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Initial Results on the Flow Dynamics of Household Water Consumption

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Abstract

Household water meters are tested/calibrated at steady flow conditions however, during their actual usage, flow conditions are not always steady and not so much known about the flow dynamics. The present paper reports about instantaneous flow rate measurements conducted at households to find out what kind of flow rate profiles exist through household meters. From these measurements, 3200 single water consumption events were extracted. Then each single event was analysed to obtain various information such as rise time, fall time, amplitude, event duration and consumed water volume. These results showed that the distributions of rise and fall times with respect to number of events are mostly around 100 to 300 ms. And more than 5% of the flow time, the meter is under dynamic flow conditions.

1. Introduction

According to OIML R49 [1] and ISO 4064 [2], water meters used for household consumption are tested/calibrated at constant flow rates in laboratory conditions. On the other hand, the measurements [3-5] conducted at households showed that water meters are exposed to highly changing flow rates. Furthermore, particles and inorganic composition [6-8] of the drinking water within distribution pipelines are also not considered by the present legal metrology requirements (e.g. type approval tests). A recently started EMPIR (European Metrology Programme for Innovation and Research) project called MetroWaMet (Metrology for Real-World Domestic Water Metering) [9] aims to establish a metrological infrastructure which will enable an integral characterization of domestic water meter performance close to real-world conditions and not at laboratory conditions as presently done. The present study was conducted within the MetroWaMet project to analyse flow dynamics of household water consumption.

In literature, there are several reports on measurement results conducted at households and a brief summary of such studies can be found in [4, 5]. In these studies, the researchers are mostly interested in identifying consumption patterns to match with usage purpose. And develop algorithms to be used with smart meters, to provide detailed water consumption statistics to users and water distributors. Although some of these studies were done with high resolution meters at households, an analysis of flow dynamics were not made.

Schumann et. al [3] reports a summary of the results obtained from the measurements conducted at 300 households. In this study, no information was provided how the measurements were conducted and technical description of the flow meters used for the measurements (e.g. time resolution). And also time scales of the flow dynamics were not made. On the other hand, the authors provided some sample flow variations and probability distribution of flow rates.

The present paper reports about test measurements conducted at households to find out what kind of flow dynamics exist through household meters. For this aim, a special water meter was built together with electronics to reach time resolution of up to 12 ms. Such time resolution was necessary in order to measure instantaneous changes accurately.

2. Measurements

Figure 1: Picture of the meter and electronic used for the measurements.

A standard meter was modified to obtain high time resolution which was 60 pulses/l. With this modified meter up to 12 ms time resolution was possible at 5040 l/h. Electronics were developed to read pulses and store the pulse data as shown in Fig. 1. This stand alone system was installed at four households just next to their actual meter. The battery shown Fig. 1 allowed to perform at least 6 days of uninterrupted measurement which can be extended by replacing the battery.

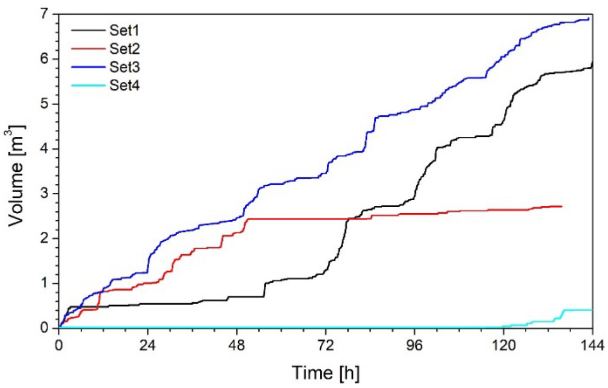

Figure 2: Raw data from four set of measurements.

Figure 2 shows the raw data from four sets of measurements conducted at four different households. As can be seen from the picture, during the measurements, two of the households (set2 and set4) were not occupied some of the time.

3. Results

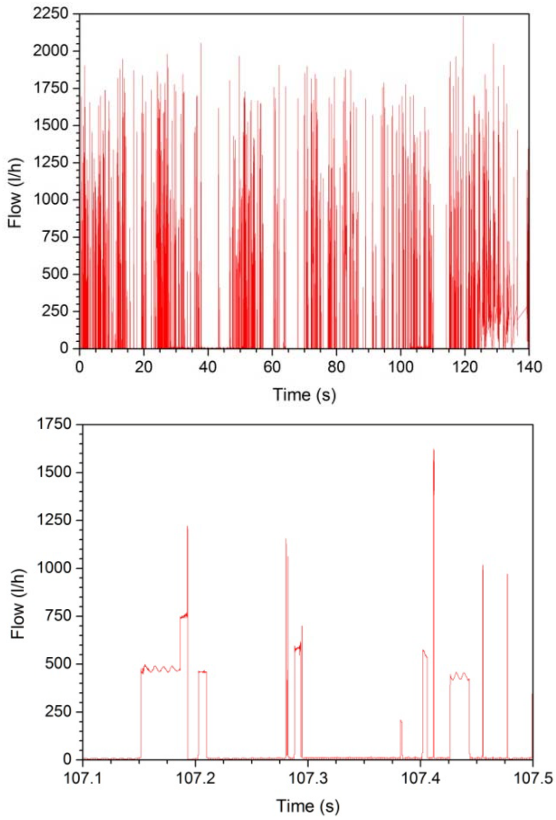

Figure 3: Flow rate variations samples.

The raw data shown in Fig. 1 were processed to obtain flow rate data and some samples are shown in Fig.1. This figure shows the complete instantaneous flow rate data of set1 and also a zoomed portion of the same data to see some of the events closely. As can be seen from these figures there are rapid flow rate changes which are occurring relatively short time intervals and these changes will be called as flow events.

In figure 4 some single flow event samples are shown. These events correspond to some certain water consumption activity and in literature there are various approaches to identify consumption activities from measured flow events, based on some known patterns, [4, 5]. In the present study aim is to characterise flow dynamics of household water consumption and hence the focus is given to characterise these events.

The extracted flow events can be grouped as single amplitude and multi amplitude events event as indicated in Fig. 4. For single amplitude events, below parameters can be defined for characterization as shown in Fig. 5;

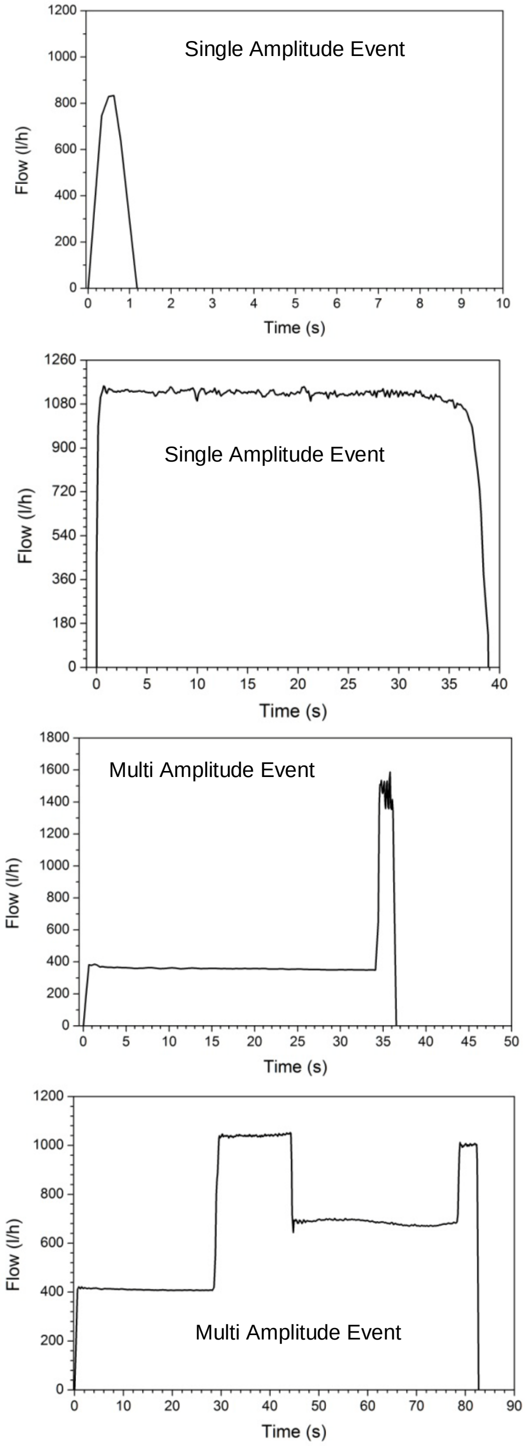

Figure 4: Flow event samples.

1. Event duration
2. Rise time
3. Fall time
4. Event volume
5. Rise volume
6. Fall volume
7. Amplitude

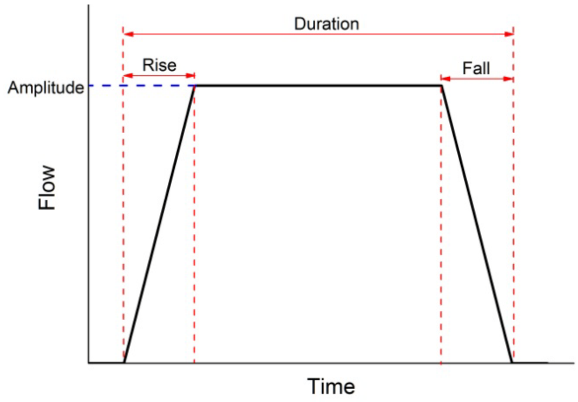

Figure 5: Characteristic parameters of a single amplitude event.

These parameters were analysed for each single event and there was 3200 events extracted from four set of measurements. A general summary of the results are given in table 1.

Table 1: Single event analysis results.

		Set1	Set2	Set3	Set4	Total
Events	#	893	565	1655	87	3200
Multi Amplitude Events	# - %	164 - 18.4	55 - 9.7	218 - 13.2	9 - 10.3	446 - 13.9
Volume (consumption)	m^3	5.9	2.7	6.0	0.53	15.1
Duration	h	6.71	3.59	10.14	0.6	21.05
Total Rise Time	%	1.4	1.94	2.04	2.36	1.83
Total Fall Time	%	2.2	2.81	2.12	1.64	2.25
Total Rise Volume	%	1.24	2.18	2.28	2.8	1.87
Total Fall Volume	%	2.47	3.45	3.33	1.82	2.96
Volume / Event	l	6.63	4.71	3.62	6.06	4.72
Duration / Event	s	27.05	22.85	22.07	24.99	23.68
Rise Time / Event	s	0.379	0.443	0.450	0.590	0.433
Fall Time / Event	s	0.595	0.642	0.468	0.410	0.533

As given in table 1; 446 of the 3200 events are multi amplitude events which means around 86% of the events are single amplitude. The total flow duration is 21 hours and around 4% of the total time the flow rate is rising/falling. This means that 4% of the total flow time, the flow is unsteady. By considering multi amplitude events, the unsteady time could be more than 5% of the total flow time.

The total measured volume is around 15 m^3 and around 5% of this volume the flow rate is rising/falling. By considering multi amplitude events, the volume measured under unsteady conditions could be more than 6.5% of the total volume.

Table 1 also provides some average information for one event. Average volume is 4.7 l, duration is

23 s, rise time is 433 ms and fall time is 533 ms for one flow event.

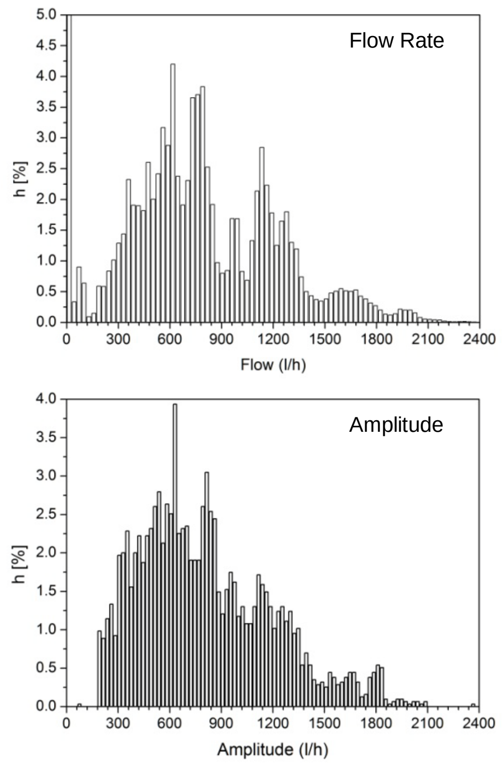

Figure 6: Distribution of measured flow rates and extracted amplitudes.

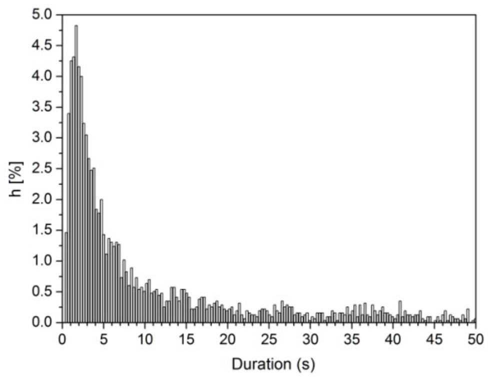

Figure 7: Distribution of event durations.

Distribution of flow rates and amplitudes are given in Fig. 6. As the figure indicates flow rate varies mostly within 200 to 1800 l/h for both measured flow rate and flow event amplitudes. It is important to note that the maximum flow rate of the actual water meter for these households is 3125 l/h and nominal flow rate is 2500 l/h which are higher than required and these meters are tested/calibrated at these constant flow rate values.

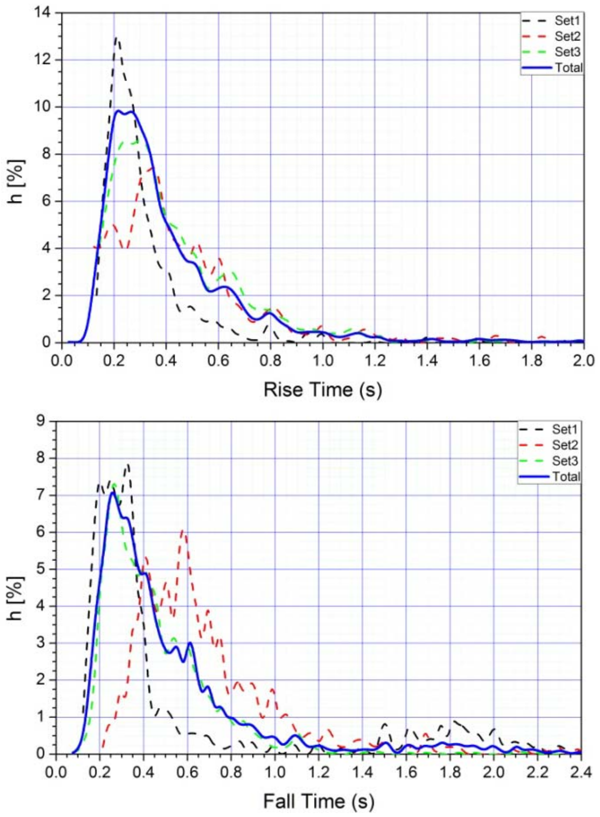

Figure 8: Distribution of rise and fall time.

Figure 7 shows the distribution of event durations. As the figure indicates important portion of the events are last less 10 seconds and the peak values are few seconds. Based on this figure; 46% of the events are having duration within 0.5 to 5 s. And 62% of them are having duration within 0.5 to 10 s.

Distribution rise and fall time for each set and also for the all extracted events are given in Fig. 8. There are some differences between the sets especially for fall time distribution. But it must be noted again that during the set2 measurement the house was not occupied every day. On the other hand, rise and fall time distributions are similar when the total distributions are considered. Both of the distributions are mostly within 0.1 to 1.2 s and the peak value is around 0.2 to 0.3 s.

It is interesting to know what fall and rise time values are important when flow duration and total volume are considered. In order to obtain this information, cross distributions were made as shown in Fig. 9. This figure indicates total events volume for the events with some certain rise time interval. Similar distributions were made for duration and the results are given in table 2 and 3.

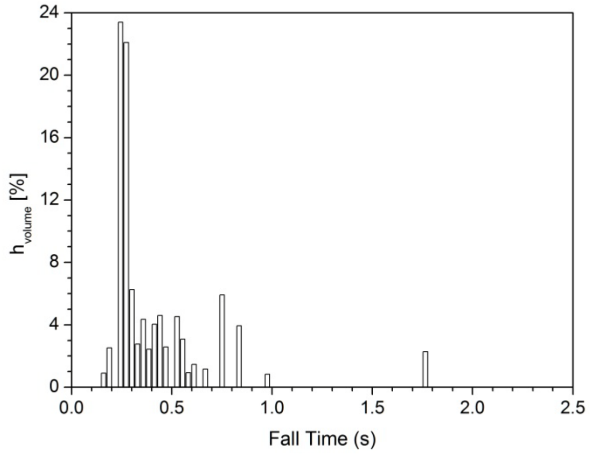

Figure 9: Cross distribution of fall time versus total events volume.

Table 2: Rise time intervals and corresponding distribution percentages.

Rise time interval [s]	h[%]	$h_{duration}$[%]	h_{volume}[%]
0.05 – 0.2	10.1	8.15	≈ 0.01
0.2 – 0.4	57.5	43.12	54.94
0.4 – 0.6	15.2	23.09	17.22
0.6 – 0.8	9.6	13.45	8.71
0.8 – 1	3.4	3.54	0.68
1 – 3.5	4.25	8.64	18.45

Table 3: Fall time intervals and corresponding distribution percentages.

Fall time interval [s]	h[%]	$h_{duration}$[%]	h_{volume}[%]
0.05 – 0.2	7.62	4.2	3.42
0.2 – 0.4	42.6	34.56	61.3
0.4 – 0.6	23.02	24.89	19.72
0.6 – 0.8	12.73	16.67	8.54
0.8 – 1	4.95	5.21	4.75
1 – 3.5	9.08	14.46	2.27

From the tables 2, 3 and figure 9, it is easy to conclude that rise and fall times of 0.2 to 0.6 s are mostly encountered with respect to total event duration and volume.

4. Conclusions

Flow rate measurements were made at four households and each measurement was almost one week long. The processed data showed that there are two water end use events as single and multi amplitude. The total number of detected events are 3200 and 14% of them are multi amplitude events.

For each event, an unsteady portion can be defined as rise time and fall time which are the durations where the flow rate reaches an amplitude from zero flow (rise time) and then after some flow time the flow rate becomes zero again (fall time) as indicated in Fig. 5. For all the events, this unsteady time is around 5% of the total flow duration and 6.5% of the total measured volume. These values are not small and it requires further investigations to check water meters performances under such unsteady conditions since presently the meters are not tested for that.

In order to test water meters for unsteady conditions, it is necessary to apply rise and fall times values. From the present measurements results, the events which correspond to 70 to 80% of the total volume are having rise and fall times within 0.2 to 0.6 s. Thus this suggests that the test-rigs for unsteady tests should be able to generate at least 0.2 s of rise and fall times within the amplitude/flow range given in Fig. 6.

Acknowledgement

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References

[1] OIML R 49, Water meters for cold potable water and hot water, 2013.
[2] ISO 4064, Water meters for cold potable water and hot water, 2014.
[3] D. Schumann, G. Wendt, J. Tränckner, “Development of a calibration process for water meters close to real world conditions”, FLOMEKO 2016, Sydney, Australia, September 26-29, 2016.
[4] B. Ellert, F. Popowich, S. Makonin, “Appliance Water Disaggregation via Non-Intrusive Load Monitoring (NILM)”, EAI International Conference on Big Data and Analytics for Smart Cities (BigDASC) 2015.
[5] K.A. Nguyen, H. Zhang, R.A. Stewart, “Development of an intelligent model to categorise residential water end use events”, Journal of Hydro-environment Research, ISSN1570-6443, 2013.

[6] JHG. Vreeburg, D. Schippers, JQJC. Verberk, C. Van Dijk, “Impact of particles on sediment accumulation in a drinking water distribution system”, Water Res., 42(16), 4233-4242, 2008.
[7] D. Banks, M. Birke, B. Flem, C. Reimann, “Inorganic chemical quality of European tap-water: 1. Distribution of parameters and regulatory compliance”, Appl. Geochem., 59, 200-210,2015.
[8] B. Flem, C. Reimann, M. Birke, D. Banks, P. Filzmoser, B. Frengstad, “Inorganic chemical quality of European tap-water: 2. Geographical distribution”, Appl. Geochem., 59, 211-224, 2015.
[9] https://www.ptb.de/empir2018/metrowamet/the-project/