Reduction of Apparent Losses Using the UFR (Unmeasured-Flow Reducer) – Case Studies

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Abstract
The demand for water is increasing due to population growth and technological development whereas water is becoming a scarce resource. There is an urgent need to find innovative solutions for water loss in water supply systems. Most water meters don't measure low flow rates (less than 12 liters per hour). The innovative solution, ***UFR (Unmeasured-Flow Reducer)***, is a product of A.R.I. Flow Control Accessories. Its main objective is to reduce the apparent losses by changing the flow regime through the water meter at low flow rates. This reduces the volume of unmeasured water at low flow rates and enables the measurement of leaks by a domestic water meter. This paper shall review water meter accuracy curve error, reduction of apparent losses using the *UFR* - function and case studies conducted around the world.

Keywords

Apparent losses, UFR, water meter accuracy curve error

Introduction
Apparent losses (often referred to as non physical, paper losses or commercial losses) are in many cases the most expensive water losses that a water system will encounter. The water meter is the cash register of the water utility and therefore any losses occurring from the meter or the handling and processing of the data thereafter will be lost at sales revenue value per unit of measure (Thornton and Rizzo. 2002).
There are four major reasons for apparent losses: meter accuracy curve error, data transfer errors, data analysis errors and unauthorized consumption.
Water meter accuracy error is considered to be a significant component of the apparent losses in a water system. The error curve of the water meter (figure 1) can affect the unregistered water volume. Every meter type has its own rate of degradation of the accuracy with time. The meter may be influenced by external parameters such as the quality of water (scale, sand etc.) and suspended particles.

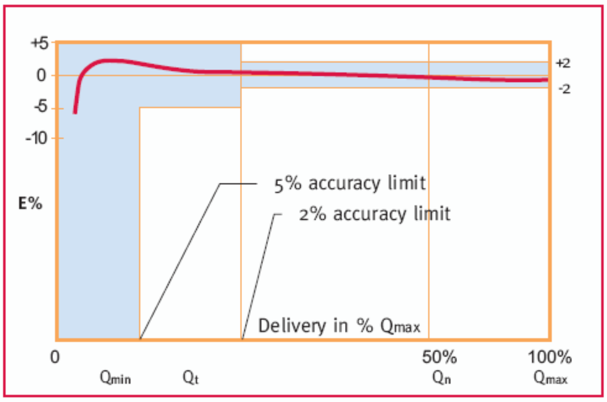

Figure 1: Error curve of a water meter

ISO standard (ISO 4064-1, Second edition, 1993) defines the performance of any type of water meter by looking at 4 main points along a flow range: Qmin, Qt, Qn, Qmax. It doesn't mention anything regarding the starting flow (usually one third of Qmin), which the water meter starts to measure. Qmin is the minimum accurate flow, accuracy of ±5%. Qt is the transitional flow, at which the meter will be stable in performance, accuracy of ±2%. Qn is the meter's nominal flow. Qmax is the maximum flow; it is determined as being twice the nominal flow. Figure 1 shows the ideal scenario for a brand new meter (Multi-jet class B), older meters will have an accuracy curve that is shifted outwards from the ideal ±2% accuracy band. The variability at low flows is much greater than at medium and high flows, the error curve is steep until reaching the minimum flowrate. Consequently the uncertainty about the real performance of meters at low flows will always be greater than at higher flows (Arregui el. 2006).

Domestic water meters

Most domestic water meters are usually of the velocity types: single jet, multi-jet; Positive-displacement: oscillating piston and nutating disc.

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. 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. If the mounting position is not correct, according to the manufacturer recommendations, it may lead to a higher degradation rate of the meter. The wear on the moving parts increases the error at low flows (figure 2). Deposits may cause over registration, at medium-high flows and under registration at low flows. However, on the long term, deposits grow so large that they can prevent the impeller from rotating, temporarily or permanently, causing a severe under registration of the meter (Arregui el. 2005).

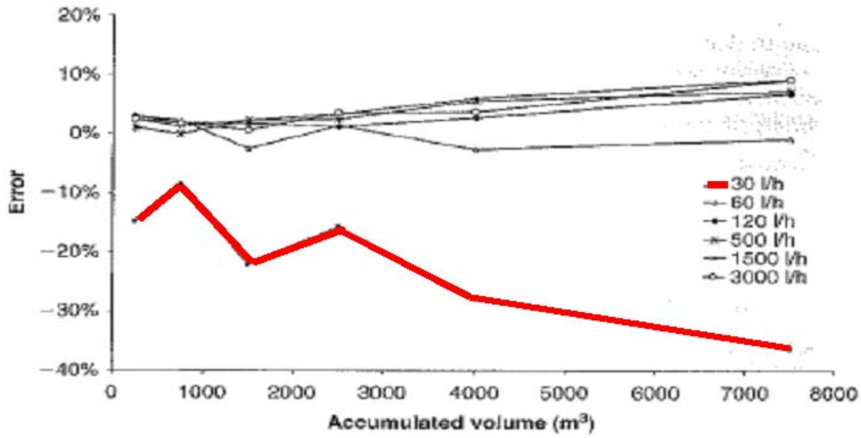

Figure 2: Multi-jet error (nominal flow 1.5 m^3/hr) on accumulated volume (Arregui el. 2006, p.21)

Positive-displacement meters are mainly used for domestic uses due to their excellent sensitivity to low flow rates and high accuracy across a wide range of flow rates. A known volume of liquid in an enclosed compartment moves with the flow of water, and the flow rate is calculated based on the number of times the compartment is filled and emptied. A reduction in the actual volume of each compartment is impossible, for this the meter will stop. Therefore, over-registration will not occur and the error curve will become more negative (under-registration) (figure 2). Consequently, these meters tend to under-register actual water usage when they become older and excessively worn.

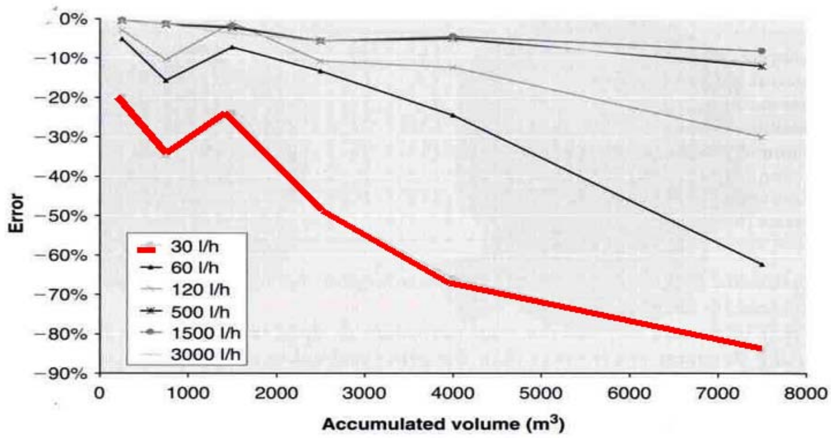

Figure 3: Evolution of the metering Error obtained from a sample of volumetric meters (1/2") (Arregui el. 2006, p.28)

Roof tanks

Water consumption at low flows is the most difficult to measure. As it can be seen in the 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 flow rates. For that reason, the under-registration expected from a meter installed by a user that consumes a great amount of water at low flows is very high. Furthermore, considering that the accuracy of a water meter degrades at a faster rate at low flows, this under-registration will increase more rapidly than in other type of users (Arregui el. 2006).

Figure 4 indicates the effect of a roof tank ball valve on the flow profile of a normal domestic household. An indirect plumbing system usually consists of the household kitchen fed straight off the inlet mains pressure whilst the rest of the household is fed via gravity from a roof tank. It is the slow closure of the roof tank ball valve that induces flows that are lower than the starting flow of the water meter, as shown in Figure 4 above. The larger the surface area of the roof tank or the higher the starting flow Q_s of the meter, the larger will be the resulting meter under-registration (Rizzo and S. John, 2006).

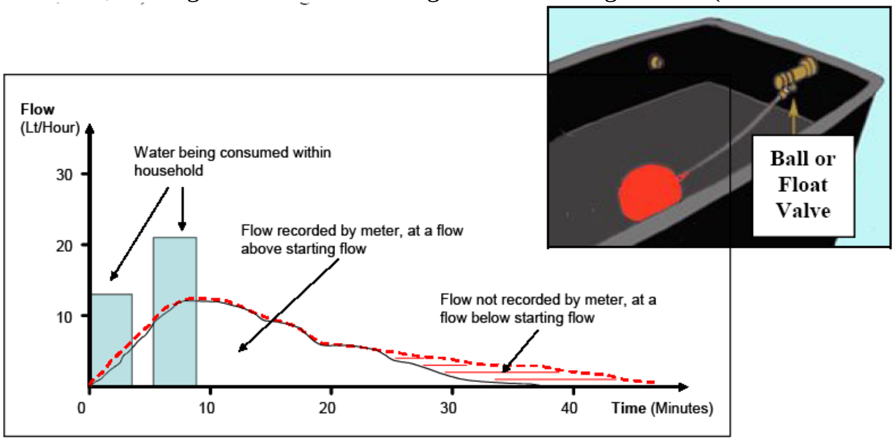

Figure 4: The effect of a roof tank on meter under-registration (Rizzo and S. John, 2006)

Figure 5 indicates the result of repeated tests carried out on standard $1m^3$ roof tanks. Data logging was carried out on water meters positioned upstream and downstream of the roof tank. The logic to these tests was that, whilst the water meter installed upstream to the tank would substantially under-register due to the ball valve effect, the water meter downstream of the tank would work fairly accurately. This would be because most of the outflows from the tank would be above Q_s or even above Q_{min}. Results confirmed that the downstream readings were over 6% higher than the upstream readings, indicating that the upstream meter was under-registering by over 6% of daily consumptions due to the ball valve effect. Replacing the new upstream meter with aged meters (having greater wear) produced under-registration figures ranging from the initial 6% to up to 95%. All tests were carried out using Class D (Q_n = $1.0m^3$/Hr) volumetric water meters (Rizzo and S. John, 2006).

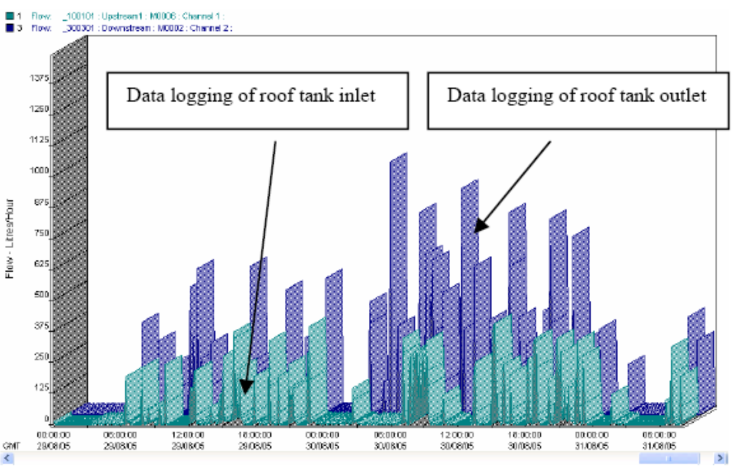

Figure 5: Data logging of water meters at roof tank inlet and outlet (Rizzo and S. John, 2006)

UFR - Unmeasured-Flow Reducer

The UFR (figure 6) works by changing the way that the water flows through the water meter at low flow rates. At low flow rates there is not enough energy in the flow to activate the water meter register. The UFR begins to operate at very low flow rates and creates batches of flow that the water meter can measure (figure 7). Due to the change in the mode of water flow to batches, the UFR enables the water meter to measure low flow rates.

Figure 6: UFR - Unmeasured-Flow Reducer

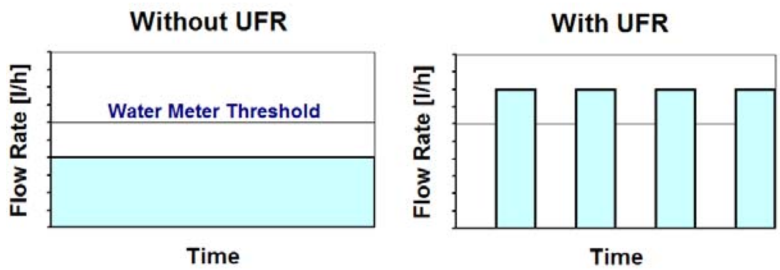

Figure 7: UFR – Principle of Operation

The UFR regulates the water flow so that there is no water flow at all part of the time, while the rest of the time, the flow is high enough to be measured. Changes in the flow discipline at low rates allow the existing water meter to measure at all water flow rates passing through it. When the flow rate increases over the water meter's measuring threshold, the UFR remains permanently open, so that it does not interfere with measurements. The UFR also acts as a non-return valve and prevents backflow (it closes when the downstream pressure and upstream pressure are equal).

The UFR is a differential non-return valve, designed in such a way that the pressure difference required to open it is more than that required to keep it open. The pressure difference to open the UFR is 0.4 bar, whilst the pressure difference to keep it open is 0.1 bar. When a leak develops (a flow rate below the measurement threshold of the water meter) the downstream pressure drops. When the downstream pressure drops below 0.4 bar of that of the upstream pressure, the UFR opens and allows for a flow rate above that of the measurement threshold (figure 8). The free flow of water through the UFR equalizes the pressure across the UFR and allows it to close (figure 9). The continuing leak downstream to the UFR will make this operation repeat itself over and over again. Every time the UFR opens, a quantity of water passes through the water meter at a flow rate above the measurement threshold of the water meter and so the flow is measured.

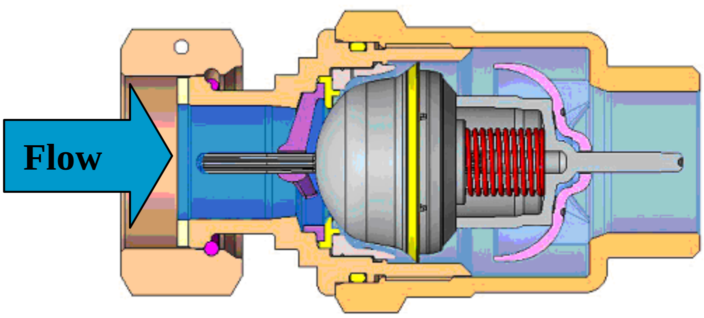

Figure 8: UFR closed: downstream pressure decreases because of leakage

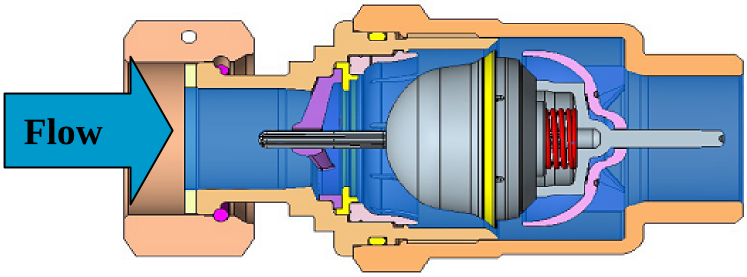

Figure 9: UFR opens: downstream pressure equals that of upstream

International case studies

The main purpose of the case studies was to answer the following questions:

1. Can a water meter measure all flow rates?
2. Can the UFR reduce the unmeasured flow?
3. Is the contribution of the UFR to the flow registration of the water meter significant?

A statistical test is conducted to find out if there is unmeasured flow passing through the water meter at low flow rates. The test procedure is as follows:

1. Verify that the water meter leak detector is stationary.
2. Close the shut off valve before or after the water meter. (If the valve is old or faulty it might not seal. In that case, this procedure is not reliable enough to determine if there is unmeasured flow or not).
3. Wait for about 60 seconds (during this time water would have drained from the household pipe work, or as a leak or as a low flow rate flow, for instance through a float valve into a water tank).
4. Open the shut off valve while watching the leak detector in the water meter carefully. If there is a leak in the household, the volume, equal to that of the drained water, will flow with enough energy to activate the water meter, and it will be seen on the leak detector. If there are no leaks, the leak detector will remain stationary.

Pilot field test methodology

In order to determine the contribution of the UFR, the following steps are taken:

1. Selection of a DMA (district metered area) consisting of reasonable number of meter connections with a single feeding source with a main master meter.
2. Establishing the current water loss without UFR by comparing the reading of the main meter with the sum of the domestic meters. The readings should be taken at long enough intervals and there should be no significant differences in the time the readings are taken in order to reduce differences resulting from additional consumption during a period of time readings were taken. AMR system enables collecting the readings from all meters at the same time is much more preferable.
3. Installation of UFR - and re-measuring the difference between the readings of the main meter and the sum of the domestic meters.

Case study 1 – Israel, Ranana

This case study was conducted in Ranana, Israel from May 2007 to February 2008. The DMA contains private houses and buildings with 40 UFRs. The water meters in this DMA are multi jet, Qn 2.5 class B (figure 10). According to table 1 the contribution of the UFR was 9%.

	With UFR's	Without UFR's	DIFFERENCE
Total consumption (m^3)	12110	11116	9%

Table1: Ranana results with and without UFR

Figure 10: UFR installed, Ranana, Israel

Case study 2 – Israel, Jerusalem, Ein Karem

In March 2005, 120 UFRs and 360 UFRs were installed in two separate DMAs in Ein Karem, Jerusalem. The water meters in these DMAs are multi jet, Qn 2.5 class B (figure 11).

Figure 11: UFR installed, Jerusalem-Ein Karem

The under registration percentage was recorded prior to and after the installation of the UFRs and is a comparison of the sum of the domestic water meter readings to that of the main water meter of the DMA. Table 2 summarizes the results of this study. The average contribution of the UFR was 8.5%.

Location	No. of Consumers	With or Without UFR	Period of Time [months]	Under-Registration [percent]
Ein Karem First DMA	120	Without UFR	8	16%
		With UFR	6	6.1%
		Contribution of UFR		9.9%
Ein Karem Second DMA	360	Without UFR	8	26%
		With UFR	6	18.8%
		Contribution of UFR		7.2%
		Average Contribution of UFR		**8.50%**

Table 2: Study results with and without UFR

Case study 3 – Cyprus, Larnaka

This case study was conducted in Larnaka, Cyprus from October 2006 to December 2006. The DMA contains a variety of households: private houses, buildings and houses with roof tanks. The water meters in this DMA are as shown in figure 12.

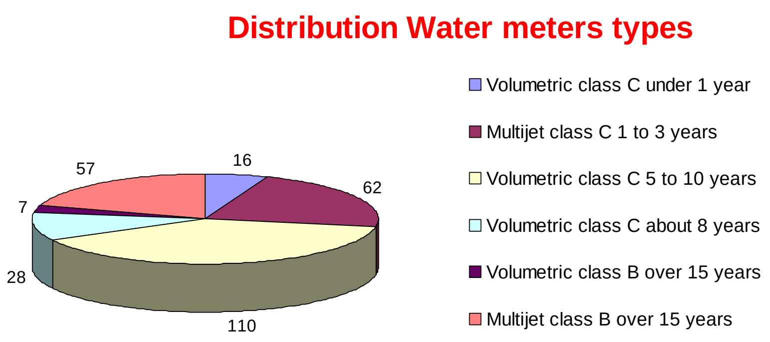

Figure 12: Distribution of Water meters types in the DMA

Weekly readings were taken before and after the installation of the UFRs. According to Table 3, the contribution of the UFR was 9.93%.

	With UFR's	Without UFR's	DIFFERENCE
Area 1 consumer meters Total (Consumption)	3242.84	3066.48	
Area 1 bulk meter total (Demand)	3556.00	3667.00	
Not registered water in M^3	313.16	600.52	287.36
Not registered water as a percentage of the total **Demand**	8.81%	16.38%	7.57%
Not registered water as a percentage of the total **Consumption**	9.66%	19.58%	9.93%

Table3: Larnaka results with and without UFR

Case study 4 – Malta

The national water utility in Malta identified a small zone for pilot study purposes. The zone was chosen in accordance with the ages of the water meters in the zone, allowing for a normal distribution of meter ages with an average of five years in age. Poezija zone has 26 domestic consumers with volumetric class D (Qn=1 m^3/hr) water meters and roof tanks on the buildings (figure 13). The UFR units increased the metered volume of water by a substantial 5.5% to 6% of the water supplied to the zone (Table 4).

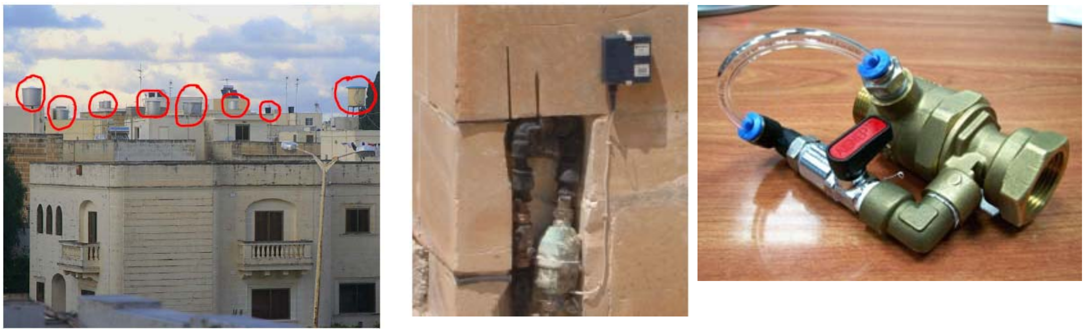

Figure 13: The pilot zone (left) where the UFR (right) was installed in Malta

Test No.	Global % Under-registration Vs. Master Meter		% Overall improvement
	Without UFR's	With UFR's	
1	18.1	12.1	6
2	26.7	21.2	5.5
3	28	22.2	5.8

Table 4: Effect of UFR's on Water Meter Under-Registration

Conclusions

Leakages and other unmeasured water flows at low flow rates were found in many of the households tested. The UFR succeeded in the reduction of unmeasured flow and was found very effective in reducing apparent losses. The UFR had a significant effect on the flow registration of the water meter. The UFR increased the water meter registration by 5% to 10%.

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