UDC 696.11

K. Kovacova, M. Kovac
Technical University of Kosice, Slovakia
Institute of Architectural Engineering, Department of Building Services

ENERGY EFFICIENCY OF DOMESTIC HOT WATER DISTRIBUTION SYSTEM

Метою роботи є аналіз тепловтрат у системах холодного і гарячого водопостачання (СГВ). Було використано методи розрахунку за чинним стандартами EN для енерго-ефективності будівлі. Аналіз енергетичної ефективності було зроблено для декількох 5-поверхових житлових будинків із загальною кількістю квартир 32 (двокімнатні та трикімнатні квартири від 2-го до 5-го поверхів). У будинку проживають 86 жителів, середнє споживання гарячої води 40 літрів на людину в день. Об'єктом аналізу є застосування електричних нагрівальних кабелів для нагрівання води у системах гарячого водопостачання. Результати порівнюються з традиційною системою гарячого водопостачання з циркуляційним контуром. Кількість енергії для приготування гарячої води, тепловтрати у трубопроводах та ємностях для зберігання гарячої води СГВ розраховано для кожного варіанта СГВ. З результатів видно, що СГВ з циркуляційним контуром потребує значної кількості енергії, а тепловтрати в ній становлять близько 30 % від енергії, необхідної для приготування гарячої води. У разі застосування електричних нагрівальних кабелів тепловтрати у системі було знижено до 15 %. Досягнутої економії енергії не враховували в експлуатаційних затратах СГВ. У разі використання нагрівальних кабелів споживання електричної енергії в СГВ збільшилось на 8 %. Якщо джерело енергії – електрична енергія, то експлуатаційні затрати на СГВ з електричними нагрівальними кабелями знизиться на 10 %.

Ключові слова: система гарячого водопостачання, тепловтрати, циркуляційний контур, електричні нагрівальні кабелі.

The aim of paper is to analyze the thermal losses of domestic hot water (DHW) distribution system. There were used calculation methods by valid EN standard for energy performance of building. The analysis of energy performance was done for multi-dwelling house with 5 floors with total number of flats 32 (two-room and three-room flats on the 2nd to 5th floors). There are total 86 residents in the house and the average consumption of DHW is at 40 litres per person and day. The object of analysis is the application of electric heat cables in order to maintenance domestic hot water temperature. The results are compared with traditional DHW distribution system with circulation loop. Energy need for DHW, thermal losses from the DHW distribution system and thermal losses from the DHW storage vessel were calculated in order to analyse the selected variants of DHW systems. From results is clear that DHW distribution system with circulation loop represents significant part of system energy need. In case of classic DHW distribution system with circulation loop the distribution thermal losses are about 30 % from energy need for DHW preparation. In case of electric heat cables application the rate of distribution thermal losses were reduced to 15 % from energy need for DHW preparation. The reached energy saving was not displayed in the operation costs of DHW system. In case of heat cables utilisation the electric energy consumption in DHW system is higher and it caused the increasing the operation costs about 8 %. In case that all energy requirements of DHW system (both variants) are covered by electricity the operation costs of DHW system with electric heat cables would be reduced by 10 % at average.

Key words: domestic hot water system, distribution thermal losses, circulation loop, electric heat cables

Introduction. The data about the final energy consumption from EUROSTAT show the significant share of buildings on the final energy consumption over the last 20 years in all states of EU. The right design of heating and domestic hot water system in term of heat sources, distribution network and system regulation significantly influence the energy consumption in buildings. Therefore the decentralised systems of heat supply are preferred nowadays that reduce thermal losses from distribution pipes. The aim of contribution is to compare energy balance of domestic hot water system in designed two variants. The analysis of energy performance is done for multi-dwelling house. It is the house with 5 floors with total number of flats 32 (two-room and three-room flats on the 2nd to 5th floors). On the 1st floor there are carports and community spaces for all residents of the multi-dwelling house. The total heating area of the house is 2 185 m^2. There are total 86 residents in the house and the average consumption of DHW is at 40 litres per person and day.

Energy for domestic hot water system. The energy need for the domestic hot water is the heat to be delivered to the needed amount of domestic hot water to raise its temperature from the cold network temperature to the prefixed delivery temperature at the delivery point. It is directly depend on physical properties of water (specific weight, specific heat capacity) and specific domestic hot water delivery temperature. In real situations it is needed to take account energy performance of the whole domestic hot water system and therefore distribution thermal losses (domestic hot water distribution system) too. The heat generator that provides the energy required for meeting the energy need for domestic hot water and for compensating the losses in other sub-systems is very important too.

The domestic hot water systems can be different. In case of centralized domestic hot water system the domestic hot water preparation is in central boiler room, in central domestic hot water storage vessel. The hot water is delivered at all delivery points in building. This systems use circulation loop in order to provide for the required minimum temperature of the domestic hot water at the user outlet. In this case the distribution thermal losses occur and have effect on final energy performance of domestic hot water system. In many cases the distribution thermal losses (during periods of circulation) are equal to amount of energy need for the domestic hot water (heating of cold water). There are primarily older systems with large distribution system (horizontal and vertical pipes), with insufficient thermal insulation of pipes (sometimes thermal insulation is missing) etc. In these cases the rate of distribution thermal losses is at values 70–100 % of energy need for domestic hot water delivered to the user. Nowadays the value of coefficient is about 25–30 % for renovated multi-dwelling houses where the renewal of domestic hot water distribution system was done including exchanging the thermal insulation.

According to energy policy of EU and valid Directive 2012/27/EU of the European parliament and of the Council of 25 October 2012 on energy efficiency demands of energy performance of buildings and building equipments are more and more strict. As amended by Act no. 321/2014 on energy efficiency the owner of building with total floor more than 1000 m^2 owe a duty:

– to hydraulic regulate the domestic hot water distribution system,
– to install the proper thermal insulation on domestic hot water pipes. [1]

Minimum thermal insulation thickness of heat and domestic hot water distribution pipes is specified in public note No. 282/2012 (see Table 1).

Table 1

The minimum thermal insulation diameter of heat and domestic hot water distribution pipes in buildings [2]

Inner diameter of pipes or fitting	Minimum thermal insulation thickness
To 22 mm	20 mm
From 23 mm to 35 mm	30 mm
From 36 mm to 100 mm	Like inner diameter of pipe
More than 100 mm	100 mm

Selected variants of domestic hot water system in analysed object. The object of analyse is the multi-dwelling house where the heat source of heating and DHW system is a cascade of 2 gas boilers (heat power 2x80 kW) located in the boiler room on the 1st floor. The analyse is oriented only on domestic hot water system (DHW).

There is central DHW preparation in storage with volume 1,500 litres (the stand-by heat loss of storage vessel is at 5.1 kWh/24h by hot water temperature 65 °C and ambient temperature 20 °C [3]. The horizontal DHW distribution system is led below ceiling of the 1st floor; rising pipes are led in vertical shaft of flats (Figure 1). There are used the polypropylene pipes (multilayer PP-R with carbon layer) with thermal insulation from polyethylene (PE). The thickness of thermal insulation is dependent on inner diameter of pipes, designed by Table 1.

There were 2 variants of domestic hot water distribution system under consideration:

1st variant – There is used standard DHW distribution system including circulation loop (Fig. 1). The circulation loop of distribution system is in operation non-stop, 24 hours per day. The average temperature of hot water in distribution pipes is considered at 50°C.

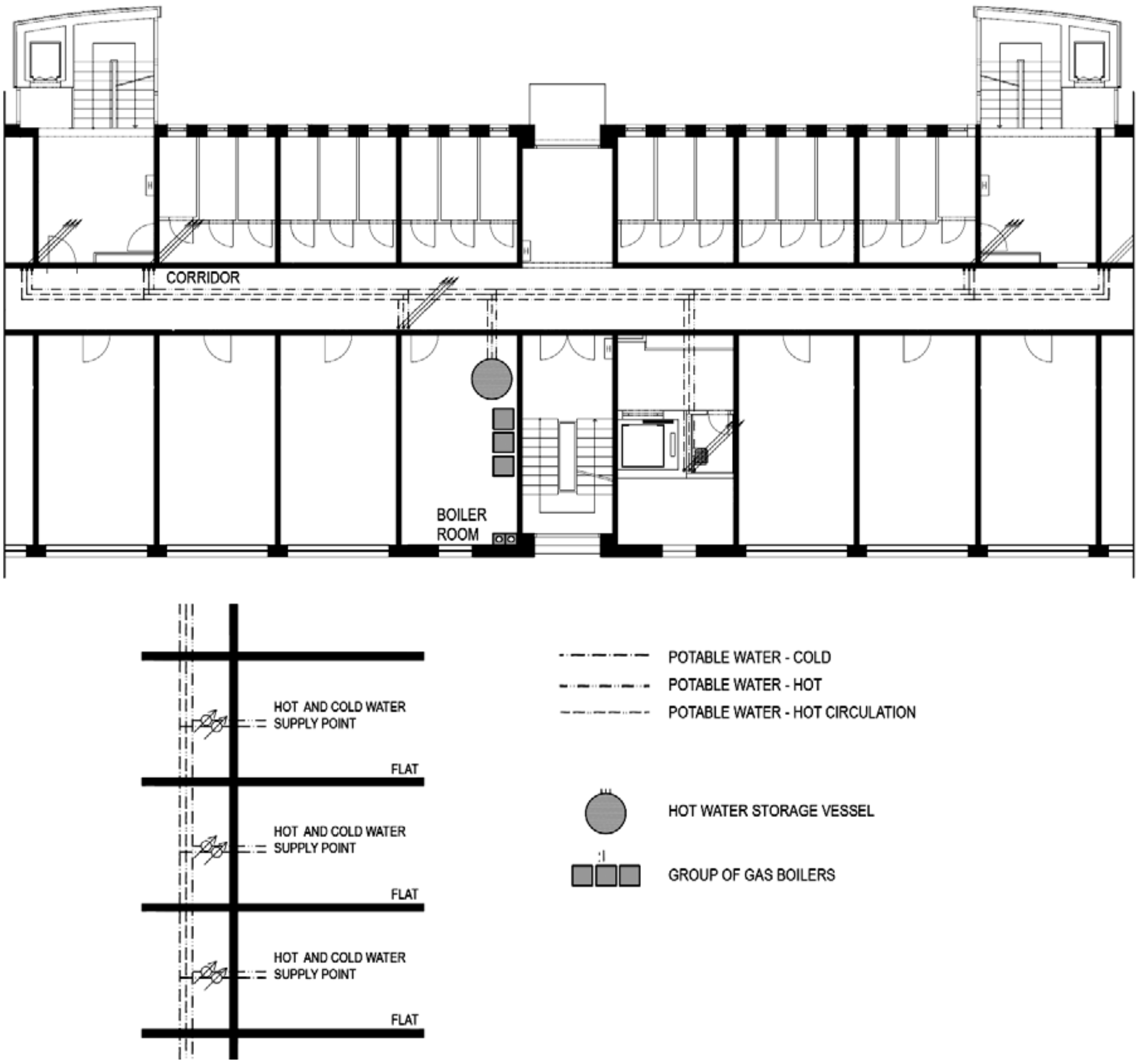

Fig. 1. DHW distribution system including circulation loop in analysed multi-dwelling house

2nd variant – In this variant the electric heat cables are designed to provide hot water temperature maintenance. In this case the DHW distribution system is designed without circulation loop. Distribution thermal losses are compensated by self-regulating electric heat trace cable installed on the hot water supply pipes (underneath standard pipe insulation) (Fig. 2).

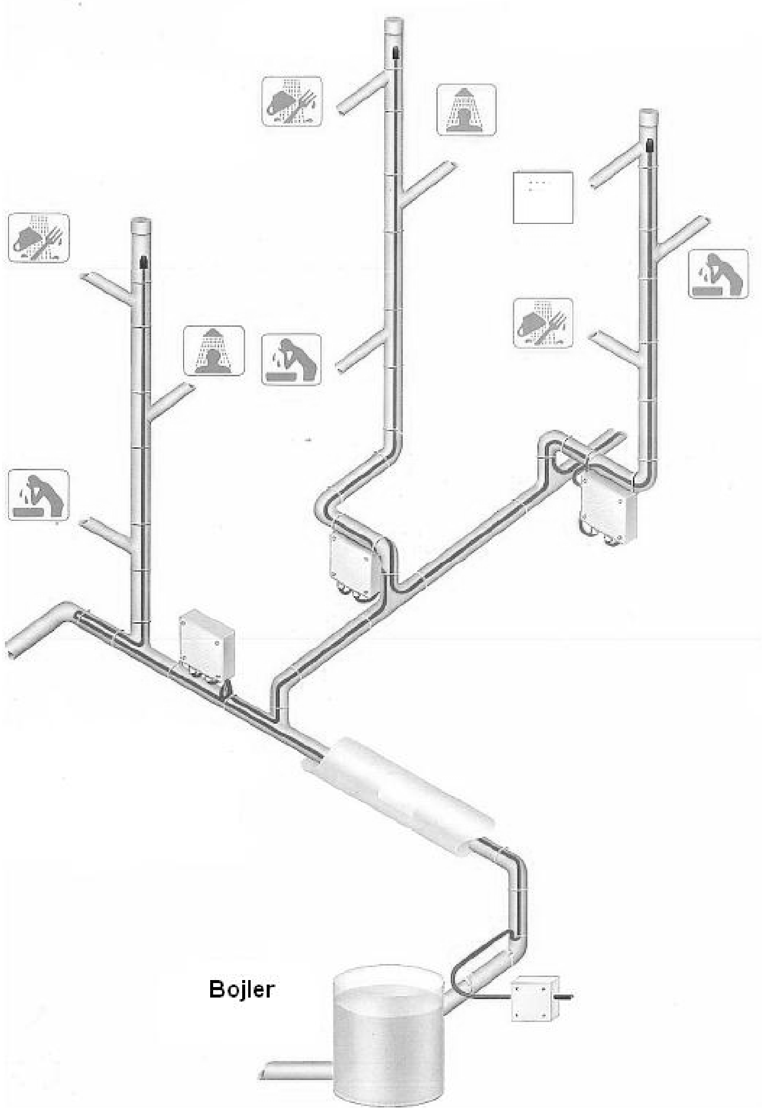

Fig. 2. Example of electric heat cables installation
[http://voda.tzb-info.cz/7794-samoregulacni-system-udrzovani-teple-uzitkove-vody-hwat-iv]

The auxiliary energy consumption for the electric heat cables is calculated by the following formula [4]:

$$W_{W,dis,rib} = \frac{L_{W,rib}.U_{W,dis}.\left(q_{W,dis,avg} - q_{amb}\right).t_W}{1000} \quad [kWh/a], \tag{1}$$

where $W_{W,dis,rib}$ – is the auxiliary energy consumption for the electric heat cables [kWh/a]; $L_{W,rib}$ – is the length of pipe section with installed heat cables [m]; U_W – is the linear thermal transmittance of pipe section [W/(m.K)] [4]; $\theta_{W,dis,avg}$ – is the average hot water temperature of pipe section [°C]; θ_{amb} – is the average ambient temperature around pipe section [°C]; t_W – is the operation time of heat cables [h/a].

Energy and financial balance of the domestic hot water system. In order to analyse the selected variants of DHW systems the following items were calculated: energy need for DHW [5], thermal losses from the DHW distribution system, calculation by [4] and thermal losses from the DHW storage vessel, calculation by [6]. The results of energy demand for all subsystems are shown in the figure below (Fig. 3).

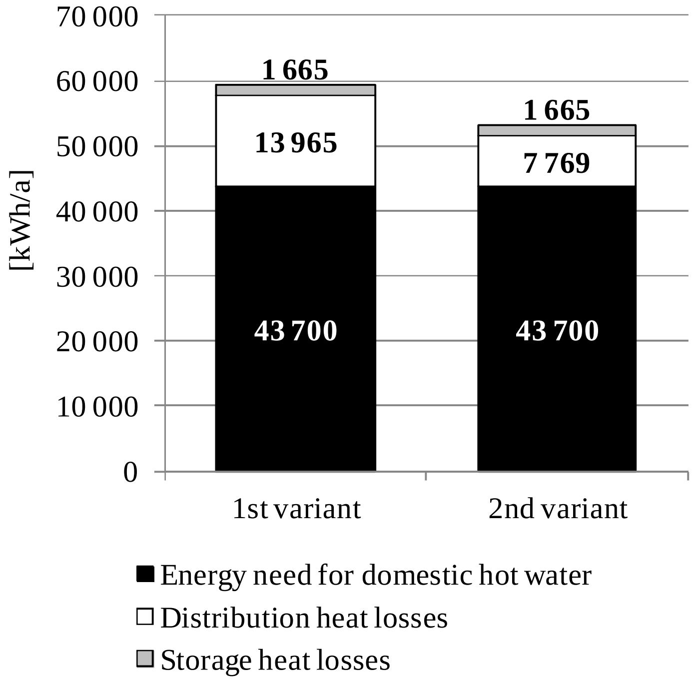

Fig. 3. Energy demand for all subsystems of DHW system

The logic result of 2nd variant application is the reduction of distribution heat losses in average to 50 %. The next step was to calculate the specific energy need and primary energy for both analysed variants (Fig. 4). The specific energy need was calculated as share of energy need for DHW system and total floor area (2,185 m^2). There was calculated with energy efficiency of gas boilers at value 95 %. The primary energy is calculated by multiplying the specific energy need and factor of primary energy (natural gas – 1.36, electricity – 2.764) [5]. In 1st variant the distribution thermal losses are covered by heat energy from natural gas. In 2nd variant the thermal losses from distribution pipes are covered by electric energy from heat cables.

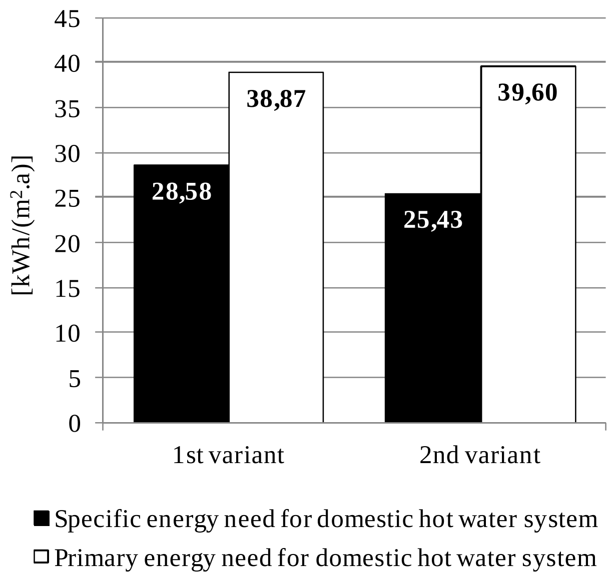

Fig. 4. Specific energy need and primary energy for DHW system

The last step of analyse was to calculate the operation cost of DHW system for both evaluated variants (Fig. 5). The price of electricity is at average three times higher than the price of gas (gas – 0.0547 Euro/kWh, electricity – 0.1379 Euro/kWh inclusive of tax).

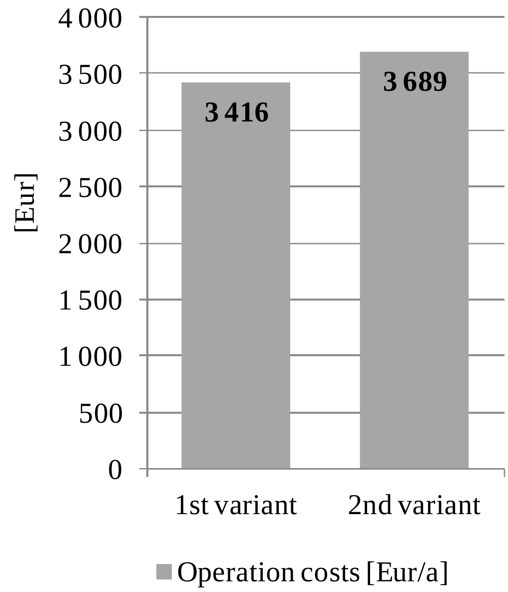

Fig. 5. Operation costs of DHW system

Conclusion. The aim of article was to analyse the installation of electric heat cables in return for circulation loop in domestic hot water system. In case of classic DHW distribution system with circulation loop the distribution thermal losses are about 30 % from energy need for DHW preparation (1st variant). In case of electric heat cables application the rate of distribution thermal losses were reduced to 15 % from energy need for DHW preparation (2nd variant). The distribution thermal losses are directly depending on:

– Length of distribution pipes,
– Quality and thickness of the pipe thermal insulation,
– Hot water temperature of pipes,
– Ambient temperature around pipes (temperature of external environment, unheated space, earthen channel).

The reached energy saving was not displayed in the operation costs of DHW system. Vice-versa the operation costs of 2nd variant are higher by 8 %. This fact is given by electricity price in Slovakia that is used to cover distribution thermal losses in 2nd variant. The important is the distribution thermal losses share in energy need of DHW system. For general analyse it is needed to consider the investments costs of DHW distribution system in object too. The investment costs for 2nd variant are 1.5 times higher than for 1st variant. The increase of investment costs is dependent on material of piping system and on system of electric heat cables.

In case that all energy requirements of DHW system (both variants) are covered by electricity the operation costs of 2nd variant would be reduced by 10 % at average.

Acknowledgements. This article was written as a project solution entitled “The use of the virtual laboratory for designing energy-efficient buildings” Project code: 052TUKE-4/2013.

1. Act No. 321/2014 (in Slovak language) 2.Regulation No. 282/2012 (in Slovak language) 3. CEN (2007) STN EN 15 316-4-2 Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies - Heat pump systems. 4. CEN (2007) STN EN 15316-3-2 Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies – Domestic hot water systems, distribution. 5. Regulation No. 364/2012 (in Slovak language) 6. CEN (2007) STN EN 15316-3-3 Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies – Part 3-3: Domestic hot water systems, generation.