Effective water balancing to optimize energy efficiency

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Needs for balancing

- To overcome difference in pipe and fittings pressure drops
- Terminal units are generally oversized
- Control valves oversizing
- Pump oversizing
Control valve oversizing

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

\[
\begin{array}{cccccccc}
\text{Kvs:} & 1.0 & 1.6 & 2.5 & 4.0 & 6.3 & 10 & 16 & \ldots \\
\end{array}
\]

For a water flow of 6 m³/h = 1.66 l/s, the commercially available control valves create a design \( \Delta pV \) of:

14, 36 or 91 kPa, nothing in between.

**Conclusion:**
Control valves are generally **oversized**.
Objectives of balancing

- Every terminal obtain design flow at design condition
- To obtain the minimum pump head required
  - In most case, index circuit takes excessive pressure drop
  - Index circuit not identified correctly

Index circuit Dp is a good indicator of how good system is optimised.
Energy saving hierarchy

Oversized plant

Balanced system at design condition
- Reduced overflow
- Optimized pump head

Dynamic balanced system
- Reduced overflow at part load
3 balancing measures

- Manual balancing valve
  - Shut off valve
  - Fixed orifice
  - Valve with removed handwheel
  - Drain
  - All in one BV

- Automatic flow controller
- Differential pressure controller

Produced by TA Hydronic College
Manual balancing

Adjusting the **design flows** in all terminal units in **design conditions**

- Design conditions are the "worst" plant operating conditions, under which maximum flow is required: control valves are all fully open.
- If design flows are adjusted under design conditions, they can be obtained in all other conditions.

This should be achieved while creating the **absolute minimum amount** of additional pressure drops.
The structure of hydronic modules can be seen as a hierarchical tree.

Before a module can be balanced, the whole descent of this module must be balanced.

Balancing order:
Automatic flow controller - characteristic

Δp FC: 0 to 14 Kpa at flow
0 to 100%
Δp FC: 14 to 220 Kpa at design flow
flow accuracy: ± 5%

Best to avoid operating above control range
Example for 14 to 220kPaD range cartridge.

Above maximum differential pressure piston fully compresses & acts as fixed orifice.

Within differential pressure range, piston responds limit to design flow ±5%.

Below minimum differential pressure piston fully extends & acts as a fixed orifice.
Automatic Balancing

CONSTANT FLOW SYSTEMS
- Good solution to avoid balancing methods
- Technical the same quality as with manual balancing valves due to constant flow and pressure conditions

VARIABLE FLOW SYSTEMS
- Works excellent with ON/OFF control valves
- Valve authority could be poor in modulating control
Control valve authority

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

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

Its value indicates how effectively the control valve can reduce the flow while it is closing.
Differential pressure variations

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

Flow

Emission

50% load

At constant supply water temperature

20% flow

4% press. drop

Pressure drops are reduced to 4% of their design value.
Variable authority of 2-way control valves

Example:

Authority in design conditions:
\[ \beta \approx \frac{15}{15 + 20} = 0.43 \]

Authority at half-load:
\[ \beta = \frac{15}{15 + 20 + 0.96 \times 65} = 0.15 \]

0.96\times65 \text{kPa} + 0.96\times20 \text{kPa} \approx 82 \text{kPa}
in excess in the valve at half-load

15 kPa in the valve
20 kPa in the circuit
$\Delta p$ variations distort the characteristic of the control valve
$\Rightarrow$ the nonlinear characteristic of the terminal unit is no longer compensated

**Effect of $Dp$ variations on controlled heat output**

**Rangeability**
area of the control valve

**Valve characteristic:**
$EQM_\vartheta = 0.33$  $R = 25$

**Control valve lift**
## Summary

<table>
<thead>
<tr>
<th></th>
<th>Manual Balancing</th>
<th>Automatic Flow Controller</th>
<th>Dp Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
<td>Constant flow, On/Off</td>
<td>Constant flow, On/Off</td>
<td>Variable flow, On/Off or Modulating</td>
</tr>
<tr>
<td><strong>Pressure drops calculation</strong></td>
<td>Necessary</td>
<td>Necessary</td>
<td>Necessary</td>
</tr>
<tr>
<td><strong>Installation requirement</strong></td>
<td>Before or after terminal unit, several diameters before and after balancing valve</td>
<td>Downstream of terminal units</td>
<td>At water return side</td>
</tr>
</tbody>
</table>
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<tr>
<td><strong>Equipment</strong></td>
<td>Manometer/comp.</td>
<td>Manometer</td>
<td>Manometer</td>
</tr>
<tr>
<td></td>
<td>uterized balancing instrument</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flow measurement</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Tolerance</strong></td>
<td>≥ ±5%</td>
<td>± 5%</td>
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</tr>
<tr>
<td><strong>Balancing time</strong></td>
<td>≈ 30min per balancing valve</td>
<td>≈ 3min per AFC (Dp verification only)</td>
<td>≈ 5min per Dp Controller</td>
</tr>
<tr>
<td><strong>Change of flow</strong></td>
<td>System level rebalancing</td>
<td>Replace cartridge/canister</td>
<td>Adjust spring pressure</td>
</tr>
</tbody>
</table>
Pfizer pharmaceutical production unit nearby Tours (France)

- Installed cooling capacity of 5.4 MW (3 chillers in cascade)
- Total design flow: 773 m³/h = 215 l/s
- Problem: production alarms!
- 80 balancing valves from DN 15 to DN 200

- Audit of plant with TA Select based on a first measurement campaign (presettings calculated, viscosity corrections checked)
- Full balancing performed using TA-Balance on one TA-CBI
Saving case 1

Before balancing:
- Industrial plant
  - 5.4 MW cooling capacity
- 889 m³/h = 247 l/s
- 335 kPa pump head

After balancing:
- 773 m³/h = 215 l/s (-13%)
- No production alarms!
- 270 kPa pump head (-20%)
- Pumping power reduction: 39 kW
- Savings: 17200 €/year
  - 13500 £/year
Saving case 2 – HKPU Dean office

- 10 x STAD DN20 at FCU terminal level, 1 x STAD DN50 and 1 x STAP DN50 in partner pair at distribution piping
- **Without balancing**: Total flow 0.9 l/s, $\Delta T=6^\circ C$, output 22.5kW
- **After balancing**: Total flow 0.6 l/s, $\Delta T=7^\circ C$, output 17.5kW
- Eliminate over-duty 5kW or 22%, total flow down 33%
  Equivalent to 284 sq. ft. of cooling space
  OR
  2 sets of 1HP window type AC
  with Grade 1 energy label
Wing P-Q hydronic system improvement at 7/F & 8/F PAUs

- Overflow analysis showed 20% overflow at 40% loading
- Replace existing balancing valve and add DP controller work in partner pair at PAU piping branch
- Re-balance with TA computerized balancing instrument
Improved controllability

**BEFORE**

**AFTER**

**Valve Status & Flow Rate Against Time on 07/07/2007~Saturday (PAU at 7/F)**

**Valve Status & Flow Rate Against Time on 20/07/2007~Friday (PAU at 7/F)**
Key results

- Over-duty reduction: 896 kWh/wk
- Energy input saving (COP = 2.5): 358 kWh/wk
- Saving per month ($0.9/kWH): $1,450.00/mth
- Equipment, installation & balancing: $20,000.00
- Payback: 13.8 mths
Through balancing, many hydronic problems may be detected:

- Filters or valves clogged
- Terminal units or exchangers wrongly mounted
- Pipe damaged or not connected as expected
- Shut-off valves partially shut
- Check valves or pumps installed back-to-front

Balancing exposes these flaws while they can still be cheaply repaired.
Questions?

Thank you for your attention!