Meter Under-Registration caused by Ball Valves in Roof Tanks

B Charalambous*, S Charalambous, I Ioannou*****

***Water Board of Lemesos, bambos@wbl.com.cy**

****Water Board of Lemesos, solomos@wbl.com.cy**

*****Water Board of Lemesos, i.ioannou@wbl.com.cy**

Keywords: Meter accuracy, roof tanks, apparent losses.

Abstract

Water Losses are made up of the Apparent and Real Losses. The Water Board of Lemesos considers that the reduction of Apparent Losses is as equally important as the reduction of Real Losses. This paper provides a detailed account of two studies that were carried out at the Water Board of Lemesos in order to quantify meter under-registration caused by the use of ball valves in customer roof tanks and the results obtained and conclusions reached are presented and discussed. The first study aimed at proving beyond any reasonable doubt that the ball valves used in customer roof tanks result in meter under-registration especially at the very low flows. The second study involved the testing of a flow manipulation device which would assist in the reduction of the un-measured flow through the customers' meters at low flows.

Introduction

The Water Loss Task Force (WLTF) of the International Water Association (IWA) has established a Standard Water Balance, which traces water from its source right through the system and derives at the end the revenue and non-revenue component. The Water Losses component of the Water Balance from urban distribution systems are made up of Apparent Losses and Real Losses. These losses together with the Unbilled Authorised Consumption comprise the Non-Revenue Water (Figure 1).

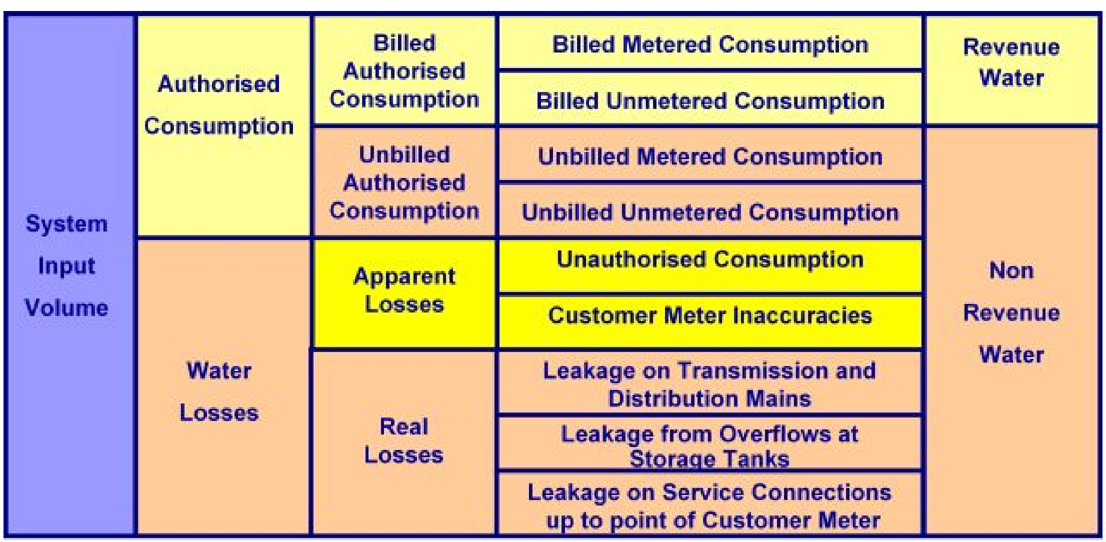

Figure 1. IWA Water Loss Task Force Standard Water Balance

Apparent Losses or commercial losses as sometimes are referred to, are valued at retail billing rates whereas the Real Losses are valued at the variable cost of water production and distribution (Thiemann, R. and Henessy, S. 2005). Apparent Losses consist of water which has been produced, distributed and ultimately consumed but not paid for by the user. Members of the WLTF dedicated considerable time in the last few years working on this issue which is considered to be of the utmost importance for any water utility. A major finding was that the Apparent Losses comprise four components, namely:

- Water theft
- Meter reading errors
- Accounting errors
- Customer meter under-registration

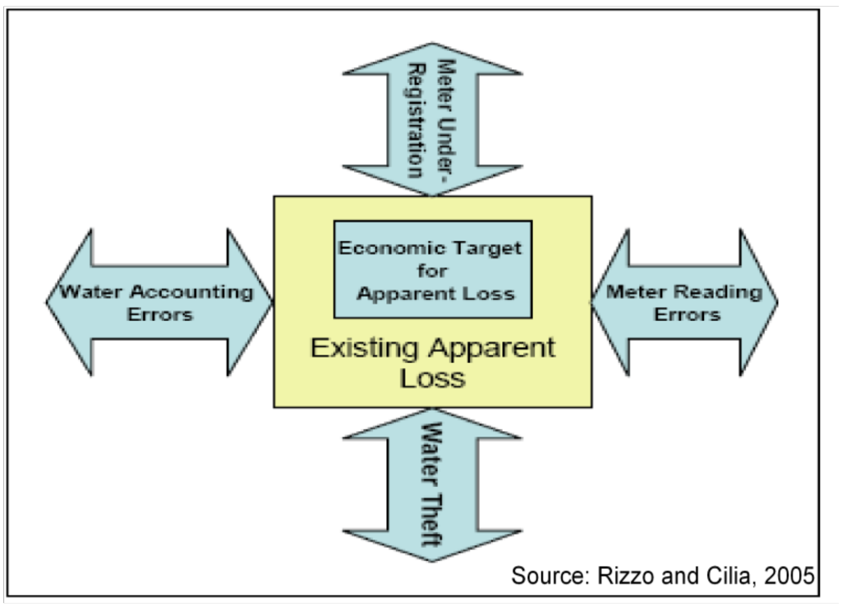

Figure 2. The Four Components of Apparent Losses

The four components can act independently but at the same time interact with each other as shown in Figure 2 in either reducing or increasing the overall value of Apparent Losses. Meter under-registration is a result of the customer water meter not registering correctly the flows which go through the meter especially at very low flows. In addition, as the meter gets older the ability to register accurately degenerates (Rizzo et al, 2007).

The Water Board has developed policies for water meter management, which include the following:

- periodical checking and replacement if necessary of all source, storage and DMA meters,
- use of high accuracy positive displacement domestic meters.

The domestic meters are inspected every four months, when they are read by the meter readers, and malfunctioning or damaged meters are reported and replaced with new ones. In addition a replacement programme for ageing domestic meters is effected every year with the aim to replace meters which are over 10 years old. This means that every year about 6000 meters are replaced but a considerable number of meters over 10 years old are still in use.

Domestic Roof Tanks

In Cyprus and generally in arid and semi-arid regions, where intermittent or unreliable water supplies due to water shortage can occur all households have storage tanks of approximately I m^3 capacity. In addition advantage is taken of the abundance of sun to provide hot water to the household through the use of solar panels (Figure 3).

Figure 3. Typical Installation of Domestic Roof Tanks in Houses

The wide use of roof storage tanks by all customers appears to be a major cause of meter under-registration especially at low flows. International experience in this field indicates that even with the most accurate of domestic water meters the percentage of under-registration at low flows is significant. It was reported by Rizzo and Cilia, 2005 that *“the average under-registration of domestic meters, class “D” resulting from low flows induced by the tank ball valve was found to be at around 6% of the total household consumption”.* Further evidence provided by Cobacho, et al, 2007 showed that in the case of a system using roof tanks and employing Class “B” water meters the overall under-registration was close to 20% during the initial years becoming much worse after 6-8 years with the under-registration reaching 30% and more.

The problem of meter under-registration is normally caused at extremely low flows through the meters, flows which are lower than the minimum flow which can accurately be registered by the meter. For metrological class “D” the minimum flow that can accurately (+/- 2%) be registered by the meter is 7,5lt/hr.

The roof tank is used to store water which subsequently is used for toilet flushing, showering, cooking, clothes and dish washing, house cleaning and for personal hygiene. For most of these uses the quantity used is relatively small causing a minute drop in the ball valve arm in the roof tank thus allowing water to drip into the tank at flows lower than the minimum flow that can be registered by the meter. Two shapes of roof tanks are in use; square (1m x 1m x 1m) which is made of galvanized mild steel and cylindrical (0,8m diameter x 1,5m long) which is made of polypropylene. For the square tanks a drop of 1mm in the level of water in the tank is equivalent to 10lt of water being used. Similarly, a drop of 1mm in a cylindrical tank is equivalent to 5lt. For most households uses the quantity of water used is less than 10lt or even 5lt and therefore the drop in the ball valve arm is not sufficient to allow flow conditions through the meter which can be registered.

The galvanized mild steel tanks proved problematic in that they were showing signs of corrosion soon after they were installed and had very limited life span. The galvanized mild steel tanks are no longer produced and are gradually being replaced by polypropylene tanks (Figure 4).

Figure 4. Polypropylene Roof Tank

The studies undertaken at the Water Board of Lemesos were inspired by the work carried out in this field by the Apparent Losses Team of the WLTF and aimed at quantifying meter under-registration caused by the ball valves in roof tanks. These were:

- Study A: Continuous monitoring of inflows and outflows from roof tanks.
- Study B: Installing flow control devices (unmeasured flow reducers).

Study A: Continuous Monitoring of Inflows/Outflows from Roof Tanks

The aim of the study was to:

- Establish that the use of the ball valves in roof storage tanks causes meter under-registration, especially at the very low flows.
- Quantify meter under-registration under several supply regimes.
- Determine the loss of revenue due to meter under-registration.

This study was carried out based on the methodology and principles of a similar study carried out by Rizzo and Cilla, 2005, in Malta where roof tanks are also used in much the same way as in Cyprus. Rizzo and Cilla, 2005, in their study proved that by using an innovative solenoid system to replace the traditional ball valve, all flows into the roof tank were accurately registered by the domestic meter without any indication of under-registration. Therefore, this aspect was not investigated in the Water Board study since the results of the Maltese study are considered universally applicable. It was therefore considered important to investigate and quantify meter under-registration for the typical roof tank installations encountered in Cyprus and particularly in the town of Lemesos which are similar to those found in other countries.

Selection of Project Site

It was considered important to investigate meter under-registration for different types of customers in order to establish whether the different patterns of customer usage are related to varying degrees of meter under-registration. To this end a Shop, a Residential Flat and an Office all located in the same multi storey building were chosen (Figure 5).

Figure 5. Project site

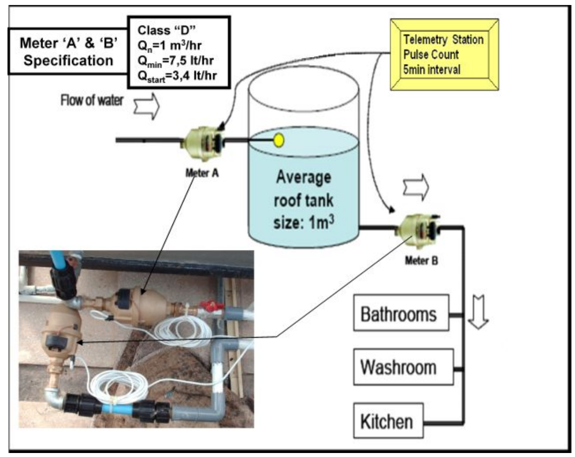

Figure 6. Test layout

Test Methodology

The methodology adopted was to install brand new class"D", Q_n=1m^3/hr, volumetric meters at the inlet and outlet to the tank as shown schematically in Figure 6 in order to measure the inflows and outflows from the tank. The inflows and outflows were logged at every 5 minute intervals and the data stored in a programmable controller which was set up on site on the roof of the multi storey building. This arrangement was adopted for each customer type under investigation, namely: shop, residential flat and office.

Results

The results obtained from the continuous monitoring of inflows and outflows are shown in Table 1 below. The measurements were taken during the period 20/11/2006 and 4/2/2007 and it is obvious from the results that the degree of meter under-registration varies according to the type of dwelling which of course is directly related to the customer's consumption pattern. The highest under-registration percentage was that of the water meter supplying the Office.

Table 1. Results of inflow and outflow readings

Roof Tank	Type of Dwelling	Period of measurements: 20/11/2006 – 4/2/2007			
		Inflow (m^3)	Outflow (m^3)	Difference(m^3)	% Difference
1	Office – 2nd floor	0,9525	1,2080	0,2555	21,15
2	Shop – ground floor	7,2800	7,5276	0,2476	3,29
3	Residence- 1st floor	20,7740	21,0990	0,3250	1,54

It should be noted that the actual water consumption for the Office was extremely small compared to the other two which show a much lower percentage of meter under-registration. The low consumption for the Office was due to the fact that water in the Office was basically used for toilet flushing and/or hand washing which meant that the quantity of water used at any time was small causing only a minute movement of the ball valve arm thus water going through was below the minimum volume that the meter was capable of accurately registering. In contrast to the other two cases where water was used in larger quantities and under different consumption patterns resulting in much lower figures for under-registration.

The above tests proved that the use of the ball valves in roof storage tanks cause meter under-registration, especially at the very low flows, and that the extent of the under-registration is closely related to the customer consumption pattern. On the basis of the above tests the average figure calculated for under-registration was 2.8%.

Study B: Installing Flow Control Devices (Unmeasured Flow Reducers)

The aim of this study was to:

- Install and test innovative flow control devices, Unmeasured Flow Reducers (UFR), based on an agreed methodology, in order to establish their functionality under field conditions.
- Investigate if the use of UFRs creates transient pressures in the network.
- Measure consumption before and after the installation of the UFRs.
- Quantify volume and cost of meter under-registration caused by the low flows induced by the ball valves in the roof storage tanks and calculate the benefit using the UFR.

In order to have a common base for comparing results from different case studies a standard test methodology established by Alex Rizzo, leader of the Apparent Losses team of the WLTF was followed. This involved a total of 4 sequential steps:

1. Selection of project site and consumer audit.
2. Pilot zone main meter.
3. Elimination of all other Apparent Loss components.
4. Installation of UFRs.

The above steps are analysed below giving details of the work which was carried out and the results obtained.

Selection of Project Site and Consumer Audit

A trial zone with 69 metered customers was chosen. This area was hydraulically encapsulated with a single entry point into the zone which was metered. The area comprised mainly large detached houses with an average daily consumption of approximately 1 m^3 per household.

Pilot Zone Main Meter

The flow into the pilot zone was initially measured by a Kent 50mm Waltmann type class 'B' meter. In order to ensure that the main meter was correctly sized the meter was logged for a period of time and the flow data analysed. As it can be seen from Figure 7 the meter was oversized and as a result the meter was registering zero for minimum night flows. Arrangements were made and the main meter was replaced with a Kent 25mm PSM class 'C' meter. The flows were logged for a similar length of time immediately after installation and as it can be seen from Figure 8 the meter was measuring correctly, within the minimum and maximum limits of the meter. From these measurement it was also concluded that there were no leaks that had to be removed as the minimum measured night flow of 0,2 m^3/hr was very close to the minimum target night flow for this particular trial zone.

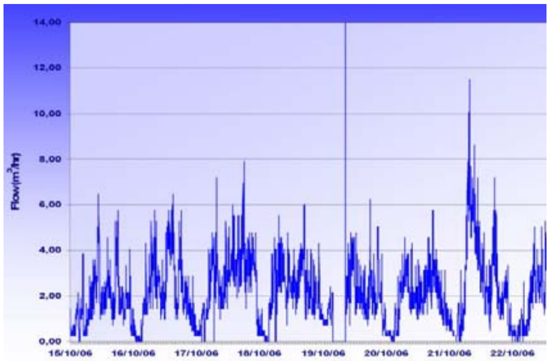

Figure 7. Kent 50mm waltmann type type ‘B’

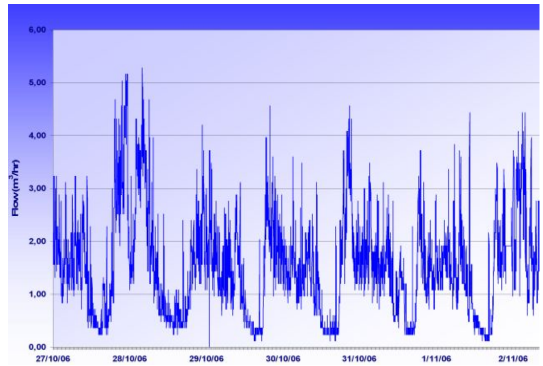

Figure 8. Kent 25mm PSM class ‘C’

Elimination of All Other Apparent loss Components

It was extremely important to remove all other apparent loss components, namely: water theft, billing errors and meter reading errors prior to carrying out the test. Before installation of the UFRs all meters were checked and the ones found malfunctioning were replaced. Furthermore, it was confirmed that there were no illegal connections. In order to avoid any billing errors it was decided that a separate recording system will be used which will be independent of the main billing system. Unfortunately it was not possible to install an automatic meter reading system so that all customer meters to be read manually. In order to avoid meter reading errors the meters were read simultaneously by two people cross checking their records after each meter was read.

Installation of UFRs

Great emphasis is now placed on minimising surges in distribution systems so it was thought important to have independent pressure measurements on the distribution mains to determine the size (if measurable) and frequency of any surges that may be induced by the UFRs. An appropriate fire hydrant location in the trial zone area was chosen and pressure measurements at 0,1 second intervals were taken before and after the UFRs' installation. Figure 9 shows the measurements after the UFRs were installed and as it can be seen no pressure surges were recorded. Therefore, it can be safely assumed that no surges are induced in the network by the use of the UFRs.

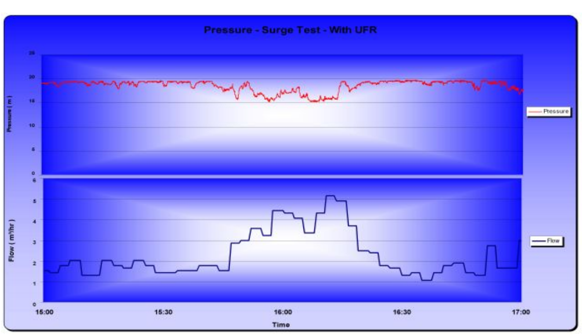

Figure 9. Pressure measurements after installation of UFR

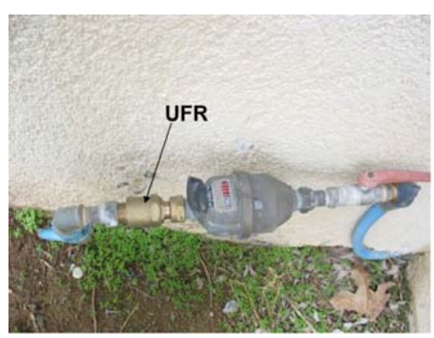

Figure 10. UFR installetion

The UFRs were installed immediately downstream of the water meters as shown in Figure 10. During the installation of the UFRs some difficulties with limited space were encountered especially in cases where the inlet and outlet pipework were fixed in concrete paving slabs. Of course the problem of space will not be an issue with new installations.

Results

The flows through the main meter were recorded automatically, stored in a programmable controller on site and transferred to a computer in the main Offices of the Water Board at preset times or on request. The domestic meters were manually read three times a week, Monday, Wednesday and Friday, for two consecutive weeks with the UFRs and for another two consecutive weeks without the UFRs. The difference between inflows and outflows without and with UFRs are shown diagrammatically in Figures 11 and 12 respectively. It is evident from the graphs that the difference is a lot less with UFR than without.

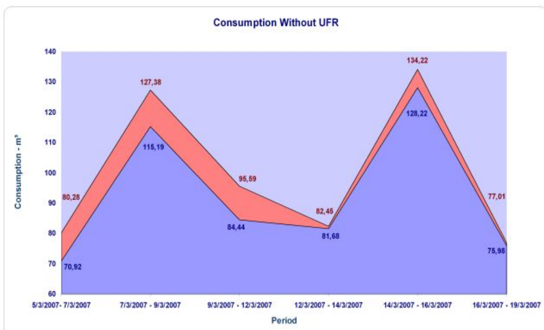

Figure 11. Difference in registered flows without UFR

Figure 12. Difference in registered flows with UFR

The above results are shown in tabular form in Table 2 below. Without the UFRs the meter under-registration was 6,79% whereas with the UFRs this figure was reduced to 2,12%. The use of the UFRs increased the volume of water which was registered by the water meters by 4,67%.

Of course the above percentage may vary according to the type and age of meters that are installed. Low percentages are usually encountered with positive displacement meters than with multi jet or single jet meters. Similarly the percentage under-registration is lower with newer meters as compared to older ones.

An analysis of the trial zone meters was carried out which revealed that all 69 meters were positive displacement meters, 43 (62%) Class 'D' and 26 (38%) Class 'C'. Also the age of the meters was analysed and showed that 26 (38%) were 1-3 years old, 7 (10%) were 4 -7 years old, 16 (23%) were 8 -11 years old and 20 (29%) were more than 11 years old.

Table 2. Results of inflow and outflow readings

Period	Main Meter consumption (m^3)	Customers' usage (m^3)	Under-registration	
			(m^3)	%
Without UFR 21/3/2007- 2/4/2007	596,93	556,43	40,50	6,79
With UFR 5/3/2007 – 19/3/2007	541,60	530,13	11,47	2,12
			Additional Registration with UFR	4,67

Therefore, bearing in mind the above figure for meter under-registration without UFRs it can be safely assumed that the Apparent Losses figure for the Water Board of Lemesos is of the order of 7% of the measured inflows into the network. This figure is extremely is extremely important in the calculation of the Standard Water Balance and in the accurate calculation of the Real Losses using the 'top down' approach.

Benefits

Table 3 shows the additional volume of water which will be registered in the trial zone in a period of 1 year based on the additional registration of 4,67% using the UFRs as well as the additional income based on the consumption tariff applicable to each customer on the basis of the 4 monthly bills issued in the year 2006. The cost of supply and installation of the 69 number UFRs was estimated at €1400 and the benefit due to the additional revenue was estimated at €2100 per year. Therefore, for the trial zone the payback period would be 8 months.

Table 3. Cost - benefit analysis for trial zone

Description	Value
Additional annual volume of water	950 m^3
Additional Annual Income	€ 2100
Supply and installation of UFR	€ 1400
Pay back period	8 months

Applying the above concept across the entire Water Board using an average consumption of 25 m^3/month at an average rate of 0,60 €/m^3 it gives a payback period of 28 months per customer. In addition on the basis of 70.000 customers the Board will have an additional income of the order of €600.000 per year.

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