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Consequences of improvements in domestic hot water circulation circuits - field studies

P.-O. Johansson, J. Wolerstrand,
Lund University/Sweden

Consequences of Improvements in Domestic Hot Water Circulation Circuits – Field Studies

M Sc Per-Olof Johansson, Ph D Janusz Wollerstrand
Department of Energy Sciences, Division for Efficient Energy Systems
Lund University, Faculty of Engineering
Box 188, 221 00 Lund, Sweden
Corresponding author: per-olof.johansson@vok.lth.se

Summary

To achieve good cooling on the primary water at a district heating substation in a building connected to the district heating network, it is important that the domestic hot water (DHW) circulation is well adjusted. With DHW circulation the temperature control of DHW is more stable and primary temperature oscillations are avoided. Too high circulation flow however increases the primary return temperature, while too little flow increases the risk of Legionella growth in the DHW system. The proper hydraulic balancing in the DHW circuit can be easy achieved if thermostatic balancing valves are used.

This paper investigates improvement of DHW circulation in an older district heating connected building. Hydraulic balancing of the circuit using thermostatic balancing valves is studied. To achieve sufficient valve authority an electronically controlled circulation pump was used. As a result temperature level in the circulation circuit increased above 50°C and became more equalized. The heat losses caused by the circulation increased which was expected. Unwanted night-time shut down of DHW circulation in the building for energy saving reasons was discovered. Such procedure is not recommendable from risk of Legionella growth point of view. During the shut down the heat losses surprisingly didn't decrease, due to self-circulation in the DHW circuit caused by increased DHW temperature from 57°C to 83°C at the outlet of the tap water heater. This over heating was caused by a leaking control valve on the primary side.

A correct adjustment of the DHW circulation ensures good temperature quality on the DHW at the tap. It was showed that the changes made in the circuit improved temperature quality of DHW in such a way that the time it took for the DHW temperature to reach 50°C at the tap decreased significantly. More over the tap water consumption significantly decreased on those taps where the temperature level of the DHW was important to the consumers.

1 Introduction

In an older building with DHW circulation circuit, the temperature level in the circuit is often poor. In order to avoid Legionella growth in the circuit it is of great importance that the DHW temperature is above 50°C in all circuit branches. To ensure temperature level above 50°C, thermostatic balancing valves can be installed, but it is of great importance to ensure that the thermostatic balancing valves have sufficient valve authority [1]. If the building is supplied by heat from a district heating system, a well balanced DHW circulation circuit ensures that the return temperature of the district heating water is as low as possible. In buildings with several floors, where the DHW circulation is arranged only in the basement the DHW temperature at the taps is poor due to considerable length of the connecting pipes. This implies poor comfort from consumers' point of view and increased hot tap water consumption.

This study is focusing on changes in DHW temperature in the circulation circuit before and after installing thermostatic balancing valves. Furthermore, we will investigate the influence on DHW temperature comfort at the tap, both with and without extended circulation. [2]

2 Temperatures in a DHW circuit

An older district heating connected university building with DHW circulation limited to the basement was investigated. The investigation was divided into following stages:

- Survey of DHW temperature level and heat losses in the circulation circuit before and after installing thermostatic balancing valves.
- Investigation of DHW temperature quality at taps in two lunchrooms and three toilets before and after DHW circulation was established.
- Additional survey of heat losses after the DHW circulation has been extended

2.1 Survey of the existing DHW circulation loop

The survey of the existing DHW circulation shows that the temperature level was below 50°C in a large branch of the circulation circuit, see figure 1. Note that the DHW circulation return temperature at the district heating substation was still 51.1°C, that means above 50°C, which could imply that the system is properly adjusted.

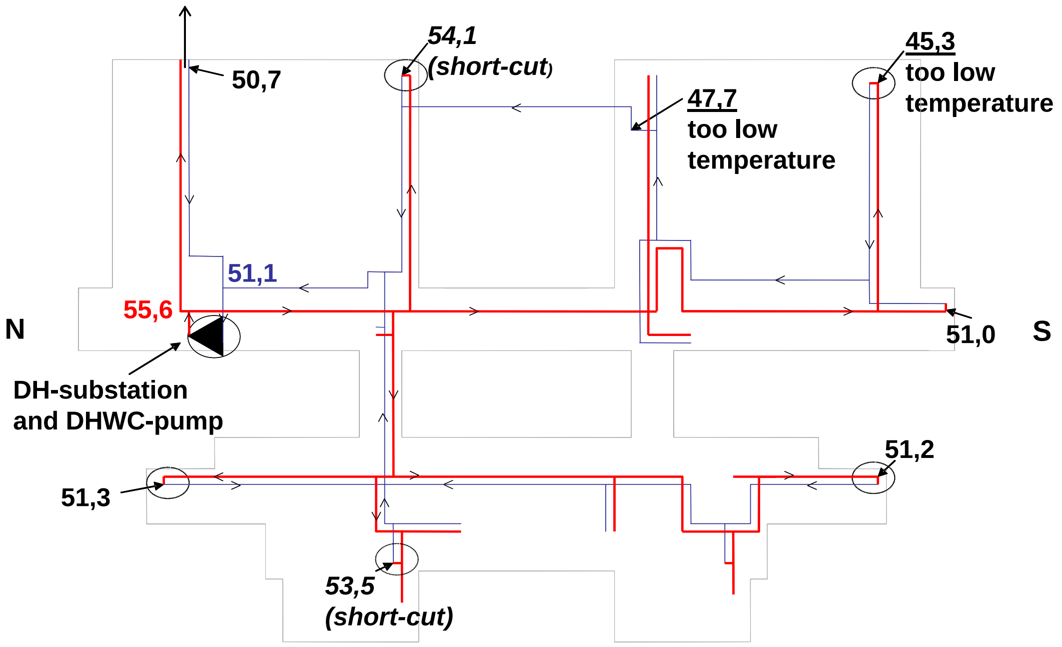


Figure 1 ***Connecting scheme of the DHW circulating system in a large university building. Short-cut points causing insufficient circulation and low temperature in one of branches of the system are shown.***

It was stated that, in order to achieve energy savings, the DHW circulation pump was automatically shut off during night time by the building owner. However, when the circulation pump was turned off the primary control valve in the district heating substation was leaking, and this led to a local overheating of the DHW and to self circulation in the DHW circulation circuit, see figure 2. For this reason the heat losses in the circuit did not decrease. Moreover, the high temperature level of the outgoing DHW lead to risk of burn injuries at taps close to the substation.

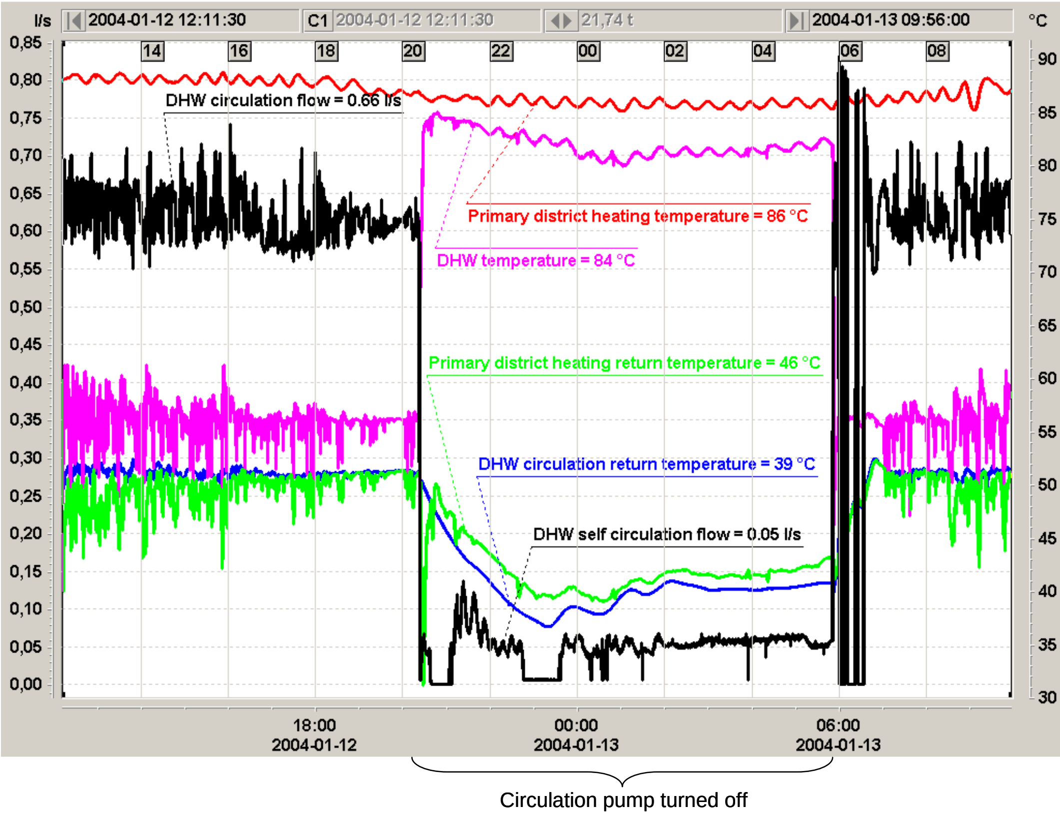


Figure 2 ***Temperature and heat losses during the day and during the night time turn off of the DHW circulation.***

2.2 Documentation after installing thermostatic balancing valves

In order to achieve correct temperature level in the DHW circuit, thermostatic balancing valves were installed, see figure 3.

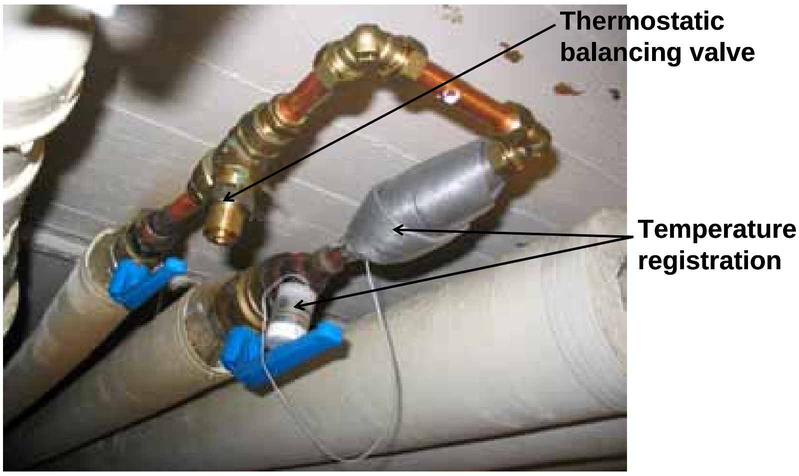


Figure 3 ***Thermostatic balancing valve installed at the end point of DHW circuit***

At the same time, to secure sufficient valve authority, the existing DHW circulation pump was replaced by a larger, electronically controlled one. As a result in all, the temperature distribution in the DHW circulation circuit became more equal, see figure 4.

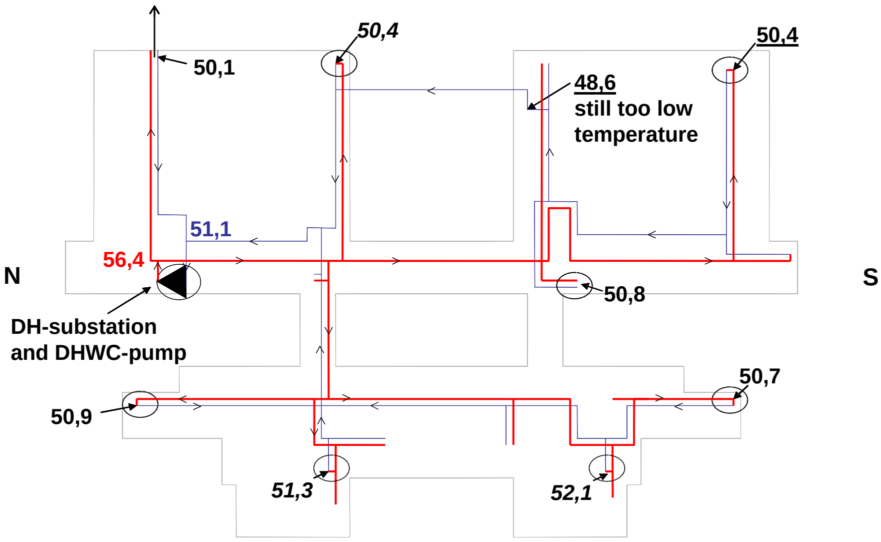


Figure 4 ***Connection scheme of the domestic hot water circulating system in a large university building. Improved temperature level is shown.***

As shown in the figure, there is still one check-point where the water temperature is slightly too low, however the temperature distribution has improved considerably in general. Due to an increased average temperature of the circuit the heat losses increased by 25% after the thermostatic valves has been installed.

2.3 Extending the DHW circulation circuit

The original DHW circulation covered the basement only, however in some parts of the building it was possible to extend the circulation to upper floors, see figure 5. During the second stage of the study the circulation was extended along four DHW stems, with turning points close to taps at two lunchrooms and three toilets. Tapping patterns as well as the temperature level at those taps were registered and compared to the corresponding values from the period before the modification of the circuit.

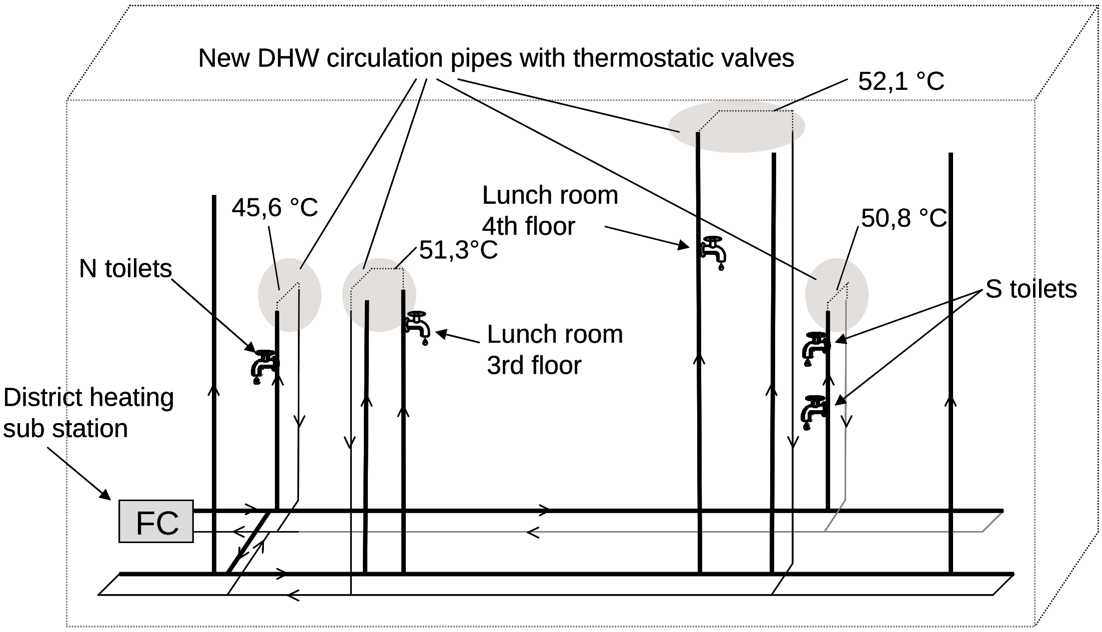


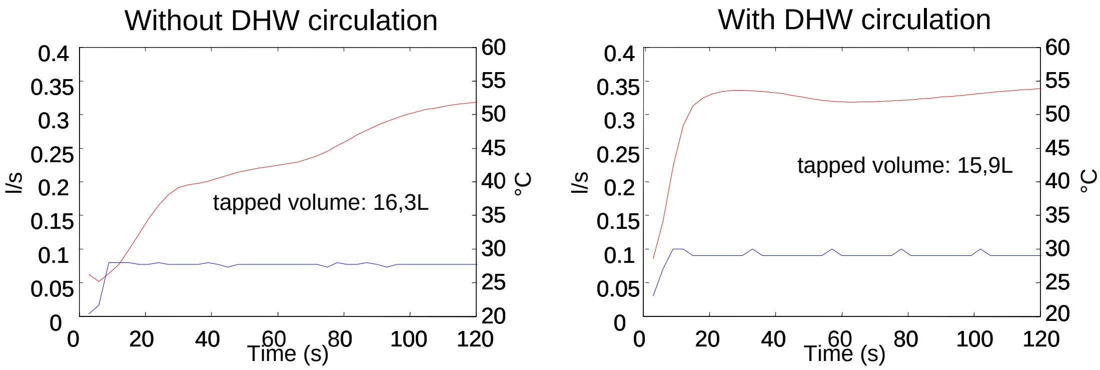
Figure 5 ***Illustration for the extended DHW circulation***

It was stated that in one of the stems (labelled “N toilets” in the figure) the DHW circulation temperature did not reach 50°C although the set point value of the thermostatic circulation valve was set to maximum (60°C). This was probably because of large pressure drop in a considerably fouled DHW supply pipe of the stem.

After the DHW circulation has been extended the heat losses have increased with almost 20% due to increased total pipe length of DHW circuit.

2.3.1 DHW quality in lunchroom

The activities in the lunchrooms are normally concentrated to lunchtime and coffee break time. The lunchroom on 3rd floor has a dishwasher connected to cold tap water. The second lunchroom, situated at the 4th floor, doesn’t have a dishwasher, for which reason the need of a correct DHW temperature is of larger importance to consumers there. Before installation of DHW circulation the time to achieve 50°C was long for the very first consumer. The phenomenon is exemplified in figure 6, where two similar tappings which occurred in the second lunchroom are presented. They are characterised by almost the same DHW flow and beginning temperature, however, the recorded temperature profiles differs strongly. In the case without DHW circulation, to the left, the DHW temperature has not reached 50°C in above one minute time while in the case with DHW circulation established, to the right, the DHW temperature reaches 50°C within 20 seconds.



a) Tap at lunchromm, 4th floor befor installation of DHW circulation

b) ***Tap at lunchromm, 4th floor after installation of DHW circulation***

Figure 6.a-b ***Tapping example before and after DHW circulation is installed***

The beginning and the final temperature of a number of tappings, before and after installation of DHW circulation respectively, are analyzed in figure 7. The boxes show the lower quartile, median and upper quartile temperature of the tappings. The whiskers are lines extending from each end of the boxes to show the extent of the rest of the data. It is implied that, after the DHW circulation has been established, diagrams to the right, the final temperature of tappings longer than 20 seconds is well balanced around 50°C.

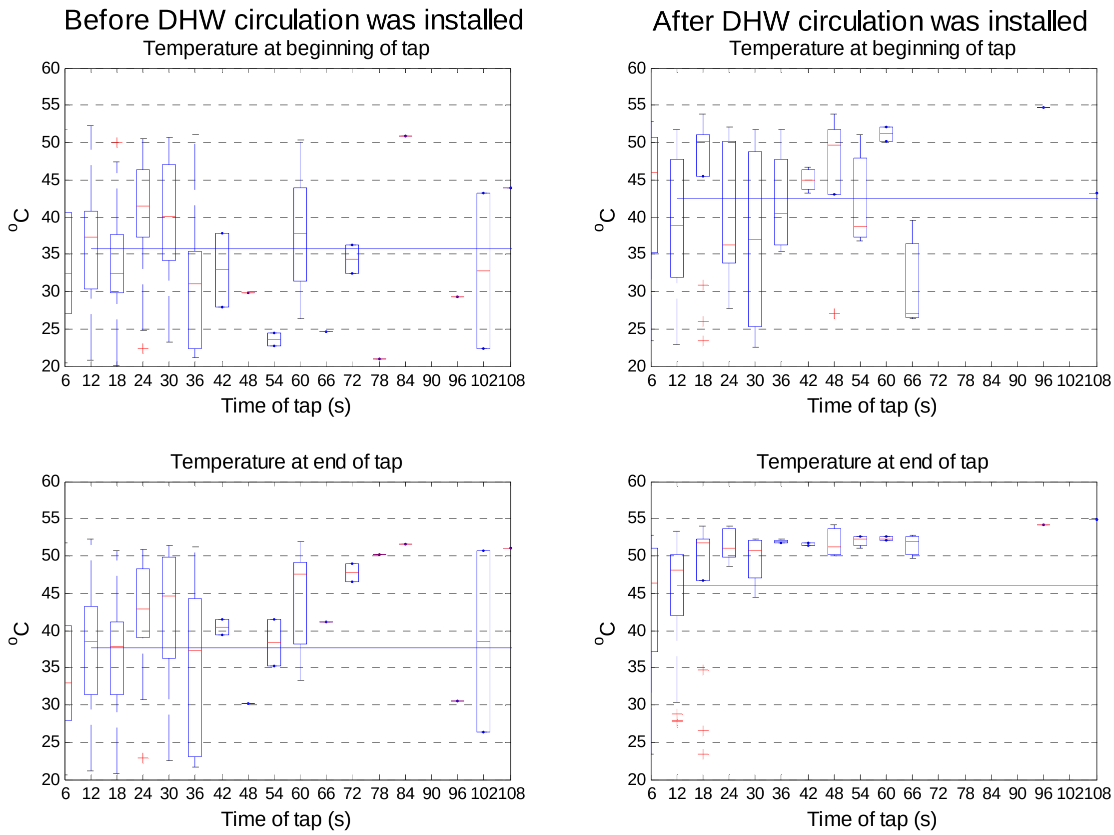


Figure 7 ***Temperature level before, respective after DHW circulation has been installed in lunch room on 3rd floor***

In figure 8 waiting time to achieve 40°C at the tap is analyzed. There is a significant difference in the waiting time depending on whether DHW circulation is established or not. The number of tappings that never reach 40°C have strongly decreased after the DHW circulation has been installed. With DHW circulation present, over 80% of all tappings longer than 10 seconds reaches 40°C, compared to around 45% without circulation respectively.

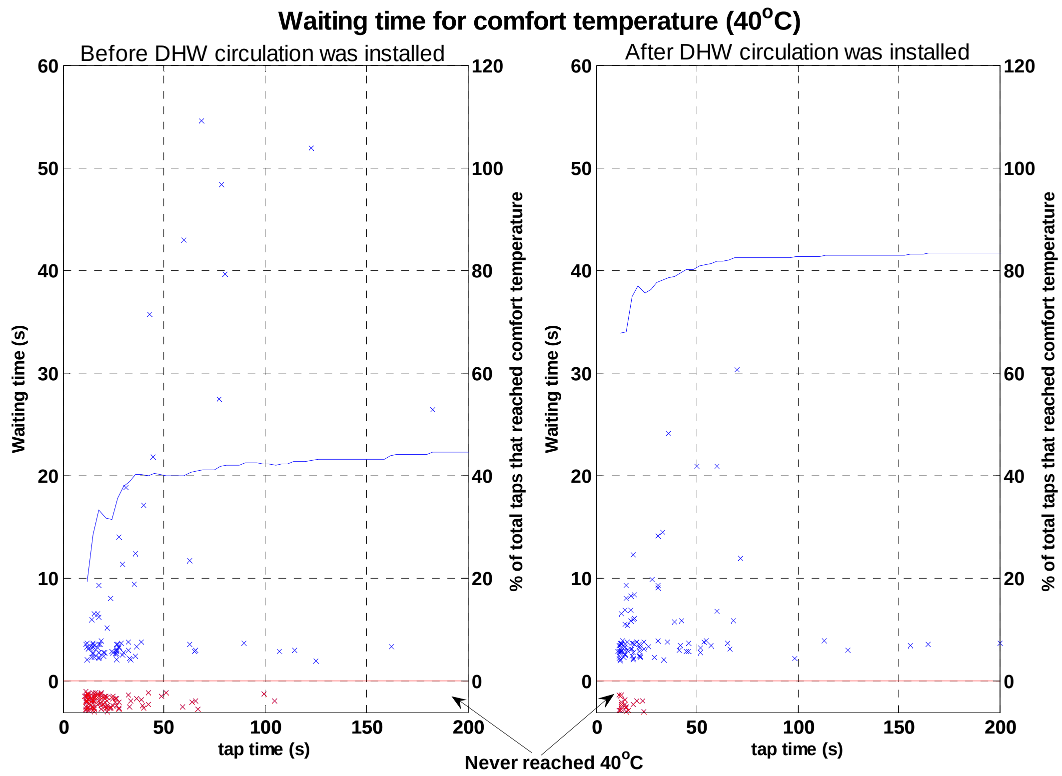


Figure 8 ***Waiting time for comfort DHW temperature in lunch room on 3rd floor before and after installing DHW circulation for tappings longer than 10 s***

2.3.2 DHW quality at the toilets

The usage of DHW differs from the lunchrooms in the usage pattern here. In the lunchrooms the usage is concentrated around lunch and coffee time, with many tappings after each other, whereas the toilets have a random use of DHW.

The two toilet areas investigated were distinguished by different usage pattern. One of them (the north) was during the measurement period frequently visited by construction workers who used the sinks for washing their hands. Therefore the temperature quality of DHW was important to the consumers at these taps.

As shown in figure 9, only around 15% of the tappings longer than 10 seconds in the north toilet area reached 40°C before DHW circulation was installed. This poor number increased to more than 35% with DHW circulation.

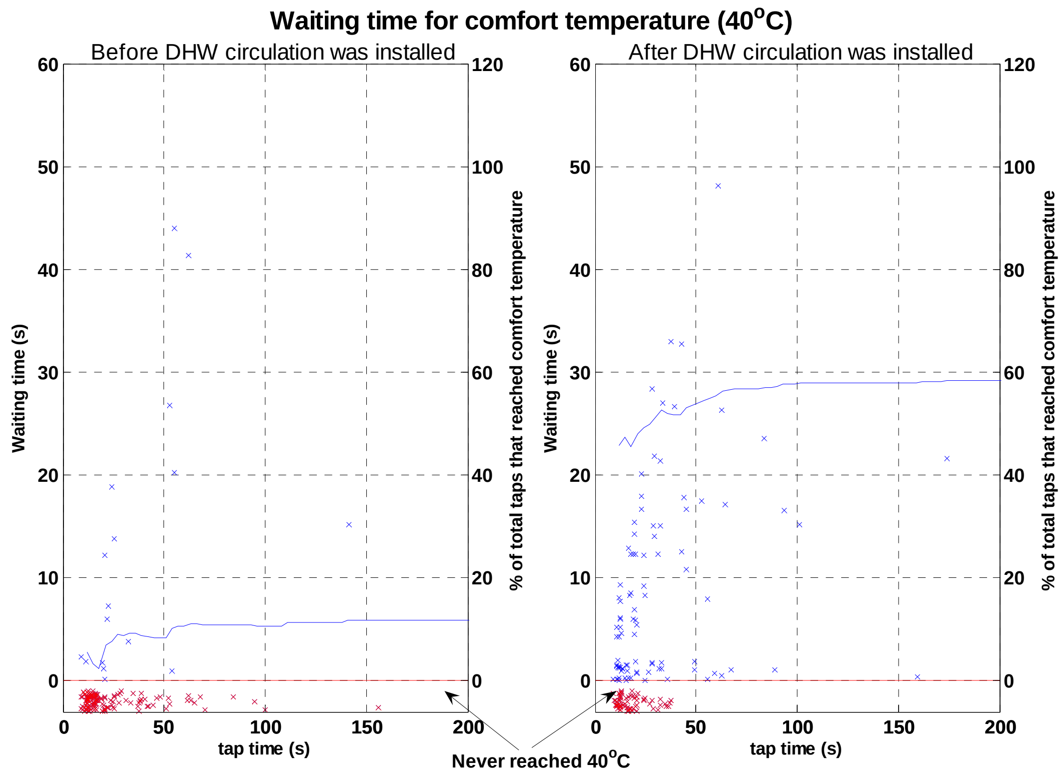


Figure 9 ***Waiting time for DHW to reach comfort temperature for tappings longer than 10 s, N toilets***

The south toilet area follows the same pattern as the north, but had very poor DHW temperature quality before DHW circulation was installed. Before the circulation was installed less than 10% of the tappings longer than 10 seconds reached 40°C compared to over 50% after DHW circulation was installed.

2.4 Energy usage

When introducing DHW circulation the DHW quality at the taps increases. However, the energy losses increase as well due to increased total pipe length of the circulation circuit. The improved temperature level in the DHW circuit also contributes to increase in heat losses. Another parameter which can be influenced by DHW quality is DHW consumption. The mean volume for a tapping has not changed dramatically in the lunchrooms or in the S toilet-region, see table 1.

Table 1 ***Changes in tapping volume before and after DH circulation was installed, tappings over 0.5 L***

	Mean volume per tapping		**Change**
	Without DHW circulation	With DHW circulation	
	(L)	(L)	(%)
Lunchroom 4th floor	3.26	3.58	9.82
Lunchroom 3rd floor	3.2	3.46	8.12
S toilets	1.5	1.43	-4.67
N toilets	2.91	2.06	-29.21

In the N toilets however, the mean volume per tapping has decreased with almost 30%. As already mentioned, the DHW consumption pattern in this toilet was rough hand wash in opposite to quick hand wash in the S toilets during the study. Construction workers who needed much water and good DHW quality frequently used these taps.

The input energy to the district heating substation is constant for heating a certain amount of water (from 17°C to 56°C in our case). This is independent of the temperature level the consumer receives at the tap. However, higher energy efficiency at the tap means higher DHW comfort for the consumer (higher temperature and/or shorter waiting time for hot water). The percentage of energy needed for heating the water at the district heating substation that one actually receives at the tap is calculated in table 2.

Table 2 ***Percentage of energy needed for preparing DHW at the district heating substation that are received at the tap before and after installation of DHW circulation.***

	% of energy needed received at the tap	
	Without circulation	With circulation
Lunchroom 4th floor	76.1	87.6
Lunchroom 3rd floor	61.4	83.1
S toilets	19.4	51.0
N toilets	52.9	61.0

It can be observed that without DHW circulation, the DHW quality was very bad in the south toilet region. Less than 20% of the energy for preparing the DHW was received at the tap. This poor result got better by installing DHW circulation. After the circulation has been installed around 50% of the energy for preparing the DHW reached the tap.

3 Conclusions

- Do not rely on DHW circulation return temperature as a minimum temperature of the whole circuit
- Do not turn off DHW circulation pump with the aim of power saving. This may cause overheating of DHW heat exchanger if the control valve is leaking or working ON/OFF. Only minor energy saving occurs.
- A properly balanced DHW circulation can be achieved by using thermostatic balancing valves (if they have proper authority)
- DHW circulation increases DHW quality at the taps at the expense of increased energy consumption
- DHW circulation can decrease DHW consumption at the taps where the DHW comfort is important for the consumer.

4 References

[1] Persson, T., *District heating for residential areas with single-family housing – with special emphasis on domestic hot water*, 2005, Phd thesis, Department of Energy Sciences, Division for Efficient Energy Systems, Lund University, Faculty of Engineering

[2] Johansson, PO., Wollerstrand, J., *Förändringar i tappvarmvattenanvändning vid införande av tappvarmvattencirkulation – Fallstudie*, (to be published)