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THE IMPACT OF SOME EXTERNAL FACTORS ON THE METROLOGICAL PROPERTIES OF A WATER METER

WPŁYW WYBRANYCH CZYNNIKÓW ZEWNĘTRZNYCH NA WŁAŚCIWOŚCI METROLOGICZNE WODOMIERZA

Abstract

The paper refers to the study of water meters and the impact of some external factors on the variability of water meters metrological parameters during their operation period. The study was conducted in three groups, depending on cause and the moment of dismounting – before expiry of operation period, at the end of operation period and to metrological expertise. In this paper, are presented results of measuring errors investigations, which show variability of errors during operation time. In the group of water meters with exceeded errors, analyses were conducted on the damage types and the factors affecting the deterioration of metrological accuracy. Research is aimed to define the conditions required in order to maintain the metrological accuracy during operation period.

Keywords: water meter, measuring error, water meter damages

Streszczenie

W artykule opisano badania wodomierzy oraz wpływ niektórych czynników zewnętrznych na zmienność parametrów metrologicznych wodomierzy w czasie ich eksploatacji. Badania były prowadzone w trzech grupach w zależności od czasu i powodu demontażu – przed upływem okresu eksploatacji, na koniec okresu eksploatacji oraz w ramach ekspertyz metrologicznych. W artykule przedstawiono wyniki badań błędów metrologicznych, które wykazują zmienność błędów wskazań wodomierzy w czasie ich eksploatacji. Wśród wodomierzy z przekroczonymi błędami pomiarowymi przeprowadzono analizę typów występujących usterek oraz czynników mających wpływ na pogorszenie własności metrologicznych. Badania zmierzają do określenia warunków pozwalających utrzymać poprawność metrologiczną przez cały okres eksploatacji.

Słowa kluczowe: wodomierz, błędy pomiarowe, uszkodzenia wodomierzy

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1. Introduction

Water meter tasks include: measurement of a physical value, processing the obtained information and making it available to the observer at certain working conditions and according to the preset requirements. The basic future of a water meter is its usable quality, i.e. metrological characteristics, which can be determined both during its selection and then throughout the life cycle. Optimizing a water metering and selling system, which comprises water meters placed in series, the operator tries to minimize the number of damaged water meters (k) within the system ($k \to 0$).

Indeed, the selection of water meters proceeds along the rules, which are specified in the regulations, but they are not precisely defined with explicit mathematical methods; this issue has been the subject of many studies and publications [1–7].

The meter, as a measuring instrument, is subjected to legal metrological control procedures. In order to obtain a correct, and above all, a legal basis for water charges, all water meters installed at the consumers should present valid certificates [8–11].

The main regulations featuring the rules of instrument admission for a commercial use and its inspection are regulated by the Polish Act on Measures Law (i.e. Journal of Laws 2004.243.2441 with later amendments). The Act tries to impose uniform measurement units and measurement accuracy for the physical values. It establishes measurement administration bodies as competent bodies to rule on matters regarding measurements within the Polish Republic. The Act comprises delegations to the implementing regulations defining the detailed requirements. The Regulation of the Minister of the Economy describes the requirements that have to be met by water meters and a detailed scope of tests performed during legal metrological control of these measuring instruments. During the next certification, a checking procedure determines water meter errors for at least three flow rates, specific to each meter. Each time, at the certification stand, the amount of water that actually flowed through the meter is compared with the amount indicated by the counter [12–15].

2. Characteristics of the Krakow's water supply metering system

The Krakow water supply system has been selected as a pilot system for the monitoring of metering instruments and their performance. The system consists of more than 54,000 water meters installed at connections to water consumers. Water meters with a diameter of 20 mm constitute by far the largest number (over 75%) of all water meters in use. They are installed mainly in single family houses and small apartment buildings. Other dimensions are used for measurements in multi-family buildings, industrial facilities and for water wholesale services to neighbouring municipalities [16].

Currently, single-jet meters, next to industrial screw water meters, are the most popular types of used water meters. The Krakow waterworks (MPWiK) also use a new kind of a water meter – a displacement water meter. This type of meter is used mostly for diameters ranging from 20 mm to 40 mm, and currently, only this type water meters are purchased because of its high metrological class. Also, water meters with an ultrasonic measuring system and an electromagnetic transducer have been tested in Krakow.

Collection and transmission of data on the water meter conditions is an integral part of a water supply metering system. The readings from water meters registers, that are managed by the Krakow MPWiK, are done either in a traditional way (by a collector), or by using remote reading of registers. Traditional data collection involves a visual inspection of a water meter by a collector; the reading is then registered in a log book. In case of water companies/ suppliers, it means that each register has to be made available for a service person to see and read the value indicated on the odometer. On the other hand, for each recipient, it usually means that a controller of each medium needs access to each meter installed at the property, or has the readings provided by the owner.

The basic system of water meters readings have been carried out in 90-day cycles. This way, nearly 50,000 of water consumers were held accountable. A remote reading system is based on water meters with radio pads which are read by collectors. They are equipped with portable computers and periodically visit the area around the city collecting data readouts. The Krakow MPWiK has also begun tests of automatic (unattended) reading systems. A pilot system of fixed readings was implemented in the area, where radio communicates are read from pads by a stationary set. Such a kit equipped with a passive radio antenna was installed on the roof of a tall building. Another option is a system in which each water meter is equipped with a unit for data transmission via the GSM network using a GPRS data packet.

3. Water maters failures

From a reliability point of view, water meters were divided into two categories: damaged (meter does not work) and meters which lost metering accuracy (meter works with errors that exceed acceptable values). Thus, the study of water meters was carried out for three data groups:

a) meters dismantled before its certification has expired,
b) meters dismantled just before its certification expires,
c) meters dismantled for inspection (the readings questioned by recipients).

The water meters came from the Krakow water supply metering system as well as from other metering systems, mainly from Southern Poland. The reasons for removing the water meter before its certification has expired included:

- damages and failures reported by the collectors or water recipients,
- metering accuracy questioned (based on the consecutive readings),
- others e.g. closure of the intake point.

It was found that most of 976 water meters tested, after their dismantling before the expiration day, had their mechanism locked; such cases constituted for 54.3% of the collected data. Another cases included counter breakdowns or a water meter burn out. Figure 1 presents the percentage of remaining water meters for which it was impossible to measure the errors of indications, broken down by cause. The data set is dominated by water meters with a flooded counter. This is a common problem for meters mounted in a men hole, when a counter is not hermetically sealed. If there is water in the men hole, a counter gets flooded, and consequently, corrosion of a steel counter axle blocks a drive. Failure of a counter results in lack of digit movements due to bearings wear off, or gears release (wear of gear teeth).

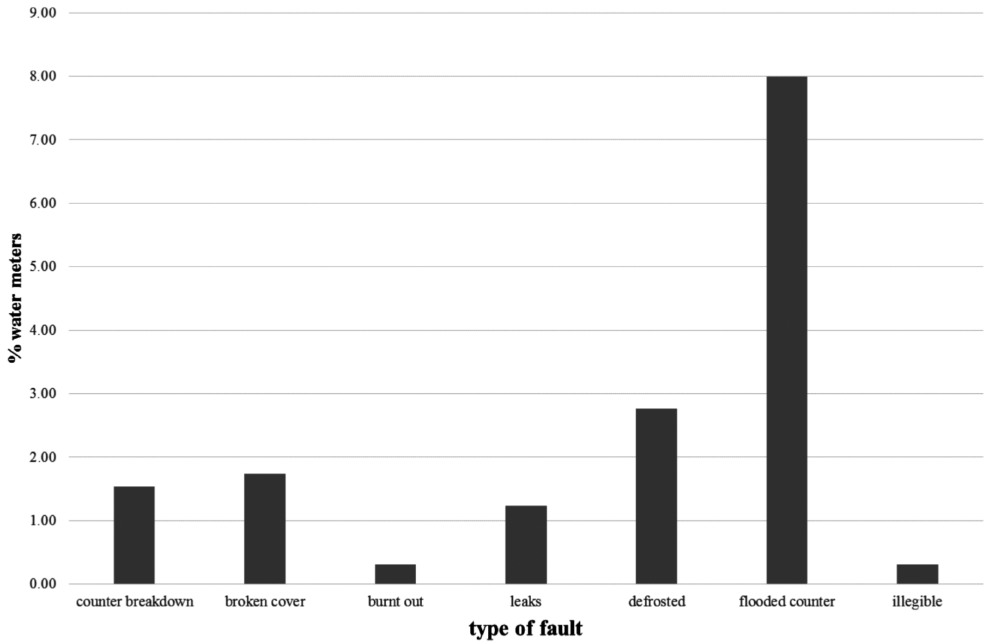

Fig. 1. Classification of water meters for which readings errors cannot be measured (broken down by a cause) [16]

A water leakage from a water meter may result from an excessive water pressure in the network or defective seal materials. The phrase "a defrosted water meter" means that damages

occurred as a result of water freezing inside the water meter. They include a water leakage from the water meter as well as other damages typical to disruption of housing or other components while ice melting. A partial deformation of a counter, or even a unit burn out, was observed as a result of an intense heating of a water meter in winter. Another reason for melting of a measuring chamber was a failure on the mains, after which the hot water from the tank "backed up" to the meter.

A percentage distribution of damaged water meters, grouped according to their service life, is shown in the Fig. 2. Analysis of all damages observed at water meters dismantled during the operation brings up the question whether the units, dismantled before their expiration day, were running. Therefore, over a thousand of such water meters were additionally studied. The study proceeded in two directions, at first, the measuring errors were determined and then analysis of causes of failures was carried out.

The survey of measurement errors of water meters after their service life and before the expiration day was carried out for almost all units (1,138 from 1,150 dismantled). The remaining 12 units were damaged in such a way that measurements of reading errors were not possible; they were simply broken. A range of measurement errors found in the examined water meters at nominal or continuous and intermediate flows were plotted in Fig. 3.

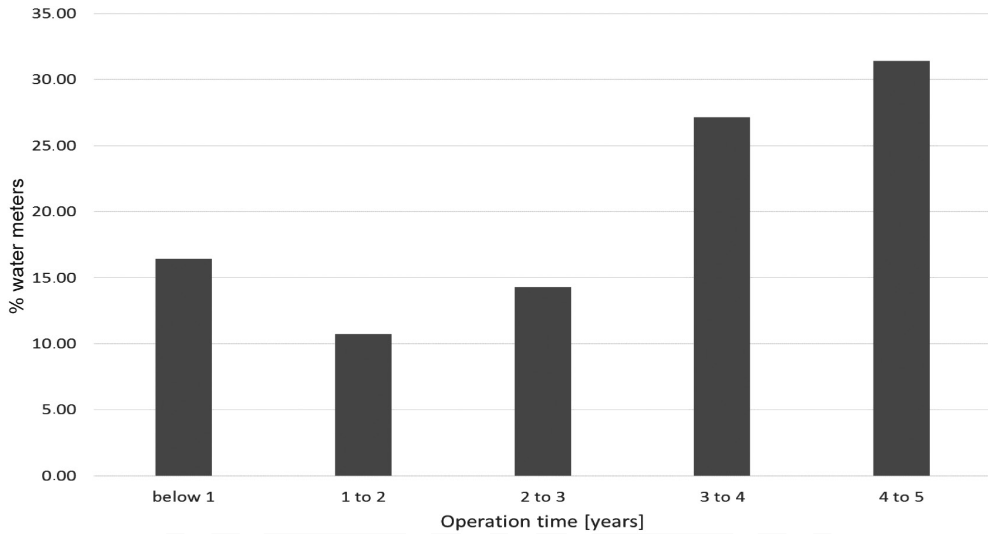

Fig. 2. Operation time of the damaged water meters [16]

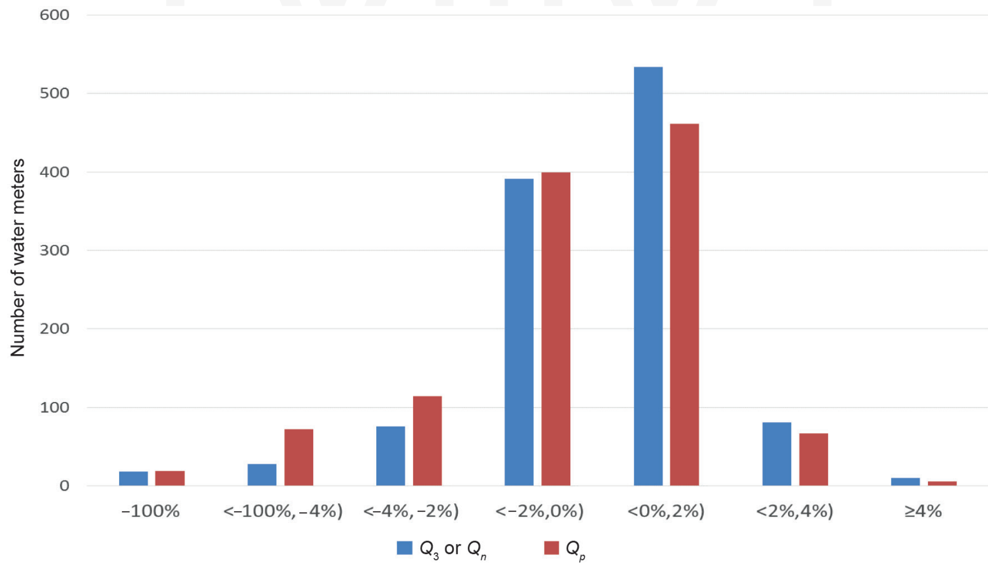

Fig. 3. Water meters and their measuring errors at nominal (Q_n) or continuous ($Q3$) and intermediate flows (Q_p) [16]

It can be noted that there is a group of water meters, which shows significant negative absolute errors or does not measure flow at all (errors greater than –4% and –100%). The maximum permissible positive errors (4%) were not exceeded in any water meter owned by the Krakow MPWiK. All units tested during metrological examinations had been certified, which proves that, during legalization, measurement errors of all water meters stayed close to 0%. Thus, analysing the changes of measurement errors it should be noted that if there is a change of metrology it is usually a shift toward negative values, which means that the measured flow is lower than the actual flow. In such situations, there is a considerable risk of generation of apparent water losses.

The cause/effect analysis of deviations associated with the operation of the water meters was combined with analysis of such features as: water quality, working pressure in the system and a previous history of water meter operation.

The largest number of cases, when measurement errors were exceeded, was found in the area supplied with water from Dobczyce Lake, as well as in areas where this water is mixed with water from other sources; the size of the zone is partially responsible for such situation. Analysing a content of sediment found inside the water meters, it may be concluded that corrosive water is also responsible for a higher number of damaged water meters; water from the Raba river up to year 2004 had elevated corrosive properties (the Langelier index <-0.4, as calculated according to the Polish standards PN-72/C-IL 04609). The situation improved after 2004 once water had been stabilized using milk of lime, and then in 2006, when the coagulant was changed from a low-alkaline PAX-16 to a high-alkaline coagulant, which resulted in elimination of a corrosion problem in water from the Raba Water Treatment Plant (WTP); since that time water has been much less corrosive.

The water meters analysed in this study have been in operation since 2008, i.e. shortly after the change of coagulants. Despite the improvement, water pipe corrosion initiated in the water system supplied by the Raba WTP before 2004, resulted in later problems associated with an increased number of corrosion products (such as iron oxides and hydroxides). Due to their ferromagnetic properties, they may adhere to inner surfaces of the water meter increasing the failure rate. In other areas, (the water systems supplied by the Rudawa, Dłubnia and Bielany WTP) water throughout the operation time was not corrosive, and therefore, adhesion of corrosion products was much lower in water meters. Also, other factors, such as the network age, pipe material, actual investments as well as current failures may have had impact on this situation. They were not analysed in detail, but you cannot rule out their influence on the measuring properties of the units.

Figure 4 shows the number of damaged water meters divided according to operating water pressure categories. The analysis shows that most water meters, which lost metrological properties during operation, worked within the pressure range of 4 to 5 bar. This is the most common pressure in the Krakow water mains. The damaged water meters were also observed in other categories with both lower and higher pressures.

Therefore, it may be concluded that water pressure has no direct impact on a failure rate of water meters in the Krakow's water supply metering system. However, it cannot be definitely excluded that such effect would be observed in other metering systems.

Some failures can be caused by an excessive wear out of water meters. For a long time of centrally controlled economy, the water works had great difficulties with a purchase of new water meters. A number of waterworks specialises in the regeneration and repair of water meters. Sometimes, even today, one can come across the notion that that every meter can be regenerated and certified again. Among the dismantled water meters they were also units produced in the eighties of the last century, which have worked through four or more certification periods. To investigate the relation between an operation time and a loss of metrological functions all damaged water meters with a diameter of 20 mm were selected, since these units made the largest group of 252 water meters. The study was confined only to one diameter to get a meaningful comparison for water meters of similar design and capacity. The results of the analysis are shown in Fig. 5.

The analysis showed that 32% of water meters had finals readings up to 500 m^3, while for more than 68% the readings were 500 m^3. The calculated median of readings for the meters with a diameter of 20 mm after the certification is 740 m^3. It leads to the conclusion that

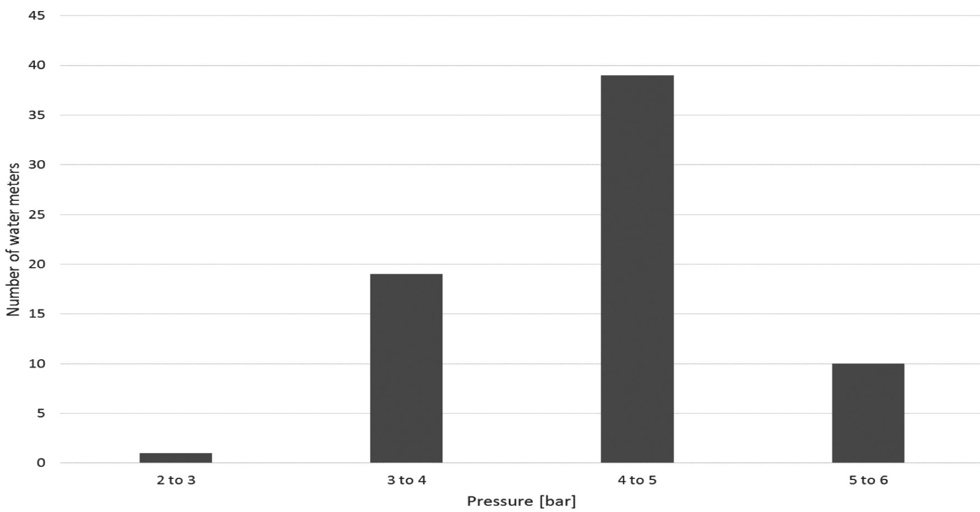

Fig. 4. Number of damaged water meters according to operating water pressures [16]

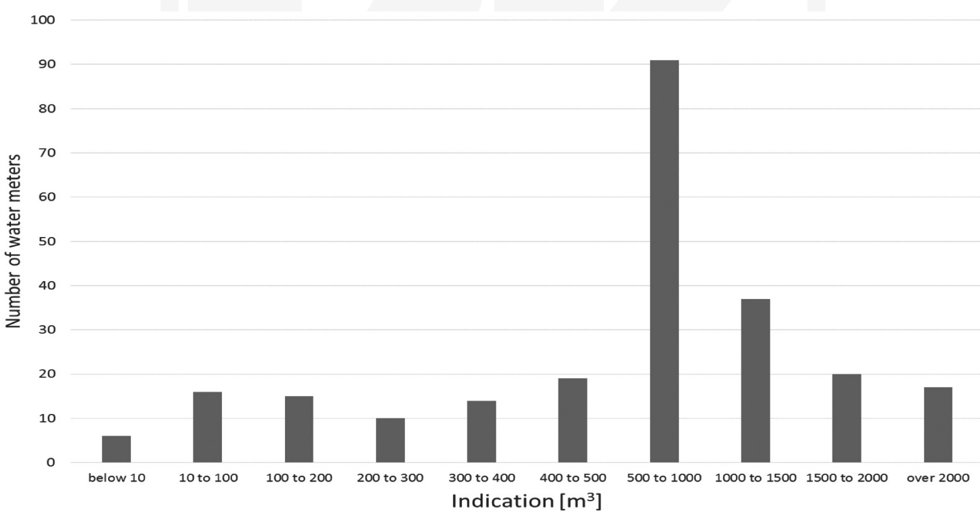

Fig. 5. Distribution of damaged water meters according to the final readings [16]

“mileage” of a water meter has an impact on the loss of metrological properties; the higher the readings, the higher the likelihood that the metrological properties get worse.

Since a number of water meters have been blocked by sediment pieces, torn off pipes, or other solids, the authors analysed whether there is a relationship between such accidents and failures that occurred on pipelines next to these units. In order to verify this fact, the group of blocked water meters was selected that were spotted in the last quarter of 2013; the group comprised 199 water meters. Taking into account the quarterly system for meter readings collection, this group of water meters was compared with the water supply network failures that had occurred in the third quarter of 2013. The detailed analysis revealed that water supply system failures were previously observed in the immediate vicinity of the 28 water meters. Other cases may have been caused by various dynamic conditions within the system such as e.g. switching changes or pressure changes. An increased number of failures are found also in old pipes in the city centre.

4. Summary

The basic principle of water meter management is to comply with the validity of the certification mark for all operating units. Therefore, they have to be gradually replaced before the expiration date. The studies confirmed that it has been a right approach, which has to be followed not only due to formal requirements, but also due to considerable risks of apparent water losses.

It is necessary to gradually accumulate the data base on failures of the water meters “in service”, as they age. The optimum situation would be if the company had its own certification stand, which runs regular tests for different types of water meters.

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