Domestic hot water consumption in apartment buildings

O. Gerin (1), B. Bleys (2), K. De Cuyper (3),
(1) olivier.gerin@bbri.be
(2) bart.bleys@bbri.be
(3) karel.de.cuyper@bbri.be
(1), (2), (3) Belgian Building Research Institute, Belgium

Abstract

Domestic hot water consumption has been measured in 12 apartment buildings of different sizes (11 to 378 apartments) in Belgium. Each building was monitored for a period of 1 or 2 months with a measurement interval of 1 second. Peak flow rates were deduced from these data for each building. The measured peak flow rates were converted to reference conditions in order to obtain flow rates which can be compared and be used for dimensioning purposes. In this article, a new conversion method is suggested and the different steps are discussed. These standardised peak flow rates are then compared to the peak flows as calculated in accordance with existing guidelines in order to determine the relevance of these guidelines for Belgium. DIN 1988-300:2012 [1] was found to be most appropriate.

Keywords
water consumption, peak flow rate, domestic hot water , domestic cold water , pipe sizing.

1 Introduction

As the energy-use for space heating continues to diminish in the European Union, due to better performances of the building envelope and the use of high performance heating appliances, the energy use for hot water production becomes increasingly relevant. Since the recast of the Energy Performance of Buildings Directive [4] stipulates that by 2020 all new buildings in the European Union should be almost near zero energy buildings, reducing the energy use for hot water production, whilst maintaining the desired comfort level for the buildings occupants, will become one of the challenges for the future.

Therefore it becomes ever more important to design hot water production and distribution installations inside our buildings -of which apartment buildings are an important part- in a more efficient way.

Also an optimal design of the drinking water system (hot and cold) is an even more important necessity in order to guarantee the hygienic quality of the water at the taps: avoiding

Legionella-problems means, between others, no stagnation of the water in oversized hot water vessels and avoiding too low velocities due to the oversized pipes. This concern requires also a better knowledge of the water consumption in our buildings.

Given the fact that Belgium has no national standard, complementing the simplified pipe sizing method of NBN EN 806-3:20016 [5], foreign methods are since long commonly used. As these methods were in general issued already many years ago -the most commonly used methods for sizing hot water distribution systems rely on methods based on consumption data of the seventies of the past century [6], [7]-, while as well the equipment level, the sanitary comfort as the technology greatly evolved since then, it is evident that there is an urgent need to get actual and reliable data on water consumption in buildings. This need was also recognized in other countries, which led them to review already their guidelines, leading -in general- to smaller peak flows and thus smaller pipe sizes, eg: Germany in 2012 [1] and The Netherlands in 2013 [8].

In previous articles we have described the first results of our domestic hot water (DHW) and domestic cold water (DWC) measurement campaigns [2] and we reported, last year in Brazil, on the fact that the hot water consumption depends significantly on the season, mainly due the seasonal variation the cold water temperature, as a result of our the latitude (about 50° N). This seasonal variation was shown to affect as well the mean daily DHW consumption as the peak flow [3].

In this paper, we will discuss the latest results of our measurement campaign on the DHW peak flow. First we propose a method for the conversion of the measured data (“raw data”) into “reference” peak flow, ie. the corresponding peak flow at 60°C, given a cold water temperature of 10°C, called “DHW_{6010} peak flow”. It is this “reference value” which normally is used for the sizing of the supply pipes.
Besides taking into account a conversion for correcting the measurements with temperatures differing from 60°C (hot) and 10°C (cold), correction is also made for the above mentioned seasonal variation.
But a correction is also made for the fact that the temperature measured at the outlet of the heating device, is not –in the mean- the temperature of the hot water just before the taps.
We also discuss some of the limitations of our conversion method and hypothesis and hope hereby to contribute to a better understanding of our measurements for other research teams and maybe open a debate to deduce a uniform method, since it seems probable to us that other teams would be confronted with some of the same challenges.

2 The BBRI measurement campaign

Since 2011 domestic hot water consumption was measured in 12 apartment buildings of different sizes (7 to 378 apartments) with centralised hot water production. Each building was monitored for a period of about 1 to 2 months.

For the measure of the water consumption, ultrasonic flow meters were used, measuring the flow rate of the water qDWH at the entrance of the heating appliance. Since these meters have sensors which are fixed on the pipes outer wall, no modification of the installation in the building was needed [2]. The cold (Tc) and hot water temperatures were measured as well, using thermocouples. For DHW systems with a circulation system, both departure (Tdepart) and return temperatures (Treturn) were measured at the level of the heating appliance. The data were stored on a data logger with a measurement interval of one second. All measurements points are located in the central boiler room as shown in figure 1.

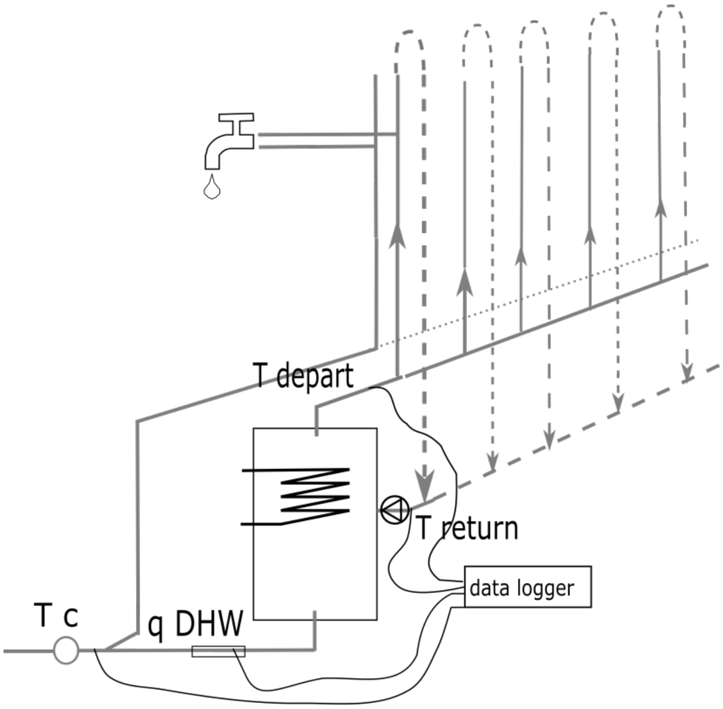

Figure 1 – Identification of measuring points in the boiler room

Table 1 gives for the different buildings the total number of apartments, as well as the length of the measurement period and the average hot (T DHW) and cold (T DCW) water temperatures.

Table 1 Measured apartment buildings and characteristics

Building number	Number of apartments	Measuring period (days)	average T DHW (°C)	average T DCW (°C)
1	11	30	45	17
2	36	22	70	18
3	57	32	55	20
4	62	58	65	20
5	93	86	52	14
6	96	81	50	13
7	113	58	53	16
8	124	78	68	13
9	277	70	50	11
10	312	64	52	12
11	320	64	57	17
12	378	36	49	13

Table 1 shows a rather large variation in both average DHW and DCW temperatures, which confirms the need of a data conversion to reference conditions in order to be able to compare the results for different buildings.

3 Results

3.1 Measurement data

Table 2 gives the measured DHW peak flow rates, the peak flow converted to standardized DHW_{6010} peak flow rates "standardized" for DHW at 60 °C for DCW at 10°C [3] and the "reference" DHW_{6010} peak flow rates, in which further data conversions are integrated. We would suggest using these latter values for dimensioning purposes.

Table 2 Measured and converted DHW peak flow rates

Building number	Raw DHW peak flow rate (1s) (L/min)	DHW_{6010} peak flow rate (2 s) (L/min)	"Reference" DHW_{6010} peak flow rate (L/min)
1	28,2	31,2	34,4
2	42,4	47,4	54,5
3	36,7	45,2	54,8
4	69,7	60,7	73,5
5	80,5	74,4	80,8
6	82,2	79,0	90,8
7	60,5	58,3	82,2
8	77,6	86,1	118,0
9	134,7	110,9	116,4
10	143,0	66,6	72,3
11	196,0	136,8	148,4
12	100,2	84,2	84,2

The different steps of our conversion method are discussed in paragraph 3.2.

3.2 Conversion method

The conversion method we applied to the measurement data contains different steps.

1) Step 1: *visual check* of the measured data (flow rates and temperatures) through daily graphs. In case of potentially abnormal data, and if the technical reason can be discovered (for instance: refilling of space heating circuit, maintenance intervention on DHW system, leakages, etc.), the data for day where the abnormal event occurred are supressed.

2) *Step 2: conversion to standardized DHW_{6010} peak flow rates*

   A frequently used formula of conversion into standardized DHW_{6010} is given in equation 1:

$$q\,DHW_{6010} = q\,DHW * \frac{(T\,DHW - 10)}{(60 - 10)} \quad \text{(eq. 1)}$$

In this equation, the actual cold water temperature is totally ignored. However, if cold water temperature is 25°C, the hot water flow will be less than the flow in the same building if the cold water is around 10°C. Each building facility had his own DHW production temperature and his own cold water temperature. The conversion of their DHW flows into standardized DHW_{6010} flows should therefore take into account both the measured cold and hot water temperatures. This formula also ignores the fact that the temperature measured at the outlet of the heating appliance, decreases in the installation due to the heat losses of the pipes, so that a tap near the heating appliance will have a lower consumption, than an the same tap with an identical use, at the end of the piping system.

The measured DHW flows were therefore converted into standardized DHW_{6010} flows according the equation (2):

$$q\ DHW_{6010} = q\ DHW \quad * \frac{\frac{(T\ DHW - Tc)}{(Tu - Tc)} * (Tu - 10)}{(60 - 10)} \qquad \text{(eq. 2)}$$

Where:

q DHW_{6010}: the standardized flow of DHW_{6010} (l/min)
q DHW : the measured flow of the domestic hot water (l/min).
T DWH: the average temperature of the hot water at the taps -see remark below- (°C)
Tc: the average temperature of the cold water at the taps -see remark below- (°C)
T*u*: the mean temperature of the mixed water at the taps -see also remark below (°C).

Remarks:

Due to the practical difficulty of measuring the flows and the temperature of both cold and hot water at each tap in larger apartment buildings, the following assumptions and evaluations were made, with respect to the following parameters of the above formula

- Tc: we assumed no warming up of the cold water while flowing through the pipes at moments of peak consumption. So the temperature value measured on the main domestic water pipe inlet, was used without correction.
- T*u*: For the average temperature of the mixed water at the taps a value of 38°C was considered. This value is more “secure” than 40°C when used in the formule (2), because *Tc* is often greater than 10°C.
- T DWH : the average temperature of the domestic hot water at the taps was estimated from the measurements of DHW temperature departure and the return of the circulation system. This T DWH was <u>estimated</u> by using equation (3).

$$\text{T DWH} = T\ \ depart - \left(\frac{T\ depart - T\ return}{4}\right) \qquad \text{(eq. 3)}$$

Where:

T *depart*: the temperature of the domestic hot water at the outlet pipe of the hot water heat exchanger or the storage tank (°C)
T *return*: the temperature of the domestic hot water at the inlet of the return pipe in the heat exchanger or storage tank

3) <u>*Step 3*</u>*: averaging DHW_{6010} peak flow rates to 2 second time step* - this step results in the DHW_{6010} peak flow rate (2s) in Table 2

4) *Step 4*: *correction for the seasonal variation* in DHW consumption, by applying the previously determined monthly correction factors [3] - this step results in the "Reference" DHW_{6010} peak flow rate in Table 2

3.3 Limitations and need of future improvements

During our measuring campaign we have encountered several difficulties and limitations, linked to either the measuring method or the conversion method.

With regard to the measuring method
Because we only measured in the central boiler room, we needed to make assumptions concerning the average tap temperature, in order to be able to take into account the cold water temperature (eq. 2 and 3).. Also the pressure at the taps could influence the peak flow. This aspect wasn't covered in our measuring campaign. Furthermore, our ultrasonic flow meters were not compatible with certain types of multilayer pipes.

With regard to the conversion method
Short-term fluctuations in the DHW temperatures in the circulation system may have a significant impact on the standardized DHW_{6010} peak flow rates. We found it very useful to verify visually the impact of each data correction. Furthermore, if the temperature of the cold water rises above 38°C, the conversion equation (eq. 2) should not be used. Another important need for future improvement is to take into account the time lag due to the circulation of the hot water in the circulation system. The conversion would be more correct if based on T°*depart* at time t, in combination with *T return* at time t + time lag.

3.4 Comparison with existing guidelines

Figure 2 represents, for the building in the measuring campaign, the reference DHW peak flow rates compared to the calculated peak flow rates following the different guidelines.

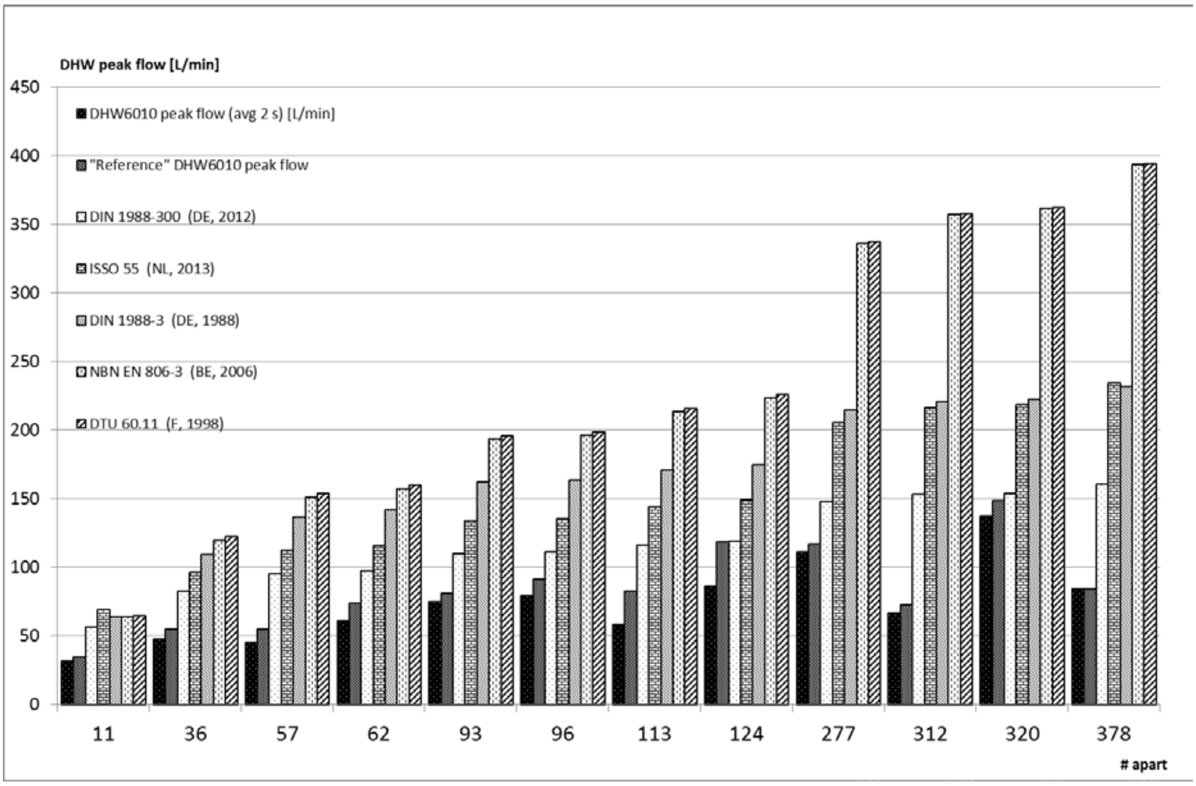

Figure 2 – Reference and calculated peak flow rate in apartment buildings of different sizes

The calculated DHW peak flow rates according to the different guidelines are systematically higher than the reference DHW_{6010}flow rate. The European standard (EN 806-3) even results in a peak flow rate which is 4 times the reference peak flow rate. Most existing guidelines overestimate the peak flow rate, especially EN 806-3 [5] and DTU 60.11 [7]. Calculations following DIN 1988-300 [1] are closest to the reference peak flow rates, followed by ISSO 55 [8]. The difference between calculated and reference peak flow rates becomes more important for larger buildings.

4 Conclusions

Most existing guidelines over-estimate the DHW peak flow rate, especially in larger apartment buildings. Overestimations up to a factor of 4 and more are no exeption. DIN 1988-300:2012 was found to be most relevant for the Belgian situation. In most buildings this standard seems still to contain a (to?)high safety margin.

6 References

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