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Rangeability and Turndown Ratio

Control Valve Sizing and Selection – Rangeability and Turndown Ratio

In our article "Valve Authority – Definition and Relevance" we outlined that for a traditional pressure dependent valve, to efficiently control the flow it must manage, it must generate sufficient pressure drop ratio across the control valve relative to the total system differential pressure, where it is installed, to exercise an acceptable level of control.

Valve Authority is a key consideration when sizing control valves but the Rangeability, Turndown Ratio and Valve Characteristic influence the control valve performance and should therefore also be understood and considered when selecting valves.

Let's firstly recap the key points of Valve Authority in hydronic systems

- Valve Authority is one of the most important aspects to correctly size a control valve.
- Valve authority is the definition of how well a modulating control valve will control flow, considering the impact of the other components in the hydronic circuit.
- Mathematically, authority is calculated by dividing the pressure drop across the control valve, fully open [ΔpV] by the pressure drop across the entire circuit including the control valve [ΔpC].
  Authority % = ΔpV/(ΔpV+ ΔpC).
- In a traditional system design incorporating 2, 3 and 4-Port Valves, a high-pressure drop, i.e., high authority, is, amongst other things, associated with higher energy consumption. Therefore, a balance must be struck between the level of control and the level of energy consumption. Good control with reasonable pressure drop is achieved at 35%-75% of authority, but ideally 40-50%.
- Pressure Independent Control Valves [PICV Valves] have 100% authority irrespective of the differential pressure acting across the valve providing it is operating above the minimum required to put the valve to work. Despite the high authority a PICV valve is highly energy efficient.

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So, what exactly is “Rangeability” and “Turndown Ratio”?

These terms complement Valve Authority and have been used traditionally to assist the sizing and selection of pressure dependant control valve products.

Control Valve Rangeability is a bench-tested factor which expresses the ratio between the maximum flow rate through a fully open valve [Q max] and the minimum controlled flow through the valve [Q min] at the same differential pressure across the valve.

Flow between the maximum and minimum controlled flow rates will follow a defined flow characteristic for the valve.
Flow below the minimum controlled rate will no longer be controlled and will fall to zero quickly.

Rangeability [R] is calculated as the percentage of the valve fully open divided by the percentage open position of the valve to give minimum controllable flow.

Mathematically, R is calculated as follows: R = [Q max/Q min] or Q %max/ Q %min.

For example:

If the maximum flow is 50 l/s [100%] and the minimum controllable flow is 1 l/s [2%]

Valve Rangeability R = [Q max/Q min] = [50/1] = 50:1
Or alternately calculated as
Valve Rangeability R =100%/2% = 50:1

Rangeability is dependent on Valve Characteristic.

Typically, it is usual for manufacturers to claim Rangeability for control valves with the following Valve Characteristics.

- Equal Percentage – 50:1
- Linear – 33:1
- Quick Opening – 20:1

Control Valve Turndown is like Rangeability except it is a factor more based on the performance of a valve when used within a practical system. The factor expresses the ratio of the flow rate through the set position of the control valve and the minimum controlled flow.

Turndown [T] is calculated as the percentage of the part open valve to give the set flow divided by the percentage open position of valve to give minimum controllable flow. This is to take into account that the spindle control length has decreased.

For example, using the same valve example set to design part open conditions:

- maximum flow is 50 l/s [100%]
- set flow is 40 l/s [40/50 x 100 = 80%]
- minimum controllable flow is 1 l/s [2%]

Turndown = 80/2 = 40:1

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The Turndown Ratio is typically smaller than the Rangeability ratio for pressure dependent control valves as the maximum turndown ratio value is the rangeability.

Historically Control Valve sizing, selection and operation was a complex process requiring considerable information regarding valve and system flow rate as well as pressure drop to calculate Valve Authority, Rangeability and Turndown Ratio.

Control Valve selection - Rangeability and Turndown Ratio regarding PICVs

PICV sizing and selection is very simple because the valve has 100% Authority at all flow rate settings. The only information required is the maximum design flow rate for the terminal unit or zone to be managed.

PICV Rangeability relevance is questionable and is not clearly defined as PICVs contain a pressure independent component, flow rate pre-setting and control feature, which in some instances can be the same.

Typically, Rangeability can be calculated as previous R = [Q max/Q min] or Q %max/ Q %min. Since the maximum and minimum flow rate can be higher and lower respectively, with a PICV compared to pressure dependent control valves, the rangeability would be higher, circ. 100:1 and above.

Rangeability can be calculated for a PICV valve but the usage of this information for comparing product requires a deeper understanding of the Valve design features.

PICV Turndown Ratio is the ratio, as previous, between the maximum and minimum controllable flow in the system.
If the PICV valve has a common flow rate setting and control feature the Turn Down Ratio is calculated as previous:

- maximum flow is 50 l/s [100%]
- set flow is 40 l/s [40/50 x 100 = 80%]
- minimum controllable flow is 1 l/s [2%]

Turndown = 80/2 = 40:1

However, if the PICV valve has a separate flow rate setting and control feature – ie. 100% stroke regardless of setting – the Turn Down Ratio is calculated as

- maximum flow is 50 l/s [100%]
- set flow is 40 l/s [100%]
- minimum controllable flow is 1 l/s [2%]

Turndown = 100/2 = 50:1

The Turndown Ratio calculated for the PICV appears to be of more value as it tends to indicate how controllable a PICV will be, which is particularly relevant to PICV valves with common flow setting and control features.
As the set flow rate is reduced the Turndown Ratio will reduce to a point where the valve travel will be small, and control will only be possible in an ON/OFF manner, requiring an alternative valve selection.

Conclusion

The introduction of PICV technology has simplified the sizing and selection of Control Valves. The continued use of traditional tools such as Rangeability is questionable, whereas Turndown Ratio could provide value. It may be of more value to consider other characteristics regarding PICV valves, such as Controllability, Mechanical Tolerance, Pressure Independency, Hysteresis, Repeatability and Actuator Resolution, which will be the subject of a future article.

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