Notes for project planning

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2-way and 3-way characterised control valves
Belimo adds «characterized control» to ball valves

Belimo has succeeded in solving the problem of the distorted flow characteristic of ordinary ball valves. A so-called «characterizing disc» in the inlet of the characterized control valve converts the valve’s characteristic to the equal-percentage kind.

The side of the characterizing disc facing the ball is concave and in contact with the surface of the ball. Thus, the actual flow is regulated by the hole in the ball and by the V-shaped aperture in the characterizing disc.

Ordinary ball valves are unsuitable as control devices

In order to ensure good stability of control, a hydraulic final controlling element must possess a flow characteristic that supplements the non-linear characteristic of the heat exchanger in the HVAC system.

An equal-percentage valve characteristic is desirable in order to produce a linear relationship between the thermal output and the opening position of the final controlling element. This means that the flow rate increases very slowly as the final controlling element begins to open.

Unfortunately, this characteristic is severely distorted in ordinary ball valves.

The reason for this is that an ordinary ball valve has an extremely high flow coefficient ($k_{vs}$ value) compared with its nominal size, several times that of a comparable globe valve. Therefore, an ordinary ball valve is not very suitable for performing control functions:
- Flow coefficient excessive due to the design
- Flow control inadequate in the part-load range

Equal-percentage characteristic

- Better controllability
- Lower installation costs

The Belimo range of characterized control valves includes 2-way and 3-way types. These are available in a variety of sizes and with a choice of $k_{vs}$ values.

A characterized control valve is supplied as a unit complete with a suitable Belimo rotary actuator.

Advantages of the Belimo characterized control valve
- Equal-percentage characteristic
- No initial jump in flow on opening
- Excellent stability of control thanks to the characterizing disk

Elements of the characterized control valve
1. Simple direct mounting using a central screw. The rotary actuator can be mounted in four different positions
2. Square stem head for form-fit attachment of the rotary actuator
3. Identical mounting flange for all sizes
4. Stem with two O-ring seals for a long service life
5. Ball and stem made of stainless steel or chrome-plated brass
6. Characterizing disc produces equal-percentage flow characteristic
7. Internal thread connection (ISO 7-1), external thread connection (ISO 228-1) and flange connection (ISO 7005-1/2)
8. Forged fitting, nickel-plated brass body
9. Vent window to prevent the accumulation of condensation
10. Thermal decoupling of the actuator from the ball valve

Optimum choice of $k_{vs}$ values of identical size
- Better controllability
- Lower installation costs
Project planning

Relevant information
The data, information and limit values listed on the “Characterised control valves” data sheets are to be taken into account and/or complied with, respectively.

Closing and differential pressures
The maximum permissible closing and differential pressures can be found in the data sheets or in the documentation “Overview of Valve-Actuator Combinations”.

Pipeline clearances
The minimum clearances between the pipelines and the walls and ceilings required for project planning depend not only on the valve dimensions but also on the selected actuator and can be found in the data sheets of the valves and actuators.

2-way characterised control valves
Characterised control valves are to be installed in the return as throttling devices. This leads to lower thermal loads on the sealing elements in the valve. The prescribed flow direction must be observed.

3-way characterised control valves
3-way characterised control valves are mixing devices. The flow direction must be observed for all pressure levels. Installation in the supply or return is dependent on the selected hydraulic circuit. The 3-way characterised control valve may not be used as a diverting valve.

Diverting circuit
Thanks to the reduced flow rate in the bypass, no balancing valve in the bypass line is necessary with the diverting circuit.

Bypass 70% \( k_{vs} \) Full load Zero load with bypass throttle Zero load with reduced bypass \( k_{vs} \)

\[ \Delta p = 9 \text{kPa} \]
\[ \Delta p = 9 \text{kPa} \]
\[ \Delta p = 9 \text{kPa} \]

Water quality
The water quality requirements specified in VDI 2035 must be adhered to.

Dirt filter
Characterised control valves are regulating devices. The use of dirt filters is recommended in order to prolong their service life as modulating instruments.

Shut-off devices
Care must be taken to ensure that sufficient numbers of shut-off devices are installed.

Design and dimensioning

Control characteristics
In order to ensure that a valve achieves good control characteristics, thus making it possible to ensure a long service life for the final controlling element, proper configuration of the valve with the correct valve authority is required.

The valve authority \( P_v \) is the measure of the control characteristics of the valve in conjunction with the hydraulic network. The valve authority is the ratio between the differential pressure of the completely opened valve at the nominal flow rate and the maximum differential pressure occurring with the closed valve. The greater the valve authority, the better the control characteristics. The smaller the valve authority \( P_v \) becomes, the more the operational behaviour of the valve will deviate from the linearity, i.e. the poorer the behaviour of the volumetric flow control. A valve authority of \( P_v \) of >0.5 is strived for in everyday practice.

Design for use with glycol
Salts were formerly added to the water to reduce its freezing point; this was referred to as brine applications. Nowadays, glycols are used and one speaks of refrigerant agents. Depending on the concentration of the refrigerant agent (type of glycol) used and the medium temperature, the density of the water/glycol mixture varies from 1% to 9%. The volumetric deviation which results from this process is less than the permitted quantity tolerance of the \( k_{vs} \) value of the valve (of ±10% in accordance with VDE 2178) and need not as a rule be taken into account, even if glycols require a slightly elevated \( k_{vs} \) value.

Depending on the type of glycol, tolerance with the valve materials used must be ensured and the permitted maximum concentration (50 percent) may not be exceeded.
Flow characteristics

2-way characterised control valve

The characteristic curve is equal-percentage, with a characteristic curve factor $n_{(gl)} = 3.2$ or $3.9$. This guarantees stable control characteristics in the elevated partial load range. The curve is linear in the lower opening range between $0 \ldots 30\%$ operating range. This ensures outstanding control characteristics, including in the lower partial load range. The operating range $0 \ldots 100\%$ corresponds to an angle of rotation of $15 \ldots 90^\circ$.

3-way characterised control valve

Same behaviour via the control path A – AB as with the 2-way characterised control valves. The flow rate in the bypass $B – AB$ is designed to be $70\%$ of the $k_{vs}$ value of the control path (A – AB). The characteristic curve in the bypass is linear.

Note

As a result of its ball construction, the 3-way characterised control valve is suitable only to a limited extent for conventional return line temperature controls. It is therefore recommended that return line temperature controls be implemented as double mixing circuits when these characterised control valves are used.

There are no restrictions with air heater mixing circuits or with injection circuits.
Notes for project planning

Design and dimensioning

Calculation diagram for 2-way and 3-way characterised control valves R2.. / R3.. / R6..R / R7..R

Application
These characterised control valves are used in open (R2.. und R6..R) and closed cold and hot water systems for modulating water-side control of air treatment and heating plants.

Media
Cold and hot water, water with glycol up to max. 50% vol.

Medium temperatures
The permissible medium temperatures can be found in the corresponding valve and actuator data sheets.

\[ \Delta p_{v100} [\text{bar}] \]

\[ V_{100} [\text{m}^3/\text{h}] \]

\[ \Delta p_{100} \]
Differential pressure with ball valve full open.

\[ V_{100} \]
Nominal flow rate with \( \Delta p_{100} \)

Formula \( k_v \)
\[ k_v = \sqrt{\frac{V_{100}}{\Delta p_{v100}}} \]

\( \Delta p_{\text{max}} \)
Maximum permitted differential pressure for long service life across control path A – AB, with reference to the whole opening range.

\( \Delta p_{\text{max}} \)
For low-noise operation (R2../R3..)

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Notes for project planning

Design and dimensioning

Calculation diagram for 2-way and 3-way characterised control valves R4..(K) / R5..(K)

Application
These characterised control valves are used in open and closed cold and hot water systems for modulating water-side control of air treatment and heating plants.

Media
Cold and hot water, water with glycol up to max. 50% vol.

Medium temperatures
The permissible medium temperatures can be found in the corresponding valve and actuator data sheets.

<table>
<thead>
<tr>
<th>$\Delta p_{v100}$ [kPa]</th>
<th>$V_{100}$ [m$^3$/h]</th>
<th>$V_{100}$ [l/s]</th>
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<td>0.01</td>
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<tr>
<td>6</td>
<td>260 – 250</td>
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<tr>
<td>8</td>
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<td>350 – 340</td>
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<tr>
<td>80</td>
<td>1000 – 990</td>
<td>1000 – 990</td>
</tr>
</tbody>
</table>

$\Delta p_{v100}$
Differential pressure with ball valve full open.

$V_{100}$
Nominal flow rate with $\Delta p_{v100}$

$k_v = \frac{\sqrt{\Delta p_{v100}}}{100}$
Formula for $k_v$:

$V_{100}$
Nominal flow rate with $\Delta p_{v100}$

$\Delta p_{v100}$
Differential pressure with ball valve full open.

Maximum permitted differential pressure for long service life across control path A – AB, with reference to the whole opening range.

$\Delta p_{v100}$
Differential pressure with ball valve full open.

$V_{100}$
Nominal flow rate with $\Delta p_{v100}$

Formula for $k_v$:

$k_v = \frac{\sqrt{\Delta p_{v100}}}{100}$
**Notes for project planning**

**Design and dimensioning**

**Calculation diagram for 2-way characterised control valves R6..W..-S8**

**Application**
These characterised control valves are used in closed cold and hot water systems for modulating water-side control of air treatment and heating plants.

**Media**
Cold and hot water, water with glycol up to max. 50% vol.

**Medium temperatures**
–10 ... 120°C

---

**Formula**

\[
\Delta p_{\text{max}}
\]

Maximum permitted differential pressure for long service life across control path A – AB, with reference to the whole opening range.

\[
\Delta p_{100}
\]
Differential pressure with ball valve full open.

\[
\dot{V}_{100}
\]
Nominal flow rate with \(\Delta p_{100}\)

\[
k_{\text{vs}} = \frac{\dot{V}_{100}}{\Delta p_{100} [\text{kPa}]}
\]

\[
\dot{V}_{100} = k_{\text{vs}} \cdot \Delta p_{100}^{100} \quad [\text{m}^3/\text{h}]
\]

---

**Diagram**

Graph showing the relationship between differential pressure \(\Delta p_{100}\) and flow rate \(\dot{V}_{100}\) for different medium temperatures and nominal flow rates.
Application: These characterised control valves are used in open and closed cold and hot water systems for modulating water-side control of water in district heating applications and in heated drinking water.

Media: Cold and hot water, drinking water, water with glycol up to max. 50% vol.

Medium temperatures: 2 ... 130°C

### Notes for project planning

Design and dimensioning

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**Calculation diagram for 2-way characterised control valves R4..D(K)**

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### Media

- Cold and hot water, drinking water, water with glycol up to max. 50% vol.

### Medium temperatures

- 2 ... 130°C

---

**Application**

These characterised control valves are used in open and closed cold and hot water systems for modulating water-side control of water in district heating applications and in heated drinking water.

**Media**

- Cold and hot water, drinking water, water with glycol up to max. 50% vol.

**Medium temperatures**

- 2 ... 130°C

---

**Formula**

\[ k_v = \frac{\dot{V}_{100}}{\Delta p_{100}} \]

- \( \dot{V}_{100} \): Nominal flow rate with \( \Delta p_{100} \)
- \( k_v \): Flow characteristic coefficient
- \( \Delta p_{100} \): Maximum permissible differential pressure for long service life with ball valve full open

---

\[ \Delta p_{v0} \]

- Maximum permissible differential pressure for long service life with closed ball valve

\[ \Delta p_{v100} \]

- Maximum permissible differential pressure for long service life with ball valve full open
Notes for project planning

Design and dimensioning

Calculation diagram for 2-way characterised control valves R4..D(K)

Differential pressure

$\Delta p_{\text{max}} = 800 \text{ kPa}$

$\Delta p_{100\text{(max)}} = 400 \text{ kPa}$

Operating pressure ratio $X_F$

Formula

$X_F = \frac{\Delta p}{p_1 - p_2} < X_{FZ}$

$\Delta p < X_{FZ} (p_1 - p_2)$

$X_F \leq Z = X_{FZ}$

Cavitation factor $Z$

Diagram

Example: $Z = 0.3$

1. No cavitation
   $X_F = 2/7.3 = 0.27$

2. Starting cavitation
   $X_F = 2.5/7.3 = 0.34$

3. No cavitation
   $X_F = 2.5/9 = 0.28$

$p_v = 2.7 \text{ bar abs.}$

$10 - 2.7 = 7.3 \text{ bar}$

$p_v$

$10 - 1 = 9 \text{ bar}$

Saturated steam curve

Absolute pressure [bar abs.]

Atmospheric pressure [bar]

$[\text{dB}]$

$[\text{°C}]$
# Characterised control valve selection table

<table>
<thead>
<tr>
<th>Rated pressure ( p_0 ) [kPa]</th>
<th>1600 PN 16</th>
<th>600 PN 6</th>
<th>1600 PN 16</th>
<th>2700 PN 16</th>
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</thead>
<tbody>
<tr>
<td>pressure class</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Max. differential pressure ( \Delta p_{\text{max}} ) [kPa]</td>
<td>350 (200 for low-noise operation)</td>
<td>200</td>
<td>100</td>
<td>400</td>
</tr>
<tr>
<td>Valve design (2-way / 3-way)</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
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<tr>
<td>Internal thread (ISO 7-1)</td>
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<tr>
<td>External thread (ISO 228-1)</td>
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<tr>
<td>Flange (ISO 7005-1/2)</td>
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<tr>
<td>Valve characteristic curve</td>
<td><img src="image" alt="Diagram" /></td>
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<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
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</tbody>
</table>

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### Notes for project planning

- **Characterised control valves**
  - **k\(v\) vs \(s\)**
  - **Characterised control valves**

<table>
<thead>
<tr>
<th>k(v)</th>
<th>DN</th>
<th>R2..</th>
<th>R3..</th>
<th>R4..</th>
<th>R5..</th>
<th>R6..R</th>
<th>R7..R</th>
<th>R6..W..</th>
<th>R4..D(K)</th>
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<tr>
<td>0.25</td>
<td>10</td>
<td>R2015-P2S-S1</td>
<td>3015-P2S-S1</td>
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<td>40</td>
<td>40</td>
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<td>40</td>
</tr>
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<td>0.3</td>
<td>10</td>
<td>R2015-P4S-S1</td>
<td>3015-P4S-S1</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
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<td>0.4</td>
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<td>1</td>
<td>10</td>
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<td>3015-P8S-S1</td>
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<td>1.6</td>
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<td>3015-P10S-S1</td>
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<td>40</td>
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</tbody>
</table>

### Medium temperature

The permissible medium temperatures can be found in the corresponding valve and actuator data sheets.

### Leakage rate

- **2-way:** Leakage rate A, air bubble tight (EN 12266-1)
- **3-way:** Control path A – AB leakage rate A, tight (EN 12266-1)
- **Bypass B – AB leakage rate class I (EN 1349 and EN 60534-4), max. 1% of k\(v\) value**

- *For all possible combinations with rotary actuators and their closing pressures and maximum permissible differential pressures, see the document “Overview Valve-actuator combinations”*
- *For detailed information concerning rotary actuators, see the data sheets for the rotary actuators*
## Designing and Dimensioning

### Differential Pressure \( \Delta p_{\text{max}} \) [kPa] and \( k_{\text{vs}} \) [m³/h] for 2-way and 3-way Open-Close Ball Valves

<table>
<thead>
<tr>
<th>Differential Pressure ( \Delta p_{\text{max}} ) [kPa]</th>
<th>0.1</th>
<th>1.0</th>
<th>3.0</th>
<th>10.0</th>
<th>( k_{\text{vs}} ) [m³/h]</th>
<th>DN [mm]</th>
<th>Connections</th>
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<tbody>
<tr>
<td>0.13</td>
<td>0.4</td>
<td>0.69</td>
<td>1.3</td>
<td>4</td>
<td>10</td>
<td>R410DK</td>
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<td>0.17</td>
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<td>R515</td>
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<td>R3050-BL4</td>
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### Flow Rate \( \dot{V}_{100} \) [m³/h] and Connections

<table>
<thead>
<tr>
<th>Flow Rate ( \dot{V}_{100} ) [m³/h]</th>
<th>Connections: R2.. / R3.. Internal thread</th>
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<tbody>
<tr>
<td>0.1</td>
<td>R4.. / R5.. External thread</td>
</tr>
<tr>
<td>1.0</td>
<td>R6.. / R7.. Flange</td>
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</tbody>
</table>

### Formula

\[
\dot{V}_{100} = k_{\text{vs}} \sqrt{\frac{\Delta p_{100}}{100}}
\]

<table>
<thead>
<tr>
<th>( k_{\text{vs}} )</th>
<th>( \dot{V}_{100} )</th>
<th>( \Delta p_{100} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>[m³/h]</td>
<td>[m³/h]</td>
<td>[kPa]</td>
</tr>
</tbody>
</table>

**Notes for Project Planning**

**Design and Dimensioning**

**Differential Pressure** \( \Delta p_{\text{max}} \) [kPa] and **Flow Rate** \( \dot{V}_{100} \) [m³/h] for 2-way and 3-way Open-Close Ball Valves.

**Formula**

\[
\dot{V}_{100} = k_{\text{vs}} \sqrt{\frac{\Delta p_{100}}{100}}
\]
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