Key Factors affecting Water Meter Accuracy

Francisco Arregui*, Enrique Cabrera Jr., Ricardo Cobacho, Jorge García-Serra

* farregui@ita.upv.es. Institute for water technology. Universidad Politecnica de Valencia.Valencia (Spain)

* qcabrera@ita.upv.es. Institute for water technology. Universidad Politecnica de Valencia.Valencia (Spain)

This paper was presented by Francisco Arregui at the IWA Water Loss Conference in Halifax, Canada, in September 2005.

KEY FACTORS AFFECTING WATER METER ACCURACY

Francisco Arregui*, Enrique Cabrera Jr., Ricardo Cobacho, Jorge García-Serra

* farregui@ita.upv.es. Institute for water technology. Universidad Politecnica de Valencia.Valencia (Spain)

* qcabrera@ita.upv.es. Institute for water technology. Universidad Politecnica de Valencia.Valencia (Spain)

Keywords: Water meter performance; water meter accuracy; apparent losses

Introduction

As any other measuring device, a water meter is not an ideal instrument and is not capable of registering the exact amount of water consumed by a user. Every water meter, no matter its type, has considerable measuring limitations. Often, part of the water that is consumed is not registered and therefore not charged to the customer. Other times, depending on the water meter technology, some particular factors may lead to the opposite result, that is, to an over registration of the water consumption. In any of these two cases, since water meter inaccuracies are recognised as a critical component of apparent losses, it is important to be capable of quantifying the magnitude of these measuring errors.

Nowadays there is a general lack of information, based on real data, about the actual effect of different parameters in the performance of water meters. Hence, technical staff in the water utility has to evaluate or estimate water meter accuracy, and analyse the factors that may have any influence on it, without the help of bibliographic reference or external experience.

This paper presents real field and laboratory data on how several factors may affect the water meter accuracy for both, domestic and industrial type of meters, and different technologies, single jet, multiple jet, oscillating piston, Woltman and Tangential meters. Particularly the influence of the following parameters in the water meter metrology will be analysed: mounting position, velocity profile distortions, fatigue tests, depositions, partial blockage of the strainer or the water meter inlet, incorrect water meter sizing, water consumption patterns and the presence of user's storage tanks.

As a result of the experiments it has been clearly shown that not every water meter has the same sensitivity to the previous parameters. Furthermore, diverse meter models of the same technology present very different behaviours depending on the specific construction characteristics of each instrument. Consequently, to reduce the magnitude of the apparent losses and to guaranty an accurate water measurement, it is not only important to select the adequate metering technology but also the right construction that suits the specific characteristics of the water supply system.

The paper is divided into two parts. The first dealing with factors that may affect domestic water meter accuracy and the second describing the most common problems in registering non-domestic water consumption.

Domestic water meters

Most domestic water meters are usually of the types single jet, multiple jet, oscillating piston and nutating disc. The latest technology is strictly used in North America while single and multiple jet water meters are widely used in rest of the world.

Volumetric water meters are insensitive to many of the influence factors that affect velocity meters. However water quality and suspended particles greatly degrade the water meter accuracy curve and in some cases produce a definitive blockage of the meter.

On the other hand, velocity meters are affected by flow distortions or dimensional changes in the meter that may interfere with the internal velocity of the flow passing through the instrument. Velocity meters are also sensitive to any increment in the drag torque on the sensor element especially at low flows.

Following important influence factors that affect the accuracy curve of domestic water meters depending on their technology are review.

Mounting position

An incorrect mounting position of the water meter increases the friction of the moving parts. The effect is only noticeable at low flows for which this term is relevant in the effective drag torque.

Table 1 shows an example of how this factor increases the measuring error at low flows, 22.5 l/h, on class B and C single jet meters. The results shown for each model is the average error of 35 meters.

Table 1. Domestic single jet water meters accuracy loss at 22.5 l/h. (Qn 1.5 m^3/h)

	Model 1 Class C	Model 2 Class B	Model 3 Class B	Model 4 Class C	Model 5 Class C
Horizontal mounting	1.5%	-0.6%	-5.7%	0.3%	0.2%
45º Mounting	-2.9%	-10.1%	-37.9%	-2.6%	-4.5%
Error Difference	4.4%	9.5%	32.2%	-2.9%	4.7%

As it is clearly seen the results are significantly different for each water meter, even for the same metrological class. This is because the friction increment caused by the mounting position varies depending on the design of the impeller bearings used in each meter. As a general rule it can be said that the error at low flows becomes more negative although for flows higher than the transitional flowrate the accuracy is maintained.

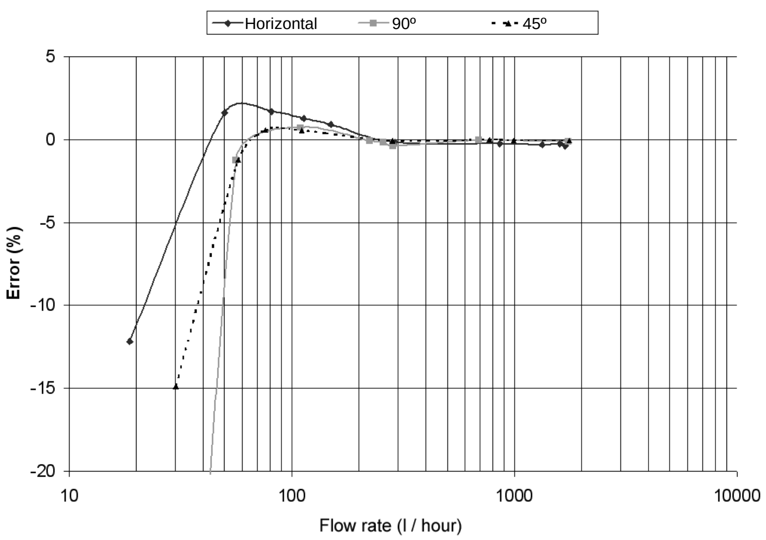

Figure 1. Accuracy curve of a 15mm single jet water meter at different mounting positions

Another important consideration about the mounting position is that if it is not correct, according to the manufacturer recommendations, it may lead to a higher degradation rate of the meter. The reason is that in such cases the moving parts or the meter are not working and standing properly.

The final economic impact of these higher errors at low flows depends on the water consumption patterns of the users and, of course, the water price. A rough estimate of the magnitude of the under registration caused by this factor in domestic consumers can be enclosed between 1% or 4% of consumed water, depending on the case.

Accelerated fatigue tests performed on domestic single jet meters

Water meters are designed to work under severe conditions for a long time. The wear of the moving parts tend to increase the friction torque on the sensing element (impeller, piston or disc) in any instrument. For that reason, as before, wear increases the error at low flows, where the friction torque is a significant component of the total drag torque. However, this effect has little or no effect at medium or high flows.

As described in the work carried out by Bowen et al. (1991) oscillating piston and nutating disc water meters are always predisposed to under register water consumption. The case of the velocity meters is similar. However, for these meters, is not necessarily always true that error become more negative. Figure 2 shows the fatigue test performed in the laboratory of the *Institute for Water Technology* for four models of class C single jet water meters. A total volume of 1500 m^3 of intermittent flow (2250 l/h), with a period interval of 15 seconds, passed through each meter during the test.

Only model 1 was capable of maintaining at the end of the experiment the accuracy curve at low flows close to the original. The remaining models exhibited a greater degradation in the lower range, while at medium and high flows the error for every model was maintained.

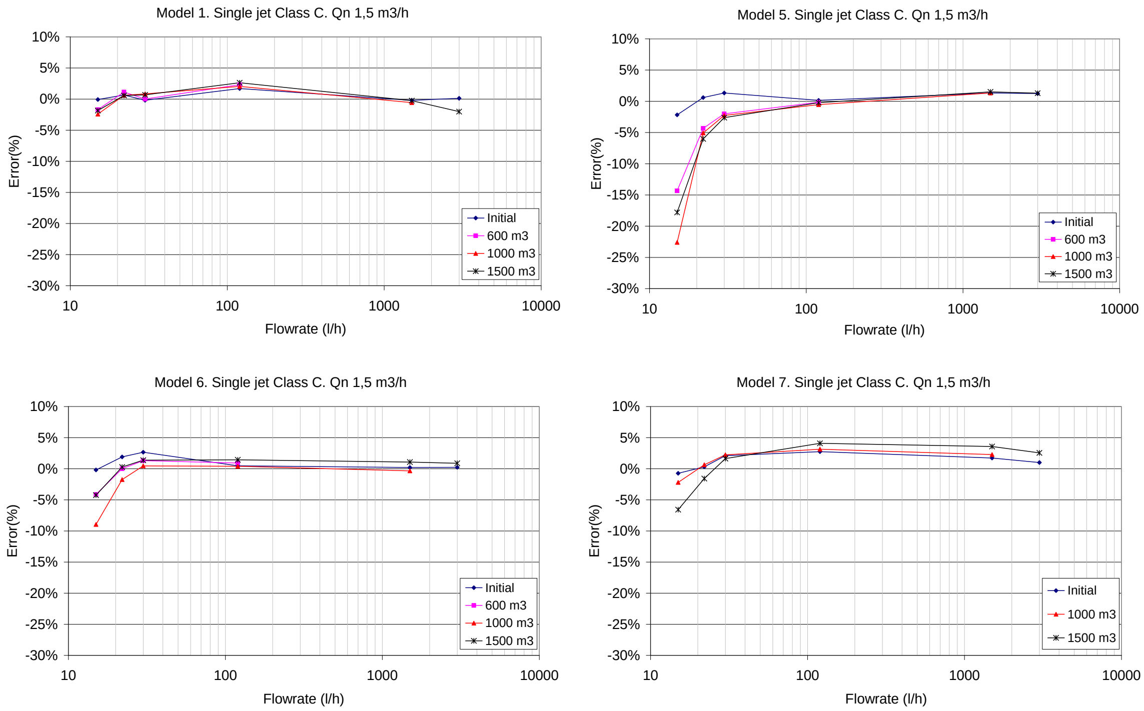

Figure 2. Fatigue tests performed for single jet water meters

Suspended solids and depositions

Water meters are significantly affected by these two parameters. Positive displacement meters may stop when a particle bigger than the spare space between the piston/disc and the chamber passes through the strainers of the meter. Although this element is designed in such a manner that in theory this can not happen, practice shows that it is possible.

The effect on velocity meters can be significantly different depending on its construction. For many designs, in first instance, depositions may cause over registration, at medium-high flows and under registration at low flows. However, on the long term, depositions grow so large that they can prevent the impeller from rotating, temporarily or permanently, causing a severe under registration of the meter. One of the reasons for such behaviour is the adjusting device used in multijet and some single jet water meters to bring the accuracy curve into the permissible error interval. This type of adjusting device derives some of the water through an alternative circuit, by-pass conduit, reducing the energy transfer at a given flowrate to the impeller.

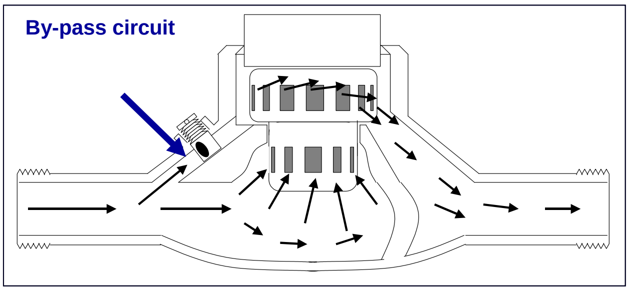

Figure 3. Adjusting device of a multi jet water meter

Some single jet designs, which use a hydraulic brake as an alternative adjusting device, are not so likely to show over registration. However, even for these meters, under some circumstances, metering errors can be of a considerable magnitude. Figure 4 shows the inside of a single jet water meter of this type in which a limescale built-up appeared. In this specific unit the over registration all over the range was close to +25%.

Figure 4. Limescale built-up in the inside of a single jet water meter housing

Leaks and user's storage tanks

Water consumption at low flows is the most difficult to measure. As it can be seen in any accuracy curve of any water meter, measuring errors are much larger in this range. Under these working conditions the energy transfer from the fluid to the sensing element is very small and any increase in friction, caused by any factor, may stop the impeller or the piston at lower flowrates. For that reason, the under-registration expected from a meter installed in a user which consumes a great amount of water at low flows is very high. Furthermore, considering that the accuracy of a water meter decays at a faster rate at low flows, this under-registration will increase more rapidly than in other type of users.

An example of the influence of a private storage tank, in water consumption patterns on a domestic user, is shown in Figure 5. It describes a typical consumption pattern caused by the refilling of the tank during one hour. Like in the time interval presented (Figure 5 left), the maximum flowrate detected during the 15 days in which the measurements took place is less than 500 l/h. Even worse, because of a leak of approximately 10 l/h in the inlet valve of the tank, for this user, more than 35% of the total volume was consumed at flows, lower than 12 l/h. A typical class B, 15 mm, single jet would present severe under registration of water consumption, being more adequate for this user positive displacement meters or smaller size single jet (Qn 0.6 m^3/h).

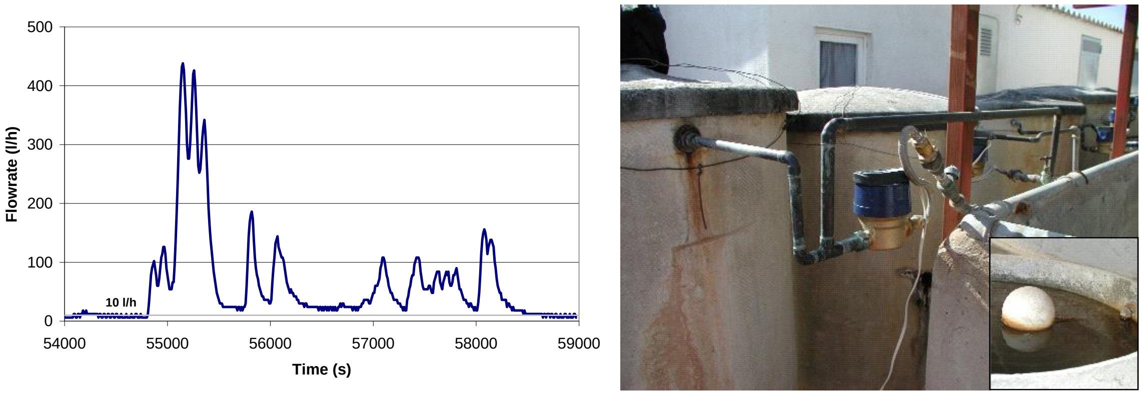

Figure 5. Influence of a private storage tank in domestic water consumption patterns

Obviously, a water supply system with this type of user will probably have serious problems in measuring water consumption, even with high metrological class meters. Besides, the replacement period needed to maintain the inaccuracies below a critical level will have to be very short.

Partial blockage of the inlet strainer

Some water meters are sensitive to the momentum of the water impacting on the impeller or the turbine. For that reason, a partial blockage of the inlet strainer may affect the accuracy of the meter. In practice, it can be proved that this parameter may only affect domestic single jet meters, while displacement and multi jet meters are insensitive to it.

To study the influence of this factor a set of experiments were performed. For such purpose, the inlet filter was blocked in two different ways. The first, reduced the entrance diameter (Figure 6.b) concentrating the flow in the central area. The second diminished (Figure 6.c) the entry section to the meter impeller in a random way.

Figure 6. Partial blockage of the inlet strainer of a single jet meter

The results of these experiments is summarised in tables 2 and 3, where the error variation with respect the reference error, with no distortions, is calculated for each meter. The first type of blockage, characteristic of an incorrect gasket mounting, led to significant positive errors. For the same disturbance, the error variation depended on the original inlet diameter (3/4" or 7/8") and the meter's length. The errors caused by the second type of disturbance were much smaller than for the first one. The reason is that, in this case, there is not a single high velocity jet passing through the disturbance, like occurred with the gasket, but multiple jets distributed along the entrance section. A velocity profile disturbed in this way needs a shorter distance to become again similar to a fully developed profile. This type of disturbance may be cause, for example, by particles blocking the inlet strainer.

Table 2. Error variation with respect the reference error of the meter for type 1 disturbance (Figure 6.b)

Flowrate (l/h)	***Model A***	***Model B***	***Model C***	***Model D***	***Model G***
1500 l/h	-1,2%	16,2%	4,8%	4,6%	-0,4%
400 l/h	-1,4%	16,2%	4,0%	-0,1%	-0,9%

Table 3. Error variation with respect the reference error of the meter for type 2 disturbance (Figure 6.c)

Flowrate (l/h)	***Model C***	***Model E***	***Model B***	***Model F***
1500 l/h	1,7%	0,2%	0,2%	-0,8%
400 l/h	0,4%	-0,7%	0,3%	-0,2%

Industrial water meters

Apart from the influence factors described above for domestic meters, industrial and commercial water meters measuring errors are much more sensitive to velocity profile distortions and proper meter sizing.

Influence of velocity profile distortions for non-domestic water meters

How much the accuracy curve is affected by an upstream flow disturbance depends on the meter technology. Table 4 gives a rough approximation of the theoretical sensitivity of different technologies to this influence factor.

Table 4. Sensitivity of different technologies to flow profile distortions

Water meter technology	**Flow profile sensitivity**
Oscillating piston	Insensitive
Nutating disc	Insensitive
Single jet	Low sensitivity
Multi jet	Very low sensitivity
Horizontal Woltman	Medium sensitivity
Vertical Woltman	Low sensitivity
Irrigation meters (paddle wheel)	High sensitivity
Proportional meters	High sensitivity

More specifically, figure 7 shows the results of the tests carried out to study the real influence of a gate valve installed 3D upstream of four types of water meters. As it can be seen, for all instruments tested but for the paddle wheel meter, a length of straight pipe of 3D was enough to mitigate the influence of the distorted flow profile produced by the gate valve, no matter its opening. In these cases the error laid in the 2% error band.

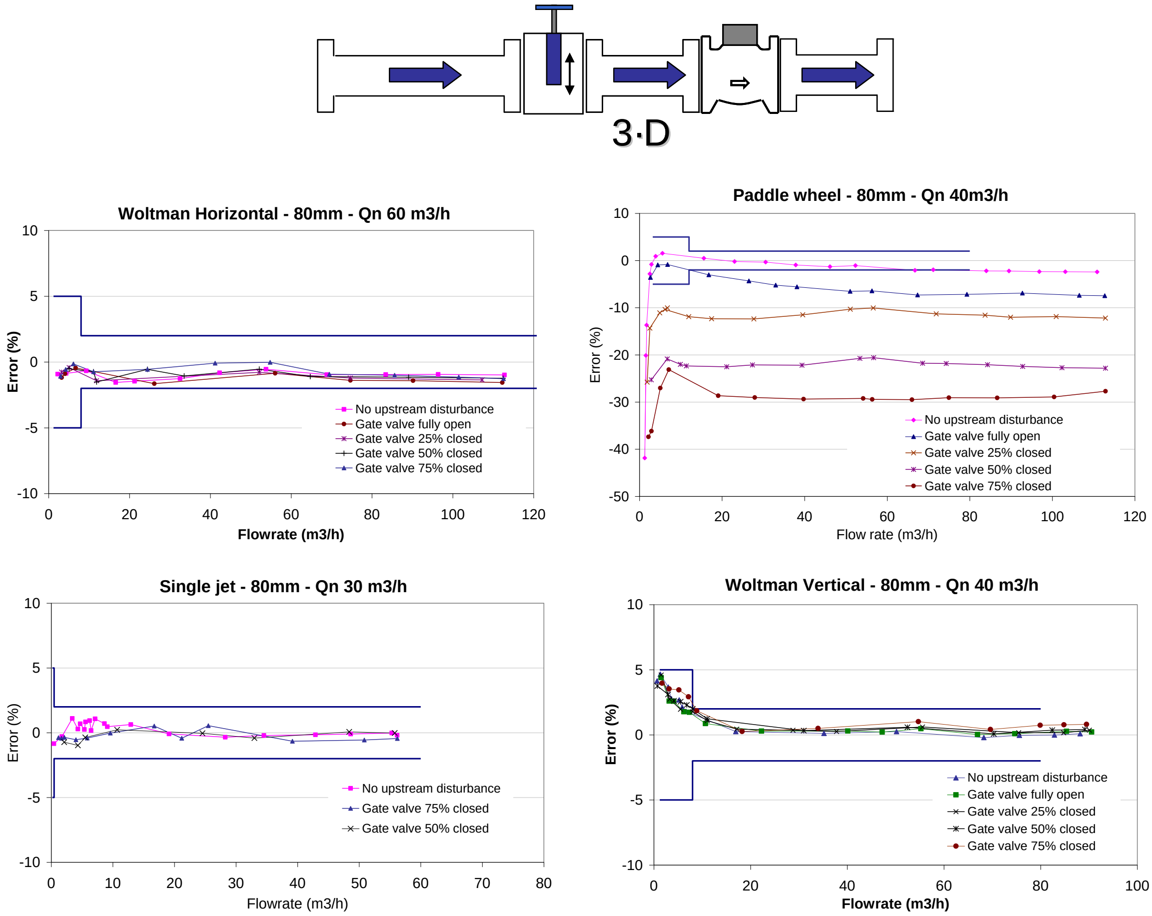

Figure 7. Influence of velocity profiles distortions caused by a gate valve on four water meter technologies

However, it should be noted that for other types of flow disturbances which produce swirl, like two consecutive perpendicular bends, the influence on the measuring error can be much more severe that the ones presented, even with longer lengths of straight pipe.

For that reason, because of the importance of this parameter in the actual metering accuracy, the latest developments of the standards ISO/FDIS-4064:3 (5.12) and EN-14154:3 (5.9) define a set of tests in order to evaluate the influence, on the error of indication, of flow profile irregularities upstream the water meter. For such purpose, these standards specify different types of flow disturbances for which the meter should not exceed the maximum permissible errors. The classification of water meter sensitivity is done on the basis of the length of straight pipe needed between the perturbing element and the instrument to meet the maximum permissible error requirement.

Water consumption patterns

The error of indication of a water meter is a function of the circulating flowrate. Therefore the ability of that instrument to accurately measure water consumption strongly depends on the flowrates at which consumers use water. Furthermore, the degradation rate of the accuracy curve it is different depending on the flowrate. The error at low flows decay much faster than at medium or high flows. Finally, a water meter functioning frequently at high flows will degrade much faster than other which always works below nominal flowrate.

Therefore, if the water meter is too large, consumption flowrates will be low for the meter, and the measuring error will be significant even from the first day of installation. On the contrary, if the water meter is too small, the accuracy degradation rate will be much higher. In this case, it is possible that the water meter registers accurately water consumption at the beginning. However, in a short period of time, the mobile parts or the pieces in contact with them, will break down leading to significant metering errors.

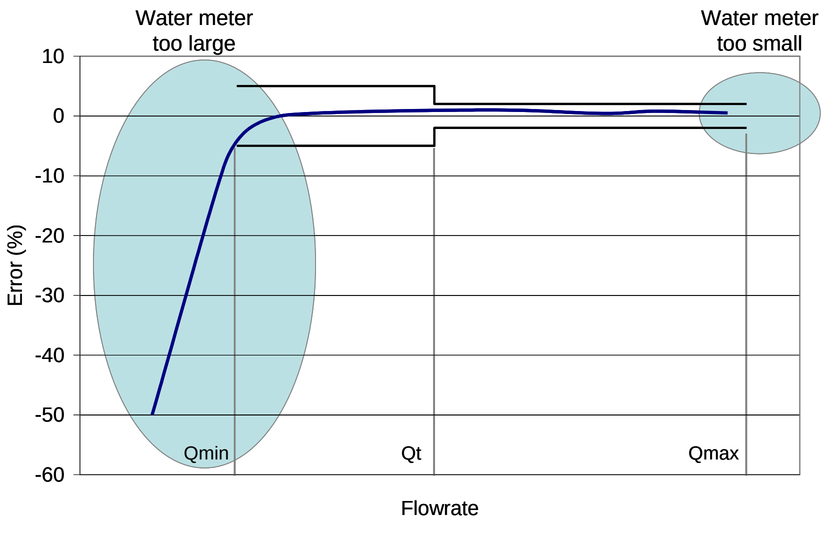

Figure 8. Importance of proper meter sizing.

The sizing difficulties appear with non-domestic users since, for these consumers, the actual circulating flowrates are much more difficult to predict in advance. In contrast with domestic users, these consumers are equipped with many different types of appliances and the user's pipe system configurations may be completely different even for the same category of user.

Often, utilities own simple sizing rules that are used to select the nominal flowrate of the meter. However, also too often these rules are too simple or use criteria that nobody in the company knows where they come from. For that reason, is not surprising finding a high percentage of industrial and commercial meters which are not properly sized.

Water utilities can use the following strategies to find the right meter size for every customer. These strategies are ordered from the most simple and inaccurate to the most sophisticated:

- Use standard tables produced by meter's manufacturers to size the instrument according to the daily water consumption of the user. The problem with this method is that the actual consumption pattern will differ a lot from the predicted one. It is possible that a customer uses a large amount of water at constant low flows.
- Record water consumption flowrates using the installed meter and an external data-logger. This procedure for estimating consumption flowrates is subject to the actual measuring errors of the installed meters. It is not convenient to use this method to predict the percentage of water consumption at low flows since its determination depends on the accuracy of the meter in this range
- Measure actual flowrates using an external flowmeter, ultrasonic or insertion type. This method is only valid to detect consumption at high flows. As the previous one, it is not suitable for measuring low flows. Special care should be taken when using this type of instrumentation, which is subject to a high level of uncertainty.
- Replace the user's meter by a reference one, previously calibrated in laboratory. This method is by far much more expensive than the others. However, the results obtained are much closer to reality. If the reference meter is chosen adequately this procedure allows estimating consumption at both, low and high flows.

As an example of a typical situation which may lead to under registration of water consumption due to an improper sizing of the meter, consider the case described in Figure 9. This user, under investigation, is a non-domestic user which corresponds to a 4 star hotel with 196 rooms. Measurements were taken for 51 days in which the average water consumption was 25 m^3 per day. The flowrate distribution is shown in Figure 10 and, as it is seen, only 2% of the water is used above a flow rate of 10 m^3/h. The reason for such low flows associated to large water consumption can be found in the intermediate reservoir placed between the meter and the appliances installed in the hotel (Figure 9).

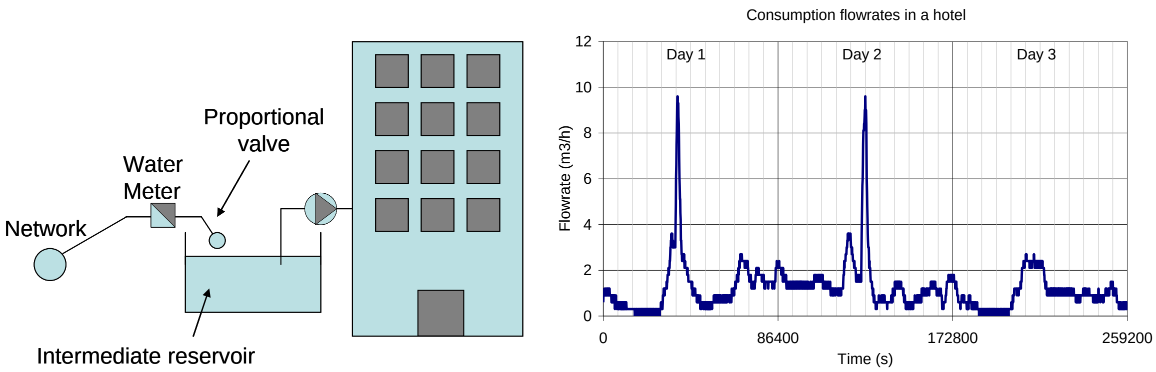

Figure 9. Flowrate through the meter refilling the intermediate reservoir

For this user the water utility selected a 50 mm horizontal Woltman meter, class B, with a nominal flowrate of 25 m^3/h. However a 40 mm, Class C, single jet meter would be a much better option. Furthermore, taking a closer look to the water consumption pattern of the hotel, it is observed, that the flowrate barely goes beyond 10 m^3/h. Only 0.16% of the time, that is 14 hours per year, the flow exceeds that value. In such case a 30 mm water meter, with a nominal flowrate of 5 m^3/h, could measure much better the low flows that constantly run through the meter and refill de reservoir.

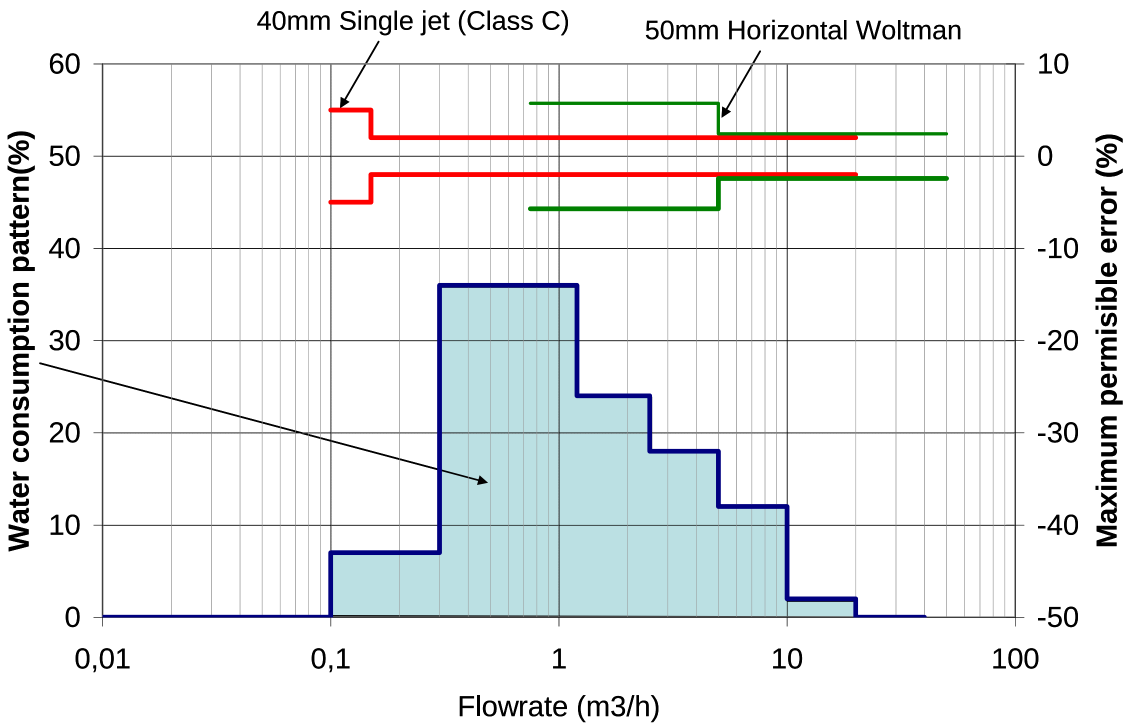

Figure 10. Water meter selection based of the water consumption profile of the hotel

Conclusions

Many are the parameters that affect water meters accuracy. This paper review some of them for both domestic a non-domestic meters.

For domestic water meters the following parameters are reviewed: mounting position, fatigue tests, depositions, partial blockage of the strainer or the water meter inlet and the presence of user's storage tanks.

On the other hand, the main parameters that need to be taken into account when measuring non domestic users are velocity profile distortions that can modify the accuracy curve of the meter and meter sizing procedures.

References

Bowen P.T., Harp J.F., Hendricks J.E. and Shoeleh M. (1991). Evaluating residential meter performance. American Water Works Association Research Foundation . *Denver, CO*. USA.