Examination of residential water meters with regard to their measurement behaviour and measurement stability during their installation in communal water supply networks

1. Initial situation

Information on the behaviour of a water meter depending on the type, service life, water consumption, water quality and the way water is drawn off is of great interest, both for water utilities and for their customers. Especially the measuring stability of the mounted devices is important as what these devices display provides the basis for the billing of water. Making generally valid statements in this respect usually requires extensive – and thus expensive – investigations in order to ensure that the results are statistically sound.

In Germany, metrological reliability for the customer is achieved, among other things, by subjecting water meters to mandatory verification [1, 2]. The verification period for water meters is currently 6 years for cold-water meters and 5 years for hot-water meters. After this period has expired, each meter must be removed and replaced by a new one. This represents a considerable overall economic effort which is an additional burden not only for the end-user (as it is added onto the actual costs of the water consumed), but also for the environment [3]. Although an extension of the verification period is possible for some of the installed water meters by carrying out special random sampling procedures, this method is questionable from today's point of view.

Metrological tests on water meters which were removed from the supply network after their regular verification period had expired were last carried out between 1982 and 1986, based on the Technical Guidelines W20 of PTB [4]. More than 30,000 water meters were then subjected to a correctness test by state-approved test centres. In accordance with these guidelines, this sampling, however, only applied to residential cold-water meters. In the meantime, not only has the state of the art of water meters been technically enhanced, but the consumption behaviour of the users and the technical equipment in dwellings have changed. Similarly, numerous new and effective examination methods are available to investigate the measurement behaviour of the meters. Moreover, a considerable proportion of all the meters in the water supply network in Germany (i.e. residential water meters) was not covered by these investigations. It can be assumed that this is currently the case for more than 20 million meters.

2. Investigation programme

Within the scope of a research project of PTB together with *Hamburg Wasser GmbH*, a large-scale test was carried out. This test consisted in examining residential water meters which had been removed from the communal water supply network after their legal verification period had expired. This concerned 1,776 cold-water meters in houses, 3,588 cold-water meters in flats, and 2,064 hot-water meters in flats – i.e. a total of 7,428 water meters.

This is the first time that statistically exploitable data have been available for water meters in flats. The following statements will be mainly limited to these meters.

For the tests performed within the scope of this *Hamburg Wasser* large-scale test, meters were selected in areas with different drinking water qualities which, however, remained stable in those areas over time. Mixed water areas were excluded from the investigations so that it was possible to assign the measurement results to a specific water quality, whose parameters can be retrieved from the drinking water analyses that must be carried out on a regular basis.

Contrary to the "usual" test algorithms (such as those applying to random samples or to in-service tests of water meters), both the number of test points and the test sequence were altered:

- Tests for the large-scale test: "upstream" Q_{min}, Q_t, Q_n and Q_{max}, then "downstream" Q_{max}, Q_n, Q_t and Q_{min}

Since the measurement series start at Q_{min}, the meter is tested in its "most sensitive" state and the premature flushing out of potential suspended particles is prevented. Similarly, for the assessment of the results, the values were compared with the operational error limits, the maximum permissible errors on verification and the sampling inspection errors.

The investigations were carried out at the water meter test rigs of PTB and of the state-approved test centre of *Hamburg Wasser*.

3. Investigation results

3.1 Measurement errors after expiry of the verification period

The measurement errors determined after the regular verification period had expired were compared with the corresponding maximum permissible errors on verification, the sampling inspection errors and the operational error limits.

- MPE: maximum permissible error on verification

  in the range $Q_t \leq Q \leq Q_{max}$: 2 % for cold-water meters and 3 % for hot-water meters; in the range $Q_{min} \leq Q < Q_t$: 5 % for both types of meters;

- SIE: sampling inspection error

  in the range $Q_t \leq Q \leq Q_{max}$: 3 % for both types of meters; in the range $Q_{min} \leq Q < Q_t$: 8 % for both types of meters;

- OEL: operational error limit

  in the range $Q_t \leq Q \leq Q_{max}$: 4 % for cold-water meters and 6 % for hot-water meters; in the range $Q_{min} \leq Q < Q_t$: 10 % for both types of meters

For information purposes, the tables also state the number of meters which stopped during the investigations on the test rig. For these meters, nothing had hinted at any blockages before they were removed from the network. Based on experience, it can be assumed that these blockages were probably caused by scaling, impurities or other foreign matter which only became loose when the meters were dismantled or transported. As a matter of course, these "blocked" meters are also included in the rows above.

Residential cold-water meters (from flats): multi-jet measuring cartridge meters Q_n 1.5 (from various manufacturers)

Test series: A – cold:

- Number of examined meters: 3,631
- Removed from: Hamburg water supply network, diverse water qualities

	Within MPE	*Within SIE*	*Within OEL*	*Outside OEL, to the consumer's disadvantage*
Test points and test sequence	Q_{min}, Q_t, Q_n, Q_{max}	Q_t, Q_{min}	Q_n, Q_t, Q_{min}	Q_n, Q_t, Q_{min}
Number	3,548	3,606	3,605	0
Percentage	97.7	99.3	99.3	0
Blocked meters				
Number	23	14	14	0
Percentage	0.6	0.4	0.4	0

<u>Residential hot-water meters (from flats)</u>: multi-jet measuring cartridge meters Q_n 1.5 (from various manufacturers)

Test series: B – hot:

- Number of examined meters: 2,064
- Removed from: Hamburg water supply network, different water qualities

	Within MPE	**Within SIE**	**Within OEL**	**Outside OEL, to the consumer's disadvantage**
Test points and test sequence	Q_{min}, Q_t, Q_n, Q_{max}	Q_t, Q_{min}	Q_n, Q_t, Q_{min}	Q_n, Q_t, Q_{min}
Number	2,041	2,058	2,056	0
Percentage	98.9	99.7	99.6	0
Blocked meters				
Number	11	5	5	0
Percentage	0.5	0.2	0.2	0

In order to verify the results which, to date, have only been available for the catchment area of *Hamburg Wasser*, the investigations are currently being extended to meters of other suppliers with other water qualities. The initial results obtained in this context confirm the statements to the fullest extent, as the example below shows.

<u>Residential cold-water meters (from flats)</u>: multi-jet measuring cartridge meters Q_n 1.5 (from various manufacturers)

Test series: C – cold:

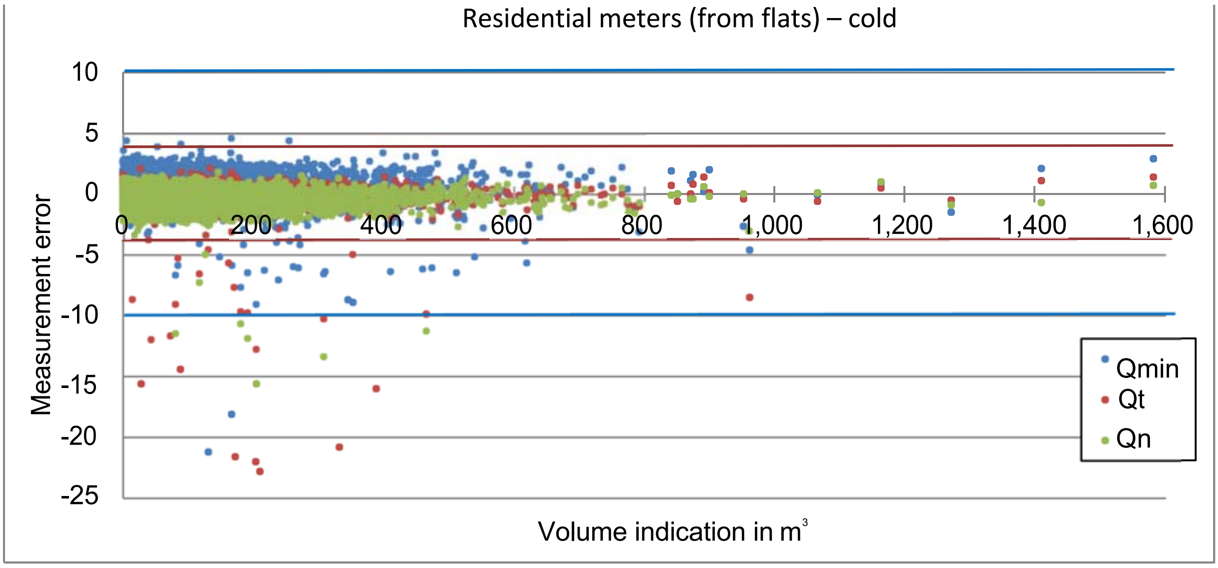
- Number of examined meters: 112
- Removed from: Water supply network of the city of XX, different water qualities

	Within MPE	**Within SIE**	**Within OEL**	**Outside OEL, to the consumer's disadvantage**
Test points and test sequence	Q_{min}, Q_t, Q_n, Q_{max}	Q_t, Q_{min}	Q_n, Q_t, Q_{min}	Q_n, Q_t, Q_{min}
Number	105	111	112	0
Percentage	93.8	99.1	100	0
Blocked meters				
Number	0	0	0	0
Percentage	0	0	0	0

A total of more than 5,800 water meters from flats were thus subjected to the aforementioned examinations. Of these meters, 99.4 % still comply with the operational error limits after the verification period has expired. Even when they were outside the operational error limits, none of these meters indicated values which would have been to the end-user's disadvantage.

3.2 Measurement behaviour depending on the total consumption during the service life of the meter

In addition, the measurement errors were also analysed with regard to the reading of each meter after it had been removed from the network. The mean consumption per water meter (from flats) was around 31.5 m³/year for cold water and 14.0 m³/year for hot water. A dependence of the measurement behaviour on the individual total consumption over the total service life of the meters in the network was not found (as can be seen in Figure 1 below).



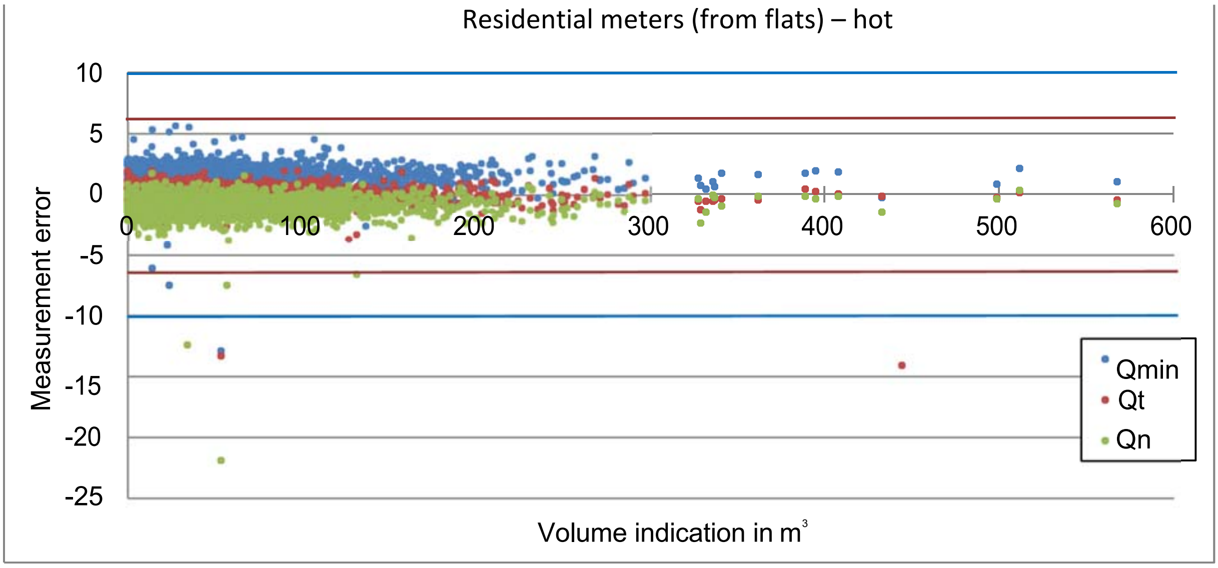


Figure 1: Measurement errors of the examined meters at the three test flowrates Q_{min}, Q_t and Q_n as a function of the total volume measured during the meter's service life in the network (without "blocked" meters with a measurement error of -100 %)
a) for cold-water meters from flats
b) for hot-water meters from flats
with the operational error limits marked in blue for Q_{min} and in red for Q_t and Q_n

3.3 Investigation of the differences in the behaviour of the meters depending on whether they were fitted horizontally or vertically

A special investigation dealt with the determination of any possible differences in the measurement behaviour of the meters depending on whether they were mounted vertically or horizontally. For this purpose, 100 additional Q_n 1.5 class A meters were used which had been removed between 0 m^3 and 3,600 m^3; they were then subjected to the same test sequence as described in Section 2 in both mounting positions (vertical and horizontal).

Residential cold-water meters (from flats): multi-jet measuring cartridge meters

Q_n 1.5 cold

Test series: D – horizontal:

- Number of examined meters: 100
- Removed from: Water supply network of the city of XX, different water qualities

	Within MPE	Within SIE	Within MPE	Outside OEL, to the consumer's disadvantage
Test points and test sequence	Q_{min}, Q_t, Q_n, Q_{max}	Q_t, Q_{min}	Q_n, Q_t, Q_{min}	Q_n, Q_t, Q_{min}
Number	93	100	100	0
Percentage	93	100	100	0
Amount of blocked meters detected:				
Number	2	0	0	0
Percentage	2	0	0	0

Residential cold-water meters (from flats): multi-jet measuring cartridge meters

Q_n 1.5 cold

Test series: E – vertical:

- Number of examined meters: 100
- Removed from: Water supply network of the city of XX, different water qualities

	Within MPE	Within SIE	Within MPE	Outside OEL, to the consumer's disadvantage
Test points and test sequence	Q_{min}, Q_t, Q_n, Q_{max}	Q_t, Q_{min}	Q_n, Q_t, Q_{min}	Q_n, Q_t, Q_{min}
Number	87	100	100	0
Percentage	87	100	100	0
Amount of blocked meters detected:				
Number	3	0	0	0
Percentage	3	0	0	0

Differences in the behaviour of the meters in the two mounting positions were only found in the test series beginning with test point Q_{min}. The readouts of all "conspicuous" meters were in the negative range and this was the case only at low flowrates, which suggests sluggishness in the starting range of the meters. Both meters which were blocked when they were mounted horizontally were also blocked when they were mounted vertically.

When the measurements were carried out in the usual test sequence (i.e. not beginning with Q_{min}), all meter readouts were within the **maximum permissible errors**.

No significant differences in the measurement results were found between the meters which were mounted vertically and those which were mounted horizontally.

3.4 Additional endurance tests under constant measurement conditions

In addition, selected types of meters were subjected to special endurance tests at PTB's test rig. One of these meters was a multi-jet measuring cartridge residential water meter for flats Q_n 1.5 which was operated at nearly Q_n over a period of 7 months in total. All the error curves were recorded at regular intervals; the results for Q_{min}, Q_t, Q_n and Q_{max} are compiled in Figure 2 as a function of the total flowrate indicated. A total of 6,430 m^3 flowed through the meter – which corresponds to more than 200 times the average consumption determined for Hamburg. Significant tendencies suggesting that the meter behaviour has been altered have not been observed for any of the test flowrates considered.

The test conditions were exacerbated after 3,720 m^3 by switching from conventional drinking water to distilled (i.e. soft) water (water hardness: 0 °dH). The analyses of the large-scale test in Hamburg had led to the assumption that if influences of the water quality on the measurement behaviour were to be observed at all, this could be the case with soft water. In the case of impeller meters, these tendencies were, however, observed neither in Hamburg nor in the tests carried out at PTB.

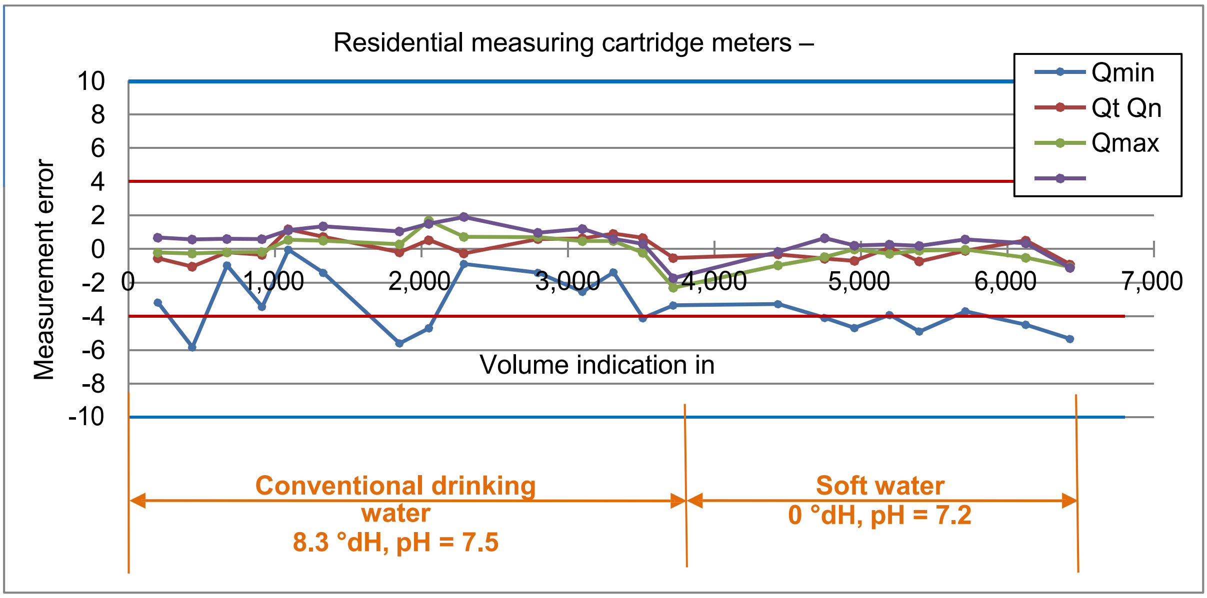


Figure 2: Measurement errors of a measuring cartridge jet meter Q_n 1.5 as a function of the volume of water flowing through it for two different water qualities, with the operational error limits marked in blue for Q_{min} and in red for Q_t and Q_n

4. Results from other research projects

To assess the measurement behaviour of residential water meters from flats under practical operational conditions, the results obtained within the scope of another research project, which focused especially on the issue of measuring cartridges and was carried out from January 2008 until 2012, should at any rate be taken into account. The reason for this project was the necessity of ensuring that measuring cartridge water meters (which represent the major type of residential water meters for flats by far) are considered as water meters, also by the European Measuring Instruments Directive MID [5] and can, thus, still be used as such. The completed measurement programme included exhaustive investigations of single- and multi-jet measuring cartridge meters with regard to their behaviour under real conditions of use. It was possible to demonstrate that, from a metrological point of view, using this type of meter does not bring about any disadvantages. On the contrary, it was shown that measuring cartridge meters are nearly insensitive to impurities and deposits of any kind due to their specific design [6].

5. Updated procedure for the sampling of water meters

Given the previous remarks, there are no metrological reasons to exclude residential water meters for flats (for cold and hot water, also in measuring cartridge meters) from the sampling test procedures as they have been practised to date for the extension of the verification period. Based on the decision of the General Assembly on Verification taken in 2014 concerning TOP 1.4, which proposes pursuing the sampling test procedure which has been practised to date, the verification period can now be extended also for hot-water meters and measuring cartridge meters. More concretely, this means:

- The procedure laid down in *PTB-Mitteilungen* [7] for the sampling and testing of cold-water meters can be used without changes also for hot-water meters and measuring cartridge meters. Where "cold-water meters" ("Kaltwasserzähler") are mentioned in the text, this is to be interpreted in a more general sense as "water meters".
- Irrespective of the fact that the maximum permissible errors and the verification period differ between cold- and hot-water meters, the same sampling inspection errors of 8 % at Q_{min} (Q_1) and 3 % at Q_t (Q_2) and the same extension period of 3 years apply to both types of meters.

6. List of references

[1] Act concerning the placement and provision of measuring instruments on the market, their use and verification, and also on prepackages (Measures and Verification Act [Mess- und Eichgesetz – MessEG]) dated 25.07.2013 (Federal Law Gazette. I p. 2722)

[2] Ordinance concerning the placement and provision of measuring instruments on the market, their use and verification (Measures and Verification Ordinance – MessEV) dated 11.12.2014 (Federal Law Gazette I, No. 58, pp. 2010, 2011);

[3] H. Schonlau, H. Rubach: Wasserzähler auf dem Prüfstand – Sind die vorgeschriebenen Eichfristen noch zeitgemäß? gwf Wasser/Abwasser, 2014

[4] Technische Richtlinie W20 der PTB: Prüfungen an gebrauchten Hauswasserzählern, PTB 01/82

Other publications on the results of the W20 investigations:
- W. Schulz: Richtigkeitsprüfungen an Kaltwasserzählern nach Ablauf der Eichgültigkeitsdauer. PTB-Mitt. **95** (1985), pp.102-108
- Prüfungen an gebrauchten Hauswasserzählern. PTB-Mitteilungen **95** (1985), p. 345 and **96** (1986), p. 348
- G. Wendt et al.: Transfernormale für strömendes Wasser. PTB Report **MA-82**, 2007, pp. 8-9

[5] Directive 2004/22/EC of the European Parliament and of the Council of 31 March 2004 on measuring instruments (MID) (OJ L 135, p. 1), last amended by (EU) Ordinance No. 1025/2012 of the European Parliament and of the Council of 25 October 2012 (OJ L 316, p. 12)

[6] G. Wendt et al.: Untersuchung und Entwicklung strömungsprofilunempfindlicher Wasser- und Wärmezähler und deren mechanischer Schnittstellen. PTB Report **MA-90**, 2012

[7] Verfahren zur Stichprobenprüfung von Kaltwasserzählern. PTB-Mitteilungen **102** 4/92, pp. 295-296

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