated in the PICV. If the measured pressure differential exceeds the start-up value provided in the selection sheet of the PICV, proceed to "measurement and setting".
5. If the start-up pressure cannot be achieved, close down sections of the pipework system or increase the pump speed until the start-up pressure is exceeded at the measurement point. Then turn the pump off and back on before commencing to measurement and setting.
6. Check the flow rate in the main branch (with the DRV installed) to verify that its value is equal to the sum of the pre-set PICV flow rates fed from the branch.
7. Manometer used shall be calibrated ones only.
8. None of the PICV shall be reverse flushed.
9. No Flow can be measured from the PICV only Start Up Pressure can be measured.
10. For Flow verification on Branch DRV flow can be measured to verify the total Branch PICV's Flow rate.

Sr. No.	Unit Reference	Location	PICV Model	Presetting position	PICV Pressure Range		Measured Pr.	Acceptable Range
					Min kPa	Max kPa	kPa	Yes/No
						600		
						600		
						600		
						600		
						600		
						600		
						600		
						600		
						600		

Further Reading

Further details on system design and commissioning can be found in:

Pettinaroli guide: assessment of alternative valve solutions for heating and chiller water system

CIBSE Guide H Building control systems

CIBSE knowledge Series Guide KS7 Variable flow pipework systems

CIBSE Commissioning Code W:2010

BSRIA Guide BG44/2013 Seasonal Commissioning

BSRIA Guide BG2/2010 Commissioning Water Systems

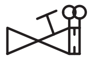
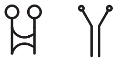
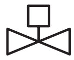
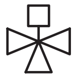
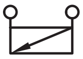
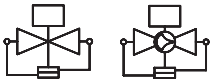
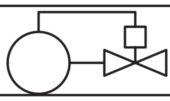
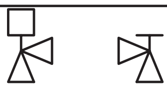
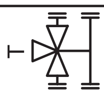
BSRIA Guide BG29/2012 Pre-commission Cleaning Of Pipework Systems

BSRIA Guide BG12/2011 Energy Efficient Pumping Systems

BSRIA Guide 30/2007 HVAC Building Services Calculations Second Edition

BSRIA Guide BG51/2014 Selection of Control Valves in Variable Flow Systems

KEY TO SCHEMATIC SYMBOLS

IV		ISOLATION VALVE
TWV		THREE WAY VALVE
STR		FILTERBALL / STRAINER
DRV		DOUBLE REGULATING VALVE
CS		COMMISSIONING SET
FMD		FLOW MEASUREMENT DEVICE
2PMV		2 PORT CONTROL VALVE
3PMV		3 PORT CONTROL VALVE
CFL		CONSTANT FLOW LIMITER
PICV		PRESSURE INDEPENDENT CONTROLVALVE
EPICV		ELECTRONIC CONTROLVALVE
DPCV		DIFFERENTIAL PRESSURE CONTROL VALVE
PRV		PRESSURE REDUCING VALVE
NRV		NON RETURN VALVE
TRV LSV		TRV / LOCKSHIELD VALVE
DC		DRAIN COCK
AV		AIR VENT
SV		PRESSURE TEMPERATURE RELIEF VALVE
IV		FLUSHING BYPASS VALVE
TP		P/T TEST POINT
UN	=	UNION

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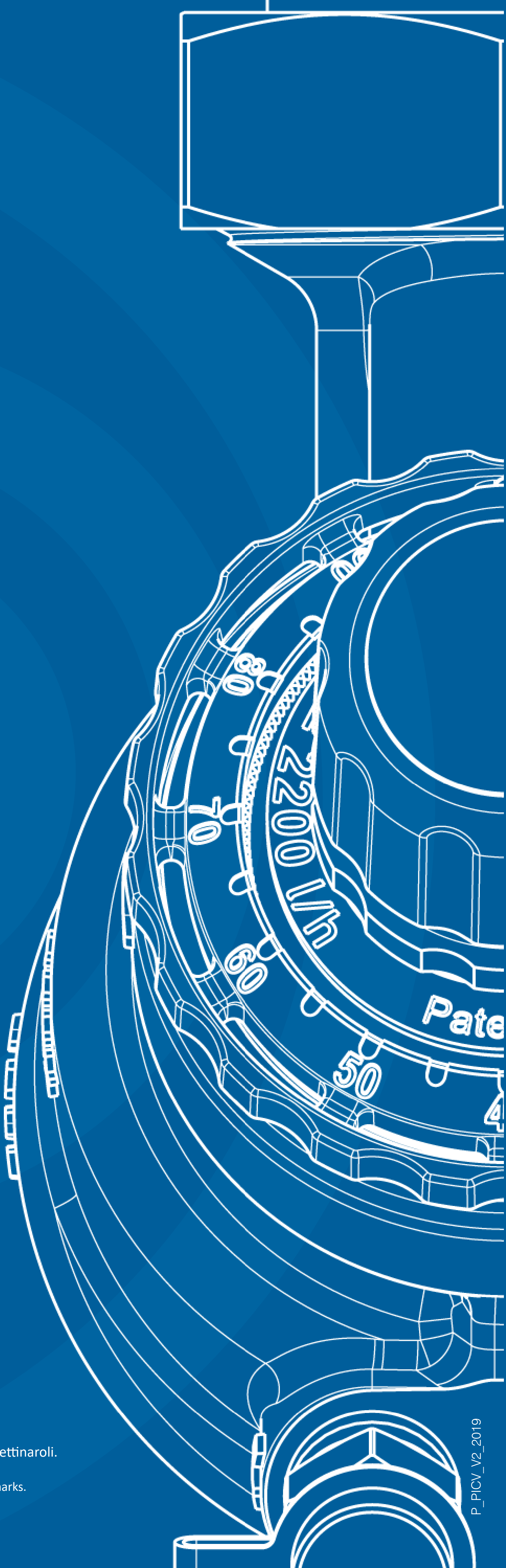

bsi. ISO 9001 Quality Management FM01402

bsi. ISO 14001 Environmental Management EMS72948

bsi. ISO 50001 Energy Management ENMS582052

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