USING THE HEAT FROM THE WASTE WATER IN LOW ENERGY BUILDING

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1. Introduction

Efficient use of energy sources is one of the most important current topics of technical building systems. Result of the analysis energy consumption in buildings, especially energy-efficient buildings is that hot water is one of the most energy demanding systems. While reduction of heat transmission loss is quite well feasible by building insulation and ventilation heat losses using the energy recovery, reduce the energy consumption of hot water is not easy (Fig.1).

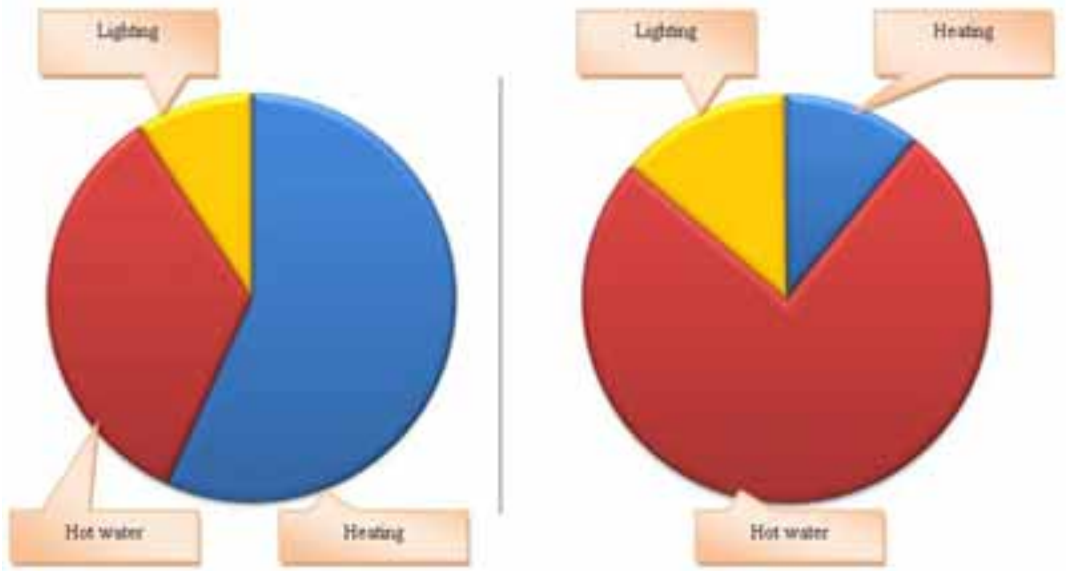

Fig. 1: Energy consumption of residential building-typical building (left) and low energy building (right) (%)

The design value used for hot water system design considers the value 82 liter per persons and day in the Czech Republic. Water temperature is 55 °C at the outlet of sanitary appliance. The characteristic pattern of consumption of hot water with evening peak hours 17-21 h is used. Value 82 liter per persons and day is not the real average value but agreed comfortable value. The real value of hot water consumption is the variable each day of the week and throughout the year. Value is related to the generational distribution of users and the number of users. Real consumption of hot water can be determined in existing building using measuring equipment installed in the building or using an ultrasonic flow meter. The ultrasonic flow meter can be installed without modification of existing installations. The average value is typically 50 $l.(person.day)^{-1}$ if more information is not available (Kabrhel 2008). Temperature of the hot water should be in the range 45-60 °C for the final consumer with the possibility of short-term decrease in the peak time. The following requirements must be guarantee at the time 6:00 to 10:00 p.m..

Methods of reducing energy consumption for hot water generation

Decrease of energy demand can be achieved by reducing the amount of hot water, reducing the temperature of hot water and using heat recovery system. Decrease of energy consumption for hot water generation is possible by reducing water consumption and using renewable energy sources, especially solar energy.

Lowering hot water temperature

It is necessary to bacterial growth in hot water for the hygienic system of hot water prevent. Bacteria growth can defend preventing stagnation of water in parts of the domestic hot water and disinfectant of hot water. It is considered heat water above 60 °C for longer than 20 minutes for effective disinfection. The temperature at the outlet of sanitary appliance is typically 55 °C. Temperature decreasing during peak demand is admitted. The temperature of hot water cannot be easily changed, but must follow the requirements of legislation. At the same time in many European countries is set the hot water outlet temperature to 60 °C. The solution, which in energy terms was effective, is reducing water temperatures in systems without health risk associated with the temperature by 5-10 °C. Reduce the temperature of the hot water is easy for local system. At the same time usually heat losses from hot water system are heat gains into an interior (Kabrhel 2010). In the case of a central system is necessary to approach the problem individually, depending on location of distribution, heat loss and hot water consumption.

Reducing amount of hot water

The average value of hot water consumption for residential buildings is very individual and varies with the exclusion of extreme behaviour in the range of 30-90 $l.(person.day)^{-1}$. Consumption relates to the degree of comfort hot water delivery. The more comfortable systems are systems with higher water consumption. Hot water consumption can be reduced by visible water meters installation. The most water is used for body cleaning, showering represent typically consumption of 25 l, bathing in a tub consumption of 40 l at 55 °C. Showering is energetically more favourable option and is also considered as a convenient system for body washing. Shower time and quantity of consumed water depends on air temperature in the bath (24 °C required), and user habits. It can be shown that in buildings for temporary accommodation (hotels, hostels) water consumption is significantly higher as showering and body cleaning is used also for relaxation.

Circulation hot water in some residential buildings with central hot water preparation can reach 50 % of energy use for water preparation. The circulation system is common in central European conditions in order to avoid cooling water and prevent stagnation of water due to the system. For a number of objects is the circulation used only in the morning and evening hours (Roubicek 2010).

The solar energy usage

The solar energy for hot water generation is the best use of the various types of renewable energy sources. Thermal solar collectors allow capturing solar energy and heating the fluids to temperatures over 250 °C (vacuum solar collectors).

Heat recovery water

Water temperature used especially for body wash is 30-45 °C and without energy recovery is drained away from the building. The question is, if an effective portion of heat can be reused. Useful would be to transmit some of the heat from waste water and pre-heated cold water to reduce energy consumption. Systems can be considered as a certain analogy to the heat recovery system used within mechanical ventilation. Heat recovery system from waste water can be solved on several levels and in different ways. The first option is the simplest solution with local energy use hot water directly in the sanitary appliance. Furthermore, it is the use of heat for a group of sanitary appliances either in apartment or in building. The most complicated variant represents heat recovery is using heat pumps.

Local flow heat recovery system

This method of heat recovery from waste water that flows through one or more sanitary appliances in the apartment. Normal the flat equipment mainly shower, tub or sink comes in consideration (Fig. 2). The technical principle is the use of waste water to preheat the cold water for a local hot water or for mixing in a thermostatic tap (Fig.3). Present drain waste water and cold water supply is necessary. Bathtub using is not so suitable. The system is also not very effective at the sink, because the amount of hot water used for washing or cleaning is low and short time. The best sanitary appliance for this purpose is the shower. Showering is now seen as the most hygienic body wash.

Fig. 2: Exchanger for placement under the shower bath (Sakal 2010)

Technical solutions for showers represent in this case a system where heat exchanger is installed in the outflow of hot water from shower baths. Exchanger is placed in the space under a shower bath. Waste water heat is used for preheating cold supply water. The exchanger must have a relatively large heat exchange area. In case of use cold water preheating is necessary to use thermostatic tap that allows automatically regulation of the temperature of the mixed water in shower.

2. Experiment description

There have been several heat recovery devices, which can be used in residential buildings. Shower operation is the most interesting because the use of waste heat is highest. According to the results of measurements is possible to determine the real behavior of the heat exchanger and the contribution of this equipment.

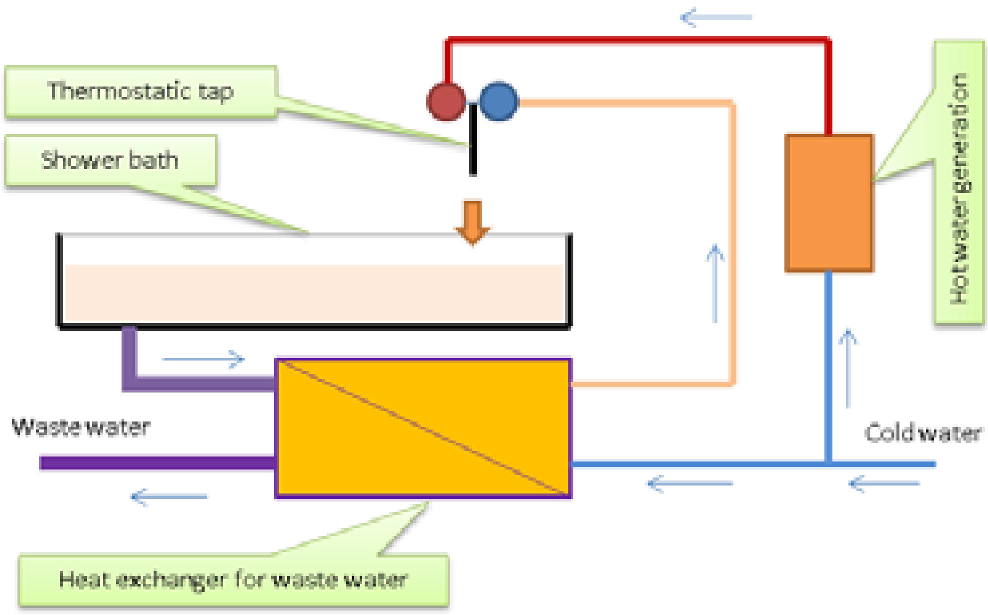

Fig. 3: Heat exchanger measurement

The aim of measurement was to determine properties of heat exchanger for heat recovery from waste water. The measurement was done at the Laboratory HVAC, Department of Microenvironmental and Building Services Engineering in Prague.

The heat exchanger for shower was measured. Exchanger is a welded box made of 5 mm plastic, own body heat exchanger is copper, net box dimensions: 560 mm x 405 mm x 100 mm, drain connection is DN 40, water connection is DN 20. Maximum working temperature is 90 °C, maximal pressure is 6 bar.

Description of measurement

Heat exchanger was connected to cold water (TinW), which was heated in the exchanger (ToutW). Water flowing into the heat exchanger as waste water (Tind) was pure water of varying temperatures created by mixing hot and cold water. Datalogger (Ahlborn 5990-2) was used as the measuring device. Water temperature and surface temperature of the heat exchanger (Tsurf) was measured using surface sensors. Contact sensor for determining the temperature of water was placed on the brass pipe couplings with good thermal conductivity, heat exchanger temperature is on the surface. The temperature of water flowing into drains was measured with NTC sensor placed directly into the stream of flowing water (ToudD). Water flow was measured using mechanical flow sensors - water (Wflow), drainage water (Dflow). Air temperature was measured at distance 5 cm from the exchanger (Fig.4). During the experiments air temperature was in the range 19-25 °C.

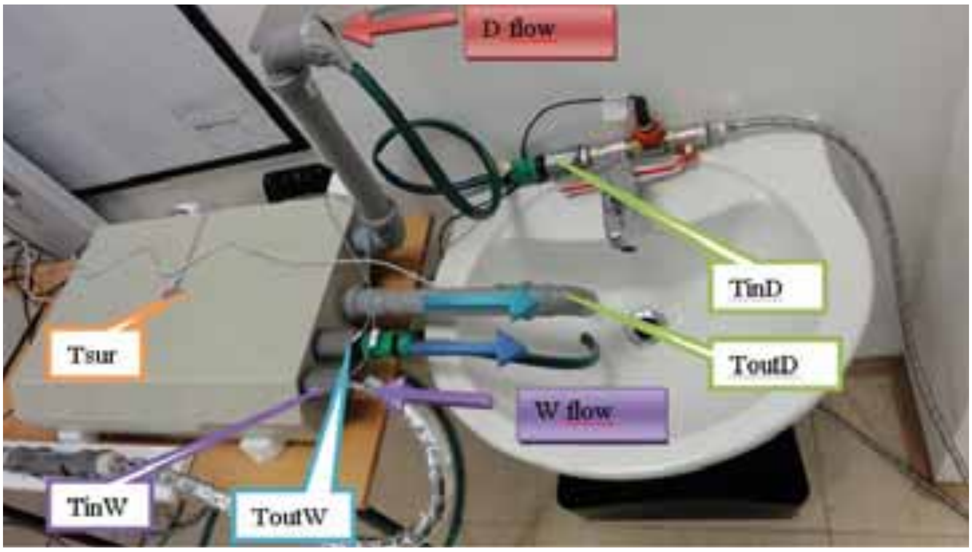

Fig. 4: Heat exchanger values

Measurement variant

Experiment 1

It was measured increasing the water temperature at different flow rates of water in experiment 1 (Fig.5). Changed the flow of water Wflow (3,4 - 1.6 - 0.8 $l.min^{-1}$) while maintaining a constant flow of waste water Dflow = 3.3 $l.min^{-1}$ at temperature 40 °C. Cold water temperature TinW from the original 15 °C increased to 22 - 28.6 - 33.4 °C).

Experiment 2

It was measured outlet temperature Toutw if change waste water flow Dflow and inlet water flow Wflow is constant (Fig.6).

Experiment 3

It was compared performance of the heat exchanger at the same flow of water over a longer period of time in experiment 3 (Fig.7).

Experiment 4

It was kept constant flow of cold water Wflow = 1.3 $l.min^{-1}$ with a temperature of 15.5 ° C and the flow of waste water changed Dflow (0.78 - 1.72 - 2.83 - 4.05 - 6.02 $l.min^{-1}$) in experiment 4 (Fig.8). A situation, where a hot water temperature difference is resulting from the mixing equation, was modeled.

Experiment 5

It was the flow of cold water 2.1 $l.min^{-1}$ and the flow of waste water 3.6 $l.min^{-1}$ in experiment 5 (Fig.9) This situation corresponds to the mixing of hot water with cold in the case set the standard flow to 5.7 $l.min^{-1}$. Cold water was heated from 15 ° C to 26.5 °C, an increase of 11.5 °C. Warming of cold water supplied to the tap is predicted in this variant. Furthermore, the flow of cold water and waste water are set to the same value of 5.7 $l.min^{-1}$. During this flow the cold water is heat to temperature 21.5 °C, temperature increases of 6.5 °C. This situation represents a variant when pre-heated cold water supply a heat storage tank.

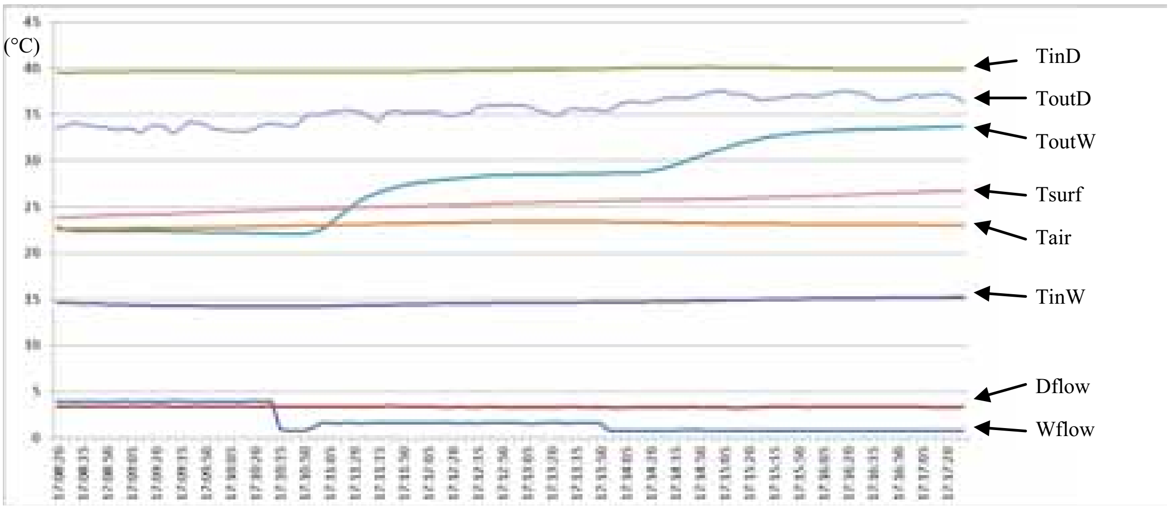

Fig. 5: Heat exchanger parameters - Experiment 1

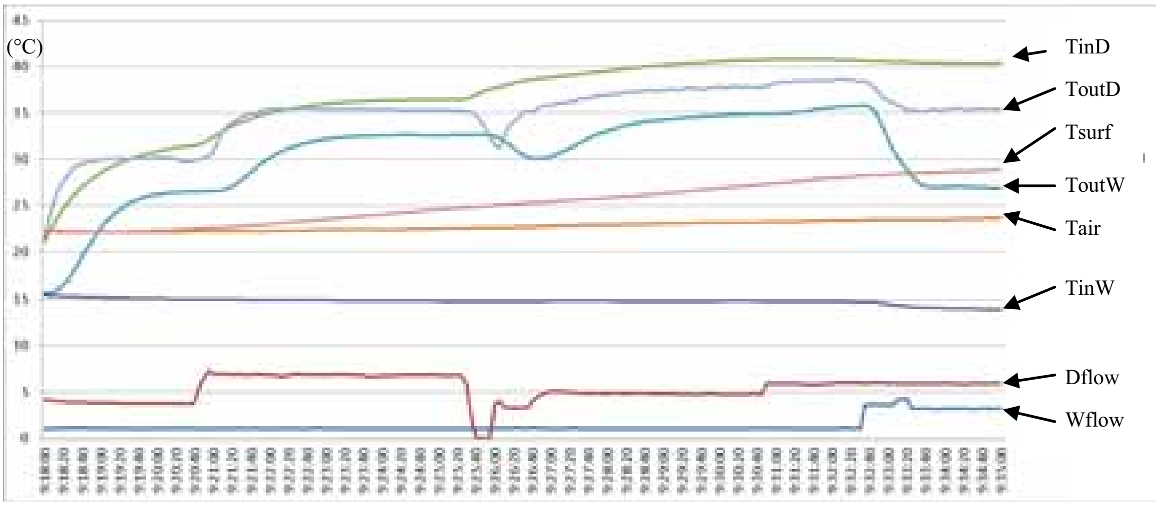

Fig. 6: Heat exchanger parameters - Experiment 2

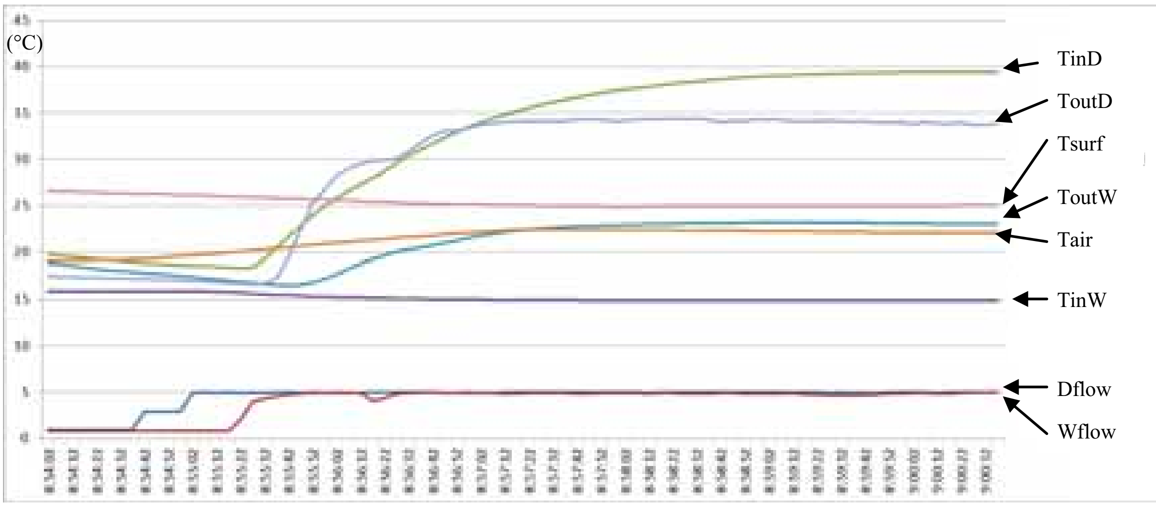

Fig. 7: Heat exchanger parameters - Experiment 3

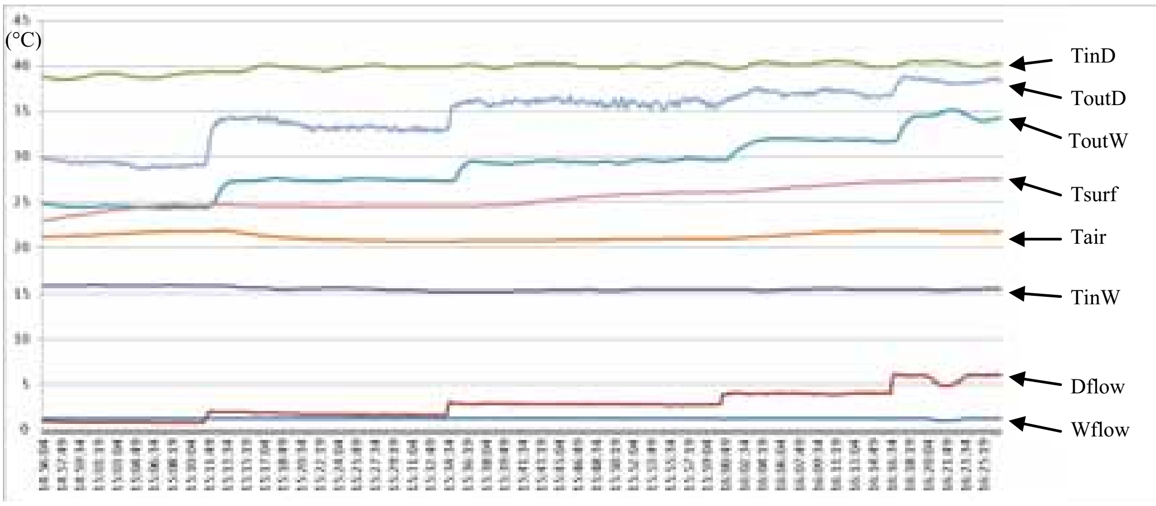

Fig. 8: Heat exchanger parameters - Experiment 4

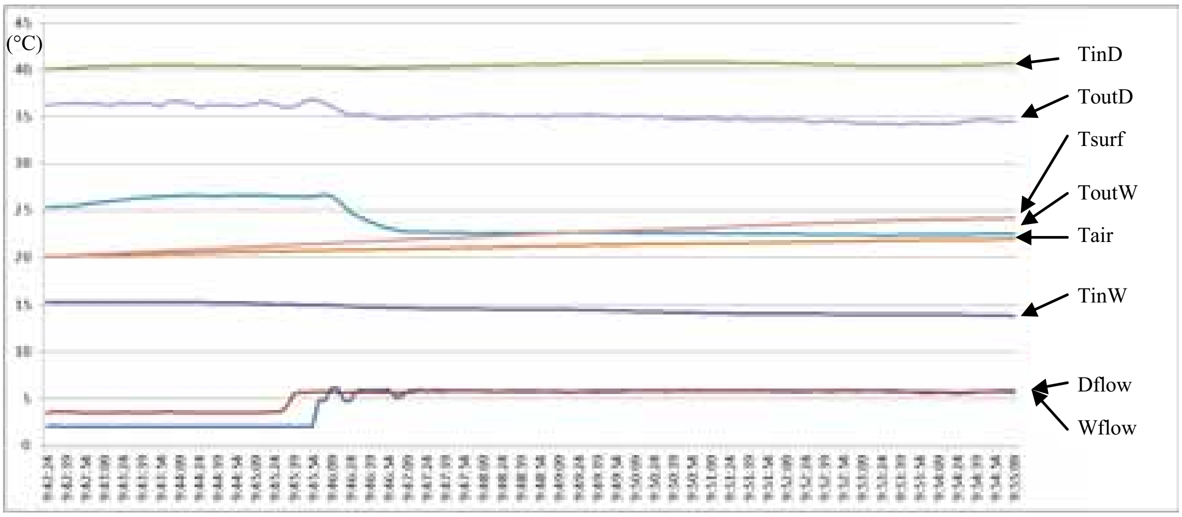

Fig. 9: Heat exchanger parameters - Experiment 5

3. Result analysis

The results show that the operation of devices in residential building is efficient. Device must be subject to certain conditions. Acquired heat can be used to preheat cold water. Water can be heated up by the results of measurements up to 15 °C. The amount of energy recovered by this system depends on the amount of waste heat in waste water and cold water temperature.

The measurement results are in charts. Exchanger behavior is seen for various boundary conditions. Experimentally was verified increasing water temperature in the exchanger from 15 °C to 22 °C with temperature of hot water entering drainage 40 °C and at the same flow of water and waste water. Increasing water temperature is about 7 °C. This situation could occur when preheated cold water is used for local hot water generation. In the case of using the shower water flow is normal flow 5.7 $l.min^{-1}$ with temperature 40 °C. The mixing ratio shows if the cold water temperature is 15 °C and hot water temperature is 55 °C mixing 2.1 $l.min^{-1}$ cold water and 3.6 $l.min^{-1}$ hot water. The outlet water temperature is between 27-29 °C, water temperature increase by 12-14 °C. This situation could occur when using the heat exchanger to preheat the cold water supplied to the mixing tap.

It is obvious that the device is very useful where there are large flows of hot water. Example can be showers at sport centers, hotels or hostels. Here is a contribution to the energy recovery significant.

4. Conclusion

Heat recovery systems in waste water can reduce the energy consumption of hot water by 5-30 %. Basic features of recovery for short return must be low exchanger costs and low operation costs.

In terms of energy may be expressed heat exchanger contribution using calorimetric equation. When heating 15 liters of cold water to 14 °C is the energy contribution of heat exchanger 0.24 kWh. This value must be multiplied by the number of use and water quantity, which is used in sanitary appliance. In the case of the average family of four persons - 2 persons used a shower 2x per day and 2 people 1x per day, the amount of heat energy gained per day would be 1.47 kWh. From an economic assessment of heat exchanger implies that its energy contribution is not major, as expected. However, it is significant and more frequent use of appliances enables quick investment return. In planning the investment should take into account costs thermostatic mixing tap and operating costs for maintenance exchanger.

5. References

Kabrhel, M., 2008. Optimization system for hot water. Proceedings of 16. International conference Heating 2008. Bratislava, Slovak Society of Environmental Engineering, 2008, pp. 317-320.

Roubicek, L., Kabrhel, M., 2010. Low energy building-charging of hot water tank during the summer 2009 - Part I. Heating-installation. No. 6, pp. 44-46.

Kabrhel, M., 2010. Thermal storage structure. Eurosun 2010. Paris: International Energy Agency, 2010, pp. 10-14.

Sakal, I., 2010. Heat exchanger SUP. Online [http://www.sakal-ovt.cz/] 1.8.2011