Measuring the Quantities of Water in the Supply Systems to Domestic Consumers Considering the Real Value of the Coefficient for the Repartition of Consumption

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Abstract: *Starting from the observation that specialists observe some measurement deviations that may appear between two measuring systems - respectively between the general water meter from the building (or staircase) and the individual water meters from apartments - this paper presents some causes of this problem by analyzing of the "k" coefficient for repartition of the water consumption. Also the paper work presents theoretical researches regarding the calculation of these quantities of water, the determination of the error closing formula and sharing it the right way, that loss hydraulic among consumers.*

Keywords: *water consumption, water meter, error closing***.**

1 INTRODUCTION

In Romania, water consumers have installed individual meters to bathroom, kitchen and so on, unlike the EU countries where the water consumption is measured by one device per apartment.

Currently, the cities are in progress to realize the metering of water consumption, mainly in blocks of flats. Reality shows that, after metering in apartments, water consumption decreased significantly, but a lot of problems have appeared. These problems are connected with discrepancy between the volume of water indicated by the general water meter from the building's or from the staircases and the sum of the volumes of water indicated by the individual meters from apartments.

In reality, these differences depend on a number of causes, can reach values of 30% - 40% at the expense of the supplier and are highlighted by the coefficient for repartition of the water consumption:

$$k = \frac{Q}{\sum_{i=1}^{n} Q_i} \quad (1)$$

where:

Q is water flow rate measured at the building's branch pipe;

$\sum_{i=1}^{n} Q_i$ is sum of water flow measured by the individual meters from apartments.

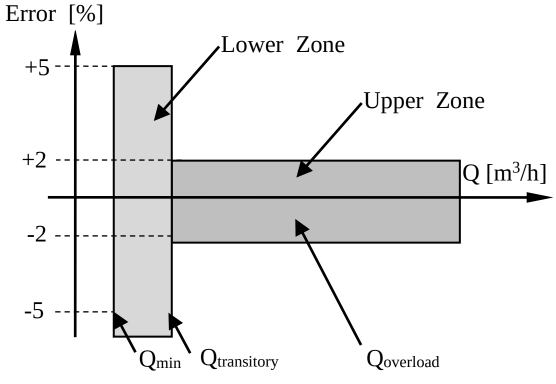

Fig.1 Curve of the measurement error of water meter [6]

To explain these differences, it goes from analysis of legal metrology norms which determine two intervals (Figure 1) - the inferior area with low flows and superior area with high flows. Here we can define three flow rates (in percent of the nominal flow rate of the meter). For these three flow rates are regulated limits of the measurement error of water meter:

$Q_{minimum}$ - error ±5%
$Q_{transitory}$ - error ±2%
$Q_{overload}$ - error ±2%

Thus, between two measurement systems: general water meter from the building and individual meters from apartments appears in absolute terms, a theoretical difference:

- ± 10% of the water volume throughput if "Q" (flowing through) is in the range: $Q_{minimum} < Q < Q_{transitory}$,
- ±4% of the water volume throughput if "Q" (flowing through) is in the range: $Q_{transitory} < Q < Q_{overload}$.

So, there was obtained a maximal theoretical value of the coefficient for repartition of the water consumption $k = 1{,}04 \div 1{,}1$, a value lower than the real value k = 1.3 ÷ 1.5, the value measured at the request of the supplier, with the housing associations' agreement.

For example, for a block of flats with 30 apartments, fully metered, with average monthly water consumption $10m^3$ / water meter would result 300m^3 total monthly water consumption. The theoretical difference which is due to measurement errors is between $12m^3$ $(12 = 300 \times 4\%)$ and $30m^3 (30 = 300 \times 10\%)$.

2 CAUSES OF DEVIATIONS BETWEEN THE THEORETICAL AND REAL VALUE OF THE COEFFICIENT FOR REPARTITION OF THE WATER CONSUMPTION

In case of double metering supplier-consumer was found a big difference between the theoretical and real value of the coefficient for repartition of the water consumption "k" which is determined by subjective and objective causes.

a) Subjective causes refer to consumer attitudes, using water without paying the water consumption, through various methods such as:

- illegal connection, before water meters, through hidden works;
- fraud water meter with magnetic coupling;
- intentional damage and / or maintaining a blocked or defective water meter into water feeding installation;
- voluntary misreporting of consumption meters from the apartments;
- meter reading errors.

b) Objective causes refer to:

- different precision class of water meters, used in the same condominium, for individual metering and for branch pipe metering, given by types and sizes;
- lack of specifications about the water meter sensitivity in the prospectuses of water meter manufacturers (respectively the starting value of flow, Q_s, which is registered with large negative errors and also the value of unregistered flow $Q_{ur} = 0{,}99Q_s$). It only takes a few indoor installation to be defective (causing leaks, defective backing plate in valves and faulty toilet tanks) so branch pipe meter to record the cumulative consumption and the individual meters do not record anything;
- reliability of meters, which, during operation, are subject to wear and become poorly calibrated with major influence on the starting value of flow, Q_s;
- incorrect mounting position of water meters;
- indoor installation losses through leakages and cracks of the distribution columns, deposits of salts and magnesium (hardness) which lead to increase the registration errors values of water meters;
- losses on non-compliant systems that allow, for various reasons, to register water consumption of other consumers which do not belong to the same condominium;
- reading errors caused by reading of individual water meter at different times from the date of reading of water meter from the entrance of building (or staircase), rounding minus the read value and involuntary erroneous reading.

3 THEORETICAL ASPECTS REGARDING THE CALCULATION OF QUANTITIES OF WATER

The differences between the water quantities delivered by the suppliers and the ones registered by the individual water meters determine the increase of the amounts of the water invoices the end consumers get, which in turn leads to social problems and tensions between partners: suppliers and consumers.

a) To partially resolve this situation, a calculation for a network has been made, with fully measured consumers, whose water meters are installed in parallel, and the suppliers' meters are linked in series with the whole system (fig. 2).

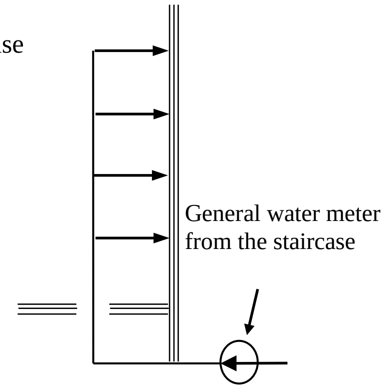

Fig.2 Supply and metering schema for a block of apartments

For this network type, seen very often among blocks of flats, we can write the mass conservation equation [1], as a continuity equation:

$$Q = \sum_{j=1}^{m} q_j \qquad (2)$$

where:

- Q is the water flow which goes through the supplier's water meter (general water meter from the staircase branch pipe)
- $\sum_{j=1}^{m} q_j$ is the sum of all flows which go through the consumers' water meters.

The relationship (2) is equivalent with the relationship between the volumes which flowed through the water meters during a time interval, Δt:

$$V_A = \sum_{j=1}^{m} v_{a,j} \qquad (3)$$

or:

$$V_A - \sum_{j=1}^{m} v_{a,j} = 0\,, \qquad (4)$$

where:

- V_A is the water volume which flew through the supplier's water meter,
- $v_{a,j}$ is the water volume which flowed through the consumer's "*j*" water meter.

If we ignore the subjective and objective causes presented above, between water meter's indications, we can write a similar relationship:

$$V_B - \sum_{j=1}^{m} v_{b,j} = 0 \qquad (5)$$

where:

- V_B is the water volume indicated by the supplier's water meter,
- $v_{b,j}$ is the water volume indicated by the individual consumer's water meter.

In reality when we take into consideration the measuring errors, we get:

$$V_A = \frac{V_B}{1+\varepsilon} \text{ si } v_{a,j} = \frac{v_{b,j}}{1+\varepsilon_j},$$

and relationship (4) becomes:

$$\frac{V_B}{1+\varepsilon} - \sum_{j=1}^{m} \frac{v_{b,j}}{1+\varepsilon_j} = 0 \qquad (6)$$

So relationship (5), where we considered that either the measuring errors do not exist ($\varepsilon = 0$), or that the errors are constant and do not depend on the types and sizes of the water meters, and do not depend on the flow which passes through and the precision class of the water meters, cannot be met.

It becomes necessary to introduce a new notion, the error of closing of the measuring system, ϵ, where:

$$\epsilon = V_B - \sum_{j=1}^{m} v_{b,j} \qquad (7)$$

Considering relationship (6) in relationship (7) we finally get the formula of the error of closing:

$$\epsilon = \sum_{j=1}^{m} v_{b,j} \frac{\varepsilon - \varepsilon_j}{1+\varepsilon_j} = \sum_{j=1}^{m} v_{a,j} \cdot (\varepsilon - \varepsilon_j) \qquad (8)$$

This error depends on the metrological characteristics of the water meters, the nominal and effective flows, and their duration. The closing error is caused by the measuring error.

Inside a block of condominiums, where all consumers own water meters, the water supplier will send an invoice based on the supplier's water meter indication V_B, and the block administrator will gather from consumers their individual $v_{b,j}$ indicators.

The new problem is to figure out how to correctly divide among consumers the closing error.

b) For a block of condominiums where only part of the consumers have water meters, the closing error becomes:

$$V_A = \sum_{j=1}^{k} v_{a,j} + W_A \qquad (9)$$

where:

- k is the count of the consumers who own water meters,
- W_A is the water volume taken in by the consumers who do not own water meters.

In this case relationship (6) becomes:

$$\frac{V_B}{1+\varepsilon} = \sum_{j=1}^{k} \frac{v_{b,j}}{1+\varepsilon_j} + W_A \qquad (10)$$

therefore the water volume assigned by the building's administrator to the consumers who do not own water meters, based on different criteria (like number of persons who live there, existence of a garage, etc.), is in reality different from the water volume taken in by those consumers W_A.

So, the block's administrator will tend to assign unmetered consumers the consumed water volume V_B:

$$V_B = \sum_{j=1}^{k} v_{b,j} + W_B \qquad (11)$$

Subtracting (10) from (11) we get:

$$W_B - W_A = V_B \frac{\varepsilon}{1+\varepsilon} - \sum_{j=1}^{k} v_{b,j} \frac{\varepsilon_j}{1+\varepsilon_j} \qquad (12)$$

4. CASE STUDY ON THE COMPUTATION OF THE COEFFICIENT FOR REPARTITION OF THE WATER CONSUMPTION

If, for example, we consider a starting flow $Q_s = 10[l/h]$, then the maximum value of the water volume consumed during a month and unmetered by the water meters for a block with 16 apartments, in theory can be (when we consider that the daily usage time of the water meters with flow greater than $Q_{transitory} = 6h$):

$$V = 16[water\ meter] \times 10\left[\frac{l}{h}\right] \times 18[houres] \times 30[days] = 86{,}4\left[\frac{m^3}{month}\right]$$

If we consider an average consumption per apartment of 10 [m³/month], we get a consumption distribution rate:

$$k = \frac{Q}{\sum_{i=1}^{n} Q_i} = \frac{16\ water\ meter \times 10\left[\frac{m^3}{month}\right] + 86{,}4\left[\frac{m^3}{month}\right]}{16\ water\ meter \times 10\left[\frac{m^3}{month}\right]} = 1{,}54$$

We can observe the computed value to be close to the real value.

5. CONCLUSIONS

- The theoretical study of coefficient *k* and the real value, show that its normal value is situated inside the interval $k = 1{,}3 \div 1{,}4$ or close to it. This coefficient is strictly linked to the water meters' sensitivity, its improvement meaning using higher precision class water meters.
- Removing the fraud possibilities and lowering the differences in recording of the water

consumption can be done only by individual metering; while water consumption using a dual measuring system, one of the supplier's and one of the consumers', will only lead to recording differences. So, if measuring the individual consumption with higher precision class water meters we can obtain a better recording precision (with 2%-3% better than an immediately inferior precision class), in the case of measuring the block with higher precision class water meters than the individual water meters will lead to increasing of the coefficient for repartition of the water consumption *k*.

- Even if the water meters would be checked and calibrated more often than recommended by the metrological mandatory verification, this coefficient will not improve unless linked with removing the losses from the inside network (defect toilet tank fittings and taps etc.)
- It is recommended rehabilitation of water supply systems, new solutions for automation systems at capture water supply untill meter reading, video inspection systems for water supply network etc.

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