Providing the Conditions for Domestic Water Consumption Measurement by Water Meter

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***Abstract*—Testings made from April 2011 through June 2012 proved, that a water meter (class B, with 20 mm rated diameter) registers water consumption with error values lower than the allowed ones only if the same flow through water meter lasts at least 1 hour (water meter reading accuracy is one litre). Using a household storage tank with installed water meter at the storage tank inlet pipe could be a solution to this problem. A thermally insulated storage tank, 60 litres in volume was made for measuring water consumption in a bachelor's flat in Subotica (consumption measurements were made in August and September 2012). Measurements proved that, without changing the temperature range of the mains water, water consumption measurement by water meter is ensured in the bachelor's flat.**

Key words: water meter, water consumption of a bachelor, thermally insulated tank, water temperature

I. INTRODUCTION

It has be determined through measurements, that 95% of domestic water consumption lasts shorter than 1 minute [6].

Under the Measurement Protocol for Water Meters in the Republic of Serbia, a domestic consumption water meter is considered appropriate for operation if its measurement errors do not exceed the permitted values, i.e. ±5% (for Q_{min}) and ±2% (for Q_t and for Q_n) of the real water volume [27]. Calibration for these flowrates is made in the duration of 10 (for Q_{min}), 12,5 (for Q_t) and 4 minutes (for Q_n) for water meters class B, 20 mm rated diameter and flowrate of Q_n=1,5 m^3/hour. From April through September 2011 and April through June 2012, based on the operation testings of this water meter it was established, that for a consumption period shorter than the calibrated time, water meter measuring error ranges could exceed the permitted error range [17-18, 21]. The most significant errors occurred at Q_{min}=0,03 m^3/hour; for example, at flow duration of 0,5 minutes the error could reach even 32,1% (for water meter reading accuracy of 2,5 centilitres), even 50,9% (for water meter reading accuracy of 1 decilitre), and even as high as 277,4% (for water meter reading accuracy of 1 litre) respectively. The minimum duration of the calibrated flow rate measuring time was defined: 5 minutes (for water meter reading accuracy of 2,5 centilitres), 9 minutes (for water meter reading accuracy of 1 decilitre) and 60 minutes (for water meter reading accuracy of 1 litre) respectively.

Using storage tanks in households can be a solution to this problem [17]. Measuring the consumed volume of water in households should be made on the inlet pipe of these storage tanks with a flow lasting long enough to provide conditions for measuring water consumption with errors not exceeding the permitted ones.

* * *

The suggested solution to the problem is not a novelty in its entirety. In the field of water meter operation testings, international experience indicates that water consumption from storage tanks used in residential buildings has been measured since 2001 in Spain and Italy (Palermo) and since 2005 on Malta and since 2006 on Cyprus [4, 7, 10-12, 14-15, 28]. In most cases, the water meter is mounted on the inlet pipe of the storage tank, yet it can be mounted on the storage tank discharge pipe as well [5, 8, 10, 12, 14-15, 28].

In settlements without continuous water supply to consumers (e.g. in Mozambique, Yemen, Jordan, Lebanon, Palestine, Bolivia, Honduras and the Mediterranean in Europe), likewise in water supply networks designed in the 19th century (for example in the UK), storage tanks are used both in family houses and in multi-storey residential buildings [7-10, 13-14, 25, 30, 34]. The storage tank regulates the water inflow and consumption in households, offices and shops and serves for keeping water for fire-fighting needs [7, 34]. In such buildings, the water supply network can have the following two forms: a) all water flows through the storage tank, or b) the water for the kitchen and the washmachine, or the water for drinking and cooking is provided from the settlement's supply mains, while the rest of the household's consumption is provided from the storage tank [7, 23, 28, 36].

The storage tank can be mounted on the roof of the building, in the attic, on the land next to the house, or can be dug in soil [1, 3, 7-10, 13-14, 16, 23, 25, 28, 30, 34, 38]. As to its shape, the storage tank can be a cube or a cylinder with horizontal or vertical axis [2-3, 7, 13, 28, 30,
34, 38]. It can be made of polyethylene, PVC, polypropylene, galvanised steel, cast iron, plexiglas, fiberglass, concrete, asbestos cement and fiber cement [7, 9, 13, 25, 30, 32-33].

The period of levelling is, usually, 1 day, however stagnation period during summer may last longer (e.g. for a period of 4 to 7 days) [13, 16, 30]. The water supply of the storage tank may be continuous (regulated by ball

float) or discontinuous (filling starts at minimum water level and lasts for 4-5 hours) [2-3, 5, 7, 10, 13, 16, 24, 28, 37]. The necessary daily capacity, calculated on the base of the number of consumers in a single household, amounts to 120 or 200-250 litres in volume for each consumer [11, 25]. The capacity of the storage tanks may be 25 litres, 100 litres, 230-360 litres, 0,5 m^3, 0,5-1 m^3, 0,5-2 m^3, 1 m^3, 1-2 m^3 and 1,5-4,5 m^3 [1, 7-9, 13, 23, 25, 28, 32-34, 36, 38]. Decreasing storage tank volume improves mixing the water [13, 30].

The supply pipe is connected to the storage tank at maximum water level, while the outlet pipe is close to the storage tank bottom [2-3, 7, 28, 30, 35]. Beyond that, the storage tank is also equipped with overflow and discharge valves [35].

The ideal water temperature in storage tanks is up to 20 ^oC, while 25 ^oC is also allowed [31, 36]. Minimum thermal insulation thickness (mineral wool, plank) of the storage tank and supply pipelines in the attic is 50 mm [24]. So called "jacketings" are used for the thermal insulation of storage tanks.

The deterioration of water quality for household purposes starts after water conditioning, continues by transport in the supply network and ends by the accumulation of water in storage tanks of the buildings [13, 25, 30, 33]. The rapidity of water quality deterioration in storage tanks is higher than the rapidity of deterioration in the mains [9].

Oversizing storage tanks and the practice of filling a storage tank after it is emptied, speed up the building of sediments in the storage tank [9, 30, 33]. Changes in water quality are linked to the age of the water and to water temperature [13, 26, 30, 32-33]. Water stagnation in storage tanks deteriorates water quality [13, 30]. Chlorinated water quality fails to meet standards after 4 hours of stagnation in storage tanks mounted on buildings [29-30]. Pathogen coliform bacteria (also) appear among the pollutants [33].

Storage tanks mounted on building roof tops are exposed to the effects of the Sun most of the day [30]. The type of the material the storage tanks are made of (polyethylene, plexi or concrete) does not affect the physical and chemical characteristics of the water significantly. From 7 am till 7 pm, water temperature in fiberglas storage tank changed for 4,65 ^oC, in fiber cement tank for 4,9 ^oC and in black polyethylene for 10,6 ^oC, at starting water temperature of 15,2 up to 23,1 ^oC. The number of bacteria in water increases at temperatures higher than 15 ^oC . Temperature changes during the day are most commonly followed by temperature changes of water in storage tanks made of black polyethylene.

The root causes of water quality deterioration in storage tanks for the water supply of household are their oversizing, keeping water for long in the storage tank and building storage tanks without thermal insulation. Aside from avoiding these mistakes, the storage tank capacity should be determined in line with the requirements for safeguarding water quality in storage tanks.

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By testing the operation of the indicated water meter from March through September 2010 and from March through April 2011, for flow lower than Q_{min}, it was established that mounting an unmeasured flow reducer at the water meter enables the identification of water losses in the household supply network [17, 19-20, 22]. As a reconciliation of interests of water suppliers and consumers, the unmeasured flow reducer should be mounted on the outlet pipe of the storage tank [17].

Therefore, using storage tanks in households, decreases water losses in supply mains.

* * *

The following fact also supports the proposal on using storage tanks in households: the use of these storage tanks will decrease maximum flow appropriate for dimensioning the pipeline network in the street [16]. Decreasing flow changes during the day will increasingly balance water flow in the pipeline network in the streets, hence it will lower water stagnation in the mains and water quality in the supply network will be less deteriorated.

Based on the above mentioned, the aim of this paper is to examine water temperature changes during the day in a thermally insulated storage tank with constant flow filling in stages and by measuring water meter errors lower than the permitted ones.

II. PROVIDING THE NEEDED WATER QUANTITY WITH ACCEPTABLE TEMPERATURES

Water consumption in a bachelor's flat in a multi-storey building in Subotica was measured from 8 to 14 August 2012. Based on the volume and duration of each consumption, a cumulative water volume curve was made.

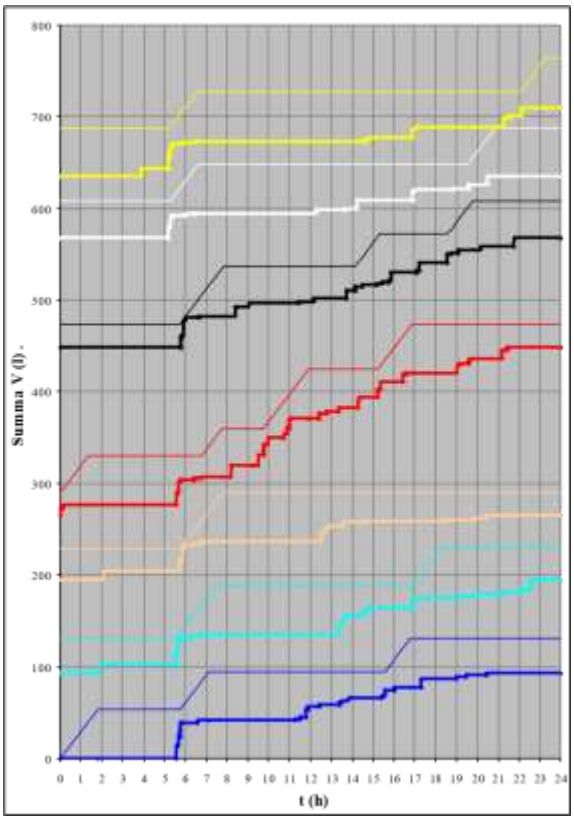

Figure 1. Cumulative water consumption curve (thick line) from 8 (Wednesday) to 14 (Tuesday) August 2012 in a bachelor's flat in

Subotica and the cumulative curve of storage tank filling at Q_{min} flow (thin line)

During measuring water consumption for filling the WC flushing cistern, the filling time of a 9 litre capacity flushing cistern was measured, while in the case of washing machine consumption, the water volume in the laundry was also measured besides the water discharged from the washing machine.

The bachelor's daily water consumption varied between 67,1 and 183,3 litres. Explanation of the result: only water consumption in the flat was taken into consideration, not the bachelor's total water consumption.

According to the volume of the used up water, 78,3% of the water volume was consumed in duration shorter than 1 minute. Water consumption lasted longer than a minute during washing (max. 68,1 sec.), taking a shower (144,2 sec.), hair-wash (119,6 sec.), teeth-brush (74,8 sec.) and dish-washing (87,2 sec.) likewise during filling the washing machine with water (90,4 sec.).

From 1 to 7 September of the same year, the water temperature (water discharge from the tap in a duration of 1 minute was measured) and the air temperature in the flat were measured as well. Water temperatures varied between 23,75 and 27,25 ^{o}C, while that of the air from 28,5 to 30,75 ^{o}C. By tasting the water, it was established, that water having maximum 25 ^{o}C is the best quality for consumption.

At storage tank filling flow of Q_{min}=0,03 m^3/hour and under the condition that filling time is not shorter than one hour, the following was established: a) the filling of storage tank should start when storage tank water volume drops to 23,5 litres, and b) filling should be ended when storage tank water volume reaches 53,5 litres. This method of filling the storage tank enabled that, for the measured consumption hydrograph, it has never emptied fully (the minimum volume of 0,1 litre was registered on Sunday in the morning between 5 55-5 56 am), while filling lasted from 1 hour up to 2 hours and 5 minutes.

III. MODEL DESCRIPTION

Plastic barrel of 60 litres capacity, thermally insulated by 10 cm thick glass wool, mounted in a plywood box with 5 cm thick plank bottom.

Figure 2. Storage tank – plastic barrel of 60 litres capacity – in the box prior to thermal insulation. 1 – 5 cm thick plank, 2 – discharge pipe, 3 – overflow valve

The 10 cm thick glass wool and the box (with plywood sides) was wrapped in polyethylene air-bubble foil with metalized layer. The water inlet is on the upper side of the barrel, and discharge is on its bottom. The barrel was equiped with overflow valve.

The storage tank was located in the bachelor's bathroom. The storage tank was filled from the flat's water supply network.

For following up the temperature of the water in the storage tank and the air in bathroom, data loggers type TidbiTv2 Temp (Part#UTBI-001), produced by HOBO were used. Data were memorized with a 1-minute time interval.

IV. RESULTS OF MEASURMENTS

The warming up of water in storage tank volumes of 23,5, 38,5 and 53,5 litres was monitored for three days. Air temperature in the bathroom changed between 30,2 and 32,3 ^{o}C.

Owing to these measurements, the time required for warming up the storage tank water from 23,75 to 25 ^{o}C, and from 23,75 to 27,25 ^{o}C was defined. The number of such measurements was between 1 and 15.

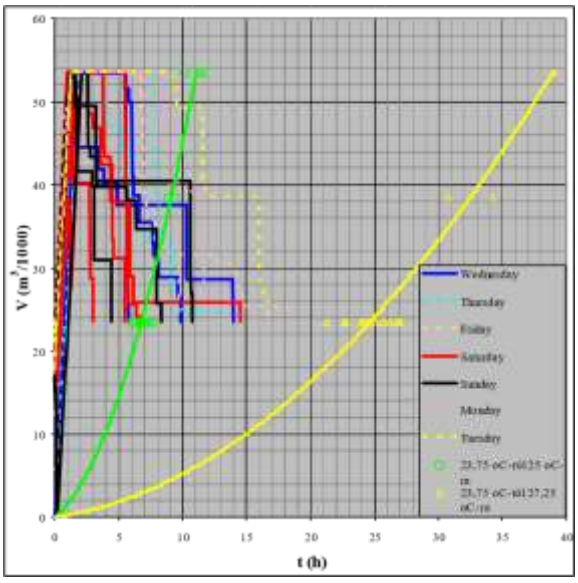

Figure 3. Water volume changes in the storage tank between two fillings and water warm up time from 23,75 to 25 °C, and from 23,75 to 27,25 °C

V. DISCUSSION

Measuring water consumption duration in a bachelor's flat underpinned observations indicated in the literature: most water quantities are consumed for a time shorter than 1 minute.

In order to provide enough time for water meter operation, contrary to the present practice, it is necessary to know the cumulative water consumption curve for sizing household storage tanks.

Under the criterion that the bachelor's storage tank is filled with Q_{min} flow for at least one hour, the required storage tank capacity of 60 litres was determined. In order to ensure water for the bachelor, the method of storage tank filling was defined: filling should start, if water volume drops to 23,5 litres during the emptying of the tank, and it should end, when the tank is filled up to 53,5 litres.

As a criterion for checking storage tank thermal insulation, the water temperature range was adopted, which was achieved during a 1-minute long water consumption from the flat's water supply network, i.e. from 23,75 to 27,25 °C. Tasting the water backed up the data indicated in the literature: water below 25 °C is excellent for drinking.

Measurements proved the following:

- if the storage tank is filled by the flat's water supply network having a temperature of 23,75 °C, the water never warms up above 27,25 °C during the observed week, and
- the water is excellent for drinking (below 25 °C) during those days (Wednesday, Saturday and

Sunday) when consumption is higher in the flat. It means, that the thermally insulated storage tank with 60 litres capacity ensured:

a) measuring water consumption by water meter (one litre as reading accuracy, which is used in remote reading) and

b) keeping water temperature within a temperature range identical with the one of the flat's water supply network.

VI. CONCLUSION

For the measured water consumption in a bachelor's flat, during a week and under the criteria:

- that the storage tank is filled by Q_{min} flow at least for one hour, and
- that filling should start, if water volume drops to 23,5 litres during the emptying of the tank, and it should end, when the tank is filled up to 53,5 litres,

the required volume of the storage tank, i.e. 60 litres, was defined.

The storage tank was made of plastic barrel, thermally insulated by 10 cm thick glass wool (wrapped in polyethylene air bubble foil) then mounted in a plywood box (wrapped in polyethylene air-bubble foil) with 5 cm thick plank bottom.

During the experiment, the air temperature was at least as high as it is, usually, in the bachelor's flat during summer.

Measurements proved the following:

- if the storage tank is filled by the flat's water supply network having a temperature of 23,75°C, the water never warms up above 27,25°C during the observed week, and
- the water is excellent for drinking (below 25 °C in temperature) during those days (Wednesday, Saturday and Sunday) when consumption is larger in the flat.

It means, that the thermally insulated storage tank with 60 litres capacity ensured:

a) measuring water consumption by water meter (one litre as reading accuracy, which is used in remote reading) and

b) keeping water temperature within a temperature range identical with the one of the flat's water supply network.

Such examinations are also necessary to be made for households with more members, in order to check other water quality characteristics in the storage tank.

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