Thermo-hydraulic implications of different design guidelines for 4th Generation District Heating Networks

Johannes Küchle
solar@uni-kassel.de / j.kuechle@uni-kassel.de
University of Kassel, Germany
Motivation: Differing design guidelines for pipe diameters

Maximum flow velocity in m/s

\[ \dot{V} = 10 \text{ m}^3/\text{h} \]

You can save one DN size

→ Which one to use?

Sources:
Motivation:
What about thermo-hydraulic performance?

Previous result: Economic comparison[1]
→ Design for higher pressure drop reduces total heat distribution cost

Now: Detailed annual simulations of the network
\[ \Delta p? \quad W_{\text{pump}}? \quad Q_{\text{loss}}? \quad \dot{m}_{\text{bypass}}? \quad \bar{T}_{\text{return}}? \]

→ Any drawbacks of designing for higher pressure drops?

Case Study:
A small LTDH-network

- Trench length: 3 km
- Efficient buildings: Heat demand 1800 MWh/a → 600 kWh/(m·a), 27 % DHW
- Low Temperature District Heating: 70 °C/40 °C
Detailed STANET-Simulation model:

- Twin pipes, standard insulation
- Fixed return temperatures
- Controlled bypasses at branch endpoints maintain 60 °C
- Annual simulation, timestep 1 h
3 Design variants:
75, 150, and 300 Pa/m

Maximum flow velocity in m/s

A → C: Network volume reduced by 40 %
Results:
Low pressure drops

→ Max. pressure drop on average only 40 % of design value
→ House lead-in pipes oversized (restricted to DN20)
→ Annual average pressure drop is 10 times smaller
Results:
Pump energy increases moderately

A→C: Maximum pump power almost doubled
A→C: Pump energy demand increases by only 20 % due to dominance of the low load period
Results:
Heat losses decrease

A→C: Reduction of heat losses by 8% due to reduced pipe diameters
Results:
Reduction of bypass flows

A→C: Bypass flows during 60% of the year (3% of total flow)

A→C: Reduction of bypass flows by 18% due to less temperature degradation in smaller pipes
Results:
Impact of bypass flows on return temperature

A, B & C: Return temperature contamination up to 12 K in summer
A→C: 0.2 K lower return temperature over the year due to less bypass flows at smaller pipe diameters
## Results: Overview

<table>
<thead>
<tr>
<th>Measure</th>
<th>Unit</th>
<th>A_75</th>
<th>B_150</th>
<th>C_300</th>
<th>Trend A→C</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta p_{\text{max}} )</td>
<td>bar</td>
<td>0.87</td>
<td>1.07</td>
<td>1.80</td>
<td>↗ +107 %</td>
</tr>
<tr>
<td>( W_{\text{pump}} )</td>
<td>MWh/a</td>
<td>3.30</td>
<td>3.48</td>
<td>3.97</td>
<td>↗ +20 %</td>
</tr>
<tr>
<td>( Q_{\text{loss}} )</td>
<td>MWh/a</td>
<td>236</td>
<td>226</td>
<td>217</td>
<td>↘ -8 %</td>
</tr>
<tr>
<td>( \dot{m}_{\text{bypass}} )</td>
<td>%</td>
<td>3.1</td>
<td>2.8</td>
<td>2.5</td>
<td>↘ -18 %</td>
</tr>
<tr>
<td>( \bar{T}_{\text{return}} )</td>
<td>°C</td>
<td>40.8</td>
<td>40.7</td>
<td>40.6</td>
<td>↘ -0.2 K</td>
</tr>
</tbody>
</table>
Conclusion

Design for high specific pressure drops up to 300 Pa/m
...has positive effects on thermo-hydraulic performance
...does not entail unfavourably high pressures and pump energy demands

Thank you for your attention!
www.solar.uni-kassel.de