FRATELLI PETTINAROLI S.p.A.

CLIMATE SYSTEMS TECHNOLOGY

The Definitive Guide to Pressure Independent Control Valves

Technical Manual

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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 of a similar type.

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.

PICVs offer the potential of improved control of thermal comfort and significant energy savings. However, the operating behaviour of the valves must be taken into account. This will require a different approach than for systems based on more traditional 2, 3 or 4 port control valve solutions.

I have previously been associated with the writing of BSRIA and CIBSE publications on related subjects including:

- CIBSE Code W: Water distribution systems
- CIBSE KS 7 Variable flow pipework systems
- BSRIA BG2/2010: Commissioning Water Systems.

This guide draws on the design and commissioning guidance provided in these existing guides and expands on those issues particularly relevant to PICVs.

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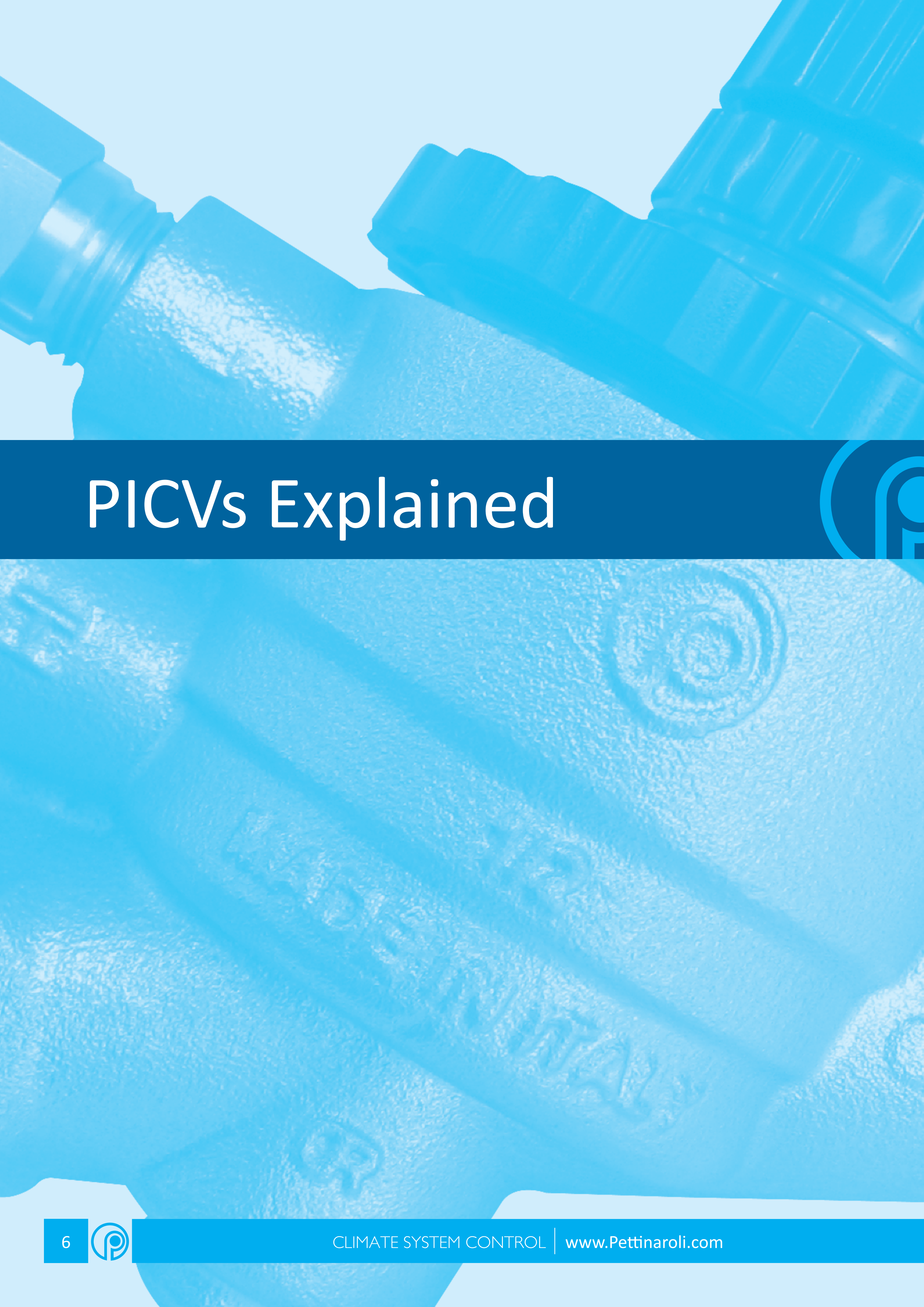
Introduction

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
- Remote® commissioning from a centralised BMS

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.



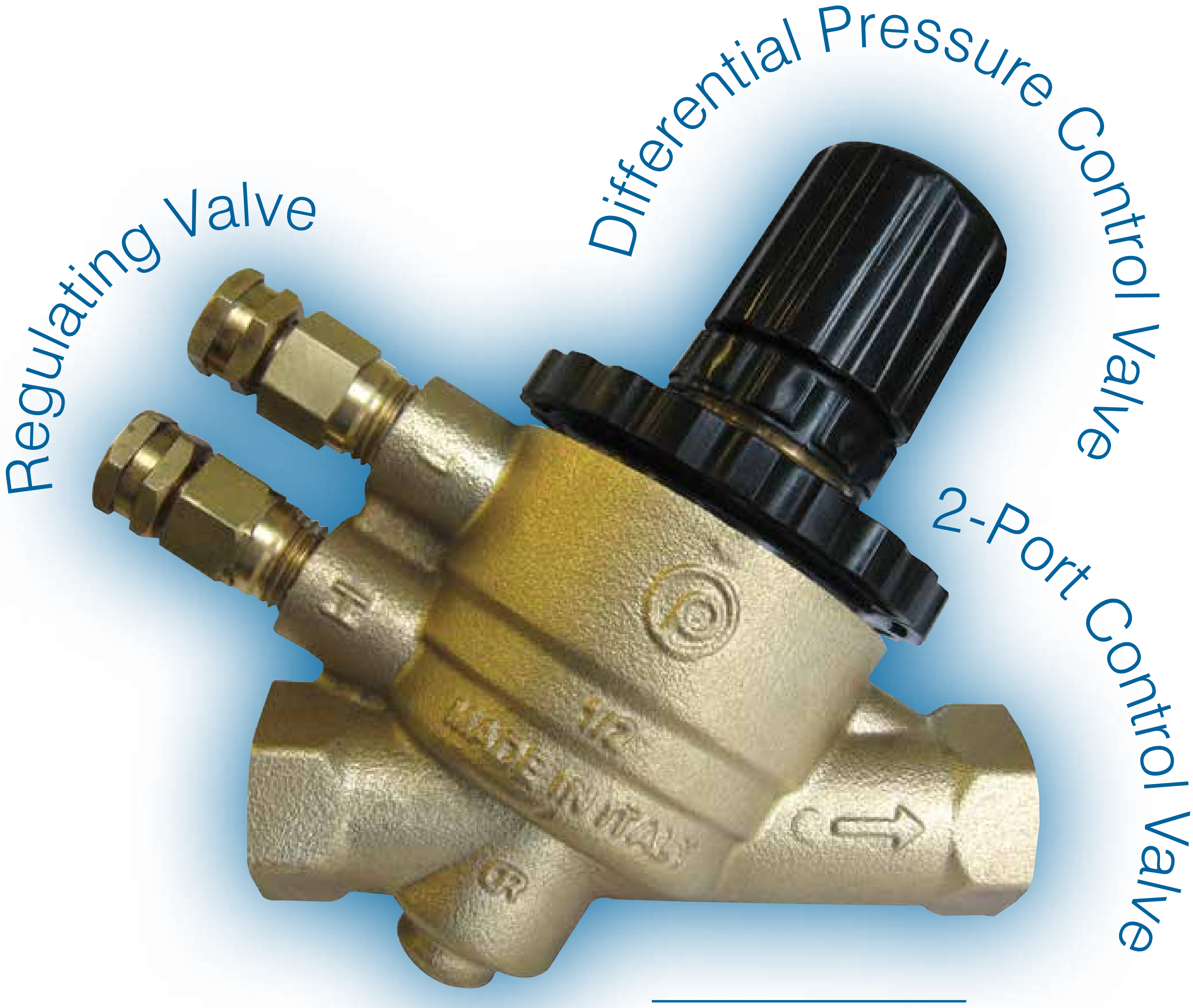
PICVs Explained

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.

PICVs resolve all of 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.

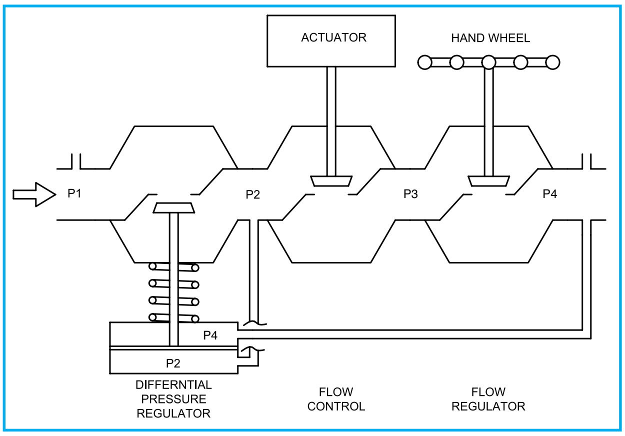


Figure 1a. Three section PICV

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 remain constant at all times 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 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

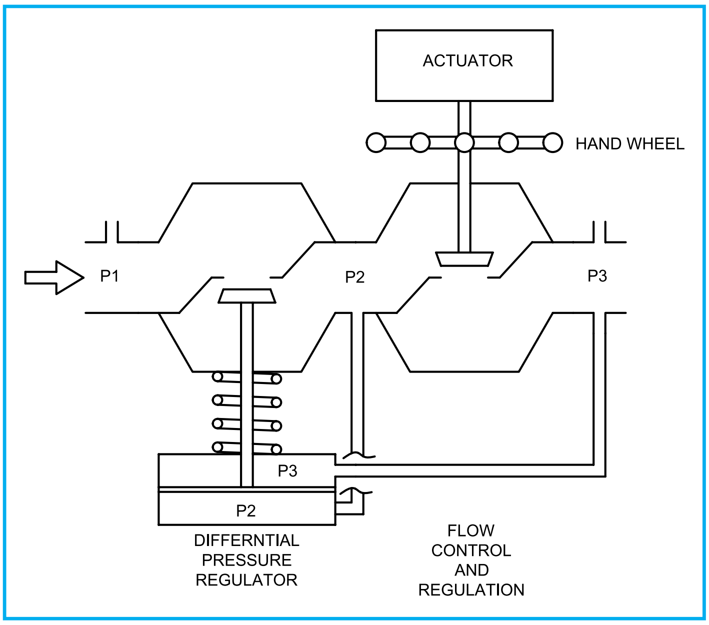


Figure 1b. Two section PICV

body. 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. Modulating flow control is only available across the remaining travel of the valve, after the flow has been set.

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

What will a PICV do?

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

It can be seen that 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.

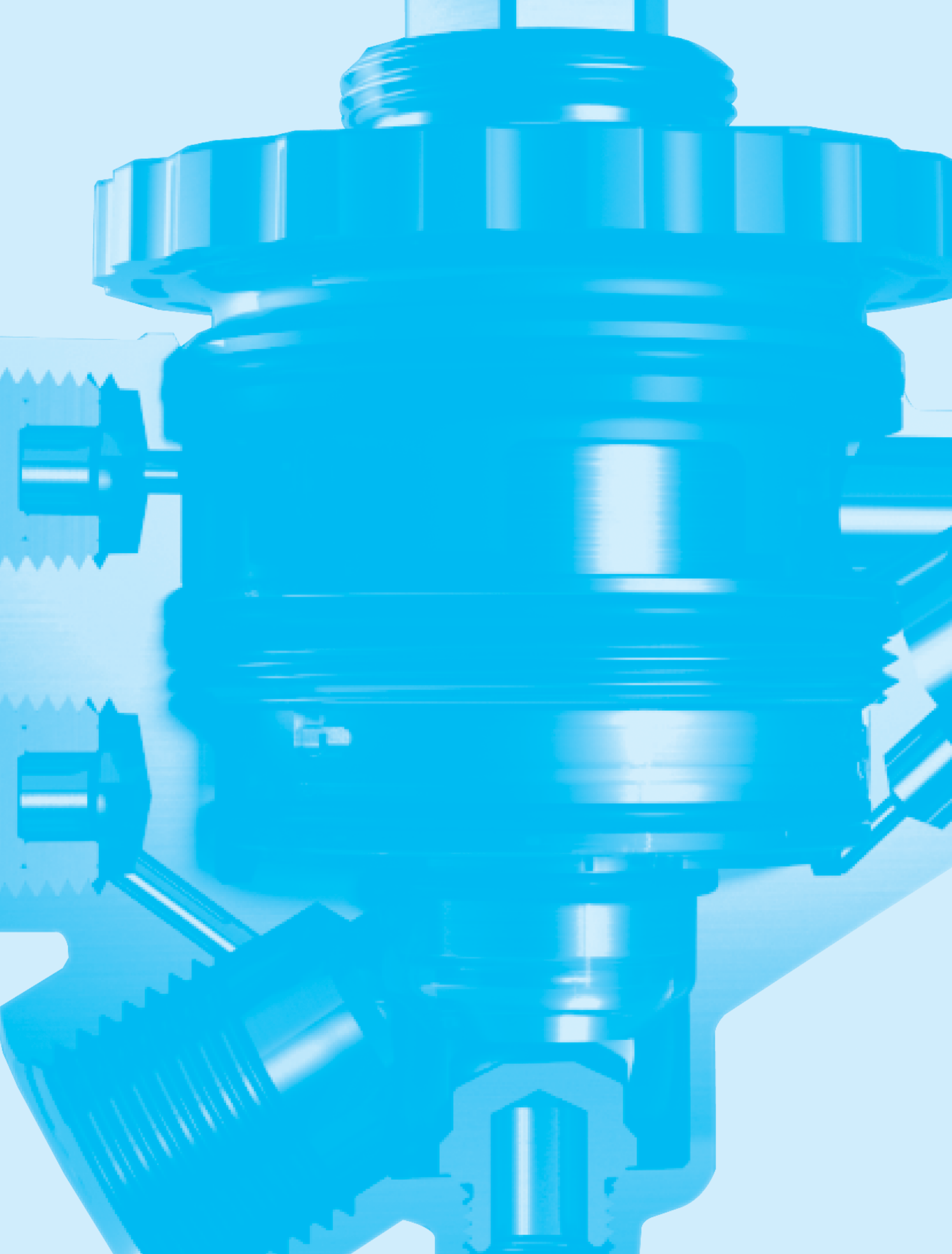
Firstly, with the control valve fully open and the flow setting device set to its required value, the valve effectively becomes a constant flow regulator (since a constant pressure differential across a constant resistance will result in a constant flow rate). Hence, if installed without the actuator, 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 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



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.

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.

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. It can be seen that 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.

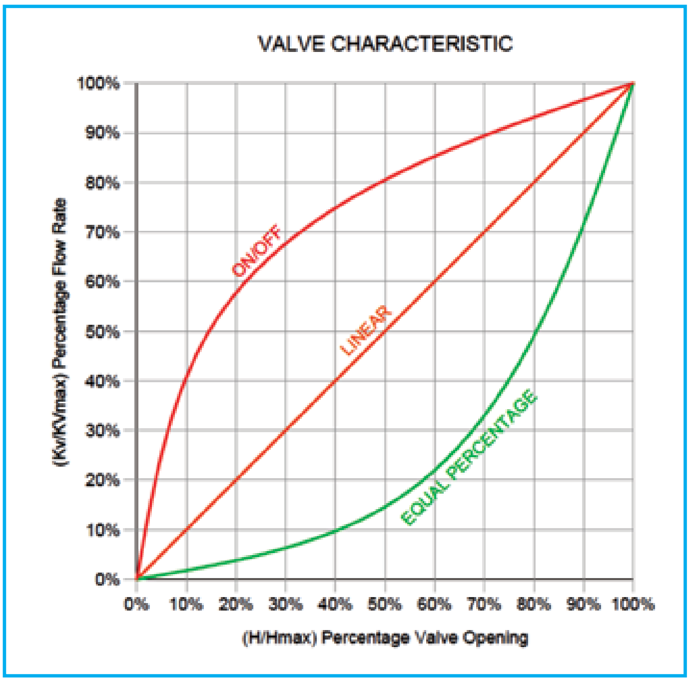


Figure 2. Control valve characteristics

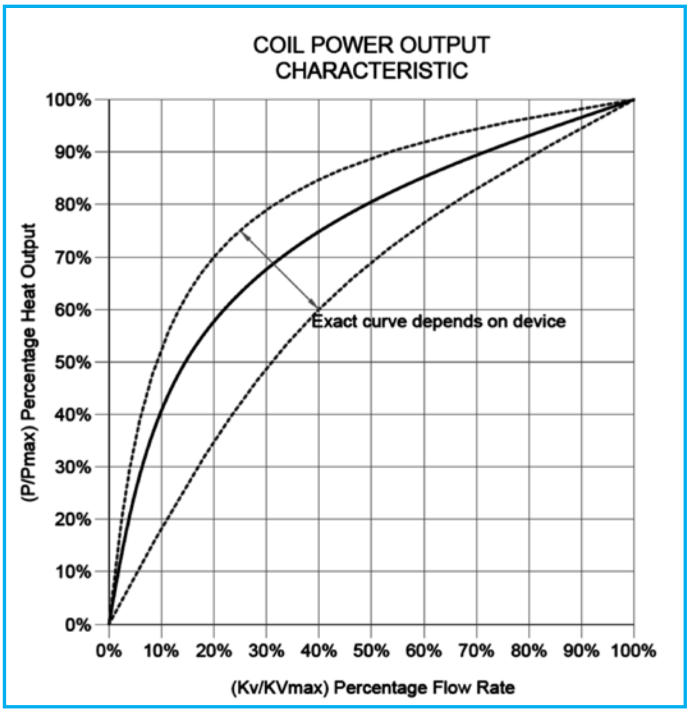


Figure 3. Heat transfer versus percentage design flow rate

Figure 4 shows the way that the heat transfer characteristic of the heating or cooling coil is modified by various control valve characteristics. It can be seen that an equal percentage characteristic gives the best control with each change in heat transfer being equal to each change in valve opening.

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.

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.

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.

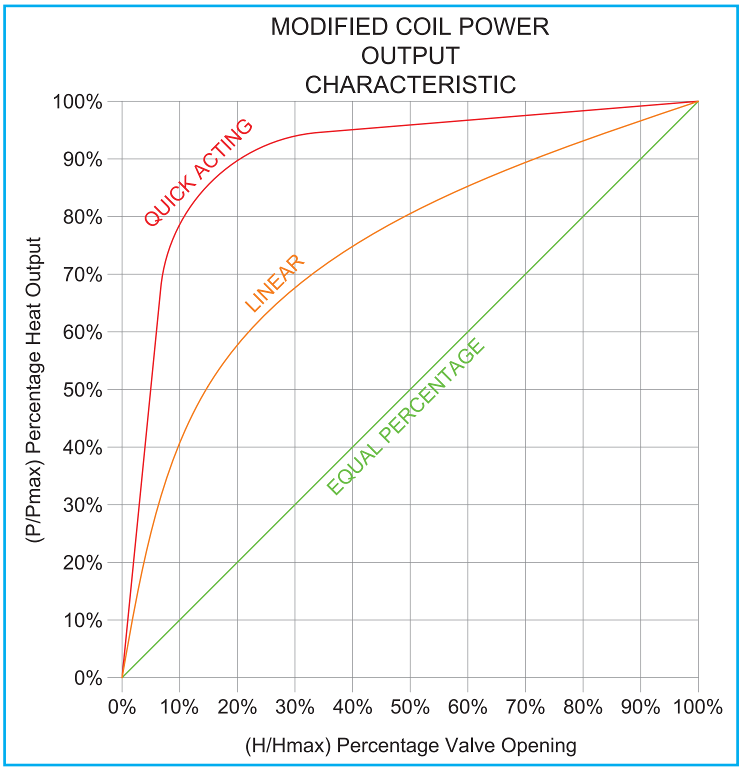


Figure 4. Heat transfer versus valve opening

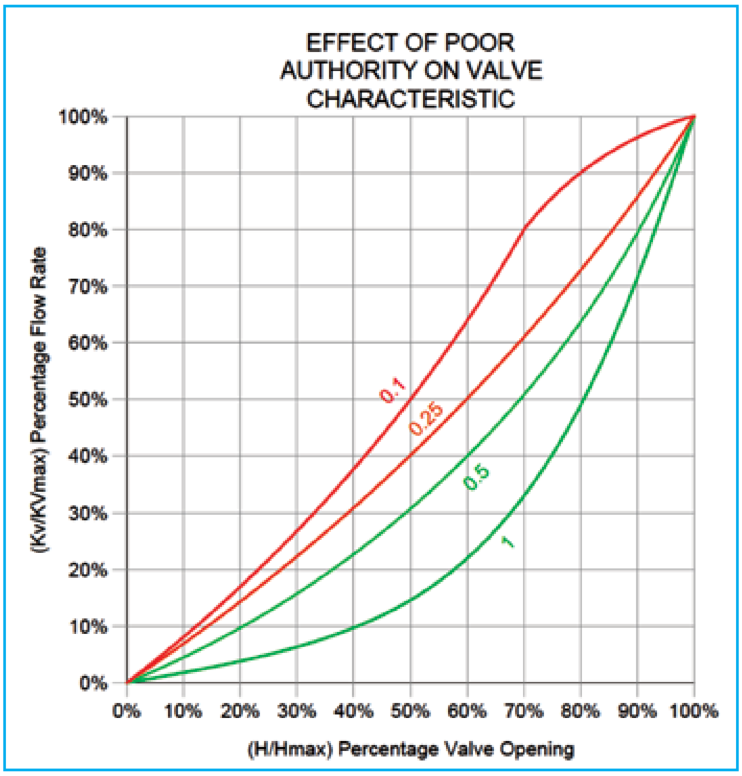


Figure 5. Loss of authority on equal percentage control valve

Active control of room 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.

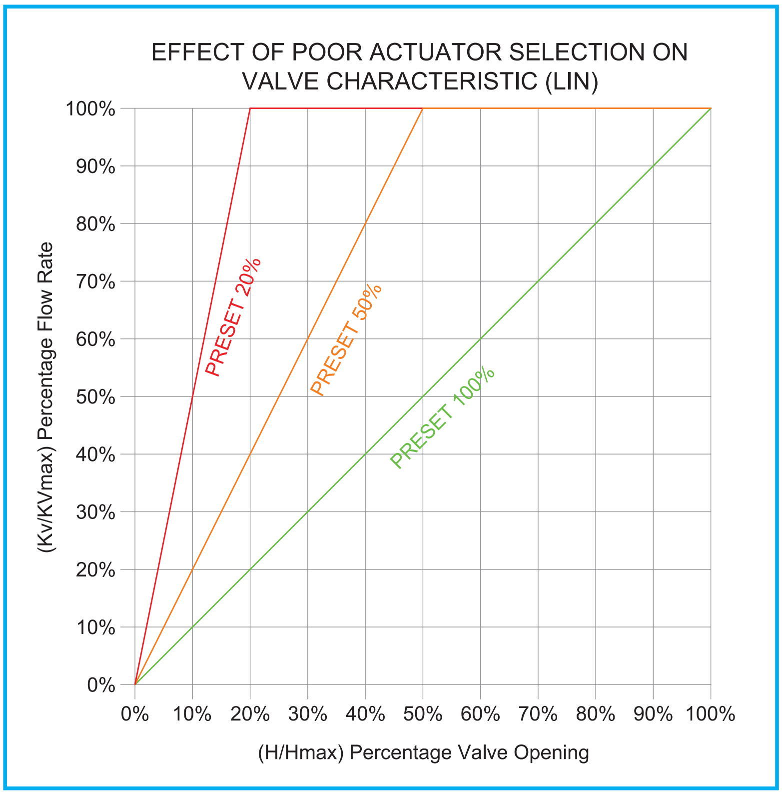


Figure 6. Degradation of valve authority (linear characteristic) by fitting of incorrect actuator to stroke limited valve

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.

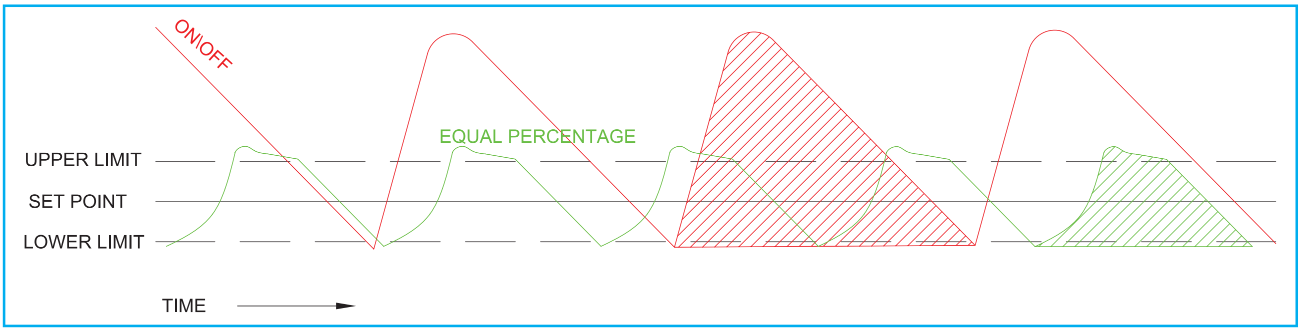


Figure 7. Typical variations in off-coil temperature for heating coils

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.

It can be seen that 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.

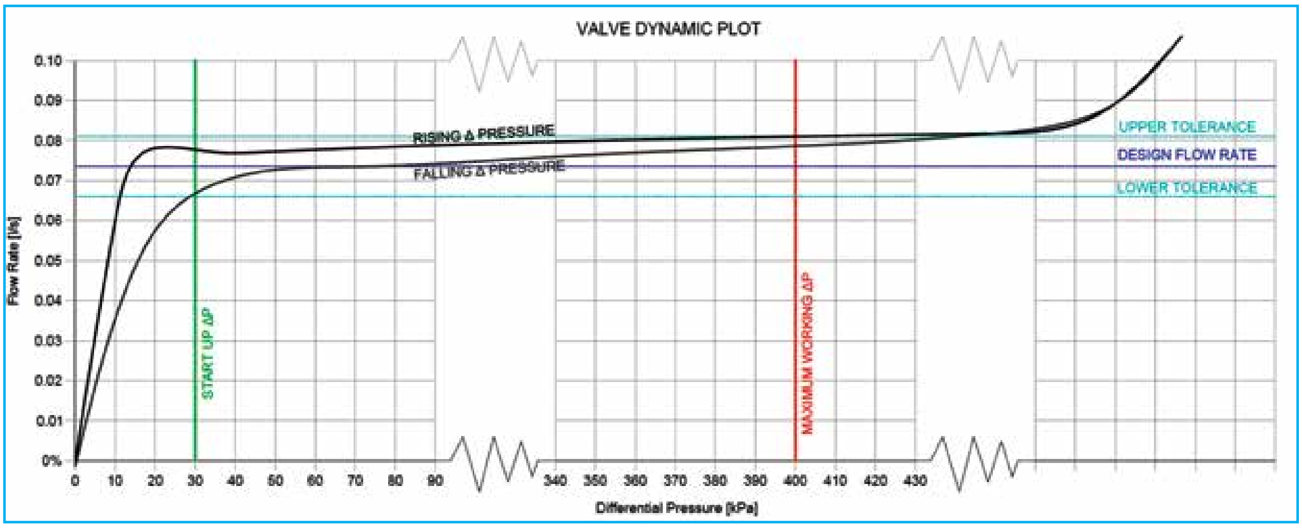


Figure 8. Flow Rate versus Differential Pressure (Typical PICV)

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 of these 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.

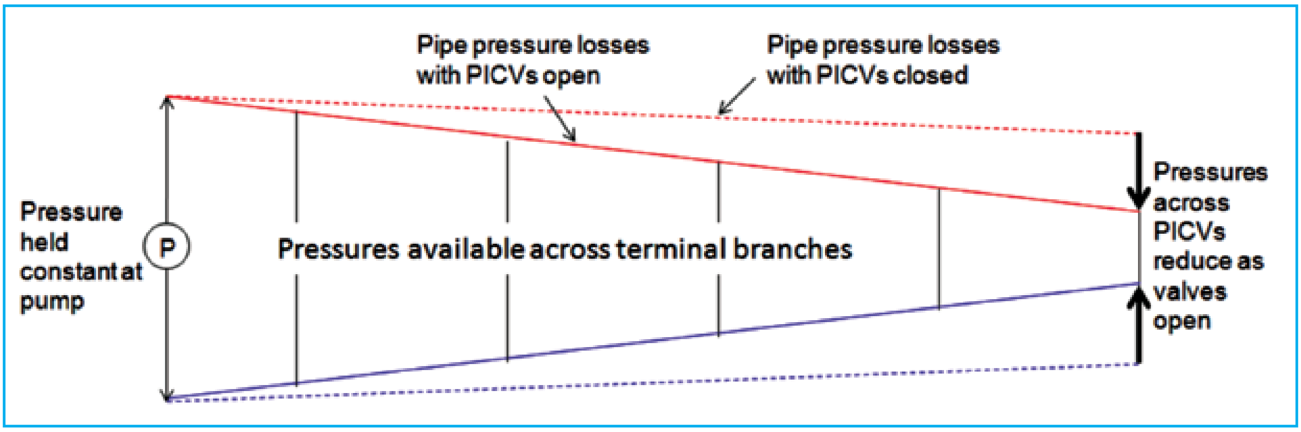


Figure 9. DP sensor fitted at pump

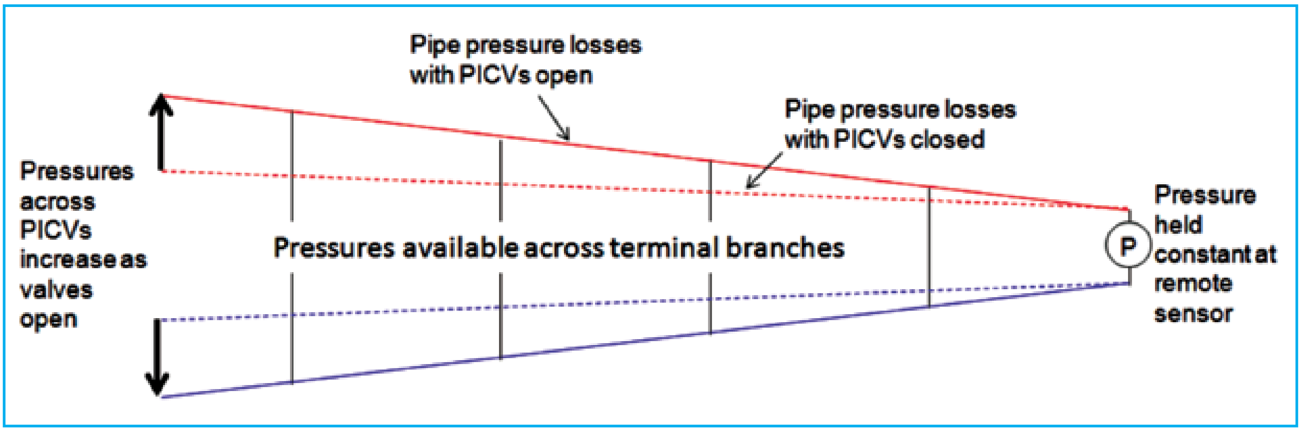


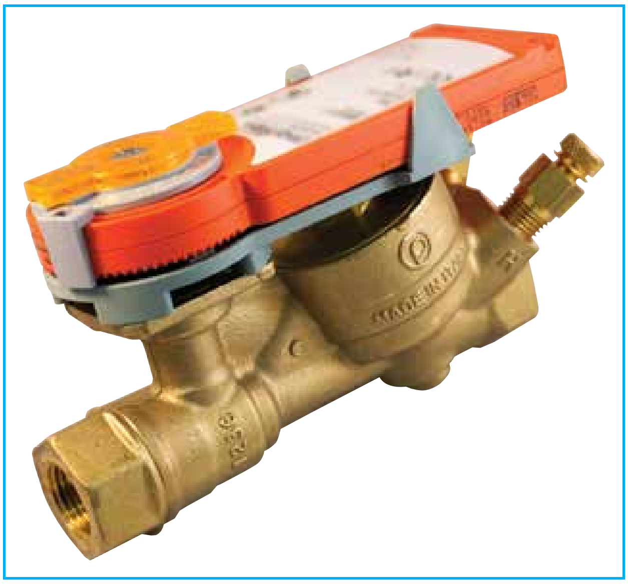
Figure 10. DP sensor fitted at index

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



Rotary PICCV with Actuator

against to close the valve. Multi-turn or characterised ball types have a rotating stem which the actuator must turn to close the valve.

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.

Both full stroke and stroke limited valve solutions are capable of providing 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.

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.

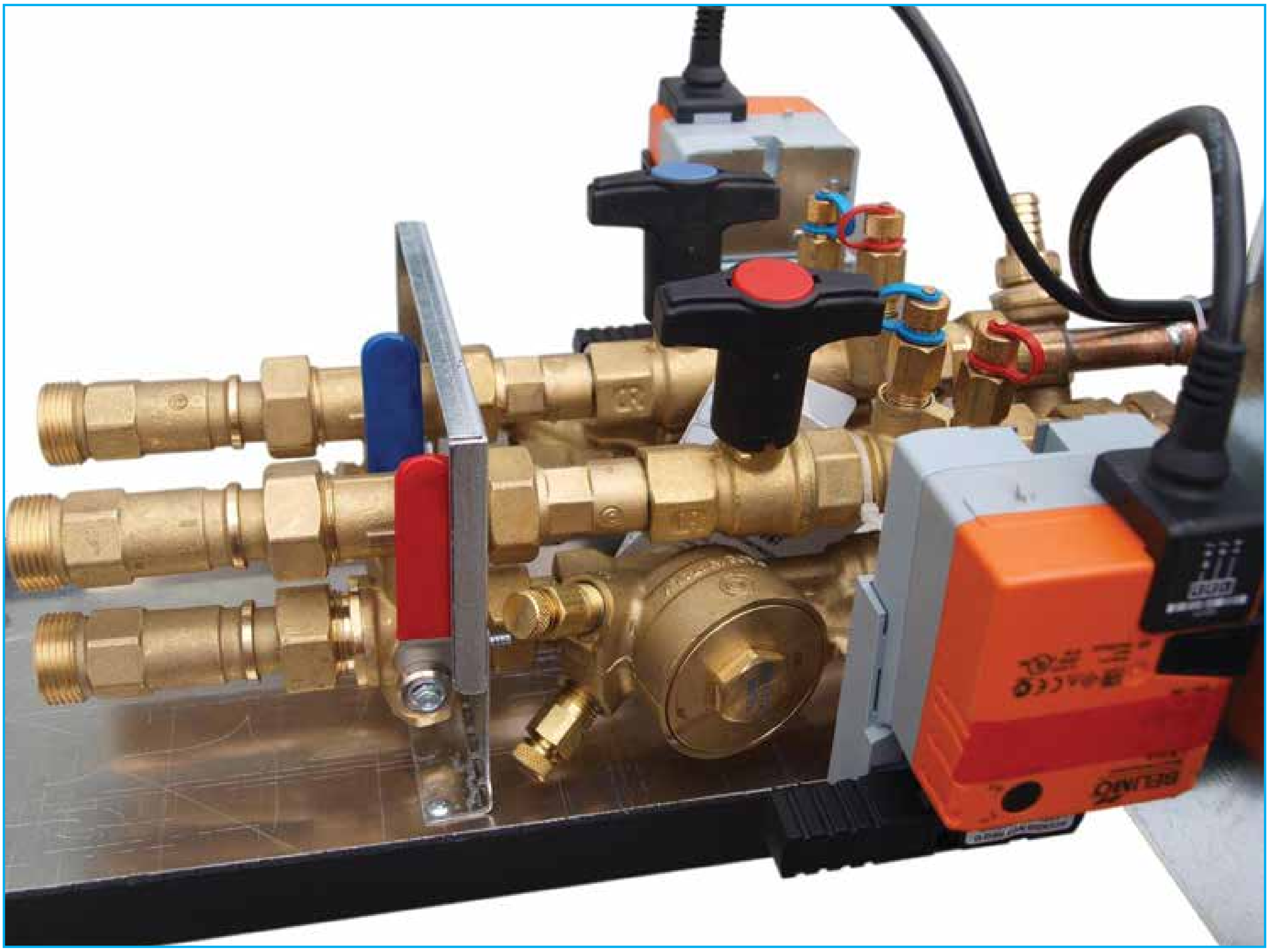
A standard BMS controller with proprietary strategy can control both heating and cooling outputs for individual terminal units. Each controller can be pre-programmed with the heating and cooling valve references and maximum design flow rate values for each valve.

During commissioning, each rotary 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.

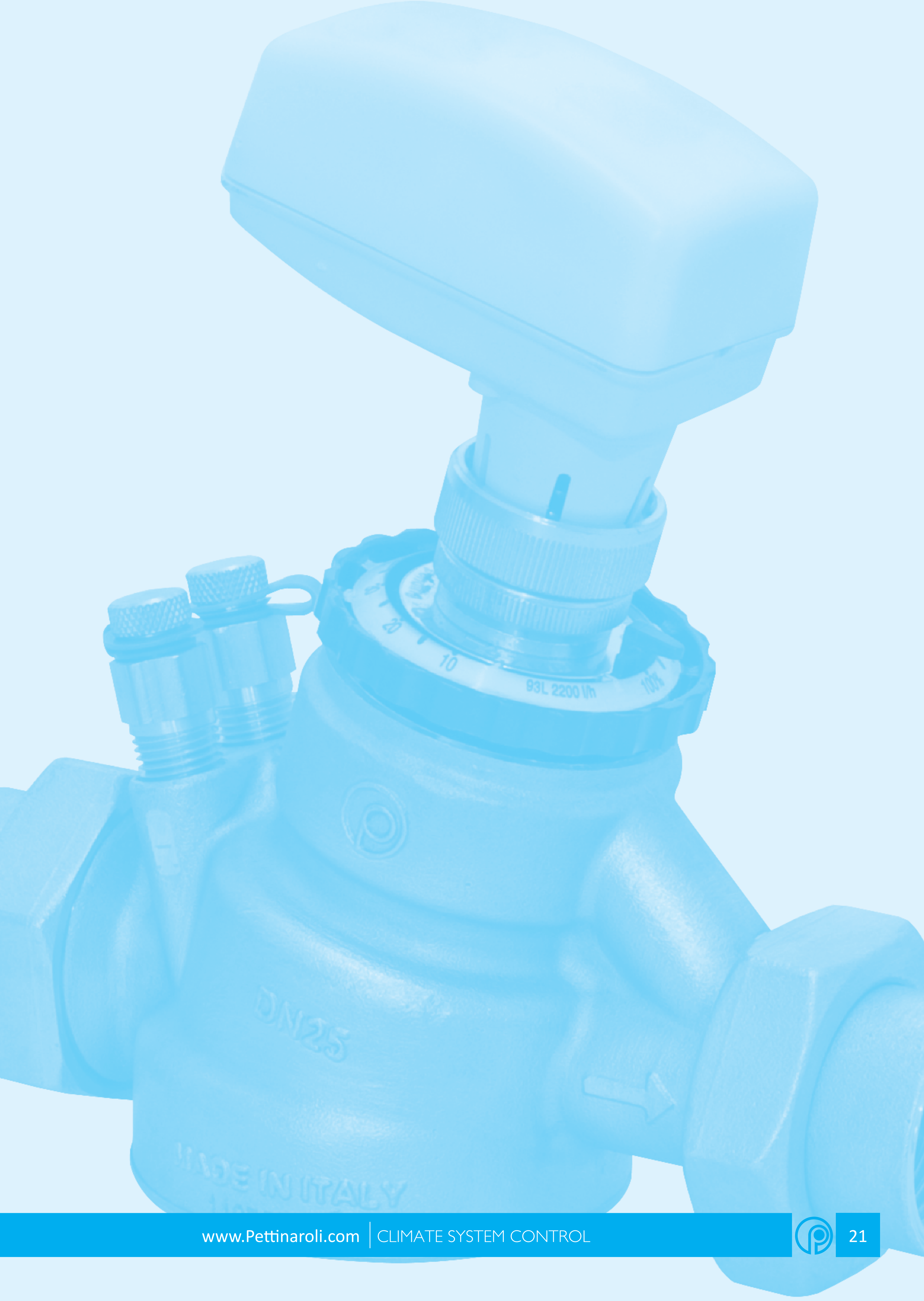
This approach provides a flexible method for establishing design flow rates during commissioning. Once set, flows will be maintained within the limits of accuracy dictated by the hysteresis limits of the spring, as explained on page 16.

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 aforementioned hysteresis effect.



Prefabricated valve assembley incorporating 2 section Rotary PICV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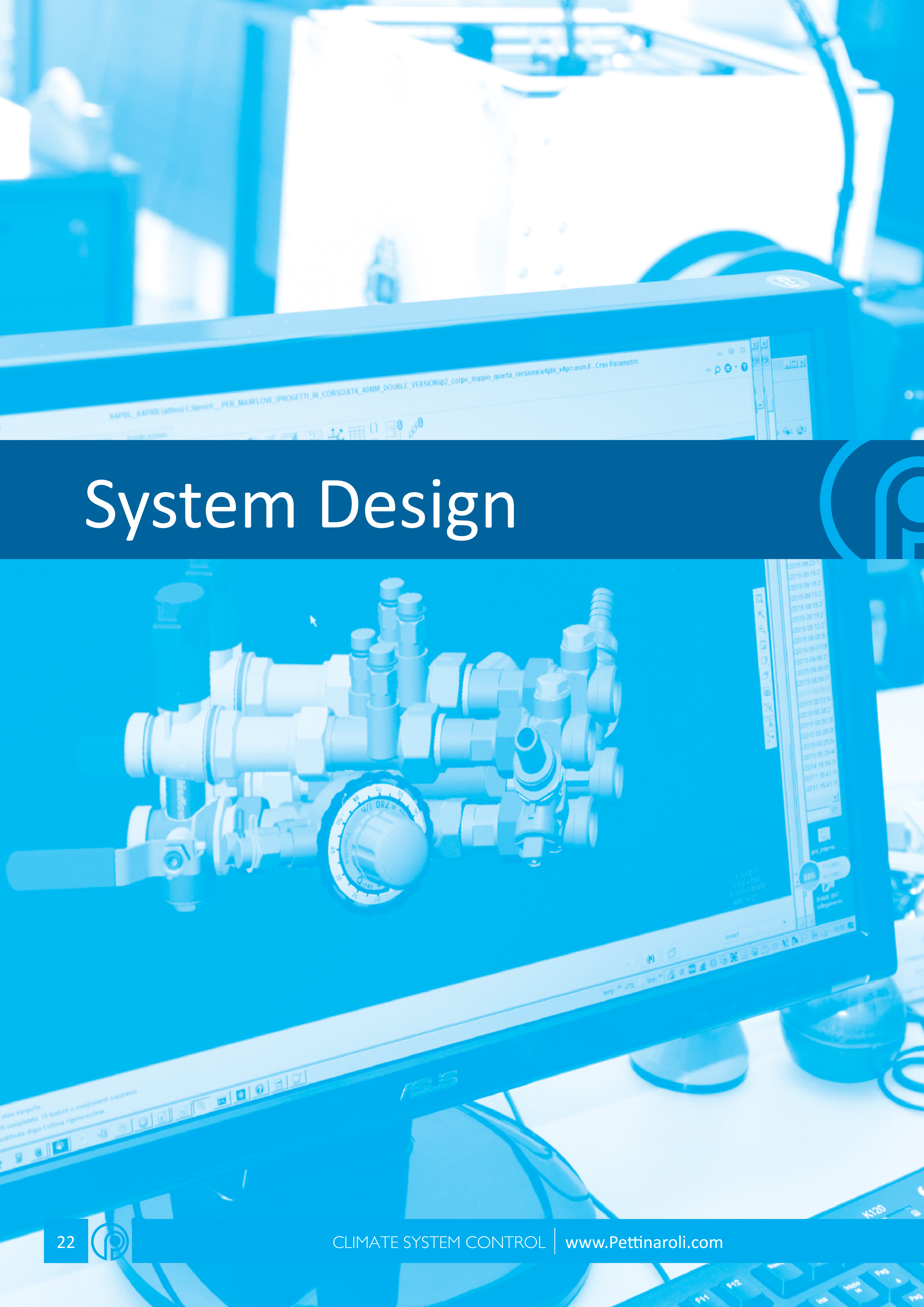
System Design



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.

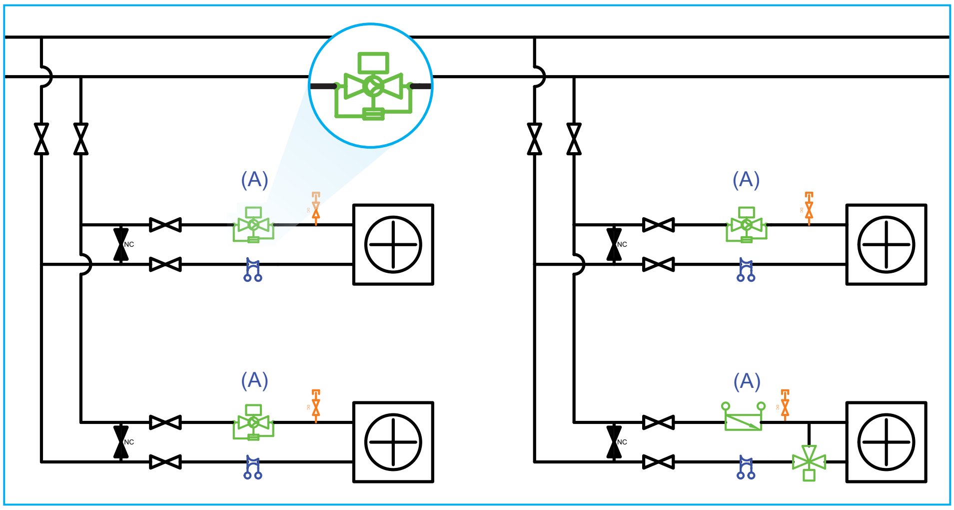


Figure 11. Typical locations for PICVs

A- Terminal Unit
B - Multi Radiator Branch
C - Single Radiator
D - Future Use Loop
E - End of Line Bypass

Please refer to key on page 40

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 is capable of delivering 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.

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 only 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.

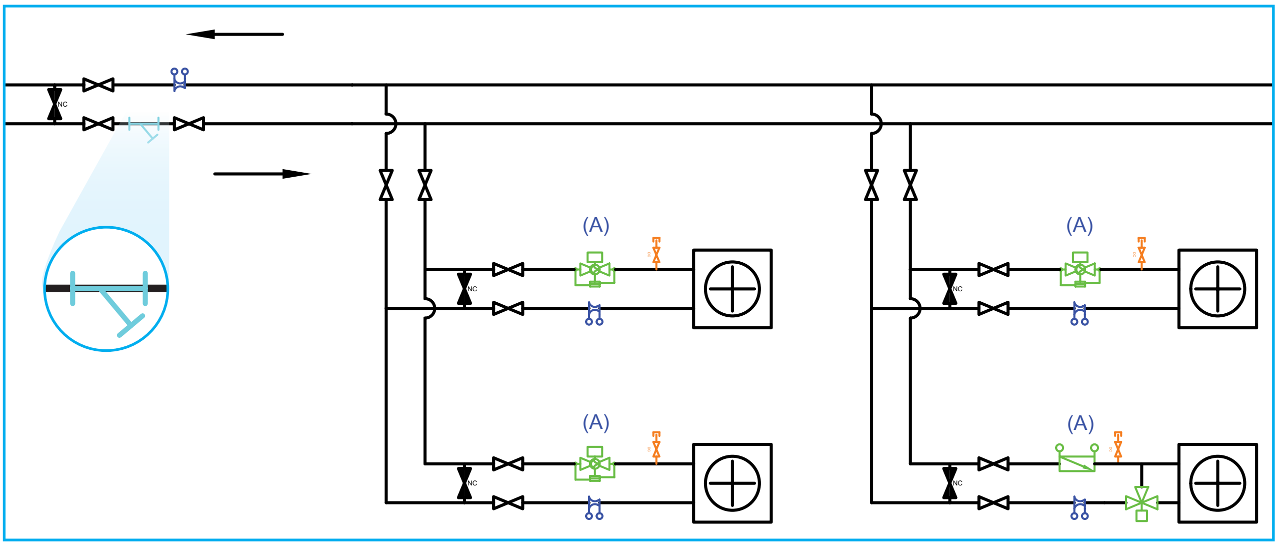


Figure 12. Strainers in main pipe branches

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 full bore 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.

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.

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.

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.

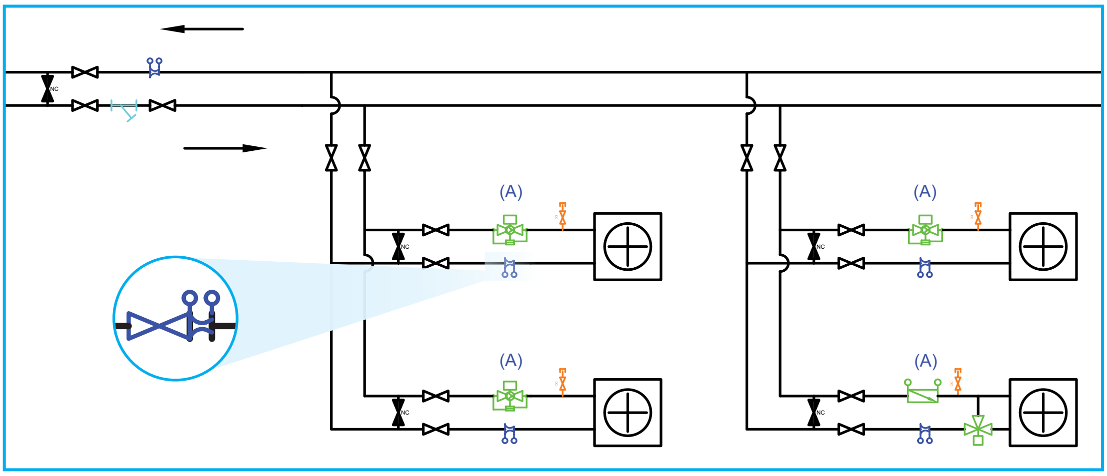


Figure 13. Location of flow measurement devices

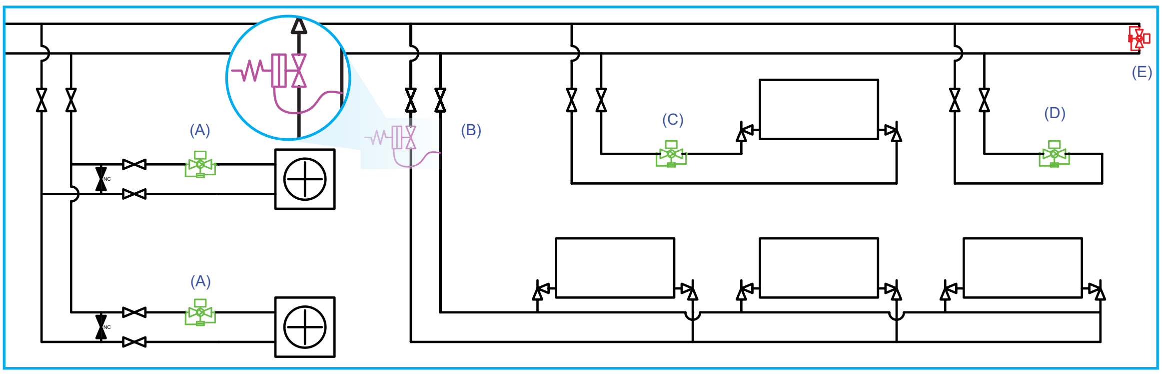


Figure 14. Branches requiring additional differential pressure control valves

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.

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.

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.

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 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.**

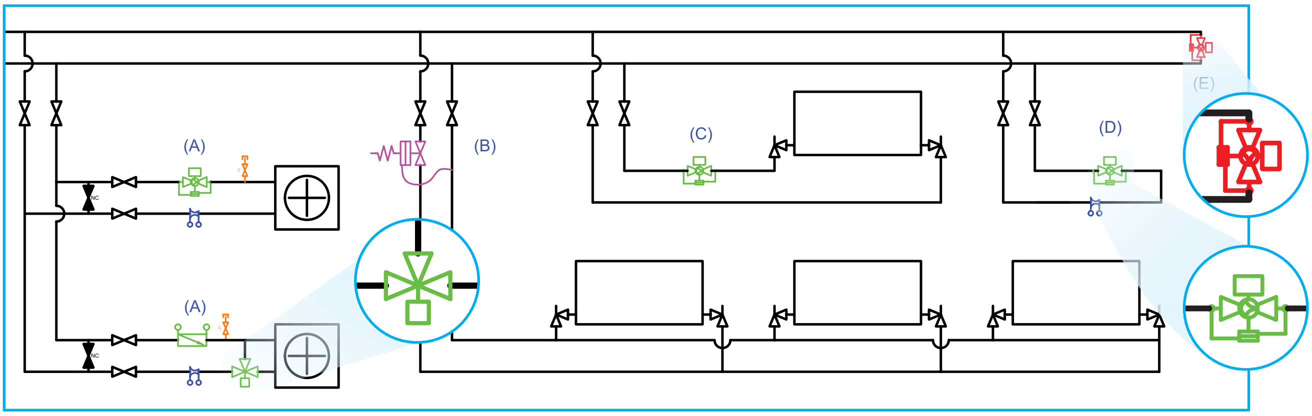
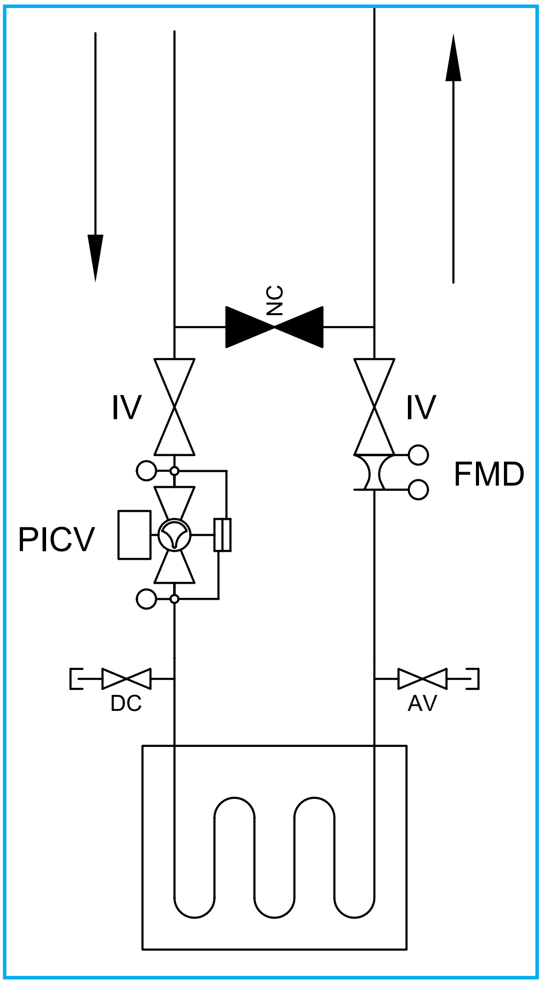
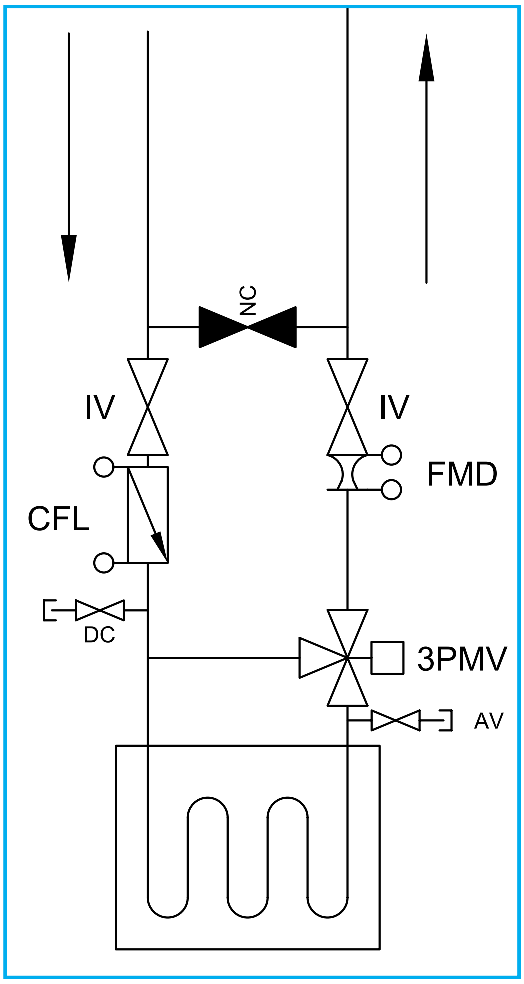


Figure 15. System by-passes

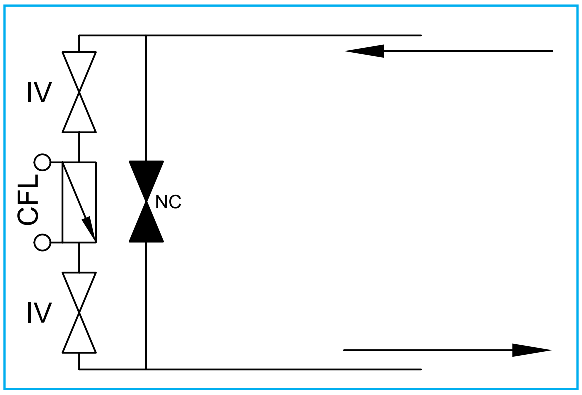
Typical Schematics



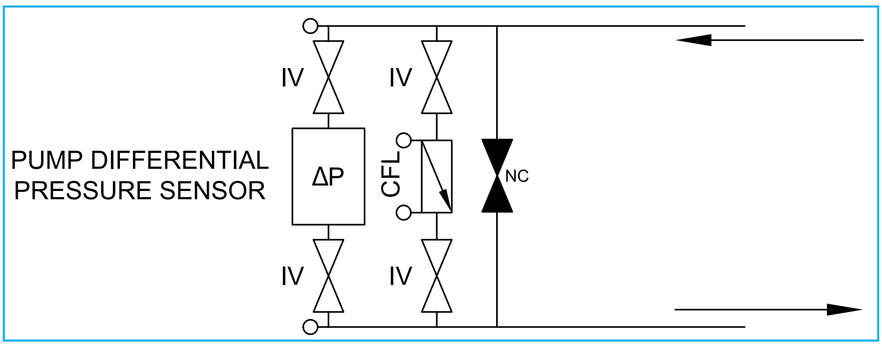
Typical PICV Terminal Schematic



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.

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 tappings 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 in the "PICV Control - Essential Consideration" chapter 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 tappings 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-synchronise.
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.


100%

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 Xterminator® 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 a number of 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

The valve has some great features:

- 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's maintenance free 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 currently available in 4 sizes: DN15, DN20, DN25 and DN32
- 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
- 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

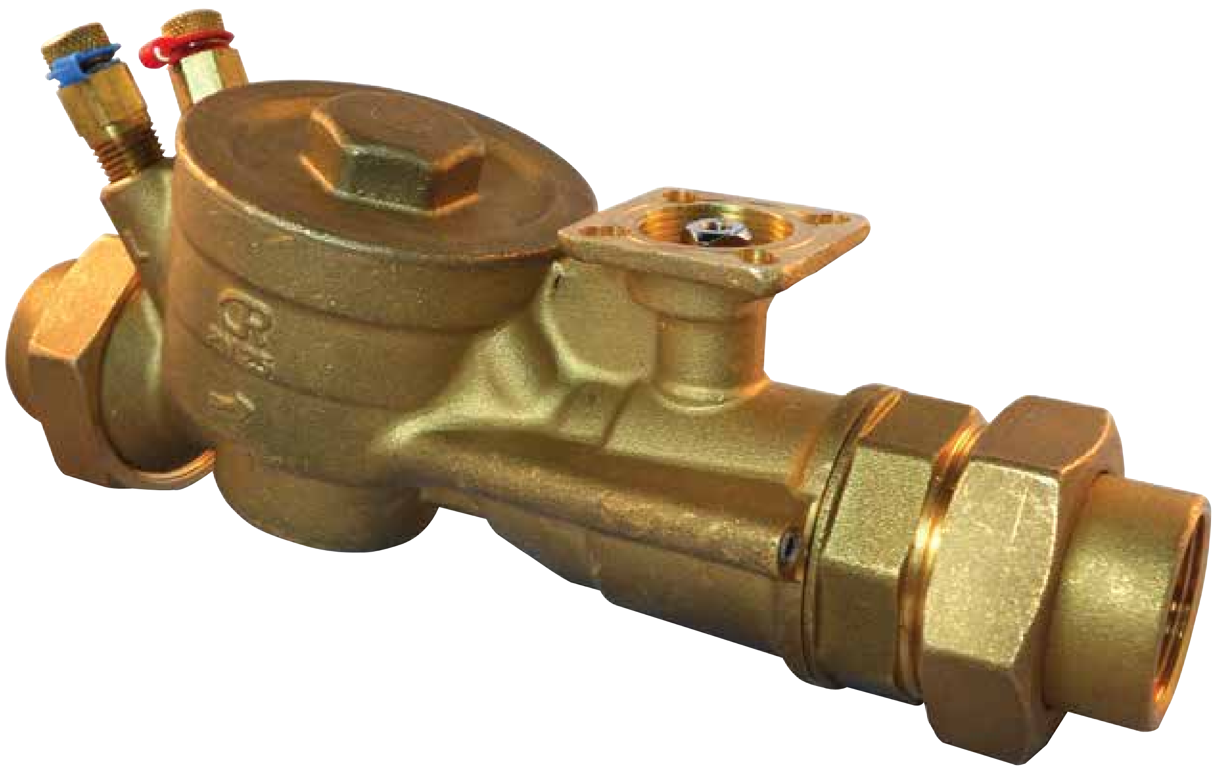
EVOPICV-R, Rotary PICV

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

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 mounting pad for quick and easy installation of actuators
- It is suitable for maximum flow rates between 0.01 and 4.7l/s
- The valve body is manufactured in dezincification resistant brass (DZR) in sizes DN15, DN20, DN25 and DN32
- The valve is also available in sizes DN40 and DN50 in cast iron
- 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



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

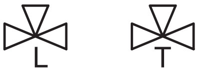
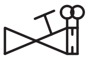
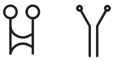
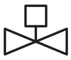
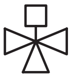
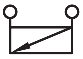
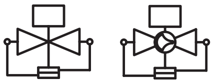
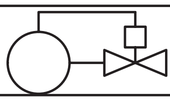
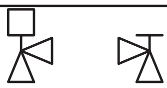
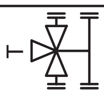
BSRIA Guide BG29/2012 Pre-commission Cleaning Of Pipework Systems

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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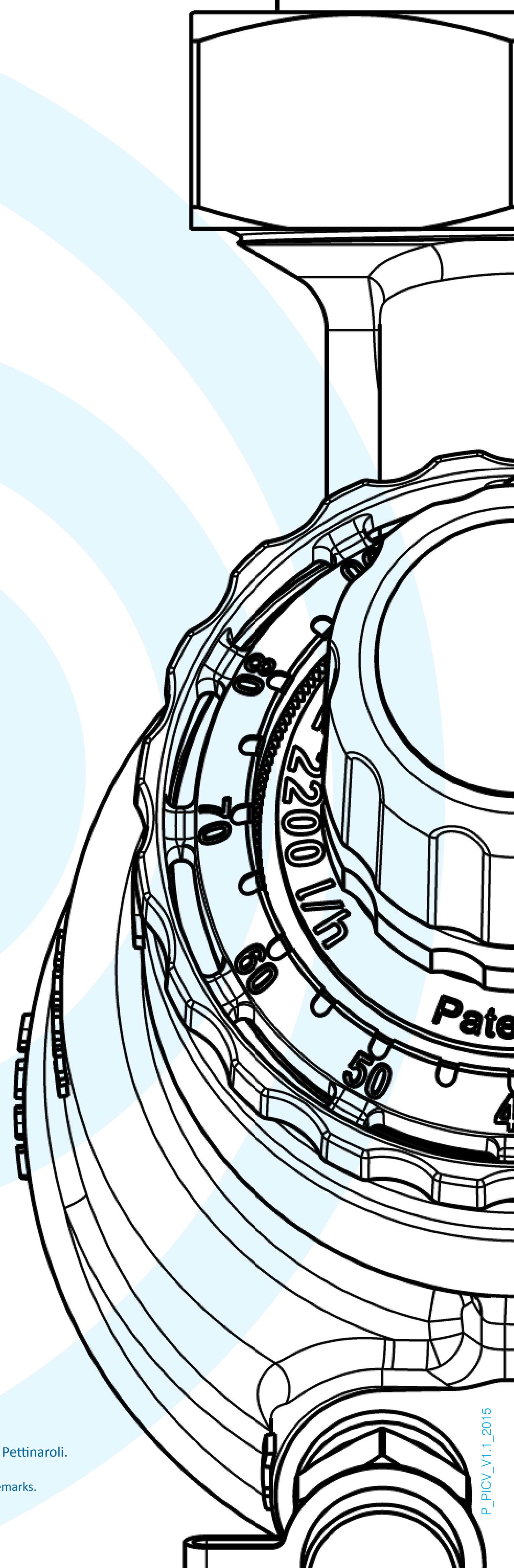

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