Solutions for low temperature heating of rooms and domestic hot water in existing buildings

Svend Svendsen, Dorte Skaarup Østergaard, Xiaochen Yang
Department of Civil Engineering, Technical University of Denmark
ss@byg.dtu.dk
Introduction

• Implementation of 4th generation district heating systems must be based on lowering the operation temperature of room heating system and the domestic hot water system.

• Step 1: Lowering the return temperature
• Step 2: Lowering the supply temperature

• Solutions for existing buildings worked on in 4DH:

WP 1.1. Heating of existing buildings by low-temperature district heating. Dorte Skaarup Østergaard
WP 1.2. Supply of domestic hot water at comfort temperatures without Legionella. Xiaochen Yang
Solutions for low temperature heating of rooms

- Focus on existing buildings with radiators
- Problem areas:
  - Type of pipe systems
  - Type of radiators
  - Type of control system
  - Design heating load and temperatures
  - Actual heating load of rooms
Type of pipe systems

• One-string connections of radiators
  – Return temperature from radiators mixed with supply flow
  – Low return not possible
  – Convert to:

• Two-string connections of radiators
  – New smaller dimension pipes
Type of radiators

• Low radiators / convectors
  – High return temperature
  – Replace with

• High panel radiators
  – No need for radiator below new windows
Type of control system central

- Central supply temperature control – weather compensation
  - In ‘bad’ systems with high heat loss from pipes outside heated rooms and errors in control low supply temperature reduces the errors
  - In systems with correct function high supply temperature reduce the return temperature
Type of control system – on each radiator

• Thermostatic radiator valves, TRV
  – Room temperatures outside the 2°C P-band opens the valve fully
  – Open windows and night set back results in reheating with fully open valve and high return temperature
  – Can be avoided by use of:

• TRV with return temperature sensor
  – Heat room with low return temperature
Design heating load and design operation temperatures

• Return temperature depends on:
  – Heat demand during the heating season
  – Heating power of radiators versus temperature difference of water and room
Heat demand during heating season

![Graph showing heat demand during the heating season. The graph plots hours on the x-axis and part load percentage on the y-axis. The data points are connected by a line, showing the decrease in heat demand over time.]
The heating power of radiators

\[ \varphi = \left( \frac{LMTD}{LMTD_0} \right)^n \varphi_0 \]  

where \( \varphi \) and \( \varphi_0 \) present the heating power at operating temperatures and design conditions (W), \( LMTD \) and \( LMTD_0 \) denote the logarithmic mean temperature difference between radiator and surroundings at the operating temperatures and design conditions (°C), whereas \( n \) is the radiator exponent and describes the exponential relationship between the mean temperature difference and the heat emitted from the radiator — 1.3 is the typical value for hydraulic radiators [12].

The logarithmic mean temperature distribution, included in the Danish standard [45], is expressed by Equation (2).

\[ LMTD = \frac{T_S - T_R}{\ln \left( \frac{T_S - T_i}{T_R - T_i} \right)} \]  

where \( T_S \) is the supply temperature (°C), \( T_R \) the return temperature (°C) and \( T_i \) is the indoor operative temperature (°C).
Optimized supply and return temperature reduction of return temperature

Fig. 6. Scenario A supply and return temperatures: optimization results.

Fig. 7. Scenario A: relation between optimized supply/return and outside temperatures.
Optimized supply and return temperature reduction of both supply and return temperature

Fig. 8. Scenario B supply and return temperatures: optimization results.

Fig. 9. Scenario B relation between optimized supply/return and outside temperatures.
Actual heating load of rooms

• The real heating load of each room
  – Difficult to calculate
  – Can be found from heat allocation meters on the radiators in the rooms

• Actual heating load and heating power of existing radiators can be used to:
  – Estimate potential of lowering temperatures
  – Control function of improved control
Evaluation of solutions for low temperature heating of rooms

• Existing buildings with existing radiators
• has a big potential for
• operation with lower return and supply temperatures

• BUT:
• Errors must be fixed
• Return temperature control necessary
Solutions for low temperature heating of domestic hot water, DHW

• Requirements:
  – Delay time of max 10s
  – Comfort temperature of DHW: 40-45°C
  – Legionella safe temperature for tanks and circulation lines: 50-55 °C
  – Legionella safe temperatures for instantaneous DHW heat exchangers with small volumes and no circulation line (flat stations): 50°C or 45°C

• Flat stations are ideal for low temperature district heating – to be used in new and renovated buildings

• Existing buildings with DHW tanks and circulation may be improved now to lower the return temperature
Solutions for low temperature heating of domestic hot water, DHW

• Problem areas:
  – Type of DHW production system
  – Type of DHW distribution system
  – Type of control system
  – Design and real DHW load
  – Design and real heat transfer capacity of heat exchanger system and heat loss of distribution system
Type of DHW production system

• Storage tank or instantaneous heat exchanger
  – Tanks require higher supply temperatures than heat exchangers
  – Heat exchangers creates a peak load in the district heating net work if DHW is used simultaneously
  – But due to short use of showers the simultaneity of DHW use is normally not a problem.
Type of DHW distribution system

• With or without circulation system
  – The supply of heat to the flat stations may be made with the room heating loop and reduced heat loss. (2 pipes versus 4 pipes)
  – Quick supply of DHW in summer can be made with use of bathroom floor heating to keep the riser warm.
Type of control system

• Tanks are typically reheated with very high capacity in short time after peak draw off due to oversized valves.

• Supply of heat to the circulation line during night periods with out use of DHW results in high return temperatures
Design and real DHW load

• DHW systems are typically oversized
• New improved control:
  • Measure use of DHW in some weeks and set up typical daily profiles of DHW use
  • Reheat the tank with a low flow that just reheat the tank before the next peak load.
• This can combine heat supply for circulation, heat loss, and heating of cold water in the tank
Typical system with high charging flow (0.25kg/s)
Average return temperature of 56°C
New system with low charging flow of 0.04 kg/s
Average return temperature of 38°C
Design and real heat transfer capacity of heat exchanger system and heat loss of distribution system

- Heat loss of distribution system can be very large compared to use of DHW
  - Insulation of DHW system made be possible by use of a special insulation that fits into the limited space available of the existing pipes.
  - Then improved control can be made useful
Implementation of solutions

• Step 1:
  • may be realized by developing technical solutions and documenting results in real cases in guideline

• Develop and implement a business model based on external investments paid back by motivation tarif.

• Step 2: based on step 1 and some renovation