THERMAL ENERGY METERS WITH SHORT INTEGRATION TIMES

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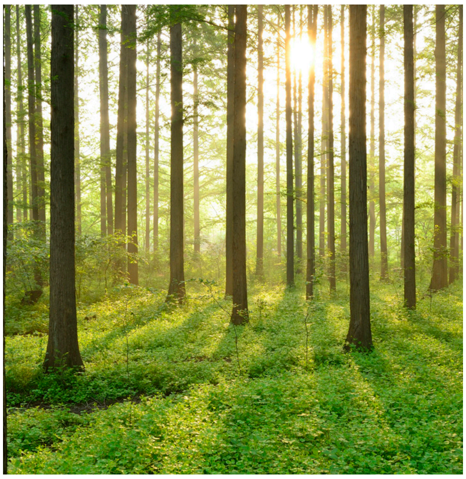

FUTUREHEAT

Energiforsk

Thermal energy meters with short integration times

BJÖRN FOLKESON, DANIEL MÅNSSON, THOMAS FRANZÉN

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Energiforsk AB | Phone: +46-8-677 25 30 | E-mail: kontakt@energiforsk.se | www.energiforsk.se

Foreword

This project, with original title of the Swedish report *Termiska energimätare med korta integreringstider, Energiforskrapport 2018:530*, has investigated a number of series connected heat meters with different integration times. The purpose is to obtain better knowledge about the meters and how accurate they can measure, as well as to find out what requirements are suitable for future thermal energy meters, also called fast response meters. This is important in a future with a higher proportion of volatile domestic hot water use at many customers, but also at introduction of battery powered meters where operating time is dependent on the measuring frequency.

The project has been led by Daniel Månsson, RISE together with Björn Folkeson, RISE and Thomas Franzén from Göteborg Energi. A focus group that has been consisting of Holger Feurstein (chair) Kraftringen; Daniel Nyqvist, Norrenergi; Joakim Holm, Tekniska Verken i Linköping; Cecilia Ibánez-Sörenson, Vattenfall R&D; Tommy Persson, E.ON Energilösningar AB; Maria Karlsson, Skövde Värmeverk AB; Thomas Franzén, Göteborg Energi; Per Örvind, Eskilstuna Strängnäs Energi & Miljö AB; Stefan Hjärtstam, Borås Energi och Miljö AB; Patric Jönnervik, Jönköping Energi and Mathias Bjurman, Grundledningen HB has followed and assured the quality of the project.

The project is part of the FutureHeat program, the long-term goal of which is to contribute to the vision of a sustainable heating system with successful companies that utilize new technological opportunities and where the municipal and governmental investments made in district heating and cooling are utilized in the best way.

The program is led by a steering group consisting of Charlotte Tengborg (chair), E.ON Lokala Energilösningar AB; Lars Larsson, AB Borlänge Energi; Magnus Ohlsson, Öresundskraft AB; Fabian Levihn, Stockholm Exergi; Niklas Lindmark, Gävle Energi AB; Jonas Cognell, Göteborg Energi AB; Lena Olsson Ingvarsson, Mölndal Energi AB; Anna Hindersson, Vattenfall Värme AB; Anders Moritz, Tekniska verken i Linköping AB; Staffan Stymne, Norrenergi; Holger Feurstein, Kraftringen; Joacim Cederwall, Jönköping Energi AB; Maria Karlsson, Skövde Värmeverk AB; Sven Åke Andersson, Södertörns Fjärrvärme AB; Henrik Näsström, Mälarenergi AB and Fredrik Martinsson (co-opted), Energiforsk.

Alternate members have consisted of Peter Rosenkvist, Gävle Energi; Johan Brossberg, AB Borlänge Energi; Mats Svarc, Mälarenergi AB; Johan Jansson, Södertörns Fjärrvärme AB and AnnBritt Hansson, Tekniska verken i Linköping AB.

Fredrik Martinsson, program manager FutureHeat

Results and conclusions from a project within a research program run by Energiforsk are presented here. The report author/authors are responsible for the content.

Summary

How often a thermal energy meter calculates the amount of delivered energy affects the measurement results during varying flow of domestic hot water. In the lab measurements performed, the slower energy meter type measured about 1 % lower flow than the faster counterparts.

During a test conducted by RISE in Borås, typical domestic hot water use representative of a day in a single-family house was simulated. The energy to provide the simulated household with domestic hot water was delivered by a district heating substation, and the delivered amount of heat was measured with energy meters of three different configurations of integration time. The integration time describes how often the energy meter reads the temperatures and multiplies with the flow that has passed since the previous reading to calculate the amount of energy that has passed the meter. The different meters were configured to integrate every 32, 8 and 2 seconds. The hypothesis was that a faster measurement (with shorter integration time) would provide a more accurate picture of the amount of energy delivered than a slower measurement (with longer integration time). In addition to the energy meters studied, the amount of energy supplied was also measured using the test equipment's flow and temperature meters.

Comparison between meters with different integration times shows that the meter that integrated the most infrequent (every 32 seconds) reported about 1 % lower energy consumption than those integrating more often (every 8 and 2 seconds). No significant difference could be observed between the two fastest meters. To verify that the difference in the result between the meter configurations could be attributed to the integration time, a constant flow test was performed. During this test no significant difference was noted between the different meter configurations, confirming the result.

Contents

1 Introduction and background

District heating is the source of more than half of the energy required for heating and domestic hot water production in Sweden's residential and commercial buildings (Swedish Energy Agency 2017). In each district heating station there is an energy meter, the purpose of which is to measure the amount of district heating delivered to the property. This is done by measuring the flow that passes through the energy meter's flow meter and by measuring the temperature of the district heating's supply and return line. A large variety of energy meters are available on the market, and more recently, several meters with short integration times have emerged as alternatives.

The integration time describes how often the meter reads the temperatures and multiplies by the flow that has passed since the previous reading to calculate the amount of energy which has passed the meter. Other factors affect how quickly an energy meter can capture differences in energy consumption, such as the time constant that describes how quickly the energy meter's temperature sensors adapts to the temperature of the liquid. While the integration time for a conventional energy meter can be tens of seconds, the time constant for the energy meter's temperature sensor is usually considerably shorter. The integration time is therefore of greater interest than other parameters to determine how accurately an energy meter can measure during rapid flow changes.

An energy meter with shorter integration time requires more energy for operation, especially if the readout is frequent. Until recently, this has meant that only energy meters with longer integration times (around 30 seconds) have been practical for battery operation while energy meters with short integration times (under 5 seconds) have required mains connection. However, on the market there are now battery-powered energy meters with short integration times equipped with batteries which the manufacturers state will last for the entire period the meter is placed at the customer. Although mains-connected energy meters have so far been more common in Sweden compared to the rest of Europe, battery operation allows greater flexibility during installation, which can reduce installation costs.

Although a faster energy meter, that is, an energy meter with a shorter integration time, cannot generally be said to be more accurate than an energy meter that integrates less often if the heat load is constant, there is reason to believe that a faster meter is more effective in capturing rapid flow changes thus giving a more accurate picture of the actual energy consumption. However, the magnitude of the impact of the integration time on the reported energy consumption in a real-life consumption pattern has not been not investigated.

The test discussed in this report was designed to study a number of series-connected energy meters with different integration times. In laboratory, a test was carried out with a defined domestic hot water draw-off cycle which was intended to simulate use of domestic hot water in a household. In addition to providing a measurement of the impact of the integration time on the reported amount of energy, a purpose was to generate data for determining suitable requirements for future thermal energy meters. Another objective was to determine whether a faster meter gives a better picture of the heat load requirement of a consumer, which may be of importance for decisions on district heating pricing models partly based on maximum heat load over a certain period. A more accurate measurement of the heat load requirement can also lead to a better control of the heat supply, which in the long term can lead to more efficient utilization of production facilities, reduced use of peak load facilities and thus reduced wear on the district heating system. A more accurate energy measurement can thus have advantages for both the heating producer and the heating consumer and contribute to achieving current energy and climate goals.

2 Method and implementation

2.1 DOMESTIC HOT WATER DRAW-OFF CYCLE

With the purpose of simulating the domestic hot water consumption in an average detached house, a domestic hot water draw-off cycle was developed by the members of Swedenergy's meter group. The domestic hot water draw-off cycle described what domestic hot water flow was drawn and for how long. Other draw-off cycles were identified as possible alternatives, such as the draw-off cycle used for testing district heating substations according to Swedenergy's technical regulations F:103-7 and the draw-off cycle used for testing heat interface units according to the UK test method UK HIU Test Regime published by BESA (Energiföretagen Sverige 2009, BESA 2016). These draw-off cycles were, however, considered to be designed to investigate the function of hot water control rather than to simulate a real-life consumption pattern, and since both draw-off cycles comprised a period of less than one hour, none of them was considered suitable for simulating a household's daily consumption of domestic hot water.

The domestic hot water draw-off cycle from Swedenergy's meter group was designed to represent a normal family in a normal-sized house during an average day, but without consideration of deviating patterns for holidays and weekdays. The domestic hot water draw-off cycle represented a simplified picture of the reality in the sense that the draw-offs were made one at a time, and not simultaneously. The domestic hot water draw-off cycle was 24 hours long and included draw-offs that were at least 30 seconds long and at most 10 minutes long. No analysis was made regarding the relevance of the length of the draw-offs. See Figure 1.

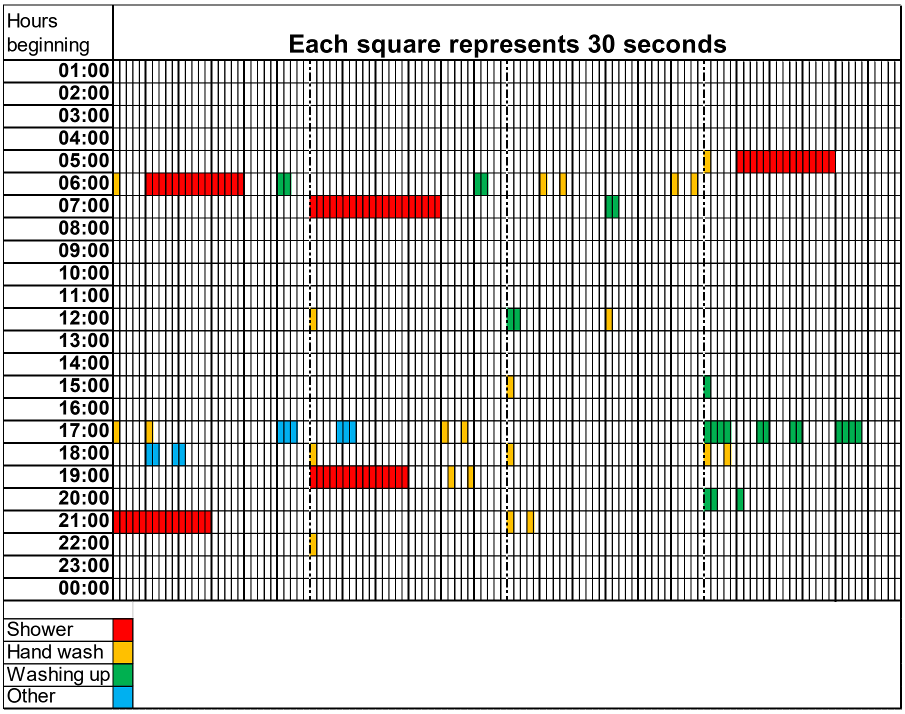

Figure 1. The domestic hot water draw-off cycle used during the test.

The draw-offs were divided into four categories: "Shower", "Hand wash", "Washing up" and "Other". To determine the domestic hot water flows to be representative of these four areas of application, data on norm flows were taken from the current consolidated version of the Swedish National Board of Housing, Building and Planning's building regulations, BBR (Boverket 2018). An assumption was made for the flow "Other", which was set to 50 % of the norm flow at wash basins, which was assumed to represent rinsing of a kitchen object or similar. See Table 1.

Table 1. Norm flows from the Swedish National Board of Housing, Building and Planning's building regulations, BBR (Boverket 2018) and description of the corresponding flow in the domestic hot water draw-off cycle.

Draw-off location (Boverket 2018)	Norm flow, l/s	Usage category in domestic hot water draw-off cycle
Bathtub	0.3 l/s	-
Other outlets	0.2 l/s	”Shower”, ”Washing up”
Wash basin and bidet	0.1 l/s	”Hand wash”
-	0.05 l/s	”Other”

The domestic hot water temperature was assumed to 55 °C, in the middle of the range 50 - 60 °C within which the domestic hot water temperature of a district heating substation should be stabilized to pass testing under varying domestic hot water flow according to Swedenergy's technical regulations F:103-7 (Energiföretagen Sverige 2009).

The norm flow was considered to describe the largest flow that can occur at a draw-off location for the current application area. However, it was not considered reasonable to assume that domestic hot water is used at 55 °C in the amount specified by the norm flow. The assumption was made that the user still draws domestic hot water in an amount corresponding to the norm flow, but at a temperature of 40 °C, which means that hot and cold water is mixed in the faucet at the tapping point to achieve the norm flow at 40 °C. During the test, this was still represented by producing domestic hot water 55 °C, but the respective flow was corrected to correspond to the flow required to produce domestic hot water at 40 °C and was calculated as below, where the temperature of incoming cold water was set to 10 °C:

$$Proportion\ domestic\ hot\ water = \frac{Temperature\ at\ draw\text{-}off\ location - Temperature\ of\ cold\ water}{Domestic\ hot\ water\ temperature - Temperature\ of\ cold\ water}$$

See Table 2 for the domestic hot water flows used for each usage category.

Table 2. Domestic hot water flow required to produce water at 40 °C according to norm flow.

Usage category	Norm flow, l/s	Corresponding flow domestic hot water at 55 °C to produce domestic hot water at 40 °C at the draw-off location at norm flow, l/s
Washing up	0.2 l/s	0.133 l/s
Shower	0.1 l/s	0.067 l/s
Hand wash	0.2 l/s	0.133 l/s
Other	0.05 l/s	0.033 l/s

With corrected flows in the domestic hot water draw-off cycle according to Table 2, a domestic hot water consumption of 466 liters at 55 °C was obtained for the 24 hours covered by the cycle.

2.2 THE TEST OBJECTS

Nine flow meters with pertaining temperature sensors and calculators constituted the test objects of the assignment. The flow meters were all ultrasonic type manufactured by Kamstrup, model MULTICAL 603 with ULTRAFLOW 54. The meters were of nominal flow Q_P 0.42 l/s and had threaded connection G3/4B. The length of the flow meters was 110 mm. The temperature sensors were of type Pt500. The nine meters had three different configurations of integration time. Three meters each had the configuration "Normal", "Fast" or "Mains". These had integration times of 32, 8 and 2 seconds, respectively, where "Mains" measured the most frequent and "Normal" the least frequent. See Table 3.

Table 3. Configuration and integration times for the test objects.

Energy meter	Configuration	Integration time
A, D, G	Normal	32 seconds
B, E, H	Fast	8 seconds
C, F, I	Mains	2 seconds

2.3 TEST SETUP

The test was conducted in a laboratory at RISE in Borås, Sweden at the unit for Energy and Circular Economy in April-May 2018. The test equipment FV4 was used, which is connected to both the district heating network and to an electric boiler. District heating was used to preheat the water in the test equipment's primary circuit and the electric boiler was used to keep the temperature stable during the test.

A district heating substation was mounted to the test equipment. In the substation, domestic hot water of 55 °C was produced in a heat exchanger by heating incoming cold water using heat from the primary circuit. The temperature of incoming cold water was kept at 10 °C and at a pressure of 4 bar. The primary circuit was 80 °C during long draw-offs and the primary static pressure was maintained at 5 bar. The differential pressure across the primary circuit was maintained at 1 bar.

In the return pipe of the test equipment's primary circuit, after the district heating substation in the flow direction, the energy meters were connected in series so that all meters were subjected to the same flow changes. The manufacturer's recommendations were followed regarding having straight sections of pipe corresponding to 10 times the DN size before each meter. The sensors for primary return temperature were integrated in the flow meters and were thus measured at the same location as the flow. In the supply line for the test equipment's primary circuit, the energy meters' supply temperature sensors were installed in series, mounted in couplings supplied by Kamstrup. The distance between the temperature sensors for primary supply was equal to the distance between the temperature sensors for primary return, which meant that the same water volume was present between each meter's primary supply and return temperature sensor. Furthermore, the flow meters were installed in order so that a meter with configuration "Normal" with integration time 32 seconds was followed by one with configuration "Fast" with integration time 8 seconds and then "Mains" with integration time 2 seconds, to restart at "Normal". For an outline of the test setup, see Figure 2.

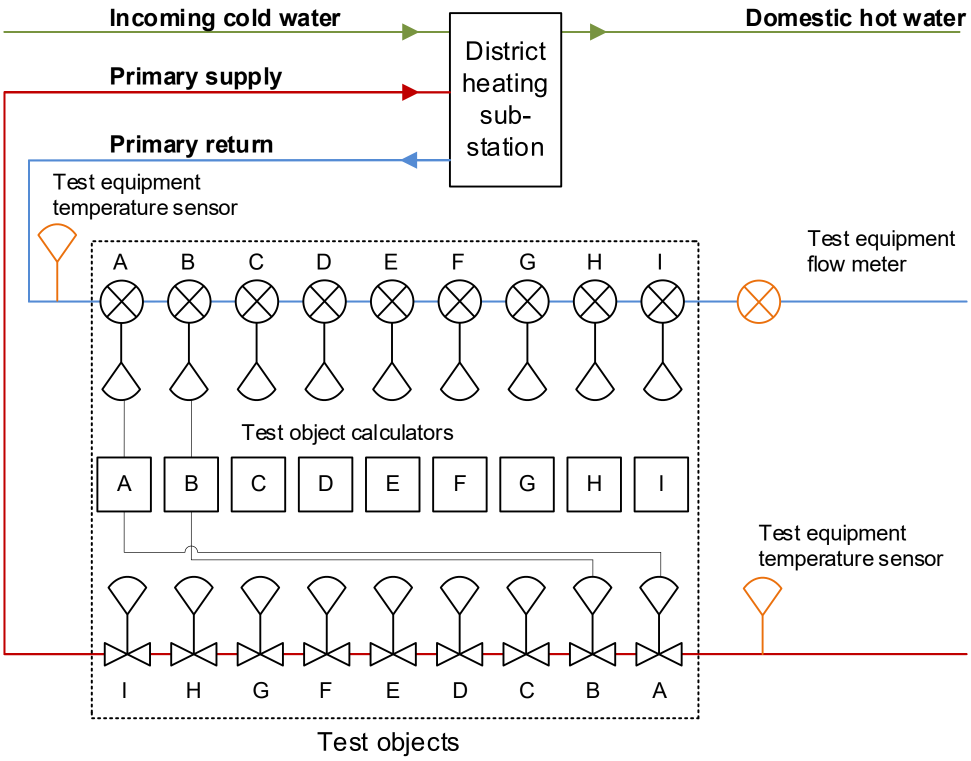

Figure 2. Outline of the test setup. For clarity, the connection between temperature sensors, flow meter and calculator is only indicated for two of the nine test objects.

The test equipment included parallel-connected control valves for domestic hot water which were opened and closed by solenoid valves. Using the control valves, the respective domestic hot water flow was set in the domestic hot water draw-off cycle, and the opening and closing of the solenoid valves was programmed to correspond to the cycle sequence. After the solenoid valves were operated, the flow meters recorded at least 90 % of the maximum flow for the current flow level within 2 seconds. The time constant of the test equipment's temperature measurement was ≤ 1.5 s and corresponded to 63 % of the final value for a momentary temperature change from 10 to 90 °C. The temperature of domestic hot water and incoming cold water was measured near the district heating substation's outgoing and incoming hot and cold water connection, respectively. The domestic hot water flow was measured by the test equipment flow meter.

The supply and return temperature of the primary circuit was also measured using the test equipment's temperature sensors of type Pt100, which were mounted just before the temperature sensors of the test objects in the flow direction of the primary circuit. The test equipment flow meter for the primary circuit was installed after the test objects. The temperature sensors and all piping between the temperature sensors and the flow meter were insulated as far as practically possible. The test equipment flow and temperature sensors measured at a sampling rate of 1 s and data from these sensors was used to calculate the amount of energy. The test equipment flow meters were calibrated for the flows used during the test.

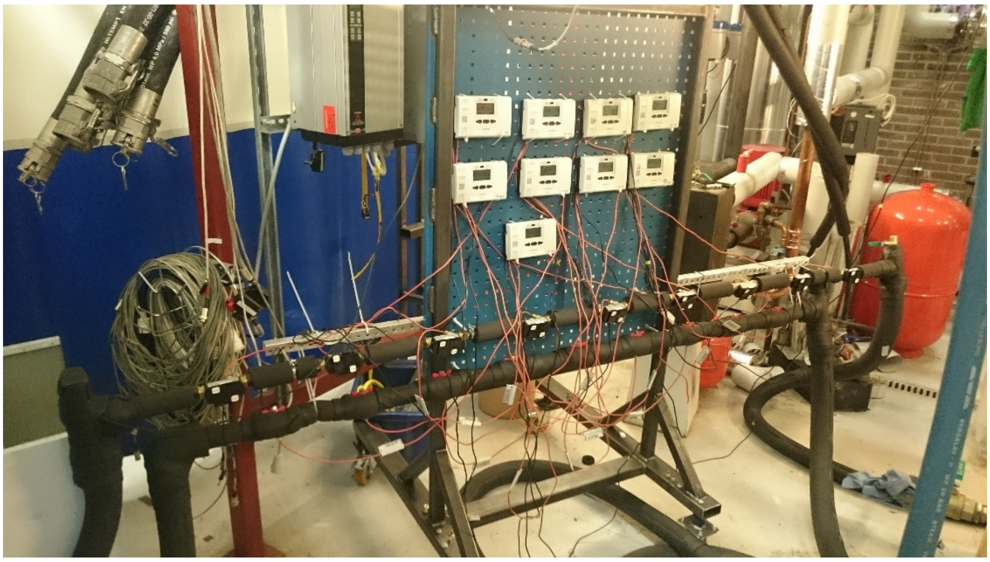

Figure 3. Test setup of energy meters.

Figure 4. Overview of the test setup including the district heating substation (right).

2.4 TEST PERFORMANCE

Under a constant domestic hot water flow of 0.133 l/s, the settings of the test equipment and the district heating substation were adjusted until temperatures were stable and within ± 0.5 °C from the values summarized in Table 4.

Table 4. Settings during testing.

Setting parameter	Value
Primary supply temperature	80 °C
Domestic hot water temperature	55 °C
Cold water temperature	10 °C
Static pressure primary circuit	5 bar
Differential pressure primary circuit	1 bar
Cold water pressure	4 bar
Domestic hot water flow, shower	0.133 l/s
Domestic hot water flow, hand wash	0.067 l/s
Domestic hot water flow, washing up	0.133 l/s
Domestic hot water flow, other	0.033 l/s

When stable conditions were achieved, the test was started where the pre-programmed cycle controlled the domestic hot water draw-off for 24 hours. After adjustment, the amount of energy was read on the displays of the test objects. After reading, the domestic hot water draw-off cycle was started. After the cycle, the displays of the test objects were read again and the amount of energy was calculated by the difference between the readings. This was compared to the amount of energy measured by the test equipment.

In the purpose to investigate whether the measurement of the test objects differed from that of the test equipment also during a constant flow, a test was carried out at a constant flow of 0.133 l/s for about 90 minutes. Adjustment, reading and calculation of the amount of energy was conducted in the same way during this test as for the test with the domestic hot water draw-off cycle.

3 Results

The test with the domestic hot water draw-off cycle was performed on April 9, 2018. The theoretical volume of domestic hot water drawn with the cycle was 0.47 m^3, but during the test the volume of domestic hot water was measured to the slightly higher 0.49 m^3. The difference was assumed to be due to minor deviations from the set point in the adjustment of the domestic hot water flows and was not considered to affect the result significantly.

The domestic hot water temperature reached the setpoint during the longer draw-offs, but during the periods when only shorter draw-offs were made, the temperature did not increase to 55 °C. The same was true for the primary supply temperature which reached the setpoint of 80 °C only during the longer draw-offs. This was due to that the pipe section that connected the district heating substation with the test equipment heat source was cooled down between the draw-offs. When the draw-offs were started, a certain amount of water that reached the district heating substation was therefore of lower temperature. It is likely that a similar situation can occur at an actual site, since the district heating service line is usually kept to a temperature a few degrees below the current supply temperature of the district heating network to limit the energy consumption and the district heating return temperature.

The primary return temperature varied between 16 and 30 °C during the test.

For an overview of the flows and temperatures measured with the test equipment, see Figure 5.

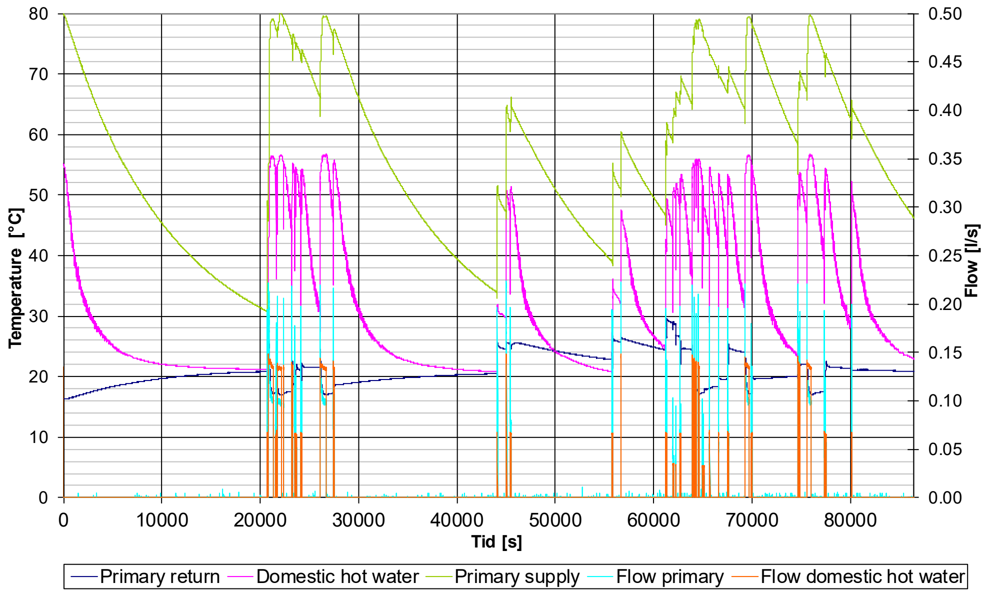

Figure 5. Overview of registered temperatures and flows during the domestic hot water draw-off cycle as measured by the test equipment.

After the test, the amount of energy measured by the test equipment was compared to that measured by the test objects to see if any differences could be identified between the meter types. The results are reported in Table 5, where "Reference" denotes the test equipment energy measurement.

Table 5. Results from test with domestic hot water draw-off cycle.

Meter	Energy measured [kWh]	Difference from reference [kWh]	Difference from reference [%]	Mean per meter type [%]
A (32 s)	25.4	-0.7	-2.8 %	
D (32 s)	25.2	-0.9	-3.6 %	-3.1 %
G (32 s)	25.4	-0.7	-2.8 %	
B (8 s)	25.5	-0.6	-2.4 %	
E (8 s)	25.5	-0.6	-2.4 %	-2.0 %
H (8 s)	25.8	-0.3	-1.3 %	
C (2 s)	25.5	-0.6	-2.4 %	
F (2 s)	25.5	-0.6	-2.4 %	-2.2 %
I (2 s)	25.7	-0.4	-1.6 %	
Reference	26.1	-	-	-

It can be read from Table 5 that all three types of meters measured lower than the test equipment energy measurement. The meters configured for 32 second integration time stood out since they measured 3.1 % lower than the test equipment's energy measurement in average, while the meters configured for 8 and 2 second integration time measured 2.0 and 2.2 % lower, respectively, compared to the test equipment energy measurement.

To investigate if the differences between the meter types were only noticeable during varying flow of domestic hot water and not during constant flow, a test was carried out at constant flow. The results of this test are presented in Table 6.

Table 6. Results from test with constant domestic hot water flow.

Meter	Energy measured [kWh]	Difference from reference [kWh]	Difference from reference [%]	Mean per meter type [%]
A (32 s)	36.3	-0.8	-2.0 %	
D (32 s)	36.3	-0.8	-2.0 %	-2.0 %
G (32 s)	36.3	-0.8	-2.0 %	
B (8 s)	36.3	-0.8	-2.0 %	
E (8 s)	36.3	-0.8	-2.0 %	-1.9 %
H (8 s)	36.4	-0.7	-1.8 %	
C (2 s)	36.3	-0.8	-2.0 %	
F (2 s)	36.2	-0.9	-2.3 %	-2.1 %
I (2 s)	36.3	-0.8	-2.0 %	
Reference	37.1	-	-	-

From Table 6 it can be read that no significant difference was measured between the meter types when testing during a constant flow. The difference between the meter types was less than 0.2 % and on average the energy meters measured about 2 % lower energy than the test equipment energy measurement.

To verify that the difference in energy measurement between the energy meters and the test equipment was not due to measurement error, an additional test was carried out. During this test, a constant flow of cold water was drawn. A second flow meter, the test equipment flow meter for domestic hot water, was connected in series with the test equipment primary flow meter and the energy meters. Compared to the test equipment primary flow meter, the energy meters showed between 1.5 and 1.8 % lower flow, on average 1.6 %. Compared to the test equipment flow meter for domestic hot water, the energy meters showed between 1.7 and 2.0 % lower flow, on average 1.8 %. Since the two test equipment flow meters showed similar results, it was considered likely that the energy meters in average measured about 2 % lower flow than the actual flow.

4 Discussion

4.1 CHOICE OF DOMESTIC HOT WATER DRAW-OFF CYCLE

The domestic hot water draw-off cycle used in the project was developed by the members of Swedenergy's meter group with the aim to represent a normal consumption pattern for one day. There were other options, including the domestic hot water draw-off cycle described in Swedenergy's technical regulations F:103-7 (Energiföretagen Sverige 2009), which is used in testing of district heating substations. However, the domestic hot water draw-off cycle described in F:103-7 was developed with the aim of testing the properties of the domestic hot water controller in the district heating substation under varying domestic hot water flow rather than simulating an average consumption pattern. Of this reason the domestic hot water draw-off cycle developed by Swedenergy's meter group was considered most suitable.

4.2 CHOICE OF DRAW-OFF FLOW LEVELS

The choice of flow levels was based on the building rules of the Swedish National Board of Housing, Building and Planning, BBR (Boverket 2018). The two highest flow levels, 0.1 and 0.2 l/s, also corresponded to the flow levels used for dynamic testing of the domestic hot water function in F:103-7 (Energiföretagen Sverige 2009). This meant that the flow levels chosen were anchored in current norms, except for the lowest flow level, usage category "Other", which was set to 0.05 l/s without any other reference than that it corresponded to half of the lowest norm flow stipulated in the BBR (Boverket 2018). Here, the lowest flow stipulated in the technical regulations F:103-7 during testing of the control properties of the district heating substation during low domestic hot water flow, 0.02 l/s, could instead have been used (Energiföretagen Sverige 2009). However, since it was not clear why the low flow rate in F:103-7 was set to 0.02 l/s, it was considered more justified to instead use 0.05 l/s, half the lowest norm flow prescribed in the BBR, to avoid taking data from multiple sources.

4.3 DOMESTIC HOT WATER CONSUMPTION LEVEL

The consumption of domestic hot water according to the domestic hot water draw-off cycle was 466 liters per day, which corresponds to 170 m^3/year. To estimate whether this consumption could be considered reasonable, the consumption was compared with reference values. Sveby assumes domestic hot water use of 20 kWh/m^2 A_{temp}*year and according to the same source, domestic hot water production requires 55 kWh/m^3 domestic hot water (Sveby 2009). Figures from Statistics Sweden for detached houses in 2006 states that an average house has an average area of 125 m^2 (SCB 2009). This gives a domestic hot water consumption of 45 m^3/year. In comparison, the domestic hot water consumption from the draw-off cycle is 3.7 times higher. It should be pointed out, however, that Sveby does not consider the number of people in the household, apart from the assumption that a larger house is normally occupied by more people. Another factor is that the domestic hot water draw-off cycle represents a day of activity in the house and does not consider differences in usage patterns between, for example, weekdays, weekends or holidays, and is assumed to be constant every day over the year. The domestic hot water consumption represented by the draw-off cycle was therefore regarded sufficiently representative for a typical day in the house where all residents are at home and activity is ongoing.

The total domestic hot water consumption was considered to be of lesser importance, since the purpose of the test was to identify differences between different types of energy meters under the type of varying flows that characterize draw-offs of domestic hot water in detached houses. Probably, the discrepancy between the different types of meters arises when measuring rapid changes in flow, that is, at the beginning and end of each draw-off. This means that a domestic hot water draw-off cycle with a larger number of draw-offs makes the significance of the integration time visible to a larger extent. The draw-off length, which influences the total domestic hot water consumption, was therefore considered to be less important than the number of draw-offs.

If the domestic hot water draw-off cycle would have been modified to reflect a consumption entirely in line with the reference values, this could have been done in three ways: reducing the number of draw-offs, the draw-off length or the draw-off flow levels. Reducing the flow would have led to unreasonably small flows that would not have been representative of normal use. Reducing the draw-off length or number of draw-offs would have been more relevant since it can be assumed that the accuracy of the measurement over the day is a function of how many draw-offs are made as well as the length of these. However, this relationship was not covered by the current study.

4.4 DEVIATION FROM THE TEST EQUIPMENT MEASUREMENT

During the test with the domestic hot water draw-off cycle, the energy meters measured an amount of energy between 1.3 and 3.6 % and on average 2.4 % lower than the test equipment. During the test at constant flow, the energy meters measured an amount of energy between 1.8 and 2.3 % lower than the test equipment. Based on the test where the two flow meters of the test equipment were connected in series with the energy meters, it was found that the discrepancy was due to differences in the flow measurement, where the energy meters measured about 2 % lower flow than the test equipment flow meter also at a constant flow.

The purpose of the tests, however, was not to investigate how accurately the test objects measured the amount of energy at constant flow in comparison with the test equipment. Instead, the aim was to investigate whether the integration time of the energy meters had an impact on the energy measurement during varying flow, and for this purpose, it was of less importance how accurate the meters were in relation to the test equipment.

4.5 THE NUMBER OF ENERGY METERS TESTED

Although several energy meters of each configuration were used during the test, it cannot be ruled out that some of the flow meters showed erroneous values due to, for example, damage during transport, damage during installation, or other reasons. Although the energy meters did not show any signs of damage either at delivery or after installation, a larger number of energy meters had given a better basis for evaluation. However, due to practical reasons, the number was limited to three of each configuration.

Even if the energy meter that showed the largest deviation from the test equipment measurement (energy meter D, 32 s) would have been excluded from the data set together with the two energy meters which showed the least deviation from the test equipment measurement (energy meter H and I, 8 and 2 s, respectively), the result would have been that the slowest meter type, on average, measured 0.4 % lower flow than the two faster configurations. The conclusion that a faster energy meter measures better than a slower one during rapid flow changes thus remains, although it is not possible to say with certainty that the difference would have been of the same magnitude if a larger number of energy meters would have been tested.

5 Conclusion and suggestion for further studies

Since no significant difference between the meter types could be determined during constant flow in comparison with the test equipment energy measurement, the difference observed between the meter types during the domestic hot water draw-off cycle could be attributed to the different integration times of the meters. The integration time of the energy meters thus affected the measurement result under varying flow, but not under constant conditions.

During the test with the domestic hot water draw-off cycle, the energy meters with configuration for 32-second integration time measured 1.0 % lower than the meters with configuration for 8-second integration time and 0.9 % lower than the meters with configuration for 2-second integration time. Since no significant difference between the meter configurations could be identified during the test with constant flow, it could be assumed that the meters configured for a 32-second integration time measured less accurately under varying flow. Since no significant difference could be observed between the two fastest configurations, it could be assumed that an integration time of 2 seconds in comparison with 8 seconds did not result in an improvement of measurement which was of practical significance for the type of application investigated during this test. However, the difference between a 32-second and 8-second integration time was significant.

Although a faster energy meter is better at measuring a varying domestic hot water flow, the amount of energy that is not measured by a slower energy meter should be put in proportion to the total household energy supply. The purpose of the test was to investigate differences in energy measurement in cases where only domestic hot water is used, but at most sites the district heating substation supplies the household with space heating as well. Since the energy for the space heating system is delivered with considerably slower changes in flow than for the domestic hot water supply, it is likely that the integration time of the energy meter does not have any major impact on the measurement of energy for space heating. It is therefore unlikely that the 1 % difference noted during the test between a fast and a slow energy meter would be reflected in the total district heating energy consumption at an actual site on a yearly basis. On the other hand, the difference between a fast and a slow energy meter increases in importance with the number of domestic hot water draw-offs carried out, and in properties with low heat demand or outside the heating season, the difference between a fast and a slow energy meter becomes more significant. This is confirmed in the technical industry requirements and advice on meter management from Swedenergy, where an energy meter with an integration time under 5 seconds is recommended in cases where the energy for domestic hot water is not measured separately (Swedenergy 2008). However, the knowledge is low regarding the importance of the integration time for the energy measurement in the cases where simultaneous use of space heating and domestic hot water occurs. This question is left as for further studies.

Based on the test results, it can be assumed that a flow meter with shorter integration time is better suited for measuring instantaneous heat load. A faster meter can be considered to provide a better basis for tariffs based on heat load, and if fast measurement is installed at a larger share of the heating customers, there may be reasons to lower the heat load tariff if there is less need to consider error measurement during rapid flow changes.

Even the two types of energy meters with the fastest integration time measured about 2 % lower amount of energy than the test equipment during the domestic hot water draw-off cycle, and all energy meters showed about 2 % lower flow than the test equipment also at constant flow. If the same discrepancy were to apply at an actual site, it would mean that a part of the heat delivered to the consumer is not measured by the energy meter. It cannot be ruled out that the energy meters would show less also at an actual site, but several factors can affect the measurement at an actual site. The recommendation is therefore to consult with the supplier of energy meters to create the best possible conditions for measuring correctly in each application.

Although it is difficult to draw conclusions about which proportion of the heat deliveries that occur during varying flow, it can be concluded that even a small difference in measurement during varying flow can result in a significant amount of energy not being measured during the lifetime of the energy meter, even if this can only be assumed to apply to the part of the energy supply that is related to domestic hot water production. How big of an impact the integration time has on the measurement of energy delivered to an actual consumer of district heating, under a longer period, is a question that is left for further studies.

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THERMAL ENERGY METERS WITH SHORT INTEGRATION TIMES

Here, the research shows that a faster energy measurement gives a better understanding of the heat load requirement. This enables better control of the heat delivery and reduced use of peak load facilities, which contributes to achieving current environmental and climate goals.

In each district heating station there is an energy meter, the purpose of which is to measure the amount of district heating delivered to the property. A large variety of energy meters are available on the market, and more recently, several meters with short integration times have emerged as alternatives.

The results show that a ”fast” energy meter with a short integration time measures more accurately than a ”slow” counterpart during rapid flow changes. This means that a faster meter provides better conditions for a correct energy measurement, which forms a better basis for a fair district heating tariff based on heat load.

In addition to lowering the costs for the heating customer, a faster energy measurement can give a more accurate picture of the heat load requirement, which allows improved control of the heat delivery and a reduced use of peak load facilities.

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