An integrated approach to large customer water meters management

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ABSTRACT

Large customers although small in number represent a significant portion of water volumes registered by meters in a water supply system. As a result, an improved large meters management can provide, with limited effort, excellent results for recovering commercial losses. This particular feature is acknowledged by many water utility managers which select this type of meters as the starting point of their programs for improving meter management.

Although, in essence, the principles of large water meters management are basically the same as the ones applied to small meters, large customer meters require specific and particular care. It should not be forgotten that the amount of money involved in economic transactions between water utilities and large customer does not allow for any miscalculation. The slightest error drift may lead to a considerably economic loss. This is why installation and acquisition costs of large meters are in most cases negligible with respect the value of the water sold to the customer.

Consequently, large meter replacement programs should always analyze the total costs of the meters, i.e. initial costs (understood as the initial acquisition and installation costs) plus the costs related to the operation of installed meters that include not only maintenance costs but also, as it has been said, the cost of the water volumes used by the customers and not paid for.

In Arregui et al. (2011) a graphical method to calculate the optimum replacement period of water meters was presented. The proposed chart was the result of a mathematical model which considered all economic costs taking part in the life cycle of a water meter.

GENERAL CONSIDERATIONS FOR MANAGING LARGE CUSTOMERS

Meters for large customers, because of their importance, need to be selected with extreme caution. Consequently, it is essential that water meters managers realize how important the following factors are in order to attain the best measuring performance:

- The shape of the error curve can play a significant role depending on the water consumption pattern of the user (Arregui et al., 2006). It cannot be assumed that the error curve of a new water meter is flat and close to zero at every flow rate. The error curves of many meters types show peculiar shapes depending on their design which can even have a decreasing or increasing slope (meaning that the error changes with the flow rate).
  As shown in Figure 1, a one year old water meter can have an error curve with greater errors (more negative) than a three years old meter. In such cases, a faulty meter installed in a large customer facility will for sure cause a considerable economical loss.

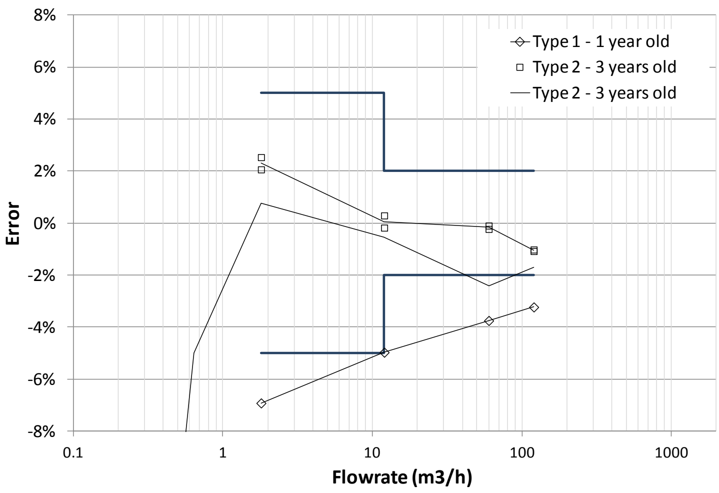

Figure 1. Error curves of two types of Woltmann meters (100 mm)

Consequently, it cannot be assumed that all new water meters have the same error curve shape. Even if the error curve is within the maximum permissible errors allowed by the standards (Typically set by the ISO-4064 or AWWA recommendations) the amount of water that two different water meters may measure for the same customer may differ by more than 2%. This small but important (in economical terms) difference will be hardly identified by the analysis of billed volumes).

From the above comments it is clear that water companies need to be perfectly aware of the error curve shape of each water meter type before they initiate any procurement process. In case that an economic assessment of all options is conducted water companies should not only include the acquisition cost but also the cost of the expected cost of the unregistered water.

- Furthermore, it cannot be assumed that all delivered meters meet the required specifications. Some manufacturers produce water meters with higher quality standards than others. However, regardless of the water meter supplier it is highly advisable to conduct an initial metrological performance test of a significant sample of all procured batches. This will ensure that all the procured meters still perform according to the expectations of the water company.
- As with domestic meters, customers' water consumption patterns can modify the amount of water registered by the meters (Grothaus R., 2007). For example, for meter type 1 in Figure 1, is not the same that 90% of the consumption takes place at 100 m^3/h, for which the error of the meter is approximately -3%, than at 4 m^3/h, for which the error is -6%.

  Water consumption pattern may also have influence on the degradation rate of mechanical meters. Obviously a high monthly consumption will reduce the lifespan of the meter when it is expressed in terms of years from installation. However, in terms of volume, a high monthly consumption may enlarge the lifespan of the meter.

  On the contrary, large flow fluctuations or flow rates higher than the maximum flow rate of the meter can damage mechanical meters (Figure 2). In some cases, damage to the meter may be easily identified from the analysis of the commercial system. However, due to typical the variability of water consumption of this type of users it is quite likely that the damage to the meter remains unidentified for two or three billing periods.
- Some meters design may fail under specific working conditions: presence of air in the pipes, presence of debris and suspended solids, low pressure conditions, frequent water transients,… For this reason installation sites should be inspected and properly protected. Meters for each installation site should be selected according to the specific site working conditions. For example, an electromagnetic meter should not be installed in areas with frequent service interruptions and low pressure conditions. In such cases a mechanical meter will probably exhibit a better measuring

performance. On the other hand, a mechanical meter will fail in a short period of time when installed in areas with a high content of suspended particles or is subject to frequent pressure and flow fluctuations.

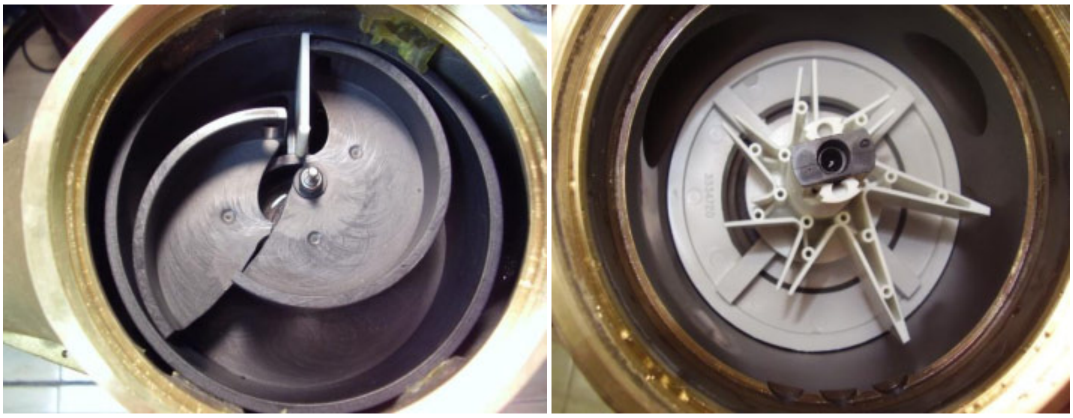

Figure 2. Examples of broken mechanical meters because of high flows

- Flow profile distortions upstream the meter does not affect all meters to the same extend (Burke and Hannah, 2010). New standards classify water meters according to their flow profile distortion sensitivity. More specifically, according to ISO 4064:2005 a water meter should be marked according to its "class on sensitivity to irregularities in the velocity field". The marking consists of the letters U (upstream) and D (downstream) followed by a number indicating the length of straight pipe required upstream and downstream the meter to ensure that the error will not vary excessively from the one obtained for an undistorted flow profile. For example a meter marked as U6/D3 need 6 diameters of straight pipe upstream the meter and 3 downstream to be unaffected by any type of flow profile distortion.

  Therefore, in those installation sites in which there is not enough space to ensure an undistorted flow profile meters having a flow profile sensitivity class of D0/U0 or D3/U0 should be installed.
- Some meters are damage because of the environmental conditions. Direct exposition to sunlight may have a devastating effect on the batteries life or the electronic performance of electromagnetic and ultrasonic meters. The same can be said about installation sites which are frequently flooded. An IP68 protection will not ensure that a meter with some electronics working under such conditions will not break after some time.
- Finally, it is obvious that some meters can be tampered by the customers more easily than others. Adequate measures should be implemented by the water company to prevent a manipulation of the meters by the customers. Typically meters having electronics, if properly installed, are more difficult to tamper since customers have a reduced knowledge of their working principles.
- Nowadays, when electromagnetic and ultrasonic meters are starting to being use for customer metering, maintenance issues should always be considered in any economic model.
- Meters measuring water consumption of large customers need a higher reading frequency than domestic meters. The use of remote reading equipment is a real option that can achieve a short payback period if properly installed and managed. However, remote reading equipment, which can certainly help in increasing reading rates, can be a waste of money if the water utility is not prepared to manage and analyze large quantities of data.

  This piece of equipment should not only be used to improve reading rates but also to inform customers about possible incidences at their facilities, like the occurrence of leaks. A fast response time will save lots of hassle and conflicts to the water utility.

CASE STUDY: INITIATING A LARGE CUSTOMERS METER MANAGEMENT PROGRAM

FACSA, a water company serving 900.000 customers and 69 cities mainly in the east coast of Spain, initiated in 2010 a program to improve large customers meters management in several cities. This research, which is ongoing, was conducted together with the research group ITA belonging to the Universitat Politècnica de València. In its first stage, the study started with an in depth analysis of the commercial data base in order to identify those customers which could have a meter installed that was not performing correctly. For such purpose, meters that could possibly be under or oversized were indentified and selected as an initial sample as shown in Table 1. More specifically, a meter was considered to be undersized when:

- For DN equal or lower than 25 mm the registered daily volume was larger than the volume calculated as 1.1 times the nominal flow rate of the meter
- For DN greater than 25 mm the registered daily volume was larger than the volume calculated as 5.5 times the nominal flow rate of the meter

And it was considered oversized when:

- For DN equal to 25 and 30 mm the registered daily volume was smaller than 1.1 m^3
- For DN equal to 40 and 50 mm the registered daily volume was smaller than 5.5 m^3

Table 1. Water meters distribution according to DN and daily registered volume

Daily consumption (m3)	DN15	DN20	DN25	DN30	DN40	D50	DN65
1	15073	252	59	17	90	7	1
2	127	8	4	2	4		
3	28	4	2		3	1	
4	10	1	4		3		
6	8		3		1		
7	4	3	1	2	1		
8	4		1	1	1		
9			1				
10	1	2			1		
11		1	2	1	1		
13					1		
14	1						
16	1				2	1	
17			1		2		
18	1		1	1			
21	3		1				
>37		2			1		1

From the above table a sample of 106 customers were chosen for a comprehensive study which included a complete customer and meter audit and a water consumption pattern measurement. The sample was selected giving priority to undersized meters (since most oversized meter correspond to fire connections). It should be kept in mind that an undersized meter could be registering a low volume of water because the meter is damaged. Furthermore, in most cities the fixed term of the tariff is paid according to the nominal diameter of the meter (not the connection). Therefore, an undersized meter produces an economic loss for the water company even if it is properly working.

The consumption profile was measured using brand new reference meters equipped with high frequency pulse output (Figure 3). The pulses were recorded by means of data-loggers and downloaded in a specific application, WOLTMANN, developed by the ITA group for water consumption pattern analysis. As said before, when installing the measuring equipment several characteristic of the customers under study were also recorded in a specific data-base including: water use, presence of a private storage tank, type of valve used to control the water into the tank, average pressure, connection pipe diameters, installation conditions of the meters, etc…

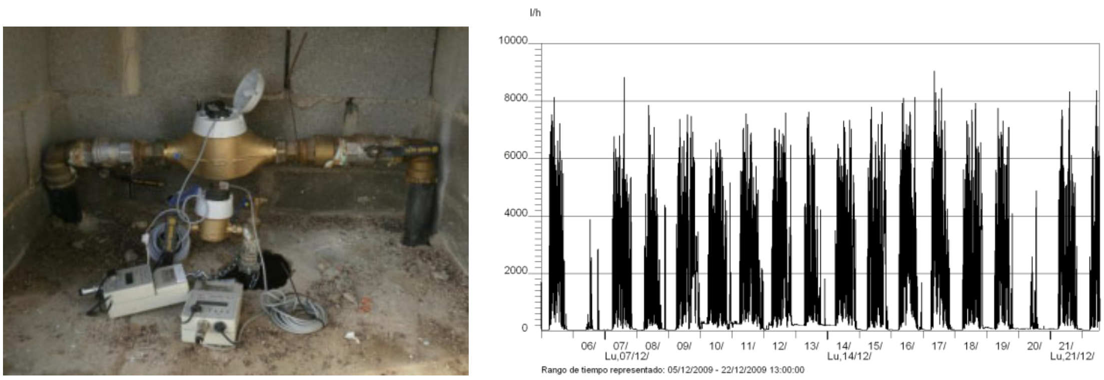

Figure 3. Water consumption pattern determination of a large customer

Having obtained the consumption pattern of the selected customers allowed for an analysis of how appropriately the meters of the sample were sized. The analysis was conducted based on the comparison between the nominal and maximum flow rates of the meter with the average and maximum flow rate measured during the water consumption pattern determination.

Table 2. Sizing analysis of the large customers' sample

		Original DN of the meter							
		15 mm	20 mm	25 mm	30 mm	40 mm	50 mm	65 mm	80 mm
Recommended DN of the meter	15 mm	6							
	20 mm	5	1		1	OVERSIZED METERS			
	25 mm	19	5	3		2	1		
	30 mm	2	5	8	7	6	1		
	40 mm			5	3	11	1		
	50 mm		UNDERSIZED METERS			5	7		
	65 mm						1		
	80 mm					1			

As it can be seen, only 33% of the meters (those in the diagonal of the table) were properly sized. Oversized meter only account for an 11% while undersized meters represent a 56% of the sample. This result is consistent considering that most customers from the sample were selected for being suspicious of having an undersized meter.

Two factors lead to the identification of a meter as undersized:

- Frequent consumption flows over the nominal flow rate of the meter
- Sporadic and/or periodic consumptions at very high flow rates

Some customers exhibited a consumption flow rate much higher than the maximum flow rate of the meter. For example, the customer in Figure 4 (left) had sporadic high flows that produced a fast failure of the meter (this fact could also be checked in the company's meter replacement history associated to this customer). In this case the installed meter was DN50 and the recommended size, from a strict technical point of view, was DN65. This facility is a clear example in which a non-mechanical meter will have a much better performance on the long run than a mechanical meter.

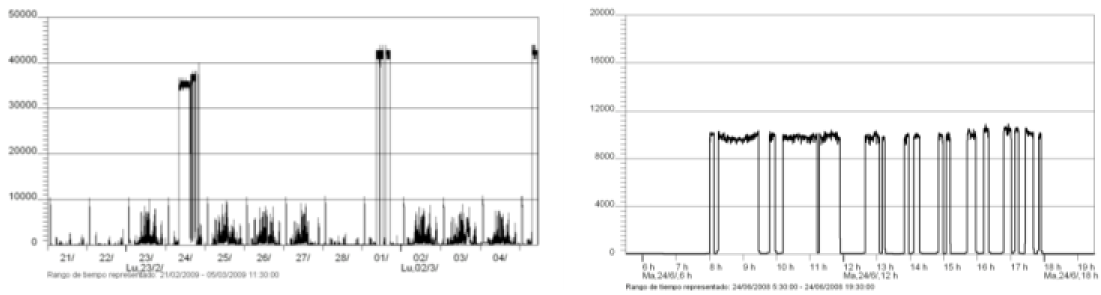

Figure 4. Examples of water consumption patterns of customers with sudden high flows

The analysis of the consumption patterns also showed an important conclusion: approximately 60% of the customers had a continuous consumption low flow. This was caused 56% of the times by an internal leak, 33% by a malfunctioning inlet valve at the private storage tank of the customer, 8% by cooling equipment.

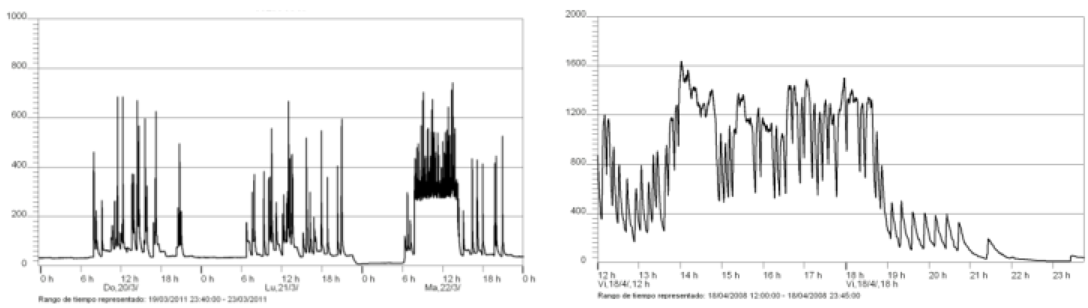

Figure 5. Water consumption pattern of customers with frequent low flows

The project aimed to improve large customers meters management and increase the general economic efficiency of installed meters in the different water supplies served by FACSA. Clearly, this objective cannot be achieved without a tariff analysis. For this purpose seven different water tariffs in the east region were selected. As in many other cities, all selected tariffs included a fixed and a variable term, which is typically proportional to the water consumption or arranged in blocks. However, for simplification purposes, the analysis did not considered any tariff structure with the variable term arrange in blocks. From this analysis it will be seen that undersizing meters is not always the best option to increase benefits.

Table 3 shows the increment on the fixed term of the tariff when the nominal diameter of the meter is increased. For example, water utility E, increases the fixed term when the size of the meter is enlarged from DN30 to DN40 in 208.19€ per year. On the other extreme utilities B and C do not vary the amount of the fixed term with the nominal diameter of the meter.

Table 3. Increment on the fixed term amount when increasing the size one nominal diameter

	Water utility						
	A	B	C	D	E	F	G
DN 15	- €	- €	- €	- €	- €	- €	- €
DN 20	33.54 €	- €	- €	- €	41.64 €	3.77 €	52.15 €
DN 25	16.75 €	- €	- €	1.32 €	39.20 €	3.77 €	52.24 €
DN 30	67.03 €	- €	- €	11.88 €	64.83 €	5.66 €	193.27 €
DN 40	167.60 €	- €	- €	- €	208.19 €	18.87 €	120.77 €
DN 50	167.44 €	- €	- €	- €	208.00 €	18.86 €	248.53 €
DN 65	167.61 €	- €	- €	- €	208.15 €	18.86 €	725.09 €
DN 80	167.59 €	- €	- €	- €	208.04 €	18.86 €	732.59 €
DN 100	335.10 €	- €	- €	- €	416.30 €	37.73 €	782.36 €

From the results in Table 3, and considering the selling price of water in city E, a calculation of the extra percentage of water volume that a smaller meter needs to register to pay for the loss of revenue on the fixed term of the tariff (compared to the immediately above diameter) was conducted. Clearly the higher the annual consumption is the less important are the changes in the fixed term. In the previous example, if the nominal diameter of the meter is reduced from DN40 to DN30 in a customer with an annual consumption of 500 m^3, the DN30 should measure 77% more volume than the DN40 to pay for the loss of revenue. If annual water consumption is 10000 m^3 this percentage reduces to the still high figure of 11%. At this point, it should be noted that a consumption of 500 m^3 per year will clearly indicate that the DN40 meter is oversized. However, from an economic perspective downsizing the meter to DN30 or smaller diameters will for sure produce a revenue loss for the water utility.

Table 4. Required measuring improvement to equalize the loss of revenue on the fixed term in utility E

	Annual consumption (m^3)				
	500	1000	5000	10000	20000
DN 15	33%	19%	4%	2%	1%
DN 20	24%	15%	4%	2%	1%
DN 25	32%	22%	6%	3%	2%
DN 30	77%	58%	19%	11%	6%
DN 40	43%	37%	16%	10%	5%
DN 50	30%	27%	14%	9%	5%
DN 65	23%	21%	12%	8%	5%
DN 80	38%	35%	22%	15%	9%
DN 100					

The abovementioned effect is minimized by the fact that a smaller meter always has smaller acquisition and installation costs. However, depending on the water tariff of the utility, this factor may turn out to be negligible when accounting for the whole meter life. For example, a large customer, having an annual water consumption of 12000 m^3 (Table 5) being served by utility E, will spend 3948€ per year if its meter is DN40, and 3740€ if its meter is DN30. Given that the selling price of a cubic meter is approximately 0.3 €/m^3, and the approximate acquisition and installation cost of a DN40 meter is 200 € and 150 € for

DN30, the optimal replacement period is approximately 4 years (Arregui et al. 2011). The difference in price of the two meters (50€) only represent a 0.3% of the total billed volume.

Table 5. Cost of an annual consumption of 12000 m^3 depending on the meter size

	Water utility						
	A	B	C	D	E	F	G
DN 15	2232 €	4471 €	5262 €	10407 €	3594 €	5101 €	4597 €
DN 20	2266 €	4471 €	5262 €	10407 €	3636 €	5105 €	4655 €
DN 25	2283 €	4471 €	5262 €	10408 €	3675 €	5108 €	4707 €
DN 30	2350 €	4471 €	5262 €	10420 €	3740 €	5114 €	4901 €
DN 40	2517 €	4471 €	5262 €	10420 €	3948 €	5133 €	5021 €
DN 50	2685 €	4471 €	5262 €	10420 €	4156 €	5152 €	5270 €
DN 65	2852 €	4471 €	5262 €	10420 €	4364 €	5171 €	5995 €
DN 80	3020 €	4471 €	5262 €	10420 €	4572 €	5190 €	6728 €
DN 100	3355 €	4471 €	5262 €	10420 €	4989 €	5227 €	7510 €

CONCLUSIONS

An improved large customers water meter management strategy should consider not only technical issues related to water meter selection and installation. It has been demonstrated that tariff structures play a critical role in deciding the optimal replacement frequency and the size of the meter that will produce a larger profit to the water utility. Some tariffs structures will lead water utilities to oversized meters, increases water meter under-registration, as the fixed term significantly increases with the diameter of the meter.

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