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**EFFICIENCY OF HOT WATER SUPPLY
SYSTEMS IN BUILDINGS**

**Summary of Doctoral Dissertation
Technological Sciences,
Energetics and Thermal Engineering (06T)**

1359

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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1. Introduction

Topicality of the problem. Heat energy for hot water production makes up about 25 % of all heat energy produced centrally for premises in Lithuania or respectively about 250 mln. Litas during a year. This sum is spent by Lithuanian inhabitants for hot water preparation. The rational hot water usage and the solution of technical supply problems let us bring down inhabitants' expenses for hot water and amount of capital expenditures.

Hot water usage with inappropriate parameters can lead to serious health problems. Hot water temperature reduction to a certain level can settle deadly dangerous bacterium and its amplification to too high level can lead to serious injuries and scald, so the selection of the right temperature becomes very important.

Hot water supply systems efficiency in this work is understood as the efficacy and usefulness of this activity, expressed by the relation of an obtained result and expenditure to achieve it.

Object of investigation – multiflat dwelling houses and public buildings (scholastic and presbytery), hot water supply systems of buildings, main principles of the hot water systems' work, hot water account, hot water usage unsteadiness and hot water temperatures.

Goals and tasks of the investigation. The goals of investigation are to evaluate hot water supply systems and their installations' work, to perform equipments' work analysis, to determine actual hot water needs for multiflat dwelling and public buildings, to determine the consistent pattern of hot water usage unsteadiness and conditions, which would ensure healthy and energetically rational water usage. The main tasks set for this work are:

- To collect hot water meter readings on building entrances and in flats. To perform meters' work analysis and to determine their errors.
- After hot water meters account analysis is performed, to determine hot water usage unsteadiness and to make suggestions for account revision.
- To determine actual hot water usage in multiflat and public buildings. To determine its alteration nature during the calendar year. To collect data for hot water consumption norms' qualification.
- To determine actual hot water usage standard deviations for multiflat and public buildings. To determine its alteration nature during the calendar year.
- To determine probability density extremum dependence on hot water usage in multiflat and public buildings.

- To determine the limits of temperature variation in a hot water circulation line and during night temperature shut down. To evaluate if this takes place within favourable temperatures for legionella bacterium.
- To evaluate the work of hot water supply systems in presbytery institutions and bring forward recommendations for its development.

Methodology of research. By the help of distant data collection and monitoring system actual hot water usage data are collected. For actual data evaluation statistical data analysis is used and normal distribution is taken into consideration.

Scientific novelty. Efficiency analysis of hot water supply systems in buildings from the viewpoint of the hot water user makes the investigation novelty. The collected data were especially precise as a result of the big collected data basis and for the first time to investigation data analysis applied distant data collection and monitoring systems. All this enabled analysis of consumer groups of multiflat and public buildings and the work of hot water systems in buildings. Data of all consumer groups let to perform the statistical analysis. For hot water supply systems, temperature analysis depending on risk factors for a consumer was performed.

The scope of the scientific work. The scientific work consists of the general characteristic of the dissertation, 5 chapters, recommendations, conclusions, list of literature and publications. The total scope of the dissertation is 101 page, 50 pictures, 6 tables and recommendations.

2. Literature Review

2.1. The Review of Efficiency of Centralized Hot Water Supply Systems in Buildings as a Scientific Investigation Object

Centralized heat and hot water supply systems are one of the most important energetic systems. There are a lot of methodologies, which gives a possibility to evaluate maximal or standard heat demands. For newly designed dwelling districts the average heat for hot water demand (kW) can be calculated from the equation:

$$Q_{k.v.}^{vid} = \frac{1,2mc(a+b)(t_{k.v.} - t_{v.v.})}{3600n}. \quad (1)$$

Here: 1,2 – coefficient, evaluating heat transfer from hot water pipes to premises, m – number of people, c – specific water heat kJ/(kgK), a – hot water standard of multiflat buildings for a person per day, b – hot water standard of public buildings for a person per day, $t_{k.v.}$ – hot water temperature, °C, $t_{v.v.}$ – cold water temperature, °C, n – number of hot water usage hours during day.

The centralized heat supply (CHS) of Lithuania started in 1903 when the low pressure centralized steam heating was installed in Vilnius central power station. CHS on a wider scale in Lithuanian began in 1947 when steam for Kaunas was started to supply from Petrašiūnai power station turbine for paper factory technological and daily needs.

The development of centralised heat supply in Lithuania and literature analysis of Lithuanian authors related to this work are shortly presented later in the work. The reviewed authors consider hot water efficiency important for Lithuania. Thus, it often becomes an object of constant investigations aimed at more precise evaluation.

The history of centralized heat and hot water supply systems in the world started in 1876 when the first centralized heat supply system was installed in New York. Its development was determined by market economic environment.

The analysis of hot water consumption during a month and cold water for hot water preparation was performed by B. Bohm and P. O. Danig who made a conclusion that alternation limits are wide and do not make a consistent pattern. A group of authors (Branco G., Lachal B., Gallinelli P., Weber W.) investigated hot water supply systems work and have determined that 77 MJ/m² of heat energy were consumed yearly for hot water of 48 °C supply. It correspondingly makes up 53 liters for inhabitant during a day. A monthly hot water consumption analysis has displayed that the lowest hot water consumption is during summer period.

Jousua Meyer has performed hot water consumption investigations of more than 770 multiflat dwelling buildings and presented results of two types. He has determined that the USA inhabitants use up to 7 times more hot water than the developed central European countries and that hot water consumption is influenced by cultural, social and economic factors. Abrams W. D. has investigated hot water supply systems efficiency during a calendar year and how the hot water heat load is influenced by the fluctuating cold water temperature. At the same time W. Winiarski investigations show that a critical parameter of heat isolation thickness is a number of working hours, so the level of isolation thickness must be related with the pipe thickness and the number of working hours. Heat efficiency of hot water heat exchanger is described by the following equation:

$$\eta_{th} = \frac{Q_{hw}}{\frac{Q_{hw} + Q_1 + Q_{stored}}{\eta_r}} . \quad (2)$$

Here: Q_{hw} – heat amount lost by hot water heat exchanger, kW, Q_1 – heat amount from hot water to surrounding, kW, Q_{in} – total heat energy consumption, kW, Q_{stored} – saved heat amount of hot water heat exchanger, kW, η_r – efficiency coefficient (0,98).

Total isolation heat transfer coefficient is calculated on a basis of heat balance equation:

$$Q_{in} = Q_1 + Q_{hw} + Q_{stored} . \quad (3)$$

Then total isolation heat transfer coefficient can be found from equation:

$$\int_0^t P_{in} dt = \int_0^t UA(T_t - T_a) dt . \quad (4)$$

Here: UA – heat transfer coefficient, $W/^\circ C$, P_{in} – for hot water heat exchanger given power, W, T_t – average hot water temperature, $^\circ C$, T_a – environment temperature, $^\circ C$, t – time, h.

The efficiency of hot water supply systems in buildings, unevenness of consumption, heat energy for hot water preparation and investigations of hot water temperatures were the objects of investigations by B. A. Lekov, D. J. Lutz, W. D. Abrams, A. Lowenstein, F. Goldner and other authors.

2.2. Characterization of Hot Water Temperatures, at Which Appear the Bacterial and Scorch Risk

Various species of bacterium have a possibility to procreate in various warm water temperatures. Such a possibility exists for a hot water supply system. One of such undesirable bacterium is legionella pneumothilla, which was firstly identified in 1977 by the USA doctor J. McDade. There are more than 34 legionella bacterium species defined. The possibility to get the disease is through inbreathing aerosols. The size of drops varies from 1 to 10 μm . The incubation period of legionellosis lasts for 2–10 days. Only 5 % of infected people get sick of this disease and 10–30 % of them die.

The multiplication of legionella is stipulated by the factors: water, oxygen, water temperature, life time, immobility, acidity, sediments and films.

The behaviour of the bacterium at different temperatures is different. At cold water (temperature below 20 °C) legionella do not multiply and only survive, at higher temperature the multiplication begins to accelerate, at the temperatures of 30–35 °C reaches optimal multiplication temperature, then the multiplication begins to go slow, at the temperatures of 50–55 °C stops, and at the temperatures higher than 60 °C bacterium rapidly die.

The main attention of above disposed information is concentrated into the legionella risk, but exists and other factors, which can not be forgotten choosing hot water temperature. For example, increasing hot water temperature to a high level would lead to high energy consumption, make a risk to get a burn by a too hot water. Most of scorch prevention proponents accept that the temperature of 49 °C is optimal for hot water supply because at this temperature adults scorch in 5–10 minutes. Whereas, at the temperature of 60 °C scorch appears in 2–6 seconds.

One of the main reasons to keep higher temperature is a risk of legionella bacterium. A lot of investigations show a marked decrease of bacterium number at the temperature of 50 °C, but during other investigations the legionella was found and at the temperature of 66 °C. So we can have a very high hot water temperature but we still can not decrease a legionella bacterium to the absolute zero level. So we need to evaluate what temperature is required to prevent legionella or, more precisely, to what degree the risk of lowering hot water temperature for scorch prevention but getting legionella is justifiable.

3. Investigation Methodology of Hot Water Supply Systems Efficiency in a Buildings

This work describes newly installed or reconstructed heat substations and their work. The heat substation is a device, connected to the heat network, which transforms the obtained heat and distributes it for object heating, ventilation, hot water and other heat energy consumption systems.

Hot water is prepared with the help of a plate heat exchanger. Hot water has a circulation line. Water temperature is regulated with the help of automatics, which correspondingly opens or closes a hot water valve. Conduit branches start at hot water circulation line and end in hot water mixers. Hot water temperature is fixed right after hot water heat exchanger. All analysed data were collected with the help of distant data control and monitoring system. Hot water actual consumption data were registered with the help of distant data control and monitoring system and its equipments.

For the investigation of hot water supply systems efficiency in multiflat dwelling and public buildings were selected. The selected 84 multiflat buildings

are typical in Vilnius, forming the largest building group in Vilnius. All of them were selected from different Vilnius districts. Data of consumed hot water in these buildings can be taken from input building meter or summed up from all inhabitant meters' readings. Account of consumed hot water is kept with the help of distant data collection system and impulse hot water meters.

For an actual data investigation statistical data analysis was used, because it was observed that the normal distribution curves differ for different types of objects and at different periods. The data were investigated according to normal distribution laws. For engineering calculations the rule of 2σ was mostly used. Applying it we knew that 95,45 % of values fell into an investigated interval.

4. Investigation Results of Hot Water Consumption Unevenness and Factors it Stipulates

4.1. Data Account Analysis of Hot Water Consumption

The hot water consumption investigation in multiflat buildings in Vilnius according to the main building meters and the sum of hot water meters in flats determined the average hot water consumption in m^3 per day of every separate month for all hot water consumption group. Hot water consumption readings show consumption characteristics during a calendar year (Fig 1).



Fig 1. Average hot water consumption during 1–12 months according to main buildings meter and sum of meters in flats, m^3/month

From these curves we can observe that the minimum of hot water per month according to the main building meters was recorded in July and equals $2,03 \text{ m}^3$, whereas the minimum according to the sum of meters in flats equals $1,86 \text{ m}^3$ per month and was also recorded in July. These values do not coincide and differ by 8,77 %, so we can predicate that one of these values is more precise. During a calendar year the difference of readings between the main building meter and the sum of meters in flats varies from 3,09 % in October to 9,06 % in March. The average difference during a year is 7,39 %. We can observe an obvious consistent pattern that the sum of readings in flats is always lower than the readings of the main building meter. Manufacturers of hot water meters declare inaccuracy from $\pm 3 \%$ to $\pm 5 \%$, depending on flowing water yield. One of the reasons of inaccuracy between main building meters and the sum of meters in flats can be the following – when an inhabitant disposing cold water opens a water mixer, it is not always only at an ultimate cold water position and passes by a small amount of hot water. This amount of water can be small enough for meters in flats to register it.

Hot water consumption in a flat was measured by water meters, having diameter of 15 mm, nominal flow rate of $Q_n = 1,5 \text{ m}^3/\text{h}$, transitional flow rate of $Q_t = 150 \text{ l/h}$, minimal flow rate of $Q_{\min} = 60 \text{ l/h}$, sensitivity threshold of 30 l/h. The relative error of hot water amount is not bigger than $\pm 5 \%$, when the water flow rate is from $Q_{\min} = 60 \text{ l/h}$ to $Q_t = 150 \text{ l/h}$. When the water flow rate is from $Q_t = 150 \text{ l/h}$ to the maximum of $Q_{\max} = 3 \text{ m}^3/\text{h}$, the relative measurement error is $\pm 3\%$.

When a water flow rate decreases the error rapidly grows to a negative side and after it reaches the starting Q_{start} value, it exceeds the limit of 5 %. So we can make a conclusion that if the hot water flow rate often is below starting Q_{start} value, in that case the sum of the readings of meters in flats will always be lower than the main building meter readings. This fact is also confirmed by figure 1, which shows that the sum of meter readings in flats is lower than the main building meter readings. An average error during a year is 7,39 %.

Another reason for error appearance is the difference between the supplied hot water temperature for building entrance meter and inhabitants' flat meters. In a building heat substation cold water flows through a measuring device for hot water metering, is heated in a hot water heat exchanger and is supplied by the hot water circulation line to inhabitants' measuring devices. The hot water flow, flowing this distance, is recorded by the main building meter being at the temperature of $10 \text{ }^\circ\text{C}$. Later it is heated in the hot water heat exchanger up to the required temperature, mainly to $44 \text{ }^\circ\text{C}$, but flowing to the inhabitants' flats it gets cool. Because of the temperature difference a building entrance meter shows 1,17 % lower hot water consumption readings than meters in flats. To

decrease this error the main building metering device should be installed not on an unheated cold water branch, but on a heated hot water branch after the hot water heat exchanger.

4.2. Evaluation of Hot Water Consumption Probability Analysis in Public Buildings

The actual hot water consumption investigation was performed in 245 public buildings – scholastic and presbytery. After the investigation the average monthly hot water consumption of a generic building group and a monthly standard deviation of the generic building group of were determined. An average monthly consumed hot water amount in education institutions was 0,087 l/m². To get the distribution laws of these values during a calendar year (Fig 2) we draw the dependence of these values upon the time function $G = f(t)$ and $S = f(t)$.

The average hot water consumption during a calendar year is not a constant value and clear behavior dynamics was observed (Fig 2).

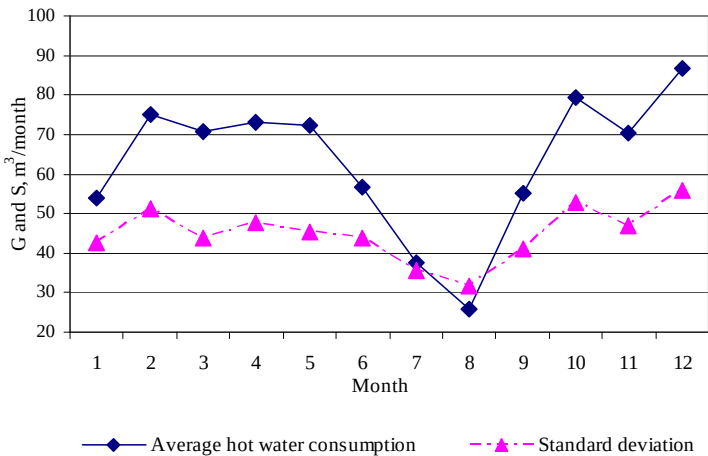


Fig 2. Hot water and standard deviation dependences from time functions t graphs $G = f(t)$ and $S = f(t)$ during year in education objects

During winter months hot water consumption is the largest and the maximum value of 86,6 m³ or the corresponding value of 0,119 l/m² is observed in December. During summer months hot water consumption is the smallest and the minimal value of 25,8 m³ value or correspondingly 0,036 l/m² is

observed in August. This can be explained by the working hours of the objects, because in summer children do not take lessons, only administrative staff stays at work. The number of children in presbytery institutions also decreases but does not decrease to a zero value, because the parts of several groups in presbytery institutions are united into one group.

The average hot water consumption during winter and spring months is almost equal and the largest during a year. The consumption during winter and spring differs only by 0,1 %. Although the average hot water consumption in winter and spring is the same, the distribution of values during these months differs. The largest distribution of values is in a winter season and the maximum hot water consumption value of $86,6 \text{ m}^3$ is in December, the minimal value of $53,9 \text{ m}^3$ is in January. So in January the average hot water consumption decreases by 37,7 % in comparison to December consumption. The smallest hot water consumption values scattering is in a spring season when the maximum value of $73,0 \text{ m}^3$ is in May and the minimal value of $70,6 \text{ m}^3$ is in March. So in March the average hot water consumption falls down only by 3,28 % from Mays consumption. Comparing all months of a year we observe that the largest scattering of values is during the summer months – from $25,8 \text{ m}^3$ in August to $56,8 \text{ m}^3$ in June. The difference makes 54,5 %. Hot water consumption in autumn is smaller than in winter by 4,9 %, and the distribution is the smallest.

Figure 3 presents hot water consumption standard normal distribution during 1–12 months.

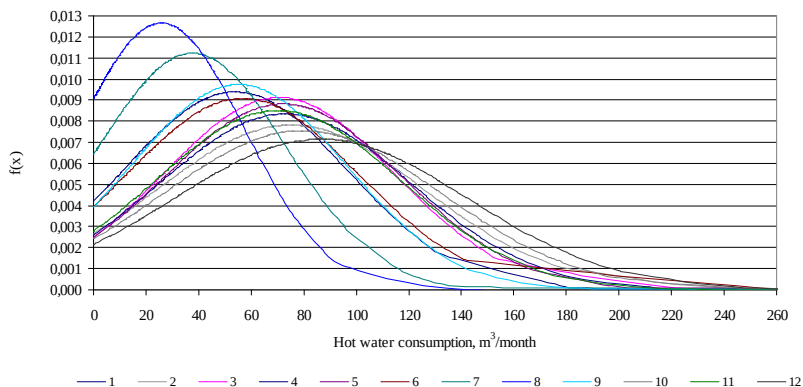


Fig 3. Standard normal distribution of hot water consumption m^3/month during 1–12 month

The shape of normal distribution is described by the function probability density maximum location with respect to x axis, brevity of bell shape and function probability density maximum location with respect to y axis or in other word the “height” of maximum.

As was mentioned in the previous pages, the smallest standard deviation is in August. Figure 3 confirms that – from all graphs the graph of August is the most narrow and the highest (function extremum is 0,013), the graph of December is the widest and lowest (function extremum is 0,007), it has the largest dispersion. We can make a conclusion that when hot water consumption increases, function extremum decreases and the dispersion of values increases. The normal distribution graph of August is the most narrow and the highest. That means that the dispersion of August is the lowest and can be easily predicted, the dispersion of December is the highest and, thus, difficult to predict.

The dependence of probability density function extremum on the hot water consumption is presented in the work. Both educational and presbytery institution curves are the constituent parts of one generic curve, which has $R^2 = 0,9456$, and an equation is expressed by:

$$y = 0,2255x^{-0,7463} . \quad (5)$$

So we can make a conclusion that the dependence of probability density function extremum on the hot water consumption in educational and presbytery institutions are constituent parts of one and the same function.

Work also compares the average hot water consumption during a calendar year with object space.

In the experimental investigation hot water consumption unevenness during a month, a week, a day and an hour in educational institutions was evaluated. Mostly $0,01 \text{ m}^3$ of hot water per minute was consumed, much more rarely $0,02 \text{ m}^3$; the maximum of $0,06 \text{ m}^3$ of hot water turned up only twice a month. After the investigation it was determined that the maximal probability density of 72,4 is observed when hot water consumption is $0,01 \text{ m}^3/\text{min}$. When hot water consumption is equal to $0,02 \text{ m}^3/\text{min}$, the density of probability sharply declines to a 21,2 value and probability density of hot water consumption of $0,03 \text{ m}^3/\text{min}$ almost equal to a zero value. That means that $0,01 \text{ m}^3/\text{min}$ hot water consumption is more than enough to ensure object hot water needs.

4.3. Evaluation of Hot Water Consumption Probability Analysis in Multiflat Dwelling Buildings

After hot water consumption analysis in 84 multiflat dwelling buildings average hot water consumption for every separate month for one square meter in liters per day and hot water consumption standard deviation were determined.

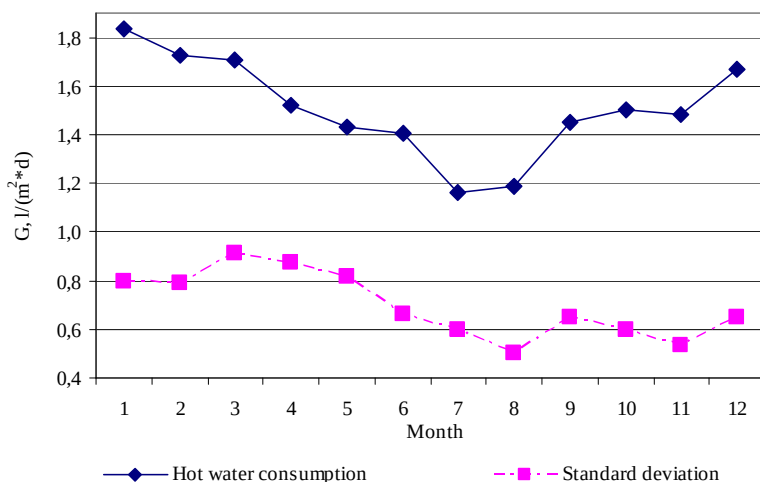


Fig 4. Hot water consumption and standard deviation dependence on time t function $G = f(t)$ or $S = f(t)$ graphs during year in multiflat dwelling buildings

From figure 4 we see that the average hot water consumption during a calendar year is not constant and there is obvious alternation characteristics observed. During winter months hot water consumption is the largest and the maximal value of $1,84 \text{ l/m}^2$ per day is in January. From January to July hot water consumption falls down to $1,16 \text{ l/m}^2$ per day value, stabilizes in August a little bit ($1,19 \text{ l/m}^2$ per day) and from August rises up again until January. These characteristics can be explained by inhabitants' rest days, holidays, living and mobility practice. On average during the calendar year one square meter of a building involves $1,51 \text{ l/m}^2$ per day ($34,7 \text{ l/day/person}$) hot water consumption.

Dependence of probability density function extremum on hot water consumption in multiflat dwelling buildings and education institutions is presented in figure 5.

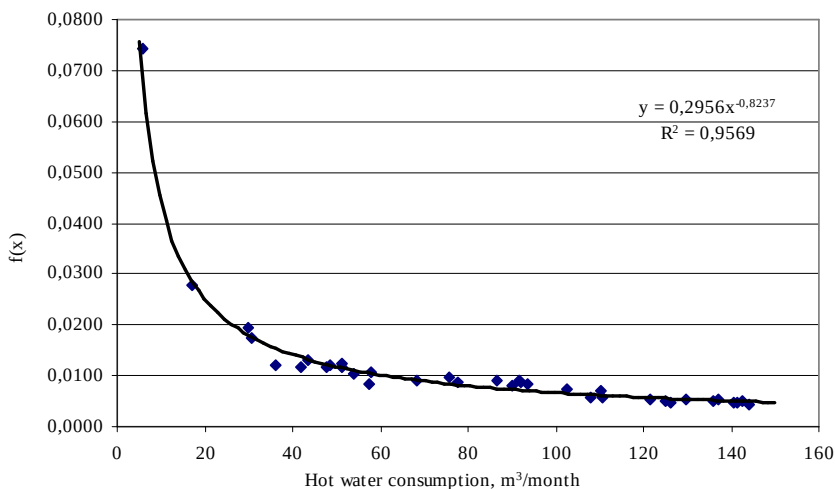


Fig 5. Dependence of probability density function extremum from hot water consumption in multiflat and education buildings

We can make a conclusion that these curves are compositional parts of one generic curve, expressed by the equation:

$$y = 0,2956x^{-0,8237} . \quad (6)$$

In figure 5 presented curve, expressed by the 6 equation, has $R^2 = 0,9569$.

5. Analysis of Hot Water Temperature in Hot Water Supply System With Constant Circulation

During the experimental investigation of hot water supply system circulation line temperatures it was determined that when hot water consumption is equal to zero, its temperature varies within the limits of $\pm 0,5$ °C (Fig 6).

When consumption is above zero, temperature changes within the limits of $\pm 0,5$ °C. Such fluctuation of temperatures can proceed an undefined time period because these temperate variations take place in unfavourable conditions for legionella bacterium.

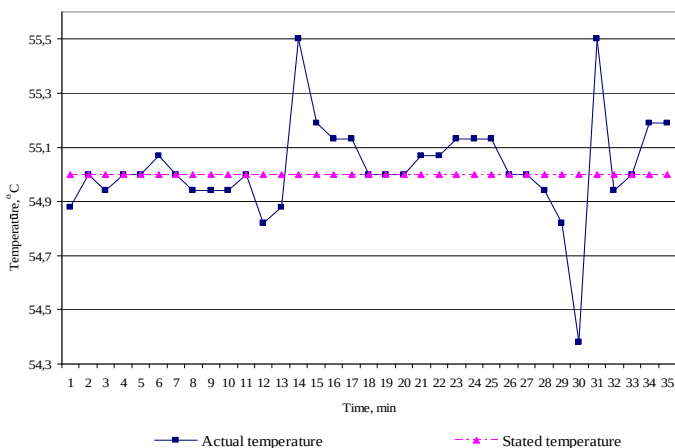


Fig 6. Hot water actual and by regulator defined temperatures when hot water is not consumed

When hot water is not heated for a longer time period (for example during night time, Fig 7), circulation in a system still takes place and hot water temperature falls down below the limit of 25 °C. Such temperature can remain for an undefined time period, because at the temperature below 25 °C legionella is in unfavourable conditions.

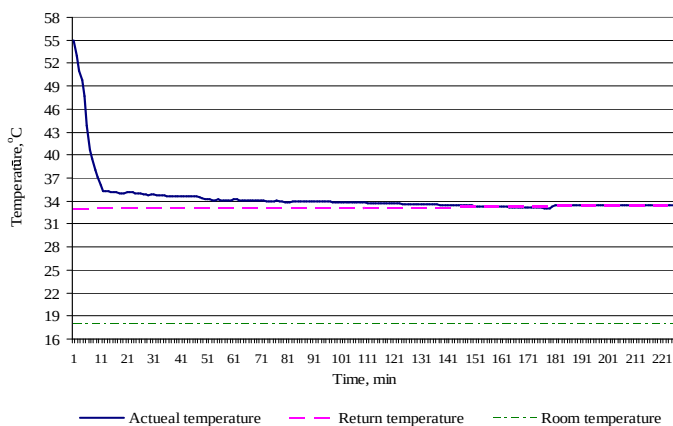


Fig 7. Actual hot water temperature during night state

Short term hot water consumption, during which a consumer opens a hot water mixer for enough short time period and hot water does not rise to the temperature of 45 °C or higher, it doesn't matter how often hot water in such manner is used, but in such a manner hot water is recommended to be used not longer than 2 days, because later strongly the risk of legionella increases. It is recommended to draw hot water off after 2 days depending on its temperature from 3 to 30 minutes.

6. General Conclusions

1. On the basis of experimental data and its analysis it was determined that actual hot water consumption is about twice smaller than a standard consumption norm of 92 l/d per person standing for many years. In obedience to that it is expedient to determine about twice a smaller hot water consumption norm for one inhabitant. Taking this norm into account it is purposeful to use twice a smaller hot water heat exchanger and other related equipment of installed power. That would increase efficiency of hot water systems in buildings.
2. After obtained data analysis it was determined that the minimal 0,036 l/m² hot water consumption per month is in educational institutions in August, the average is 0,087 l/m² and the maximum of 0,119 l/m² is in December. Monthly hot water consumption tendency during a year was also determined.
3. Obtained data analysis shows that the average standard deviation value in educational institutions is 0,0021 l/d, in multiflat buildings 0,70 l/d. The standard deviation curve reflects a hot water consumption tendency curve. The scattering of hot water consumption values in educational institutions is bigger than in multiflat buildings.
4. It was determined that increasing hot water consumption Gauss distribution probability density function extremum decreases and the scattering of values increases. Precision of hot water consumption prognosis increases when hot water consumption decreases. The equation describing probability density function extremum dependence on consumed hot water amount was also determined.
5. Temperature variations in the hot water circulation line due to equipment activity were defined. These variations take place in inauspicious for legionella multiplication temperatures and can proceed for an undefined time period. Hot water temperature decrease during night period does not give favourable conditions for legionella multiplication if during the remaining time hot water temperature stands up as defined.

6. It was defined that the hot water supply system in presbytery institutions is not perfect, the system contains favourable temperature for legionella multiplication provoking a danger for children health. On the purpose to eliminate this shortcoming, it is recommended to install a hot water supply scheme according to the one presented in this work.
7. Generalization of obtained data shows that the readings of the main building hot water meter are bigger than the sum of flat readings. Investigation data show that one of the reasons of this discrepancy is technical specifications of meters and hot water temperature difference. The performed investigation shows that this difference in Vilnius was 7,39 %, of which –8,56 % was due to technical characteristics and +1,17 % due to temperature differences. In order to have more precise hot water consumption data, I recommend to use the readings of main building hot water meter.
8. The carried out thorough hot water reading data analysis shows data discrepancy. For the reason to decrease it I recommend to use hot water meters with about twice smaller minimal flow $Q_{\min}$. In order to decrease discrepancy due to temperature differences I recommend to install a hot water meter not on a cold water branch but on a almost heated hot water branch after the hot water heat exchanger.

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1. SAVICKAS, R. Heating systems controll and maintenance using Rubisafe distant data transmtion system. In: *Republic conference “Engineering Systems”, held in Vilnius Gediminas Technical University on 27 February, 2004*. Vilnius: Technika, 2004, p. 66–69. ISBN 9986-05-712-4.
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“Young Energetics 2006”, held in Lithuanian Energy Institute on 08 June, 2006. ISBN 9986-492-92-0, 8 pages, CD–rom.

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KARŠTO VANDENS TIEKIMO SISTEMŲ PASTATUOSE EFEKTYVUMAS

Santrauka

Mokslo problemos aktualumas. Šiluminės energijos sąnaudos karštam vandeniui ruošti sudaro apie 25 % nuo viso Lietuvoje centralizuotu būdu pagaminamo šilumos kiekio pastatams šildyti arba atitinkamai apie 250 mln. litų per metus. Šią sumą Lietuvos gyventojai išleidžia karšto vandens ruošimui. Todėl racionalus karšto vandens naudojimas ir tiekimo techninių problemų sprendimas leidžia sumažinti Lietuvos gyventojų išlaidas šiluminei energijai bei kapitalinių įdėjimų dydį.

Tyrimo objektas – daugiabučiai gyvenamieji ir visuomeniniai (mokyklos ir darželiai) pastatai, pastatų karšto vandens tiekimo sistemos, pagrindiniai jų darbo principai, karšto vandens apskaita, karšto vandens vartojimo netolygumai ir karšto vandens temperatūros.

Darbo tikslas ir uždaviniai – įvertinti karšto vandens tiekimo sistemų bei jų įrenginių darbą, surinkti ir susisteminti jų veikimo duomenis ir atlikti jų analizę, nustatyti faktinius karšto vandens poreikius daugiabučiuose ir administracinės paskirties objektuose, nustatyti karšto vandens suvartojimo netolygumo dėsningumus bei sąlygas, kurios užtikrintų sveiką ir energetiškai racionalų vandens vartojimą.

Tyrimų metodika. Nuotolinės duomenų surinkimo ir monitoringo sistemos pagalba surinkti faktiniai karšto vandens suvartojimo duomenys. Faktinių

duomenų įvertinimui yra naudota statistinė duomenų analizė, įvertinti normaliojo pasiskirstymo dėsniumi.

Mokslinis naujumas. Darbo naujumą sudaro karšto vandens tiekimo sistemų pastatuose efektyvumo analizė karšto vandens vartotojo požiūriu. Nuotolinės duomenų surinkimo sistemos pagalba surinkta didelė duomenų bazė, atlikta karšto vandens tiekimo sistemų pastatuose darbo analizė, statistinė analizė, karšto vandens temperatūros analizė.

Disertacijoje yra nagrinėjamas karšto vandens tiekimo sistemų pastatuose efektyvumas, karšto vandens tiekimo sistemų darbo parametrai, nagrinėjamos karšto vandens temperatūros atsižvelgiant į rizikos faktorius vartotojui.

Apžvalgoje yra pateiktas centralizuoto karšto vandens tiekimo sistemų efektyvumo, kaip mokslinio tyrimo objekto, apibūdinimas. Pristatoma centralizuoto šilumos ir karšto vandens tiekimo sistemų samprata, raida bei efektyvumo tyrimai Lietuvoje ir užsienio šalyse. Apžvalgoje nemažas dėmesys skiriamas ir yra apibūdinamos įvairios karšto vandens temperatūros, kurioms esant atsiranda rizikos faktoriai vartotojui.

Metodologijos dalyje yra pateikiami karšto vandens netolygumo bei efektyvumo tyrimo metodai, priemonės bei vartotojų grupės. Priemonių plane yra pristatoma nuotolinė duomenų surinkimo sistema, jos principinė schema. Tyrimui pasirinkti visuomeniniai bei daugiabučiai gyvenamieji pastatai, turintys nepriklausomą šildymo ir karšto vandens ruošimo sistemą bei cirkuliacinę karšto vandens tiekimo liniją. Faktinių duomenų įvertinimui naudota statistinė duomenų analizė, tiriami surinktų duomenų Normaliojo skirstinio dėsniumi.

Tyrimo dalis susideda iš dviejų pagrindinių skyrių, kurių pirmasis apžvelgia karšto vandens vartojimą, apskaitą, vartojimo netolygumus bei tai sąlygojančius veiksnius, o antrasis analizuoja karšto vandens temperatūras karšto vandens tiekimo sistemose su nuolatine cirkuliacija.

Pirmojoje tyrimo dalyje yra pateikiama karšto vandens suvartojimo duomenų apskaitos analizė, duomenų įvertinimas dėl apskaitos netikslumo, dėl temperatūrų skirtumo ir suformuluoti apibendrinantys rezultatai. Darbe yra atliktas karšto vandens suvartojimo tikimybinės analizės visuomeniniuose ir daugiabučiuose pastatuose įvertinimas. Šiam tikslui yra pasirinktos ugdymo įstaigų bei gyvenamųjų pastatų vartotojų grupės. Šioms vartotojų grupėms yra atlikta karšto vandens suvartojimo per mėnesį, per parą bei per laiko vienetą analizė, karšto vandens paros bei valandinių pikų analizė.

Antroje tyrimo dalyje atlikta karšto vandens temperatūros analizė atsižvelgiant į baktericidinį pavojų, tiriamas karšto vandens netolygumas

cirkuliaciniame kontūre ir atšakoje nuo jo iki maišytuvo. Pristatoma, kaip kinta karšto vandens temperatūros priklausomai nuo automatikos darbo režimo.

Rekomendacijų dalyje yra pateikiamos rekomendacijos dėl karšto vandens tikslesnės apskaitos ir karšto vandens tiekimo schemos ugdymo įstaigose.

Išvadų dalyje yra pateikiami apibendrinantys karšto vandens tiekimo sistemų efektyvumo pastatuose rezultatai bei išvados, kurios galėtų prisidėti prie normų tikslinimo, investicijų į karšto vandens tiekimo sistemas dydžio tikslesnio įvertinimo priklausomai nuo gautų rezultatų.

Romanas Savickas

**EFFICIENCY OF HOT WATER
SUPPLY SYSTEMS IN BUILDINGS**

**Summary of Doctoral Dissertation
Technological Sciences, Energetics and Thermal Engineering (06T)**

Romanas Savickas

**KARŠTO VANDENS TIEKIMO SISTEMŲ
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