ACCURATE ASSESSMENT OF UNDER METERING IN MADRID WATER SUPPLY

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ABSTRACT

Improved metrological knowledge of all installed water meters in a Water Distribution System drives to a more accurate calculation of its apparent losses.

To achieve this aim, Canal de Isabel II, Madrid Region water supply utility, undertook a research project from 2006 to 2008.

Deep analysis of data from a representative sample of over 2.000 on-site tested water meters and 6 months of continuous monitoring of consumed flows on an additional sample of 226 meters, have led to a better understanding of water meters behaviour and of the variables and parameters that can influence them, as well as of consumption flow histograms.

The valuable information provided by this project has dramatically increased the previous estimation of under-registered volumes (based on bibliography) and has contributed to a revision of criteria on sizing, replacement and maintenance policies for more efficient water meter management.

The paper will describe in detail the methodology, studied variables, development, results and conclusions of the work performed.

INTRODUCTION

The importance of deep and scientific knowledge of the accuracy of measurement of water consumption by individual installed meters is a priority for a water supply utility. Canal de Isabel II supplies water to over 6 million inhabitants in Madrid Region and has over 1.2 million meters installed to register their consumption.

There are regulations regarding the inspection and evaluation of new meters, but these do not apply to their entire useful life. A significant lack of homogenous criteria in maintenance and replacement policies of the companies in the sector is evident.

For this reason, Canal de Isabel II has established a line of investigation in its R&D&I Plan for the development of a series of projects designed to deepen this knowledge. The company has dedicated an important portion of its resources and efforts to this task.

Specifically, in 2006, a research project was undertaken, complementing other studies previously performed in the laboratory and at the user's installation, to evaluate the accuracy of domestic water meters. This project also allowed to identify and quantify the influence of diverse variables and parameters that affect accuracy.

DESCRIPTION OF THE RESEARCH PROJECT

Objectives

The objectives of the project are, on the one hand, to determine the volumetric measurement error of water meters installed in Madrid Region and its variation with relevant variables, and, on the other hand, to analyze the policies for sizing and maintaining currently applied.

Methodology

Error in the measurement of consumption by a water meter is defined as the difference between the volume registered by the meter and actual consumption.

Because measurement errors in a meter vary depending on the flow rate, this difference must be calculated by weighing the error that is produced at each consumption flow rate by the percentage of the volume that the user consumes at this flow rate.

Clearly, measurement error in a meter depends on how errors vary due to different operating flow rates, defined as their error curve, and the manner in which the user consumes water, or the consumption histogram.

The error curve of the meter (Figure 1) represents the measurement error, given in percentage, calculated for each flow rate circulating through the meter. This error is obtained by a test that compares the volume registered by the meter to the volume registered by a monitoring device or a master meter.

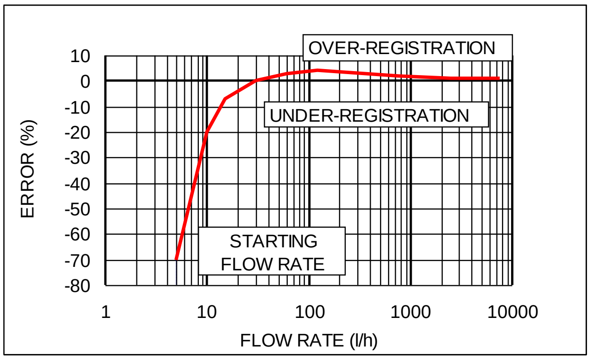

Figure 1. Generic error curve of a meter.

When the volume accumulated by the meter is less than the actual volume consumed, the error value is negative, which represents under-registration. When the volume registered by the meter is greater than actual consumption, the error value is positive, which represents over-registration.

The starting flow rate of a meter represents the flow rate value that triggers metering, or the minimum flow rate that maintains the meter in operation. This rate constitutes the starting point of the error curve of the meter.

On the other hand, the consumption histogram (Figure 2) represents the variation, given in percentage, of consumed volumes for each flow rate, or the user's consumption distribution, obtained by continuous monitoring.

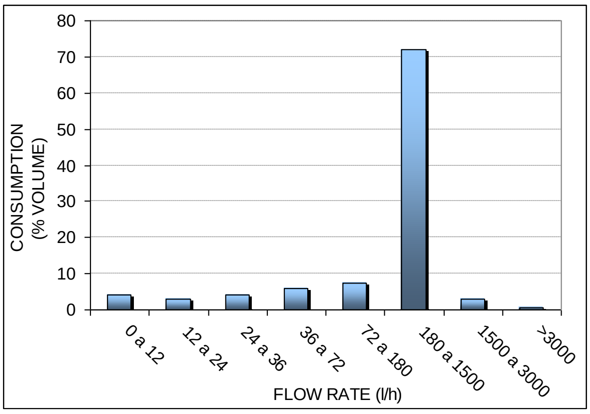

Figure 2. Example of a consumption histogram.

The weighing of the errors for each flow rate with the volumes consumed at these same rates determines the measurement error produced by the meter.

Project development

In Madrid Region, a study of 1.2 million installed meters and the consumption patterns of over 6 million users can only be accomplished by defining and establishing representative samples.

Canal de Isabel II has been engaged in the business of supplying water for over 150 years. For this reason, there is a huge variety of installed water meters with various brands and models and different metering policies of other municipal water suppliers absorbed by Canal de Isabel II in recent years.

As a consequence of this, defining a sample is highly complicated.

Seeking maximum representation, the population was stratified into several groups based on the variables that might influence the behaviour of the meters: diameter, model, metrological class, age, registered consumption, environmental conditions…

These variables were weighed according to their influence on the objectives of the study. For example, the oldest meters are more heavily represented in the sample than they should correspond to the population, because their behaviour seems to be more relevant.

To reduce the possibility of reaching erroneous conclusions for a group due under-representation, the sample assigned, for each group, a minimum number of meters to be tested.

Considering all above, a sample of approximately 2.000 meters having diameters between DN13 and DN40 were defined to determine the error curves representing 98.6% of the installed base of water meters.

Similarly, another sample of 226 users was selected to determine the consumption histograms. To define this second sample, stratification criteria based on geographic distribution, dwelling type (single-family, multi-family) and size, degree of occupation, number of bathrooms, the existence of a garden, etc., were taken into account to ensure full representation.

Once the samples were defined, specific devices and equipments were suitable designed and manufactured for working on-site, in order to ensure the acquisition of reliable data.

The devices defined to perform the field tests of meters had the following requirements: highly accurate master meter, reliable system of recording data, ease of use, autonomy, portability, robustness, and limited size and weight.

The reference or master meters were volumetric class C, with rotary pistons and pulse emitters.

The above mentioned devices are equipped with a series of regulation valves to precisely adjust the different test flow rates. These flow rates vary from the starting flow rate to the maximum one, for each diameter of the meters selected to be tested.

The devices also included cut-off valves, the necessary protection filters, purging valves, pressure and temperature gauges, a data logger and a laptop.

In order to certify the suitability of the devices and validate them, they were subjected to repeated verification cycles in the laboratory to determine the error inherent in each and the uncertainty associated with their measurements.

Similarly, the devices were subjected to successive verifications during the entire field tests period to ensure their metrological characteristics. The master meters were substituted when it was relevant.

A patent application to the Spanish Patent and Brand Office has been submitted thanks to the innovation represented by these devices

On the other hand, the devices needed for determining the consumption histograms by monitoring, were equipped with highly accurate volumetric meters with rotary pistons and data loggers, capable of registering very low flow rates, from 1 litre per hour.

It was necessary to perform over 6.500 inspections of installed meters, before obtaining the 2,000 field tests of error curves (Figure 3) foreseen in the established sample.

Besides, 226 selected users were monitored during a 6 months period to obtain the consumption histograms.

Not just any meter is suitable for testing. The defined test procedure required total absence of leakage, and stability in flow rates and pressure during the test period. Also, it was necessary to take into account diverse technical and logistical considerations required by previous mentioned inspections performed to find suitable locations.

In addition, not all the tests that were performed were valid. In case of rejection, the test should be handled again, using alternative locations corresponding to meters in the same sample group.

Figure 3. Example of a field test.

The field tests were carried out by suitably qualified operators following a defined and structured procedure to verify the absence of trapped air and water leaks in the installation, as well as to set the accurate adjustment of the test flow rates, the stability of the flow rate and pressure value, and finally to determine the starting flow rate of the meter by gradually reducing the test flow rate.

The measured error of the user's tested meter was corrected by the inherent error of the verification devices for the same flow rates, which were determined, as previously mentioned, in the laboratory.

The data obtained from the field tests and monitoring were subjected to statistical cleansing procedures to detect and eliminate atypical and/or erroneous values. Subsequently, the cleansed samples were verified to ensure both remain representative.

RESULTS

After the data analysis and the study of the influences of different related variables, the error curves for installed meters ranging from DN13 to DN40, were determined (Figure 4).

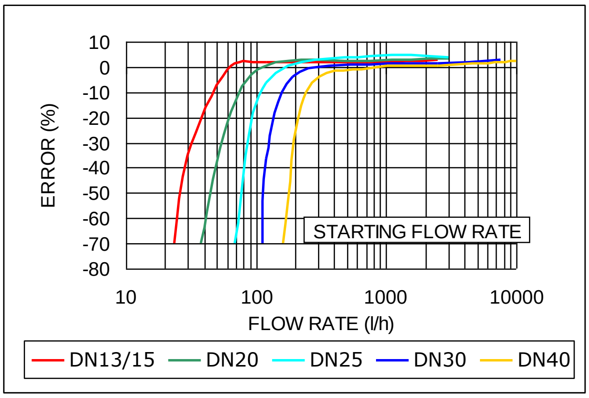

Figure 4. Error curves for meters with diameters between DN13 and DN40.

In a similar way, the consumption histograms of users with domestic meters and diameters between DN13 and DN40 were defined. (Figures 6 and 10).

CONCLUSIONS

An examination of the abovementioned error curves (Figure 4) shows a marked under-registering in the range of low flow rates for each diameter and a slight over-registering for the rest of the flow rates.

The starting flow rate of the meters increases with their age, diameter, consumption and exposure to environmental conditions.

It was observed that for any diameter, class C meters show lower starting flow rates than corresponding class B ones.

A deviation (Figure 5) can be observed in the accuracy of the meters, once installed, with respect to the metering criteria established in the regulations for new meters.

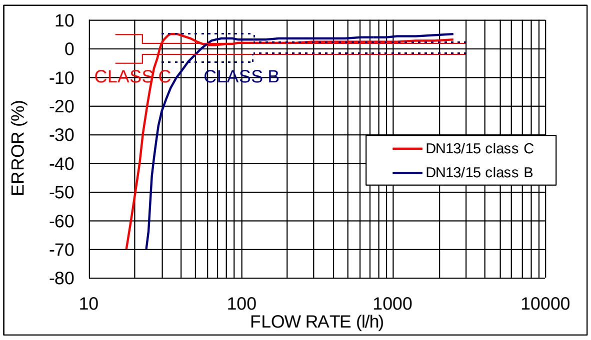

Figure 5. Error curves of class B and C DN13/15 meters with a maximum age of 2 years.

No correlation of any kind was detected between pressure or water/ambient temperature and the error curves, in the study of the influence of these variables.

The weighing between the histograms and the error curves allows to analyze the "under-registered" and "over-registered" consumption for each flow rate and each diameter in the group of studied domestic meters (Figures 6 to 10).

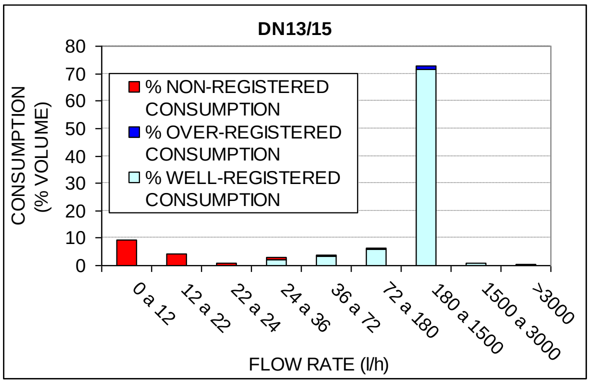

Figure 6. Under-registered and over-registered water volumes in the DN13/15 consumption pattern.

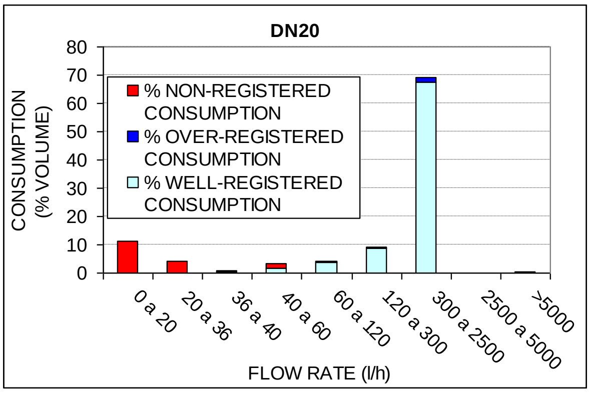

Figure 7. Under-registered and over-registered water volumes in the DN20 consumption pattern.

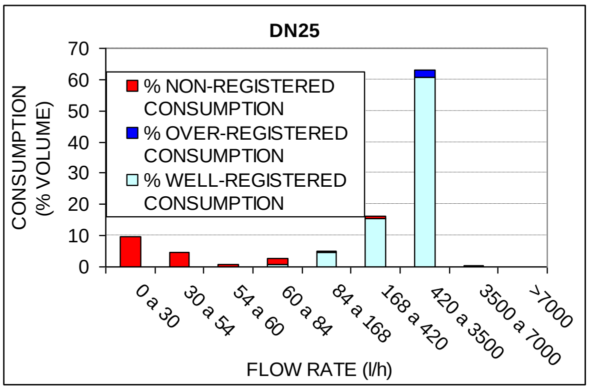

Figure 8. Under-registered and over-registered water volumes in the DN25 consumption pattern.

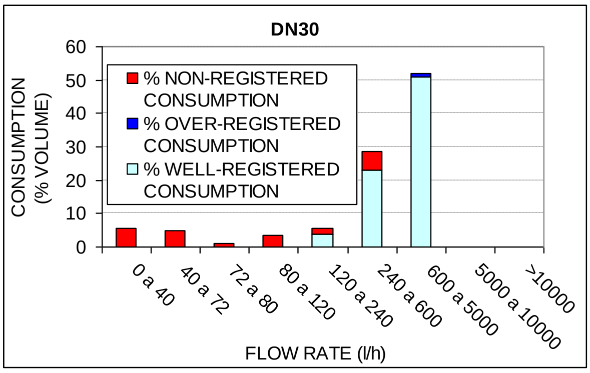

Figure 9. Under-registered and over-registered water volumes in the DN30 consumption pattern.

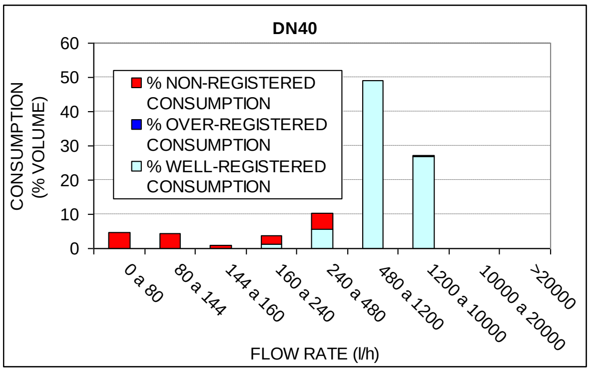

Figure 10. Under-registered and over-registered water volumes in the DN40 consumption pattern.

In all previous cases, for each studied diameter, it was observed that the influence of the water meters' negative error values was greater than that of its positive values, meaning that the volume registered by these meters were, in net terms, lower than actual consumption.

Comparing the total under-registered volume to the total volume registered, the global error of the installed base of domestic meters of diameters between DN13 and DN40 represents –14.32% of the total measured.

Regarding the sizing criteria for the meters, it was observed in the defined consumption histograms, that the majority of consumption occurs at flow rates that coincide with the nominal flow rates for each diameter, which in principle drives to validation of these criteria.

However, greater disaggregation of the flow rate intervals of the consumption histograms close to the abovementioned nominal flow rates reveals a small discrepancy, indicating moderate over-sizing for all the diameters studied.

It was also observed in the histograms that there is a percentage of the consumption that occurs at very low flow rates which cannot be registered by the meter, or which is registered as a minimal fraction. This is because at this range the meter's error flow rates show very high negative values (under-registering).

An analysis of the variation in the accuracy of the meters and their influencing variables leads to the conclusion that the useful life of the meters increases as their metering quality improves, in accordance with the comparative study performed of class C and class B meters.

It is important to precise that the class C meters analysed use an axial turbine and therefore their results cannot be extrapolated to the conclusions obtained for meters with other structural characteristics.

With respect to the evolution of meters with age, large errors in starting measurements were observed for newer meters and those recently installed. These errors were much more influential than those due to age deterioration.

Except in the case of operating errors, the class B meters up to DN30 should be replaced after 12 years and the DN40 meters after 7 years.

Class C meters could remain installed for even longer. In these cases, life battery would be more important than the loss of accuracy for renewal and maintenance policies.

Further information at Canal de Isabel II R&D&I Booklets.

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