Control Valve Authority and Pressure Independent Systems

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Agenda

Why differential controllers?
• Controllability in ATC valves
• Energy Savings
• Retrofit-ability

How to use Dp controllers?
• How does it work
• Where do they go
• Balancing the system

How TA/Victaulic can help
• Hydronic College Seminars
• TA Select 4
• Engineering Services Center
Why Differential Pressure Control?

• Control valves work with **improved authority**, therefore their performance is improved

• Reducing **pump head** and keep high controllability in the system

• Control valves are **pressure relieved**, so low force (= lower cost) actuators can be used

• **Noise** in control valves is reduced or removed completely

• Circuits are pressure independent modules. Which means:
  • *That the changes in other parts of the system do not affect the circuit*
  • *Large plants can be balanced module by module independently*
  • *New modules can be added to the system without rebalancing*
Differential Pressure Variations

\[ \Delta P \propto q^2 \]

At constant supply water temperature, flow is reduced to 20% and pressure drops are reduced to 4% of their design value.
Control Loop

Sensor $k_1$ \[ \Delta x = U - x \]

Controller $k_2$

Set value $U$

$0 - 10$ volts

Signal $0 - 100\%$

Actuator $k_3$

Lift $0 - 100\%$

Valve $k_4$

Flow $0 - 100\%$

Terminal $k_5$

Power output $0 - 100\%$

Room $x$

$x = \text{controlled value}$

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Terminal unit characteristic

Control valve characteristic

Power output %

Flow in %

Lift h in %

Flow in %

Power output %
Control Valve Authority

The authority ($\beta$) formulates how much the differential pressure builds up on the control orifice of a control valve when it is closing.

\[ \beta = \frac{\Delta P_{\text{Control valve fully open and design flow}}}{\Delta P_{\text{Control valve fully shut}}} \]

Its value indicates how effectively the control valve can reduce the flow while it is closing.
2-way Control Valve Authority (Variable Flow)

**Constant** as soon as the valve $C_v$ is chosen ($\Delta p_v$).

$$\beta = \frac{\Delta P_{\text{Control valve fully open and design flow}}}{\Delta P_{\text{Control valve fully shut}}}$$

**Variable**, depends on flows in the piping, thus also on the opening of all the other control valves.

In a **variable** flow distribution, the authority of a control valve is **variable**.
Distortion of Valve Characteristic

The lower the authority, the larger the $\Delta p$ variations on the control valve, the larger distortion of the valve characteristic.

Control valve with Equal-percentage characteristic (EQM)
Variable Authority of 2-way Control Valves

Authority in design conditions:
\[ \beta \approx \frac{5}{5+7} = 0.42 \]

Authority at half-load:
\[ \beta = \frac{5}{5+7+0.96 \times 21} = 0.15 \]

Low flow (half-load)

0.96*21 ft in excess in the valve at half-load

5 ft in the valve

7 ft in the circuit

VSP does not allow to compensate for all local Dp variations in the plant
Control Valve Sizing

Control valves are commercially available with Cv values increasing according to the Reynard series:

Cv: ....... 2.0 3.0 4.0 5.0 10 20 30 .......

Flow to a FCU of 29 gpm, Δp 5 psi and 2 psi in connecting pipes. The commercially available control valves create a design ΔpV of:

<table>
<thead>
<tr>
<th>Cv</th>
<th>ΔpV [psi]</th>
<th>β_{design}</th>
<th>ΔH [psi]</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>7</td>
<td>0.5</td>
<td>14</td>
</tr>
<tr>
<td>20</td>
<td>2.12</td>
<td>0.23</td>
<td>9.12</td>
</tr>
<tr>
<td>10</td>
<td>8.49</td>
<td>0.55</td>
<td>15.49</td>
</tr>
</tbody>
</table>

NOTHING in between

Conclusion:
Control valves are generally **oversized**.
Effect of Dp Variations

Δp variations distort the characteristic of the control valve  
⇒ the nonlinear characteristic of the terminal unit is no longer compensated
Noise

Sound pressure level [dB]

RULE OF THUMB:
Static pressure at the inlet of the valve should be at least twice the pressure drop in the valve.
Closing of Control Valves

According to its design, each valve has a required actuation close-off force or torque that depends on:
- Tension of the return spring, if any,
- Friction with o-rings and seals,
- Differential pressure applied on the plug.

Each control valve/actuator combination has a certain close-off differential pressure

<table>
<thead>
<tr>
<th>Type</th>
<th>Conn. DN in.</th>
<th>Kv</th>
<th>Cv</th>
<th>Kv</th>
<th>Cv</th>
<th>MZ18/L / 18A / 18B 180 N (40 lbf.) Max. ΔPc kPa psi</th>
<th>MZ10T 96 N (22 lbf.) Max. ΔPc kPa psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>VZ22</td>
<td>15 ½&quot;</td>
<td>0.16</td>
<td>0.19</td>
<td>1600</td>
<td>232</td>
<td>500</td>
<td>87</td>
</tr>
<tr>
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<td>0.29</td>
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<td>232</td>
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<tr>
<td>VZ22</td>
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<td>232</td>
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<td>87</td>
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<tr>
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<td>0.63</td>
<td>0.74</td>
<td>1600</td>
<td>232</td>
<td>500</td>
<td>87</td>
</tr>
<tr>
<td>VZ22</td>
<td>15 ⅛&quot;</td>
<td>1.00</td>
<td>1.17</td>
<td>1200</td>
<td>174</td>
<td>180</td>
<td>26</td>
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<tr>
<td>VZ22</td>
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<td>1.6</td>
<td>1.9</td>
<td>1200</td>
<td>174</td>
<td>180</td>
<td>26</td>
</tr>
<tr>
<td>VZ22</td>
<td>20 ¼&quot;</td>
<td>2.5</td>
<td>2.9</td>
<td>400</td>
<td>58</td>
<td>50</td>
<td>7.3</td>
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<tr>
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<td>4.0</td>
<td>4.7</td>
<td>400</td>
<td>58</td>
<td>50</td>
<td>7.0</td>
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</tbody>
</table>

A-AB: | B-AB:
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<tr>
<td>VZ32</td>
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</table>
Agreed?

The differential pressure across control valves must not vary too much.
Control Valve Authority

To achieve good control it’s recommended to fulfill two rules on authority:
1. Size the control valve with a Cv with $\beta_{\text{design}} \geq 0.5$
2. Ensure that $\beta_{\min} \geq 0.25$

**Rule no 1:**
$\Delta p_V \geq \Delta p_C + \Delta p_{\text{pipe}} + \Delta p_{\text{STAD}}$

or
$\Delta p_V \geq 0.5 \times \Delta H$

$\beta_{\text{design}} \geq 0.5$

**Rule no 2:**
$\Delta p_V \geq (\Delta p_{\text{piping}} + \Delta p_C)/3$

or
$\Delta p_V \geq 0.25 \times H$

$\beta_{\min} \geq 0.25$
**Rule no 1:**
For obtaining a design authority of 0.5:
\( \Delta p \) in control valve must be \( \geq 0.5 \times \Delta H \)

Since \( \Delta p \) circuit = 7 ft, 
\( \Delta p \) in control valve must be \( \geq 7 \) ft

**Final pump head** = 40 + 7 = **47 ft**

\( \beta_{design} = \frac{7}{14} = 0.5 \) but

\( \beta_{min} = \frac{7}{47} = 0.15 \)

**Rule no 2:**
For obtaining a minimum authority of 0.25:
\( \Delta p \) in control valve must be \( \geq 0.25 \times H \)

Since \( \Delta p \) piping + circuit = 33 + 7 = 40 ft, 
\( \Delta p \) in control valve must be \( \geq 13.3 \) ft \((40/3)\)

**Final pump head** = 40 + 13.3 = **53.3 ft**

\( \beta_{design} = \frac{13.3}{20.3} = 0.66 \) and

\( \beta_{min} = \frac{13.3}{53.3} = 0.25 \)
Improved Control with Reduced Pumping Energy

Control valve sizing with Dp control:
For obtaining a design authority of 0.5 and min of 0.25:

\[ \Delta p \text{ in control valve must be } \geq 0.5 \times \Delta H \text{ and } \geq 0.25 \text{ of stabilized } \Delta p \]

Since \( \Delta p \text{ circuit} = 7 \text{ ft} \),
\( \Delta p \text{ in control valve must be } \geq 7 \text{ ft} \)

Final stabilized \( \Delta p = 7 + 7 + 2 = 16 \text{ ft} \)
\[ \beta_{\text{design}} = \frac{7}{14} = 0.50 \text{ and } \]
\[ \beta_{\text{min}} \frac{7}{16} = 0.44 \]

Final pump head = 31 + min \( \Delta p \) of DpC (2 ft) + 2 + 7 + 7 = 49 ft
How Does it Work?

Measuring valve

Flow measurement

Differential pressure Stabilization

Dp controller

$\Delta H$

$\Delta P$
Dp Controller Position

Depending on project structure, Dp control will be applied:

On risers,

On branches,

On control valves.
Your Plant Could Have it All
Find the best Dp control solution...

First, decompose the plant into modules
Dp Control Solution… (1)

Dp control on each control valve

Parameters:
On-off or modulating control
Dp in pipes; length of branches
Material cost
Dp Control Solution... (2)

Parameters:
- On-off or modulating control
- Dp in pipes; length of branches
- Material cost

Dp control on branches
Key 2 Take away …

Using differential pressure controllers is the most cost effective method to insure a minimum stabilized control valve authority.

Dp Controllers can reduce your operating cost.

Maintain control of what gets installed in your design by including in your spec minimum control valve authority ≥ 0.25 to be verified during submittal process.
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- Engineering Support Center
Thank you for your attention!

Questions?