Analysis of the Structure of Water Demand with the Example of Selected Buildings [†]

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Abstract: The basis for the desing of water supply devices is knowledge of the distribution of water demand. The purpose of this work was to determine the structure of water demand for selected building objects. Differences between real and literature values of water flow and water demand were determined. On the basis of the analysis, water meters were selected and peak factors were determined. The analysis was performed based on current legal acts, technical literature, and data obtained from Dabrowskie Wodociagi Sp. z o.o. in Dabrowa Gornicza, Poland.

Keywords: water demand; momentary volumetric flow; peak factor; water meters

1. Introduction

The key issue in the design and operation of water supply networks and systems is to evaluate the volume of water supplied, which represents the basis for the calculating of such systems. Water meters are mainly used as devices for measuring volumetric flow. The optimum choice for a water meter is not simple. There is no easy and effective method which would allow for correct measurements of service connection. This is due to the following factors influencing the structure of water distribution: differentiation of consumers in terms of water demand and the resulting varied volumetric water streams over time; residential buildings, hotels, restaurants, schools, industrial plants, shops, etc.; a constant reduction in water consumption by consumers, due to the introduction of modern and more efficient equipment and fittings, as well as for economic reasons; the impact of weather and climate changes on water demand; the large variety of types and sizes of measuring devices [1–5].

Measurements of water consumption performed in order to enable settlements between water suppliers and consumers require the use of water meters. They are designed for the automatic measurement and registration of the volume of flowing water. Properly designed and chosen measurement equipment installed in the water supply system should guarantee the reliability of measurements and ensure water supply for all consumers without any breaks and with appropriate pressure. The reliability of a water supply system depends on the reliability of its individual components, including water meters [6]. Water meters have to meet increasingly high metrological requirements and work over wide measuring ranges. This is necessary due to the substantial variation of water volume streams resulting from the variability in water demand, e.g., taking into account the demand for fire-fighting purposes [7,8].

Water is used unevenly to meet the needs of the population; there occur daily and hourly flow variability. These values are directly related to the way that people use water, their lifestyle (sleep,

working hours, meal preparation, washing, etc.). The emergence on the market of smart water meters allows for better knowledge of the average daily demand for water and the maximum daily and hourly demand. We can calculate the daily and hourly peak factors on the basis of the flow variability, and based on these data, we can choose the optimal water meter for a particular customer [9,10].

2. Aim and Scope of the Study

The aim of this study was to determine the structure of water distribution for single-family buildings. The differences between the actual and literature values of maximum water flow rates and water demand per unit of time were determined. The analysis allowed for determination of actual peak factors of water distribution to individual objects. These values were used to choose optimal measuring devices.

The analysis was performed based on current legal acts, technical literature, and data made available by Dabrowskie Wodociagi Sp. z o.o. in DabrowaGornicza, Poland. Two types of water meters were used for data recording: the electromagnetic iPerl meter and volumetric type 640 (SENSUS) meter. The water meters were equipped with integrated digital recorders and radio modules for remote data transmission.

3. Methods of the Research

The research was conducted in the area of the city of DąbrowaGórnica (Silesian region). There were 116,916 inhabitants registered for permanent residence at the end of 2016 in this town. The average daily water consumption in DąbrowaGórnica was $q = 83 \text{ dm}^3/\text{inhabitant} \cdot \text{day}$.

The analysis of water consumption included 10 single-family houses and was carried out in 2017 and 2018. Water consumption and maximum volume flow for every house were recorded at hourly intervals. The duration of the measurement in individual building objects ranged from two to six months. The measurement period was dependent on the type of device, the number of programmed parameters, and the time of installation of a water meter. The metrological parameters of installed water meters are shown in Table 1.

Table 1. parameters of installed and planned to be installed water meters.

Type	Diameter mm	Q ₁ dm ³ /h	Q ₂ dm ³ /h	Q ₃ m ³ /h	Q ₄ m ³ /h	R
640	15	6.3	10	2.5	3.125	400
iPerl	15	3.13	5	2.5	3.125	800
640	20	10	16	4	5	400
iPerl	20	5	8	4	5	800

Markings Q₁, Q₂, Q₃, Q₄ and R in accordance with Measuring Instruments Directive 2014/32/EU [11].

The number of inhabitants, the total water consumption during the year, and water demand per unit were determined for each building. The following graphs (Figure 1) present hourly water consumption for two selected buildings, for weekly periods in which the maximum values of the measured volumetric flow were observed. Graphs showing the maximum of momentary volumetric flows in the analyzed periods are shown in Figure 2.

The following figure (Figure 3) shows the distribution of water consumption for a day with maximum demand for the same buildings, which is shown in Figures 1 and 2. The maximum of momentary volumetric flows were not always observed in the same day when the maximum demand for water appeared. Using the obtained data, the daily and hourly peak factors were calculated for each building.

Figure 1. Examples of hourly water consumption in weekly periods in selected single-family houses: (a) building no. 1, (b) building no. 7.

Figure 2. The maximum of momentary volumetric flows in selected single-family houses: (a) building no. 1, (b) building no. 7.

Figure 3. Examples of variability of hourly water consumption in a day with maximum demand in selected single-family houses: (a) building no. 1, (b) building no. 7.

4. Discussion of Results

For ten selected single-family houses, the average unit water demand was equal to $q = 124 \text{ dm}^3/\text{inhabitant} \cdot \text{day}$ (Table 2). This value was higher than the consumption in the regulations [12] for buildings equipped with water supply, toilet, bathroom, and local hot water source ($q = 80 \div 100 \text{ dm}^3/\text{inhabitant} \cdot \text{day}$). Average consumption in the analyzed buildings was also higher than the average water consumption for DąbrowaGórnica— $q = 83 \text{ dm}^3/\text{inhabitant} \cdot \text{day}$.

Single-family houses were characterized by a large variation in water consumption per capita, in the range of 60 to 231 $\text{dm}^3/\text{inhabitant} \cdot \text{day}$. The highest consumption occurred in building no. 7 and 8. These buildings were relatively new, equipped with automatic watering systems. It should be noted that new, single-family houses, as well as urban green areas, are increasingly equipped with automatic watering systems. In this case, it had a significant impact on increasing the average value of water demand. However, for most buildings, the average daily demand was close to or lower than the values in the regulations [12] and in the literature [4,13].

Table 2. results obtained for single-family buildings.

Building	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	Average
the number of inhabitants	3	4	4	4	5	4	2	3	3	5	3.7
q , l/Mk*d	109	108	167	104	96	60	231	181	80	107	124
Q_{dsr} , m ³ /h	0.326	0.430	0.668	0.416	0.482	0.238	0.463	0.542	0.241	0.534	0.43
q_{max} , m ³ /h	0.849	0.793	0.490	0.499	0.592	1.386	0.859	1.668	0.446	0.491	0.81
N_d	2.89	1.83	1.78	1.81	2.54	1.40	2.95	3.37	2.88	1.04	2.25
N_h	6.51	2.97	3.16	4.06	5.61	3.29	9.18	14.71	5.10	5.35	5.99

q —average daily water consumption per customer, Q_{dsr} —average daily water demand per building, q_{max} —maximum momentary volumetric flow, N_d —daily peak factor, N_h —hourly peak factor, the maximum results have been marked with a grey background.

5. Conclusions

The analyzed buildings were characterized by a diversified demand for water per capita. This indicator was lower for most of the buildings compared to those contained in the regulations of the Ministry of Infrastructure on average water consumption standards. The calculated peak factor of daily N_d and hourly N_h unevenness ranged from 1.4 to 3.4 and from 3.0 to 14.7, respectively. These values are much higher than the peak factors available in the technical literature [13].

In technical conditions specified by some water supply companies, the use of DN 20 mm water meters for single-family houses is required. The analysis revealed that it is possible in these buildings to use water meters with a smaller diameter (DN 15 mm) instead of the currently used meters. This will allow for reduction in the cost of purchasing new water meters, whereas installation of devices with a different diameter will increase the costs insignificantly and the costs will be incurred only once. It should be also emphasized that current DN 20 water meters have very good metrological parameters and do not adversely affect the amount of water measured. For this reason, their replacement will be advisable only after the expiry of the verification period.

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