Hydronic systems - operation

Heating, Ventilation and Air Conditioning Systems
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Valves

**Regulation**
Adjusting temperature/flow rates in a hydronic circuit so that users are satisfied in different operating conditions (e.g. partial loads)

**Balancing**
Adjusting pressures/flow rates in a hydronic circuit so that flow/heat is evenly distributed at full load.
Regulation valves

**Flow factor** $k_v$: flow rate ($m^3/hr$) across the valve at 5-30°C under $\Delta p = 1$ bar

$k_{v1}$: flow rate ($m^3/hr$) at 5-30°C under $\Delta p = 1$ bar with valve fully open ($x = x_1$)
Regulation valves

Characteristic curve of the valves:

\[ \frac{k_v}{k_{v1}} = f\left(\frac{x}{x_1}\right) \]

According to the characteristic curve, there are three types of valves:

- Quick opening
- Linear
- Equal-percentage
Regulation valves

Qualitative shape of the obturators

Equal percentage

Linear
Regulation valves

Valve characteristic curve

Mass flow

Heat output

Heat output
# Regulation valves

## Classification

<table>
<thead>
<tr>
<th>Type</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick-opening control valves</td>
<td>- Frequent on-off systems&lt;br&gt;- Systems where instantaneous supply of large flow rates is needed (e.g. cooling systems, safety circuits..)</td>
</tr>
<tr>
<td>Linear control valves</td>
<td>- Liquid level or flow control&lt;br&gt;- Systems where $\Delta p$ across the valve is expected to remain fairly constant</td>
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<tr>
<td>Equal percentage control valves</td>
<td>- Temperature control&lt;br&gt;- Pressure control&lt;br&gt;- Systems where $\Delta p$ across the valve is expected to vary significantly</td>
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</tbody>
</table>
## Regulation valves

### Quick-opening

<table>
<thead>
<tr>
<th>Type</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball valves</td>
<td>• Low cost</td>
<td>• Limited throttling</td>
</tr>
<tr>
<td></td>
<td>• Versatile (high pressure, high temp, high flow)</td>
<td>• Prone to cavitation</td>
</tr>
<tr>
<td></td>
<td>• Low leakage</td>
<td>• Unsuitable to slurries</td>
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<tr>
<td></td>
<td>• Tight sealing with low torque</td>
<td></td>
</tr>
<tr>
<td>Gate valves</td>
<td>• Low cost</td>
<td>• Poor control</td>
</tr>
<tr>
<td></td>
<td>• Suited to fully open/fully closed operation</td>
<td>• Cavitates at low $\Delta p$</td>
</tr>
<tr>
<td></td>
<td>• Suited to slurries</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Tight shut-off</td>
<td></td>
</tr>
</tbody>
</table>
# Regulation valves

## Linear/equal-percentage control

<table>
<thead>
<tr>
<th>Type</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butterfly valves</td>
<td>• Reliable for frequent operation with low Δp</td>
<td>• High torque required for control (poor throttling characteristics)</td>
</tr>
<tr>
<td></td>
<td>• Cheap solution for high flow applications (water treatment, fire protection)</td>
<td>• Prone to cavitation at low flow</td>
</tr>
<tr>
<td>Globe valves</td>
<td>• Precise flow regulation</td>
<td>• Expensive</td>
</tr>
<tr>
<td></td>
<td>• Frequent and wide throttling</td>
<td>• Low shut-off capability</td>
</tr>
</tbody>
</table>
Regulation valves

$k_{v0}$: Minimum flow rate (m³/hr), below which regulation is not possible: curve deviates from equal percentage law due to «noisy» shut-off

**Rangeability**

$$R = \frac{k_{v1}}{k_{v0}}$$

Rangeability is an important metric of in **equal-percentage valves** because:

1) It determines the minimum controllable flow $k_{v0}$
2) It gives the curvature of the characteristic curve

$$\frac{k_v}{k_{v1}} = R^{[(x/x_1) - 1]}$$
Regulation valves

Valve authority
It describes how well a throttling valve will control flow under the influence of other elements in the HVAC system

\[ \alpha = \frac{\Delta p_v(x_1)}{\Delta p_v(x_1) + \Delta p_c} \]

- \( \alpha < 30\% \) unstable to fair control with low \( \Delta p \)
- \( 30\% < \alpha < 50\% \) fair to good control with reasonable \( \Delta p \)
- \( \alpha > 50\% \) very good control with high \( \Delta p \)
Regulation valves

Note

• Flow factor $k_v$: flow rate ($m^3/hr$) across the valve at 5-30°C under $\Delta p = 1$ bar
• $\Delta p \approx f(Q^2)$

$$\Delta p [mm] = 0.01 \left( \frac{Q [l/hr]}{k_v[m^3/hr]} \right)^2$$
Regulation valves

Two-way valves

Typical use
Adapting flow rate to local energy demand in hydraulic circuits with variable flow

Examples
• Thermostatic valves in radiator systems
• 2-way valves in fancoil circuits
• 2-way valves in substations of DH networks with variable flow rate
Regulation valves

Two-way valves

2-way valve normally closed actuator

2-way installed on the supply

2-way installed on the return
Regulation valves

Example: selection of a two-way valve

Choose between valve A ($k_{v_1} = 18 \text{ m}^3/\text{hr}$), valve B ($k_{v_1} = 6 \text{ m}^3/\text{hr}$) and valve C ($k_{v_1} = 3 \text{ m}^3/\text{hr}$) to control the flow rate in a circuit with design flow rate equal to 1500 l/hr. The corresponding pressure loss in the circuit, excluding the valve, is 6 kPa.
Regulation valves

Three-way valves

Typical use
Supply temperature control via mixing/ diverting in hydraulic circuits with constant flow

Examples
• Mixing valves on the supply line downstream heat generation systems (heat pumps, gas boilers etc)
• Diverting valves on the return line downstream heat loads (heat exchangers)
Regulation valves

Three-way valves
Regulation valves

Three-way mixing valves
Regulation valves

Three-way diverting valves

3-way installed on the supply in diverting configuration

3-way installed on the return

3-way valve normally closed actuator

3-way Zone valves can be fitted with NC actuators only.

Note! Rotate 180° the valve body for NO applications
Constant speed pumps

Control at constant speed

\[ \Delta p \]

\[ Q_v \]

A

B

n
Variable speed pumps

Control at constant $\Delta p$

Diagram showing $\Delta p$ vs $Q_v$ with points A and B, and curves for $n$ and $n'$.
Variable speed pumps

Control at proportional $\Delta p$
\[ P = \dot{m} \cdot g \cdot \Delta z \]

\[ P = \frac{55}{3.6} \times 11.5 \times 9.81 \]

\[ = 1723 \text{ W} \]

\[ \eta = 75\% \]

\[ P = \frac{1723}{0.75} = 2300 \text{ W} \]

\[ P = \frac{40}{3.6} \times 11.5 \times 9.81 \]

\[ = 1253 \text{ W} \]

\[ \eta = 70\% \]

\[ P = \frac{1253}{0.7} = 1790 \text{ W} \]

\[ \Delta P = -22\% \]
\[ P = \dot{m} \cdot g \cdot \Delta z \]

\[ P = \frac{55}{3.6} \times 11.5 \times 9.81 = 1723 \text{ W} \]
\[ \eta = 75\% \]
\[ P = 1723 \div 0.75 = 2300 \text{ W} \]

\[ P = \frac{35}{3.6} \times 9.5 \times 9.81 = 906 \text{ W} \]
\[ \eta = 67\% \]
\[ P = 906 \div 0.67 = 1352 \text{ W} \]

\[ \Delta P = -41\% \]
Balancing valves

Reverse return distribution (Tichelman loop)
Balancing valves

Direct return distribution
Balancing valves

Application examples

To adjust the flow rate to each riser

To adjust the flow rate to each terminal
Balancing valves

Operating principle

• The balancing valve is a hydraulic device that regulates the flow rate of the medium passing through it.

• Regulation is performed using a knob that governs the movement of an obturator, to regulate the flow of the medium.

• The desired flow rate is obtained by adjusting the Δp value, which is measured through two piezometric connections suitably positioned on the valve.
Balancing valves

Static vs dynamic balancing

• Variable flow rate systems are the most difficult to balance because the differential pressures, and therefore the network flow rates, vary continuously in relation to the opening or closing position of the 2-way valves.

• These variations can only be controlled with balancing devices that work in dynamic conditions, i.e. in variable positions.

• In variable flow rate systems, static devices can only limit the maximum flow rates, but they are not able to cope with the continuous pressure and flow rate change that characterizes the operation of these systems.
Balancing valves

Static balancing

Flanged connection

Threaded connection
Balancing valves

Static balancing

\[ k_v = \frac{Q}{\sqrt{\Delta P}} \]
Balancing valves

Application examples
Balancing valves

Dynamic balancing

FLOW RATE DYNAMIC BALANCING

**Automatic flow rate regulator**

The automatic flow rate regulators are able to keep a constant flow rate of the medium that passes through the circuit in which they are installed.

**Independent regulator from pressure**

They are pressure independent flow regulators (they are indicated by the abbreviation PICV: Pressure Independent Control Valve). They keep the flow constant to the preset value when the operating conditions change. By means of a suitable actuator they can change the nominal flow rate.
Balancing valves

Dynamic balancing

\[ G_{\text{constant}} = K_v(\text{variable}) \cdot \sqrt{\Delta P(\text{variable})} \]
Balancing valves

Balancing flow rate
The balancing flow rate is the new flow rate obtained by varying the head applied to a circuit.

It can be calculated, with good approximation, using the following formula:

\[ G = G_o \left( \frac{H}{H_o} \right)^{0.525} \]
Regulation valves

Example: selection of a three-way valve
Choose the mixing valve to control the supply temperature for a house with 6 radiant system circuits.
References

• Manuale d’ausilio alla progettazione termotecnica – Miniguida AICARR (III ed.)
• Caleffi Handbooks (available online both Italian and English)