Domestic water measurement in two Danish office and educational buildings - Data set description

Frandsen, Martin; Madsen, Jakob Vind; Jensen, Rasmus Lund; Pomianowski, Michal Zbigniew

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by

Martin Frandsen
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1. Foreword

This DCE Technical Report aims to present measured data from three domestic water systems in two Danish office and educational buildings: CREATE, Rendsburggade 14, 9000 Aalborg and TMV23, Thomas Manns Vej 23, 9220 Aalborg Ø. Before use, the measurement equipment is calibrated in the Laboratory for Indoor Environmental and Energy Engineering at Aalborg University. The data set can be found in [1].

This technical report and data set are supplementary material for the journal paper “High frequency flow and temperature measurements of domestic water in two office and education buildings”.

In the master thesis [2], the measurement equipment, calibration, and results are more detailed described.

NB By using the data set in published work, the authors should cite the paper “High frequency flow and temperature measurements of domestic water in two office and education buildings”.
2. Abstract

Measurement data of domestic water in non-residential buildings is sparse. More data is needed to describe the non-residential buildings’ domestic hot water (DHW) demand and to be able to design more efficient DHW systems. This DCE Technical Report aims to present and describe the data set: “Data set - Domestic water at CREATE and TMV23”. This data set contains measurement data from two office and educational buildings in Aalborg, Denmark. The measurements in the building CREATE are conducted from October 2018 to January 2019 and in the building TMV23 from April 2021 to May 2021. The data set consists of water flow rates and temperatures for the domestic cold water, domestic hot water, district heating for DHW production, and DHW circulation circuit.
3. Three domestic water systems

The data set consists of measured data from three domestic water systems in the two buildings in two different periods:

- CREATE, one system, measurement period from 19-10-2018 to 03-01-2019.
- TMV23, two systems, measurement period from 12-04-2021 to 24-05-2021.

Both buildings are academic buildings with staff and students using the draw-off points. Domestic hot water (DHW) is produced instantaneously with a heat exchanger (HEX) utilizing district heating (DH).

Figure 1, shows a sketch of the measured draw-off points in the domestic water system in CREATE. At the highlighted six draw-off points, water temperature and flow rate are measured (four washbasins, one kitchen sink, and one service sink). The pale color draw-off points exist but are not measured. At the HEX for DHW production, the following are measured: DH flow rate, DH supply temperature, DH return temperature, DHW circulation flow rate, DHW circulation return temperature, DHW supply temperature, and domestic cold water (DCW) flow rate to the HEX.

Figure 2, shows the sketch for TMV23 with two DHW systems. The 2nd floor has six measured draw-off points (three washbasins, two kitchen sinks, and one service sink), and the 3rd floor has three draw-off points (three washbasins). Besides the measured quantities described for CREATE, the DCW temperature at the HEX is measured at TMV23. An overview of the measured quantities is shown in Table 1 in the following section.

![Figure 1: Sketch of the domestic water system in CREATE (not to be scaled). The measured draw-off points are highlighted. CW - circulation water.](image1)

![Figure 2: Sketch of the two domestic water systems in TMV23 (not to be scaled). The measured draw-off points are highlighted. CW - circulation water.](image2)
4. Measurement equipment

A small variety of measurement equipment has been used to measure the quantities in the domestic water systems. Table 1 lists the measured quantities, location, and equipment used. The measurement equipment and the location of use are described in the following.

At the draw-off points, Huba flow sensor type 236 [3], see Figure 3, is used to measure water flow rate and temperature. The Huba flow sensor is a vortex flow sensor that measures one flow rate and one temperature. Therefore, two sensors are necessary to measure a draw-off point with a hot and cold water supply. The sensors have been mounted below the sinks right before the faucet. To capture short and rapid changes in the flow rate and temperature without having a large data storage, a specially developed logging system with Porcupines by Seluxit [4], see Figure 4, is developed. The Porcupine only logs data (flow rate and temperature) if a flow is detected. When a flow occurs, the sampling rate of the Huba flow sensor is up to 8 Hz. In periods with no flow, the Porcupine logs data every five minutes to register temperature decay/rise in the stagnated water in the pipes. This logging solution catches the rapid flow rate changes and minimizes the need for data storage.

At the HEX for DHW production, see Figure 6, the buildings’ Building Management System (BMS) measures the flow rate, supply temperature, and return temperature at the DH side of the HEX. On the DHW side of the HEX, the BMS measures the DCW flow rate, the DHW supply temperature, and the DHW circulation return temperature.

The DHW circulation flow rate and DCW temperature are measured by KATflow 100 [5], see Figure 5. The temperature is measured with a PT100 sensor and flow rate with ultrasonic clamp-on sensors. The KATflow 100 has a sample rate of 100 Hz and logs average values per second to a Raspberry Pi from where the data is accessible.

Before use, the Huba flow sensor and KATflow 100 are calibrated in the Laboratory for Indoor Environmental and Energy Engineering at Aalborg University. All equipment complies with the manufacturer’s stated accuracy. Specification of the Huba flow sensor and KATflow can be seen in Table 2. The sensors types and specifications in the BMS system have not been available, therefore they are not listed in this report.
<table>
<thead>
<tr>
<th>Location</th>
<th>Quantity</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw-off point</td>
<td>Cold water flow rate</td>
<td>Huba flow sensor + Porcupine</td>
</tr>
<tr>
<td></td>
<td>Hot water flow rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold water temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hot water temperature</td>
<td></td>
</tr>
<tr>
<td>Heat exchanger</td>
<td>DH flow rate</td>
<td>Building management system</td>
</tr>
<tr>
<td>In technical room</td>
<td>DH supply temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DH return temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DCW flow rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DHW supply temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Circulation return temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Circulation flow rate</td>
<td>KATflow 100</td>
</tr>
<tr>
<td></td>
<td>DCW temperature</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Overview of the measured quantities in CREATE and TMV23.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Huba flow sensor 236</th>
<th>KATflow 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample rate</td>
<td>≤8 Hz</td>
<td>100 Hz</td>
</tr>
<tr>
<td>Measure method</td>
<td>Vortex</td>
<td>Ultrasonic</td>
</tr>
<tr>
<td>Measure range</td>
<td>1.8 to 32 l/min</td>
<td>0.01 to 25 m/s</td>
</tr>
<tr>
<td>Accuracy</td>
<td>&lt;50 % fs: &lt;1 % fs¹</td>
<td>±1.25 °C</td>
</tr>
<tr>
<td></td>
<td>&gt;50 % fs: &lt;2 % rd³</td>
<td>0.5 % rd</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.001 l/min</td>
<td>0.25 mm/s</td>
</tr>
</tbody>
</table>

Table 2: Specification of Huba flow sensor 236 and KATflow 100. From manufacturers' data sheet.

¹ Unfortunately, there are no DCW temperature for CREATE. The temperature sensor has been placed too close to the HEX, and heat transmission in pipe material and water, has to high impact on the measured temperature.

2 Percentage of full scale. For Huba flow sensor type 236 the full scale is 32 l/min.

3 Reading scale - the measured value.
5. Data set structure

To understand the data in the data set, a structure and description of the files are presented and shortly elaborated in this chapter.

The data set structure is in two folder levels. Level 1 has a folder for CREATE and TMV23. Where level 2 consists of all the .mat-files. The .mat-files concerning the draw-off points consist of measured data from all draw-off points in the building. Each column in the draw-off point files is a draw-off point, and Table 3 shows this order and draw-off type. The order is the same for all draw-off point .mat-files for CREATE and TMV, but the order for the two buildings differs. The last column in Table 3 lists the draw-off types that should not be used because of unreliable data due to problems with measurement equipment.

<table>
<thead>
<tr>
<th>Building</th>
<th>Washbasin</th>
<th>Kitchen sink</th>
<th>Service sink</th>
<th>Do not use</th>
</tr>
</thead>
<tbody>
<tr>
<td>CREATE</td>
<td>4, 5, 6, 7</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>TMV</td>
<td>2, 6, 7, 8</td>
<td>5, 9</td>
<td>1</td>
<td>3, 4</td>
</tr>
</tbody>
</table>

Table 3: Order of columns in .mat-files for draw-off points in CREATE and TMV23. Concerning both flow rate and temperature .mat-files.

In Table 4 is seen an overview of the .mat-files for CREATE. There are nearly 11 weeks of draw-off point data, from 19-10-18 to 03-01-19. The measured data interval at the HEX that produces hot water is two weeks, from 18-12-18 to 03-01-19. Be aware that the files “Temp_DHW_Supply”, “Flow_Circulation”, “Temp_Circulation_Return”, and “Flow_Hot_HEX” have an associated Timestamp file.

Table 5 shows the overview of .mat-files for TMV23. Here there are four weeks of draw-off point data, from 12-04-21 to 24-05-21. The measured data at the HEX is around nine weeks, with a slight variation in the measurement period start date and the measurement period end date.
<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Name .mat-file</th>
<th>Period start</th>
<th>Period end</th>
<th>Draw-off point</th>
<th>HEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHW flow rate</td>
<td>l/min</td>
<td>Flow_Hot_All</td>
<td>19-10-18 02:04:15</td>
<td>03-01-19 12:38:14</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DCW flow rate</td>
<td>l/min</td>
<td>Flow_Cold_All</td>
<td>19-10-18 02:04:15</td>
<td>03-01-19 12:38:14</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mixed/tapped water flow rate</td>
<td>l/min</td>
<td>Flow_Mixed_All</td>
<td>19-10-18 02:04:15</td>
<td>03-01-19 12:38:14</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DHW temperature</td>
<td>°C</td>
<td>Temp_Hot_All</td>
<td>19-10-18 02:04:15</td>
<td>03-01-19 12:38:14</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DCW temperature</td>
<td>°C</td>
<td>Temp_Cold_All</td>
<td>19-10-18 02:04:15</td>
<td>03-01-19 12:38:14</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mixed/tapped water temperature</td>
<td>°C</td>
<td>Temp_Mixed_All</td>
<td>19-10-18 02:04:15</td>
<td>03-01-19 12:38:14</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Duration of draw-off actions</td>
<td>s</td>
<td>Draw-off_Duration_All</td>
<td>19-10-18 02:04:15</td>
<td>03-01-19 12:38:14</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Duration of time between draw-off actions</td>
<td>s</td>
<td>Breaks_Duration_Draw-off_All</td>
<td>19-10-18 02:04:15</td>
<td>03-01-19 12:38:14</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Supply DHW temperature from HEX</td>
<td>°C</td>
<td>Temp_DHW_Supply</td>
<td>18-12-18 08:00:21</td>
<td>03-01-19 10:39:51</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Circulation flow rate</td>
<td>l/s</td>
<td>Flow_Circulation</td>
<td>18-12-18 08:00:23</td>
<td>03-01-19 10:39:53</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Return temperature circulation to HEX</td>
<td>°C</td>
<td>Temp_Circulation_Return</td>
<td>18-12-18 08:00:23</td>
<td>03-01-19 10:39:53</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DHW flow rate measured at HEX</td>
<td>l/s</td>
<td>Flow_Hot_HEX</td>
<td>18-12-18 08:00:23</td>
<td>03-01-19 10:39:53</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Timestamp DHW supply temperature</td>
<td>dd-mm-yyyy tt-mm-ss</td>
<td>Temp_DHW_Supply_Time</td>
<td>18-12-18 08:00:21</td>
<td>03-01-19 10:39:51</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Timestamp DHW flow rate</td>
<td>dd-mm-yyyy tt-mm-ss</td>
<td>Flow_Hot_HEX_Time</td>
<td>18-12-18 08:00:23</td>
<td>03-01-19 10:39:53</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Timestamp circulation flow rate and temperature</td>
<td>dd-mm-yyyy tt-mm-ss</td>
<td>TempAndFlow_Circulation_Return_Time</td>
<td>18-12-18 08:00:23</td>
<td>03-01-19 10:39:53</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DCW flow rate to HEX</td>
<td>l/s</td>
<td>Flow_DCW_HEX</td>
<td>18-12-18 07:00:21</td>
<td>04-01-19 13:31:21</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DH flow rate</td>
<td>l/s</td>
<td>Flow_DH</td>
<td>18-12-18 07:00:21</td>
<td>04-01-19 13:31:21</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DH supply temperature to HEX</td>
<td>°C</td>
<td>Temp_DH_Supply</td>
<td>18-12-18 07:00:21</td>
<td>04-01-19 13:31:21</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DH return temperature from HEX</td>
<td>°C</td>
<td>Temp_DH_Return</td>
<td>18-12-18 07:00:21</td>
<td>04-01-19 13:31:21</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

*Table 4: Overview of .mat-files in the CREATE folder.*
<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Name .mat-file</th>
<th>Period start</th>
<th>Period end</th>
<th>Draw-off point</th>
<th>HEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHW flow rate</td>
<td>l/min</td>
<td>Flow_Hot_All</td>
<td>12-04-21 00:00:00</td>
<td>24-05-21 23:59:59</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DCW flow rate</td>
<td>l/min</td>
<td>Flow_Cold_All</td>
<td>12-04-21 00:00:00</td>
<td>24-05-21 23:59:59</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mixed/tapped water flow rate</td>
<td>l/min</td>
<td>Flow_Mixed_All</td>
<td>12-04-21 00:00:00</td>
<td>24-05-21 23:59:59</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DHW temperature</td>
<td>°C</td>
<td>Temp_Hot_All</td>
<td>12-04-21 00:00:00</td>
<td>24-05-21 23:59:59</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DCW temperature</td>
<td>°C</td>
<td>Temp_Cold_All</td>
<td>12-04-21 00:00:00</td>
<td>24-05-21 23:59:59</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mixed/tapped water temperature</td>
<td>°C</td>
<td>Temp_Mixed_All</td>
<td>12-04-21 00:00:00</td>
<td>24-05-21 23:59:59</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Duration of time between draw-off actions</td>
<td>s</td>
<td>Breaks_Duration_Draw-Off_All</td>
<td>12-04-21 00:00:00</td>
<td>24-05-21 23:59:59</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Supply DHW temperature from HEX 2nd floor</td>
<td>°C</td>
<td>Temp_DHW_Supply_2floor</td>
<td>29-03-21 02:56:03</td>
<td>28-05-21 07:35:48</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Supply DHW temperature from HEX 3rd floor</td>
<td>°C</td>
<td>Temp_DHW_Supply_3floor</td>
<td>27-03-21 03:03:39</td>
<td>27-05-21 09:56:24</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Circulation flow rate 2nd floor</td>
<td>l/min</td>
<td>Flow_Circulation_2floor</td>
<td>01-04-21 00:03:06</td>
<td>25-05-21 01:03:31</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Circulation flow rate 3rd floor</td>
<td>l/min</td>
<td>Flow_Circulation_3floor</td>
<td>28-03-21 01:02:34</td>
<td>25-05-21 01:03:14</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Return temperature circulation to HEX 2nd floor</td>
<td>°C</td>
<td>Temp_Circulation_Return_2floor</td>
<td>29-03-21 02:56:03</td>
<td>28-05-21 07:35:48</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DCW flow rate to HEX 2nd floor</td>
<td>l/s</td>
<td>Flow_DCW_HEX_2floor</td>
<td>29-03-21 02:56:03</td>
<td>28-05-21 07:35:48</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DCW temperature to HEX 2nd floor</td>
<td>°C</td>
<td>Temp_DCW_HEX_2floor</td>
<td>01-04-21 00:03:06</td>
<td>25-05-21 01:03:31</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DCW temperature to HEX 3rd floor</td>
<td>°C</td>
<td>Temp_DCW_HEX_3floor</td>
<td>28-03-21 01:02:34</td>
<td>25-05-21 01:03:14</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DH flow rate 2nd floor</td>
<td>l/s</td>
<td>Flow_DH_2floor</td>
<td>29-03-21 02:56:03</td>
<td>28-05-21 07:35:48</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DH supply temperature to HEX 2nd floor</td>
<td>°C</td>
<td>Temp_DH_Supply_2floor</td>
<td>29-03-21 02:56:03</td>
<td>28-05-21 07:35:48</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DH supply temperature to HEX 3rd floor</td>
<td>°C</td>
<td>Temp_DH_Supply_3floor</td>
<td>27-03-21 03:03:39</td>
<td>27-05-21 09:56:24</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DH return temperature to HEX 2nd floor</td>
<td>°C</td>
<td>Temp_DH_Return_2floor</td>
<td>29-03-21 02:56:03</td>
<td>28-05-21 07:35:48</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DH return temperature from HEX 3rd floor</td>
<td>°C</td>
<td>Temp_DH_Return_3floor</td>
<td>27-03-21 03:03:39</td>
<td>27-05-21 09:56:24</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Overview of .mat-files in the TMV23 folder.
References


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