PICVs

IN ULTRA LOW FLOW HVAC APPLICATIONS

BACKGROUND TO COMMISSIONING WATER-BASED SYSTEMS

Accurate commissioning and control of water distribution systems in buildings is essential. In England and Wales, Building Regulations 2010, volume 2, part L1, which set the energy efficiency standards requires that “reasonable provision shall be made for the conservation of fuel and power in buildings by providing and commissioning energy efficient fixed building services with effective controls”.

Generally, BSRIA guide, Commissioning Water Systems, BG 2/2010, and Water Distribution Systems, CIBSE Commissioning Code W:2010 provide adequate information to design and put to work hydronic systems in buildings. It is important, however, to recognise that these two prominent documents are applicable to system flow rates above 0.015 l/s. Flow rates below 0.015 l/s are defined as “Ultra-Low Flow Rates”.

Ultra-low flow rates are increasingly specified by designers, particularly for heating systems, due to a trend towards smaller heating loads in modern, well-insulated buildings. Furthermore, larger design temperature differentials (and hence lower flow rates) are more common to make better use of environmentally friendly heat sources.

The purpose of this paper is to understand the implications of commissioning systems with ultra-low flow rates utilising PICVs [Pressure Independent Control Valves], the limitations of PICVs and associated equipment and to manage expectations regarding what can be reliably and consistently achieved because hitherto there are no clear guidelines available.

PICVS FOR ULTRA-LOW FLOW APPLICATIONS

When the BSRIA & CIBSE guides were drafted, PICVs were not available to operate at ultra-low flow rates, hence the cut off at 0.015 l/s. More recently several manufacturers have developed PICVs to address the demand for ultra-low flow balancing and control.

GENERALLY ACCEPTED COMMISSIONING FLOW RATE TOLERANCES

BSRIA guide, Commissioning water systems, BG 2/2010, section 2.12 states:

As part of the commissioning specification, the designer should specify the tolerances bands within which the final witnessed flow measurements must lie.

CIBSE Code W Water Distribution Systems provides tables of acceptable commissioning tolerance bands for different applications within the hydronic system, stating that for a proportional balance to be achieved, the upper and lower tolerance levels should not be exceeded. The lower, i.e., negative value, is the minimum value the least favoured or index unit should achieve.

Suggested Tolerances for flow regulation chilled water systems CIBSE Code W: 2010	
Component	**Tolerance**
Cooling coils where flow rate is < 0.015 l/s	To be determined and agreed
Cooling coils where flow rate is ≥ 0.015 l/s & < 0.1 l/s	-5% to +10%
Cooling coils where flow rate is > 0.1 l/s	0% to +10%
Branches	0% to +10%
Mains [flow from the pump]	0 to +10%

Suggested Tolerances for flow regulation heating systems CIBSE Code W: 2010	
Component	**Tolerance**
Natural convectors such as radiators & radiant panels	Return temperature all within ±3°C
Forced convection, fan driven, heating coils where flow rate is < 0.015 l/s	To be determined and agreed
Forced convection, fan driven, heating coils where flow rate is ≥ 0.015 l/s & < 0.1 l/s	
Heating ΔT ≤ 11°C	±15%
Heating ΔT > 11°C	±10%
Forced convection, fan driven, heating coils where flow rate is > 0.1 l/s	
Heating ΔT ≤ 11°C	±10%
Heating ΔT > 11°C	±7.5%
Branches	
Heating ΔT ≤ 11°C	±10%
Heating ΔT > 11°C	±7.5%
Mains [flow from the pump]	0 to +10%

In practice, Code W recommended commissioning tolerances of ± 10% of design flow rate is usually applied to the performance of all PICVs by the Commissioning Engineer and considered to be an acceptable tolerance by the Consultant.

Recently, with ultra-low flow systems becoming more common, and in the absence of any other recommendations, the generally accepted commissioning tolerance has been adopted and has proved to be problematic. Adopting the general tolerance of ± 10% for ultra-low flow rate applications is at best misleading and, in practice, cannot be consistently achieved.

PRACTICALITIES OF COMMISSIONING AND VERIFYING ULTRA-LOW FLOW PICV PERFORMANCE

In this paper, we will discuss the three key components required to commission and verify the ultra-low flow PICV performance and how working with ultra-low flow rates is different to higher flow rates.

- PICV, ultra-low flow capability.
- Metering station, flow range capability.
- Electronic flow measuring computer accuracy.

The interaction between all three components needs to be understood, interpreted, and applied practically.

PICV ULTRA-LOW FLOW CAPABILITY

All PICVs, irrespective of the manufacturer, quote a range of nominal flow rates, which can be achieved at each valve setting, some are limited, and some have quite a wide setting range. They all also have a ± tolerance for each setting. This is not always shown clearly in the product data sheets or instructions.

We make no attempt to make a comparison between the different PICV models available but will concentrate on the application of the FlowCon Ultra-Low Flow PICV, the GreEQ.0.

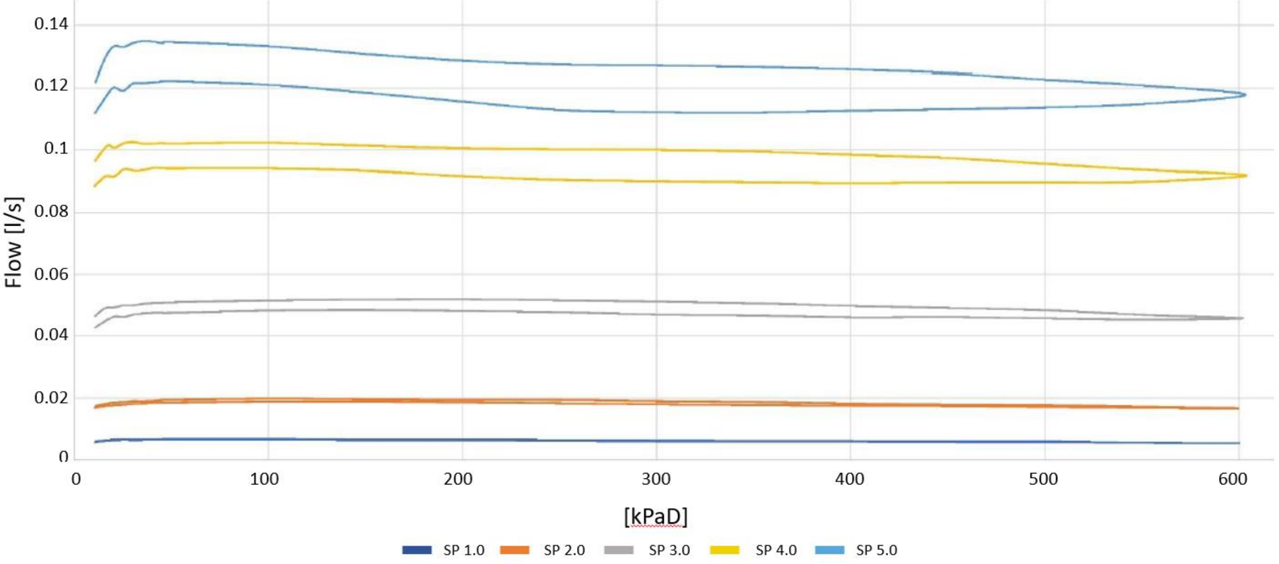
The GreEQ.0 was developed as an Equal Percentage PICV with separate features for setting the maximum flow rate for balancing and for operating as a control valve. It has also proven to be good for working with ultra-low flow rates because of the number of set points within the ultra-low flow rate range.

The PICV has a nominal settable maximum flow rate of 0.00482 l/s at setting 1.0 and 0.0188 l/s at setting 2.0. However, with the geared valve setting mechanism, 11 distinct settings between setting 1.0 and 2.0 can be achieved with a difference between each setting of circ. 13% - 15% offering a wide fine setting range.

Setting	l/h	l/s	Difference	Difference %
1.0	17.3	0.0048		
1.1	19.7	0.0055	0.0007	13.9%
1.2	22.6	0.0063	0.0008	14.7%
1.3	26.1	0.0073	0.0010	15.5%
1.4	30.1	0.0084	0.0011	15.3%
1.5	34.7	0.0096	0.0013	15.3%
1.6	40	0.0111	0.0015	15.3%
1.7	45.9	0.0128	0.0016	14.8%
1.8	52.5	0.0146	0.0018	14.4%
1.9	59.7	0.0166	0.0020	13.7%
2.0	67.7	0.0188	0.0022	13.4%

The GreEQ.0 performance has been independently verified by BSRIA witness testing in accordance with BTS 1/2019 and performs well at ultra-low flow rates, as follows:

FlowCon GreEQ.0 Flow Limitation Tests with a maximum differential pressure of 600 kPa



The five curves above show the valve performance between settings 1.0 [0.00482 l/s] & 5.0 [0.126 l/s]. Of particular interest for ultra-low flow applications is the valve performance at settings 1 [0.00482 l/s] & setting 2 [0.0188 l/s].

BSRIA concluded from these tests, that the measured flow rate compared to claimed nominal flow rates were repeatable within ± 5% and the flow rate stability was within ± 5% for all settings except setting 1.0. This highlights the practical problem with relying on percentages when working at the bottom end of the "Ultra-Low" flow rate range with such small numbers. The performance curve for setting 1.0 is excellent, but in percentage terms, it is outside the tolerance reported for all other settings.

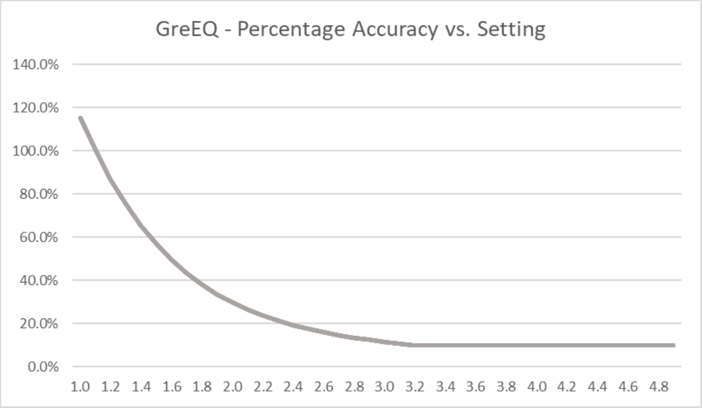
For a nominal flow rate of 0.00482 l/s to have a tolerance of ± 10% [tolerance currently adopted for commissioning] the variance between the nominal and maximum/minimum flow rate would need to be 0.0005 l/s or lower, the issue being how to measure such small flow rates accurately and consistently.

FlowCon, like all other manufacturers, issue a range nominal flow rates achievable at various settings, together with a tolerance, which can be expected at each setting. The tolerance rate -in percentage terms - increases the closer the PICV flow rate setting is decreased, as follows:

Standard accuracy: Greatest of either ± 10% of controlled flow rate or ± 5% maximum flow rate.
If used in pressure range 200 – 800 kPaD greatest of either standard accuracy or -20%/+0% applies.

For the GreEQ PICV the tolerance statement above translates to ±10% for all settings 3.2 and above. Below 3.2 a fixed tolerance of 0.006 l/s applies for all settings. Although a fixed tolerance of 0.006 l/s is extremely small, the graphical representation of the standard tolerance below indicates how misleading percentages can be when very small numbers are involved.

It is important to understand that this tolerance curve is typical for all PICVs irrespective of the manufacturer.



The standard tolerance quoted above is an all-embracing tolerance and covers the mechanical tolerance, pressure independency and hysteresis tolerance for the standalone PICV when setting the flow rate using the setting dial.

METERING STATION SELECTION AND ACCURACY

To measure and verify PICV ultra-low flow rates it is important to partner with the correct metering station, which can generate an acceptable signal above 1 kPa, according to BG2, to ensure flow rate accuracy. Metering stations are now commercially available with a Kvs of 0.263, which is ideally suitable to measure flow rate between 0.008 and 0.015 l/s generating a signal between 1.20 and 4.22 kPa.

All metering stations are designed to BS 7350 and have an accuracy of ±5% for orifice type and ±3% for a venturi, which in theory, needs to be added to the PICV tolerance.

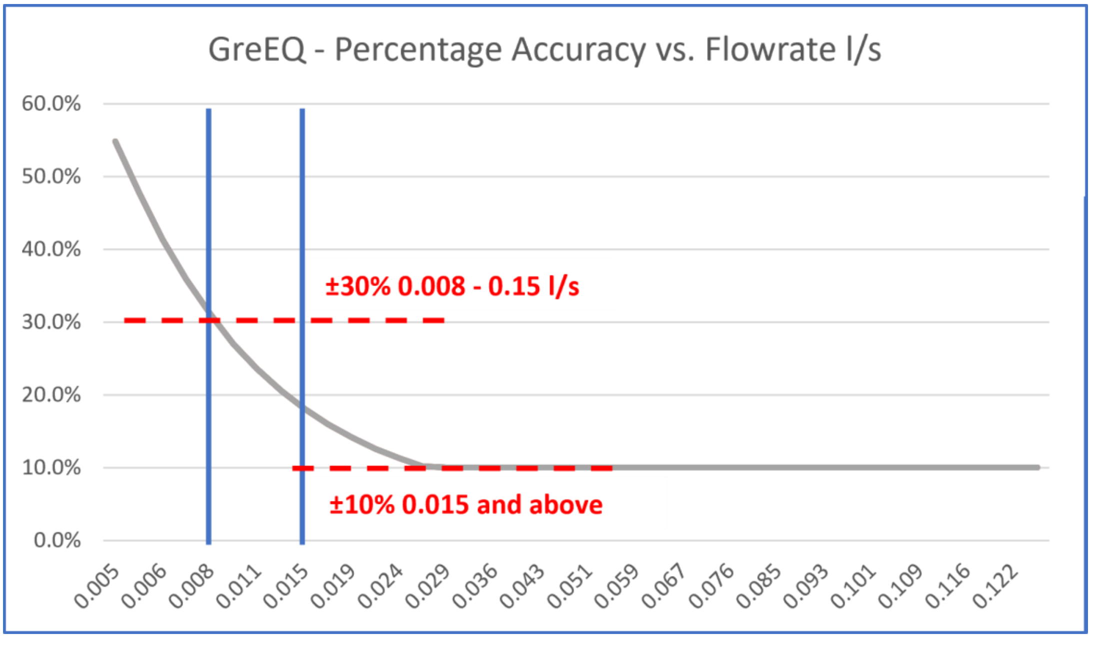
Flow Rate l/s	Kvs	Signal kPa
0.008	0.263	1.20
0.009	0.263	1.52
0.010	0.263	1.87
0.011	0.263	2.27
0.012	0.263	2.70
0.013	0.263	3.17
0.014	0.263	3.67
0.015	0.263	4.22

A PRACTICAL APPROACH TO COMMISSIONING ULTRA-LOW FLOW SYSTEMS

If we were to adopt the manufacturers' tolerances as quoted for the PICV and the metering station, the tolerances in percentage terms would be very high and quite frankly unacceptable to all concerned other than the manufacturer.

We have found that the PICV mechanical tolerance can be eliminated, and the metering station tolerance is minimal if we ignore the setting scale on the PICV and set the PICV using the flow rate measured at the metering station.

Flow rate accuracy of the combined PICV and metering station when setting the PICV with the flow rate measured at the metering station as follows:



If we adopt the metering station with a Kvs of 0.263, which is recommended, and maintain a minimum dP of 1 across the metering station, the minimum measurable flow rate has been shown to be 0.008 l/s. Flow rate accuracy for a flow rate of 0.008 l/s appears to be ±30% when set using the metering station.

It is proposed that we adopt the ±30% tolerance for flow rates between 0.008 and 0.015 l/s.

This may look high in percentage terms, but it is a very small flow rate and is realistic when commissioning ultra-low flow rates. Even though on the graph above the tolerance at 0.015 l/s is higher than ±10%, it is proposed to adopt the Code W tolerance of ±10%.

We must bear in mind user comfort. It is important to ensure that the space being temperature controlled always have sufficient flow rate to deliver or absorb the energy required for the space.

It is also recommended that the flow rate setting during the initial balancing procedure for flow rates between 0.008 and 0.015 l/s is set at the top end of the tolerance, i.e., set at the design flow rate plus 30%.

The flow rate tolerance quoted is an average, in practice the flow rate will fall between the top and bottom tolerance and in theory the aggregate actual plus and minus flow rates will even each other out. By setting the flow rate at 30% above design, it will ensure that design flow rate as a minimum will be achieved in the controlled space.

If the actual flow rate is toward the top end of the tolerance the overflow will be taken care off when the actuator is fitted and the PICV will be closed to deliver the appropriate flow rate to achieve the space temperature setting. For flow rates below 0.008 l/s the ±30% tolerance will need to be increased. It is recommended that when adopting such ultra-Low flow rates agreement is reached with the manufacturer to the correct approach.

FLOW MEASUREMENT ACCURACY

It also needs to be appreciated that the equipment being used to measure the flow rate has a tolerance. Under normal circumstances this is negligible. However, when used to measure ultra-low flow rates it needs to be considered for a truly pragmatic approach to be taken when interpreting and verifying measured flow rates. It is quite usual for the Commissioning Engineer to use an electronic flow computer. A leading electronic flow computer manufacturer quotes the calibrated accuracy of ±0.1 kPa when used to measure ΔP up to 100 kPa. This has a potential to impact on the accuracy of the flow rate measured:

Nominal Flow l/s	Kvs	Signal kPa	Signal Tolerance kPa	Minimum Signal kPa	Minimum Signal Flow kPa	Difference to nominal kPa	Difference to nominal %	Maximum Signal kPa	Maximum Signal Flow kPa	Difference to nominal kPa	Difference to nominal %
0.008	0.263	1.20	0.10	1.10	0.007659	0.000341	4.26%	1.30	0.008327	0.000327	4.09%
0.009	0.263	1.52	0.10	1.42	0.008698	0.000302	3.35%	1.62	0.009292	0.000292	3.24%
0.010	0.263	1.87	0.10	1.77	0.009729	0.000271	2.71%	1.97	0.010263	0.000263	2.63%
0.011	0.263	2.27	0.10	2.17	0.010755	0.000245	2.23%	2.37	0.011240	0.000240	2.18%
0.012	0.263	2.70	0.10	2.60	0.011776	0.000224	1.87%	2.80	0.012220	0.000220	1.84%
0.013	0.263	3.17	0.10	3.07	0.012793	0.000207	1.59%	3.27	0.013204	0.000204	1.57%
0.014	0.263	3.67	0.10	3.57	0.013808	0.000192	1.37%	3.77	0.014189	0.000189	1.35%
0.015	0.263	4.22	0.10	4.12	0.014821	0.000179	1.19%	4.32	0.015177	0.000177	1.18%

It is interesting to note that for the same signal tolerance of ±0.1 kPa and the same flow, the percentage difference for the maximum and minimum calculation is different, clearly indicating the problem of calculating percentages with very low numbers.

The accuracy of the flow measurement device has not been included in the consideration to adopt ±30% outlined above. It is therefore important to bear this in mind if the measured flow rate is marginally outside the proposed tolerance.

KEY TAKE-AWAYS

- Ultra-low flow rates are being increasingly specified.
- PICVs are now available to address the demand for ultra-low flow systems.
- Commissioning and verifying ultra-low PICVs have proven to be difficult when applying generally accepted accuracy and repeatability tolerances.
- Special consideration must be given when commissioning ultra-low flow systems.
- When commissioning an ultra-low flow system with flow rates between 0.008 and 0.015 l/s a practical approach is proposed to set the PICV at the design flow rate plus 30% using the metering station reading.
- When verifying flow rates bear in mind the accuracy of the flow measuring device being used and be prepared to be pragmatic regarding interpreting results.

Want to share your own experience?

Contact the author, Dennis Taylor, Technical Director FloControl Ltd., or our team of engineers.