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ACCURACY OF WATER METERS DURING THEIR OPERATION

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ABSTRCT: The article describes the study on water meters after their five-year period of operation. Water meters were tested at a certification stand to check for possible reading errors. The following devices have been included in the study: water meters with a diameter of 20 mm (single-jet, multi-jet and volumetric) as well as single-jet and screw water meters with a diameter of 50 mm. The faulty water meters were disassembled to identify causes of damage specific for various types of water meters. The percentage of faulty water meters differed among individual types of water meters, as well as among single-jet water meters of different manufacturers. The tests carried out should verify the actual errors of water meter readings during and after operation, and check whether the errors vary for different types of water meters. After many years of operational experience, it may be concluded that water meters, if lose their correct metrological properties, they usually show a smaller values than the actual flow. In such cases, faulty water meters cause the apparent water loss. Based on the study the authors found that volumetric water meters had the highest reliability among household water meters while screw water meters among industrial water meters. The studies have confirmed that damaged water meters can contribute to higher apparent water losses.

KEY WORDS: water losses, water meters, faulty water meters

Introduction

The objective management, planning and management of a widespread and complex water/sewage infrastructure is possible as a result of a fast and reliable analysis based on the collected data. Nowadays, representatives of a water and sewage sector more and more often reach for tools such as information systems to comprehensively manage the structure. The systems, apart from the geographic information system, contain also a geospatial monitoring system, a hydraulic model system and optimization algorithms.

Particularly important are measurements of water delivery and consumption, because to measure it means to save.

For operators of water networks, water meter economy can also be an important tool for setting directions of modernization and development, not only in the area of water supply metering, but also in utilization of resources and modernization needs (Bergel, Kulig, 2010; Cichoń. Królikowska, 2016).

Optimization of costs and water consumption using smart water meters together with information and communication systems is now becoming a standard for both water users and suppliers. Smart metering is a major technological, business and an organizational challenge, which helps better manage resources and so increase its efficiency.

The water meter carries out its task, i.e. measures a given physical quantity, processes the information obtained from measurements and then makes it available to the user once certain operating conditions and requirements are met. The basic requirement for water meters is their quality, not only at a selection stage but also over the entire lifetime, when the specific metrological characteristics of water meter has to be maintained (Cichoń, 2010; Cichoń, 2013; Tuz, Gwoździej-Mazur, 2012).

Water meters have a certification mark valid for five years, so their readings should remain within the acceptable error limits over this period.

Water meter characteristics

Water meters, installed on a water connection to buildings, are used to set fees between the water supplier and the property owner; in multi-family buildings they help to control water consumption implementing "pay for use" system (Cichoń, Królikowska, 2016; Tuz, 2011).

Mostly mechanical water meters are mounted in installations. They include: wing, screw and volume water meters, equipped with a rotor that is moved by the water flow. Wing water meters (nominal diameter DN 15-40 mm) are used to measure small water volumes. They have a built-in rotor with an axis perpendicular to a water flow; the rotor is provided with several evenly spaced flat blades (wings). When the water passing through the meter forms one stream, which drives the rotor flowing from one side of the axis, it is a single-jet water meter (figure 1). In multi-jet water meters, the water flow is divided into streams flowing through openings in a special chamber surrounding the rotor. The wing water meters have quite high start-up thresholds and a low dynamic of measurement. They are also quite sensitive to water quality and contamination.

In terms of the working environment of water meter counters, water meters can work as dry-running and wet-running meters.

Screw water meters are used to measure large volumes of water (nominal diameter DN>50 mm). Their rotor is placed perpendicularly to the flowing water, i.e. the rotor axis is parallel to the flow (figure 1).

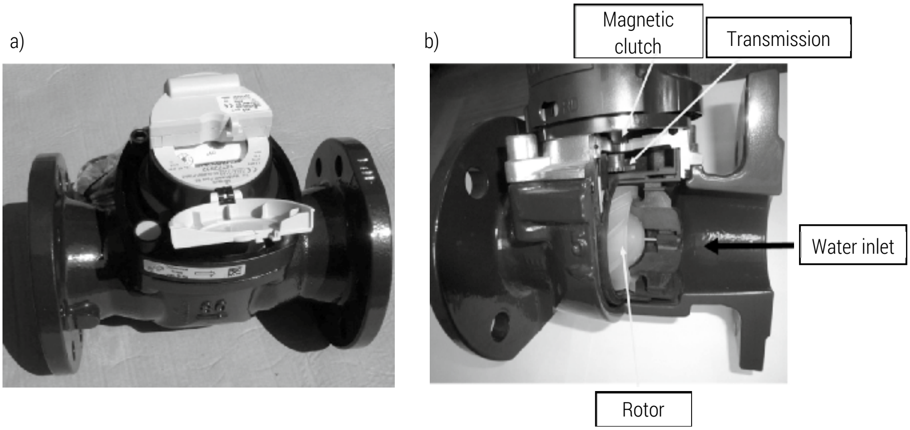

Figure 1. Screw water meter: a) view, b) cross-section
Source: author's own work.

Other options are volumetric water meters, with their very high accuracy, a low start-up threshold, and wide measurement dynamics. Here, water passing through a water meter chamber sets in motion an eccentric piston located there (figure 2).

The chamber is filled and emptied in a cyclic mode. The piston rotates and transfers a portion of water towards the outlet. Then water fills the entire chamber moving the piston until the outlet is exposed and a new inflow of water will be possible. The piston rotations are transferred to the counting system via a mechanical transmission or a magnetic clutch.

Figure 2. Rotor of a volumetric flow meter

Source: author's own work.

Static (digital) water meters represent a measurement technique that does not use moving parts. They measure the water flow rate using sensors and calculate the water volume passing using ultrasonic or electromagnetic waves.

In the case of ultrasonic water meters, two ultrasound heads send signals running simultaneously in opposite directions; one follows the water flow while the other runs just in the opposite way. The time difference measured between these signals is converted to a flow rate and thus to a water volume.

In the electromagnetic flow measurements, according to the Faraday's magnetic induction law, an electromagnetic force is induced in the conductor (water) moving in a magnetic field. The force depends on the magnetic field strength and the water velocity.

Figure 3. Electronic static water meter

Source: author's own work.

Static water meters are maintenance-free. They show low pressure losses compared to mechanical water meters, and any solids present in water have no effect on their metrological parameters or wear and tear. Properly selected water meters can measure both large and small water flows and thus allow to limit losses resulting from incorrect readings, which directly affects the economy of the company.

Static water meters usually provide communication thanks to the special radio modules mounted in them (Koral, 2006). Such provisions allow for remote water consumption readings, controls on their accuracy and delivery of more advanced information on e.g. backflows, leaks or water shortages (Cichoń, Królikowska, 2016; Geresz, 2011; Koral, 2017).

Research need on water meter management in an enterprise

The company, as an element of the water meter management system, purchases and installs water meters according to the manufacturer's recommendations It also conducts periodic readings, checks their condition, controls the accuracy of readings and periodically validates water meters. In case of a water meter failure or inaccuracy of readings, the company makes repairs and accepts complaints from consumers regarding accuracy of readings, according to the conditions specified in the regulations. It is much easier to carry out management tasks when a computer program with a database of recipients, water meters and the amount of water sold is available. Such data can serve as the basis for selecting water meters. Separate measurements, carried out at connections with registration of both water volume and water pressure at the measurement site, can also be useful. Also the pressure at the water meter installation site can affect its selection. If possible, the recipients' data should be supplemented with information on the number of residents using the connection. Such measurements should become the basis for a preliminary selection of a water meter for buildings with a given number of flats and for making decisions on a possible replacement or repair of the water meter. The purchase of more expensive water meters with a higher accuracy should be preceded by a cost/benefit analysis. Due to a cost structure of a water supply and sewage disposal system, obligatory tariff rules and technological conditions of water meter measurements, these devices mostly serve as a tool for cost allocation. Therefore, the device with a similar accuracy class should be used for all residents. The activities carried out by professionals, as part of water meter management in a water and sewage company, are much more in compliance with the requirements set out in standards and regulations. Neither owners of water meters in their households nor managers of multi-family buildings will ensure a good management of water meters. Housing owners may also alter housing water meters readings; they use some techniques to increase reading errors. In the case of mechanical water meters, these are e.g. devices that reduce a rotor speed of the water meter. It should also be noted that the current fee policy is so structured that the economic effects resulting from a replacement of a faulty water meter quickly disappear after a change of prices and tariff rates. Therefore, the company that takes actions in water meters management, checking and analyzing readings as well as through validation, repair and replacing of water meters with more accurate ones, should carefully monitor related additional expenditures. Systematic legalizations, verification of readings and their analyzes allow to avoid sudden cost increases during the year without limiting activities undertaken as part of water meter management.

The selection of water meters and the rules for their proper installation are aimed to achieve the best metrological properties during their normal operation. However, the assumption is that the metrological parameters of water meters are constant over time, at least within the limits of acceptable errors. The tests carried out should verify the actual errors of water meter readings during and after operation, and check whether the errors vary for different types of water meters. After many years of operational experience, it may be concluded that water meters, if lose their correct metrological properties, they usually show a smaller values than the actual flow. In such cases, faulty water meters cause the apparent water loss.

Methods

Results of the research

The reading errors for various types of water meters manufactured by different producers were analyzed; they were in operation in various water supply systems. The following devices have been included in the study: water meters with a diameter of 20 mm (single-jet, multi-jet and volumetric) as well as single-jet and screw water meters with a diameter of 50 mm. The single-jet and multi-jest water meters with a diameter of 20 mm had the metrological class R80, whereas the volumetric water meters were of the R160 class. The single-jet water meters with a diameter of 50 mm had the metrological class R315. Most water meters have been dismantled due to passing the expiration day, i.e. after a five-year service life. Some water meters were dismantled for various reasons earlier than after 5 years. Several were also dismantled since they did not measure the flow of water at all. In total, 160 water meters were subjected to the study. During the test metrological properties of the water meters were checked at the certified validation station by comparing the readings of a given water meter with water volumes that actually flowed through it. Each water meter was tested at three characteristic flow rates: at the minimum flow rate Q1, an intermediate flow rate Q2 at a continuous flow rate Q3.

In accordance with the provisions of the Ordinance of the Minister of Economy on the requirements of water meters and the detailed scope of checks performed during legal metrological control of these measuring instruments (Rozporządzenie Ministra Gospodarki z dnia 23 października 2007 r. w sprawie wymagań…), the following error values apply for the initial verification and re-verification of cold water meters, i.e. up to 30°C:

$$\pm 5\% \text{ for } Q_1 \leq Q < Q_2$$

$$\pm 2\% \text{ for } Q_2 \leq Q < Q_4$$

According to the provision of §15 of the Regulation, permissible errors of water meters in use may exceed two times the limit of permissible errors valid for legalization. After metrological tests, water meters were divided into groups in terms of reading errors. The following sets of water meters have been singled out, which:

- met validation requirements (errors ≤±2% or ≤±5% for Q1),
- met the requirements permissible during operation (errors exceed two times the errors permissible during legalization) (errors ≤±4% or ≤±10% for Q1),
- had errors exceeding the permissible limiting errors (errors >±4% or >±10% for Q1),
- did not perform any measurements (error -100%).

Therefore, correct metrological properties had water meters in the first and second group. Of all the water meters tested, 61 units did not meet the requirements, i.e. their reading errors were greater than the permissible errors during operation. In figure 4 the number of water meters in each individual range of reading errors for the minimum flow rate is presented.

In addition to the working water meters, the figure 4 shows also water meters, which reading errors are greater than the permissible limiting errors. It is interesting, that all faulty water meters have an error with the sign "-", which means that their readings were lower than the actual flow. The opposite was not the case with any water meter. Similar were the readings for intermediate (Q2) and continuous (Q3) or nominal (Qn) flow rates. The number of water meters in individual ranges of reading errors is shown in figure 5.

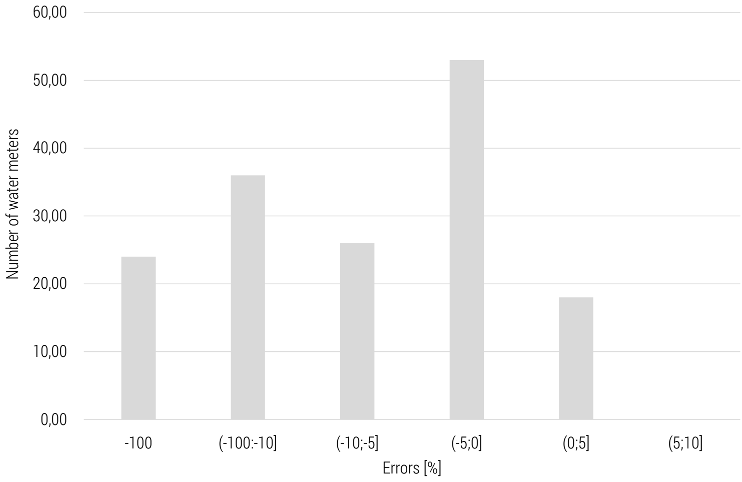

Figure 4. Number of water meters in each range of reading errors at the minimum flow rate

Source: author's own work.

After metrological tests, faulty water meters were dismantled to identify the reasons for such inaccurate readings. The tests showed some failures, characteristic for particular types of water meters.

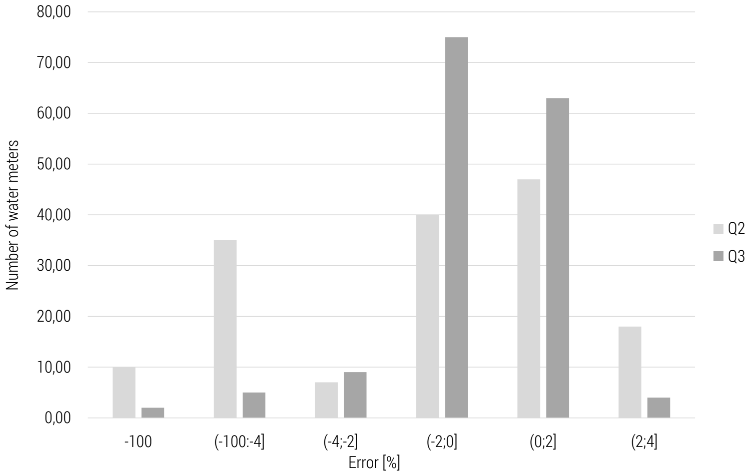

Figure 5. Number of water meters in each range of reading errors at intermediate, continuous or nominal flow rates

Source: author's own work.

In the case of screw water meters, iron particles accumulating on a surface of a magnetic coupling on a rotor side caused the failure. A view and a microscopic view of these particles is shown in figure 6. The aggregates can cause additional friction on the rotor until it gets blocked.

In the case of single-jet industrial water meters with a diameter of 50 mm, failures are caused by calcium carbonate scaling accumulated on a rotor bearing. The scaling accumulates on the surface of both the axis and the rotor. It increases a bearing surface and its roughness, which in turn increases a bearing friction. Microscopic photos of the bearing surface are shown in figure 7.

In single-jet water meters with a diameter of 20 mm, the most common cause of failure was deformation (flattening) of the rotor axis and calcium carbonate scaling. The microscopic view of the tip of the rotor axis is shown in figure 8.

a) b)

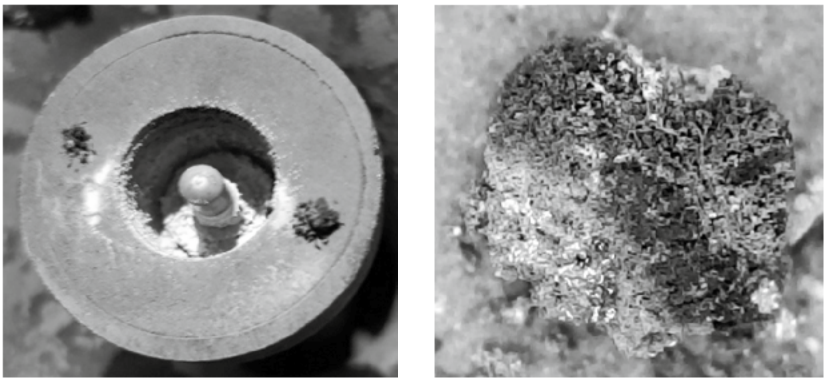

Figure 6. Magnetic coupling of a screw water meter a) view of a magnetic coupling surface with precipitates, b) a microscopic view

Source: author's own work.

a) b)

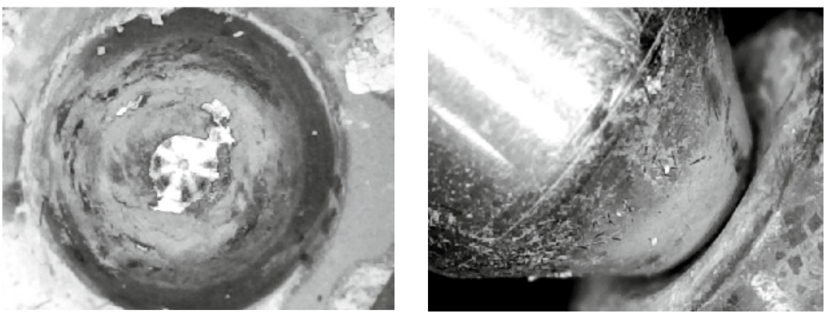

Figure 7. Bearing of the rotor of an industrial single-jet water meter covered with scaling a) microscopic view of a bearing with scaling, b)microscopic view of a bearing profile

Source: author's own work.

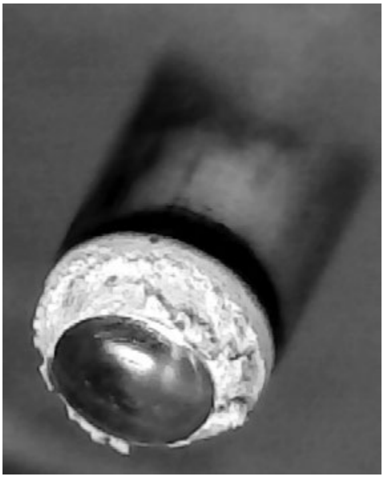

Figure 8. Tip of the rotor axis of the single-jet water meter with a diameter of 20 mm
Source: author's own work.

The tip of the rotor axis has become flat (instead of semi-circular) and additionally the contact surface has grown due to calcium carbonate scaling. These changes resulted in a higher friction, and thus an greater reading errors type "–".

Water jet meters that worked at hydrant bases were also tested. In this type of damaged water meters, the impeller axis was worn probably due to too rapid flow changes or excessive flow rates. Figure 9 shows a water meter, which rotor axis was originally 3 mm in diameter and now was less than 0.5 mm.

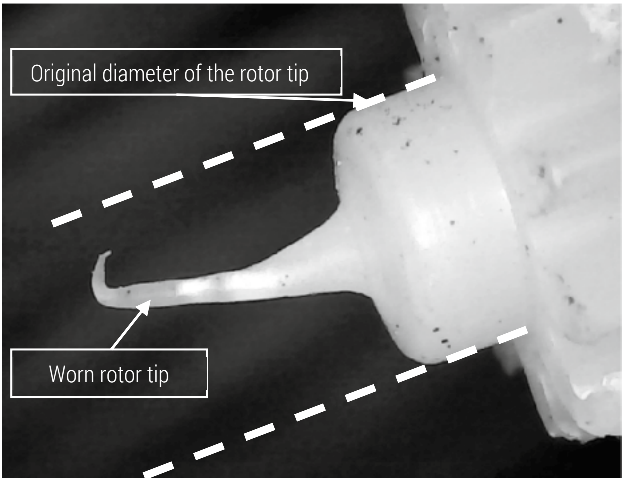

Figure 9. Worn rotor axis of a water meter working at a hydrant base
Source: author's own work.

In the case of volumetric water meters, only one water meter from all units disassembled after 5 years of operation had reading errors exceeding the limit values. In this single case, the water meter showed 7273 m^3, which is rare for water meters with a diameter of 20 mm, because their reading after five years of operation is usually less than 1000 m^3. This water meter has probably also worked at high flow rates and its damage resulted from the worn side surface of the water meter piston. Also, a number of cavities have been found on a surface of a measuring chamber making the piston's sliding surface porous and uneven. The view of the worn side of the piston is shown in figure 10.

The percentage of faulty water meters differed among individual types of water meters, as well as among single-jet water meters of different manufacturers. This applied to counters of various metrological classes in a similar range. It should be noted that the highest efficiency was found in volumetric water meters; only one of them exceeded reading errors after the period of operation. Two other damaged volumetric water meters, dismantled after a short period of operation (as blocked) were also tested. One of them had a broken magnetic clutch while the other was blocked with sediment particles. However, this kind of damage is easy to spot during operation. Screw water meters turned out to be the most reliable among industrial water meters.

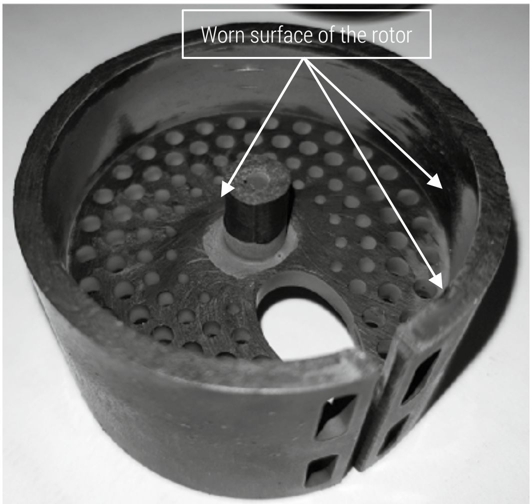

Figure 10. Worn side of the piston in a volumetric water meter

Source: author's own work.

Conclusions

The study confirmed that water meters might lose their metrological properties over time. The authors presented typical faults that may occur in individual types of water meters and cause a higher apparent water loss. Therefore, it is important not only to properly select water meters diameters and a metrological class but also to maintain good metrological properties throughout the entire period of operation. The analysis of faulty readings of water meters during and after their operation is a very important tool, that a water and sewage company may use to select the water meters that are the most reliable throughout their lifetime, in a given water system. Based on the study the authors found that volumetric water meters had the highest reliability among household water meters while screw water meters among industrial water meters. This is also confirmed by many years of research experience in meteorological expertise carried out at a certified validation point.

Readings of the water meter are the basis for calculating water and wastewater fees. It is therefore worth knowing that the device operates correctly, especially now when all efforts are directed to the rational use of water resources.

The contribution of the authors

Tomasz Cichoń – conception, literature review, acquisition of data, analysis and interpretation of data – 50%
Jadwiga Królikowska – conception, literature review, acquisition of data, analysis and interpretation of data – 50%

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