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# Analysis of Apparent Water Losses, Case Study

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**Abstract**

Apparent losses are the nonphysical losses that occur when water is successfully delivered to the customer but, for various reasons, is not measured or recorded accurately, thereby including a degree of error in the amount of customer consumption. According to data from the Lithuanian Water Supply Association, in 2012 about 124 mln. m³ of ground water was supplied to the network, but only 92 mln. m³ of it was sold, while the remaining share represented water losses – 32 mln. m³ per year. An average water loss level in Lithuania is 30%, varying from 53% to 15%. Local water utilities take a little care of apparent water losses, as they account for about 20–30% of the total water losses. This article deals with an investigation of apparent losses in Alytus city, Lithuania. The article highlights the significance of apparent losses and explains possible options for the control of these losses in order to recover revenue in systems with metered customers. One test was carried out with bulk water meters at blockhouses, using Class B and C water meters constructed sequentially. The other test was carried out at apartments of blockhouses, where new Class C flow meters are installed. Both tests showed a significant volume of apparent water losses due to inaccuracy of used flow meters. An average calculated pay-back period for the installation of Class C water meters is about 1 year.

**Keywords:** apparent water losses; accuracy of water meters; flow meter.

## 1. Introduction

Apparent losses occur as a result of inefficiencies in the measurement, recording, archiving and accounting operations used to track water volumes in a water utility. These inefficiencies can be caused by inaccurate or oversized customer meters, poor meter reading, billing and accounting practice, or weak policies. Apparent losses also occur from unauthorized consumption which is caused by individual customers or others tampering with their metering or meter reading devices, and other causes. For any types of apparent loss, it is incumbent on utility mangers and operators to realistically assess metering and billing inconsistencies, and then develop internal policies and establish programs to economically minimize these inefficiencies. It is also important to clearly communicate with customers, governing bodies of the utility and municipalities, financing agencies, and the media the problems of apparent losses and the need to control them [1], [2].

Customer meters that inaccurately measure the volumes passing through them can be a major source of apparent loss in drinking water systems. All Lithuanian drinking water utilities meter their customer consumption. When auditing such systems, meter accuracy cannot by evaluated as an apparent loss, and utilities must employ others methods to quantify the amount of customer consumption and separate it from components of authorized consumption and water losses [3], [4].

Single flow water meters of Class B are normally used for water accounting in Lithuania. Pursuant to legislation, periodic verifications are conducted:

- every 4 to 6 years for household customers water meters;
- every 2 years for bulk metering instruments, industrial and public customers.

Normally, customer water meters are replaced every 8–12 years, while bulk water meters – only when they do not pass metrological verification. Tested meters of adequate quality are re-installed at industrial water inlet.

The country's water utilities use meters only of metrological Class B. Such metrological definition of meters is inaccurate, as a new EU standard adopted in 2005 discontinued using the metrological classes of meters. LST EN 14154-1:2005 standard defines metrological classes by $Q_3/Q_1$, ratio, which by analogy to the former Class B should exceed 50, while by analogy to Class C should be above 160.

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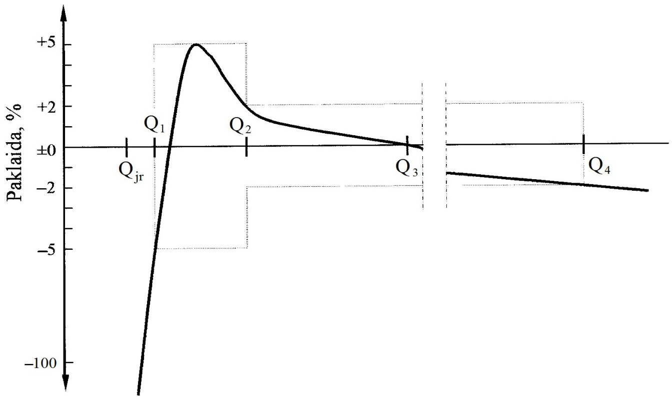


Fig. 1. Accuracy curve of water flow meters

Typical water meter measurement errors are shown schematically in Fig. 1. There are five flow values that need to be evaluated in order to analyse water meters. *Minimum flow rate* ($Q_1$) – lowest flow rate at which the meter is to operate within the maximum permissible errors. *Transitional flow rate* ($Q_2$) – flow rate between the permanent flow rate and the minimum flow rate that divides the flow rate range into two zones, the upper flow rate zone and the lower flow rate zone, each characterized by its own maximum permissible errors. *Permanent flow rate* ($Q_3$) – highest flow rate within the rated operating conditions at which the meter is to operate within the maximum permissible errors. *Overload flow rate* ($Q_4$) – highest flow rate at which the meter is to operate for a short period of time within the maximum permissible errors, while maintaining its metrological performance when it is subsequently operating within the rated operating conditions. *Starting flow* ($Q_{jr}$) – lower level of water flow, when the water flow overcomes the mechanical strength and resistance meter and meter will starts to turn. However, a measuring error of water flow from the starting to the minimum flow is not regulated.

The maximum permissible error at flow values between the transitional ($Q_2$) and the overload ($Q_4$) flow rates should be ±2%. And at flow values from the minimum ($Q_1$) to the transitional ($Q_2$) flow rate the maximum permissible errors are ±5%. Where water flows at a rate lower than the minimum flow rate ($Q_1$), the measuring error of a meter is not regulated. It is evident, however, that a meter records a water flow only if it exceeds the starting flow. When water passing through the meter is below the level of sensitivity the meter discontinues recording water flow.

The previously applied metrological Classes B and C are much clearer and better rooted within society. Therefore, for the sake of better clarity, the article will use the accuracy terms used for Class B and C meters. Pursuant to paragraph 74 of Lithuania's Technical Construction Regulation STR 2.07.01:2003, practically only the meters of Class C or $Q_3/Q_1=160$ should be used. Three main arguments why they are not used:

- Class C meters are very expensive;
- Class C meters rapidly become clogged up with deposits;
- Class C meters measure water volumes compared to standard meters, is rather small.

Therefore, one of the main aims of this paper was to assess whether or not all these presumptions are correct and reasoned. In many cases all presumptions rely on emotions rather than on documented tests.

There are 610 blockhouses with 22 942 apartments in Alytus. Nearly all apartments pay for consumed water according to the readings of water meters installed in them. The readings of the house's bulk water meter and the volume of water declared by apartments differ. In many cases the bulk water meter records a higher volume of water than meters in residents' apartments do. This gives rise to apparent losses which are detrimental to the water utility. The performed calculations of water supply balance have shown that apparent losses of around 258 thousand $m^3$ generated in Alytus water-supply system in 2011. The peculiarity of apparent losses lies in the fact that even though water is consumed and wastewater is produced, consumers do not pay for that double service, i.e. water utility supplies water, collects and treats wastewater, but is not paid for that. The average water and wastewater price in Alytus amounts to 5.5 LTL/$m^3$. Thus, in 2011 the water utility incurred a loss of LTL 1.4 million due to apparent losses.

One of possible ways to minimize apparent losses is to upgrade metering instruments to achieve better and more accurate measurements [5], [6]. The aim of the work was to assess whether or not the replacement of the current meters by more efficient ones will result in water loss reductions. Two types of research were performed in the work: (a) evaluation of the accuracy of bulk water meters installed in blockhouses; and (b) evaluation of the accuracy of Class C meters installed in the apartments of blockhouses.

## 2. Water flow meters used for analysis

During the project Class B and C meters were mounted sequentially in eleven blockhouses in Alytus; their layout is given in Fig. 2. Blockhouses in which water losses range between 8% and 35% were selected for the tests. These blockhouses belonging to apartment societies are of different size, having 22 to 100 apartments each, and do not differ from the majority of other houses in the town and in the country.

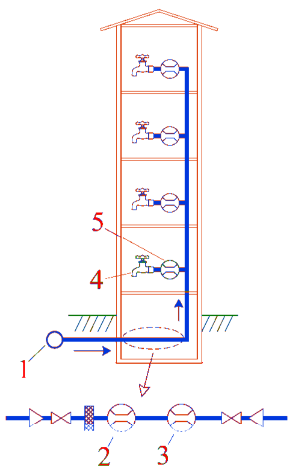


Fig. 2. Bulk water flow meters installed in series at blockhouses: 1 – water main pipe; 2 – B class water meter; 3 – C class water meter

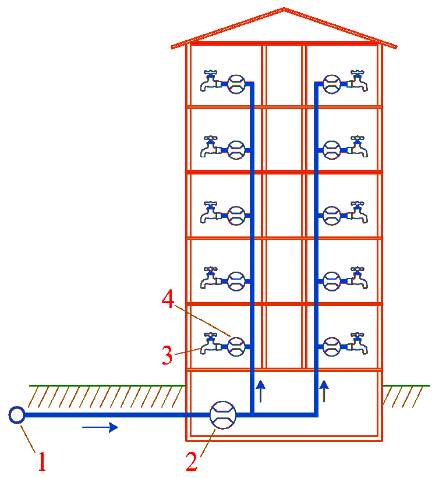


Fig. 3. Layout of water meters installed at blockhouses: 1 – water main pipe; 2 – B class bulk water meter; 3 – water user; 4 – C class customer water meter

Class B meters were the existing ones mounted in these houses before the tests. The research used Class C meters that were operated for four years before the test. These meters were used for four years from 2007 and afterward placed in a storage facility. In order to check their reliability these meters underwent metrological verification. Since all meters successfully passed metrological verification and their readings complied with the standard requirements, they were used in this test. Parameters of the meters used during tests are presented in Table 1.

Table 1. Data of water meters

| Model | Class | DN, mm | Start flow, l/h | $Q_1$, l/h | $Q_2$, l/h | $Q_3$, m$^3$/h | $Q_4$, m$^3$/h |
|---|---|---|---|---|---|---|---|
| Smart C+, PoWoGaz | C | 15 | 5 | 10 | 16 | 1.6 | 2.0 |
| Residia, Sensus | B | 15 | 15 | 30 | 120 | 1.5 | 3.0 |
| 405S, Sensus | B | 25 | 20 | 70 | 280 | 3.5 | 7 |
| Actaris, Fludis | C | 25 | 10 | 35 | 53 | 3.5 | 7 |
| Master C+, PoWoGaz | C | 32 | 21 | 63 | 100 | 10 | 12.5 |
| Actaris, Fludis | C | 32 | 12 | 60 | 90 | 6 | 12 |
| MKT, Zenner | B | 32 | 63 | 120 | 480 | 6 | 12 |

The aim of the second test was to evaluate water losses in a single blockhouse apartment. For this purpose meters were replaced in the apartments of three blockhouses in Alytus town. The existing old customer water meters of Class B, 15 mm in diameter, were replaced by new meters of Class C. Parameters of the old and the new customer (DN15) meters are given in Table 1. Three blockhouses were chosen for the test. The choice of these houses has been prompted by the fact that it was about time to replace their meters and the water losses in these houses corresponded to the average water losses in blockhouses. In addition, meters were installed vertically in one of the houses. The 2012 water losses in the houses:

- Blockhouse 1: 40 apartments, apparent water losses in the house represents 18%, 323 m$^3$/year;
- Blockhouse 2: 50 apartments, apparent water losses in the house represents 14%, 202 m$^3$/year;
- Blockhouse 3: 60 apartments, apparent water losses in the house amounts to 7%, 150 m$^3$/year.

The layout of water meters installed at blockhouses is given in Fig. 3. Meters in these blockhouses were replaced during March 2013. Two or four meters were not replaced in non-inhabited apartments. Since these apartments do not consumer water, they had no influence on the accuracy of research.

## 3. Results

Measurement data of sequentially-mounted meters are given in Table 2. The relative difference between the readings of Class C and B meters ranges from 4% to 18%. Measurements took 1 to 3 months, which can be treated as a sufficiently representative period because the test compared only bulk water meters whose readings do not depend on water consumption in apartments. It has to be noted that readings were taken every week and an absolutely uniform trend was observed, i.e. the differences in water volume measurements were proportionate after two weeks and after two months. Consequently, a longer measurement period would not change anything. The essential and key point determined – Class C meters measure larger volumes of water, the average difference represents 0.33 $m^3$/d per blockhouse or 3.1 $m^3$/apartment/year, compared to the currently used meters in Class B.

Table 2. Cold water volumes at inlet to blockhouses

| No. | Flat No. | DN, mm | B class water meter, $m^3$ | C class water meter, $m^3$ | Difference, $m^3$ | Difference, % | Duration, day | Difference, $m^3$/d | Difference, $m^3$/flat/annual |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 22 | 25 | 105 | 123 | 19 | 18% | 43 | 0.43 | 7.1 |
| 2. | 31 | 25 | 113 | 123 | 11 | 9% | 48 | 0.22 | 2.6 |
| 3. | 100 | 40 | 505 | 526 | 21 | 4% | 62 | 0.35 | 1.3 |
| 4. | 40 | 25 | 225 | 233 | 8 | 4% | 45 | 0.18 | 1.6 |
| 5. | 60 | 32 | 194 | 207 | 13 | 7% | 33 | 0.40 | 2.4 |
| 6. | 50 | 32 | 160 | 184 | 24 | 15% | 46 | 0.52 | 3.8 |
| 7. | 23 | 32 | 223 | 235 | 12 | 6% | 74 | 0.17 | 2.7 |
| 8. | 22 | 25 | 72 | 78 | 5,2 | 7% | 33 | 0.16 | 2.7 |
| 9. | 31 | 32 | 68 | 72 | 4,4 | 7% | 27 | 0.16 | 1.9 |
| 10. | 40 | 25 | 137 | 156 | 19 | 14% | 33 | 0.58 | 5.3 |
| 11. | 60 | 25 | 129 | 142 | 13 | 10% | 27 | 0.47 | 2.9 |
| **Average:** | | | 176 | 189 | 14 | 9% | 43 | **0.33** | **3.1** |

It has to be repeatedly noted that tests involved used (old) Class C meters after four years of operation. This is a particularly important aspect as it is often argued that Class C meters are sensitive to deposits, rapidly lose their accuracy and cannot be used. If to rely on such presumptions, new Class C meters should produce a yet bigger difference. Furthermore, it has to be stressed that Class C meters also have the limit of sensitivity and do not measure ultralow water flows and therefore a yet larger volume of water had to pass through them.

The argument that meters of Class C quickly get clogged up with deposits is rather strange because if deposits are present in a pipe they clog all meters regardless of their meteorological classes. The problem of clogging is addressed quite simply – the installation instructions for all meters require the mounting of mechanical filters prior to the installation of meters. During this test, therefore, filters were installed before the meters according to instructional requirements.

In order to better understand the determined water difference between meters of Classes B and C, Fig. 4 shows a chart of water consumption in a standard blockhouse (50 apartments). It shows water consumption in a blockhouse. The chart also gives the minimum and the transitional flow rates for meters in Classes B and C, which clearly show how important it is for the flow rate measuring instrument to accurately measure the water volume. A Class B meter actually does not measure within 2% error range, which demonstrates an inappropriate accuracy of the existing B meters.

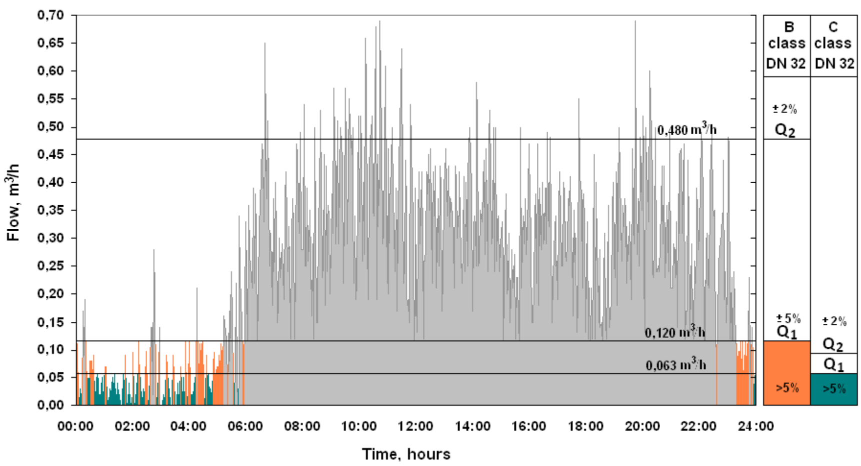


Fig. 4. Water inlet into blockhouse and range of accuracy of flow meters

Approaches to meter functionality and management have advanced in ways that promote greater accuracy of customer consumption measurements. General roles were to size customer service connection and meter based on the peak flow rates that the meter was expected to encounter. Because peak flow occurs only rarely, most of the time meter registers flows in the low end of their design range. All meter types are less accurate in the low end of their flow range with very low flows not capture at all. Idea of this research was focuses on the flow range most usually encountered, not seldom occurring peak flows.

The performed analysis of the flow rate supplied to blockhouses during the standard day has shown that most of the time, 15 hours, Class C meters measure with 2% error, being the minimum value of an error. In the meantime Class B meters measure with a minimum error only for around an hour. Class C meters measure with 5% error for around 3 hours, whereas Class B meters – about 13 hours. On the basis of actual measurements data it is possible to know how many hours a day meters measure at one or other level of accuracy. It is evident that the existing Class B meters are not suitable and should be replaced by more accurate measuring instruments.

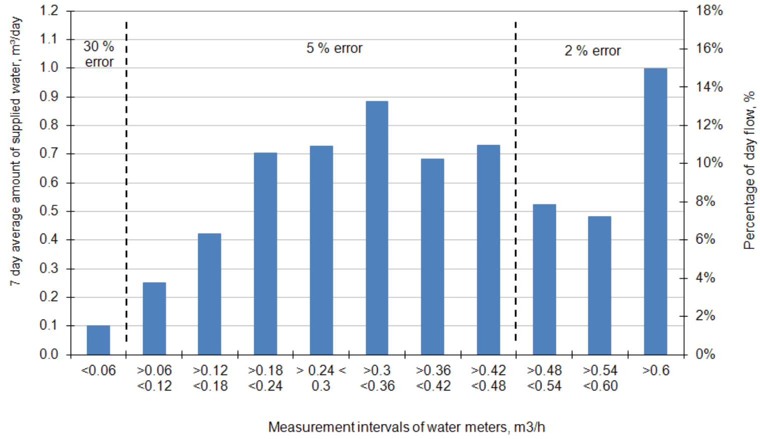


Fig. 5. Percentage of time in given flow ranges for blockhouse

The use of Class C meters in cold water inlets into blockhouses can be useful for one purpose only – to obtain more accurate information about the actual volumes of water supplied to blockhouses and the actual apparent losses. However, Class C meters must be mandatorily mounted at all industrial enterprises and public customers, i.e. those that directly pay the utility according to the readings of bulk water meters. It has been determined that Class B meters are inefficient in measuring low flow rates and therefore they should be replaced by Class C meters. Differences in the prices of Class B and C meters are not big, up to LTL 150, depending on the diameter and manufacturer. Therefore, the replacement of meters would pay back after 9 to 12 months at the latest. Furthermore, it is necessary to install more accurate meters at inlets into blockhouses for hot water preparation. Taking into account possible wear of meters and bigger errors of outdated meters it is recommended to replace bulk water meters by new ones at least every six years. In the event of an evident decrease in water volumes, meters can be replaced more frequently.

The second test analysed the data of customer water meters mounted in the apartments of blockhouses. Household meters of Class C (DN15) were installed in March 2013. The last data were received in January 2014. The comparison of water consumption volumes in 2012 and 2013 clearly shows that lower water consumption in all three houses concerned was in 2013. This is not related to the replacement of meters as a reduction in water consumption was also recorded by bulk water meters (Fig. 6). Below are presented measurement data obtained during 10 months:

- House 1: Class C customer meters measured a larger volume of water, by 45 $m^3$/month, than Class B meters a year ago. Nearly all customer meters were installed vertically in that house;
- House 2:  Volume of measured water increased by10 $m^3$/month;
- House 3: No positive result was obtained as the volume of measured water was lower by 1 $m^3$/month.

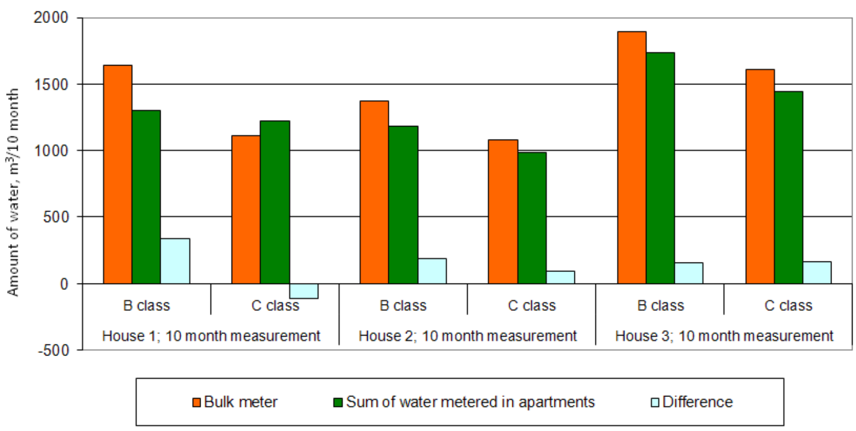


Fig. 6. B and C class customer water meter differences

Although the test involved only three blockhouses, the data can be used for initial preliminary assessment. Certainly, the meters will remain installed and in the future we will have data for a longer period. One interesting fact with regard to the three blockhouses concerned is that none of the apartments had meters installed according to the manufacturers' instructions, i.e. horizontally. Any deviation from a horizontal position impairs the accuracy of measurement and enlarges the range of errors. After replacing household meters of Class B by those of Class C it has been determined that average losses of 12 litres/day or around 4 $m^3$/apartment/year can accrue in apartments.

Considering that the price difference between customer meters of Class B and Class C is around LTL 20, while the prices of installation and other works are the same, only the difference in meter prices can be used in economic calculations. It is proposed to replace meters every six years. Alytus town has around 22 900 apartments. Therefore, additional costs resulting from increased meter prices will be equal to 22 900 · 20 = LTL 458 000. Meanwhile the installation of new meters of Class C will result in a higher accuracy of measurements and additional revenue: 22 900 · 4 · 5.5 · 6 = LTL 3.0 million. Here: 22900 – the number of apartments in Alytus, 4 $m^3$ – an average increase in the measured water volume in an apartment per year, 5.5 Lt/$m^3$ – water price; 6 years – frequency of meter replacement. It follows from the foregoing that the costs of meter replacement will pay back quicker than in a year.

## 4. Conclusions

It is recommended to install water meters of Class C at inlets to hot water preparation; at industrial enterprises and public customers, i.e. those that directly pay to utility according to the readings of bulk water meters.

Customer water meters of Class C need to be installed for household customers. An estimated pay-back period for Class C meters is one year.

Water metering instruments of higher accuracy will help reduce apparent losses. More accurate water accounting devices are intended for more accurate measurement of water consumed by customers but not for cheating the customer.

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