Trends in domestic hot water consumption in Estonian apartment buildings

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Abstract. Domestic hot water consumption trends in Estonian apartment buildings during the last 30 years have been investigated. Measurement results show that the factual maximum consumption values are substantially less than the design values. For dimensioning instantaneous heat exchangers for domestic hot water heating a new load calculation formula is recommended.

Key words: apartment building, domestic hot water, consumption profile.

1. INTRODUCTION

In the 1970s the domestic hot water consumption in residential buildings was relatively high; for example, in the former Soviet Union 95 l/d per person or more [1,2]. The latest investigations tell us about a decrease in domestic hot water consumption: in Russia 68–92 l/d per person (as design values) [3], in Finland about 85 l/d per person [4] and in USA residential homes 46–85 l/d per person [5]. Changes in the consumption profile are different in different countries. There are only minimal changes in domestic hot water consumption profile in Russia [6]. Nowadays, domestic hot water consumption profile of apartment buildings in Estonia [7] is close to consumption profiles in USA [8] and Denmark [9].

The share of heat consumption for water heating in Estonian apartment buildings in the general heat consumption has been about 20–40% during the last 30 years. The larger numbers belong to the 1970s. The total heat consumption in apartment buildings has changed from 350 in the 1970s to 200 kWh/m^2 per year in 2004.

The first investigation of domestic hot water consumption in the 1990s was carried out in Tallinn in 1998 [10]. The first more extensive analysis of domestic hot water consumption by the authors of the paper was made in 2000 on the basis of the 1999 consumption data [11]. The latest one was made in 2005 [7].

2. CHANGES IN DOMESTIC HOT WATER CONSUMPTION

The domestic hot water consumption dynamics in apartment buildings from 1999 to 2004 is shown in Table 1. We can see a considerable decrease in consumption. In small cities of Estonia the domestic hot water consumption is about 15% less.

Comparison of the weekly consumption data in 1974 and 2005 is shown in Fig. 1. From 1974 to 2005 the domestic hot water consumption in apartment buildings has decreased more than three times.

Table 1. Domestic hot water consumption $l/(m^2 \cdot d)$ in investigated apartment buildings from 1999 to 2004

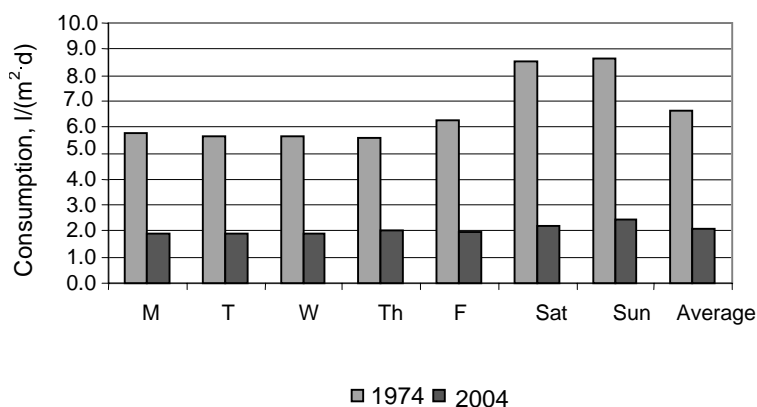| Consumption	1999	2000	2001	2002	2003	2004
Average	2.8	2.6	2.3	2.2	2.1	2.0*
Range	1.6–3.6	2.1–3.3	1.8–3.1	1.7–2.8	1.6–2.6	1.7–2.7

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* 44 l/d per person.

Fig. 1. Domestic hot water consumption on weekdays and on average in 1974 and 2004; the area is the general area of apartments.

3. DOMESTIC HOT WATER CONSUMPTION PROFILE

Maximum domestic hot water consumption and consumption profile in apartment buildings were investigated in 1974 (using an experimental data logging system) and in 2005 using impulse water meters (one impulse per one litre), which were connected with data loggers; the measurement schema is shown in Fig. 2. The water consumption data collection of different apartment buildings was made during a week.

During 30 years considerable changes in people's lifestyle have taken place. To prove it, daily consumption profiles of two apartment buildings in 1974 and 2005 are shown in Figs. 3 and 4.
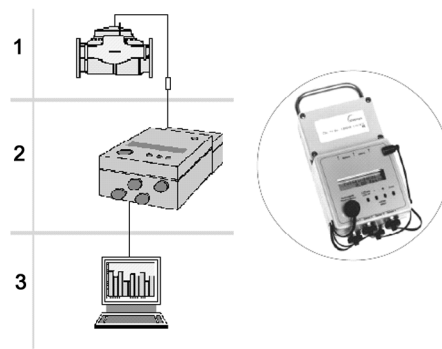
1 – impulse water meter, 2 – datalogger, 3 – data processing

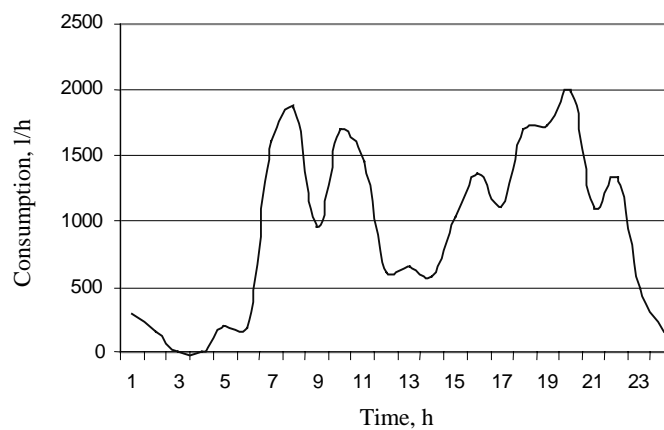**Fig. 2.** Data measurement and processing system.

Fig. 3. Consumption profile of a 90-apartment building in 1974 (on Monday).
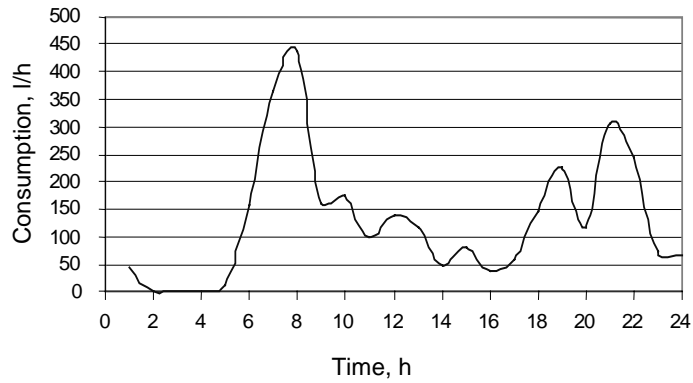
Fig. 4. Consumption profile of a 30-apartment building in 2005 (on Tuesday).

The maximum hourly variation in domestic hot water consumption is characterized by the ratio k_h of the maximum hourly consumption to the average hourly consumption of a week, which is calculated as:

$$k_h = \frac{G_h^{max}}{G_h^{avg}}, \qquad (1)$$

where G_h^{max} is the maximum and G_h^{avg} is the average hourly domestic hot water consumption of the week.

The dependence of k_h on the number of apartments in a building is shown in Fig. 5.
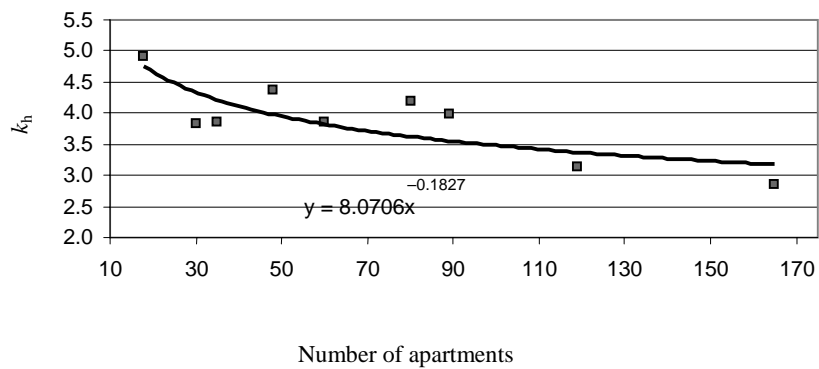

Fig. 5. The dependence of k_h on the number of apartments in the building.

In recent years great changes in the relative domestic hot water consumption during the weekend have taken place. The increase in the consumption during the weekend is not so considerable any more. In comparison with the water consumption on workdays the rise in the weekend consumption in 1974 was 1.5 times while now it is only 1.2 times. At present the daily consumption is characterized by the morning maximum (Fig. 4) and it is more close to the consumption profiles in the West European countries [9] and USA [8].

4. MAXIMUM CONSUMPTION AND A NEW LOAD CALCULATION FORMULA

The maximum domestic hot water consumption has decreased and is considerably lower than that calculated using [12] (Fig. 6).

Calculation of the domestic hot water design flow rate in residential buildings is based on the sum of nominal flows of standard type of water outlets. Calculation is made using a graph, table or formula

$$q_{dh} = q_N + \Theta(Q - q_N) + A\sqrt{q_m \cdot \Theta}\sqrt{Q - q_N}, \qquad (2)$$

where q_{dh} is the design flow rate of the domestic hot water (l/s), q_N is the maximum flow rate of domestic hot water for water outlets (l/s), q_m is the weighted mean flow rate of domestic hot water for water outlets (0.2 l/s), Q is the sum of the nominal flow rates of domestic hot water for water outlets (nominal flow rates are 0.2 l/s for shower, 0.3 l/s for bath tube and 0.2 l/s for kitchen sink), A and θ are constants depending on the desired safety against overloading (for residential buildings $A = 3.1$ and $\theta = 0.015$).
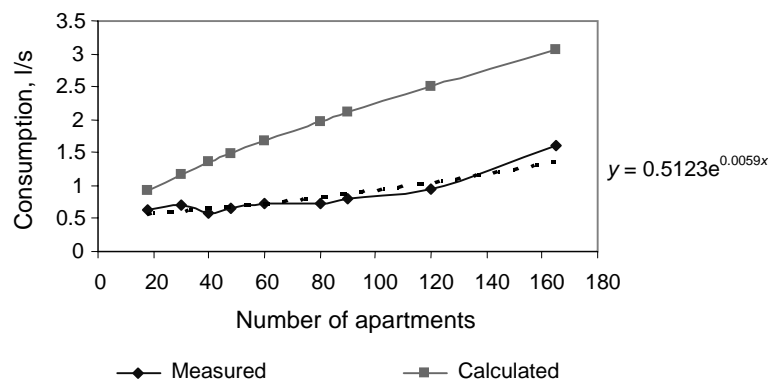

$y = 0.5123e^{0.0059x}$

Fig. 6. Measured and calculated (on the basis of EVS [12]) values of maximum domestic hot water consumption in different apartment buildings in 2005.

For calculating the domestic hot water load Φ for dimensioning instantaneous heat exchangers, the following formula was derived:

$$\Phi = B(30 + 15\sqrt{2n} + 0.2n),\qquad(3)$$

where n is the number of apartments, B is a coefficient that takes into account the domestic hot water temperature ($B = 1.0$ if hot water design temperature is 55 °C, $B = 1.1$, if this temperature is 60 °C and $B = 1.2$, if this temperature is 65 °C). Equation (3) is valid for apartments with one bathroom and a kitchen.

Figure 7 shows domestic hot water heating load values for dimensioning instantaneous heat exchangers in different apartment buildings on the basis of Eq. (3).

Figure 8 presents domestic hot water heating load design values calculated by formula (3), by the Estonian Standard EVS 835:2003 (identical with D1 – the Finnish Construction Code), by SDHA (the Swedish District Heating Association) method and by SNiP 2.04.01-85 (the Soviet Construction Code). Calculation formulas are presented in the article Kõiv and Toode (2001) [3]. In Fig. 8 we can see that the results calculated by formula (3) are closer to the SDHA method, the reason being a very close number of residents in apartments.

Figure 9 shows design loads, calculated by formula (3), by the EVS/D1 method and by the measured values in 2005. We can see that for large apartment buildings EVS and D1 give about twice higher loads.
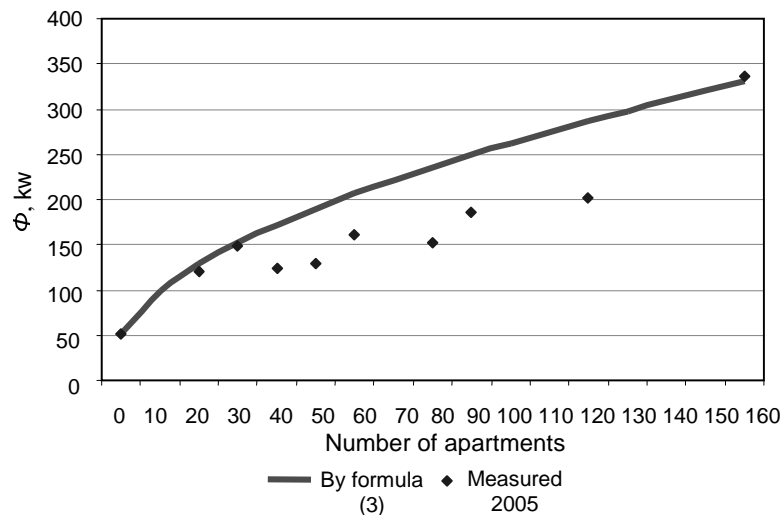

Fig. 7. Domestic hot water heating load values for dimensioning instantaneous heat exchangers in different apartment buildings, calculated using Eq. (3), and values calculated on the basis of measured domestic hot water consumption values.
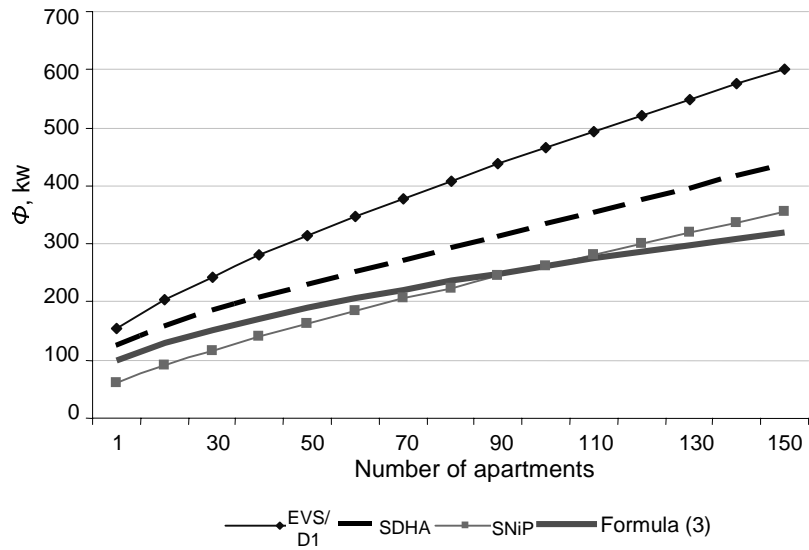
Fig. 8. Domestic hot water heating load design values calculated by different methods: EVS – Estonian Standard EVS 835:2003; D1 – Finnish Construction Code; SDHA – Swedish District Heating Association; SNiP – Soviet Construction Code SNiP 2.04.01-85.
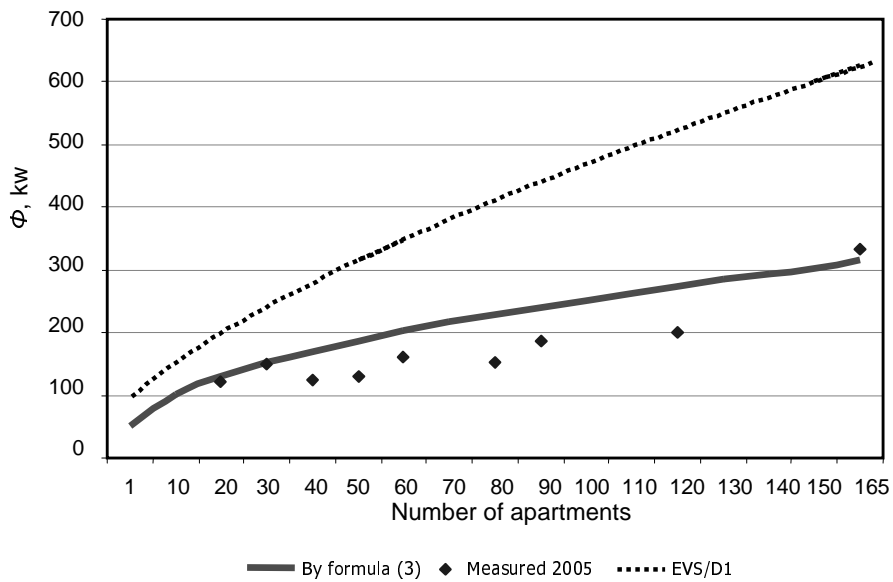

Fig. 9. Comparison of domestic hot water heating loads calculated by formula (3), by the EVS/D1 method and on the basis of measured values.

5. CONCLUSIONS

In the last 30 years great changes in domestic hot water consumption in apartment buildings have taken place (Fig. 1). The main reasons for the decrease in domestic hot water consumption are:
– consumption metering in apartments and payment for real consumption;
– increasing cost of water and heat;
– extensive renovation of domestic hot water systems, including renovation of the circulation;
– use of modern water saving equipment (taps, showers).

At the same time there have been considerable changes in maximum water consumption. Following that a new methods for dimensioning instantaneous heat exchangers in apartment buildings is recommended. This improves the control of domestic hot water temperature, especially in conditions of low external temperature, and decreases expenses on the equipment.

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