REPUBLIC OF MOLDOVA

APA CANAL CHISINAU

CHISINAU WATER SUPPLY & SEWAGE TREATMENT - FEASIBILITY STUDY

Contract No: C21156/ECWC-2010-01-01



Assessment of Metering Under-Registration

July 2012

seureca A Subsidiary of VEOLIA ENVIRONNEMENT

In association with and Business Consulting Institute

European Bank for Reconstruction and Development and EU Neighbourhood Investment Facility

LIST OF ABBREVIATIONS AND ACRONYMS

ACC	Apa Canal Chisinau
APLP	Asociatia Proprietarilor de Locuinte Private
CCL	Cooperative de Constructii de Locuinte
DN	Nominal Diameter
IMGFL	Intreprinderi Municipale de Gestionare a Fondului Locativ
IWA	International Water Association
MDL	Moldovan Leu
MPE	Maximum Percentage Error
PT	Payback Time
Q_{min}	Minimal Flow
Q_t	Transitional Flow
Q_{max}	Maximal Flow
Q_N	Nominal Flow
WWTP	Waste Water Treatment Plant

TABLE OF CONTENTS

1. INTRODUCTION 1

2. DOMESTIC METERING UNDER-REGISTRATION 2

2.1. RATIONALE 2

2.2. DEFINITION OF REPRESENTATIVE CONSUMPTION HISTOGRAMS OF DOMESTIC CUSTOMERS 2

2.3. DEFINITION OF REPRESENTATIVE METROLOGICAL ERROR CURVES OF WATER METERS' MODELS 5

2.4. CALCULATION OF METERING UNDER-REGISTRATION 8

2.5. IMPACT ON METERED WATER CONSUMPTION AND BILLING 9

2.6. IMPLEMENTATION OF CLASS C WATER METERS 11

2.7. BLOCK METERING IN ACC SERVICE AREA 12

3. TESTING OF NEW WATER METERS (MADDALENA CD-ONE TRP) 13

3.1. STANDARD HORIZONTAL INSTALLATION 15

3.2. INCLINED INSTALLATION (60°, 120°) 16

3.3. VERTICAL INSTALLATION (ASCENDING POSITION) 18

3.4. INSTALLATION WITH UPSTREAM-DOWNSTREAM ELBOWS 19

3.5. AFTER A FLOW SURGE (2 X Q_{MAX}) OF 1 HOUR 20

3.6. SENSITIVITY TO FRAUD BY USING A MAGNET: 22

3.7. CONCLUSION 23

4. NON-DOMESTIC METERING UNDER-REGISTRATION 24

4.1. INTRODUCTION 24

4.2. SAMPLE OF NON-DOMESTIC CUSTOMERS 24

4.3. I.M. EFES VITANTA MOLDOVA BREWERY S.A. 26

4.4. S.A. BUCURIA 28

4.5. I.M.S.P. SPITALUL CLINIC REPUBLICAN 29

4.6. I.M.S.P. CENTRUL NATIONAL STIINTIFICO-PRACTIC DE MEDICINA URGENTA 30

4.7. I.M.S.P. SPITALUL CLINIC MUNICIPAL SFANTA TREIME 32

4.8. I.M.S.P. INSTITUTUL DE CARDIOLOGIE 33

4.9. COMPANIA COCA-COLA IMBUTELIERE CHISINAU S.R.L. 34

4.10. CONCLUSION AND RECOMMENDATIONS 36

5. CONCLUSION 39

LIST OF FIGURES & TABLES

Figure 1 : Example of metering point during the study 3

Figure 2 : Domestic consumption histogram in Chisinau 4

Figure 3 : One of the test benches operated by ACC 5

Figure 4 : Metrological results for a standard horizontal installation 7

Figure 5 : Superposition of the domestic water consumption histogram and the metrological error curves of the three tested water meters' models 9

Figure 6 : Superposition of the domestic water consumption histogram and the metrological error curves of class C water meters 11

Figure 7 : Water meters on the LECE test bench during the tests 14

Figure 8 : Metrological results for a standard horizontal installation 15

Figure 9 : Metrological results for an inclined installation (60°) 16

Figure 10 : Metrological results for an inclined installation (120°) 17

Figure 11 : Metrological results for a vertical installation 18

Figure 12 : Metrological results for an installation with upstream-downstream elbows 19

Figure 13 : Airborne water meter installation 20

Figure 14 : Metrological results after a flow surge (2 x Q_{max}) of 1 hour 21

Figure 15 : Metrological results under magnetic fraud 22

Figure 16 : Portable ultrasonic flowmeter installed in S.A. BUCURIA 25

Figure 17 : Consumption histogram for NON-DOM #1 26

Figure 18 : Metering point configuration before the ZENNER unit (NON-DOM #1) 27

Figure 19 : Consumption histogram for NON-DOM #2 28

Figure 20 : Metering point configuration before the STVG unit (NON-DOM #2) 29

Figure 22 : Consumption histogram for NON-DOM #3 (STV unit #2) 29

Figure 23 : Consumption histogram for NON-DOM #4 31

Figure 24 : Metering point configuration before the STV unit (NON-DOM #4) 31

Figure 25 : Consumption histogram for NON-DOM #5 32

Figure 26 : Metering point configuration before the STVG unit (NON-DOM #5) 33

Figure 27 : Consumption histogram for NON-DOM #6 33

Figure 28 : Metering point configuration before the STV unit (NON-DOM #6) 34

Figure 29 : Consumption histogram for NON-DOM #7 35

Figure 30: Standard installation schematics for horizontal helix Woltmann meters........................... 37

Table 1: Percentage of domestic water consumption per flowrates ranges 5

Table 2: Results of the metrological verification of the water meter test bench...................................6

Table 3: Testing flows used during the calibration program 7

Table 4: Metrological results for a standard horizontal installation 7

Table 5: Superposition of the domestic water consumption histogram and the metrological error curves of the three tested water meters' models 9

Table 6: Metrological results for a standard horizontal installation 10

Table 7: Superposition of the domestic water consumption histogram and the metrological error curves of class C water meters 11

Table 8: Metrological results for a standard horizontal installation 15

Table 9: Metrological results for an inclined installation (60°)... 16

Table 10: Metrological results for an inclined installation (120°)... 17

Table 11: Metrological results for a vertical installation 18

Table 12: Metrological results for an installation with upstream-downstream elbows 19

Table 13: Metrological results after a flow surge (2 x Q_{max}) of 1 hour.. 20

Table 14: Metrological results under magnetic fraud 22

Table 15: Initial sample of large customers to be studied.. 24

Table 16: Summary for non-domestic customers 36

1. INTRODUCTION

The main purpose of reliable customer metering is to generate economic revenue. The accuracy of water meters is also a key issue in water balance calculations, such as the one recognized by the International Water Association (IWA). The impact due to theft, meter tampering/damage, incorrect estimates, illegal connections can only be solved through strong pro-active measures, based on both legal and commercial actions, with very few technical inputs.

On the contrary, metering under-registration is related to many technical issues:

- Improper meter type and sizing;
- Incorrect meter installation;
- Meter encrustation and deterioration with age;
- Flowrates lower than the minimal flowrate the meter can reliably register;
- Insufficient maintenance/replacement;
- Frequency of calibration;
- Inability to obtain meter indexes and influence of meter reading cycles;

During the Feasibility Study, physical losses were assessed thanks to several items, such as the hydraulic measurement campaign on the drinking water network and its calibrated hydraulic model, and the leak detection and location campaign.

This report foresees to present a preliminary assessment of the main component of commercial losses: the non-registered volumes consumed by domestic and non-domestic customers in Chisinau, which deprive ACC of much needed financial resources.

On-site metering campaigns were performed to assess metering under-registration, with two different methodologies depending on the type of customers, as details below:

For domestic customers, metering under-registration was determined thanks to:

- The definition of representative consumption histograms of domestic customers living in individual houses and apartments;
- The definition of representative metrological error curves of water meters' models among the most common ones in ACC service area;

For non-domestic customers, metering under-registration was determined thanks to:

- Volumetric comparison between the customers' mechanical water meters and the results of flow measurements carried out with portable flowmeters;
- The definition of representative consumption histograms of a sample of customers among the largest 50 water consumers in the service area;
- The analysis of the metering point characteristics: water meter type and sizing and current hydraulic conditions (presence of flow disturbing elements);

2. DOMESTIC METERING UNDER-REGISTRATION

2.1. RATIONALE

Domestic customers in the service area operated by ACC can be divided into two representative categories (total potable water consumption in 2010 equal to 35.8 Mm^3):

- Customers living in individual houses, with direct contracts with ACC regarding water supply and wastewater services.
- Customers living in apartments inside blocks as part of different legal condominium entities (IMGFL, APLP, CCL...) which can be of municipal or private status. Apartments are allowed to have direct contracts with ACC but the majority prefer being managed through their respective legal condominium entities.

Customers with direct contracts are billed based on the readings of the water meters equipping their service connections. Meters are owned and installed by customers. Readings are carried out once a month by ACC meter readers.

For blocks, ACC owns and installs large -block- water meters on the main service connections supplying the buildings. Readings are made once a month by ACC meter readers with the objective of billing the legal condominium entities which retroactively bill apartments under their responsibility. However until very recently (January 2012 reportedly), IMGFL for example, has refused to pay for the volumetric difference between the large meter registering the whole water consumption of the block and the sum of individual meters registering the water consumption of the apartments. This specific problem results in large commercial losses which reached 6.1Mm^3 in 2010.

Commercial losses can also include water theft, meter tampering/damage, incorrect estimates and illegal connections. This report focuses on the assessment of metering under-registration, which for domestic customers was based on two main components:

- The definition of representative consumption histograms of domestic customers living in individual houses and apartments;
- The definition of representative metrological error curves of water meters' models among the most common ones in ACC service area;

2.2. DEFINITION OF REPRESENTATIVE CONSUMPTION HISTOGRAMS OF DOMESTIC CUSTOMERS

A sample of 50 customers[1] (25 individual houses and 25 individual apartments) was equipped with new water meters (oscillating piston type) imported from France with the following characteristics[2]:

[1] A form was prepared for each customer and its specific metering point. All forms are attached in the appendices.

[2] The technical specifications for the water meters are attached in the appendices.

- ITRON AQUADIS+ Class C[3], D_N 15 mm, Q_N 1.5 m^3/hr;
- Minimum flowrate Q_{min}: 15 L/hr;
- Transitional flowrate Q_t: 22.5 L/hr;
- Maximum flowrate Q_{max}: 3,000 L/hr;

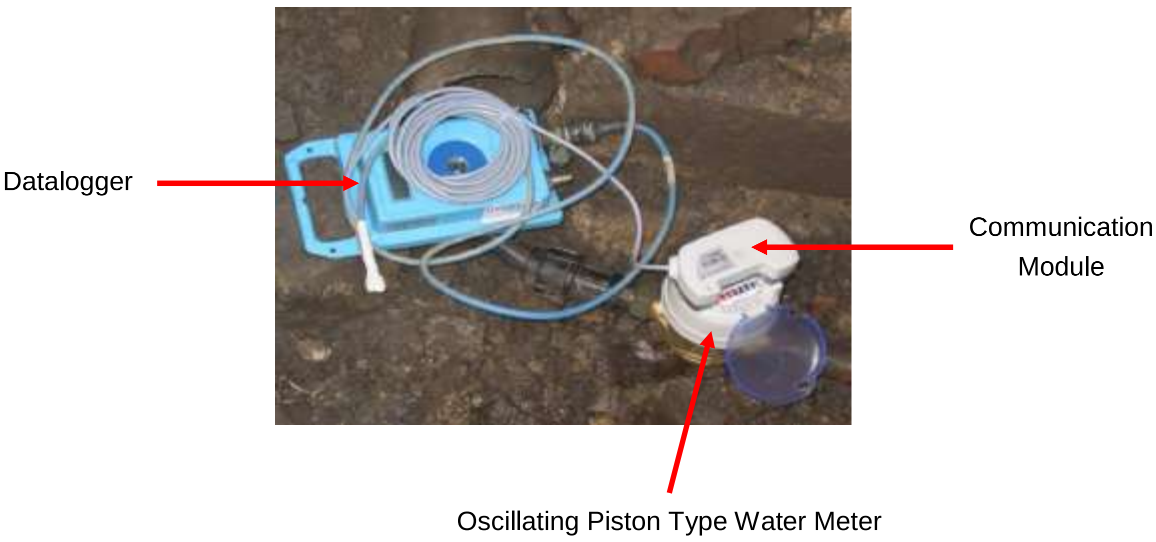
These meters are pre-equipped with the Cyble technology for data transmission, which allows fitting them with communication modules such as the Cyble Sensor[4]:

- Magnetic tampering is impossible since the non-magnetic target is not influenced by an external magnet;
- As the detection is by change of induction the unit can be operate in flooded pits;
- The unit is not sensible to pipe vibrations. Parasitic pulses do not disturb metering;

25 modules were provided for the study (model with 2 wires, which signal is equivalent to a dry contact signal or reed switch) with a K factor of 1.

The water meter equipped with the communication module emits a pulse every time 0.1 litre passes through the piston chamber. This output signal can then be captured and stored by a datalogger such as the one used during the water supply measurement campaign (a time-step of 30 seconds was used during the datalogging process).

Figure 1 : Example of metering point during the study



Metering points which gave problems (no datalogging, no water consumption...) were excluded from the analysis. The remaining data from 45 metering points were processed using computerized tools in order to allocate the measured volumes according to different ranges of flow rates.

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[3] In compliance with the European Directive 75/33/EEC on cold water meters (24 June 1975).

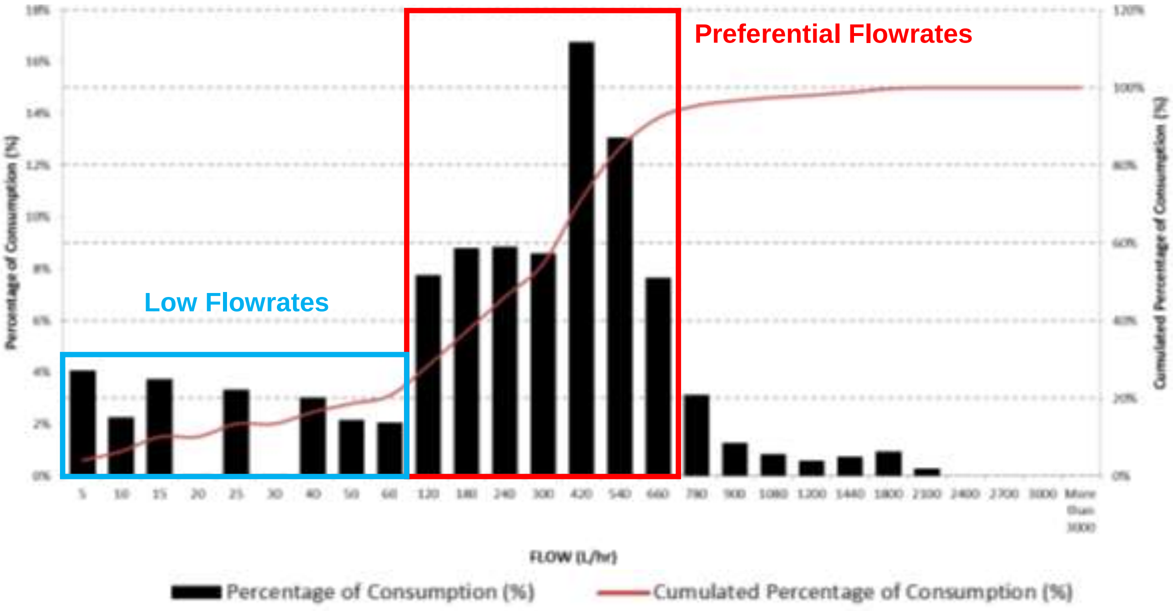
[4] The technical specifications for the communication modules are attached in the appendices.

It is then possible to switch from a view in "l/h" to a view in "% of volume per range of flow rates", which constitutes the consumption histogram or, otherwise said, the allocation of consumption in function of several flow ranges.

The graph below can be read as follows:

- About 12.5% of the water is for example consumed with a flow of 540 L/h;
- About 85% of the water consumption is made with flows lower than 540 L/h.

Figure 2 : Domestic consumption histogram in Chisinau



Main outcomes:

1. It can be observed that domestic water consumption in Chisinau preferentially ranges between 120 L/hr and 660 L/hr (approximately 72% of total consumption), with peaks between 420 L/hr and 540 L/hr.
2. The maximum flowrate of 3 000 L/hr was never reached as the maximum registered flowrate was 1 900 L/hr for a domestic customer living in an individual house.
3. 21% of domestic water consumption is done within flow ranges lower or equal to 60 L/hr, with 10% between 0 L/hr and 15 L/hr (Q_{min} for the Class C) and 13% between 0 L/hr and 30 L/hr (Q_{min} for the Class B).

The following table compares the distribution of domestic water consumption with the characteristic flows for different types of water meters.

Table 1: Percentage of domestic water consumption per flowrates ranges

Flowrates Ranges	CLASS B	CLASS C
	Percentage of domestic water consumption	
$Q < Q_{min}$	13%	10%
$Q_{min} < Q < Q_t$ (MPE ±5%)	15%	3%
$Q_t < Q < Q_{max}$ (MPE ±2%)	72%	87%
$Q > Q_{max}$	0%	0%
Total	100%	100%

These preliminary results show that there's a high incidence of low flows due to leakage after the water meter and within private premises (on service connections or due to defective internal plumbing), which could result in substantial losses if not accurately measured by current water meters.

2.3. DEFINITION OF REPRESENTATIVE METROLOGICAL ERROR CURVES OF WATER METERS' MODELS

Before launching the water meters' calibration program, the test bench selected for the study, property of ACC and located at the WWTP compound, was tested to verify its metrological accuracy, which was found to be perfectly suited for the study. Each bench owned by ACC is periodically checked and retrofitted each year.

Figure 3 : One of the test benches operated by ACC

Table 2: Results of the metrological verification of the water meter test bench

Testing flows (L/hr)	3	8	13	22	36	90	150	210	420	900	1 500	2 500
	3	8	13	22	36	90	151	209	419	898	1 500	2 425
Variation in testing flows (L/hr)	-	7.9 - 8.1	13 - 13.1	21.9 - 22	35.3 - 35.8	89 -91	150 - 151.5	208 - 210	418 - 419.5	896 - 899.5	1499.5 - 1501.5	2400 - 2450
Volume by flowmeter (START) (L)	-	9 487.9	9 492.2	9 498.3	9 504.8	9 515.9	9 554.5	9 583.3	9 643.0	9 707.4	9 879.2	351 663.0
Volume by tank (START) (L)	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Testing Time (hrs:mins:ss)	-	00:30:45	00:22:45	00:13:43	00:09:00	00:06:31	00:04:01	00:13:30	00:06:48	00:06:31	00:03:54	00:02:17
Volume by flowmeter (STOP) (L)	-	9 491.9	9 497.3	9 503.3	9 510.1	9 525.6	9 564.6	9 630.4	9 690.5	9 804.8	9 977.1	351 755.0
Volume by tank (STOP) (L)	-	4.0	5.0	5.0	5.3	9.7	10.1	47.2	47.5	97.7	98.0	92.8
Total volume by flowmeter (L)	-	4.1	5.1	5.0	5.3	9.6	10.1	47.1	47.5	97.4	97.8	92.0
Total volume by tank (L)	-	4.0	5.0	5.0	5.3	9.7	10.1	47.2	47.5	97.7	98.0	92.8
Average flow (L/hr)	-	7.8	13.2	21.9	35.3	88.8	150.1	209.8	419.1	899.5	1 507.7	2 438.5
Average error on flowmeter (%)	-	2.2%	1.4%	0.4%	0.5%	1.3%	0.4%	0.4%	0.1%	0.2%	0.5%	0.6%
Average error on volume (%)	-	1.9%	1.8%	0.7%	0.6%	0.0%	0.4%	0.2%	0.0%	0.3%	0.2%	0.9%

The main difficulty in defining a sample of water meters to be tested during the study was due to the fact that ACC does not own individual domestic water meters (property of the customers). It was not possible to go on site and take out the needed water meters from houses or apartments. It was therefore necessary to select the meters to be tested among the units brought by customers to ACC metrological laboratory and due for periodical verification.

Considering that there is also a lack of a structured database, it is impossible to define a sample which takes into account many parameters such as the age or the water consumption attached to a specific model.

The initial sample planned to test 200 water meters (DN 15 mm Class B single-jet type) among the most common models in ACC service area:

- 80 MADDALENA CD-ONE TRP;
- 60 G. GIOANOLA SISMA DBRF;
- 30 ZENNER ETK;
- 30 BMETERS GSD;

Finally, due to the aforementioned constraints, the sample contained 170 water meters:

- 105 MADDALENA CD-ONE TRP (manufactured between 2005 and 2011);
- 43 G. GIOANOLA SISMA DBRF (manufactured between 1993 and 2008);
- 16 BMETERS GSD (manufactured between 2006 and 2008);
- 4 ZENNER ETK (manufactured in 2007);
- 2 LORENZ ETK (manufactured in 2001);

In order to keep some statistical balance, only the three main models were selected for a detailed analysis with units manufactured after the year 2000[5] for a total of 155 water meters tested:

- **105 MADDALENA CD-ONE TRP;**
- **34 G. GIOANOLA SISMA DBRF;**
- **16 BMETERS GSD;**

Each water meter was tested at 11 flows (each flowrate range being related to a specific consumption histogram range). Moreover, a test at 3 000L/hr was carried out to track down any slipping and a test to determine the starting flow of the meters was performed.

Table 3: Testing flows used during the calibration program

	Testing Flows (L/hr)			Consumption Histogram Ranges
	Min	Average	Max	
TF1	2.75	3	3.25	0 ; 5
TF2	7.5	8	8.5	5 ; 10
TF3	12.5	13	13.5	10; 15
TF4	22.5	23.75	25	15 ; 25
TF5	34	35.5	37	25 ; 40
TF6	86	90	94	40 ; 120
TF7	145	150	155	120 ; 180
TF8	200	210	220	180 ; 240
TF9	400	420	440	240 ; 540
TF10	880	900	940	540 ; 1080
TF11	1450	1500	1550	1080 ; 3000

The results from the tests are presented below:

Table 4: Metrological results for a standard horizontal installation

MODEL	TESTING FLOWS (L/hr) and RELATED METERING ERROR (%)											
	3	8	13	24	36	90	150	210	420	900	1 500	2 400
MADDALENA CD-ONE TRP	-100.0%	-53.9%	-37.1%	-24.0%	-18.9%	-7.3%	-3.9%	-2.0%	-0.8%	-0.5%	-0.8%	-0.8%
G. GIOANOLA SISMA DBRF	-100.0%	-65.0%	-23.0%	-5.4%	-4.3%	-3.1%	-2.7%	-2.7%	-1.6%	-0.9%	0.9%	0.9%
BMETERS GSD	-100.0%	-84.2%	-48.7%	-8.4%	-1.7%	-1.3%	-0.4%	-0.3%	0.2%	0.7%	0.7%	1.2%

Figure 4 : Metrological results for a standard horizontal installation

[5] The raw results (metrological error curve) obtained on the test bench for each unit from the 170 water meters sample are attached in the appendices.

For a standard horizontal installation, the ranking of the tested water meters is the following (#1 being the best):

1. **G. GIOANOLA, SISMA DBRF model: average error of -4.2% (for Q ≥ 10 L/hr);**
2. **BMETERS, GSD model: average error of -5.8% (for Q ≥ 10 L/hr);**
3. **MADDALENA, CD-ONE TRP model: average error of -9.6% (for Q ≥ 10 L/hr);**

These 3 models represent 83% of the overall DN 15 mm units used as water meters by customers having direct contracts with ACC (individual houses and individual apartments): 54% for the CD-ONE TRP, 24% for the SISMA DBRF and 4% for the GSD.

2.4. CALCULATION OF METERING UNDER-REGISTRATION

Metering under-registration is obtained by multiplying the percentage of consumption from each flowrate range (TF1 to TF11) by the average measuring error from the metrological error curve in the same flowrate range.

The overall metrological efficiency (or billing efficiency) of the water meter is obtained by subtracting the total under-registration obtained.

Figure 5 : Superposition of the domestic water consumption histogram and the metrological error curves of the three tested water meters' models

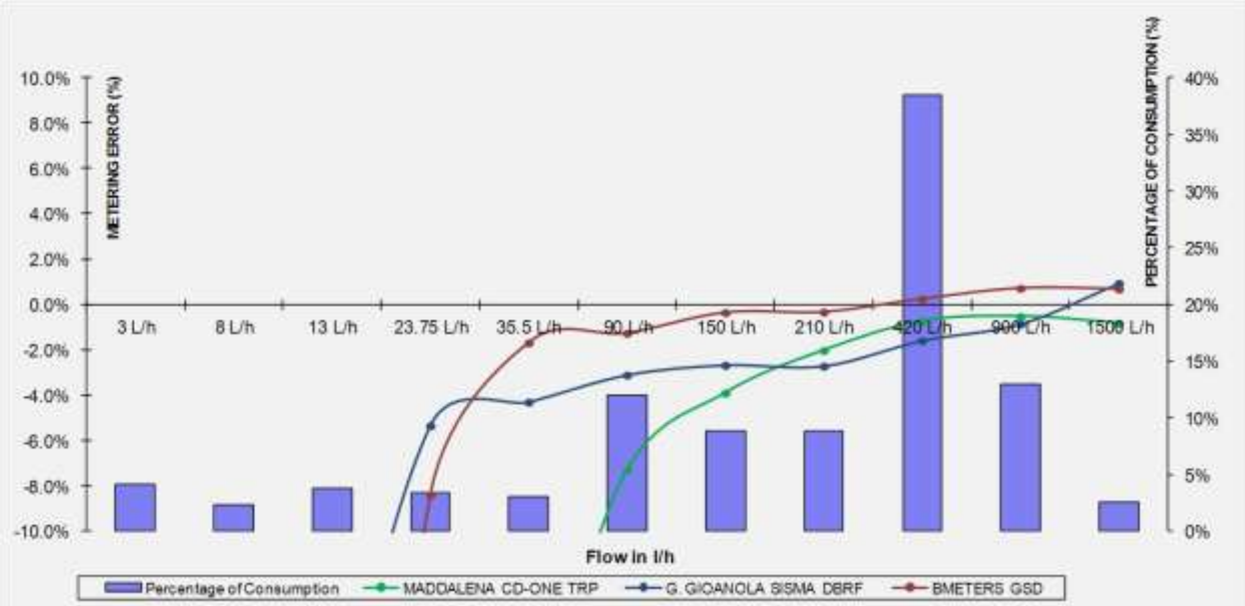


Table 5: Superposition of the domestic water consumption histogram and the metrological error curves of the three tested water meters' models

Flowrates Ranges (L/hr)	Percentage Of Consumption (%)	Under-Registration MADDALENA CD-ONE TRP	Under-Registration G. GIOANOLA SISMA DBRF	Under-Registration BMETERS GSD
0;5	4.1%	-4.1%	-4.1%	-4.1%
5;10	2.3%	-1.2%	-1.5%	-1.9%
10;15	3.7%	-1.4%	-0.9%	-1.8%
15;25	3.3%	-0.8%	-0.2%	-0.3%
25;40	3.0%	-0.6%	-0.1%	-0.1%
40;120	12.0%	-0.9%	-0.4%	-0.2%
120;180	8.8%	-0.3%	-0.2%	0.0%
180;240	8.9%	-0.2%	-0.2%	0.0%
240;540	38.4%	-0.3%	-0.6%	0.1%
540;1080	12.9%	-0.1%	-0.1%	0.1%
1080;3000	2.5%	0.0%	0.0%	0.0%
TOTAL	100%	-9.8%	-8.3%	-8.1%
	Metrological Efficiency (%)	90.2%	91.7%	91.9%

When taking into account the weighting of each model (on a 100 basis), **the overall under-registration for DN 15 mm units used as water meters by customers having direct contracts with ACC is considered to be approximately 9.3%, which is equivalent to a metrological efficiency of 90.7%.**

2.5. IMPACT ON METERED WATER CONSUMPTION AND BILLING

The Water Demand Study performed in the framework of the feasibility study gives the average household size and the average daily per capita consumption in Chisinau. It is then possible to deduce the average yearly consumption of a household.

The table below shows that the average yearly household consumption is approximately 139 cubic metres per year (with data from current water meters).

Table 6: Metrological results for a standard horizontal installation

Average Household Size (persons)	2.9
Average Daily Per Capita Consumption (L/d)	131
Average Yearly Household Consumption (m^3/year)	**139**

The real average yearly household consumption should therefore be approximately:

139 m^3/year x (100 / 90.7) = **153 m^3/year**

For each household, it is estimated that 14 cubic metres per year are not metered by current water meters' models in the service area.

Considering a tariff of 9.2 MDL per cubic metre[6] (0.58€ at an exchange rate of 1 € = 16 MDL), it means that a total of 128.8 MDL is not invoiced by ACC each year per household (total of 8.1 €).

It implies the following losses for the categories of domestic customers having direct contracts with ACC:

- **562 620 m^3/year for individual houses, equivalent to 326 k€/year;**
- **79 230 m^3/year for individual apartments[7], equivalent to 46 k€/year;**

[6] Water Supplyand Wastewater

[7] The apartments considered here are only the customers having a direct contract with ACC, as the customers having a contract with a condominium are billed based on the block water meters, that were not tested in this study.

2.6. IMPLEMENTATION OF CLASS C WATER METERS

If ACC decides to take over the ownership of water meters for domestic customers, they should consider the replacement of the current Class B single-jet models by Class C models, either volumetric (oscillating piston) or single-jet.

Indeed, the class C water meters have better performances for small flow rates and would be profitable after a few years. The payback time (PT) is calculated taking into account the purchase costs of new water meters (Class B and Class C), water tariffs as well as the potential economic gain in terms of billing thanks to the new water meter:

PT = (Cost of new Class C – Cost of new Class B) / Economic Gain

Figure 6 : Superposition of the domestic water consumption histogram and the metrological error curves of class C water meters

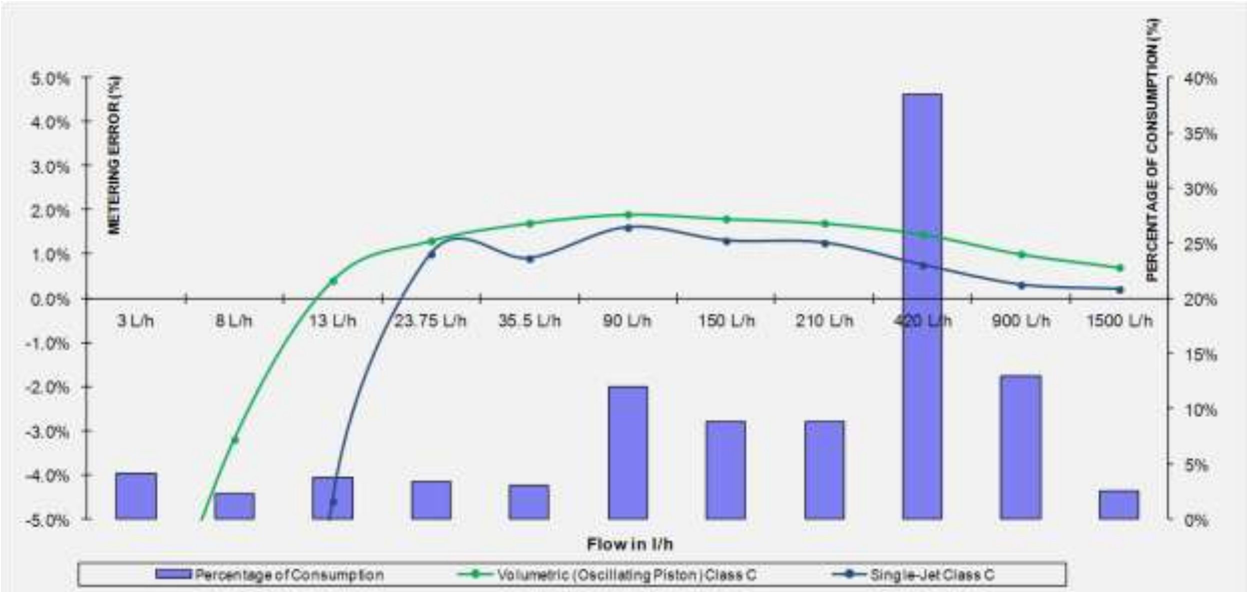


Table 7: Superposition of the domestic water consumption histogram and the metrological error curves of class C water meters

Flowrates Ranges (L/hr)	Percentage Of Consumption (%)	Under-Registration VOLUMETRIC CLASS C	Under-Registration SINGLE-JET CLASS C
0;5	4.1%	-0.4%	-4.0%
5;10	2.3%	-0.1%	-0.6%
10;15	3.7%	0.0%	-0.2%
15;25	3.3%	0.0%	0.0%
25;40	3.0%	0.1%	0.0%
40;120	12.0%	0.2%	0.2%
120;180	8.8%	0.2%	0.1%
180;240	8.9%	0.2%	0.1%
240;540	38.4%	0.6%	0.3%
540;1080	12.9%	0.1%	0.0%
1080;3000	2.5%	0.0%	0.0%
Under-registration on Total consumption		**+0.29%**	**-0.03%**
Metrological Efficiency (%)		**100.29%**	**99.7%**

Considering an average cost of 50 € for a Class C water meter (800 MDL) and 17.5 € for a Class B water meter in Chisinau (280 MDL for a MADDALENA CD-ONE TRP), the respective payback time for a Class C volumetric meter (oscillating piston) and a Class C single-jet meter are[8]:

$PT_{volumetric}$ = 4.0 years;

$PT_{single\text{-}jet}$ = 4.2 years;

The lifespan of a robust Class C water meter is estimated to be at minimum equal to 15 years, which means that the ratio lifespan over payback time is close to 3.8. Payback time will decrease sharply as water tariffs increase, making the implementation of Class C water meters even more interesting financially for ACC.

2.7. BLOCK METERING IN ACC SERVICE AREA

The aforementioned results (14 cubic metres per year per household are not metered by current water meters' models in the service area) consolidate the need to clearly base billing procedures for blocks on readings of the main water meter (which monitors the building's overall water consumption).

Block metering in Chisinau should continue with the current practises: one water meter on the service connection (owned by ACC) and one or several individual meter(s) per apartment (owned by the customers):

- ACC's responsibility will stop at the second shut off device (ball valve), including all piping, fittings and water meter located before it (by-pass also);
- ACC will bill the building's legal condominium entity based on the monthly reading of the main water meter, which will be located in a secure location and easy to access by the meter reader (implementation in basements or external chambers for example);

Individual water meters' installations will be at the charge of customers, following design and installation standards provided by ACC. These meters will be used by the legal condominium entity to internally bill water charges to each apartment.

The payment of the volumetric difference between the main meter and the sum of individual apartments will be borne directly by the legal condominium entity which will subsequently allocate it to the apartments in the housing charges.

An agreement has been found in 2012 between ACC and the Municipality of Chisinau, so that the legal condominium entities such as IMGFL and ACC will consider the block meters as the basis for invoicing and billing.

[8] Comparing the new water meters of the class C with the average performances of the water meters in Chişinău (described above in Table 5)

3. TESTING OF NEW WATER METERS (MADDALENA CD-ONE TRP)

Water meters can be imported and sold in the Republic of Moldova after obtaining a certification, legally valid for a determined period of time. Therefore, the water meters' market abounds with numerous brands and models which have obtained their certification. However, many of them may not be suited for the strict technical and economical demands of a modern water utility.

The most common water meter in the market is "MADDALENA CD-ONE TRP", from the single-jet type and manufactured in Italy. 5 new units (DN 15 mm) bought in Chişinău were brought to France to be tested in the LECE, one of the two major metrological laboratories of VEOLIA WATER, located in Nancy (eastern France).

The manufacturing quality of water meters is monitored by French utilities in partnership with manufacturers. Periodically, the latter publish the results of metrological signatures performed over significant samples of their production. For a DN 15 mm meter for example, the metrological signature is established on the basis of errors measured with ten test flows ranging from 3 L/hr to 3,000 L/hr.

The results from primary verifications are used for statistical analysis. Factory samples are periodically taken for calibration on the utilities' test benches and are then compared to the results obtained in the factory.

Finally, samples are taken from the utilities' existing stocks. Metrological signatures performed on these samples will determine whether there is any deterioration of metering quality as a result of transportation or storage.

The assessment of the metrological signature during various stages of production enables to track its variation which can be due to:

- A lack of process control, especially due to temperature fluctuations in the factory when no centralized cooling system is used where plastic parts are injected;
- No control over the evolution of the model, either as a consequence of the use of parts from a new sub-contractor or as a result of the design modification of certain parts of the meter;

The model's non-conformities detected during its operational life span are also accounted for. The non-conformity ratio is a pertinent indicator that should be closely monitored.

The water meters brought from Chisinau were exposed to the following tests to define their metrological signature:

- **For a standard horizontal installation;**
- **For an inclined installation (60°, 120°);**
- **For a vertical installation (ascending position);**
- **For an installation with upstream-downstream elbows;**
- **After a flow surge (2 x Q_{max}) of 1 hour;**

Their sensitivity to fraud was also tested by using a magnet, one of the most common items used by customers to alter the metrological behaviour of water meters by increasing the under-registration.

Figure 7 : Water meters on the LECE test bench during the tests

The sensitivity of single-jet type water meters to installations that do not follow the strict guidelines (i.e. strict horizontality with no elements which creates flow perturbations) is shown hereafter in the tests results from the LECE[9].

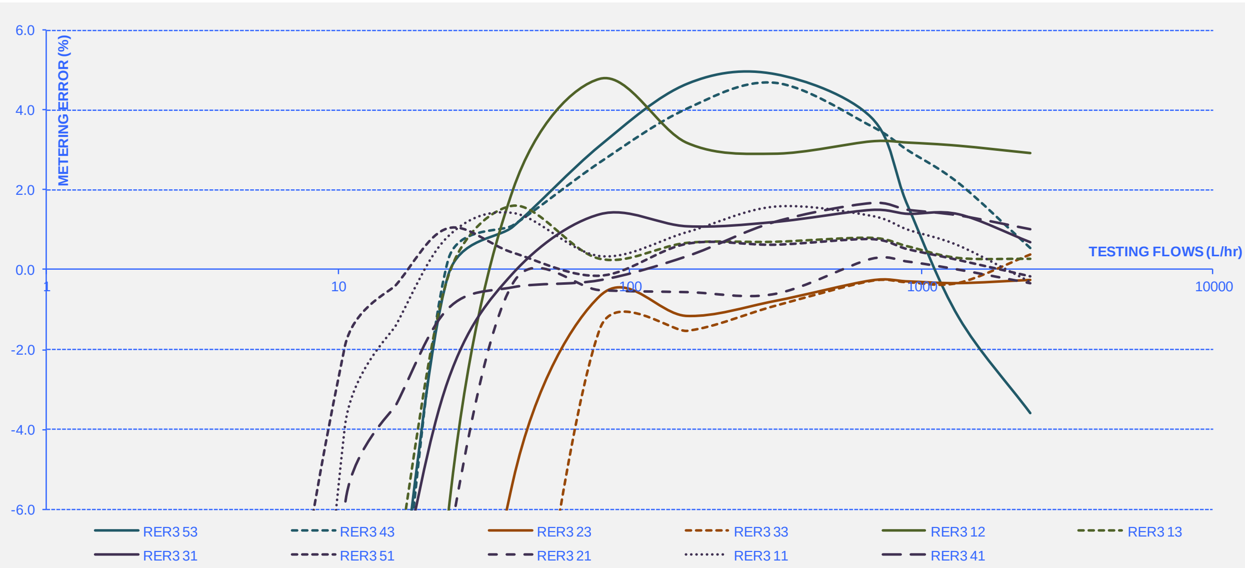
[9] The results obtained with the single-jet water meters models brought from Chisinau are compared to multi-jet water meter models very common in CIS countries: **BMETERS GMDX, NINGBO LXSG-15E and ABSERON CSS-15M**.

3.1. STANDARD HORIZONTAL INSTALLATION

Table 8: Metrological results for a standard horizontal installation

							TESTING FLOWS (L/hr)												
REF	MODEL	SERIAL #	INDEX	YEAR	Lot	QN	3	6	11	16	24	40	79	158	315	675	900	1350	2375
RER3 53	GMDX	10___00391672	0	2010	1781	1.5 m3/hr CLASS B	-100.0	-100.0	-19.4	-9.2	-0.2	1.1	3.1	4.6	4.9	3.8	1.6	-1.2	-3.6
RER3 43	GMDX	10___00391765	0	2010	1781	1.5 m3/hr CLASS B	-100.0	-100.0	-21.8	-10.1	0.2	1.1	2.7	4.0	4.7	3.6	3.0	2.2	0.5
RER3 23	LXSG-15E	11___00003344	1	2011	1781	1.5 m3/hr CLASS B	-100.0	-99.4	-72.0	-43.1	-17.5	-5.3	-0.7	-1.2	-0.8	-0.3	-0.3	-0.3	-0.3
RER3 33	LXSG-15E	11___00005040	1	2011	1781	1.5 m3/hr CLASS B	-100.0	-100.0	-99.8	-60.1	-24.9	-13.5	-1.5	-1.5	-0.9	-0.3	-0.3	-0.3	0.4
RER3 12	CSS-15M	11___00007717	1	2011	1781	1.5 m3/hr CLASS B	-100.0	-100.0	-46.1	-25.0	-6.2	2.0	4.8	3.2	2.9	3.2	3.2	3.1	2.9
RER3 13	CSS-15M	11___00007839	1	2011	1781	1.5 m3/hr CLASS B	-100.0	-100.0	-15.9	-7.6	-0.2	1.6	0.3	0.7	0.7	0.8	0.6	0.3	0.3
RER3 31	CD-ONE TRP	11___00123845	0	2011	1781	1.5 m3/hr CLASS B	-100.0	-90.0	-14.7	-8.4	-2.8	-0.1	1.4	1.1	1.2	1.5	1.4	1.4	0.7
RER3 51	CD-ONE TRP	11___00123894	0	2011	1781	1.5 m3/hr CLASS B	-72.3	-17.1	-2.0	-0.4	1.0	0.4	-0.2	0.6	0.6	0.8	0.5	0.2	-0.2
RER3 21	CD-ONE TRP	11___00123930	0	2011	1781	1.5 m3/hr CLASS B	-100.0	-100.0	-27.9	-16.8	-7.0	-0.3	-0.5	-0.6	-0.6	0.3	0.2	0.0	-0.3
RER3 11	CD-ONE TRP	11___00124000	0	2011	1781	1.5 m3/hr CLASS B	-95.6	-31.8	-4.0	-1.4	0.8	1.4	0.3	0.9	1.6	1.3	1.0	0.6	-0.3
RER3 41	CD-ONE TRP	11___00124109	0	2011	1781	1.5 m3/hr CLASS B	-98.5	-51.2	-6.0	-3.4	-1.0	-0.4	-0.3	0.3	1.2	1.7	1.5	1.4	1.0
Average with 11 tested water meters			C.C.M. = -4.7 %				**-96.9**	**-80.9**	**-30.0**	**-16.9**	**-5.2**	**-1.1**	**0.9**	**1.1**	**1.4**	**1.5**	**1.1**	**0.7**	**0.1**

Figure 8 : Metrological results for a standard horizontal installation



The metrological results obtained for a standard horizontal installation show that:

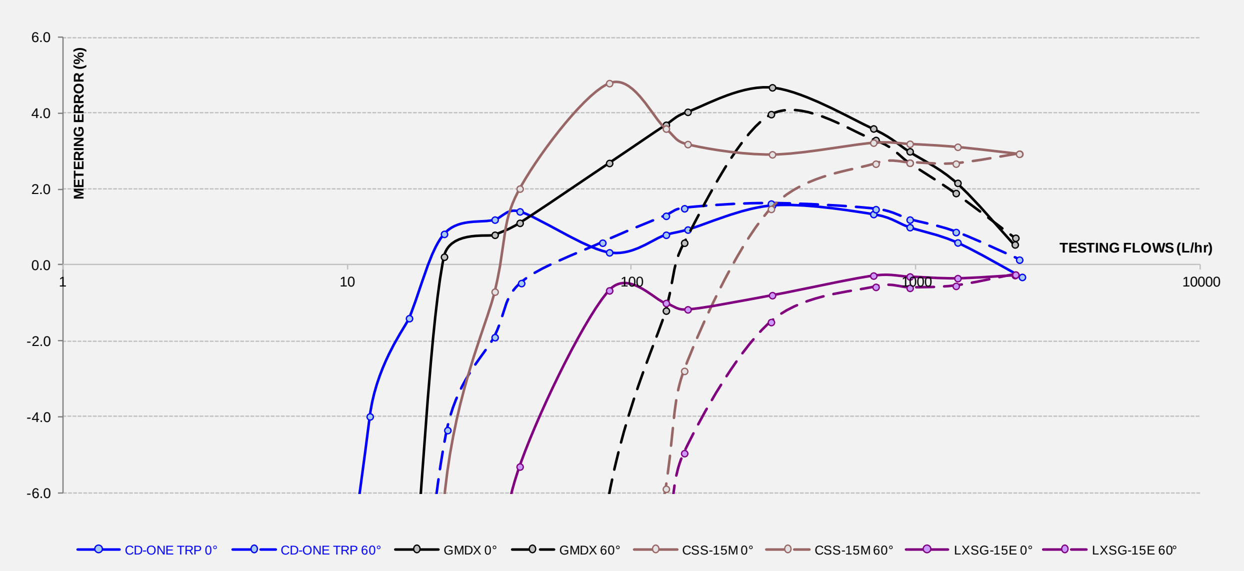
- The two GMDX units (RER3 53 and RER3 43) have MPE values higher than ±2% for multiple flowrates above Q_t, i.e. they do not compel to the Class B standards
- The two LXSG-15E units (RER3 23 and RER3 33) have MPE values higher than ±5% for one flowrate above Qmin, i.e. they do not compel to the Class B standards
- One of the CSS-15M units (RER3 12) has MPE values higher than ±2% for multiple flowrates above Q_t, i.e. they do not compel to the Class B standards

3.2. Inclined installation (60°, 120°)

Table 9: Metrological results for an inclined installation (60°)

REF	MODEL	SERIAL #	INCLINATION	QN	TESTING FLOWS (L/hr)														
RER3 11			CD-ONE TRP 0°	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2358
	CD-ONE TRP	11___00124000			-95.6	-31.8	-4.0	-1.4	0.8	1.2	1.4	0.3	0.8	0.9	1.6	1.3	1.0	0.6	-0.3
REUA 11			CD-ONE TRP 60°	1.5 m3/hr CLASS B			11	17	23	33	41	79	132	153	309	721	950	1380	2306
							-23.7	-12.7	-4.4	-1.9	-0.5	0.6	1.3	1.5	1.6	1.5	1.2	0.9	0.1
RER3 12			CSS-15M 0°	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2309
	CSS-15M	11___00007717			-100.0	-100.0	-46.1	-25.0	-6.2	-0.7	2.0	4.8	3.6	3.2	2.9	3.2	3.2	3.1	2.9
REUA 12			CSS-15M 60°	1.5 m3/hr CLASS B			11	17	23	33	41	79	132	153	309	721	950	1380	2304
							-100.0	-100.0	-100.0	-81.6	-71.2	-16.6	-5.9	-2.8	1.5	2.7	2.7	2.7	2.9
RER3 23			LXSG-15E 0°	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
	LXSG-15E	07_--01128849			-100.0	-99.4	-72.0	-43.1	-17.5	-9.3	-5.3	-0.7	-1.0	-1.2	-0.8	-0.3	-0.3	-0.3	-0.3
REUA 23			LXSG-15E 60°	1.5 m3/hr CLASS B			11	17	23	33	41	79	132	153	309	721	950	1380	2236
							-100.0	-100.0	-100.0	-81.1	-70.5	-15.9	-7.4	-5.0	-1.5	-0.6	-0.6	-0.5	-0.2
RER3 43			GMDX 0°	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
	GMDX	10___00391765			-100.0	-100.0	-21.8	-10.1	0.2	0.8	1.1	2.7	3.7	4.0	4.7	3.6	3.0	2.2	0.5
REUA 43			GMDX 60°	1.5 m3/hr CLASS B			11	17	23	33	41	79	132	153	309	721	950	1380	2236
							-100.0	-100.0	-100.0	-56.7	-32.4	-7.2	-1.2	0.6	4.0	3.3	2.7	1.9	0.7

Figure 9 : Metrological results for an inclined installation (60°)



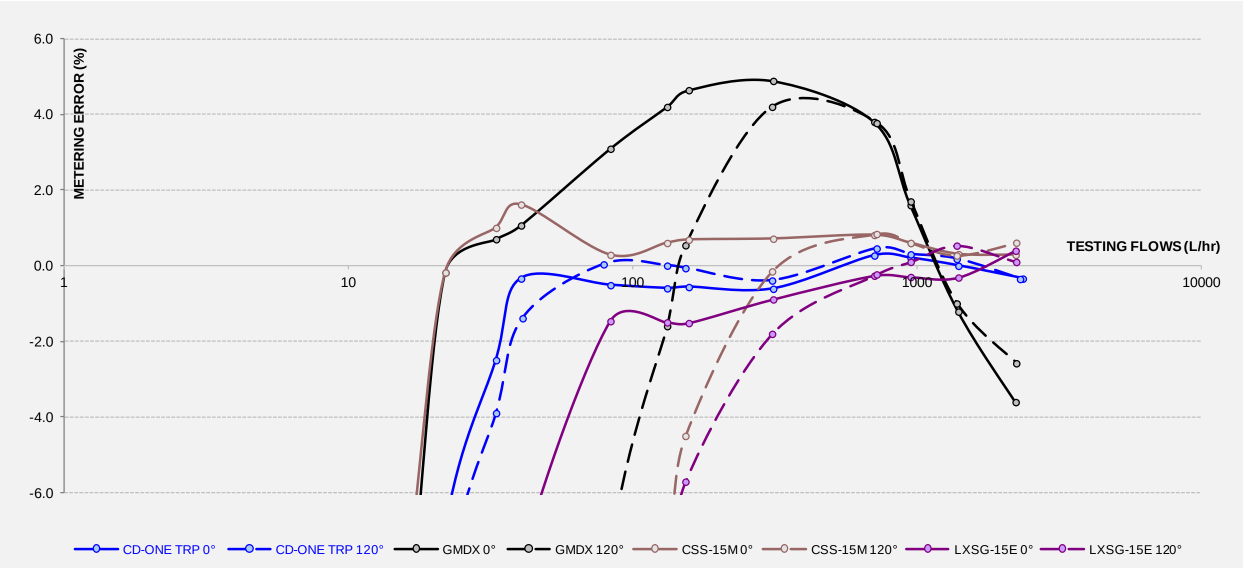
The impact of an installation with an angle of 60° is strong, the most degraded water meters (i.e. with higher metering errors) being in order (#1 being the worst):

1. **ABSERON, CSS-15M model (REUA 12):**
   - **increase of the average error by 32.1 points, compared to the horizontal installation;**
2. **BMETERS, GMDX model (REUA 43);**
   - **increase of the average error by 29.2 points, compared to the horizontal installation;**
3. **NINGBO, LXSG-15E model (REUA 23);**
   - **increase of the average error by 25.5 points, compared to the horizontal installation;**
4. **MADDALENA, CD-ONE TRP model (REUA 11);**
   - **increase of the average error by 3.0 points, compared to the horizontal installation;**

Table 10: Metrological results for an inclined installation (120°)

REF	MODEL	SERIAL #	INCLINATION	QN	TESTING FLOWS (L/hr)														
RER3 21	CD-ONE TRP	11___00123930	CD-ONE TRP 0°	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2358
					-100.0	-100.0	-27.9	-16.8	-7.0	-2.5	-0.3	-0.5	-0.6	-0.6	-0.6	0.3	0.2	0.0	-0.3
REUA 21			CD-ONE TRP 120°	1.5 m3/hr CLASS B			11	17	23	33	41	79	132	153	309	721	950	1380	2306
							-43.2	-23.5	-8.5	-3.9	-1.4	0.0	0.0	-0.1	-0.4	0.5	0.3	0.2	-0.4
RER3 13	CSS-15M	11___00007839	CSS-15M 0°	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-15.9	-7.6	-0.2	1.0	1.6	0.3	0.6	0.7	0.7	0.8	0.6	0.3	0.3
REUA 13			CSS-15M 120°	1.5 m3/hr CLASS B			11	17	23	33	41	79	132	153	309	721	950	1380	2236
							-100.0	-100.0	-100.0	-73.7	-58.9	-17.8	-7.5	-4.5	-0.2	0.8	0.6	0.3	0.6
RER3 33	LXSG-15E	11___00005040	LXSG-15E 0°	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-99.8	-60.1	-24.9	-13.5	-7.9	-1.5	-1.5	-1.5	-0.9	-0.3	-0.3	-0.3	0.4
REUA 33			LXSG-15E 120°	1.5 m3/hr CLASS B			11	17	23	33	41	79	132	153	309	721	950	1380	2236
							-100.0	-100.0	-100.0	-87.6	-80.6	-18.4	-8.5	-5.7	-1.8	-0.2	0.1	0.5	0.1
RER3 53	GMDX	10___00391672	GMDX 0°	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-19.4	-9.2	-0.2	0.7	1.1	3.1	4.2	4.6	4.9	3.8	1.6	-1.2	-3.6
REUA 53			GMDX 120°	1.5 m3/hr CLASS B			11	17	23	33	41	79	132	153	309	721	950	1380	2236
							-100.0	-100.0	-100.0	-64.9	-45.3	-9.0	-1.6	0.5	4.2	3.8	1.7	-1.0	-2.6

Figure 10 : Metrological results for an inclined installation (120°)



The impact of an installation with an angle of 120° is even stronger than an installation with an angle of 60°, the most degraded water meters (i.e. with higher metering errors) being in order (#1 being the worst):

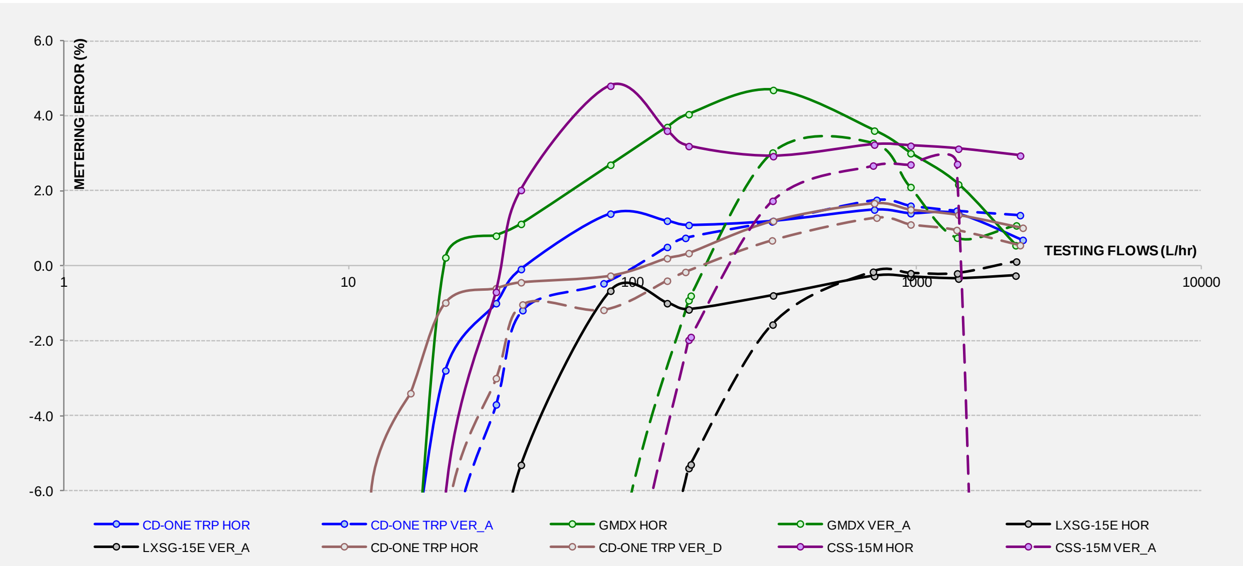
1. **ABSERON, CSS-15M model (REUA 13);**
   - **increase of the average error by 34.1 points, compared to the horizontal installation;**
2. **BMETERS, GMDX model (REUA 53);**
   - **increase of the average error by 31.1 points, compared to the horizontal installation;**
3. **NINGBO, LXSG-15E model (REUA 33);**
   - **increase of the average error by 22.3 points, compared to the horizontal installation;**
4. **MADDALENA, CD-ONE TRP model (REUA 21);**
   - **increase of the average error by 1.8 points, compared to the horizontal installation;**

3.3. VERTICAL INSTALLATION (ASCENDING POSITION)

Table 11: Metrological results for a vertical installation

REF	MODEL	SERIAL #	HOR/VER	QN	TESTING FLOWS (L/hr)														
RER3 31	CD-ONE TRP	11___00123845	CD-ONE TRP HOR	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2358
					-100.0	-90.0	-14.7	-8.4	-2.8	-1.0	-0.1	1.4	1.2	1.1	1.2	1.5	1.4	1.4	0.7
REUA 31			CD-ONE TRP VER_A	1.5 m3/hr CLASS B			11	17	23	33	41	79	132	153	309	721	950	1380	2306
							-40.0	-21.9	-8.0	-3.7	-1.2	-0.5	0.5	0.7	1.2	1.8	1.6	1.5	1.3
RER3 41	CD-ONE TRP	11___00124109	CD-ONE TRP HOR	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2358
					-98.5	-51.2	-6.0	-3.4	-1.0	-0.6	-0.4	-0.3	0.2	0.3	1.2	1.7	1.5	1.4	1.0
REUA 41			CD-ONE TRP VER_D	1.5 m3/hr CLASS B			11	17	23	33	41	79	132	153	309	721	950	1380	2306
							-29.5	-16.4	-6.4	-3.0	-1.0	-1.2	-0.4	-0.2	0.7	1.3	1.1	1.0	0.5
RER3 12	CSS-15M	11___00007717	CSS-15M HOR	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2309
					-100.0	-100.0	-46.1	-25.0	-6.2	-0.7	2.0	4.8	3.6	3.2	2.9	3.2	3.2	3.1	2.9
REV1 21			CSS-15M VER_A	1.5 m3/hr CLASS B	3	6	11	17	23	33	43	80	157	160	311	701	950	1386	2237
					-100.0	-100.0	-100.0	-100.0	-100.0	-75.4	-57.3	-14.4	-2.0	-1.9	1.7	2.7	2.7	2.7	-54.5
RER3 23	LXSG-15E	10___00391765	LXSG-15E HOR	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-99.4	-72.0	-43.1	-17.5	-9.3	-5.3	-0.7	-1.0	-1.2	-0.8	-0.3	-0.3	-0.3	-0.3
REV1 11			LXSG-15E VER_A	1.5 m3/hr CLASS B	3	6	11	17	23	33	43	80	157	160	311	701	950	1386	2237
					-100.0	-100.0	-100.0	-100.0	-100.0	-98.9	-98.1	-18.5	-5.4	-5.3	-1.6	-0.2	-0.2	-0.2	0.1
RER3 43	GMDX	10___00391765	GMDX HOR	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-21.8	-10.1	0.2	0.8	1.1	2.7	3.7	4.0	4.7	3.6	3.0	2.2	0.5
REV1 31			GMDX VER_A	1.5 m3/hr CLASS B	3	6	11	17	23	33	43	80	157	160	311	701	950	1386	2237
					-100.0	-100.0	-100.0	-100.0	-100.0	-68.4	-45.2	-10.3	-0.9	-0.8	3.0	3.3	2.1	0.7	1.1

Figure 11 : Metrological results for a vertical installation



The impact of a vertical installation is strong, the most degraded water meters (i.e. with higher metering errors) being in order (#1 being the worst):

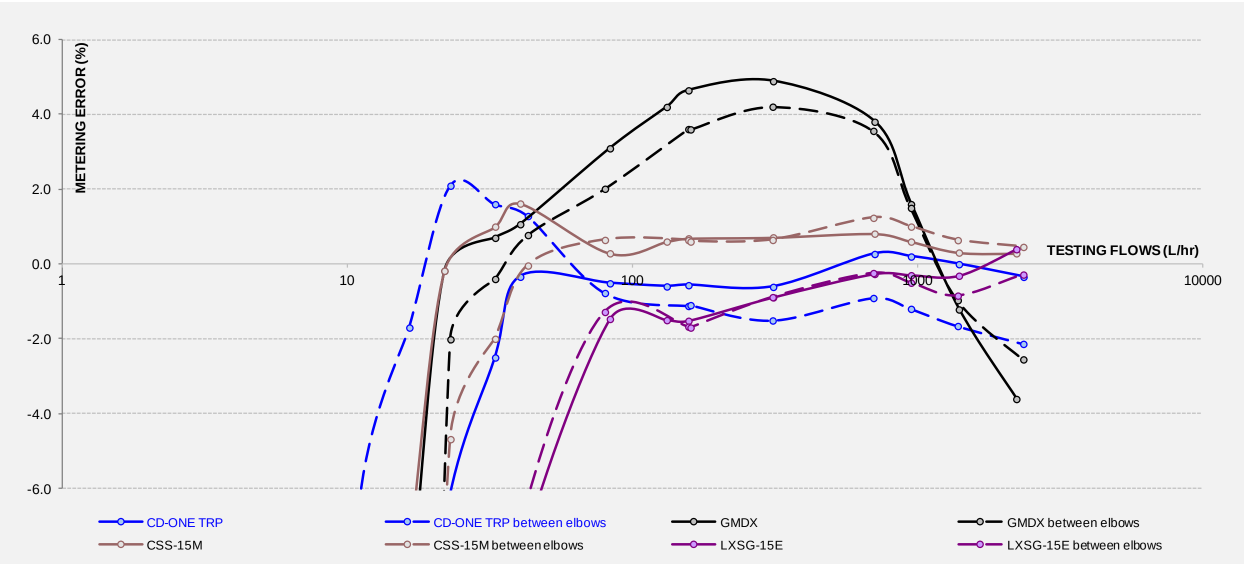
1. **ABSERON, CSS-15M model (REV1 21);**
   - **increase of the average error by 34.3 points, compared to the horizontal installation;**
2. **BMETERS, GMDX model (REV1 31);**
   - **increase of the average error by 31.6 points, compared to the horizontal installation;**
3. **NINGBO, LXSG-15E model (REV1 11);**
   - **increase of the average error by 28.9 points, compared to the horizontal installation;**
4. **MADDALENA, CD-ONE TRP model (REUA 31);**
   - **increase of the average error by 3.8 points, compared to the horizontal installation;**

3.4. INSTALLATION WITH UPSTREAM-DOWNSTREAM ELBOWS

Table 12: Metrological results for an installation with upstream-downstream elbows

REF	MODEL	SERIAL #	UPS/DOW ELBOWS	QN	TESTING FLOWS (L/hr)														
RER3 21	CD-ONE TRP	11___00123930	CD-ONE TRP	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2358
					-100.0	-100.0	-27.9	-16.8	-7.0	-2.5	-0.3	-0.5	-0.6	-0.6	-0.6	0.3	0.2	0.0	-0.3
REV1 12			CD-ONE TRP between elbows	1.5 m3/hr CLASS B	3	6	11	17	23	33	43	80	157	160	311	701	950	1386	2354
					-97.8	-31.4	-6.3	-1.7	2.1	1.6	1.3	-0.8	-1.1	-1.1	-1.5	-0.9	-1.2	-1.7	-2.1
RER3 13	CSS-15M	11___00007839	CSS-15M	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-15.9	-7.6	-0.2	1.0	1.6	0.3	0.6	0.7	0.7	0.8	0.6	0.3	0.3
REV1 22			CSS-15M between elbows	1.5 m3/hr CLASS B	3	6	11	17	23	33	43	80	157	160	311	701	950	1386	2354
					-100.0	-100.0	-68.2	-33.7	-4.7	-2.0	0.0	0.6	0.6	0.6	0.6	1.2	1.0	0.6	0.5
RER3 33	LXSG-15E	11___00005040	LXSG-15E	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-99.8	-60.1	-24.9	-13.5	-7.9	-1.5	-1.5	-1.5	-0.9	-0.3	-0.3	-0.3	0.4
REV1 42			LXSG-15E between elbows	1.5 m3/hr CLASS B	3	6	11	17	23	33	43	80	157	160	311	701	950	1386	2354
					-100.0	-100.0	-100.0	-56.4	-19.9	-12.0	-6.3	-1.3	-1.7	-1.7	-0.9	-0.2	-0.5	-0.8	-0.3
RER3 53	GMDX	10___00391672	GMDX	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-19.4	-9.2	-0.2	0.7	1.1	3.1	4.2	4.6	4.9	3.8	1.6	-1.2	-3.6
REV1 32			GMDX between elbows	1.5 m3/hr CLASS B	3	6	11	17	23	33	43	80	157	160	311	701	950	1386	2354
					-100.0	-100.0	-100.0	-46.7	-2.0	-0.4	0.8	2.0	3.6	3.6	4.2	3.6	1.5	-1.0	-2.6

Figure 12 : Metrological results for an installation with upstream-downstream elbows



The impact of an installation with upstream-downstream elbows is strong, the most degraded water meters (i.e. with higher metering errors) being in order (#1 being the worst):

1. **BMETERS, GMDX model (REV1 32);**
    - **increase of the average error by 9.5 points, compared to the horizontal installation;**
2. **ABSERON, CSS-15M model (REV1 22):**
    - **increase of the average error by 6.6 points, compared to the horizontal installation;**

The two other models (maddalena CD-ONE TRP and NINGBO LXSG-15E) have an average error which slightly decreases (no impact).

Upstream/downstream elbows are very common when water meters are installed above ground -on a concrete slab when using HDPE service pipes or completely airborne when using galvanized steel service pipes.

Airborne installations, besides impacting the metrological behaviour of the water meter, might get blocked by the apparition of air pockets, in case of schedule supply[10].

Figure 13 : Airborne water meter installation

3.5. After a flow surge (2 x Q_{MAX}) of 1 hour

Water meters are tested at 2 x Q_{max} (6 m^3/hr in this case) during one hour, and after that, the water meters errors at preferential flows should not differ by more than 0.3% from those obtained before the test[11].

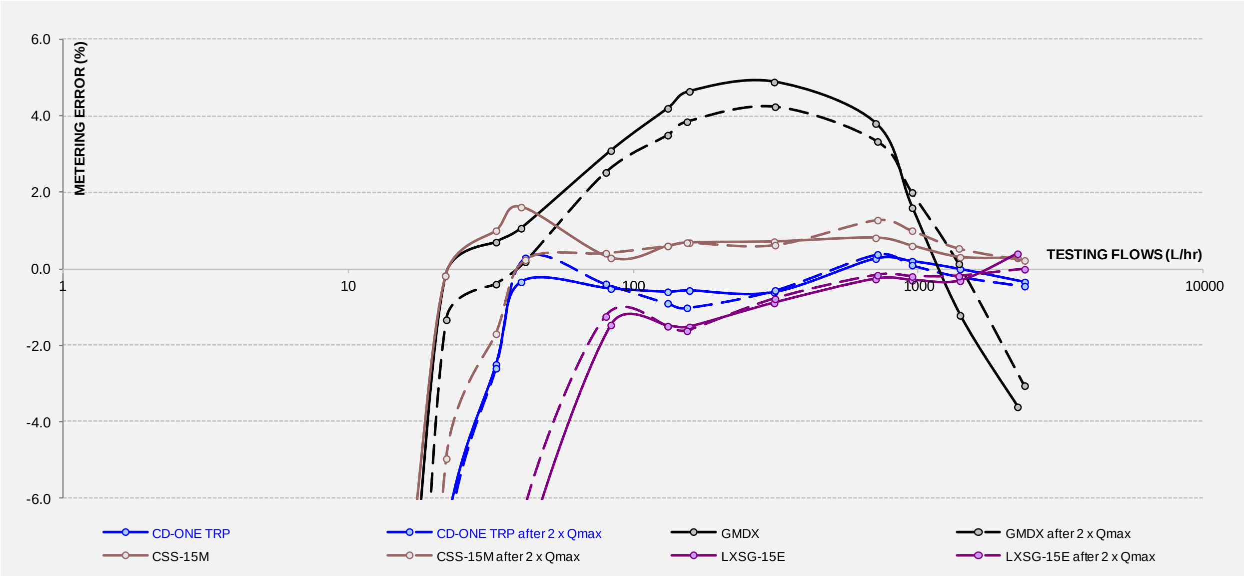
REF	MODEL	SERIAL #	AFTER 2 x QMAX	QN	TESTING FLOWS (L/hr)														
RER3 21	CD-ONE TRP	11___00123930	CD-ONE TRP	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2358
					-100.0	-100.0	-27.9	-16.8	-7.0	-2.5	-0.3	-0.5	-0.6	-0.6	-0.6	0.3	0.2	0.0	-0.3
REW1 23			CD-ONE TRP after 2 x Qmax	1.5 m3/hr CLASS B	2	5	11	17	22	33	42	80	132	154	314	718	950	1386	2356
					-100.0	-100.0	-57.9	-27.8	-7.6	-2.6	0.3	-0.4	-0.9	-1.0	-0.6	0.4	0.1	-0.2	-0.5
RER3 13	CSS-15M	11___00007839	CSS-15M	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-15.9	-7.6	-0.2	1.0	1.6	0.3	0.6	0.7	0.7	0.8	0.6	0.3	0.3
REW1 33			CSS-15M after 2 x Qmax	1.5 m3/hr CLASS B	2	5	11	17	22	33	42	80	132	154	314	718	950	1386	2356
					-100.0	-100.0	-47.7	-22.2	-5.0	-1.7	0.2	0.4	0.6	0.7	0.6	1.3	1.0	0.5	0.2
RER3 33	LXSG-15E	11___00005040	LXSG-15E	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-99.8	-60.1	-24.9	-13.5	-7.9	-1.5	-1.5	-1.5	-0.9	-0.3	-0.3	-0.3	0.4
REW1 53			LXSG-15E after 2 x Qmax	1.5 m3/hr CLASS B	2	5	11	17	22	33	42	80	132	154	314	718	950	1386	2356
					-100.0	-100.0	-100.0	-52.8	-20.9	-11.7	-6.2	-1.2	-1.5	-1.6	-0.8	-0.2	-0.2	-0.2	0.0
RER3 53	GMDX	10___00391672	GMDX	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-19.4	-9.2	-0.2	0.7	1.1	3.1	4.2	4.6	4.9	3.8	1.6	-1.2	-3.6
REW1 43			GMDX after 2 x Qmax	1.5 m3/hr CLASS B	2	5	11	17	22	33	42	80	132	154	314	718	950	1386	2356
					-100.0	-100.0	-36.0	-15.3	-1.3	-0.4	0.2	2.5	3.5	3.9	4.2	3.3	2.0	0.1	-3.1

Table 13: Metrological results after a flow surge (2 x Q_{max}) of 1 hour

[10] Other issues raised by airborne installations are the lack of protection of water meter and accessories to heat, UVs and physical deterioration.

[11] This allows evaluating the mechanical resistance of the water meter's measuring mechanisms to sudden flow surges, such as those created by pumps. For example, some water meters have problems with the magnetic transmission at very high flows: the register stops turning even though water continues to flow through the water meter.

Figure 14 : Metrological results after a flow surge (2 x Q_{max}) of 1 hour



The impact of a flow surge (2 x Q_{max}) of 1 hour is strong, the most degraded water meters (i.e. with higher metering errors) being in order (#1 being the worst):

1. **ABSERON, CSS-15M model (REW1 33):**
   - **increase of the average error by 4.2 points, compared to the horizontal installation;**
2. **MADDALENA, CD-ONE TRP model (REW1 23);**
   - **increase of the average error by 3.2 points, compared to the horizontal installation;**
3. **BMETERS, GMDX model (REW1 43);**
   - **increase of the average error by 2.1 points, compared to the horizontal installation;**

The other model has an average error which slightly decreases (no impact).

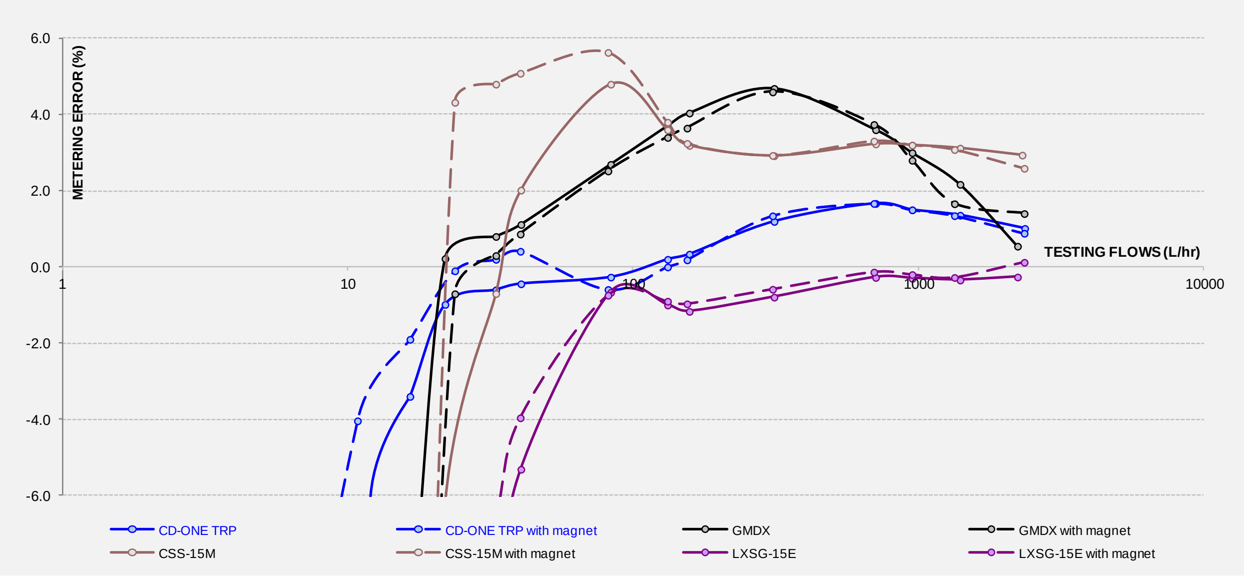
3.6. SENSITIVITY TO FRAUD BY USING A MAGNET:

Magnets are one of the most common fraud techniques used by customers to alter the metrological behaviour of water meters (others that can be very common are clamps and hot needles). By setting-up a magnet on top of the register, it creates a disturbance in the magnetic transmission, thus reducing the metered volumes.

Table 14: Metrological results under magnetic fraud

REF	MODEL	SERIAL #	FRAUD WITH MAGNET	QN	TESTING FLOWS (L/hr)														
RER3 41	CD-ONE TRP	11___00124109	CD-ONE TRP	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2358
					-98.5	-51.2	-6.0	-3.4	-1.0	-0.6	-0.4	-0.3	0.2	0.3	1.2	1.7	1.5	1.4	1.0
REY N 21			CD-ONE TRP with magnet	1.5 m3/hr CLASS B	3	6	11	17	24	33	40	82	132	154	308	698	950	1337	2348
					-80.4	-16.8	-4.0	-1.9	-0.1	0.2	0.4	-0.6	0.0	0.2	1.3	1.7	1.5	1.3	0.9
RER3 12	CSS-15M	11___00007717	CSS-15M	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2309
					-100.0	-100.0	-46.1	-25.0	-6.2	-0.7	2.0	4.8	3.6	3.2	2.9	3.2	3.2	3.1	2.9
REY N 31			CSS-15M with magnet	1.5 m3/hr CLASS B	3	6	11	17	24	33	40	82	132	154	308	698	950	1337	2348
					-100.0	-100.0	-67.2	-28.6	4.3	4.8	5.1	5.6	3.8	3.2	2.9	3.3	3.2	3.1	2.6
RER3 23	LXSG-15E	11___00003344	LXSG-15E	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-99.4	-72.0	-43.1	-17.5	-9.3	-5.3	-0.7	-1.0	-1.2	-0.8	-0.3	-0.3	-0.3	-0.3
REY N 11			LXSG-15E with magnet	1.5 m3/hr CLASS B	3	6	11	17	24	33	40	82	132	154	308	698	950	1337	2348
					-100.0	-99.0	-70.2	-38.3	-11.0	-6.6	-4.0	-0.7	-0.9	-1.0	-0.6	-0.1	-0.2	-0.3	0.1
RER3 43	GMDX	10___00391765	GMDX	1.5 m3/hr CLASS B	3	5	12	17	22	33	40	83	132	157	312	708	950	1399	2225
					-100.0	-100.0	-21.8	-10.1	0.2	0.8	1.1	2.7	3.7	4.0	4.7	3.6	3.0	2.2	0.5
REY N 41			GMDX with magnet	1.5 m3/hr CLASS B	3	6	11	17	24	33	40	82	132	154	308	698	950	1337	2348
					-99.0	-100.0	-51.0	-23.9	-0.7	0.3	0.9	2.5	3.4	3.6	4.6	3.7	2.8	1.7	1.4

Figure 15 : Metrological results under magnetic fraud



The impact of magnetic fraud is strong, the most degraded water meters (i.e. with higher metering errors) being in order (#1 being the worst):

1. **BMETERS, GMDX model (REY N 41);**
   - **increase of the average error by 3.5 points, compared to the horizontal installation;**
2. **ABSERON, CSS-15M model (REY N 31):**
   - **increase of the average error by 0.4 points, compared to the horizontal installation;**

The two other models have an average error which slightly decreases (no impact).

3.7. CONCLUSION

These tests show the highly importance of strict installation guidelines which ensure that the water meters will perform at their best, to the benefit of both ACC and its customers. Future installations done by in-house or subcontracted crews will therefore need to be thoroughly supervised and re-done in case of observed mistakes/defaults.

The most common model in the service area, the MADDALENA CD-ONE TRP, which is recommended by ACC, is quite suited to the current situation due to its low price and the low water tariffs. However, its aging within the service area supply conditions strongly affects the metrological performances:

- **Average error of -1.3% (for Q ≥ 10 L/hr) when new;**
- **Average error of -9.6% (for Q ≥ 10 L/hr) when been in operation for less than 10 years (see results in Section 2);**

It is quite weak when compared to other single-jet models available on the market (FLODIS from ITRON for example) with proven and reliable metrological results in many water utilities around the world.

Sponsoring the use of single-jet type water meters is quite justified by all results obtained with the 3 different models of multi-jet units.

French water utilities are very attached to equity: the first consequence is the suppression of multi-jet meters on networks containing aggressive or corrosive water, when local regulations allow the cost effective installation of volumetric or single-jet meters. Indeed, multi-jet meters are known to over-register in aggressive or corrosive waters but also, to a lesser extent, in hard waters.

If multi-jet meters cannot be suppressed, they are subjected to periodic verifications to ensure that they respect the current regulations and if necessary, embark on a water meter renewal program.

Metrological studies carried out in France in the eighties showed that more than 50 % of calibrated multi-jet meters, in service for over ten years, had over-registering indexes beyond the values allowed by regulations for one or multiple flowrates[12].

[12] Multi-jet water meters present a long strainer inside the inlet pipe and another one covering the openings to the metering chamber. A clogged entry strainer will not have any effect on the metrology of the meter. However, the obstruction of the strainer located near the metering chamber could lead to an increase in the impact velocity on the impeller for the other openings. This would result in a faster rotation of the impeller for a given flowrate and in undesirable metering errors. It is not rare to observe the errors for medium and high flows drifting to positive values (over-registration), due to the obstruction of the bypass circuit and the chamber entry strainer.

4. NON-DOMESTIC METERING UNDER-REGISTRATION

4.1. INTRODUCTION

Non-domestic customers' water consumption was about 8.7 Mm^3, with the addition of an extra 1.8 Mm^3 of pre-treated water in 2010. Within the service area operated by ACC two representative categories can be distinguished:

- Non-domestic customers with public status;
- Non-domestic customers with private status, among which can be found ACC's largest water consumer, i.e. SA CET-2;

Meters are owned and installed by customers. Readings are made once a month by ACC meter readers. This report focuses on the assessment of metering under-registration, which for non-domestic customers was based on two main components:

- The definition of representative consumption histograms of a sample of customers among the largest 50 water consumers in the service area;
- The analysis of the metering point characteristics: water meter type and sizing and current hydraulic conditions (presence of flow disturbing elements);

4.2. SAMPLE OF NON-DOMESTIC CUSTOMERS

Initially, a first sample of the 17 largest customers was selected for the study, representing 38% of the total consumption of the non-domestic category in 2010.

Table 15: Initial sample of large customers to be studied

#	NAME OF THE CUSTOMER	WATER CONSUMPTION (m^3) (2010)
1	S.A. CET-2	1 672 481
2	I.M. EFES VITANTA MOLDOVA BREWERY S.A.	478 324
3	S.A. TERMOCOM	502 132
4	S.A. BUCURIA	207 691
5	I.M.S.P I.C.S. IN DOMENIUL OCROTIRII SANATATII MAMEI SI COPILULUI	134 332
6	S.A. CET-1	132 004
7	I.M.S.P. INSTITUTUL ONCOLOGIC	103 761
8	I.S. FABRICA DE STICLA DIN CHISINAU	93 573
9	S.A. TUTUN - CTC	89 250
10	I.M.S.P. SPITALUL CLINIC REPUBLICAN	88 218
11	I.M.S.P. CENTRUL NATIONAL STIINTIFICO-PRACTIC DE MEDICINA URGENTA	90 943
12	I.M. GLASS CONTAINER COMPANY S.A.	75 552
13	I.M.S.P. SPITALUL CLINIC DE PSIHIATRIE	72 836
14	S.A. CARMEZ	68 226
15	CENTRUL REPUBLICAN DE RECUPERARE A INVALIZILOR SI PENSIONARILOR SPERANTA	61 945

16	I.M.S.P. SPITALUL CLINIC MUNICIPAL SFANTA TREIME	60 717
17	PENITENCIARUL NR.13 CHISINAU	56 150
	TOTAL (m^3) (2010)	**3 988 135**

Initially, it was decided to perform the flow measurements with a portable ultrasonic flowmeter (ChronoFLO from HYDREKA), installed in serial and upstream of the customers' water meters, which are usually horizontal helix Woltmann type devices.

Figure 16 : Portable ultrasonic flowmeter installed in S.A. BUCURIA

However, in some metering points, the implementation of this flowmeter was impossible due to the lack of satisfying hydraulic conditions and no flow measurements could be performed.

Some customers have a specific seasonality in their water consumption patterns (S.A. CET-1, S.A. CET-2 and S.A. TERMOCOM for example): very high demand in fall-winter and very low in spring-summer. No interesting flow measurements could be carried out due to the implementation of the equipment during the very low water demand period.[13]

Other customers such as I.S. FABRICA DE STICLA DIN CHISINAU had their production lines stopped at the moment of the study.

In the specific case of I.M. EFES VITANTA MOLDOVA BREWERY S.A., a chamber was built at the junction between the distribution network and the service connection supplying the customer. Flow measurements were performed with an electromagnetic insertion flowmeter (HydrINS 2 from HYDREKA), in addition to initial flow measurements done with the ChronoFLO.

Finally, flow measurements are available for the following customers:

- I.M. EFES VITANTA MOLDOVA BREWERY S.A.
- S.A. BUCURIA

[13] S.A. CET-1 and S.A. CET-2 have differential pressure flowmeters from ROSEMOUNT, which are highly precise devices used for industrial process monitoring.

- I.M.S.P. SPITALUL CLINIC REPUBLICAN
- I.M.S.P. CENTRUL NATIONAL STIINTIFICO-PRACTIC DE MEDICINA URGENTA
- I.M.S.P. SPITALUL CLINIC MUNICIPAL SFANTA TREIME
- I.M.S.P. INSTITUTUL DE CARDIOLOGIE
- COMPANIA COCA-COLA IMBUTELIERE CHISINAU S.R.L.

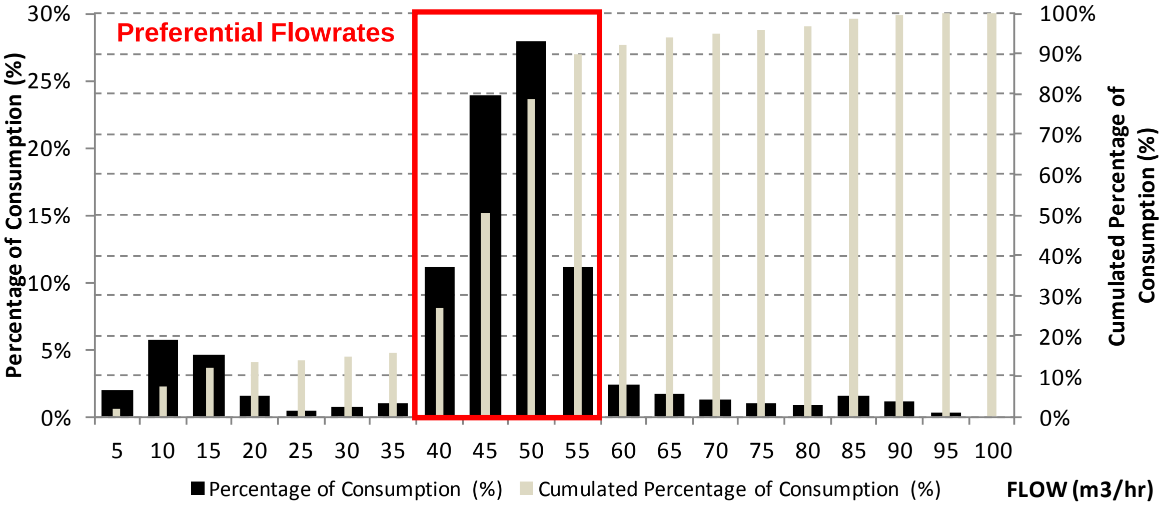
4.3. I.M. EFES VITANTA MOLDOVA BREWERY S.A.

This customer is equipped with a horizontal helix Woltmann type water meter with the following characteristics:

- ZENNER WPH-ZF-N (DN 150 mm);
- Nominal flowrate Q_N: 150 m^3/hr;
- Minimum flowrate Q_{min}: 3.5 m^3/hr;
- Transitional flowrate Q_t: 12 m^3/hr;
- Maximum flowrate Q_{max}: 350 m^3/hr;

The flow measurements carried out with the HydrINS 2 allowed defining the consumption histogram for this customer (NON-DOM #1):

Figure 17 : Consumption histogram for NON-DOM #1



- Average measured flowrate Q_{AV}: 56 m^3/hr;
- Minimum measured flowrate Q_{min}: 0.4 m^3/hr;
- Maximum measured flowrate Q_{max}: 183 m^3/hr;

Water consumption is essentially concentrated within the flowrates 40 m^3/hr and 55 m^3/hr. This water meter seems to be oversized based on the preliminary results.

No access was granted to the customer's water meter during the flow measurements with the HydrINS 2, which took place after preliminary flow measurements done with the ChronoFLO.

It was possible to take readings on the ZENNER unit to compare it to the ChronoFLO and determine an estimation of the metering under-registration:

- ZENNER measured volume: 547.4 m^3;
- ChronoFLO measured volume: 3 997.1 m^3;
- **Metering under-registration: 86%**;

This water meter seems to have mechanical problems in addition to its over-sizing (it is damaged). While the measured average daily water consumption figures of the HydrINS 2 and the ChronoFLO are within the range of the historical values of 2010, the ZENNER unit seems to be defective:

- ZENNER average measured daily volume: 274 m^3;
- ChronoFLO average measured daily volume: 1 999 m^3;
- HydrINS 2 average measured daily volume: 1 355 m^3;
- 2010 average measured daily volume: 1 310 m^3;

The primary element of a horizontal helix Woltmann water meter is a wheel facing the flow in its axial direction. The rotational speed of this wheel is a function of the flowrate, which determines the impact velocity of water on the blades, and the design of the blades and their angle. This a key issue, since the relative impact angle of the water on the blade of a given Woltmann meter is a function of the velocity profile, and consequently **an improper installation of the meter will affect its performance significantly (especially when swirly flow is generated upstream the meter). Larger perturbations, such as the ones created by regulations valves, elbows and tees can have drastic consequences on the performance of the meter.**

It is the case of the metering point of this customer, where the ZENNER unit is located just after a 90° elbow (less than 1.2 meters when manufacturers usually recommend at least 1.8 meters). Velocity can reach peaks between 2.5 m/s and 3 m/s in the service connection. Therefore turbulent flow affects the mechanical water meter and could damage the whole metering mechanism.

Figure 18 : Metering point configuration before the ZENNER unit (NON-DOM #1)

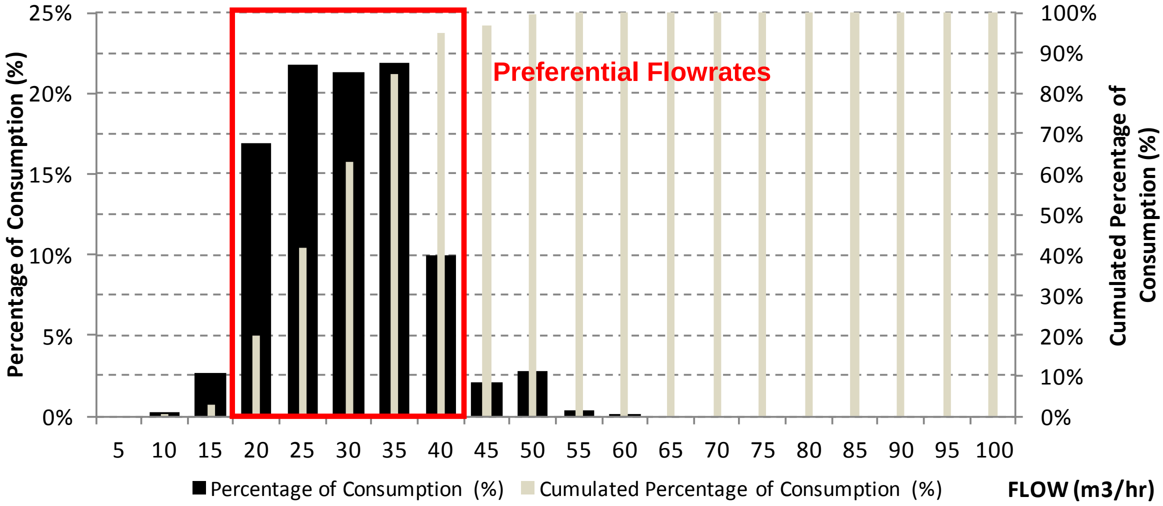
4.4. S.A. BUCURIA

This customer is equipped with a horizontal helix Woltmann type water meter with the following characteristics:

- STVG (DN 80 mm);
- Nominal flowrate Q_N: 50 m^3/hr;
- Minimum flowrate Q_{min}: 1.6 m^3/hr;
- Transitional flowrate Q_t: 5.5 m^3/hr;
- Maximum flowrate Q_{max}: 100 m^3/hr;

The flow measurements carried out with the ChronoFLO allowed defining the consumption histogram for this customer (NON-DOM #2):

Figure 19 : Consumption histogram for NON-DOM #2



- Average measured flowrate Q_{AV}: 26 m^3/hr;
- Minimum measured flowrate Q_{min}: 7 m^3/hr;
- Maximum measured flowrate Q_{max}: 56 m^3/hr;

Water consumption is essentially concentrated within the flowrates 20 m^3/hr and 40 m^3/hr. This water meter seems to be oversized based on the preliminary results.

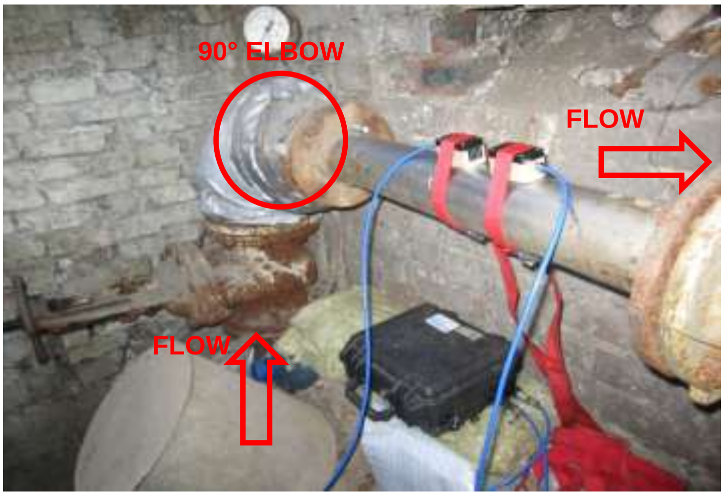
It was possible to take readings on the STVG unit to compare it to the ChronoFLO and determine an estimation of the metering under-registration:

- STVG measured volume: 1 028.5 m^3;
- ChronoFLO measured volume: 1 208.5 m^3;
- **Metering under-registration: 15%**;

The STVG unit is located just after a 90° elbow (less than 0.5 meters when manufacturers usually recommend at least 1.2 meters). Velocity can reach peaks at 2.5

m/s in the service connection. Therefore turbulent flow affects the mechanical water meter and could damage the whole metering mechanism.

Figure 20 : Metering point configuration before the STVG unit (NON-DOM #2)



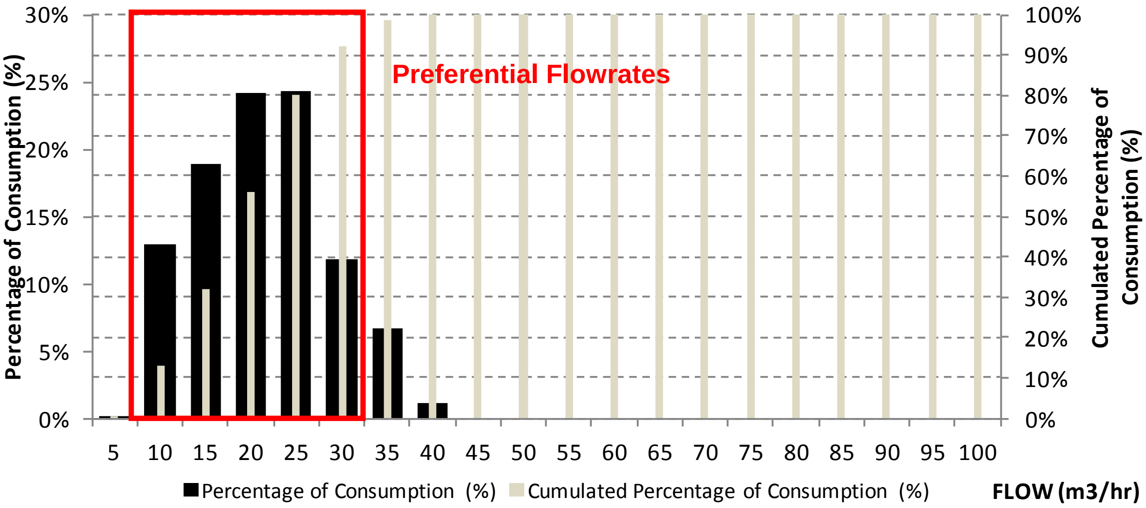
4.5. I.M.S.P. SPITALUL CLINIC REPUBLICAN

This customer is equipped with one horizontal helix Woltmann type water meter with the following characteristics:

- STV (DN 100 mm);
- Nominal flowrate Q_N: 90 m^3/hr;
- Minimum flowrate Q_{min}: 2.4 m^3/hr;
- Transitional flowrate Q_t: 9 m^3/hr;
- Maximum flowrate Q_{max}: 180 m^3/hr;

The flow measurements carried out with the ChronoFLO allowed defining the consumption histogram for this customer (NON-DOM #3):

Figure 21 : Consumption histogram for NON-DOM #3 (STV unit #2)



- Average measured flowrate Q_{AV}: 16 m^3/hr;
- Minimum measured flowrate Q_{min}: 3 m^3/hr ;
- Maximum measured flowrate Q_{max}: 40 m^3/hr ;

Water consumption through STV unit #2 is essentially concentrated within the flowrates 10 m^3/hr and 30 m^3/hr. This water meter seems to be oversized based on the preliminary results.

It was possible to take readings on the STV to compare it to the ChronoFLO and determine an estimation of the metering under-registration:

- STV measured volume: 564.1 m^3;
- ChronoFLO measured volume: 767.1 m^3;
- **Metering under-registration: 26%**;

The STV is located just after a 90° elbow (less than 0.5 meters when manufacturers usually recommend at least 1.2 meters). Velocity can reach peaks at 2.0 m/s in the service connection. Therefore turbulent flow affects the mechanical water meter and could damage the whole metering mechanism.

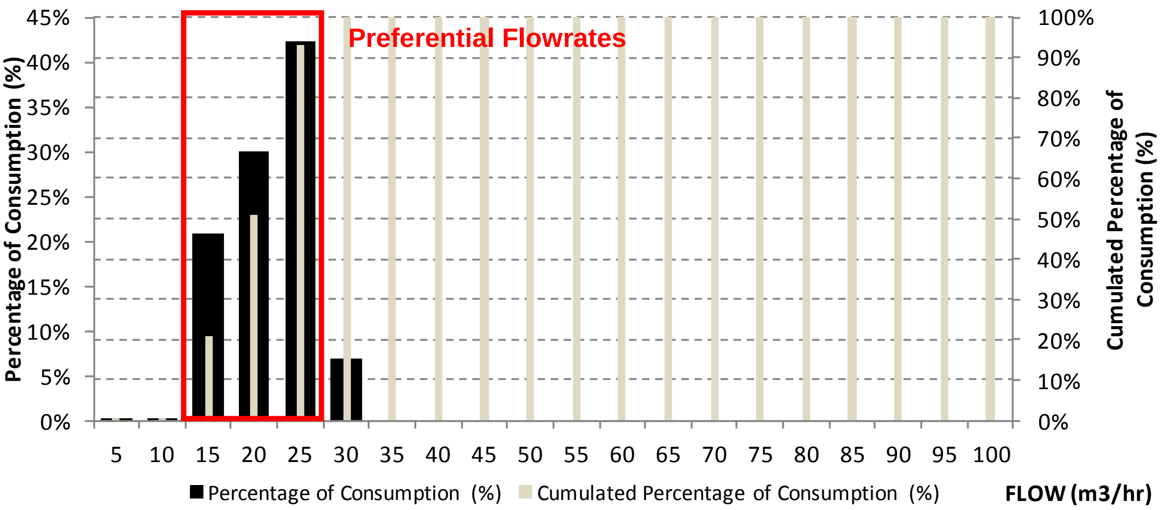
4.6. I.M.S.P. CENTRUL NATIONAL STIINTIFICO-PRACTIC DE MEDICINA URGENTA

This customer is equipped with a horizontal helix Woltmann type water meter with the following characteristics:

- STV (DN 65 mm);
- Nominal flowrate Q_N: 35 m^3/hr;
- Minimum flowrate Q_{min}: 1.2 m^3/hr;
- Transitional flowrate Q_t: 3.5 m^3/hr;
- Maximum flowrate Q_{max}: 70 m^3/hr;

The flow measurements carried out with the ChronoFLO allowed defining the consumption histogram for this customer (NON-DOM #4):

Figure 22 : Consumption histogram for NON-DOM #4



- Average measured flowrate Q_{AV}: 19 m^3/hr;
- Minimum measured flowrate Q_{min}: 5 m^3/hr;
- Maximum measured flowrate Q_{max}: 29 m^3/hr;

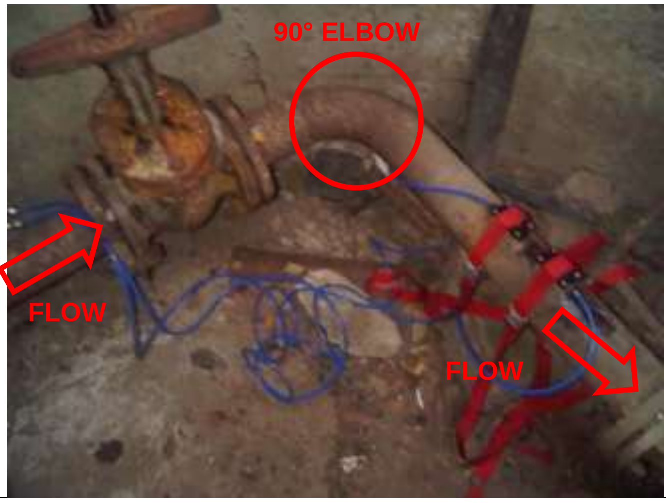
Water consumption through STV unit is essentially concentrated within the flowrates 15 m^3/hr and 25 m^3/hr. This water meter seems to be oversized based on the preliminary results.

It was possible to take readings on the STV unit to compare it to the ChronoFLO and determine an estimation of the metering under-registration:

- STV unit measured volume: 384.6 m^3;
- ChronoFLO measured volume: 765.8 m^3;
- **Metering under-registration: 50%**;

The STV unit is located just after a 90° elbow (less than 0.4 meters when manufacturers usually recommend at least 1.2 meters). Velocity can reach peaks at 1.5 m/s in the service connection. Therefore turbulent flow affects the mechanical water meter and could damage the whole metering mechanism.

Figure 23 : Metering point configuration before the STV unit (NON-DOM #4)

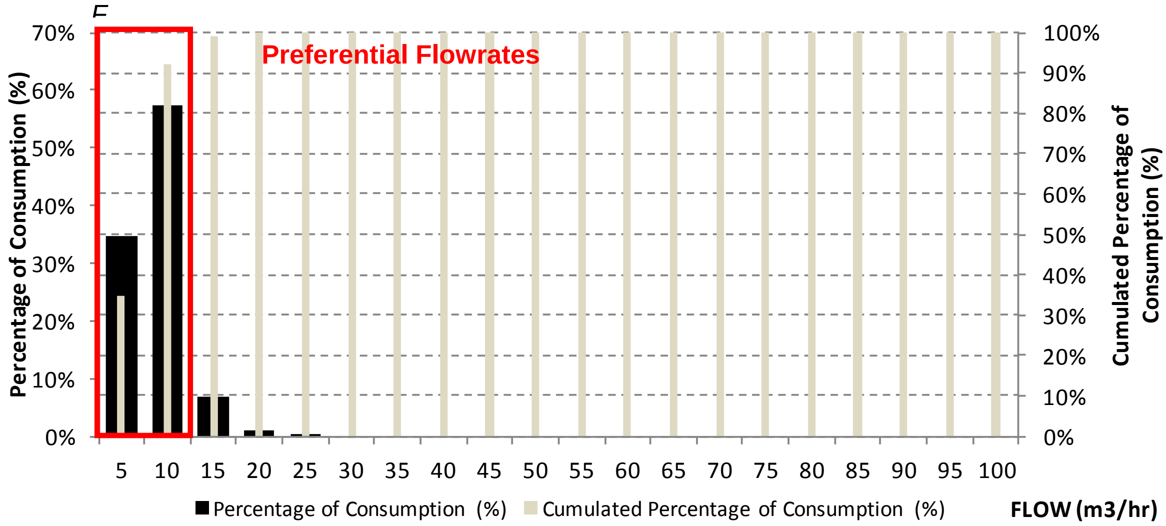


4.7. I.M.S.P. SPITALUL CLINIC MUNICIPAL SFANTA TREIME

This customer is equipped with a horizontal helix Woltmann type water meter with the following characteristics:

- STVG (DN 80 mm);
- Nominal flowrate Q_N: 50 m^3/hr;
- Minimum flowrate Q_{min}: 1.6 m^3/hr;
- Transitional flowrate Q_t: 5.5 m^3/hr;
- Maximum flowrate Q_{max}: 100 m^3/hr;

The flow measurements carried out with the ChronoFLO allowed defining the consumption histogram for this customer (NON-DOM #5):



nsumption histogram for NON-DOM #5

- Average measured flowrate Q_{AV}: 6 m^3/hr;
- Minimum measured flowrate Q_{min}: 2 m^3/hr;
- Maximum measured flowrate Q_{max}: 24 m^3/hr;

Water consumption through STVG unit is essentially concentrated within the flowrates 0 m^3/hr and 10 m^3/hr. This water meter seems to be oversized based on the preliminary results.

It was possible to take readings on the STVG unit to compare it to the ChronoFLO and determine an estimation of the metering under-registration:

- STVG unit measured volume: 291.9 m^3;
- ChronoFLO measured volume: 311.9 m^3;
- **Metering under-registration: 6%**;

The STVG unit is installed with good hydraulic conditions (no flow perturbations) as can be seen on the following figure.

Figure 25 : Metering point configuration before the STVG unit (NON-DOM #5)

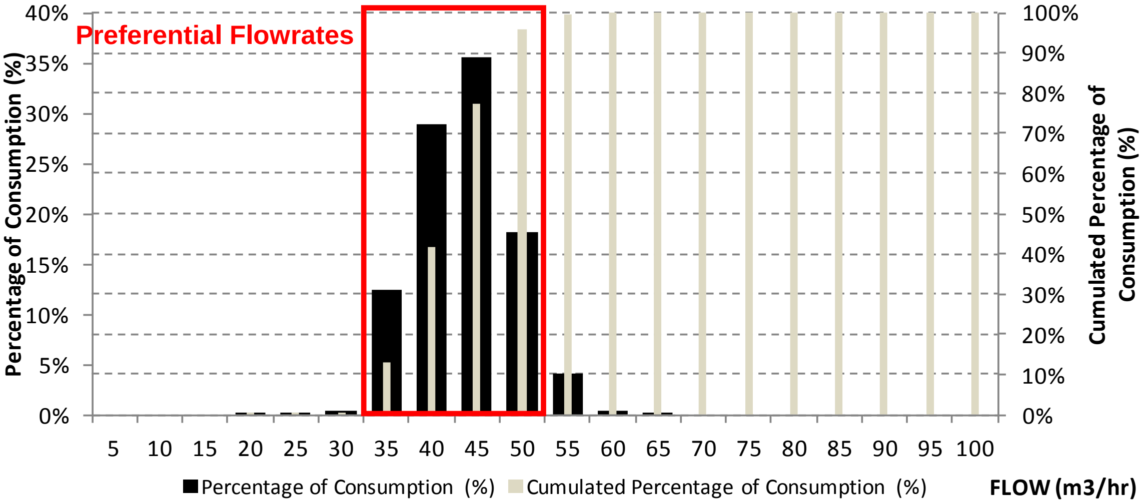
4.8. I.M.S.P. INSTITUTUL DE CARDIOLOGIE

This customer is equipped with a horizontal helix Woltmann type water meter with the following characteristics:

- STV (DN 65 mm);
- Nominal flowrate Q_N: 35 m^3/hr;
- Minimum flowrate Q_{min}: 1.2 m^3/hr;
- Transitional flowrate Q_t: 3.5 m^3/hr;
- Maximum flowrate Q_{max}: 70 m^3/hr;

The flow measurements carried out with the ChronoFLO allowed defining the consumption histogram for this customer (NON-DOM #6):

Figure 26 : Consumption histogram for NON-DOM #6



- Average measured flowrate Q_{AV}: 42 m^3/hr;
- Minimum measured flowrate Q_{min}: 20 m^3/hr;
- Maximum measured flowrate Q_{max}: 61 m^3/hr;

Water consumption through STV unit is essentially concentrated within the flowrates 35 m^3/hr and 50 m^3/hr. This water meter seems to be correctly sized based on the preliminary results.

It was possible to take readings on the STV unit to compare it to the ChronoFLO and determine an estimation of the metering under-registration:

- STV unit measured volume: 315.1 m^3;
- ChronoFLO measured volume: 1 121.2 m^3;
- **Metering under-registration: 72%**;

The STV unit is located just after a 90° elbow (less than 0.3 meters when manufacturers usually recommend at least 1.2 meters). Velocity can reach peaks at 3 m/s in the service connection. Therefore turbulent flow affects the mechanical water meter and could damage the whole metering mechanism.

Figure 27 : Metering point configuration before the STV unit (NON-DOM #6)

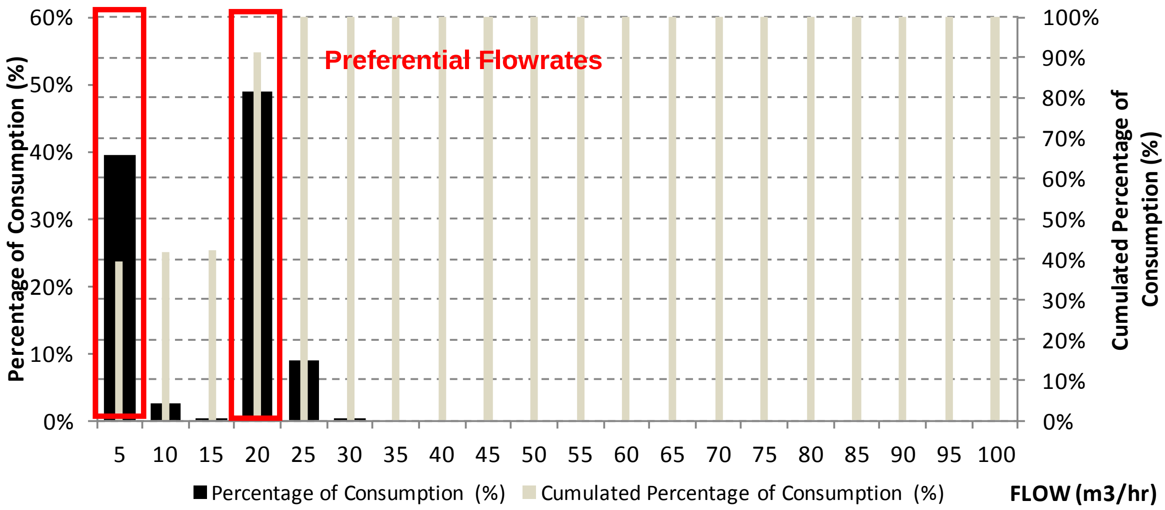
4.9. COMPANIA COCA-COLA IMBUTELIERE CHISINAU S.R.L.

This customer is equipped with a single-jet type water meter with the following characteristics:

- MADDALENA CD-FOCUS (DN 80 mm);
- Nominal flowrate Q_N: 63 m^3/hr;
- Minimum flowrate Q_{min}: 1.3 m^3/hr;
- Transitional flowrate Q_t: 2.0 m^3/hr;
- Maximum flowrate Q_{max}: 78.8 m^3/hr;

The flow measurements carried out with the ChronoFLO allowed defining the consumption histogram for this customer (NON-DOM #7):

Figure 28 : Consumption histogram for NON-DOM #7



- A
  verage measured flowrate Q_{AV}: 7 m^3/hr;
- Minimum measured flowrate Q_{min}: 0 m^3/hr;
- Maximum measured flowrate Q_{max}: 30 m^3/hr;

Water consumption through STV unit is essentially concentrated within the flowrates 0 m^3/hr and 5 m^3/hr and within the flowrates 15 m^3/hr and 20 m^3/hr. This water meter seems to be oversized based on the preliminary results.

It was possible to take readings on the MADDALENA unit to compare it to the ChronoFLO and determine an estimation of the metering under-registration:

- MADDALENA unit measured volume: 303.5 m^3;
- ChronoFLO measured volume: 365.0 m^3;
- **Metering under-registration: 17%**;

The water meter is located just after a check valve (about 0.5m when it is recommended to have at least 1.2m). Velocity can reach peaks at 1.6 m/s in the service connection. Therefore turbulent flow affects the mechanical water meter and could damage the whole metering mechanism.

4.10. Conclusion and Recommendations

The results of the campaigns performed on water meters of non-domestic customers are summarized in the table below:

Table 16: Summary for non-domestic customers

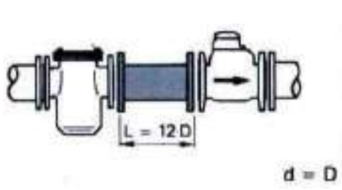
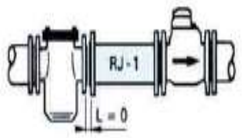
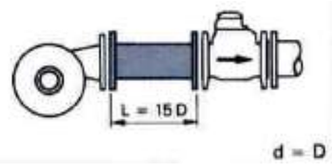
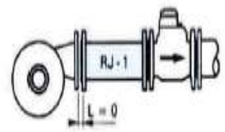
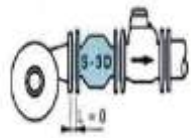
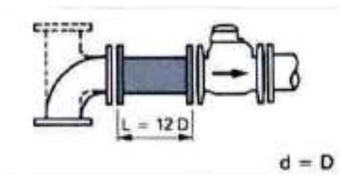
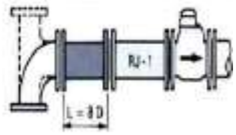
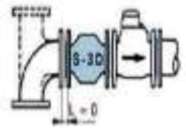
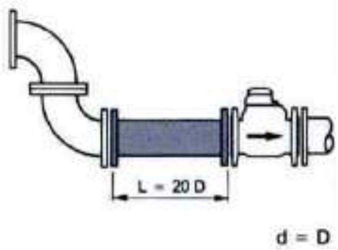
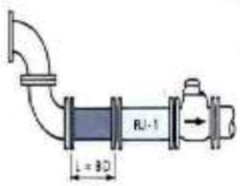
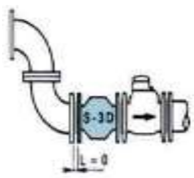
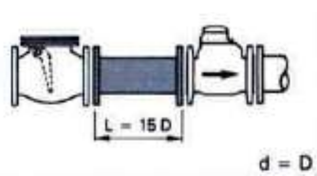
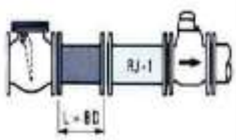
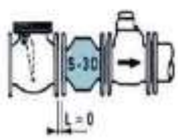
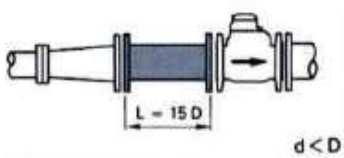
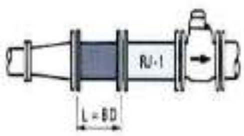
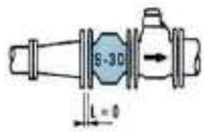
Name of the industrial customer	% of under-registration assessed	Comments
EFES Vitanta	86%	Water Meter oversized and Hydraulic conditions unfavorable (90° elbow)
Bucuria	15%	Water Meter oversized and Hydraulic conditions unfavorable (90° elbow)
Spitalul Clinic Republican	26%	Water Meter oversized and Hydraulic conditions unfavorable (90° elbow)
Spitalul din urgenţa	50%	Water Meter oversized and Hydraulic conditions unfavorable (90° elbow)
Spitalul Sfanta treime	6%	Water Meter oversized
Cardiologic institute	72%	Hydraulic conditions unfavorable (90° elbow)
Coca Cola	17%	Water Meter oversized and Hydraulic conditions unfavorable (check valve)

The standard installation procedure of horizontal helix Woltmann type water meters should ensure that:

- The water meter is installed in a low point of the pipe alignment;
- The internal diameter of the flanges' gaskets does not diminish the flow section;

Disturbing elements located downstream of the water meter do not have any influence on the metrological behavior of the device. However, disturbing elements located upstream of the water do have an influence, creating turbulences in the flow lines. In order to protect the water meters, a straight line long enough should be respected; or flow stabilizers should be installed (as indicated in the following table):

Figure 29: Standard installation schematics for horizontal helix Woltmann meters

Disturbing element located upstream of the water meter D = Ø of water meter d = Ø of pipe	L = Straight length of pipe needed upstream of the water meter		
	Without flow stabilizer	With flow stabilizer	
		RJ-1 type	S-3 D type
Strainer			
Pump			
Elbow / Tee			
2 Elbows Tee and elbow Tailpipe Diaphragm Flow regulating valve Throttled valve			
Check-valve			
Divergent cone			

Moreover, large non-domestic customers should be equipped with water meters adapted to their water demand. As seen on site, Woltmann meters' DNs are generally the same as those of service connections supplying the customers. This is also the case of single-jet or multi-jet water meters registering the consumption of large non-domestic users.

A specific study for each customer in that category should be carried out to see if the current water meter (purchased and installed by the customer) is correctly sized in terms of nominal flow. If the water meter needed is smaller or larger than the current one, it should be replaced with a new meter installed on the existing service connection with the necessary pipe reductions/augmentations (convergent and divergent cones).

5. CONCLUSION

Preliminary results show that the metering under-registration for domestic customers is estimated to be approximately 9.3%, leading to an average of 14 m^3 per year of billing losses per domestic household.

It implies the following losses for the categories of domestic customers having direct contracts with ACC:

- **562 620 m^3/year for individual houses, equivalent to 326 k€/year.**
- **79 230 m^3/year for individual apartments, equivalent to 46 k€/year.**

It also impacts the management of billing procedures in blocks, as it increases the volumetric difference between the main meter and the sum of individual apartments. The redistribution and payment of this difference can be a problematic issue depending on the legal condominium entity managing the blocks. However, these preliminary results confirm that ACC needs to focus the billing of blocks strictly on the readings of the main meter monitoring the buildings overall water consumption.

For non-domestic customers, many issues have been observed thanks to the site visits and the preliminary results:

- Water meters are quite often oversized when compared to the customers' preferential flowrates on their water consumption patterns.
- For large users, horizontal helix Woltmann type units are preferred but are usually installed incorrectly, very often just after a 90° elbow with high risks of turbulent flow. **An improper installation of the meter will affect its performance significantly (especially when swirly flow is generated upstream the meter). Larger perturbations, such as the ones created by regulations valves, elbows and tees can have drastic consequences on the performance of the meter.** When horizontal helix Woltmann units need to be installed in places with limited piping distances, the use of a flow stabilizer (RJ-1 type or S-3 D type) is necessary. Strainers are also recommended as they protect the blades from suspended particles in the water flow.
- 7 customers among the 50 largest water consumers of the service area were monitored to evaluate their metering under-registration. The values are dispersed between 6% and 86%. These are preliminary figures, obtained with a portable ultrasonic flowmeter which can also suffer from insufficient hydraulic conditions. However, it highlights an incorrect metrological behaviour of the customers' water meters, a closer inspection study should therefore be done on them.

Finally, during the next decade, ACC should start to progressively take control (ownership) of the water meters used for billing purposes to ensure that metering under-registration is kept to a minimum, especially in the scenario of a decrease in the cross-subsidies rate. The blocks main water meters are already owned by ACC, it will however be necessary to equip others (non-domestic users and domestic customers with direct contracts) with more accurate water meters as tariffs increase.