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CALCULATION OF LOAD OF THE DOMESTIC HOT WATER HEAT EXCHANGER IN RESIDENTIAL BUILDINGS

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Abstract. Different methods of load calculation of domestic hot water instantaneous heaters in residential buildings are described. Results of the calculation of the heat load for various numbers of apartments in a building are presented. A load calculation formula of domestic hot water heat exchangers for residential buildings in Estonia is recommended. Heat load calculation results by the recommended and the Swedish District Heating Association method are compared. Actual average loads of heat exchangers in renovated heat substations are compared with the calculated ones.

Key words: domestic hot water heat exchanger load, calculation methods.

1. INTRODUCTION

At present, many district heating substations have been renovated in Estonia. While designing of heat exchangers for space heating system is not complicated, no suitable method for calculating the load of domestic hot water heat exchangers is available. Usually control valves are chosen on the basis of the load of heat exchangers. But oversized control valves reduce control quality.

In practice, the design method of the Finnish construction code D1 [1] or the method of district heating of Helsinki [2] are mostly used. Old systems were designed by the method of SNiP [3].

2. METHODS FOR LOAD CALCULATION OF DOMESTIC HOT WATER HEAT EXCHANGERS

2.1. Method D1 [1]

Determination of the design domestic hot water flow rate in residential buildings is based on the sum of nominal flow rates of standard type water outlets (Table 1). Calculation is made using a graph, table, or formula

$$q_{\mathrm{dh}} = q_N + \theta (Q - q_N) + A\sqrt{\theta\, q_{\mathrm{m}}}\sqrt{Q - q_N}, \tag{1}$$

where q_{dh} is the design flow rate of domestic hot water, l/s, q_N is the maximum flow rate, q_{m} is the weighted mean flow rate, and Q is the sum of the flow rates of domestic hot water for water outlets; A and θ are constants dependent on the desired safety against overloading.

Table 1. Nominal hot water flow rates at frequently used outlets in residential buildings, l/s

Type of water outlets	Finnish and Swedish codes	SNiP
Bath tub	0.3	0.18
Shower	0.2	0.09
Kitchen sink	0.2	0.09

The load for designing the domestic hot water heat exchanger Φ (kW) is calculated as

$$\Phi = q_{\mathrm{dh}} c \rho \Delta t, \tag{2}$$

where c is the heat capacity of water [kJ/(kg °C)], ρ is the density of water (kg/l), and Δt is the temperature difference of the hot and cold water (°C).

2.2. Method of SNiP [3]

In residential buildings with the same type of water outlets, probability of simultaneous use of domestic hot water per hour is calculated as

$$P_{\mathrm{hr}} = \frac{q_{\mathrm{hr,u}} U}{q_{N,\mathrm{hr}} N}, \tag{3}$$

where $q_{\mathrm{hr,u}}$ is the maximum consumption of domestic hot water by the consumer (constant for apartments with different equipments), U is the number of consumers, $q_{N,\mathrm{hr}}$ is the flow rate of domestic hot water for water outlets with maximum consumption, and N is the number of water outlets in the building.

The design flow rate of the domestic hot water is calculated by formula

$$q_{\mathrm{dh,hr}} = 0.005\, q_{N,\mathrm{hr}}\, \alpha, \ \mathrm{m^3/h}, \tag{4}$$

where α is a factor which depends on the number of water outlets N and on P_{hr}.

The design load of the domestic hot water heat exchanger is calculated by Eq. (2) where $q_{\mathrm{dh}} = q_{\mathrm{dh,hr}}/3.6$.

2.3. Method used in district heating of Helsinki (DHH) [2]

The load of the domestic hot water heat exchanger is calculated using empirical formula

$$\Phi = 29 + 20\sqrt{4N_{\mathrm{k}} - 2}, \ \mathrm{kW}, \tag{5}$$

N_{k} is the number of apartments in the building.

2.4. Method of Swedish District Heating Association (SDHA) [4]

The domestic hot water flow rate calculation is based on a diagram (Fig. 1). The domestic hot water flow rate depends on the number of apartments in the

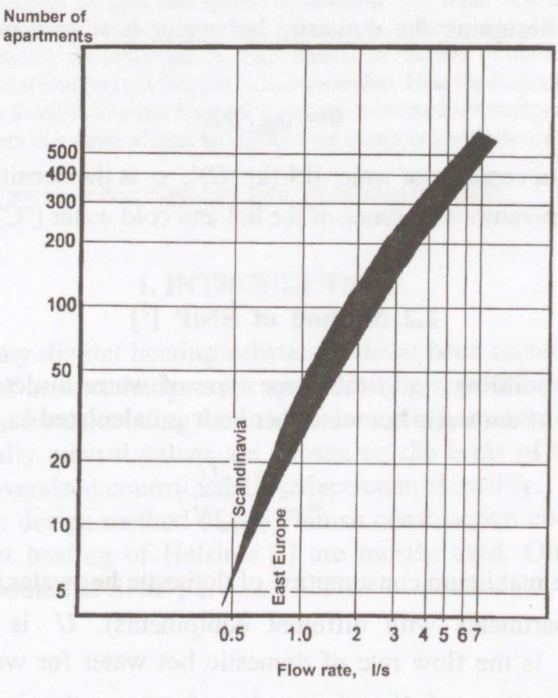

Fig. 1. Probability of simultaneous use of domestic hot water.

building. In the analysis probability of simultaneous domestic hot water consumption in Scandinavia (assuming two inhabitants in an apartment) is used. This number is valid also in Estonia (in apartment buildings).

The domestic hot water heat exchanger load is calculated by Eq. (2).

2.5. Comparison of different methods

In different countries different nominal domestic hot water flow rate values for water outlets are used. In Finland and Sweden hot water flow rates for typical water outlets have the same values, but they are different in SNiP (Table 1).

The design domestic hot water flow rate in the method D1 is based on the sum of hot water flow rates for water outlets, the maximum hot water flow rate for water outlets, and probability of simultaneous hot water consumption. In the method of SNiP the design domestic hot water flow rate depends on the probability of simultaneous hot water consumption, number of hot water outlets, maximum hourly hot water consumption of the consumer, and hot water flow rate for water outlets with maximum consumption. Design load calculation of domestic hot water heat exchangers with the DHH method is very simple; one must know only the number of apartments in the building.

Dependence of design loads of domestic hot water heat exchangers on the number of apartments, calculated with different methods, is compared with actual loads in Fig. 2. Actual domestic hot water heat exchanger loads are calculated on the basis of heat exchangers in 42 residential buildings in Mustamäe.

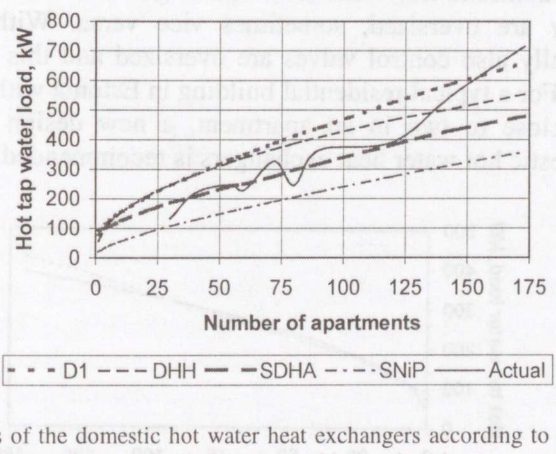

Fig. 2. Design loads of the domestic hot water heat exchangers according to different calculation methods and actual heat exchangers loads in renovated heat substations.

3. RECOMMENDED CALCULATION METHOD

The idea of the method is simplicity and minimum acceptable load. All presented design load calculation methods of domestic hot water heat exchangers and their influence factors were analysed. As a starting point, the SDHA method with two inhabitants in an apartment was used. The following calculation formula for design load of domestic hot water heat exchangers in Estonian conditions is recommended

$$\Phi = B(32 + 15\sqrt{4N_k - 2}), \tag{6}$$

where 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).

In Fig. 3 the recommended and calculated with the SDHA method design load values are compared. In residential buildings with average number of inhabitants more than two, it is recommended to use the SDHA method for flow rate calculation and Eq. (2) for load calculation of heat exchangers. In Fig. 2 for high actual loads of the heat exchangers too high load increase can be observed compared with calculated loads. The result is oversized heat exchangers for high loads. This is not only an economic problem but also a problem of control quality.

4. CONCLUSIONS

Selection of domestic hot water heat exchangers has been done arbitrarily. Sometimes they are oversized, sometimes vice versa. With oversized heat exchangers usually also control valves are oversized and this may lead to low control quality. For a typical residential building in Estonia with average number of inhabitants close to two in an apartment, a new design load calculation formula of domestic hot water heat exchangers is recommended.

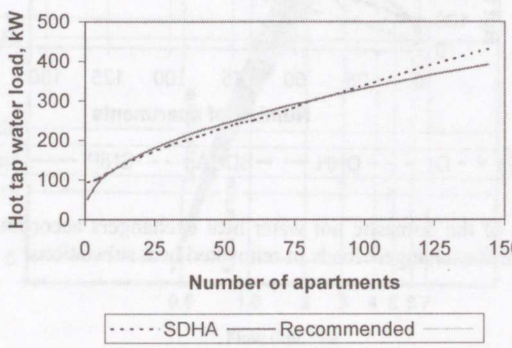

Fig. 3. Comparison of design load values calculated using recommended (Eq. (6)) and the SDHA method.

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ELAMUTE SOOJA TARBEVEE SOOJUSVAHETITE SOOJUSKOORMUSE MÄÄRAMINE

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On kirjeldatud elamute sooja tarbevee soojusvahetite soojuskoormuse arvutuse erinevaid meetodeid. Soojuskoormuse arvutuse tulemuse olenevus korterite arvust on esitatud graafiliselt. Soojusvahetite soojuskoormuse määramise uut valemit on võrreldud Rootsi Kaugkütte Assotsiatsiooni meetodiga. On toodud renoveeritud soojussõlmede sooja tarbevee soojusvahetite tegelike võimsuste võrdlus erinevatel arvutusmeetoditel saadutega.