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Solid particles and their impact on water meter operation

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ABSTRACT

Each entity that uses water meters to monitor water consumption stays responsible for their daily service/repair work and accuracy inspections. Valid legalization certificates for water meters are required by the law. The tests of metrological properties run during water meter operation show that the readings may change over time. The article looks into one particular source of failure of typical water meters, that is, deposition of particles, including iron microparticles. The tested water meters came from various water supply systems and had several years of operation. They were examined for readings errors at the legalization stand. The paper summarizes also the effects of regeneration of volumetric water meters with an ultrasonic cleaner. The efficiency of t is method has been illustrated by photo documentation.

Keywords: Measurements; Solid particles; Water; Meter operation

1. Introduction

Every water supply and sewage company, among other duties, has to keep its water meters in good operation conditions since they are the valuable source of information on water usage. In order to fulfill this task, water meters are checked regularly and then successively replaced, if the legalization certificate expires. The tests of metrological properties run during water meter operation show that the readings may change over time. In some cases, the reading errors may exceed the maximum permissible values resulting in overbilling or underbilling the consumers. The false reading of a water meter can be caused by broken water meters and/or other operation failures [1–3]. Mostly single-jet water meters have been mounted in the installations operated by municipal water supply systems. They have a built-in rotor with an axis perpendicular to a water flow; the rotor has several evenly spaced flat blades (wings). If water passing through the meter forms one stream, which drives the rotor from one side of the axis, it is a single-jet water meter. Such mechanism has been found in both very old units and new meters with very good metrological parameters. The method is mostly used in small water meters (15, 20 mm), but it can also be found in industrial meters with diameters up to 150 mm. The main advantage of single-jet water meters is their simple construction and therefore an affordable price. Their metrological parameters remain usually at the average level and one of their disadvantages is sensitivity to a mounting position. They works the best if placed in a horizontal position, that is, with the meter face upwards.

Multi-jet water meters are a specific type of jet water meters. In principle, they operate in the same way as single-jet water meters, but water is supplied to the rotor through a set of many small openings so the stream of incoming water is divided into many tiny flows. Multi-jet water meters are available in diameters ranging from 20 to 40 mm; they are extremely sensitive to sediments accumulating

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inside the openings to the rotor. A screw water meter, also known as the Woltman water meter, is the most common type among larger water meters (diameters of 50 mm and more). It comes with a vertical or horizontal rotor axis and its rotor is perpendicular to the water flow, that is, the rotor axis is parallel to the direction of flow.

The design of volumetric water meters is much more sophisticated. They are also called piston water meters since they operation involves the water flow around the rotating piston, inside the measuring chamber each rotation of the piston in the measuring chamber represents a given volume of water passing through. Volumetric water meters are becoming more and more popular since they stay highly sensitive at very low flow rates. The side view of the measuring chamber of the volumetric water meter is shown in Fig. 1 while in Fig. 2 the working cycle of the measuring chamber is presented.

The arrows show a direction of a water flow. The water enters through a strainer (see the photo) and is discharged on the other side of the Teflon partition [4]. This type of construction is also sensitive to solids. They can block the rotor inside the chamber since there is just a very small gap left between the chamber wall and the rotor surface. An unquestionable advantage of this meter is its resistance to interference caused by an external magnetic field. The volumetric water meter readings are not disturbed by incoming water and the meter does not require any straight pipe sections ahead. Volumetric water meters can be mounted in any position; the position does not affect their metrological properties.

The accuracy of water meters is a function of many factors that can either upset readings or even block a water meter measuring system. Recently, the amendment to the Regulation of the Minister of Entrepreneurship and Technology of March 22, 2019 on legal metrological control of measuring instruments [5] opened a possibility of water meter re-validation by the statistical method; this way validity of the certificate can be extended by 3 y. For this reason and to limit possible water losses, it is very important to closely monitor any changes in the metrological properties of water meters during their operation. [6–9].

The evaluation of the tested water meters focused on verification of their reliability and suitability for re-validation and possible reuse during the next verification period. Also, the possibility of re-validation using the statistical method was assessed.

2. Materials

The mechanical water meters were investigated; they have been dismantled after 5 y of operation, once their validity expired. The tests took into account the type of measurement system and its specific features. In this article, the authors focused on the volumetric water meters, which seems to be especially sensitive to solid particles present in water.

2.1. Methods

The approach to the research comes from the international standardization, which described the requirements for water meters [10,11].

The tests were carried out on some selected sets of water meters that had been dismantled from the system due to overdue certificates. The meters were made by various manufacturers and operated in different water supply systems. Water meters with diameters from 20 to 40 mm were dismantled and tested for 12 months. At first, each water meter had its settler and strainer rinsed and then the unit was mounted at the validation stand and subjected to a standard test, just like during re-validation. Hence, the evaluation was carried out with respect to the criterion of reading errors (as during verification) and did not take into account the permissible double error limit.

The basic rule for verification of the water meters accuracy, written in the law, defines that the tests of accuracy have to be done only on the test bench in the legalization laboratory with accreditation. The example of such a laboratory

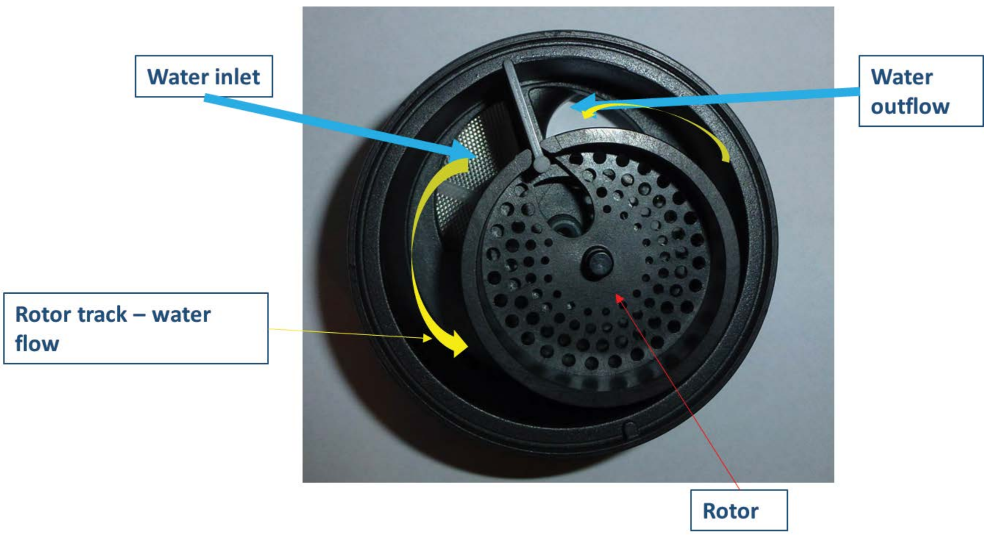

Fig. 1. Measuring chamber of the Altair volumetric water meter.

Fig. 2. Working cycle of the measuring chamber (the Altair volumetric water meter).

with computer control of the process is shown in the picture (Fig. 3).

The water in the test bench is pumped to the weighing tank. The computer chooses the quantity of water and the time of the test. After each flow rate, the program compares the indication of the water meters with the quantity of water in the tank. The difference determines measurement errors of water meters.

The water meters with false reading values, that ruled out re-validation for the next 5 y of operation, were dismantled to investigate the cause of failure using microscopic analysis. The pictures of the damaged parts of water meters were taken with 100× magnification. The authors used the digital microscope.

3. Results

Reading errors of 1,028 water meters were checked and only 141 units met the criteria for re-validation without additional repairs, for example, regeneration of parts. Most of the tested meters had nominal diameters of 20 mm (403 units) and 40 mm (489 units). Over 92% of the water meters with a diameter of 20 mm met the criteria for re-validation without dismantling and regeneration. Nearly 85% of the water meters with a diameter of 40 mm also met these criteria. The maximum permissible error for the transitional and permanent flow rate is 2% and the minimum flow rate is 5%. The water meters passing the criteria of permissible errors during the verification and failing these criteria are presented in Fig. 4.

In the case of volumetric water meters, their reading errors most often fall within the range of permissible errors or are close to –100%. It means that these water meters must have rotors blocked or very high head losses; such incidents occur mostly at minimum flow rates.

Visual inspection and microscopic analysis showed that the rotor was blocked by calcium carbonate scaling and solid particles, as shown in Fig. 5 and 6. Fig. 6 shows a microscopic view of the rotor surface covered with calcium carbonate scaling.

The water meter was cleaned with an ultrasonic cleaner to remove scaling from both the rotor and the measuring chamber surfaces; the ultrasonic cleaner removed most of the scaling. The surface (after cleaning) is shown in Fig. 7.

However, in the case of water meters that have not been dismantled, the ultrasound effect is suppressed by a metal body of the water meter. To improve the cleaning operation, a flow-through unit can be used where washing water flows inside the water meter.

In some cases, even after scaling removal with the cleaner, the water meter readings still exceeded the

Fig. 3. The test bench for water meters.

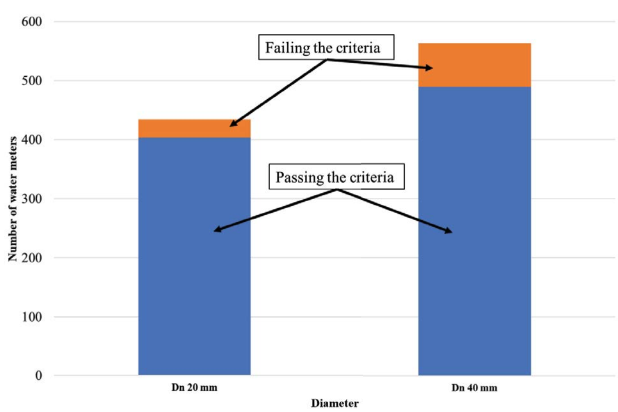

Fig. 4. Number of water meters passing or failing the criteria of permissible errors during verification.

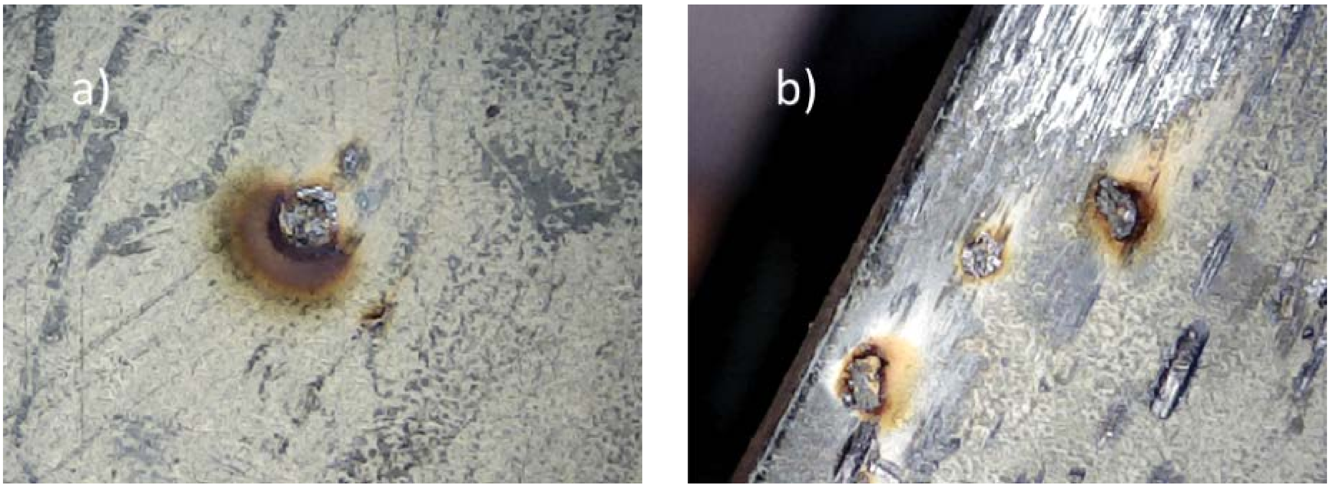

Fig. 5. Microscopic view (100x) of particles responsible for blockage of the volumetric water meter rotor.

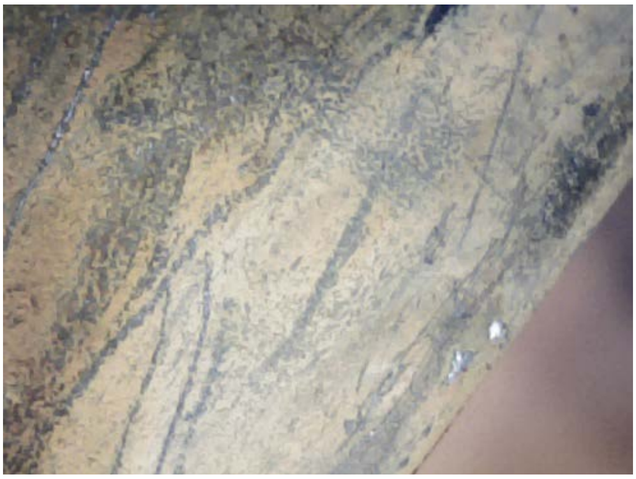

Fig. 6. Microscopic view (100x) of the rotor surface covered with calcium carbonate scaling.

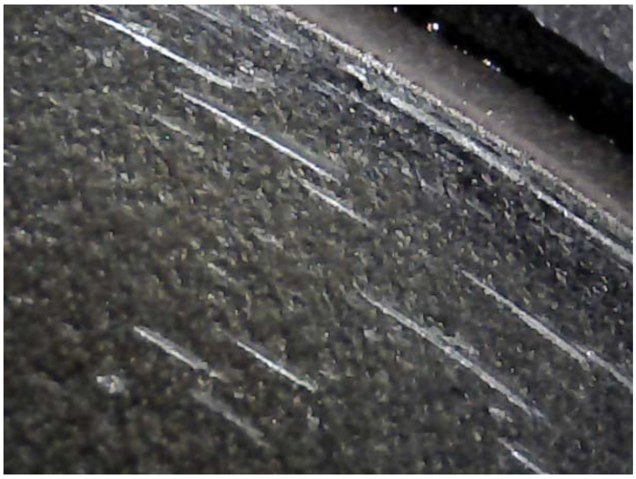

Fig. 7. Microscopic view (100x) of the rotor surface after removal of scaling with an ultrasonic cleaner.

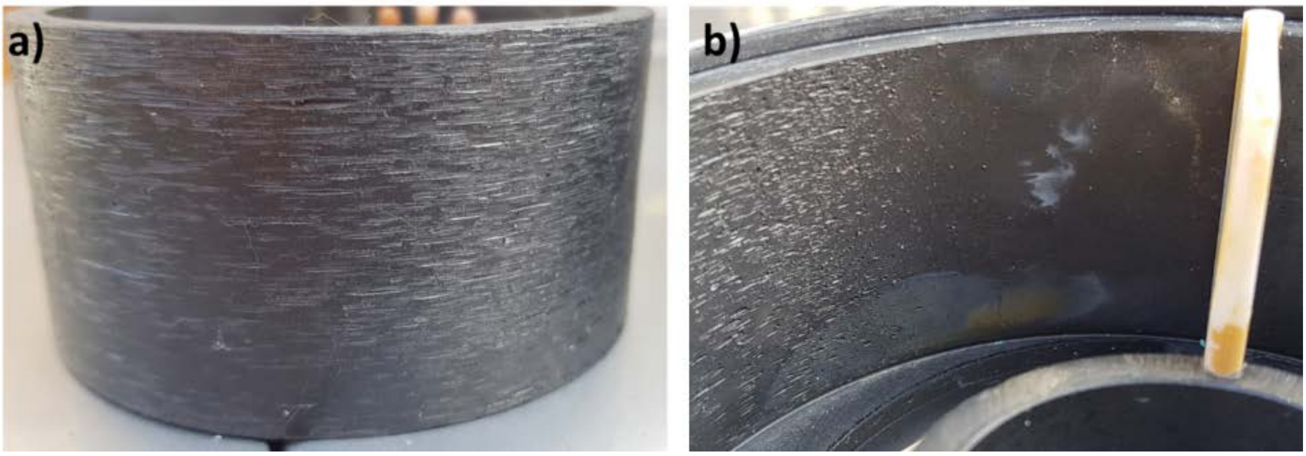

Fig. 8. Visible mechanical cracks in the volumetric water meter: (a) rotor surface and (b) – internal surface of the measuring chamber.

Fig. 9. View of the magnetic coupling of the water meter with iron deposits.

permissible error at the minimum flow rate. After dismantling several water meters it was found that the measuring chamber walls or the rotor surface had cavities – furrows, which caused additional leaks. The measuring chamber wall and the rotor surface with visible mechanical damages – "furrows" are presented in Figs. 8a and b.

In some other cases, iron particle deposits were found on the surface of the magnet – a clutch of the water meter; washing without previous dismantling also was not successful in this case (Fig. 9).

4. Summary

The studies proved good reliability of volumetric water meters and very good stability of their metrological parameters throughout the 5 y period. Over 90% of the tested water meters (a diameter of 20 mm) after the legalization period still met both operation and re-validation requirements. However, in case of a possible statistical verification, which would potentially extend the validity of the certificate by 3 y, it should be stated that the test sample would not confirm compliance with the requirements.

The studies show that the key impact for the metrological accuracy of tested water meters had the calcium carbonate and the solid particles.

The water meters with reading errors exceeding the permissible ones had their metrological parameters significantly improved once calcium carbonate deposits accumulated on the surface of the measuring chamber and rotor were removed. The study on metrological parameters helped to describe and implement a quick method of assessment of water meter suitability for re-legalization.

The studies of the reasons exceeded errors are necessary to improve the reliability of the water supply metering system.

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