Valve Sizing and Selection for Hydronic Flow Optimization
Achieve your design intent with the right valve

This guide will help you size and select the right valve but more importantly, it will help you understand the value of the Siemens Pressure Independent Control Valve (PICV) for its ease of sizing and selection and its energy saving benefits.

Reasons why it’s important to choose the right valve:

- Hydronic systems are highly interdependent systems. Each system component will interact with one another and impact performance.
- Valves are the critical devices that control heat transfer in hydronic systems.
- Proper valve sizing and selection involves looking at the complete system.
- Valves not sized and selected correctly lead to undesirable outcomes not only at the heat transfer device, but also the overall mechanical system.

Every component in a hydronic system has some level of influence on the control and performance of a hydronic system. Valves are key because they are the controlling devices at the critical areas of heat transfer.

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Conventional valve sizing

- Valves are sized based on a capacity, or flow coefficient.
- The flow capacity of a valve at different pressure drops may be calculated based on this coefficient.
- The coefficient in English units is expressed as a “Cv”. This same coefficient in metric units is expressed as a “Kv”.

Valve Sizing – Equation

The formula for determining Cv for water valves is:

$$C_v = Q \sqrt{\frac{S}{\Delta P}}$$

When working with water, this may be simplified to:

$$C_v = \frac{Q}{\sqrt{\Delta P}}$$

Where:
- $S$ = Specific Gravity of media
- $C_v$ = Flow Coefficient
- $Q$ = Volumetric Flow (gpm) with valve fully open
- $\Delta P$ = Differential Pressure (psi) with valve fully open

IMPORTANT NOTE: Equipment in the hydronic industry is typically rated at a standard temperature for clean water (68°F). At this temperature the specific gravity of water is essentially 1.
Valve sizing and actuator selection

Valve Sizing and Selection
There are a couple of engineering design questions that need to be answered in order to help maintain design intent of the system. In this section, you will be provided with the 18 steps on how to properly size and select valves, actuators and assemblies.

1. Determine valve type. Knowing this upfront will enable us to make adjustments in our sizing and selection.
2. Determine medium being controlled.
3. Determine flow rate of equipment to be controlled. (This should be provided, or on the coil schedule.)
4. Determine specified pressure drop. For correct valve authority, the pressure drop across the valve should be equal to the total pressure drop across the controlled branch, including the valve.

Calculating GPM Flow
GPM requirement may be determined if the BTU/hr requirement and water desired $\Delta T$ is known.

$$ GPM = \left( \frac{q}{500(\Delta T)} \right) $$

GPM may be determined more precisely if % glycol is known:

$$ GPM = \left( \frac{q \sqrt{S}}{500(\Delta T)C_p} \right) $$

**GPM** = flow in gallons/minute

q = Heat added or removed in BTU/hr

$\Delta T$ = Water temperature rise or drop across the coil

S or SG = Specific Gravity of media

Cp = Specific heat of media

Determining a Rated Flow Rate
Common differential temperatures for chilled water equipment is 12°F, and 20°F for hot water systems. This should be double checked with the design engineer on what the intended equipment differentials are for the coils as well as the major equipment such as the boilers and chillers in the system.

If glycol is being used in the system, some modifications to the upper equation can be done to accommodate the difference in specific gravity and specific heat of a mixed fluid compared to standard water.
Specific Gravity of Glycol Solutions

To compensate for a water/glycol mixture, the previous equation for GPM requires two additional pieces of information. The first thing you will need is the specific gravity of the water/glycol mixture at the mix percentages. That can be obtained from Specific Gravity of Glycol Solutions chart. In North American hydronic systems, 50/50% water/glycol is typical. Most manufactures have rated their equipment to similar mixture limits.

<table>
<thead>
<tr>
<th>Specific Gravity- SG -</th>
<th>Ethylene Glycol Solution (% by volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°F)</td>
<td>25</td>
</tr>
<tr>
<td>-40</td>
<td>1)</td>
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<tr>
<td>0</td>
<td>1)</td>
</tr>
<tr>
<td>40</td>
<td>1.048</td>
</tr>
<tr>
<td>80</td>
<td>1.04</td>
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<tr>
<td>120</td>
<td>1.03</td>
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<tr>
<td>160</td>
<td>1.018</td>
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<tr>
<td>200</td>
<td>1.005</td>
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<tr>
<td>240</td>
<td>2)</td>
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<td>280</td>
<td>2)</td>
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</tbody>
</table>

1) Below freezing point
2) Above boiling point

Specific Heat of Glycol Solutions

You will also need the specific heat of the water/glycol mixture at the design percentages to get the correct rated flow rate. That information is available on the Specific Heat of Glycol Solutions chart below.

<table>
<thead>
<tr>
<th>Specific Heat Capacity - c_p - (Btu/lb.*F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°F)</td>
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<tr>
<td>------------------</td>
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<tr>
<td></td>
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<tr>
<td>-40</td>
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<td>0</td>
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<td>40</td>
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<td>80</td>
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<td>120</td>
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<td>160</td>
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<tr>
<td>200</td>
</tr>
<tr>
<td>240</td>
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<tr>
<td>280</td>
</tr>
</tbody>
</table>

1) Below freezing point
2) Above boiling point

• 1 Btu/(lb*m°F) = 4,186.8 J/(kg K) = 1 kcal/(kg°C)
**Valve Authority**

The Valve Authority is generally defined as the ratio of the pressure drop across the fully open valve compared to the pressure drop across the entire circuit (including the valve) at design flow conditions. This is represented as a percentage.

**Information needed for calculations:**
- \( \Delta P \) total controlled branch: this is the sum of all pressure drops in the controlled branch including the control valve, as well as the isolation valve, strainer, coil, control valve, balance valve, and potentially another isolation valve plus all of the piping that connects components from supply to return piping.
- \( \Delta P \) valve: the pressure across the control valve at 100% design flow.
- Selecting control valves with percent authority between 25% - 50% is typically desired.

\[
\text{Percent Authority} = \left( \frac{\Delta P \text{ Valve}}{\Delta P \text { Total controlled branch}} \right) \times 100
\]

With respect to pressure drop, the best method in sizing would be to understand the total pressure drop of the controlled branch and figure a pressure drop across the fully opened valve that would give the control valve good authority of control in that branch. This however may not be possible all the time. Apply the valve guidelines that are commonly used to assign pressure drop for sizing.

**Valve Sizing Guidelines**

If the pressure drop is not specified, or the pressure drop across the controlled branch is unknown, the following guidelines may be used.

**The pressure drop is based on the system differential pressure – per the following rules**

1. If the system differential pressure is < 20 psi, use 5 psi
2. If the system differential pressure is > 20 psi and < 45 psi, use 25% of the system differential pressure
3. If the system differential pressure is > 45 psi, use 15 psi

5. Calculate Cv using the equation for water valves (on page 4)
6. Determine number of ports (2-way or 3-way).
7. Determine required ANSI Pressure Class rating (125 or 250).
8. Determine required Flow Characteristic; typically Equal Percentage for water applications and Linear for steam applications.
9. Determine Trim Requirements
   - a. Bronze / Brass (usually for low \( \Delta P \) water applications)
   - b. Stainless Steel (usually for higher \( \Delta P \) water applications and steam applications)
10. Determine type of packing, if applicable (Standard or High Temperature)
11. Determine type of mechanical connection to the piping system. (NPT-FxF, NPT – FxUM, Flanged, Sweat, etc.)
12. For the actuator, determine Normal Position and Failsafe requirements (NO – Normally Open, NC – Normally Closed, SR – Spring Return or Fail-Safe, NSR – Non-Spring Return or Fail-in-Place).
13. Determine type of actuator and control signal (2 position, floating, 0-10 vdc, etc.).
14. Determine if Manual Override is required.
15. Based on all of these inputs, select an orderable valve assembly.
16. Check close off pressure (specified, or at least system differential pressure).
17. Calculate actual pressure drop based on valve selected using CV formula.
18. Check for Percent Authority, where:
   - Percent Authority should be between 25% and 50%.

*Note, not all valves are created equally. Select Cv that is closest to the design Cv from initial calculations.*
Common valve types and applications

**Ball Valve**

**Best Suited Control:**
Equal percentage

**Recommended Uses:**
• Fully open/closed applications
• Modulating applications

**Advantages:**
• Relatively low cost
• High flow capacity
• Tight sealing with low torque
• High close off pressure

**Disadvantages:**
• Inherent dead bands

**Butterfly Valve**

**Best Suited Control:**
Linear, equal percentage

**Recommended Uses:**
• Fully open/closed applications
• Throttling applications
• Small pressure drop applications

**Advantages:**
• Relatively low cost
• High flow capacity
• Low pressure drop

**Disadvantages:**
• High torque requirements for control
• Low flow cavitation risk

**Globe Valves**

**Best Suited Control:**
Linear, equal percentage

**Recommended Uses:**
• Precise flow regulation
• Frequent and wide throttling
• High pressure drop applications

**Advantages:**
• Suited for water and steam
• Efficient and precise throttling
• Highly accurate flow control

**Disadvantages:**
• Relatively low flow coefficients
• Relatively higher costs than other valves

**Pressure Independent Control Valves**

**Best Suited Control:**
Linear, equal percentage

**Recommended Uses:**
• Frequent system pressure changes
• Precise flow regulation
• Frequent and wide throttling
• High pressure drop applications

**Advantages:**
• Efficient and precise throttling
• Highly accurate flow control
• Automatic dynamic balancing
• Flow limiting capabilities

**Disadvantages:**
• Relatively higher costs than other valves
Valve Characteristics

Equal Percentage Characteristics:
- Typically used for water applications
- Used in systems with large changes in pressure drops
- Used where a small percentage of the total pressure drop is permitted by the valve
- Used in temperature and pressure control loops

Linear Characteristics:
- Typically used for steam applications
- Used in liquid level or flow loops
- Used in steady state systems
- Used when pressure drops across the valve is a large portion of the total pressure drop

Quick Opening Characteristics:
- Used for frequent on/off service
- Used for systems where “instant” large flow is required (i.e. safety systems)

Why do we need to be aware of the valve characteristics?

Simply put, it is because of the nature of the equipment we are using. For control of the system, we desire a linear response and output, but we are dealing with a heat transfer device that is highly non-linear. From image A, we have a typical heating coil characteristic. You can see it is highly non-linear. A small percentage of flow change at the high end does not result in a reduction in output capacity until you start going past 50% flow.

The flow through the coils are regulated by our control valves and the characteristics they inherently hold. In order to get the desired linear response/output for the control system, we need to match up coil and valve characteristics that give us the desired response type. In this case, we’re matching up an equal percentage valve characteristic with the heating coil to produce the linear response system. Keep in mind that this is an ideal condition though, and the real world does not always happen in this fashion.
PICVs simplify your sizing and selection

An Easier ΔT Solution 3-in-1 Control Valve

The Siemens pressure independent control valve is a three-in-one device. The main difference with Siemens is that the field adjustable flow limiter is independent of the stroke. With other PICVs, the way that flow is adjusted is by adjusting the stroke. So, by reducing the flow, the stroke is reduced. Since the Siemens PICV is independent, you can maintain full stroke, full controllability, regardless of the maximum flow setting of the PICV.

Field Adjustable Flow Limiter
- Full stroke always maintained for higher control accuracy
- Easily adjust maximum flow at any time
- Presetting prevents oversupply to the coil

Control Valve
- Linear stroke control valve with 100% stroke regardless of flow limitation

Automatic Pressure Regulator
- Auto adjusts to pressure fluctuations
- Maintain consistent flow at all times

So how does it really work?

PICVs combine a control valve, automatic differential pressure regulator and an field adjustable flow limiter.

1. The control valve controls the flow through the coil to maintain the required room temperature
2. The automatic differential pressure regulator maintains consistent flow regardless of system pressure changes
3. The field adjustable flow limiter preset limits to maximum flow while maintaining full valve stroke

The control portion of the valve controls the flow through the coil to maintain the required room temperature based on the load. At any given setting or position of the control valve, the differential pressure regulator is constantly adjusting to any pressure changes in the system to maintain consistent flow.

The adjustable flow limiter is preset. Set it once at the beginning – set that equal to the design flow of the coil, and you will never get overflow because that limits the maximum amount that can flow through the valve.

The presetting is very easy to set. The scale is in gallons per minute, so there is no calculation just straight gallons per minute on our threaded PICV. There is no need to know what the maximum possible flow is and to do a percentage.
Advantages of PICV

Here’s a comparison of some of the basic system requirements. From our market research, 90% of the market requires these features. The first thing you will notice is the Siemens mechanical PICVs have all the features of conventional control valves and are easier to size and select. In addition, these PICVs perform dynamic balancing, with minimal pressure drop, and are field adjustable.

Basic Control Valve & Balance Valve Requirements

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Conventional Control Valve</th>
<th>Siemens Mechanical PICV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy Selection</td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Dynamic Balancing</td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>High Close Off</td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Low Minimum Pressure Drop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field Adjustable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leakage Class</td>
<td>ANSI Class IV</td>
<td>≤ ANSI Class IV</td>
</tr>
<tr>
<td>Warranty</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Full Stroke</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

90% of the market requires these features

Easier Sizing & Selection

Pressure independent control valves are easier to size and select.
The first step is to determine the design flow of your coil, then look at the flow ranges of the valves, and find the one that falls within your design flow range.

A typical guideline is to select a valve that’s one size down from the pipe size. You can also select a valve the same size as the line size, either one has no effect because these are pressure independent and will control to that flow.

If there are multiple valves the design flow falls within, the recommendation is to choose a valve where the design flow falls in the middle of the flow range.

If you choose a valve that your design flow is close to the upper range or the lower range and the system design changes or adjustments need to be made, then you may be limited on those adjustments. So putting it in the middle of the range provides the most flexibility.

1. Determine design flow of coil
2. Find PICVs with max flow range compatible with coil design flow
3. Typically select a PICV one size down or select on line size
4. It is possible to select a PICV with max flow buffer for post design adjustments
**Siemens PICV Advantages**

Achieve your design intent through hydronic flow optimization with PICVs. Optimize delta T through precise flow control and make your building operations more efficient to bring balance to your bottom line.

<table>
<thead>
<tr>
<th>Project Phase</th>
<th>Control valve</th>
<th>Siemens PICV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Characteristic</td>
<td>• Cv value, pressure dependent</td>
<td>• Maximum flow setting in GPM, Pressure Independent.</td>
</tr>
<tr>
<td>Design</td>
<td>• Accurate calculation of the network differential pressure drops and required flow.</td>
<td>• Small effort for specification of components using only design flow.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Multi phase projects can be implemented independently.</td>
</tr>
<tr>
<td>Selection</td>
<td>• Calculation of valve authority is important.</td>
<td>• No need to calculate valve authority.</td>
</tr>
<tr>
<td></td>
<td>• Recalculation required each time changes are made during the planning phase.</td>
<td></td>
</tr>
<tr>
<td>Sizing</td>
<td>• Required: Pressure drop across the heat exchanger and design flow, optionally temperature differential.</td>
<td>• Simply select a valve that delivers the required design flow.</td>
</tr>
<tr>
<td>Installation</td>
<td>• Control valve and balancing valves required.</td>
<td>• No balancing valves required.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduced leak risks in installation.</td>
</tr>
<tr>
<td>Commissioning</td>
<td>• Hydronic balancing. Verification of functioning under different operating conditions required.</td>
<td>• No hydronic balancing and no line balancing required.</td>
</tr>
<tr>
<td>Operation</td>
<td>• As load changes system becomes unbalanced, overflow occurs, and energy efficiency decreases.</td>
<td>• As load changes, circuits flow and heat transfer maintained, energy usage optimized.</td>
</tr>
</tbody>
</table>

Rely on Siemens for the best possible system performance.
The right HVAC device matters to make your perfect place a reality.