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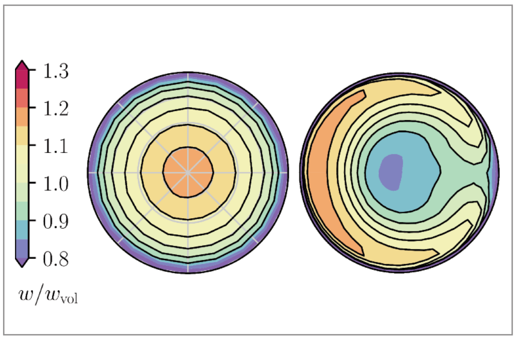

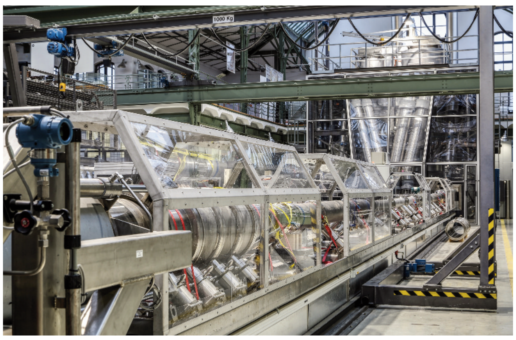

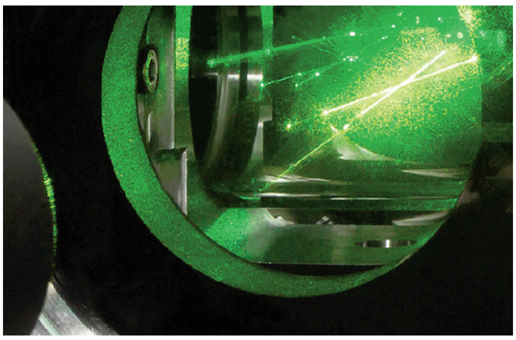

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Heat and cooling meters in legal metrology

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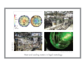

Paul Dixon
BIML Assistant Director

The OIML Certification System (OIML-CS): challenges and opportunities in a global pandemic

The COVID-19 pandemic has presented many unexpected challenges, but also many opportunities. This was clearly demonstrated last year when the decision was taken to cancel, at short notice, the OIML Certification System (OIML-CS) Management Committee (MC) meeting that was planned for New Delhi, India in March 2020. At the time, it seemed like a very difficult decision to take as the hosts had made great efforts to organise the meeting and participants had made travel plans. However, with what we know now, it was clearly the correct decision to take.

In consultation with the Acting MC Chairperson, Bill Loizides, it was decided to hold an online MC meeting as a trial for using video technology for meetings with external entities. For the BIML, this was very much a learning experience, however the success of the first online MC meeting resulted in two further online MC meetings being held in 2020. These online meetings allowed the MC to successfully progress the work of the OIML-CS during the pandemic, to the extent that based on this experience the 55th CIML Meeting was able to be held as an online meeting for the first time.

OIML Issuing Authorities and their Test Laboratories have shown tremendous adaptability in response to the pandemic. Despite an initial drop in the number of OIML-CS certificates issued during the early stages of the pandemic, the number of certificates issued rebounded strongly at the end of 2020. Organisations (including the BIML) have adapted very quickly to enable their staff to work from home, and have implemented procedures to allow safe working conditions. Test Laboratories are a prime example and this adaptability, together with the opportunity to implement new working practices, have meant that the number of OIML-CS certificates issued in 2020 was slightly higher than the number issued in 2019.

Due to the ongoing situation regarding the pandemic, a decision was taken quite early to hold the Sixth MC Meeting as an online meeting on 24–25 March 2021. The meeting - chaired by the new MC Chairperson Mannie Panesar - was very successful. A report on the meeting can be found in this edition of the Bulletin.

Despite the challenges of what has been an unprecedented and extraordinary 12 months, the MC has taken the opportunity to explore and implement new ways of working. This has resulted in the continued development and growth of the OIML-CS, and has led to the adoption of online meetings across the Organisation.

The OIML and the Bureau staff will continue to embrace this new way of working, but let us hope that we can meet again in person in the not too distant future! ■

WEIGHING

Monitoring the validity of reported results in weighing operations according to ISO/IEC 17025:2017

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Abstract

This article presents the second part of the author's work related to section 7.7.1 of ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*.

The first part, published in the *Journal of Physics: Conference Series*, Volume 1065/2018, mainly presented the use of intermediate checks in the calibration/verification of weights and mass comparators. In the present article, the approaches regarding intermediate checks performed in the field of NAWI (non-automatic weighing instruments) are completed with two additional applications in the pharmaceutical/medical field.

Also in this article, other possibilities mentioned in 7.7.1 of ISO/IEC 17025:2017 are analyzed, for monitoring the validity of the results it produces, either by internal or external means, such as:

- replicating verification/calibration tests using the same or different methods;
- correlation of the results for different characteristics of an item; and
- proficiency testing/interlaboratory comparison (performed in the legal metrology or accreditation fields).

This article can be of use for those who carry out their activity either in a legal metrology laboratory, or in an accredited laboratory.

Introduction

In section 7.7.1 of ISO/IEC 17025, it is stipulated that a laboratory shall have a procedure for monitoring the validity of the results it produces, either by internal or by external means. Thus, the requirements for monitoring carried out within the laboratory are separated from those involving a comparison with other laboratories (participation in proficiency testing or/and participation in inter-laboratory comparisons other than proficiency testing).

Considering that in the new version of the ISO/IEC standard, monitoring the validity of results is a subject that is not clearly explained in terms of a procedure, it is up to each laboratory to carry out these operations according to defined procedures and schedules as well establishing the acceptance criterion.

The laboratory shall plan its activities to ensure the validity of its test results. In Figure 1 we can see the various steps that need to be considered in the stages of monitoring the validity of the reported results.

While the first part of the author's work [2] mainly presented the use of intermediate checks in the calibration of weights and mass comparators, in the present article the approaches regarding intermediate checks performed in the field of NAWI are completed with two other additional applications in the pharmaceutical/medical field:

- the use of an intermediate check for a NAWI in accordance with [3]; and
- an intermediate check for a NAWI using control, alert and action limits.

Also in this article, other possibilities mentioned in section 7.7.1 of ISO/IEC 17025 are analyzed (see Figure 1), for monitoring the validity of results performed inside/outside the laboratory, such as:

- replicate verification/calibration tests using the same or different methods;
- correlation of the results for different characteristics of an item; and
- proficiency testing/interlaboratory comparison (performed in the legal metrology or accredited fields).

2 Intermediate checks performed in the field of NAWI

2.1 General aspects

Intermediate checking is the process of verifying the calibration status of a measuring instrument between calibrations. This is done in order to verify whether there is any drift in the indication of the instrument over a period of time. For this reason, the place where a

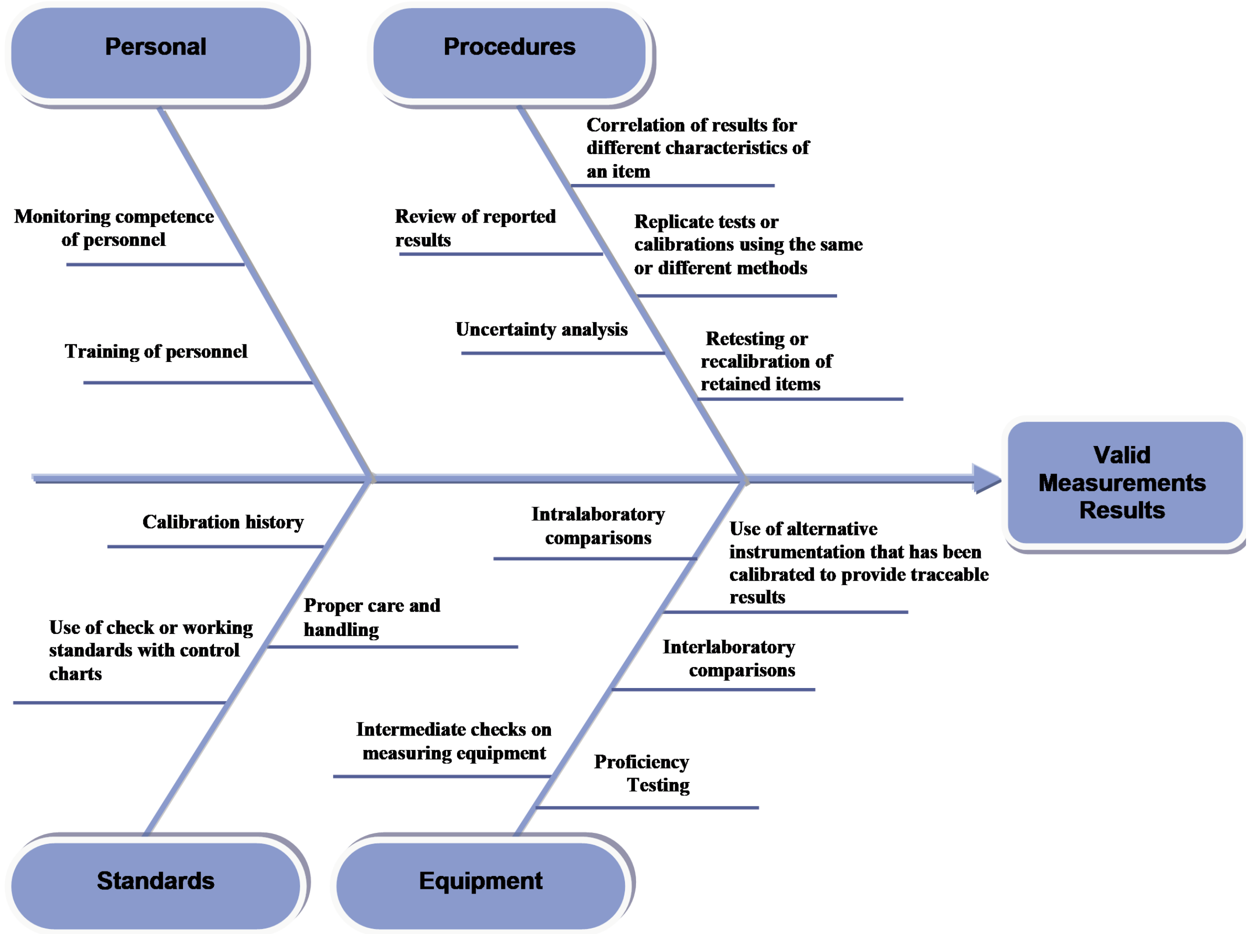


Fig.1: Ishikawa diagram showing ways of monitoring the validity of measurements results

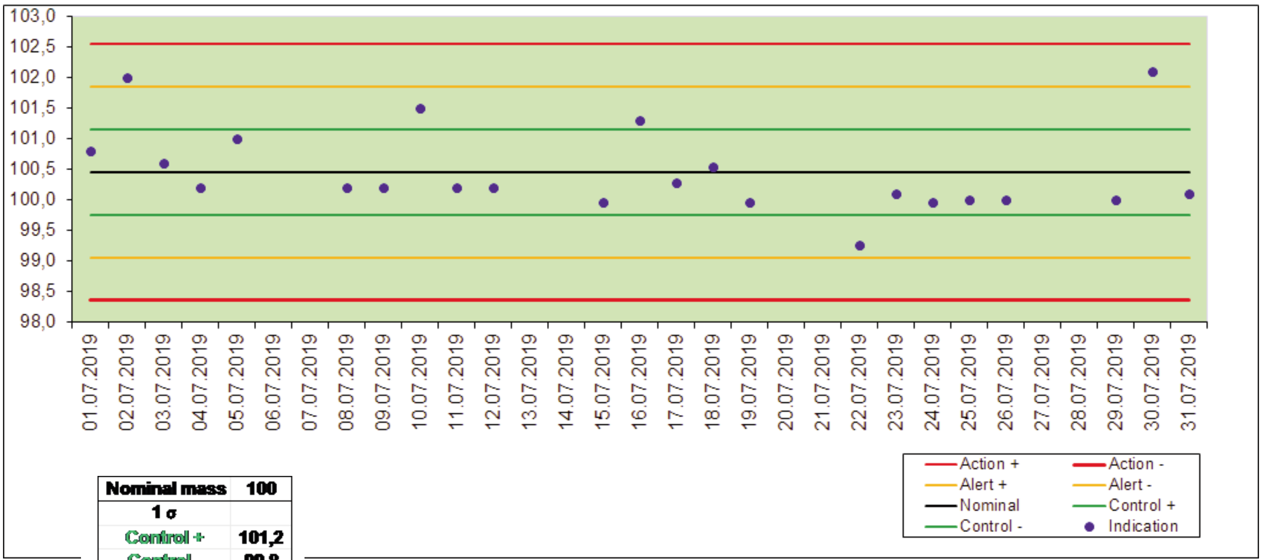
weighing instrument (WI) is installed is especially important for the subsequent utilizations, because it is not recommended to perform intermediate checks in different locations.

Generally, a balance is used on the site at which the calibration was performed. If an instrument is moved to another location after the calibration, possible effects due to the difference in local gravity acceleration, variations in environmental conditions, and mechanical and thermal conditions during transportation are likely to alter the performance of the instrument and may invalidate the calibration [4].

For this reason, moving the instrument after calibration should be avoided, unless immunity to these effects of a particular instrument, or type of instrument has been clearly demonstrated. Where this has not been demonstrated, the calibration certificate should not be accepted as evidence of traceability [4].

When an intermediate check is performed in the field of NAWI, the following necessary preliminary operations should be considered:

- the air temperature at the place where the balance is located should be determined and recorded at the beginning and completion of the calibration (or at least once during the calibration);
- dirtied or contaminated standards should be avoided, therefore the cleanliness of both the balance and the place in which it is located should be carefully checked;
- particular attention should be paid to the load receptor of the WI; if necessary, it should be cleaned before putting any weights on it;
- the instrument should be energized prior to calibration during an appropriate period, e.g. for as long as the warm-up time specified for the instrument, or as set by the user;
- it should be verified whether the indication of the WI at no-load is zero and, if necessary, the instrument should be set to zero;
- the check-weight should be picked up with tweezers/forks for weights below 2 kg or using gloves for bigger weights and carefully placed on the balance pan.



Nominal mass	100
1 σ	
Control +	101,2
Control -	99,8
2 σ	
Alert +	101,9
Alert -	99,1
3 σ	
Action +	102,6
Action -	98,4

Fig.2: Intermediate check of a NAWI using control, alert and action limits

2.2 Intermediate check for a NAWI in accordance with the USP document "1251 Weighing on Analytical Balance", Chapter 35

According to [3], the test consists in weighing a fixed check-weight on a daily basis over an extended period of time.

The accuracy of the weight is not important. The check-weight may be any object whose mass remains constant and does not exceed the maximum capacity of the balance. Usually, a balance is purchased with a check-weight which should be kept either inside the balance, or outside, near the balance, in an appropriate container such as in a box or under a glass bell, etc. The intermediate check should be performed before the first weighing of the day, by the first person using the balance, or after any event that might disturb the balance's calibration or adjustment [3].

2.2.1 *Analytical balances*

A check-weight is carefully placed in the center of the balance pan a number of times and the indications of the weighing instrument are recorded. The mean value of the readings is calculated. The variation in the observed weight should not exceed ± 0.2 mg.

Example: a weight having a nominal value equal to 50 g is placed many times on the pan and the indications of the balance are recorded. If the mean value of the readings is 50.0014 g, the "tolerance" would be from 50.0012 g to 50.0016 g.

According to [3], the "tolerance" is intentionally tight to reveal possible drift or calibration errors.

In the present case, 0.01 mg represents 0.1 % of the material weighed (10 mg). If 1 mg is weighed, the tolerance is 0.001 mg (see [3]).

2.2.2 *Microbalances*

The balance is loaded several times with a check-weight having a nominal value between 80 % and 100 % of its maximum capacity. The indications of the balance are recorded.

The variation in the weighings shall not be greater than 0.1 % of the amount of material typically weighed on the balance. For example in [3], if 10 mg samples are routinely weighed, the variation in the weighings of the check-weight cannot exceed 0.01 mg.

2.3 Intermediate check for a NAWI using control, alert and action limits

The intermediate check should be performed before the first weighing of the day by the first person using the balance, or after any event that might disturb the balance's calibration. The pan of the balance is loaded with a check-weight having a nominal value between 80 % and 100 % of its maximum capacity. The indication of the balance is recorded. For this intermediate check, the assessment criteria are similar to those used for the Z-score [6].

If the mass indications taken over a certain period of time (for example one month) are below the control limits, the balance functions correctly. When the indications of the balance |*I*| are between the control and alert limits, we can say that the balance gives a “warning signal” and finally, when the readings are between the alert and action limits, an action signal is generated to remedy the situation. It is likely that the balance’s characteristics have changed significantly since it underwent its last full calibration. Thus, the recalibration interval should be reduced.

Action limits (having a process tolerance role) and alert limits are specified by the user as a result of their specific needs, according to laboratory work methods to ensure the validity of the results. The control limits are taken from experimental data, previously obtained over a certain period of time. The lab aims for the results to be within the control limits (acceptable). The average and standard deviation obtained from all the readings are used in the determination of the control, alert and action limits (see Figure 2).

3 Replicate verification/ calibration tests using the same or different methods

The validity of the results can also be ensured by replicate verifications/calibrations performed by the same person using different methods, or the same/different procedure performed by different users. The acceptance criterion is either the normalized error, E_n (for calibrations), or the Z-score (for verifications).

In the formula for E_n, E represents the difference between the errors obtained during the initial and replicate calibrations, whereas U_1 and U_2 are their associated uncertainties.

In the formula for z, $x_i - X$ represents the difference between the errors obtained during the initial and replicate verification and $\hat{\sigma}$ is the standard deviation calculated using the maximum permissible error (MPE/3).

$$E_n = \frac{\Delta E}{\sqrt{U_1^2 + U_2^2}} \qquad z = \frac{x_i - X}{\hat{\sigma}}$$

4 Correlation of results for different characteristics of an item

This method for monitoring the validity of results is mainly exemplified in the calibration of accuracy class E_1 weights when a subdivision or multiplication method is used. There are different ways to check if a correlation of results exists.

4.1 Comparing the calculated mass differences (using mass errors of the weights) against observed mass differences (obtained on the balance)

In the calibration of class E_1 weights, mass determinations are carried out by subdivision (to link standards having different nominal values with a reference standard).

By the method of least squares adjustment, the mass departures and their standard deviations are calculated.

With a reference standard of 1 kg, the weights having nominal values of 500 g, 200 g, 100 g, and 100* g are calibrated using a 1 kg mass comparator.

An example containing the results obtained in the first decade of calibration, using the subdivision method, is given in Table 1.

Table 1: Results obtained in the first decade of calibration of E_1 weights

Nominal value	Mass error	U
g	mg	mg
1000	–0.156	0.080
500	0.085	0.044
200	–0.016	0.020
200*	0.005	0.020
100	0.014	0.014
100*	–0.023	0.014

Starting from the data presented in Table 1, we can check the correlation of the results in the calibration of E_1 weights using the normalized error, E_n, according to Table 2. In column 2 of Table 2, there are comparisons between the weights (only some of the weighing equations were chosen). The calculated mass differences (using mass errors of the weights from Table 1) are given in column 3.

Column 4 of Table 2 contains the observed mass difference (obtained on the balance), whereas the 5th column represents the difference between the 4th and 3rd columns.

In the 5th and 6th columns, the following ways are given to establish the correlation between the results:

a) if the differences from the 5th column are smaller than the standard deviations from the 6th column (obtained in the corresponding comparison), then it can be said that there is a correlation of the results;

b) calculation of the normalized error, E_n, with $-1 \le E_n \le 1$,

where:

Δ represents the difference (observed – calculated) from column 5;

Table 2: Correlation of results in the calibration of E_1 weights using E_n

1	2	3	4	5	6	7
No	Mass comparisons between the weights	Calculated mass differences (using mass errors of the weights) mg	Observed mass differences (obtained on the balance) mg	Difference Δ (col. 4 – col. 3) mg	*s* (standard deviation of each mass comparison) mg	E_n
1	Σ 1 kg –1 kg	0.2444	0.2325	–0.0119	0.0164	0.18
2	500 – Σ 500	0.0821	0.0870	+0.0049	0.0145	0.09
3	500 – Σ 500*	0.1194	0.1110	–0.0084	0.0160	0.16
4	200 – Σ 200	–0.0078	–0.0010	+0.0068	0.0089	0.24
6	100 – 100*	0.0373	0.0390	–0.0017	0.0019	0.09

Table 3: Difference between the measurements performed on the balance

Determinations on the balance		Difference between the equations		Correlation between the equations
y_1	–0.0458			
y_2	0.1535	$y_2 - y_1 = y_8$	0.1535 + 0.0458 = 0.1993	0.1993 – 0.1974 = 0.0019 < 0.01
y_3	0.1885			
y_4	–0.2080	$y_3 - y_4 = 2y_8$	0.1885 + 0.2080 = 0.3965	0.3965 – 2*(0.1974) = 0.0017 < 0.01
y_5	–0.0080			
y_6	0.1715			
y_7	0.1795	$y_6 - y_7 = y_5$	0.1715 – 0.1795 = 0.008	0.008 – 0.008 = 0 < 0.01
y_8	0.1974			

U_{st} is the uncertainty of the weight(s) considered as standard in a comparison, and

U_Σ is the uncertainty of the weight(s) considered as the test.

$$E_n = \frac{\Delta}{\sqrt{U_{st}^2 + U_\Sigma^2}}$$

4.2 Correlation between equations

During the measurements, we can check whether there is any incoherence between the mass differences resulting from the equations, and take corrective action before completing the calibration. For example, the following equations (combination between the weights) are considered:

$$
\begin{aligned}
&(5) - (2) - (2^*) - (1) &&= y_1\\
&(5) - (2) - (2^*) - (1^*) &&= y_2\\
&(2) - (2^*) + (1) - (1^*) &&= y_3\\
&(2) - (2^*) - (1) + (1^*) &&= y_4\\
&(2) - (2^*) &&= y_5\\
&(2) - (1) - (1^*) &&= y_6\\
&(2^*) - (1) - (1^*) &&= y_7\\
&(1) - (1^*) &&= y_8
\end{aligned}
$$

Table 3 presents the results obtained on the balance (for these eight determinations), the difference between equations, and the correlation among them.

Considering that this evaluation is performed at the first sight, during the measurements, a criterion can be chosen in relation with the scale division (the absolute difference between the equations should be less than one scale division). The balance used for determinations has d = 0.01 mg. The last column shows that there is no incoherence between the equations results.

4.3 Estimation of an internal consistency of the observed weighing results

A ratio of the group standard deviation, s (used to ascertain the quality of the adjustment) and a normalization factor, σ_o, is calculated. In the ideal case, $s/\sigma_o = 1$ is valid. Values of $s/\sigma_o > 1.2$ often result from some inconsistencies in the observed weighing results, whereas values of $s/\sigma_o > 1.5$ in most cases indicate major mistakes. This method is detailed in [5].

5 Participation in proficiency testing/interlaboratory comparisons

According to section 7.7.2 of [1], “the laboratory shall monitor its performance by comparison with the results of other laboratories, where available and appropriate”.

In this way, for monitoring the validity of the results by external means, a laboratory can participate in proficiency testing (PT) or interlaboratory comparisons (ILC) other than proficiency testing.

The laboratory performance, as well the quality of their measurement system (method, equipment, personnel) can be assessed and demonstrated.

5.1 Participation in PT/ILC in the field of legal metrology

In the field of legal mass metrology, PT/ILC are organized for both the verification of weights and NAWI.

The measurement instructions for the verification of non-automatic weighing instruments concern the determination of the weighing performance, in accordance with [7] and [8]: weighing/accuracy test, repeatability, weighing test using an eccentrically placed load, and weighing tests for tare. Measurement results obtained in an inter-laboratory experiment are inspected for outliers (the Cochran test or the Grubbs test can be used).

For the verification of weights, the measurement instructions concern the determination of the conventional mass and the measurement uncertainty, obtained in accordance with [9].

In the field of NAWI, the performance of the participating laboratories is calculated according to statistical methods used in quantitative proficiency testing and is based on the Z-score, which is calculated for every test (accuracy, repeatability, eccentricity and tare) [10], for each load provided in the PT protocol using the following formula:

$$z = \frac{x_i - X}{\hat{\sigma}}$$

Where:

x_i represents the results (or the average of the results) reported by a participant for the measurement,

X is the assigned value, and

$\hat{\sigma}$ is the standard deviation for the proficiency assessment.

According to section 9.4.2 from [11], the performance evaluation of the participating laboratories is based on the following criteria:

- $|z| \leq 2$ is the performance considered as being “acceptable” and does not generate any signal. Result: “correct”;
- $2 < |z| < 3$ is the performance considered as being “questionable” and generates a “warning signal”;
- $z \geq 3$ is a result considered as being “unacceptable”, generating an action signal requiring the situation to be remedied; Result: “incorrect”.

For the verification of weights, either the Z-score or the normalized error, E_n, can be used as the acceptance criteria.

Participants whose results led to a “questionable” performance, generating a “warning signal”, should analyze the reasons, in order to remedy and correct them.

5.2 Participation of accredited laboratories in PT/ILC

PT/ILC are organized in the field of weights calibration and NAWI, and are an important requirement for both accredited laboratories and accreditation bodies.

The aim of the comparisons is not only to compare the measurement results of the participant with those of the reference laboratory, but also to analyze the measurement uncertainty, the choice of the calibration points, and the content of the calibration certificates.

In evaluating the standard uncertainty associated with the error of indication, the following contributions are considered [4]: reference standard, resolution of the weighing instrument, repeatability of indications, effect of air buoyancy, and the effect of an eccentrically placed load.

The results are analyzed using E_n (normalized errors) values. The result is considered successful if the value of the normalized error is $-1 \leq E_n \leq 1$. In this case the participating laboratory agrees with the reference value within the stated uncertainty. If a laboratory has any unsuccessful results, i.e. $E_n < -1$ or $E_n > 1$, it is expected that the laboratory investigates the reason for the disagreement and implements corrective actions.

6 Conclusions

This article represents the second part of the author’s work [2] in relation to section 7.7 of ISO/IEC 17025:2017.

A laboratory shall have a procedure for monitoring the validity of the results it produces, either by internal or external means. Thus, the requirements for monitoring carried out within the laboratory are separated from those involving a comparison with other laboratories (participation in proficiency testing or/and inter-laboratory comparisons).

In the present article, the approaches presented in [2] regarding intermediate checks performed in the field of NAWI are completed with two additional applications in the pharmaceutical/medical field.

In this article, other possibilities mentioned in 7.7.1 of ISO/IEC 17025:2017 were also analyzed, for monitoring the validity of the results it produced, either by internal or external means, such as:

a) replicate verification/calibration tests using the same or different methods (based on normalized error, E_n or the Z-score);
b) the correlation of results for different characteristics of an item: in this article three examples are presented of ways to demonstrate the correlation between measurement results performed in mass determinations, especially in the calibration of E_1 weights;
c) proficiency testing/interlaboratory comparisons (performed in legal metrology or accreditation field) for weights and NAWI.

According to [1], data from monitoring activities shall be analyzed, used to control and, if applicable, improve the laboratory's activities. If the results of the analysis of data from monitoring activities are found to be outside pre-defined criteria, appropriate action shall be taken to prevent incorrect results from being reported.

As a result, considering that a balance is the main "actor" in a weighing operation, it may be necessary to review the validity of measurements made on this instrument since the previous verification/calibration. Consideration should also be given to the repair and/or adjustment of the balance, and to the modification of any external factor that may have caused the change in accuracy.

Considering all these aspects, the laboratory shall shorten the intervals between calibrations (and maintenance, where appropriate) when the results of intermediate checks or other monitoring activities indicate that the measuring and test equipment is no longer performing in accordance with the specified requirements.

All the control procedures mentioned in 7.7 of [1] are important for both the legal metrology and the accreditation fields, either to decide whether the recalibration interval can be maintained, prolonged, or reduced, or whether corrective actions shall be implemented. ■

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[9] OIML R 111 *Weights of classes* E_1, E_2, F_1, F_2, M_1, M_{1-2}, M_2, M_{2-3} *and* M_3.

[10] A. Vâlcu, F. Iacobescu, R. Todor, S. Baicu, *Investigation of laboratories performance carrying out verifications in legal mass metrology*, OIML Bulletin, Vol. LIX, No. 2 2018

[11] ISO 13528:2015 *Statistical methods for use in proficiency testing by interlaboratory comparison*

THERMAL ENERGY MEASUREMENTS IN LIQUIDS

Heat and cooling meters in legal metrology

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1 Abstract

Thermal Energy metering is of globally growing interest for economic and environmental reasons. Standards and normative documents act as a backbone for legal requirements imposed on thermal energy meters. While there is always room for further improvements, standardization aims at displaying state-of-the-art technical developments and reliably applying them in trade. Current problems of thermal energy metering in liquids include fast response metering, the development of a new disturbance generator, smart metering, and liquids other than water. These topics have been declared as work items for standardization bodies, and this article deals with the scientific findings and developments regarding these problems.

2 Introduction

Heating and cooling accounts for 50 % of global final energy consumption, which makes it the largest energy end-use. It contributes to 40 % of global carbon dioxide emissions. While 50 % of the total thermal energy consumption is used for industrial processes, approximately 46 % is consumed in buildings, particularly for the climatization of premises (both heating and cooling) and water heating [1]. Obviously, heating and cooling is of great importance for humanity. Likewise, the measurement of thermal energy is of outstanding significance since inaccurate measurements or biased errors can lead to considerable financial and ecological issues during the process of transport, trade and, finally, sales to the consumer.

When it comes to the climatization of industrial and domestic buildings, demands vary across the globe due to climatic conditions and economic development. Consequently, legislation and regulation differ from country to country. However, in general there is a growing tendency worldwide to measure and charge thermal energy consumption. Three main goals are of interest:

i. To determine energy costs incurred by the consumer as exactly as possible, based on reliable and comprehensible measurements.
ii. To make the consumer aware of the benefits of using thermal energy in a more economic and environment-friendly way, assuming that alternatives are offered.
iii. To ensure that more reliable measurements improve the efficiency of heating or cooling systems as processes run closer to optimum.

For example, the European Union aims at fulfilling its climate goals, for example by raising energy efficiency [2]. Member states of the European Union are obliged to measure thermal energy, not only coming from district heating, but also individually in multi-apartment buildings. The latter can be done either by thermal energy meters or in combination with heat cost allocators [3: (Phrase 28)].

Compared to the use of heat cost allocators, thermal energy meters have advantages. Individually consumed thermal energy is directly indicated by the meter in legal units (e.g. kW·h). Consumption determined by heat cost allocators (i) splits up the relative proportions between other consumers in the building using a superordinated thermal energy meter and (ii) is based on complicated procedures computed in the aftermath, which are often not transparent for consumers. Another advantage of thermal energy meters is the place of installation, which can be chosen independently of various radiator designs and outside the living space. However, the technical requirements that thermal energy meters are subject to are, compared to other consumption meters, relatively high. For example, a heat meter intended for domestic use must measure correctly and consistently under a much more demanding scope of services compared to an electrical energy meter.

Furthermore, the thermal energy meter cannot fundamentally measure thermal energy directly, only indirectly through an orchestrated interplay of three functional groups. Each of its functional groups can be based on various physical operating principles (see chapter 3). And each of these functional groups can be affected by ambient conditions such as temperature, electromagnetic radiation, glitches, piping construction faults and humidity, etc. Additionally, the meter's functional groups can be affected by the liquid itself: disturbed flow profiles, liquid flow fluctuations and varying conveying liquid quality may occur. In sum, the influences can lead to incorrect measurements of thermal energy and must therefore be researched to achieve the goal of reliable measurements. Results of scientific research permanently lead to new empirical findings which result in the formulation of new possibilities, but also in restrictions for thermal energy meters (see chapters 4 and 5). National, regional and international technical committees and their respective working groups use these findings to formulate amendments to standards (e.g. EN 1434-1 [4]) or normative documents (OIML R 75-1 [5]).

3 Fundamentals of thermal energy measurements

The principle of measuring thermal energy can be described using the example of a stationary heating system (see Figure 3.1). During a period of time Δt, a stationary mass flow $\dot{m}$ of a heat-conveying medium enters the heater through the inlet, while an equal mass flow leaves it through the outlet.

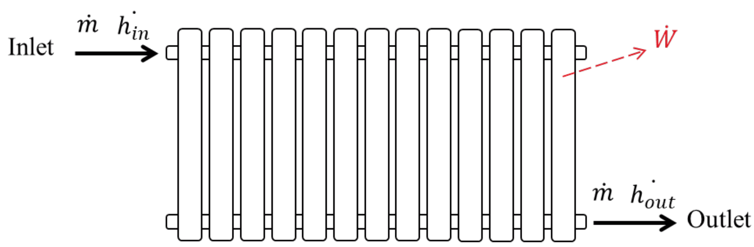


Figure 3-1: Principle of measuring thermal energy of a heating system

As the heat W is submitted by the heater to the surrounding air, the specific enthalpy h_i of the medium decreases between the inlet and the outlet as it cools down. The measurement of consumed thermal energy is based on the specific enthalpy difference Δh [J/kg] comparing the specific enthalpy ("specific" means "per unit of mass") of the heat medium in inlet h_{in} and outlet h_{out}.

$$W = \int_{t_0}^{t_1} \dot{m} \cdot \Delta h \cdot dt \tag{1}$$

Since the measurement of the specific enthalpy difference between inlet and outlet Δh cannot be done directly, the relation of the specific enthalpy and the specific heat capacity at constant pressure $c_p(\vartheta)$ for incompressible fluids is used:

$$\Delta h = c_p(\vartheta) \cdot (\vartheta_{in} - \vartheta_{out}). \tag{2}$$

As the volume flow is easier to measure compared to the mass flow, the volume flow $\dot{V}$ and the inlet and outlet temperatures ϑ_{in} and ϑ_{out} are measured. However, the direct consequence of measuring volume flow instead of mass flow introduces temperature dependency. Consequently, one of the temperature sensors has to be installed directly at the volume flow meter. The heat output W is finally calculated using the pressure- and temperature-dependent heat coefficient k, which is a function of the specific heat capacity at a constant pressure $c_p(\vartheta)$ and the density $\rho(\vartheta)$ of the heat-conveying medium at the inlet and the outlet. Thus, the following technical working equation can be given for a thermal energy meter:

$$W = k(p, \vartheta_{in}, \vartheta_{out}) \cdot (\vartheta_{in} - \vartheta_{out}) \cdot V \qquad (3)$$

Note, that $(\vartheta_{in} - \vartheta_{out}) > 0$ applies if heat is withdrawn from the heat-conveying liquid, while $(\vartheta_{in} - \vartheta_{out}) < 0$ applies if heat is supplied to the heat-conveying liquid.

According to equation (3), a thermal energy meter basically consists of three functional groups responsible for:

1. volume flow measurement;
2. two temperature measurements (in inlet and outlet); and
3. calculating the change in enthalpy.

A brief introduction to those functional groups is given in the following chapter.

4 Setup of thermal energy meters

The thermal energy meter's three functional groups or sub-assemblies can either be designed inseparably ("Complete thermal energy meter"), or interchangeable if the electrical compatibility of each sub-assembly is given. Each of the sub-assemblies offered by the manufacturers can be based on various principles which will be presented below as well as the ambient influences that may disturb the measurement process.

4.1 Flow sensor

The volume sensor determines the amount of a liquid which flows through a well-defined cross section (for example a pipe) during a certain time interval. It can be based on a series of measurement principles, resulting in a vast variety of differently sophisticated sensor types which are able to measure the flow rate of a likewise vast variety of media such as water, fuel, gas, multiphase substances, solids or even cryogenics such as liquid helium. To name just a few, conventional methods for liquids are:

- direct volume sensors such as the positive displacement meter (an example is the oval wheel meter);
- indirect volume sensors with moving parts (so-called dynamic flow meters) such as turbine flowmeters; or
- sensors which do not require any moving parts (so-called static flow meters) such as ultrasonic, electromagnetic, fluidic or Coriolis flowmeters.

Different measurement principles may lead to varying influences that can affect the process of measuring the flow rate. Flowmeters are usually calibrated with a certain fluid to ensure measurements respecting the legal normalized conditions. The process of calibration happens under laboratory conditions where a lot of disturbing influences can be minimized. In comparison with laboratory conditions, field conditions (e.g. piping installation, ambient temperature and humidity, electromagnetic field) may differ a lot. Especially disturbed flow profiles can lead to distinct measurement errors (particularly for those flowmeter types that are heavily dependent on flow conditions).

Typical deviations from the fully developed, axis-symmetric and turbulent flow profile (see Figure 4-1, left) are asymmetric velocity distributions (see Figure 4-1, middle) and swirl. Flow disturbances may occur in incorrectly installed meters or in faulty pipe configurations. Common types of disturbance develop downstream of bend configurations, reducers or tees but are also related to partially closed valves or badly installed flange gaskets. Once a flow profile disturbance occurs, the effect on the sensor is hard to foresee.

It may over-read or under-read, based on its measurement principle. Usually, certain lengths of straight inlet and outlet pipe are recommended by flowmeter manufacturers. Flow straighteners or conditioners are alternative options if the piping design of the application is limited in space.

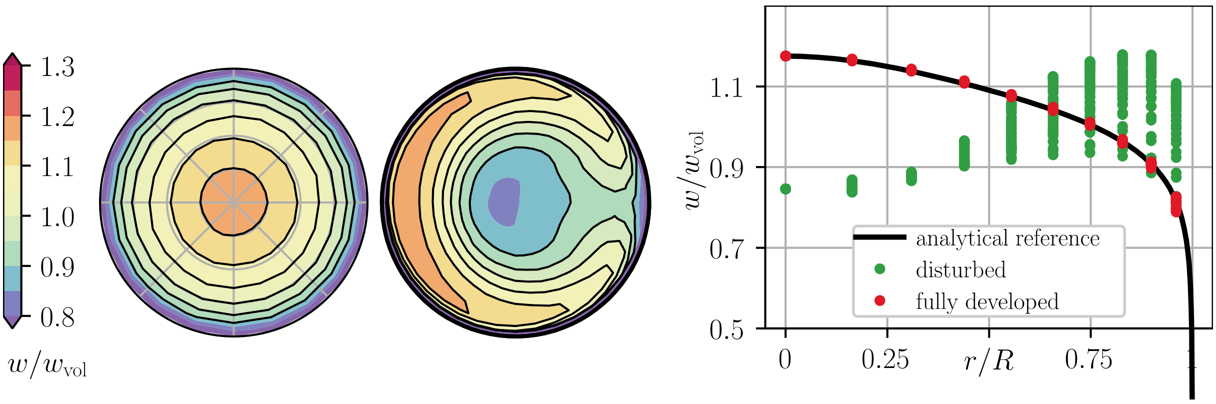


Figure 4-1: LDV-Data of a fully developed turbulent flow profile for Re=500000 (left) and a disturbed profile (middle) 2.4 diameters downstream of a single 90° bend. The graph on the right side depicts the velocity distribution along the pipe radius for fully developed flow (red) and disturbed (green) in comparison to the analytical reference by Gersten and Herwig (black) [49].

Principles which are often applied when it comes to metering thermal energy are turbine meters (impeller or Woltmann flowmeters) and ultrasonic flowmeters. These principles will be briefly introduced in following chapters.

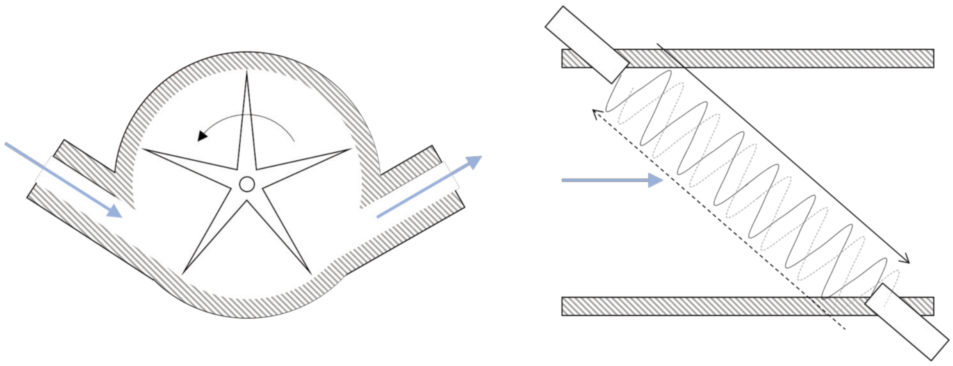


Figure 4-2: Basic principle of Turbine Flowmeter (left) and Ultrasonic Flowmeter (right)

4.1.1 Turbine meters

Turbine meters use the kinetic energy of the flowing liquid to propel an impeller. In single-jet design, the liquid enters the measuring chamber through an inflow channel. Inside the chamber, the liquid flows tangentially onto the impeller blade before leaving this section through the outflow channel as shown in Figure 4-2. During the process, the rotation of the impeller is read out by counting pulses. The pulse rate is then calculated to a matching mean flow rate. In a simplified, frictionless assumption, the impeller's angular velocity is approximately proportional to the flow velocity of the medium [6]. However, a realistic approach must include the influence of the liquid's viscosity, density, flow velocity and specific sensor design.

The turbine flow meter design may appear to be simple, but the flow conditions inside the measuring chamber are complex. The sensor may consist of baffle ribs, bypass throttling, a special inflow channel design, or special impeller blade angles. Calibration of the flow sensor is needed to achieve a reliable relationship between a specific liquid's flow rate, temperature, pressure and the impeller's circumferential speed. This type of sensor is particularly sensitive to disturbances in the inlet and outlet flow as flow profile disturbances directly affect the flow on the impeller. Sensors based on multi-jet design are less sensitive to disturbances. They consist of several inlet and outlet flow channels, thus improving bearing friction and making them more robust to disturbances.

Typical applications of turbine-type flow sensors include common domestic and industrial water supply but also measuring fluids such as heating oil, fuels and natural gas.

4.1.2 Ultrasonic flowmeter

Ultrasonic flowmeters are based on the liquid's flow velocity, which either accelerates or decelerates an ultrasonic signal which is sent in or against the flow direction. A signal which is carried by the medium in the flow direction needs less time than a signal that passes the same distance against the medium's flow direction. This so-called time-of-flight measurement can be used to calculate the average flow velocity over a particular measuring section, which might only cover a part of the total cross-sectional area. The basic design includes two piezo transducers which act as ultrasonic transmitters and receivers. Both are introduced into the measuring section in a way that allows their signals to be either accelerated or decelerated by the liquid flow as shown in Figure 4-2 (simplest approach: single beam design). The transit time difference between both signals, its sum and knowledge of the distance between both transducers is used to calculate the average flow velocity over the measurement section. Furthermore, the medium's speed of sound can approximately be deduced using the average of both transient times. Knowledge of the speed of sound can be beneficial for monitoring processes.

As this principle does not require moving parts, ultrasonic flowmeters interfere less with the liquid flow. Compared to turbine meters, the pressure loss might be lower. The measurement is strongly dependent on the flow profile, especially in single beam design. More sophisticated multi-beam flowmeters average the velocity along several paths, making them less sensitive to disturbed flow profiles.

The applications are multiple for ultrasonic flowmeters due to their versatility and robustness. They are deployed for domestic to industrial scale consumption as well as for scientific applications, measuring a wide range of liquids.

4.2 Temperature sensor pair

Typical applied principles of temperature measurement are platinum resistance thermometers (indicated by: Pt) or semiconductor temperature sensors (NTC).

The most used types for thermal energy metering are industrial platinum resistance thermometers and platinum temperature sensors which are classified into tolerance classes according to IEC 60751 [7] or OIML R 84 [8]. These are based on platinum's temperature-dependent electrical resistance, which can be described by the Callendar-Van Dusen equation:

$$R_\vartheta = R_0(1 + \mathrm{A}\vartheta + B\vartheta^2 + \mathrm{C}(\vartheta - 100)\vartheta^3), \qquad (4)$$

where R_ϑ is the resistance at the temperature ϑ in °C and R_0 is the resistance at 0 °C. For thermal energy meters, temperature sensors of at least tolerance class B are recommended [4]. Typical nominal resistances for industrial use are Pt100, Pt500 and Pt1000 (the number after Pt corresponds to the nominal resistance in Ohms at 0 °C, e.g. a Pt100 has nominal value of 100 Ω at 0 °C).

Semiconductor temperature sensors work comparable to platinum resistance thermometers: the temperature dependency of a certain material's electrical resistance is used to determine the temperature. Compared to platinum, the temperature-dependency of such materials is less linear than that of a Pt, which limits the semiconductor's field of use as well as its uncertainty.

4.3 Calculator

The microprocessor-controlled calculator combines flow and temperature sensor data to calculate the supplied thermal energy by factoring in the heat coefficient k. The heat coefficient of water can be calculated based on equations of state (see IAPWS 95 or IAPWS-IF 97). However, for other heat conveying liquids, k must be determined by calorimetric measurements of the specific heat capacity at constant pressure, and the density. See chapter 5.3 for more information regarding liquids other than water.

The calculator can additionally display the calculated heat output or further data such as the actual flow and temperatures. Stored data can also be accessed via interface.

5 Legal requirements for thermal energy meters

As mentioned above, regulatory actions may vary across the globe as well as legal requirements. This chapter considers examples from the *European market* and its current international approach as well as examples from the *American* and *Asian* markets.

5.1 European Union

To improve energy efficiency, the European Union released the Directive 2012/27/EU and amending Directive (EU) 2018/2002, which require individual measurement devices (thermal energy meters, possibly in combination with heat cost allocators) to be installed in buildings that contain several apartments or have multi-purpose use and which are supplied with heating, cooling or hot water [9][10]. Thermal energy meters belong to the list of meters that must fulfil certain requirements that are crucial for protecting public interest such as health and safety, and help protecting consumers and environment [11].

The European Measuring Instruments Directive 2014/32/EU (MID), which takes precedence over national regulations in member countries of the European Union, aims at creating a common market for measuring instruments across the EU by allocating MID approval, if a measuring device complies with the essential requirements [12]. This approval is recognized by many countries in and outside the EU. Compared to the classic national approach, where a measuring device is placed on the market after receiving the type approval (delivered by the national metrology institute) and after passing the initial calibration by the calibration authority, the current approach is more open. Prior to placing a device on the market, the manufacturer and the conformity assessment body assess conformity based on a modular concept (see [12], ANNEX II). Selectable modules for thermal energy meters are either:

- B (EU type examination) + D (conformity to type based on quality assurance of the production process);
- B + F (conformity to type based on product verification); or
- H1 (conformity based on full quality assurance plus design examination).

After passing conformity assessment, the manufacturer provides the required labelling of the device and declares conformity. Once the meter is put on the market, nationally implemented regulations apply for the surveillance of meters.

Measuring instruments which are in conformity with harmonized standards or normative documents are presumed to be in conformity with the essential requirements set out by the MID. The applicable standard for thermal energy metering is the harmonized European Standard EN1434 [13]. The combined parts of EN 1434-1 to 1434-6 define general and constructional requirements, data exchange, type approval and initial verification testing, as well as installation, monitoring and maintenance. OIML R 75:2002/2006 is a normative document regarding heat meters. It is based on parts of EN 1434 as of 1997. Although not every requirement of the MID is covered [14][15] in this OIML Recommendation, it is widely used around the globe.

5.2 America

Two examples from America of legally metering thermal energy demonstrate the differences with the European approach.

5.2.1 United States

In the United States of America, metering energy is required in federal buildings to improve efficiency and reduce costs [16], [17]. However, hydronic thermal energy metering is uncommon. More common is the measurement of electricity or gas which is used for heating and cooling. Apart from the Energy Policy Act of 2005 and the recent Presidential Executive Order 13834 there is currently no uniform regulation to measure thermal energy. Thermal energy metering is mainly present in renewable niche sectors. To give an example, there are state programs that aim at introducing new technologies such as solar thermal energy in California [18] or heat pumps as well as solar thermal systems in Massachusetts [19]. These state-level programs require metering to receive incentives based on usable delivered energy. Despite its niche status, a heat metering standard has recently been developed, ASTM E 3137 M 18 [20], based on OIML R 75 and EN 1434. Thus, calibration facilities now have a national standard to refer to. The development of a testing infrastructure is obviously linked to the metering market, which right now is in a market niche. However, thermal energy metering could become more important for the US if further legal steps are taken towards raising energy efficiency of buildings.

5.2.2 Canada

In Canada, the “Weights and Measures Act” [21] and the “Weights and Measures Regulations” [22] are the basic framework for legally regulated trade. Since recently, thermal energy meters used for trade fall under these regulations and must subsequently meet certain requirements to receive approval [23]. The implementation schedule allows unapproved meters that had been installed prior to July 1st, 2019 to be allowed until July 2026 [24]. EN 1434, OIML R 75 and the current Canadian standard for thermal energy metering CAN/CSA 900 (which is based on and almost identical to EN 1434), are regarded as being equivalent to the terms and conditions for the approval [25]. Thus, meters that are approved under those standards or normative documents are approvable in Canada.

5.3 Asia

The Asian continent with its booming countries such as China and India is the world’s biggest energy consumer [26]. In China, rapid industrialization and urbanization along with a rising standard of living have triggered a high energy demand. To promote energy efficiency, the Chinese Government enacted the “VII Energy Conservation Law”, which includes metering thermal energy in households [27]. For various reasons, the rate of implementation is currently relatively slow. Some of the reasons for this are [28]:

- retrofitting in existing buildings is expensive;
- heat stations as well as piping must be renovated to deal with greater expected variations in heat demand; and
- heat providers who block reforms as profit margins may shrink.

Currently, the approach to use the heated area for proportional billing is more common than measuring the actual consumption. Furthermore, the climate varies across China, leading to the situation that heating in winter is mostly concentrated in northern parts of the country, while heating in the southern parts of the country is unusual. There are also differences between less developed rural and more developed urban areas. In the end, heat metering is mainly present in northern cities. There are several standards that can be referred to. JGJ 173-2009[29] defines the technical specifications for heat metering of district heating systems. The national standard for heat meters is GB/T 32224-2015 [30], which is based on parts 1, 2 and 3 of EN 1434. Verification and approval of heat meters are also carried out in accordance with parts 4 and 5 of EN 1434 and are described in JJG225-2001 [31], which adopted OIML R 75.

6 Current challenges

Research and development are the driving forces for innovation, resulting in the formulation of new possibilities but also restrictions for thermal energy meters. Once scientifically researched and secured, these new empirical findings find their way into production and thus into the market. Where trade and billing are incorporated, legal metrology and subsequently standardization face the challenge of adjusting to innovation. The following fields of work are currently considered in standardization of thermal energy metering.

6.1 Fast response thermal energy meters by Dr. Arne Kaehler

The author of this chapter Dr. Arne Kaehler, Head of Research & Development at Techem Energy Services GmbH, is actively engaged in German and European Standardization Committee Work. As an expert for thermal energy metering, he developed mathematical models and appropriate simulation software to gain insights into the behavior of fast response thermal meters in relation to dynamic heating and fast hot water systems. The following chapters summarize his research activities.

6.1.1 Current field situation and normative requirements

Fast response thermal energy metering is typically required in heating systems with fast hot water tapping processes such as:

- systems without boilers (no hot water storage);
- combined dynamic heating and fast hot water systems without hot water storage;
- district heating systems with small heating in-house substations without hot water storage.

The EU market share of these systems is growing and is today in the range of around 10 % to 15% for new installations [32]. State of the art thermal energy meters (heat meters) typically use sampling intervals longer than or equal to 16 seconds, applying different types of temperature sensors (with lower or higher inertness). Some types of thermal energy meters apply different adaption modes for sampling or integration, which influences the registration essentially. The challenging questions deal with (i) the real influence on energy consumption calculation and billing and (ii) with the requirements to minimize this influence regarding sensor inertness, sampling times, integration time and integration methods of thermal energy meter calculators in fast thermal metering appliances. To answer these questions, it is necessary to research the influence of dynamic hot water generation processes on the energy consumption calculation depending on the tapping profiles of consumers and dynamic characteristics of the thermal energy meter. The practical (in this case monetary) influence on energy consumption calculation and billing of deviations in hot water consumption should be estimated. The following parameters are assumed: costs of 6 Eurocents/kW·h for gas and oil, 9 Eurocents/kW·h for district heating, a flat with a typical living space of 70 m^2, and an energy consumption for hot water generation of 32 kW·h/m^2 [32].

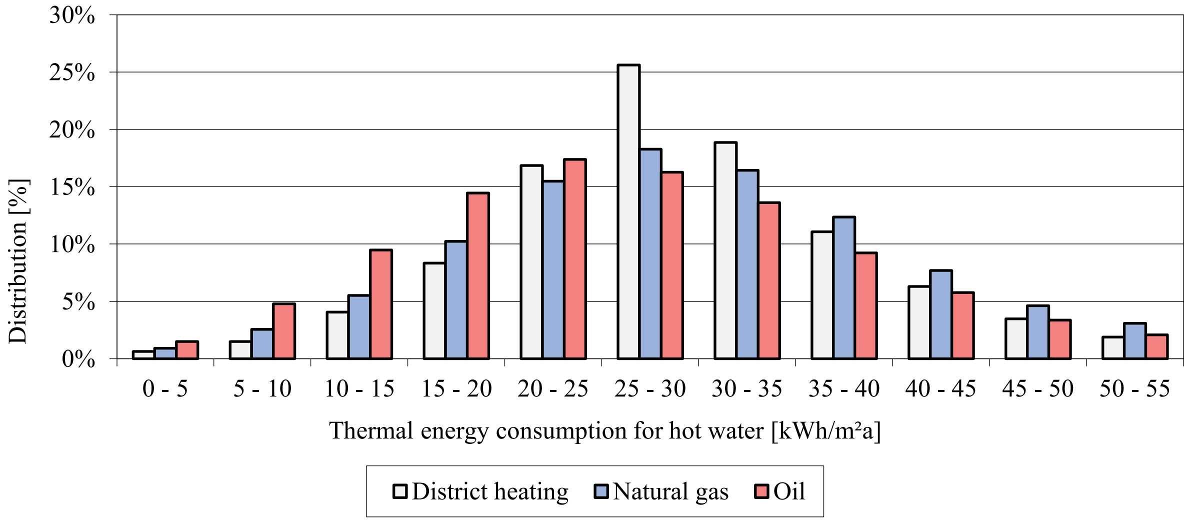


Figure 6-1: Energy and cost distribution of hot water generation in relation to total energy consumption compared to annual costs for space heating and hot water generation in multi-family apartment buildings in Germany [32]

The average annual total costs for space heating and hot water generation for multi-family apartment buildings in Germany are in the range of 600 Euros per flat with a typical size of around 70 m² [32]. Figure 6-1 shows the spread of energy and cost distribution of hot water generation in comparison to the total energy consumption for space heating and hot water generation for multi-family apartment buildings in Germany.

Figure 6-2 illustrates the resulting typical cost allocation shift per year caused by measurement deviations of thermal energy for hot water generation for a typical flat in a multi-family apartment building. As observable, the amount of costs is up to 100 Euros per flat and year. By the way: The annual CO_2 emissions caused by space heating and hot water generation with natural gas or oil consumptions are in the range of around 2.5 tons per flat.

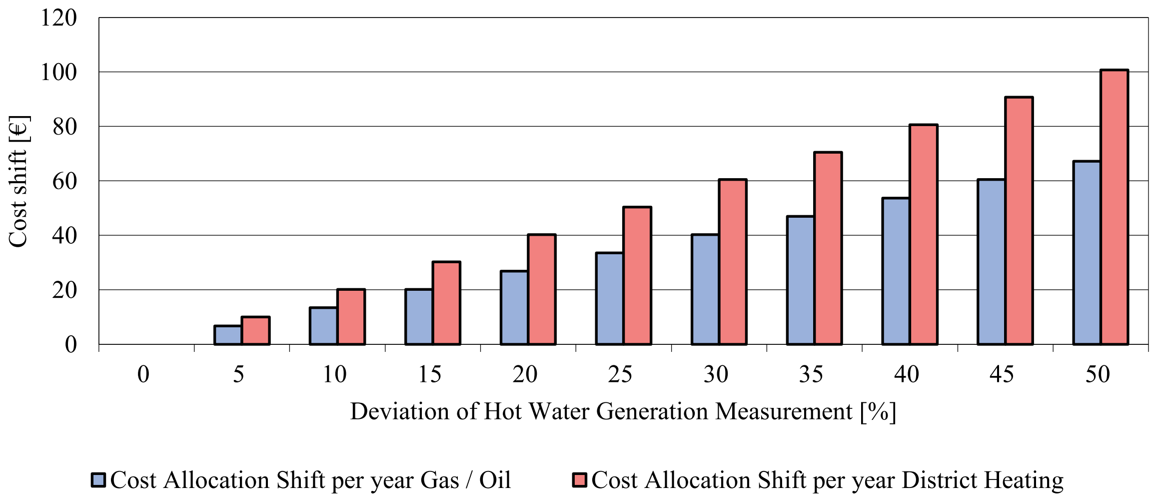


Figure 6-2: Influence of measurement deviations for hot water generation in multi-family apartment buildings in Germany

To avoid these cost shifts it is necessary to correctly assign the real consumed heat and the resulting costs. Consequently, it is very important to measure the amount of thermal energy for space heating and hot water generation with the appropriate precision and accuracy. The current standard EN 1434/1:2015 addresses this problem by defining the following requirements on fast response meters [33]:

- Response time ($\tau_{0.5}$): max. 6 s for long temperature sensors; max. 2.5 s for short temperature sensors;
- For battery driven meters the time between measuring samples (flow and temperature) as well as incremental energy calculations:
  - For time interval-based measurement, 8 s are recommended;
  - For volume quantum-based measurement, 8 s at q_p/q or equivalent volume fraction are recommended;
- For meters driven by the mains the time between measuring samples (flow and temperature) as well as incremental energy calculations:
  - For time interval-based measurement 4 s are recommended;
  - For volume quantum-based measurement 4 s at q_p/q or equivalent volume fraction are recommended.

The goal of the research is to clarify whether these requirements describe the real technical demands properly with respect to the expected measurement deviations and the resulting cost shifts under dynamically changing conditions for hot water generation processes. Thus, for fast hot water tapping processes in systems without boilers (without hot water storage), e.g. in district heating systems, the impact on the calculation results of the thermal heat energy meter should be clarified and quantized. Considered quantities include:

- characteristics of the tapping profile;
- inertness or response times of temperature sensors for the measuring inlet and outlet flow temperatures;
- sampling times of flow or volume and temperature measurands;
- integration time intervals of the heat meter calculator; and
- the inertness or response time of the heat exchanger or its valve.

In 2017, this research on fast response meters were declared as a work item in Working Group 2 of CEN TC 176. The necessary studies were supported and funded by the association EMATEM (European Metrology Association for Thermal Energy Measurement). The normative goals of this research are the definition of requirements in EN 1434/2020 on fast response meters as well as the definition of appropriate test procedures.

6.1.2 Research methodology

Symbols and abbreviations

HEX	Heat exchanger circle
K	Fitting parameter heat exchanger model
K_{Sensor}	Transmission factor of sensor (stationary ratio between inlet and outlet, set to 1)
k_{Water}	Heat coefficient of water
K_{Valve}	Transmission factor of valve (stationary ratio between inlet and outlet, set to 1)
$\dot{m}_{HW}$	Mass flow in hot water circle
$\dot{m}_{HEX}$	Mass flow in heat exchanger circle
μ	Ratio of volume flow rate between heat exchanger circle and hot water circle
η	Energy efficiency of heat exchanger
p	Laplace operator
Φ	Heat transfer characteristic of ideal stationary heat exchanger
q	Flow rate
q_p	Nominal flow rate of sensor
$\dot{Q}_{TAP}$	Rate of heat flow during tapping
$\dot{Q}_{HEX,HW}$	Rate of heat flow from heat exchanger to hot water circle
$\dot{Q}_{HEX}$	Rate of heat flow in heat exchanger circle
$\dot{Q}_{HEX,id}$	Ideal rate of heat flow in heat exchanger circle (=$\dot{Q}_{HEX,ideal}$)

$\dot{Q}_{THEM,REF}$	Rate of heat flow calculated by "ideal" reference thermal energy meter
$\dot{Q}_{THEM}$	Rate of heat flow calculated by "real" thermal energy meter
$\dot{Q}_{Losses}$	Rate of heat flow due to losses in heat exchanger
$Q_{THEM,REF}$	Heat output calculated by "ideal" reference thermal energy meter
Q_{THEM}	Heat output calculated by "real" thermal energy meter
$\Delta\dot{Q}$	Deviation of rate of heat flow between "ideal" and "real" thermal energy meter
ΔQ_{24h}	Daily deviation of heat output between "ideal" and "real" thermal energy meter
$t_{Transport}$	Transport time of valve for control of flow temperature
$t_{50\%}$	Time until temperature amplitude reaches 50 % of set value
$t_{\mathrm{Sampling,Temp}}$	Sampling time of temperature values
$t_{\mathrm{Sampling,Volume}}$	Sampling time of volume values
ϑ_{HW}	Temperature in hot water circle
ϑ_{In}	Temperature at inlet of the temperature sensor
ϑ_{Inlet}	Temperature at inlet of heat exchanger
$\vartheta_{Outlet,ideal}$	Theoretic ideal stationary intermediate variable of outlet temperature
ϑ_{Outlet}	Theoretic stationary intermediate variable of outlet temperature with losses
ϑ_{Sensor}	Temperature output by temperature sensor
ϑ_{CW}	Temperature of cold water
$\vartheta_{Inlet,HW}$	Temperature of water in hot water circle entering the heat exchanger
$\vartheta_{Outlet,HW}$	Temperature of water in hot water circle leaving the heat exchanger
$\vartheta_{HEX,OUT}$	Outlet temperature of heat exchanger circle
ϑ_{TAP}	Tapping temperature
$\vartheta_{THEM,OUT}$	Measured temperature of sensor in outlet of heat exchanger circle
$\vartheta_{THEM,IN}$	Measured temperature of sensor in inlet of heat exchanger circle
$\vartheta_{HEX,OUT}$	Temperature in outlet of heat exchanger circle
$\vartheta_{HEX,IN}$	Temperature in inlet of heat exchanger circle
$\vartheta_{HEX,IN,VALVE}$	Temperature in inlet of heat exchanger circle, after control valve
τ_1	Time constant of temperature sensor
τ_2	Time constant of temperature sensor
τ_{HEX}	Time constant of heat exchanger
τ_{Valve}	Time constant of control valve
$\dot{V}_{HW}$	Volume flow in hot water circle
$\dot{V}_{HW,TAP}$	Volume flow of tapped hot water
$\dot{V}_{CW}$	Volume flow of cold water
$\dot{V}_{CW,TAP}$	Volume flow of tapped cold water
$\dot{V}_{TAP}$	Volume flow of tapping valve
$\dot{V}_{THEM}$	Volume flow of thermal energy meter in heat exchanging circle
$\dot{V}_{HEX}$	Volume flow in heat exchanging circle
$\dot{V}_{HEX,IN}$	Volume flow of water from the heating system entering the heat exchanger circle (inlet)
$\dot{V}_{HEX,IN,VALVE}$	Volume flow of water in the heat exchanger circle inlet exiting the control valve
$\dot{V}_{HEX,OUT}$	Volume flow of water leaving the heat exchanger in the heat exchanger circle (outlet)

Dynamic simulation of tapping processes

To research the items above, a dynamic simulation approach was chosen. This approach is based on modularized and connected dynamic modelling of all considered and essentially influencing components as shown in Figure 6-3.

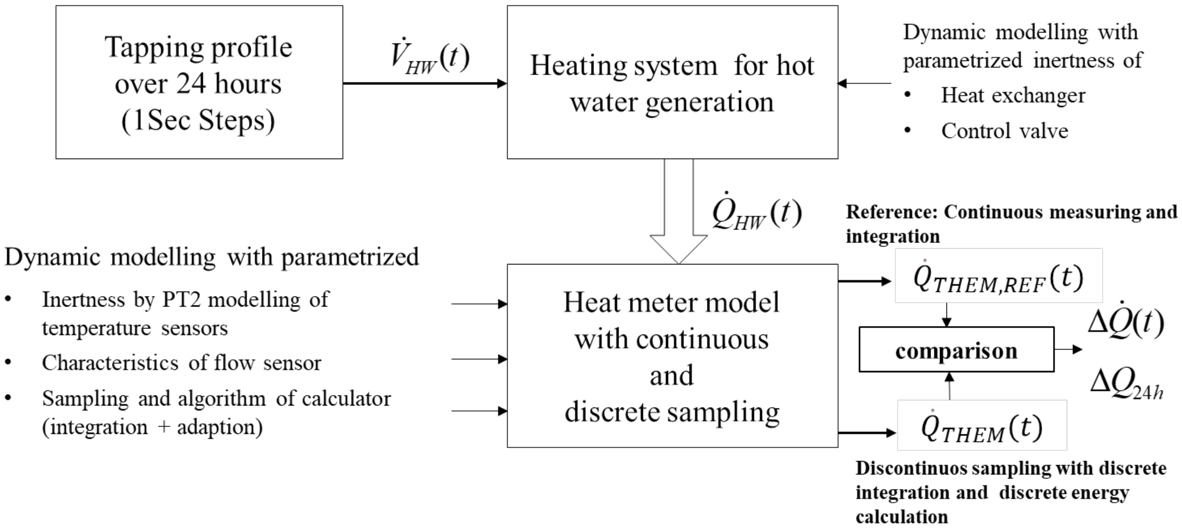


Figure 6-3: Modularized and dynamical modelling and simulation of hot water tapping, hot water generation and thermal energy calculation

Regarding the tapping profile, to reflect real applications, it was chosen to distinguish between (i) residential (multi-family) buildings and (ii) non-residential buildings. Both are assumed to come with differently frequented tapping situations which should result in differing tapping profiles. The respective daily tapping profile for a time interval of 24 h is modelled using a resolution of one second per time step.

The heating system for hot water generation includes the heat exchanger as well as the control valve. Furthermore, inertness of these components has been considered by including parameterized response times into the process of modelling their dynamic behavior. A reference thermal energy meter model ("THEM,REF") with continuous measuring of flow and temperatures and continuous integration has been developed. Inertness of temperature sensors as well as the characteristics of the flow sensor are considered. Thus, influences regarding flow measurement and temperature difference measurement are included, while the calculator (which is responsible for sampling, integration, and parameter adaption) is assumed to work continuously and flawlessly. It represents the ideal metering device for dynamic processes and serves as the reference to compare "real" meter readings to. The modelled thermal energy meter "THEM" with time discrete sampling of flow and temperatures also reflects the respective discrete numeric integration and its influences on thermal energy calculation. Thus, discontinuous sampling with discrete integration and energy calculation are included to model real metering processes.

Tapping modelling

Regarding the modelling of the tapping profiles, a flexible method for generating daily tapping profiles has been developed to analyze the influence of the behavior of different consumers. Basically, a daily tapping profile is considered as a sequence within a daily 24 h cycle of different tapping events resulting from hand washing, dish washing, other tapping events or showering. A Swedish profile ("SWE") from RISE Institute and Swedish Building Regulations (BBR) with slightly deviating tapping events with typically longer tapping durations has also been incorporated. While the tapping temperature is generally assumed to be 40 °C, the different tapping events are defined as follows:

- Hand washing: 15 … 30 s at a flow rate of 8 L/min
- Dish washing short (kitchen): 15 … 30 s at a flow rate of 10 L/min
- Dish washing long (kitchen): 30 … 120 s at a flow rate of 10 L/min
- Shower: 120 … 300 s at a flow rate of 12 L/min
- Hand washing: 3 … 15 s at a flow rate of 6 L/min
- Hand washing (SWE): 30 …90 s at a flow rate of 4 L/min
- Dish washing (SWE): 30 … 120 s at a flow rate of 8 L/min
- Other tapping (SWE): 30 … 90 s at a flow rate of 2 L/min
- Shower (SWE): 300 … 600 s at a flow rate of 8 L/min

The combination of these tapping types with different frequencies within a daily 24 h cycle allows a very flexible generation of different daily tapping profiles. To analyze the influence of different user behavior three basic daily tapping profiles, shown in Figure 6.4 were applied, (i) the residential building, (ii) the non-residential building and (iii) a Swedish profile from RISE Institute and BBR.

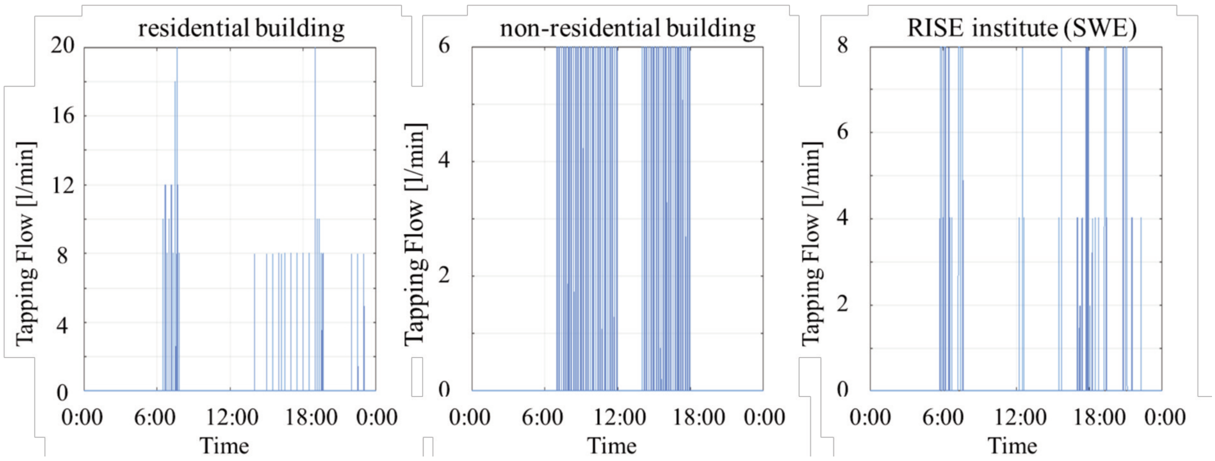


Figure 6-4: Applied tapping profiles for residential and non-residential buildings

Modelling of the heating system and the thermal energy calculation

Regarding the heating system for hot water generation, its dynamic modelling approach (as shown in Fig. 6.5) includes following components:

- temperature sensors (in the inlet and outlet of the heat exchanger circle);
- heat exchanger;
- control valve for controlling the heat exchanger power to set the hot water temperature.

The configuration of the system basically consists of three major groups: the heat exchanger circle, the hot water circle and the tapping valve.

The heat exchanger circle ("HEX") consists of the inlet piping coming from the heating system, the heat exchanger, the control valve, and its outlet piping back to the heating system. In this part of the system, the thermal energy meter's flow sensor is installed in the return pipe measuring $\dot{V}_{THEM}$, while the temperature sensors are installed in the inlet measuring $\vartheta_{THEM,IN}$ and the return, measuring $\vartheta_{THEM,OUT}$, respectively. As the water temperature drops between inlet and outlet, the thermal energy Q_{THEM} that has been transferred through the heat exchanger to the hot water circle during a certain time span can be determined here.

The hot water circle ("HW") consists of a circulation pump as well as the piping to connect the heat exchanger with the cold water inlet and tapping valve.

The tapping ("TAP") valve can either be fed with cold water ("CW") or hot water coming from the hot water circle.

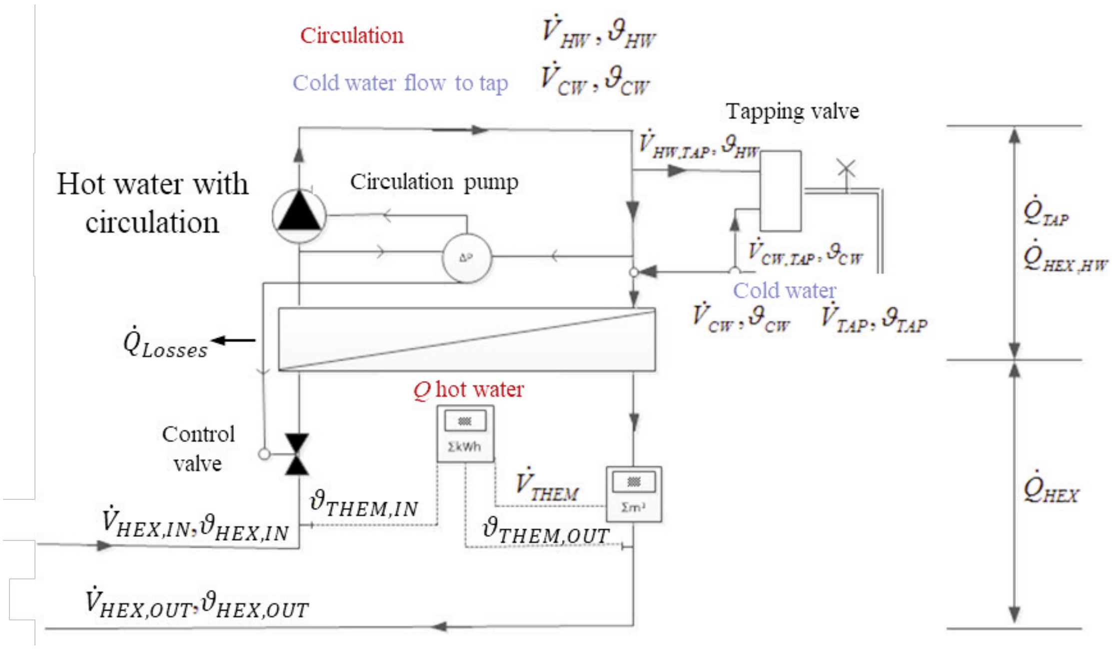


Figure 6-5: Configuration of hot generation heating system, shown here for the case 'hot water circulation'

The dynamic modelling of all these connected components and the corresponding simulation, as well as the energy calculation for the discrete realized calculator of the thermal energy meter, were developed and realized using Matlab/Simulink. Using this modelling it was possible to perform simulation studies with different influencing parameters under stable and constant conditions regarding other effects that may have an impact.

A dynamic modelling approach was applied to the temperature sensors, which included different designs with varying inertness values leading to certain step responses as shown in Figure 6-6.

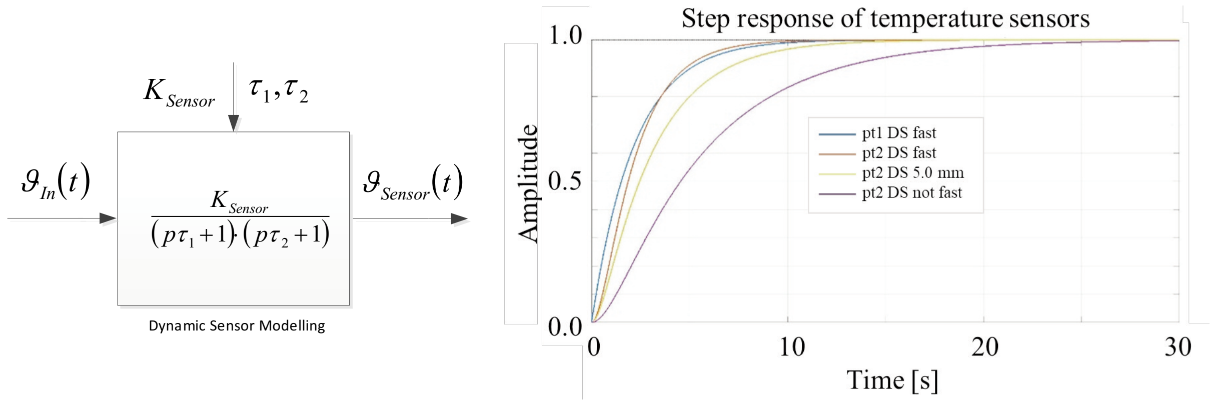


Figure 6-6: Dynamic modelling of the dynamic behavior of temperature sensors

The heat exchanger including input values affecting its function is modelled as shown in Figure 6-7. An important feature of this model is the possibility to reflect stationary and dynamic characteristics. The inlet and outlet temperatures of the heat exchanger circle and the hot water circle are considered, as well as its respective volume flow values, thermal energy losses, and inertia features.

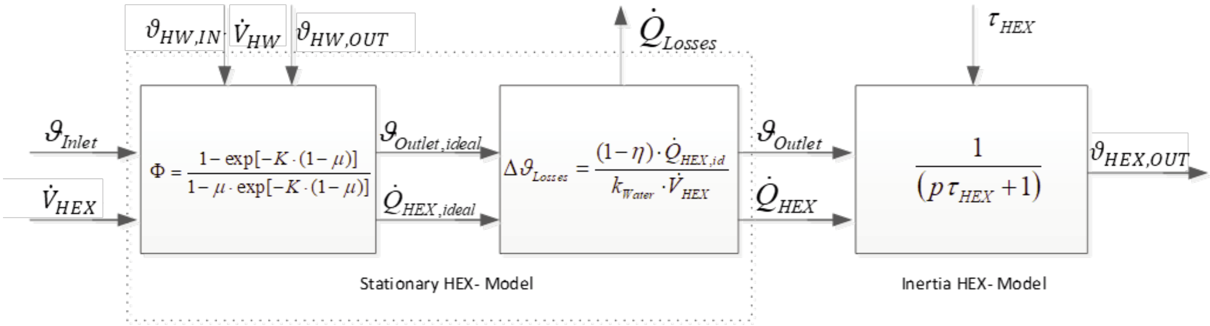


Figure 6-7: Dynamic modelling of heat exchanger dynamic behavior

The modelling of the system's control valve including its dynamic characteristics is realized as shown in Figure 6-8.

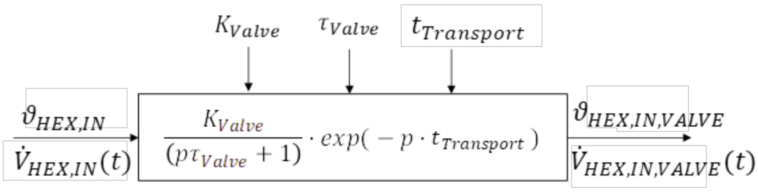


Figure 6-8: Dynamic modelling of the control valve

The reference heat energy for hot water generation measured by the ideal thermal energy meter was calculated according to:

$$Q_{THEM,REF}(t) = \int_{t0}^{t} \dot{Q}_{THEM,REF}(\tau)d\tau \qquad (5)$$

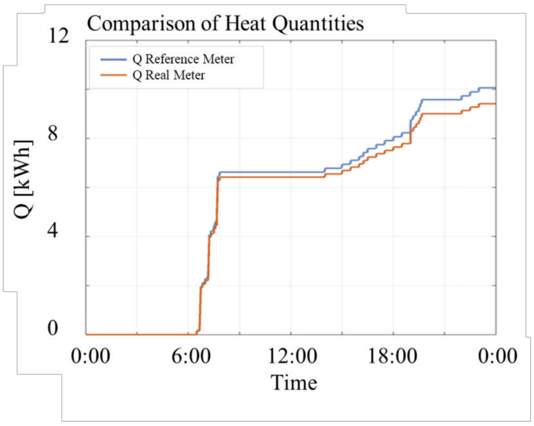
with

$$\dot{Q}_{THEM,REF}(t) = k_{water}(\vartheta_{THEM,IN}, \vartheta_{THEM,OUT}) \cdot \dot{V}_{THEM}(t) \cdot [\vartheta_{THEM,IN}(t) - \vartheta_{THEM,OUT}(t)]. \qquad (6)$$

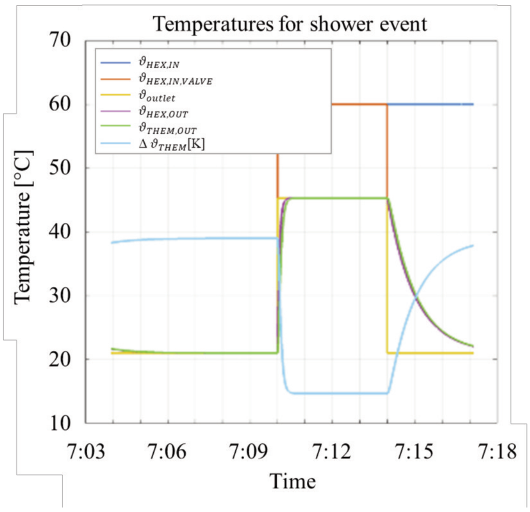
The following parameter ranges were used in the simulation studies:

- time constant temperature sensors τ_1 sensor [s]: 0.5 … 1.0
- time constant temperature sensors τ_2 sensor [s]: 1.5 … 5.0
- time constant heat exchanger 'heating up' τ_{HEX} [s]: 2 … 8
- time constant heat exchanger 'cooling down' τ_{HEX} [s]: 50 … 150
- transport time of valve for control of flow temperature $t_{\text{Transport}}$ [s]: 0.2 … 1.0
- time constant of valve for control of flow temperature, τ_{VALVE} [s]: 0.1 … 0.5
- temperature sampling time [s]: 2, 4, 8, 16, 32
- volume sampling time [s]: 1, 2 (,4, 8)
- time integrator (equal to volume sampling time): 1, 2 (,4, 8)
- variation of ratio ($t_{\text{Sampling,Temp}}$: $t_{\text{Sampling,Volume}}$) 1:1, 2:1(,...32:1...32:2)

Figure 6-9 illustrates some simulation and result plots based on the respective parameter values (see table in upper right part of Figure 6-9) regarding shower (see lower left) and hand washing (see lower right) events as well as a comparison between an "ideal" reference thermal energy meter and a time-discrete "real" thermal energy meter for a daily tapping profile (see upper left). The figure clearly illustrates the dynamic effects caused by sensor, valve and heat exchanger inertness as well as sampling and integration. It makes transparent why the calculated heat energy by a real, discontinuously operating meter is typically lower than the actual heat energy calculated by the ideal continuously acting meter.



Parameter	Value [s]
τ_{HEX} heating up	4.0
τ_{HEX} cooling down	60.0
$\tau_{Sensor,IN}$	2.2
$\tau_{Sensor,OUT}$	3.6
$t_{sampling,Temp}$	4.0
$t_{Sampling,Volume}$	4.0
time integrator	4.0
$K_{Sensor,IN}$	1.0
$K_{Sensor,OUT}$	1.0



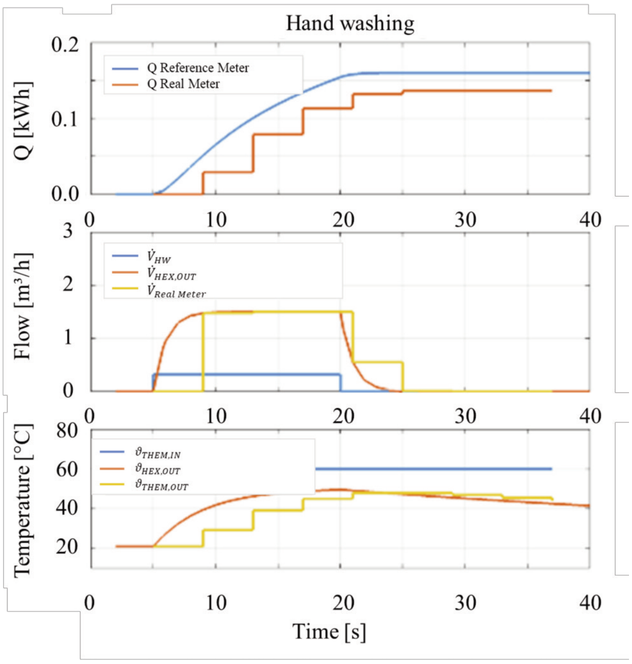


Figure 6-9: Dynamic modelling results for a daily tapping profile (upper left) based on certain parameter settings (upper right). Results of the respective shower (lower left) and hand washing (lower right) events are presented in more detail.

6.1.3 Research results and normative recommendations

The parameter studies described above applying different tapping profiles and different sampling time intervals lead to significant deviations between the reference case ‘continuous measuring and energy calculation’ and ‘discontinuous measurement and discrete integration’ as shown in Figure 6.10.

A very clear and plausible outcome is that lowering the sampling rate of the thermal energy calculator leads to a significantly lower value of the calculated heat. In other words: the lower the sampling rate, the higher is the resulting undercalculation of heat. Another result is that the influence of the considered sensor inertness is lower than the influence of the sampling rate and this therefore affects the resulting undercalculation of heat subordinated.

Residential building tapping profiles such as typical family tapping profiles with low frequented tapping events lead to lower deviations than tapping profiles with more frequent tapping events in non-residential buildings. The Swedish tapping profile leads to lower deviations due to typically longer tapping times. More frequently occurring tapping events lead to more pronounced deviations compared to the sampling rate. Thus, requirements imposed on fast response meters must be distinguished depending on tapping profile types.

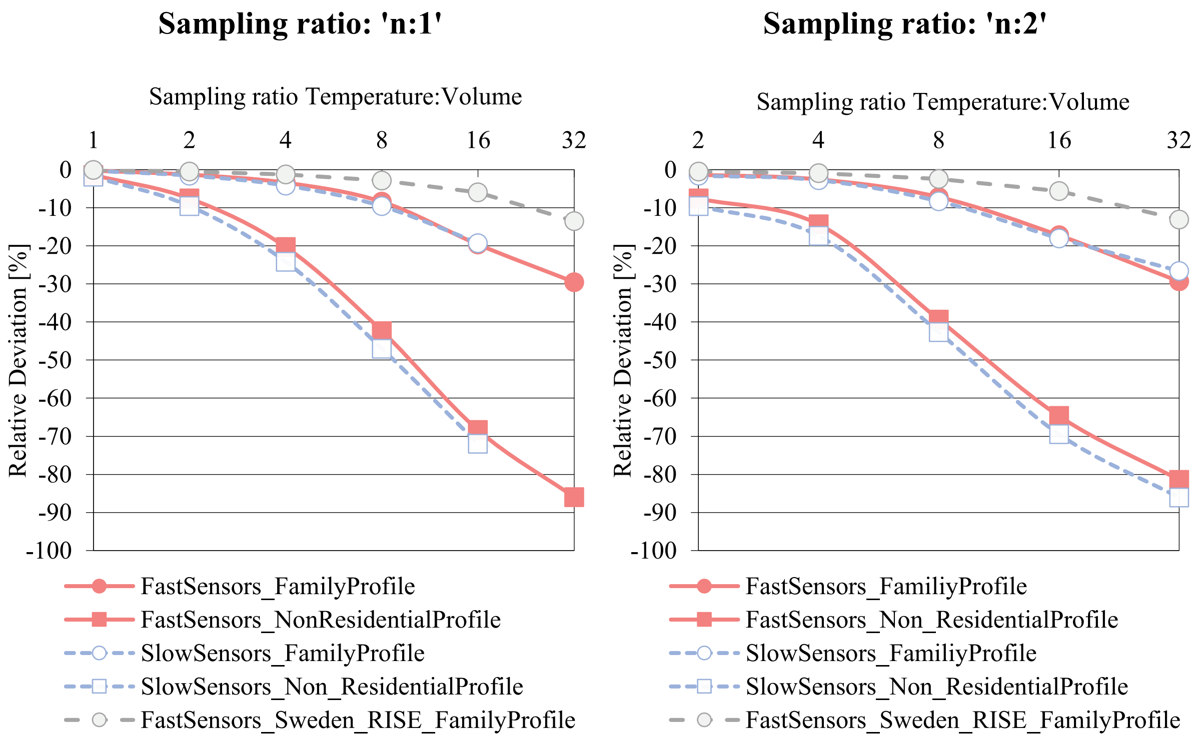


Figure 6-10: Connected modelling and simulation results for different tapping profiles and sampling ratios

Based on the performed parameter studies embedded in modularized modelling and simulation, the following recommendations on requirements for fast response thermal energy meters or sub-assemblies could be derived and included in EN 1434/2020 (Annex C of part 1):

- Temperature sampling time / sampling time interval should be:
    - 4 seconds or lower for non-residential buildings, e.g. for medical practices;
    - 8 seconds or lower for residential buildings (family houses, multi-apartment buildings);
- Volume sampling time should be 2 seconds or less for both cases;
- Integration time shall not be longer than the maximum of the sampling time for volume or temperature (however, the simulation shows that better results would be achieved if the minimum is chosen);
- The response time (‘50 % value’: $t_{50\%}$) of direct short temperature sensors should be 3 seconds or lower ($t_{50\%}$ = 3 seconds corresponds to tau1 for Pt1 modelling = 4.3 seconds).

Regarding the testing of fast response flow sensors, a new proposal reflecting hot water tapping events was introduced into Part 4 of EN 1434/2020. The main corner stones are:

- Tapping flow profile: combination of periods with flow rate = q_p or 0 (switching), starting with q = 0 (see Table 6-1 and Figure 6-11);
- applicable for flow sensors of size $q_p \leq 2.5$ m^3/h;
- defined test start: q = 0 l/h for at least 60 seconds;
- the water temperature shall be in the range (20 ± 5) °C;
- opening & closing time of the utilized valve: < 1 second;
- uncertainty of the real test volume: $V_{test} \pm (0.1 \cdot V_{test})$;
- 6 samples of identical flow meters (15 repetitions with each);
- averaged deviation ($q - q_{Test}$) of 15 repetitions of all 6 samples shall not exceed the MPE;
- only 5 out of 15 deviations determined for all 6 samples are allowed to exceed the MPE.

Table 6-1: Tapping flow profile consisting of flow and pause durations for fast response flow sensor test [34]

i	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Flow duration [s]	6	10	17	14	7	10	9	13	16	9	13	15	14	13	12
Pause duration [s]	30	25	20	25	30	35	60	30	35	25	10	30	15	20	20
i	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Flow duration [s]	7	90	5	12	11	60	14	30	5	15	6	15	8	8	11
Pause duration [s]	20	35	15	30	10	25	10	15	10	35	20	25	60	15	15

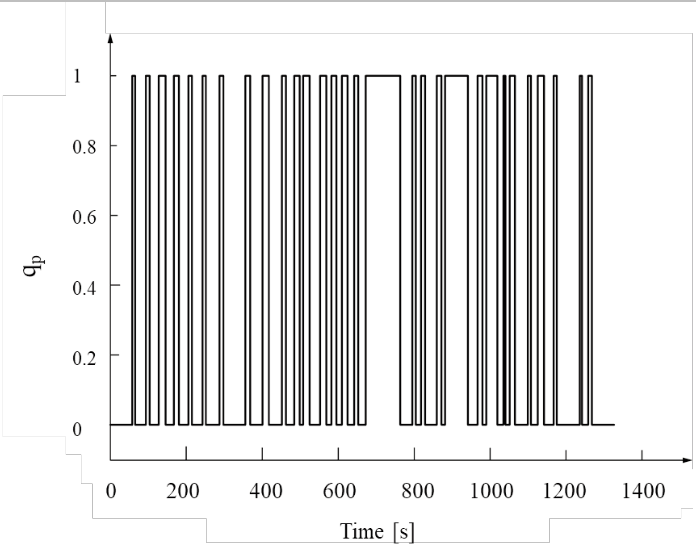


Figure 6-11: Tapping flow profile for fast response flow sensor test consisting of flow and pause durations [s], [34]

Alternatively, the required sampling times (defined in EN 1434-1 rev. 2020, Annex C [34]) can be proven by measuring the sampling times of temperature sensor pairs and the volume sensor e.g. with the help of an oscilloscope or a counter. In this case, the manufacturer has to specify the testing procedure. Additionally, it shall be proven that the software for the calculation of thermal energy is able to fulfil the requirements for fast response meters.

6.1.4 Summary and outlook

It could be shown that the connected dynamic modelling and simulation approach allows explorative research of dynamic effects in discontinuous measurement and sampling of flow (respectively volume and temperatures) as well as discrete energy calculation for fast response thermal energy meters in relation to hot water tapping profiles. The approach to find a model with high stability and repeatability could also be applied to research into modern combined dynamic heating and fast hot water systems without storage in relation to energy and cost allocation.

The modularized modelling and simulation approach developed can adapt to different practical configurations for the generation of heat and hot water by adjusting changeable model parameters. In this context, new field data reflecting the broad range of hot water tapping, heat usage and heating systems is highly welcome. An interesting step in that direction is the experimental research of Mr. Bott of JUMO on the temperature sensor response behavior in real pipe installations. The author would like to acknowledge the helpful support by Mr. Franzen from Göteborg Energi in providing data from the field.

Currently, there is a lack of test benches for dynamic testing of fast response thermal energy meters due to high requirements on dynamic behavior and stability. Therefore, the development of test benches based on the "Hardware-in-the-loop" approach with the embedding of an authentic thermal energy meter calculator could be an interesting and economic option.

6.2 New disturbance generator developments by Martin Straka

Martin Straka belongs to the scientific staff of the PTB's working group 7.53 "Flow Analysis for Thermal Energy Measurement". His scientific work includes the characterization of pipe flow conditions with numerical and laser-optical methods.

6.2.1 Introduction

Disturbed inflow conditions can have a significant impact on the measurement accuracy of any flow meter design. For utility meters, compliance with specified error limits under disturbed flow conditions must therefore be demonstrated as part of the standardized type approval procedure. If valves and other displaceable system components can be avoided, disturbed flow conditions are mainly caused by pipe fittings such as 90°- bends and double bends out-of-plane (see Figure 6-12, top), which allow a change of direction. As test setups with actual bends configurations are difficult to implement at flow facilities, the standards for water meters (ISO 4064 [38], OIML R 49 [40]) and heat meters (EN 1434 [41]) rely on synthetic replications created with the aid of so-called disturbance generators. In the interests of consumer protection and to prevent market distortions, it is important that disturbance generators can reproduce the flow conditions encountered in practice. In the expiring version of EN 1434 [41] from 2015, flow disturbance tests are performed with the right-handed (symmetric) swirl generator from the water meter standards. This disturbance generator consists of eight uniformly distributed angled blades and has the task of creating a swirl component and axial velocity distribution found downstream of double bends.

6.2.2 Shortcomings of the standardized swirl generators from the water meter standards

The standardized swirl generator has been researched and criticized by various authors. Wendt [42] and Tawackolian [39] demonstrated the poor match between the disturber and the flow features of real double bends, which are not only characterized by a swirl component, but also an asymmetric axial velocity distribution. This asymmetry is known to significantly affect the accuracy of flow meters. Additionally, the symmetrical flow conditions downstream of the disturbance generator pose a rather unstable equilibrium, which can easily be unbalanced by random influences. An unpredictable degree of asymmetry was reported by Eichler and Lederer [35] and Graner et al. [43], who researched the flow profiles with particle image velocimetry (PIV) and laser Doppler anemometry (LDA). The identified sensitivity towards the inlet flow conditions or minor geometrical tolerances compromises the reproducibility of the testing procedure, which is in contrast with the concept of standardized testing.

6.2.3 The asymmetric swirl generator

To bypass the disadvantages of the standardized, symmetrical swirl generator, Tawackolian [39] introduced an asymmetrical version of the disturbance generator, called the asymmetric swirl generator. As depicted in Figure 12 (bottom), it consists of five angled blades and a segmental orifice plate with a segment height of 12.5 % × DN – nominal diameter – (covering around 7 % of the pipe's cross section), which creates the desired and reproducible asymmetry. Tawackolian [39] observed an asymmetric flow profile at a distance of 10 × DN by means of LDA measurements. Following his findings, the asymmetric swirl generator was put forward to be included in the 2020 revision of EN 1434 [41], replacing the utilization of the referenced swirl generator from the water meter standards.

A first large-scale research with the new disturbance generator was conducted by Turiso et al. [37], who compared the flow conditions of the asymmetric swirl generator and a double bend in DN 15 at distances between 12 and 105 × DN using LDA. As a result, the realistic reproduction of the double bend could be verified in the far-field range.

Subsequently, Straka et al. [36] researched the flow development in the near-field range at a smallest possible distance of around 2 × DN to specify implementation provisions for the revision of the flow test in the EN 1434. Due to the insufficient degree of asymmetry in the near field, an optimized geometry for the asymmetric swirl generator with a segment height of 16.5 % × DN was introduced. A maximum degree of resemblance with the near-field flow conditions of the double bend was found 7 × DN downstream of the optimized disturbance generator (see Figure 6-12), at which the real disturbance is reproduced at a distance of approximately 5 × DN. In addition, a total of four relative angular orientations between the disturbance generator and the meter under test were determined to account for the angular dependency of commonly used flow meters. Consequently, the expected value of the detected measurement error could be increased to approximately 90 % of the maximum possible error.

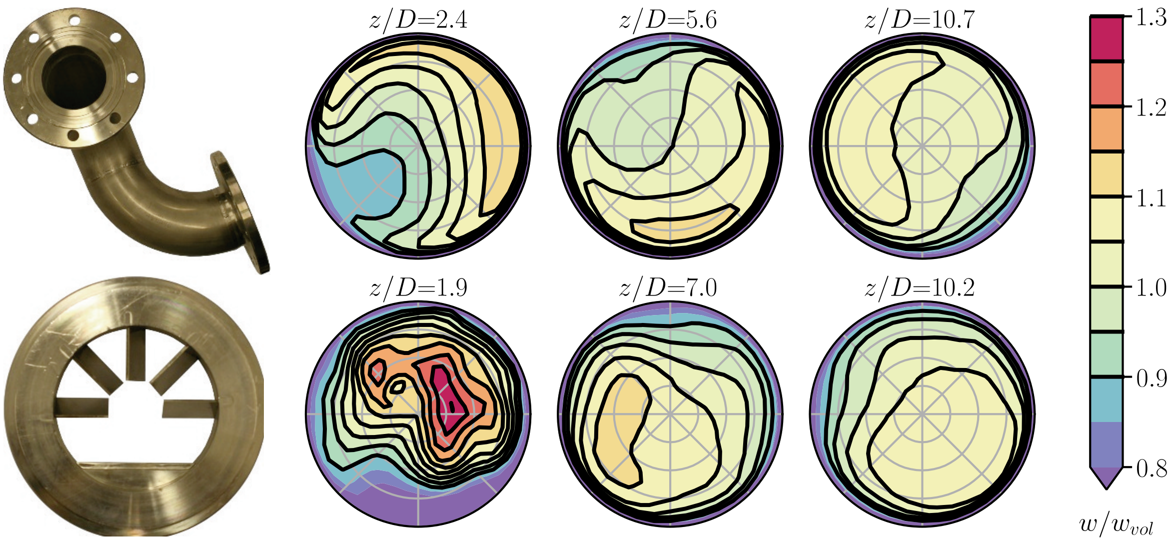


Figure 6-12: Flow profiles downstream of a double bend out-of-plane (top) and the asymmetric swirl generator (bottom), measured with a laser Doppler anemometer. Shown is the axial flow component *w*, normalized by the volumetric velocity w_{vol}, at different measuring positions. The axial distance *z* is given as a multiple of the pipe diameter *D*.

6.2.4 Outline

The new asymmetric swirl generator as proposed for the 2020 revision of EN 1434 [41] constitutes a significant improvement in comparison to the current flow disturbance test of 2015. However, the research by Straka et al. [36] suggest that the asymmetric swirl generator as a single disturbance generator may not be capable of representing the entire spectrum of relevant inflow conditions in terms of reproducing a meter error of similar scale. This applies in particular when the near-field range (≤ 5 × DN) of potential flow obstacles is considered to be covered by the standardized test. Apart from double bends, the most relevant and severe flow disturbances in piping systems are caused by 90°-bends, diameter jumps resulting from the variety of standardized pipe geometries and different types of valves.

An accessible type approval for an inlet length of 0 × DN is a requested condition for the flow disturbance test in EN 1434. As compliance with the maximum permissible errors at 0 × DN may not be guaranteed for all relevant disturbances within the current scope of testing, a further extension of the testing procedure in the next revision of 2025 is currently under research. Tests with real disturbances, or the addition of a disturbance generator that can preferably emulate the 90° bends in the near field, remain potential alternatives for a justified approval with 0 × DN.

6.3 Smart metering by Dr. Jürgen Rose

Dr. Jürgen Rose is the head of the PTB's Working Group 7.51 "Thermal Energy Measurement", which deals mainly with conformity assessment and testing of thermal energy meters and their sub-assemblies in the legally regulated area. He is a leading member of all relevant national and international committees in the field of thermal energy metrology (e.g. CEN TC 176 WG 2, OIML TC 11/p 1 and Welmec WG 11/WG 13).

6.3.1 Political background, efforts and benefits

To limit the negative consequences of climate change, the politicians announce that they aim to drastically reduce CO_2 emissions and move to a more economical use of fossil fuels. Measures taken in this regard include the creation of saving incentives to encourage responsible heat consumption. To achieve this, consumption has to be reported to consumers immediately via controlled networks [44].

Therefore, the thermal energy meters as primary measuring instruments which are currently in development will have to be able to transmit the accumulated heat quantities e.g. in separate energy registers to the collection centers of the billing services via remote read-out interfaces. The measurements in this process must be accurately timed and traceable to the individual end consumer. Thereby, it must be possible to take advantage of competitive prices in the case of changing from one district heating provider or billing company to another.

The new generation of adaptable intelligence measuring instruments shall allow ratings of results of measured process quantities such as e.g. the outlet temperature and temperature difference which will entice the consumer to save energy. Thus, it enables cost saving in order to exploit the energy potentials for optimal energy feeding processes of the district heating provider into the secondary consumer networks. The so-called “smart communicative meter generation” requesting a high performance and measuring stability over time shall fulfil the demanded goals that have been set by politics, while meeting the requirements with respect to logistics, development, approval processes and verification.

If the installation has been carried out correctly and the measuring instrument is used the proper way, state-of-the-art heat and cooling meters ensure that the legal requirements are fulfilled in order to ensure that billing is correct. Furthermore, saving incentives for consumers can be created to adopt a more responsible behavior regarding the use of fuels of all kinds that power thermal energy.

6.3.2 Example of intelligent smart metering

Currently, district heating suppliers face major challenges regarding the implementation of political requirements to increase the efficiency of district heating grids and to implement renewable energy. Therefore, grid operators are confronted with the need to reduce losses caused by transport and delivery [45]. On the one hand, the grid’s supply temperature must be reduced allowing renewable energies to be fed to the grid; on the other hand, the grid’s return temperature must be reduced to allow a maximum of temperature difference. Lowering the return temperature of the grid is only possible if the return temperature of the consumer’s house system is lowered. Therefore, the supplier needs an incentive pricing regulation applying a “bonus/malus” system depending on, for example, the fixed return temperature or the minimal temperature difference which is stipulated in the contract.

For this purpose, the heat meter requires additional calibrated registers to collect and transfer the accumulated energy to the billing system. This requirement is included in the standard EN 1434 with designs of specific loggers for a separated accumulation of thermal energy depending on adjustable return temperatures. Conformity assessments and technical regulations are included in the standard regarding verification with a required accuracy of 1 K when the measured return temperature is used for additional energy accumulations [46]. In the case of platinum resistance sensors according to EN 60751, at least class B with a 4-wire connection is recommended.

6.3.3 Recent international activities in standardization

Currently, EN 1434 is in revision and will officially be ratified at the end of 2021 [46]. In its Part 1: “General requirements”, Part 3: “Data exchange and interfaces”, Part 4: “Pattern approval tests”, Part 5: “Initial verification tests” and Part 6: “Installation, commissioning, operational monitoring and maintenance”, helpful instructions and hints are given for modern thermal energy meters for several aspects of smart metering as primary measuring instruments. The next step in international standardization will be the unification of the European standard with the OIML R 75 to avoid trade barriers.

Thus, the high physico-technical quality of modern thermal energy measuring instruments is in constant development thanks to the PTB's activities in the field of approvals, as well as concerted research and development work with partners in the European countries, and to contributions to international standardization in the field of thermal energy measurement.

6.4 Heat conveying liquids other than water by Humphrey Spoor and Dr. Sebastian Baack

Humphrey Spoor is a scientist working in the field of thermal energy meters for decades. While gaining expertise on measuring liquids other than water, working for Sontex and Belimo, he is also an expert for CEN's Technical Committee 176 Working Group 2, which deals with the development of EN 1434. Sebastian Baack belongs to the scientific staff of the PTB's working group 7.51 "Thermal Energy Measurement" and primarily works on thermal energy metering with glycol-water mixtures.

6.4.1 Motivation

Due to its favorable physical properties, water is the most efficient heat conveying medium known. However, the use of alternative liquids such as oil, water mixtures such as brines (salt solutions) or diluted glycols, becomes necessary when temperatures drop below the freezing point of pure water. This is for example encountered in cooling circuits or solar thermal systems. Besides, more and more water operated systems are doped with additives such as oxygen scavengers, antioxidants, anti-toxics and biocides, in order to prevent progressive rust or excessive magnetite- and / or scale clogging from forming. Adding even a small percentage of sulphite as an oxygen scavenger to a water system will significantly change the density and specific heat coefficient.

Water has the largest specific heat capacity c_p [kJ/kg/K] of all practical applicable liquids. The direct consequence of this is the reduction in the thermal energy conveying capacity and an increase in the kinematic viscosity, both leading to the need for increased pumping power in order to compensate.

Traditional antifreeze solutions are brines and water-glycol mixtures, the latter being based on propylene glycol (PG) and ethylene glycol (EG), also known as propane-1,2-diol or ethane-1,2-diol. However, as these liquids also have health and environmental hazards, there is a tendency to develop alternatives. Besides, their negative influence on flow viscosity and heat transfer properties will have direct consequences on the metrological behavior of thermal energy meters. This is evidenced in the behavior of both flow sensor and temperature sensor pair, as well as the calculation unit.

As mentioned in chapter 4, metering devices that are intended for billing purposes shall meet certain requirements. Therefore, thermal energy measurements with liquids other than water cannot be subjected to legal verification, and consequently cannot be allowed for custody transfer. So, thermal energy meters using these liquids cannot receive type approval. This leads to the situation that both provider and consumer have to negotiate by handshake, knowing that a *systematic* deviation of the thermal energy meter will be present for liquids other than pure water. Financial losses might best be shared equally between provider and consumer. As thermal energy generation and transport shifts towards renewable sources, the number of systems using liquids other than water such as solar plants, geothermal plants or heat pumps will steadily increase. Improved volume flow sensor technology can help to raise the efficiency of those systems and thus ensure fair billing for the consumer. However, much work is currently underway to move closer to legal standardization.

CEN TC 176, which is accountable for working on amendments to EN 1434, approached the topic of liquids other than water by officially listing it as a high priority work item. After years of active research, the knowledge obtained has been incorporated into the current draft of EN 1434 which is nearing final ratification. General basics will be discussed in the following chapters.

6.4.2 Basics

Glycol mixtures are typically made on a basis of mono ethylene glycol (MEG) or mono propylene glycol (MPG). But these mixtures are seldomly used as pharmaceutical or technical plain solutions because of their aggressive chemical and environmental behavior and toxicity. Commercial products contain cocktails of additives (blending) such as corrosion inhibitors, oxygen scavenger, biocides, anti-toxic and anti-fouling products in limited quantities. Even in small doses, these additives may change the physical quantities disproportionally to their concentration. Besides, if self-mixing concentrates are being used instead of ready-to-use products, the water quality used is a supplementary concern. Furthermore, ageing of one or more of its components will add another unknown instability factor.

For an adequate thermal energy transport calculation, thorough knowledge of the heat content and transport phenomena of the thermal energy conveying liquid must be present. Therefore, the density ρ [kg/m^3], the specific heat capacity c_p [kJ/kg/K], and the kinematic viscosity ν [m^2/s] should be available as a function of both temperature (ϑ) and volume fraction (α) for their ranges of interest. The exchanged thermal energy measurement (the so-called enthalpy difference ΔH [kJ]) strongly depends on these quantities. Exchanged can either mean thermal energy delivered (heating) or taken away (cooling). This enthalpy difference consists for about 97 % of thermal energy difference and for the other 3 % of compensation of hydrodynamical transportation energy losses within the section considered (comparable to the electrical case).

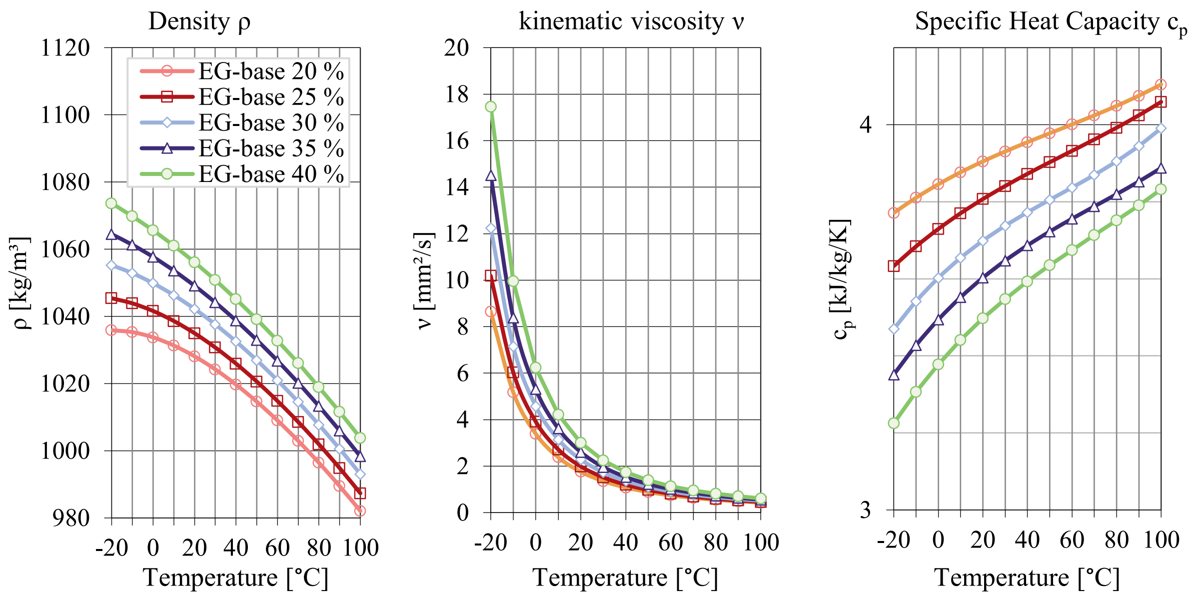


Figure 6-13: Density ρ, kinematic viscosity ν and specific heat capacity c_p of EG-based liquid depending on concentration and temperature [47]

These quantities and their dependencies are often presented as tables or in graphs. An example of each quantity is shown in Figure 6-13. These functionalities are non-linear and also show non-uniqueness for some classes of liquids in certain fields (i.e. several different (ϑ,α)-states can have the same value).

Problems may arise due to unexpected concentration variations of liquid mixtures when brought into use. Especially periodical refill makes regular concentration measurements indispensable (same product batch? same mixture? same ageing?). To get an idea of the impact of the uncertainty of the actual concentration, Table 6-2 shows examples of the variation in the values of the physical properties and subsequently on thermal energy metering. For a temperature of 20 °C and an erroneous concentration of 42 % in comparison to the intended 40 % propylene glycol, the viscosity rises by 7 %, the specific heat capacity decreases by ~ 1 %, while the density rises by 0.17 %. The rise in viscosity leads to an indirect but noticeable influence on the flow conditions, also resulting in a shift in the Reynolds number. The change in density and specific heat capacity lead to a change in the heat coefficient of ~ 0.9 %, which has a direct influence on thermal energy metering. That the density and specific heat partially compensate is just coincidence here, but that could also be different.

Table 6-2: Concentration variations and their impact on physical properties of PG-based liquid

ϑ = 20 °C	Water	MPG 25 %	MPG 30 %	MPG 35 %	MPG 40 %	MPG 42 %
kinematic viscosity [mm²/s]	~ 0.98	2.56	3.09	3.71	4.44	~ 4.76
spec. heat capacity [kJ/kg/K]	~ 4.18	3.96	3.91	3.83	3.72	~ 3.68
density [kg/m³]	~ 1000	1025.01	1030.41	1035.35	1039.88	~ 1041.70
heat coefficient [kWh/kg/K]	~ 1.162	1.129	1.118	1.101	1.074	~ 1.065

The manufacturers and blenders of thermal conveying liquids should guarantee and be liable for the correctness of supplied physical product data to the thermal energy meter companies for the indispensable traceability. Incomplete or invalid data have a direct influence on the billing. The obligatory material safety data sheets (MSDS) do not provide this physical information at all.

The following is required in order to ensure correct enthalpy calculation:

1) The exact manufacturer's name, brand, batch number, and blending type if applicable (traceability).

2) The density ρ (α_V, ϑ) in relation to the volume fraction α_V and temperature ϑ for the applicable range.

3) The specific heat coefficient c_p (α_V, ϑ) in relation to the volume fraction α_V and temperature ϑ for the applicable range.

4) The kinematic viscosity v (α_V, ϑ) in relation to the volume fraction α_V and temperature ϑ for the applicable range.

Note: For brines, usually the weight fraction α_W it taken, as salt solutions are dosed by weight instead of by volume.

6.4.3 Flow measurement

The way in which these mixtures react metrologically on the flow measurement (assume volume flow metering) may differ between measurement principles and geometrical constructions. An important aspect is due to viscosity changes. For liquid mixtures with larger or more complex molecule structures the rheological behavior might not be Newtonian anymore; but this is not considered here.

The kinematic viscosity for a particular mixture will logarithmically increase with decreasing temperature. With increasing viscosity (e.g. by decreasing temperature, or other reason), keeping other variables constant, a metrological curve will shift towards the higher flow region (the right-hand side), independent of the measurement principle. The left part of Figure 6-14 demonstrates this shift of a metrological curve. In this figure the blue curve belongs to a lower temperature than the red one. Consequently, a meter start-up will also be at higher flow values. If the shift becomes too severe, the lower part might become unstable or missing, jeopardizing accurate measurement.

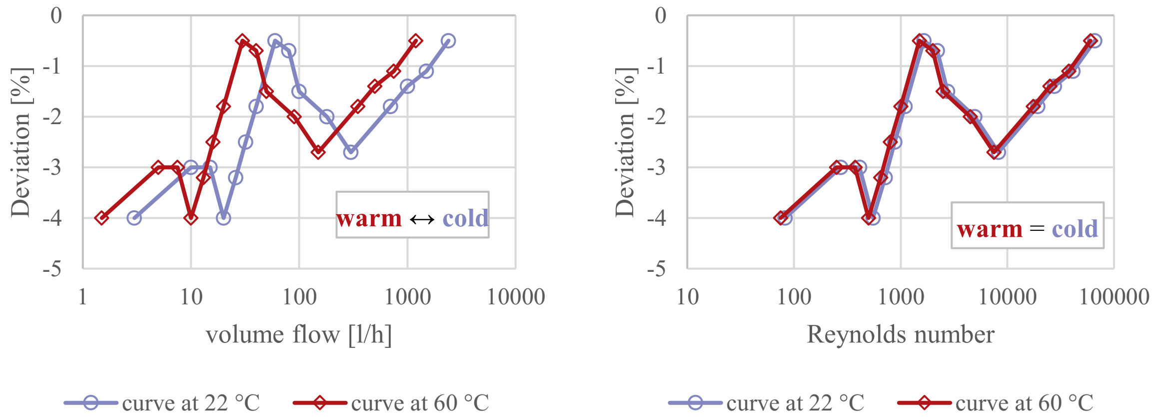


Figure 6-14: Metrological curve of flow sensor, depending on flow rate (left) and on the dimensionless Reynolds number (right)

Its origin can be found in the fact that metrological curves will fundamentally stay unchanged in a dimensionless presentation, using the Reynolds number as a dimensionless flow, instead of volume flow. In such a presentation, one curve serves all. Its consequence is shown in Figure 6-14 (right side), which serves as a typical signature for that specific meter principle and its geometry. Both figures represent real measured data.

This shift might not always be clearly visible, especially when internally some kind of digital data processing action has already been carried out, but fundamentally it is present. The shift changes with liquid composition (viscosity), so if by refill or replenishment in a system the concentration has changed this shift will also be different. Additionally, depending on the principle, the curve could also be affected in the vertical sense (i.e. its metrological deviation).

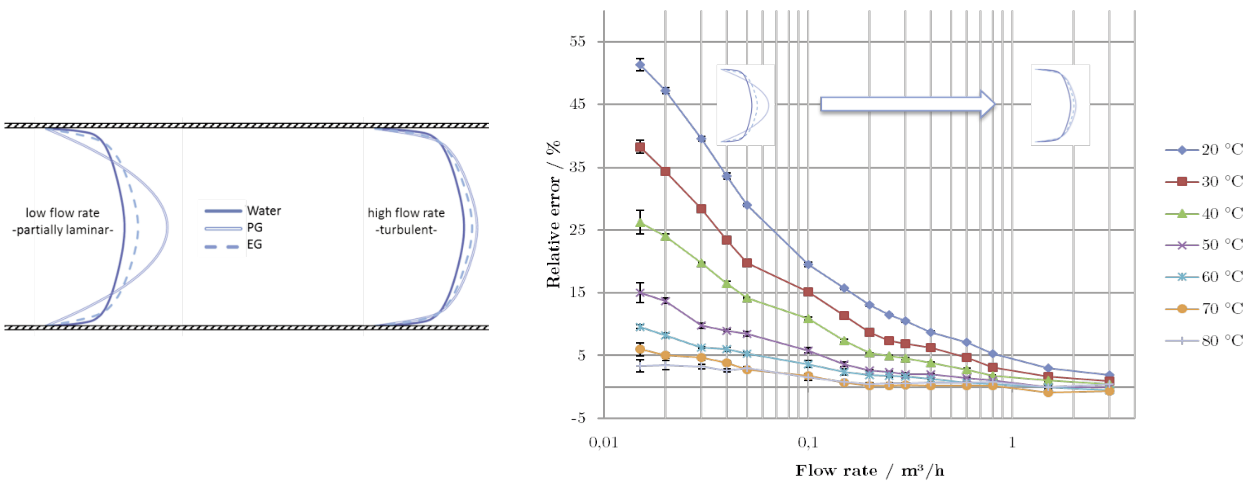


Figure 6-15: Flow profiles of different media (left) and their influence on a certain flow measurement (right)

Theoretical fully established flow profiles (so-called full-developed flow) and their relation to real flow measurement have their influence. At lower flows, there are situations where flow profiles of water and an ethylene-based glycol (EG) are turbulent, while the flow profile of a propylene-based glycol (PG) is still in its laminar flow regime (see left part of Figure 6-15). For this case the flow velocity, measured by a sensor, can be highly overestimated, depending on its measurement principle. Even at higher flows the differences between the liquid viscosities can cause a slight overestimation of the flow velocity (see right part of Figure 6-15). For commercial ultrasonic flow sensors with similar geometry this overestimation can be observed. At lower flows the volume flow values are overestimated, depending on liquid temperature, due to viscosity - and flow profile dependency. At higher flows, the problem becomes less pronounced. Note that relative errors at 80 °C are below 4 % (the viscosity of this medium approaches the viscosity of water at 20 °C).

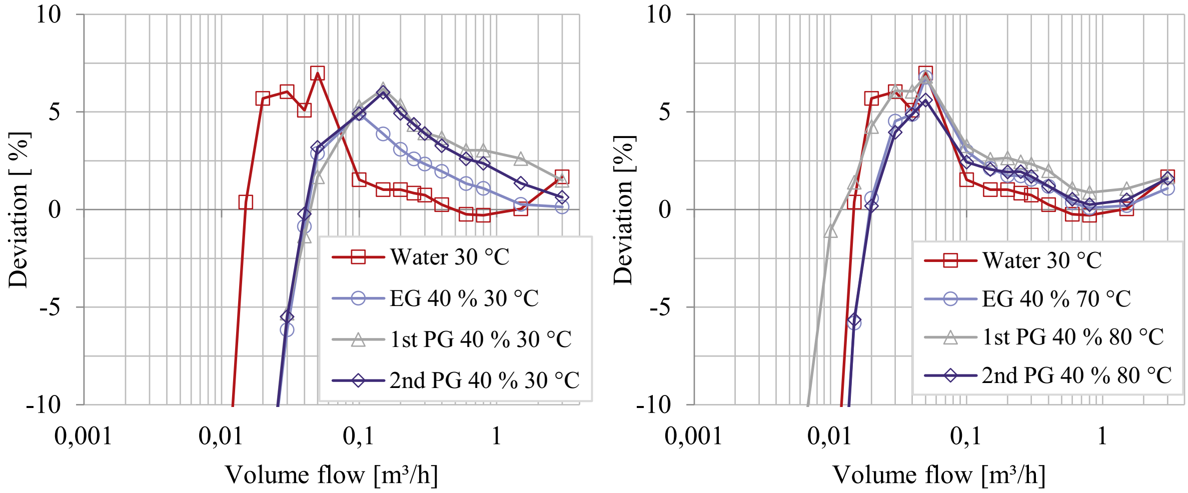


Figure 6-16: Flow measurement results of impeller flow meter with different liquids at the same temperature (left) and with different temperatures leading to similar viscosities (right)

In recent years various volume sensors have been measured at PTB-Berlin with several different liquids. In Figure 6-16, impeller flow meter results are presented to give an example. For the same sensor at the same temperature, the error curves for various glycols are shifted to higher flows with respect to the water curve. However, if on the contrary the viscosities of the various media are kept constant by means of varying the temperatures, all liquids have almost similar placed error curves, in accordance with the theoretical reflection above.

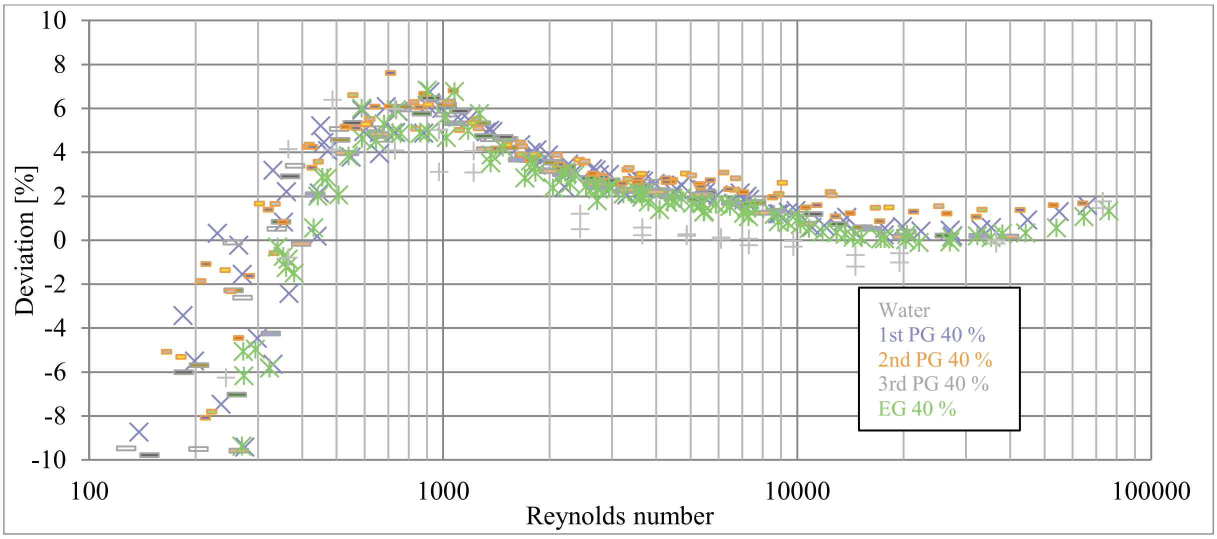


Figure 6-17: Deviations of impeller flowmeter with water and different glycol-based liquids depending on the Reynolds number Re

This behavior can be underlined by looking at the flowmeter's deviations in dependence of the Reynolds number *Re* as shown in Figure 6-17. Generally, the deviations with several glycol-based liquids and water lie in a narrow band. The Reynolds number on the horizontal axis works as a dimensionless flow, and according to the theory, all the curves become one. This opens the way to predict this curve shift for other circumstances, which might be more difficult to measure.

As the viscosity normally increases for one of the glycol mixtures mentioned above in comparison to water of the same temperature, the Reynolds number will decrease, i.e. towards the laminar region. The fully developed flow condition, necessary to define uniquely the flow regimes, will hardly be affected. Consequently, the minimum upstream length will hardly be affected, and if it is, then slightly shortened.

Note: As various distinct geometric ultrasonic layouts are possible, as well as several time difference measurement methods, no suitable generalized harmonization can be given for this liquid composition dependency among each other. For instance, some arrangements use the sound velocity and other do not, and others again only use it for secondary influences. A general conclusion on the capabilities of the ultrasonic flow measurement principle can therefore not be given.

Note: As it is easy to get to the untreated data for turbine or impeller meters, these meters clearly show this Reynolds concept mentioned above. Measurements from the PTB have experimentally confirmed this theoretical effect. The only fluidic meter on the thermal energy market also follows this concept clearly, once its compensation is disabled.

Regarding the two notes above, a general conclusion in favor of one particular meter principle or manufacturer does not seem to be substantiated.

6.4.4 Temperature difference measurement

Two effects take place: one is the flow profile change around the sensor due to the viscosity changes and the other is the change in thermal conductivity of the liquid. As the thermal conductivity does not increase as much as the specific heat capacity of the liquid decreases with temperature, the net effect will probably be a slight decrease in reaction time of the temperature measurement. Its general validity however must still be proven.

Since these influences on temperature measurements are likely to be similar for both upstream and downstream temperature sensors, the net effect on the temperature difference measurement might be small. Research into these effects on temperature measurements with glycol-water mixtures are still ongoing.

6.4.5 Calculator

Several influences have already been dealt with in the previous parts of this section. In order to take this dependency into account, it is indispensable for proper functionality to (i) either enable real-time measurement of at least the density and the specific heat or (ii) rely on traceable liquid data, while also performing control measurements (at least) annually regarding the liquid's composition. Anyway, future tendency is objected to include also measuring other physical quantities in addition to flow and temperatures. As visualized in Table 6-2 in chapter 6.4.2, the impact of concentration errors on heat metering is not negligible. Accordingly, emphasis must be put on the following aspects:

- The quality of the supplied data of the physical properties of the liquids must be guaranteed. The liquid manufacturer has a strong responsibility in supplying correct, accurate, and traceable data, based on real laboratory measurements. If traceability is not given, liquid data has to be determined based on traceable measurements prior to any measurement intended for billing.
- Proper traceability of the complete measurement chain is also indispensable. The thermal energy meter manufacturer depends completely on these data without any possibility to control this.
- The concentration of the respective liquid in use should be accurately known, or in other words: what is the tolerance in concentration in its original packaging and between different production batches?
- The periodic surveillance of the concentration in praxis has to be determined, as well as the possibility for adequate reprogramming of any changes appearing in composition in the field.

So, the responsibility and the risk must be spread between the liquid manufacturer, the thermal energy meter manufacturer, and the distribution network management. In other words, the part and the whole: i.e. the conveying liquid, the metering, the transport circuitry, together composing the entire system.

6.4.6 Outlook regarding thermal energy metering with liquids other than water

As shown, metering liquids other than water is possible on a reliable basis if the proposed measures are implemented. This includes traceable measurements of liquid data (density, viscosity and specific heat capacity), increased effort in characterizing the flow sensor with regard to the liquid's flow behavior and its influence on the specific measuring instrument, but also monitoring of the liquid in field use. EN 1434, which is currently in the process of being ratified, incorporated scientific findings to define special requirements with regard to liquids other than water concerning general requirements (Part 1) construction (Part 2), approval testing (Part 4), initial verification (Part 5) and monitoring (Part 6). Thus, billing thermal energy with liquids other than water could be allowed once EN 1434 is published.

Further developments could possibly improve the process of metering liquids other than water. Especially the thermal energy meter's additional capability to conclude the liquid type and concentration via online measurements of liquid data could be beneficial. On the one hand, the aforementioned inevitable monitoring of liquid concentration could run in real time. On the other hand, this capability could be the foundation for meter adaptations to a changing liquid, e.g. by adjusting enthalpy coefficients and flow sensor calibration factors.

7 Summary

Thermal energy metering in liquids is applied in various ways around the globe, depending on environmental conditions, technical development and political objectives. Using the example of the European standard EN 1434 and its ongoing enhancements, the aim to display state-of-the-art technical developments, while allowing reliable trading, is presented. Accordingly, if the installation has been carried out correctly (see [48]) and it is used the proper way, state-of-the-art thermal energy meters ensure that the legal requirements comply, allowing correct billing. Thereby, the EN 1434 internationally acts as the foundation of most normative documents regarding thermal energy metering.

One of the current problems of thermal energy metering is the fast response meter used in certain dynamic heating systems. Applying a simulation-based study was the basis for establishing the respective requirements and testing routines for these measuring devices in EN 1434. Another example is the development of a new disturbance generator, which allows an asymmetric flow profile to be induced inside a testing facility. It enables flow sensors to be tested under harsh conditions that are usually present in field. Smart metering is projected to raise awareness of individual consumption to minimize the environmental footstep.

Finally, the possibility of metering thermal energy with liquids other than water has been the subject of scientific studies and incorporated in standardization through special requirements. It allows new fields of heat energy conversion to be included in trade opening the market e.g. for renewable energy systems.

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2020 CEEMS AWARD

Key reforms in the Indonesian Legal Metrology System

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Abstract

This article introduces the Legal Metrology System in Indonesia, which received the OIML CEEMS Award in 2020. It also includes information on developments in the country, such as the roles of the central and local governments in strengthening and regulating the legal metrology infrastructure, the needs identified, future areas of focus, and current activities.

1 Introduction to Indonesia

1.1 Geography and society

Indonesia is located in Southeast Asia across the Equator and is surrounded by Australia, the Pacific Ocean and the Indian Ocean (see Figure 1). Indonesia is as wide as the distance between San Francisco and New York, or London and Moscow. It is the largest archipelago country in the world consisting of 18 000 islands that cover a land area of 1.9 million km^2 and territorial waters nearly four times the area of the land. Famous islands are Sumatra, Java, Bali, Kalimantan, Sulawesi, Maluku Islands and Papua. The islands are bordered by white sandy beaches, many of which are still uninhabited and some are not yet even named.

Indonesia has a series of active volcanoes, as it sits on the edge of three tectonic plates: Eurasia, Indo-Australia and the Pacific. It has experienced many disasters including landslides, earthquakes, eruptions, tsunamis and cyclones. Therefore, the term "meteorology" is much better known than "metrology"!

With a population of nearly 270 million in 2018, Indonesia is the most populous Muslim country and the fourth most populous country in the world.

1.2 History

The name "Indonesia" is relatively new, and was used for the first time during the Second Youth Congress in 1928. Long before that, Indonesia was known as "Nusantara", meaning "outer islands". Various kingdoms existed within this archipelago, although they were often colonized by foreign nations that sought abundant natural resources.

In 1509, the Portuguese succeeded in controlling the Malacca, Ternate and Madura areas. A trading company, the Dutch East India Company, was formed in the early 17th century to control spices. After the Company was dissolved, Herman William Daendels was appointed as the Governor-general of the East Indies. After being

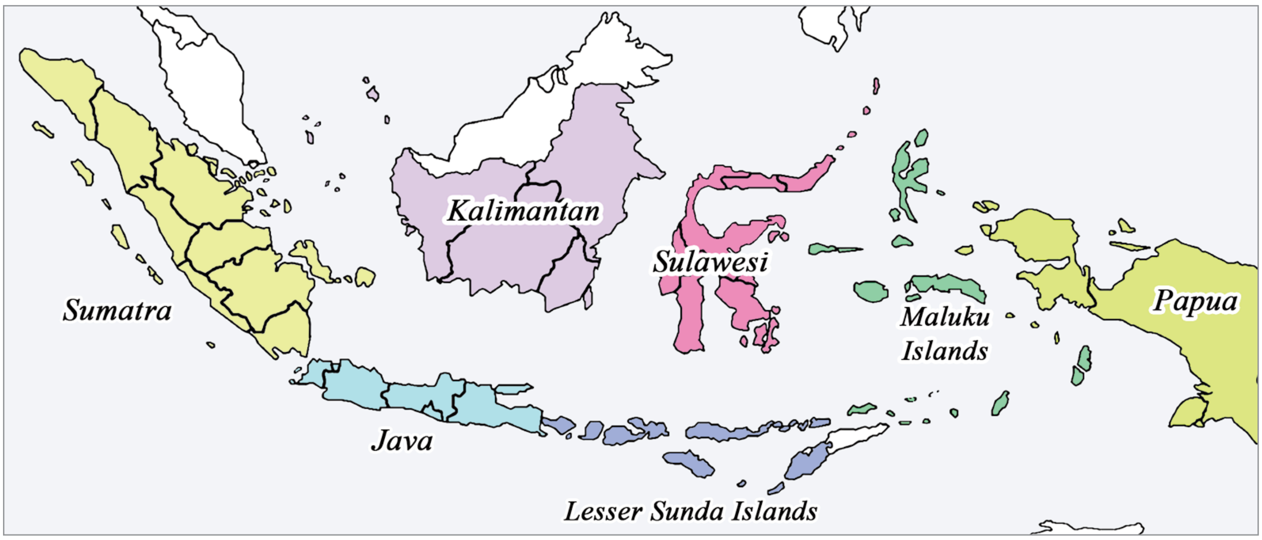

Figure 1: Map of Indonesia

governed by The Netherlands for 350 years and by Japan for three years, Indonesia proclaimed its independence on 17 August 1945, which was finally accepted in 1949. After gaining independence, Indonesia ratified and stipulated its new Constitution of 1945.

1.3 Economy

The World Bank and the International Monetary Fund (IMF) estimate that by 2024, Asian countries will be ranked in the top five world economic powers, and Indonesia is predicted to be one of them. The growing middle-class population is the primary reason for this growth in power. According to the World Economic Forum, the labor force in Indonesia is expected to increase sharply over the next few years. During the period 2015–2018, the Indonesian economy continued to grow at an average rate of 5.0 % per year. This rate is higher than the 4.5 % average rate for developing countries. This figure reached 10 % during the era of President Soeharto (1968–1998), when Indonesia was praised as being one of the Asian Tigers.

2 History of the legislation system and of the metrology institute

Although the term "metrology" might be less familiar, it plays an important role as the basis for scientific and technological development in the economy. Metrology originated in a small region of France in order to provide uniformity of "weights and measures" and later developed into the global system now used worldwide. Today, metrology contributes not only to the assurance of fair trade but also to the promotion of safety, security, health and preservation of the environment.

In the 1920s, Indonesia issued first generation colonial regulations on metrology as Ordinances 1923 and 1928. At that time, a variety of traditional measurement units were used, and they were finally withdrawn in 1928 with the transition to the SI units. The metrology institute during this period was the Verification Bureau (Diesnt Van Het Ijkwesen).

After Indonesia gained independence, the government system was implemented under the Constitution of 1945 and the regulation on metrology was revised into Ordinance 1949. The legal metrology institute was initially established as Jawatan Tera, then renamed to Jawatan Metrology and finally in 1962, the institute was renamed to the present name, the Directorate of Metrology (DoM) in the Ministry of Trade as the central governmental agency.

In the 1960s, local inspection offices were set up in the provinces, although there were some differences in their schemes including verification marks. In the late 1970s, special regions were formed in Jakarta, Aceh and Yogyakarta.

In 1981, Indonesia finally established its Metrology Law. Ordinance 1949 was replaced with a new Law on Legal Metrology No. 2, enacted in 1981. This law regulated:

a) measurement units and symbols;
b) measurement standards;
c) measuring instruments;
d) verification marks;
e) prepackaged goods;
f) prohibited actions;
g) criminal provisions;
h) supervision and investigation; and
i) transitional rules.

In 1999, a study showed that a centralized system was not able to increase welfare in the local provinces. Based on Law No. 22 (1999) on regional governments, which was superseded later by Laws No. 32 (2004) and No. 23 (2014), the affairs in legal metrology including all human resources and assets were transferred from central government to districts/cities.

3 The metrology system, including central and local governments

3.1 Structure of the government

The government system of Indonesia is Presidential, where the highest power is in the hands of the President, and he/she carries out duties assisted by Ministers. Institutionally, a ministry is a government agency at the central level that carries out tasks as a regulator and a facilitator.

Based on the Law No. 23 enacted in 2014, government affairs in legal metrology are divided into two layers, namely the central and city/district levels as follows:

a) Central Government (**Figure 2**) is the supervisor and controller of the national legal metrology policy as well as maintaining the traceability of measurement standards used by the provinces. The central government also organizes calibration of special measuring instruments including those used for geographical data across the country and for the energy sector; and

b) District/city Governments (**Figure 3**) carry out calibrations (recalibrations) / verifications (reverifications) of measuring instruments as well as metrological supervision in legal metrology. There is usually a Legal Metrology Office in each district/city.

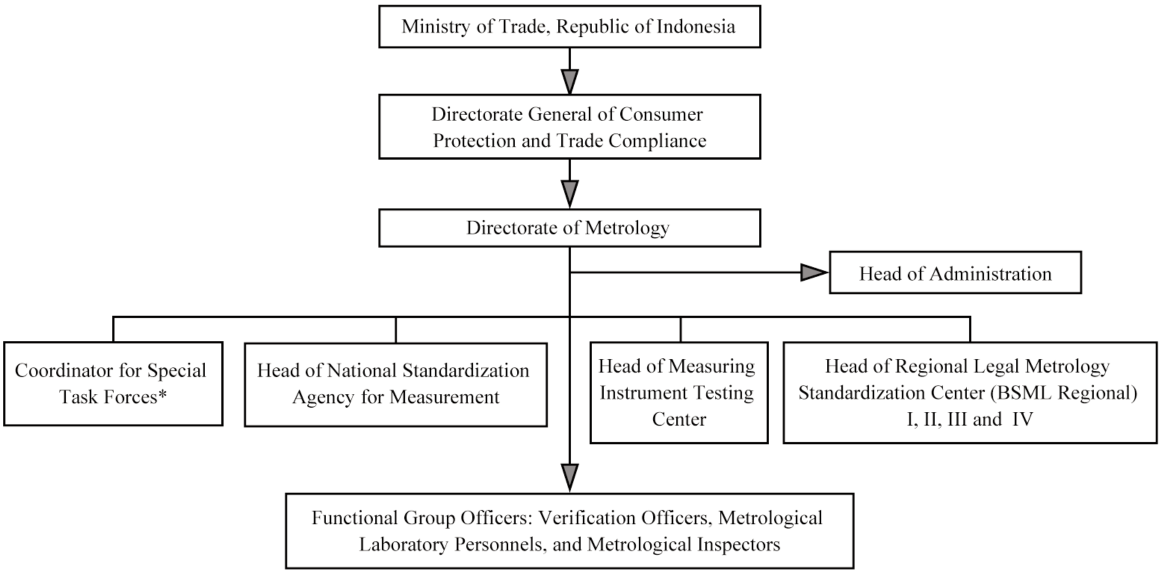

Figure 2: Structure of the central government in metrology

* The coordinator is responsible for metrological analysis, measurement tools, standard measures, human resources, law enforcement, operational guidance and assessment of metrology institutes.

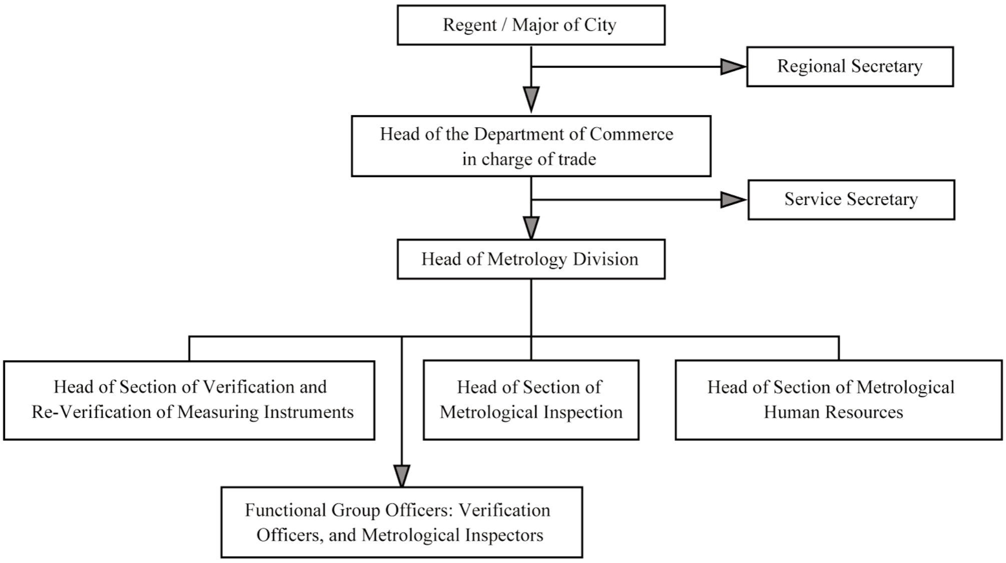

Figure 3: Main structure of the district/city government in metrology

3.2 Central Government

Based on Law No. 23, the Central Government is responsible for legal metrology and prepares and manages:

a) guidelines and directions for national metrology policies;
b) regulations related to legal metrology;
c) national legal metrology infrastructure for districts/cities;
d) human resources;
e) the establishment of local Legal Metrology Offices;
f) the implementation of governance through assessments; and
g) the traceability of the standards used for legal metrology.

The role of the central government is implemented by the DoM.

3.3 Maintenance of measuring instruments by Legal Metrology Offices

There are 516 districts/cities in the 34 provinces throughout Indonesia. The districts/cities may establish a Legal Metrology Office after receiving a recommendation and assessment from the Provincial Government.

With financial assistance, the total number of Legal Metrology Offices has increased. In 2011, there were only 51 offices. The total number reached 98 in 2017, and then increased rapidly to 350 in 2020 (covering 68 % of all districts/cities). This number will continue to increase because assessments of new offices are still in progress.

An important impact of the increasing number of Legal Metrology Offices is the increasing number of measuring instruments that comply with legal requirements. Based on a survey, the ratio of reverified measuring instruments to the total number to be covered (69 million units) increased from 38 % to 80 % in the period 2015–2019. It is expected that in time, all measuring instruments will meet the requirements and that orderly measurements will be carried out throughout all parts of the country.

3.4 Metrological supervision

Metrological supervision is an important scheme to ensure the proper implementation of measuring instruments and equipment. This supervision is carried out through two approaches:

a) preventive action in the form of socialization through raising awareness within the business sectors and consumers using measuring instruments; and
b) proper maintenance of the measuring instruments and equipment.

The DoM, together with the Legal Metrology Offices, carries out supervision with a preventive approach and the enforcement of the Law No. 2 in a balanced manner. If necessary, Government Courts punish violations of this law in the form of a fine.

3.5 Special fund

In order to provide legal metrology services and to conduct metrological supervision, an infrastructure is necessary, which includes offices, laboratory buildings, working standards and supporting equipment, as well as transportation to cover the region including cars, motorbikes and ships/boats. However, the budgets of city/district governments are limited. Therefore, in 2011 the central government established the Metrological Special Allocation Fund for the development of infrastructures within the districts/cities, and around USD 57 million was distributed up to 2019.

4 Identified needs

The DoM continues to encourage the creation of a Legal Metrology Office in each district/city, but it has identified that the following steps need to be addressed:

a) increasing each community's understanding of the existence of a legal metrology system and how it operates globally;
b) outlining the benefits of a Legal Metrology Office within a community;
c) developing optimum operational procedures for Legal Metrology Offices supported by the central government;
d) providing a metrology budget to support the districts/cities;
e) establishing a system to maintain appropriately trained human resources for the long term including maintaining their competence;
f) appointing suitable officials to each Legal Metrology Office; and
g) ensuring that all team leaders in the Legal Metrology Offices have fulfilled the national requirements for competence in management.

5 Future focuses

Given the above needs to establish an orderly metrology system within Indonesia, the DoM will focus on the following objectives:

a) provision of maximum support for establishing Legal Metrology Offices throughout the country;
b) development of a good governance scheme in metrology and ensuring it is maintained consistently for the long term; and
c) development of a new metrology information system based on Industry 4.0 (The Fourth Industrial Revolution: an ongoing transformation of traditional manufacturing and industrial practices combined with the latest smart information technology).

6 Current activities (see Figure 4)

Current activities to achieve the future goals include, but are not limited to, the items listed in 6.1–6.5 below.

6.1 Raising awareness

a) Enhancement of social awareness towards metrology through various occasions and media, including collaboration with the Ministry of Home Affairs, which is responsible for local governments, and other relevant ministries and/or agencies.

b) Facilitation of the understanding of the significance, duties and functions of metrology for stakeholders so that a comprehensive and holistic understanding grows within the nation. This activity intends that metrology affairs become an important priority in the regional development plan of the government.

Figure 4 (a): Socialization of legal metrology to the public

Figure 4 (b): A visit by the Deputy Minister of Trade to one of the DoM laboratories

Figure 4 (c): One of the local Legal Metrology Offices (BSML Regional I, Medan)

Figure 4 (d): Building, vehicles of the district/city Legal Metrology Office supported by the central government, and verification activities of measuring instruments

Figure 4: Current services in metrology in Indonesia

6.2 Management

a) Review of the structures and work procedures of the Legal Metrology Offices in districts/cities based on applicable regulations.

a) Implementation of the Regulation of the Minister of Home Affairs No. 90 enacted in 2019 so that the duties and functions of the Legal Metrology Offices are carried out optimally.

6.3 Human resources

a) Formulation of joint regulations between the Ministry of Trade and the Ministry of Home Affairs for maintaining human resources will prevent stagnation in the Legal Metrology Offices. This regulation supports a scheme where the level of competence is maintained regardless of changes in human resources.

b) Development of another scheme where a human resources transfer must obtain a recommendation or permission from the relevant ministry.

c) Reallocation of those competent officials who temporarily left legal metrology, to be returned to the Legal Metrology Office.

d) Assignment of a competent official as the director of a Legal Metrology Office.

e) Introduction of a scheme that allows an official who has not passed the competency test to undertake an internship at a Legal Metrology Office. When the official is declared to be competent, she/he is authorized as a verifier to carry out the necessary tasks.

f) Introduction of a scheme where an official participates in the training organized by the Metrological Resource Development Center of the Ministry of Trade. A certificate of completion is issued when the official successfully finishes and the DoM is also informed.

6.4 Certified Measurers

The DoM has developed various creative ways so that people in the community are involved in the movement to build a culture for orderly measurements. One of the activities is the creation of "Certified Measurers" who are members of the community including the employees or managers of business sectors and government agencies. The Measurers are trained to understand various types of measuring instruments in legal metrology and follow the requirements of the ministry for carrying out the necessary examinations and observations. People in the community are encouraged to be a Measurer because the creation of a Certified Measurer is evaluated positively by local government. Current activities by the Measurers are as follows:

a) provision of explanations to the users of measuring instruments about how to use them correctly;

b) provision of a survey on measuring instruments in the markets with a report to the Legal Metrology Office. If there is an inappropriate measuring instrument, the Measurers instruct the user not to use it;

c) using wisdom from within the local culture so that the significance of metrology is recognized. The community then understands that correct measurement is not an obligation but is an essential requirement for the community itself and that the metrology services should be based on local needs. The more the community understands metrology, the higher they will value the government's work;

d) using innovative ideas proposed by the community is necessary because a Legal Metrology Office has limited staff compared to the area and the number of measuring instruments in the region.

6.5 Technical services provided by the DoM

To establish an orderly metrology system in Indonesia, the DoM is responsible for technical services, including the testing of measuring instruments. Current technical activities are as follows:

a) The DoM is responsible for testing measuring instruments for issuing national type approval certificates.

b) The DoM is improving the testing capabilities with a view to becoming an OIML Issuing Authority for type approval in the framework of the OIML Certification System (OIML-CS). New or updated testing laboratories, including the facility for radiated EMC (Electromagnetic Compatibility) will be ready in 2021. The categories of measuring instrument planned to be covered are as follows:

   1) Non-automatic weighing instruments (NAWI) in compliance with OIML R 76:2006;
   2) Gas meters in compliance with OIML R 137:2012;
   3) Water meters in compliance with OIML R 49:2013;
   4) Liquid hydrocarbon flow meter in compliance with OIML R 117:2019.

c) The DoM accepts certificates issued under the OIML-CS. In 2021, the DoM will apply to be a Utilizer under the OIML-CS. In 2022, the DoM plans to apply to become an OIML Issuing Authority for NAWIs (R 76) and water meters (R 49), after discussion with the related parties in the DoM.

d) The DoM provides measurement standards at the higher levels used by the districts/cities for legal metrological purposes.

e) Some testing capabilities will be also utilized for initial and subsequent verifications conducted by the DoM.

7 Concluding remarks

Indonesia has a long history in developing legal metrology institutions and metrology systems. The way forward had to be managed according to the political situation and the government of the day.

There are many obstacles in finding the most appropriate scheme that can ensure an orderly metrology system in Indonesia.

Indonesia owes her success in building a legal metrology system not only to the Ministry of Trade represented by the DoM but also to many parties such as other ministries/agencies and district/city governments.

Support and involvement of the local communities in monitoring measuring instruments are expected to form an alternative scheme that supports the achievement of the orderly metrology system. Such involvement led Indonesia to obtain the OIML CEEMS Award in 2020.

The DoM must be responsible for changing the present system for governance flexibly to accommodate expected innovations in the future that may arise from Industry 4.0.

2020 recipient of the OIML CEEMS Award:
The Directorate of Metrology
under the Ministry of Trade
of the Republic of Indonesia

OIML-CS

Sixth OIML-CS Management Committee meeting

Paul Dixon, BIML

Introduction

Due to the ongoing situation with the COVID-19 pandemic, the Sixth OIML-CS Management Committee (MC) Meeting was held as an online meeting on 24–25 March 2021. This built on the experience gained when holding the successful online MC meetings in May, June and July 2020.

Review Committee and Maintenance Group meetings

Unlike in 2020 when only the MC met online, this year the MC meeting was preceded by online meetings of the Review Committee (RC) and Maintenance Group (MG) on 24 February and 3 March respectively. This replicated the approach normally taken when in-person meetings were held in 2018 and 2019, and enabled the RC and MG to discuss key issues and to develop proposals for consideration and decision at the MC meeting.

MC meeting

The MC meeting was chaired by the new MC Chairperson, Mr Mannie Panesar, and 20 of the 22 MC Members from OIML Member States were present or represented. This meant that a quorum of MC Members was achieved at the meeting, so the MC was able to take decisions in accordance with the voting rules in the OIML-CS documentation. In addition, there were representatives from the following liaison organisations: CECIP, CECOD, ILAC/IAF, and ISO CASCO.

Meeting over two consecutive days allowed for a full agenda, and some of the key items that were discussed and considered were as follows:

- feedback and experiences of participants in the OIML-CS, covering items such as acceptance of certificates, modular approvals, and experience of remote assessments;
- reports by the RC Chairperson and MG Chairperson, including proposals on the activities of the RC and approvals of OIML-CS documents;
- a proposal from the ISO/IEC 17065 Working Group to allow OIML Issuing Authorities (OIML IAs) to use ISO/IEC 17020 (with additional requirements) as an alternative to ISO/IEC 17065 to demonstrate competence;
- review of OIML IA Annual Reports for 2020 and confirmation of their continued participation;
- progress report on the update of OIML R 60:2017;
- high priority publications and periodic reviews; and
- update on the work of the OIML-IECEx JWG.

Recommendations to the 56th CIML Meeting

The MC agreed to the proposal to allow OIML IAs to use ISO/IEC 17020 (with additional requirements) as an alternative to ISO/IEC 17065 to demonstrate competence, so a recommendation will be made to the CIML for them to approve this approach. In addition, a recommendation will be made to the CIML for them to approve a project proposal to develop a new OIML Document to provide guidance and interpretations regarding the application of ISO/IEC 17020 in the field of legal metrology. It is also anticipated that the work on the update of R 60:2017 will be completed in time to allow CIML approval at the 56th CIML Meeting.

Looking forward

The meeting has again demonstrated that an online meeting can be a very useful tool in supporting the work of the MC to ensure that the OIML-CS continues to operate smoothly. It also provided an opportunity to test certain working methods and meeting protocols that can be used at the 56th CIML Meeting and 16th International Conference in October 2021.

It is hoped that an in-person MC meeting can be held in March 2022, but this will require a significant improvement in the global situation regarding OVID-19. The situation will be closely monitored and, if an in-person meeting is not feasible, an online meeting will again be used to ensure continuity in the work of the MC and the smooth running of the OIML-CS.

More use of online meetings will continue to be considered by the various committees and working groups established under the OIML-CS to reduce the need for face-to-face meetings and the associated travel, and to convene ad-hoc meetings to address issues that cannot wait until the formal annual meeting. ■

OIML Certification System (OIML-CS)

Introduction

The OIML-CS is a system for issuing, registering and using OIML Certificates and their associated OIML type evaluation reports for types of measuring instruments (including families of measuring instruments, modules, or families of modules), based on the requirements of OIML Recommendations.

The OIML-CS comprises two Schemes: Scheme A and Scheme B. Competence of the OIML Issuing Authorities and their Test Laboratories is demonstrated through self-declaration under Scheme B and accreditation or peer assessment under Scheme A.

The aim of the OIML-CS is to facilitate, accelerate and harmonize the work of national and regional bodies that are responsible for type evaluation and approval of measuring instruments subject to legal metrological control. In the same way, instrument manufacturers, who are required to obtain type approval in some countries in which they wish to sell their products, should benefit from the OIML-CS as it will provide evidence that their instrument type complies with the requirements of the relevant OIML Recommendation(s).

It is a voluntary system and OIML Member States and Corresponding Members are free to participate. Participating in the OIML-CS commits, in principle, the signatories to abide by the rules of the OIML-CS that are established in OIML B 18:2018 *Framework for the OIML Certification System (OIML-CS)*. Signatories voluntarily accept and utilize OIML type evaluation and test reports, when associated with an OIML Certificate issued by an OIML Issuing Authority, for type approval or recognition in their national or regional metrological controls.

The OIML-CS was launched on 1 January 2018 and has replaced the former OIML Basic Certificate System and the OIML Mutual Acceptance Arrangement (MAA).

Further information can be found at:

https://www.oiml.org/en/oiml-cs

For enquiries regarding the OIML-CS, please contact the OIML-CS Executive Secretary Paul Dixon (executive.secretary@oiml.org).

OIML certificates

OIML certificates issued under Scheme A and Scheme B can be downloaded from the database on the OIML website at https://www.oiml.org/en/oiml-cs/certificat_view.

The database also includes certificates issued under the former OIML Basic Certificate System and the MAA. Although these two systems are no longer in operation, the certificates remain valid.

OIML Issuing Authorities, Utilizers and Associates

A summary of the approved OIML Issuing Authorities is published on the next page, followed by a summary of those Utilizers and Associates that have declared that they will accept OIML certificates and/or OIML type evaluation reports as the basis for a national or regional approval.

Recent OIML-CS events

The Review Committee and Maintenance Group held online meetings on 24 February 2021 and 3 March 2021 respectively.

The OIML-CS Management Committee held an online meeting on 24–25 March 2021. A report on the MC meeting can be found in this edition of the Bulletin.

OIML Certification System (OIML-CS)

List of OIML Issuing Authorities and their scopes

The list of OIML Issuing Authorities is published in each issue of the OIML Bulletin and can be downloaded at www.oiml.org/oiml-cs/oiml-issuing-authorities

Updated: 2021-03-30

		R 21:2007	R 46:2012	R 49:2006	R 49:2013	R 50:2014	R 51:2006	R 60:2000	R 60:2017	R 61:2004	R 61:2017	R 75:2002	R 76:1992	R 76:2006	R 85:2008	R 99:2008	R 106:2011	R 107:2007	R 117:1995	R 117:2007	R 117:2019	R 126:1998	R 129:2000	R 134:2006	R 137:2012	R 139:2014	R 139:2018
AU1	National Measurement Institute Australia (NMIA)												■	■													
CH1	Federal Institute of Metrology (METAS)							■						■													
CN2	National Institute of Metrology, China (NIM)						■	■	■	■	■		■	■													
CZ1	Czech Metrology Institute (CMI)				■		■				■			■						■	■				■		
DE1	Physikalisch-Technische Bundesanstalt (PTB)				■		■	■	■	■		■		■													
DK2	FORCE Certification A/S				■	■	■	■	■	■	■			■			■	■					■	■	■		
FR2	Laboratoire National de Métrologie et d'Essais (LNE)			■	■		■	■	■					■													
GB1	NMO				■		■	■	■				■	■						■	■						
JP1	NMIJ/AIST							■	■				■	■													
NL1	NMi Certin B.V.	■	■	■	■	■	■	■	■	■	■		■	■	■			■	■	■	■		■	■	■	■	■
SE1	Research Institutes of Sweden (RISE)						■	■	■	■	■			■	■				■	■	■						
SK1	Slovak Legal Metrology (SLM)			■	■									■													

OIML Certification System (OIML-CS)

List of Utilizers, Associates and their scopes

The list of Utilizer and Associate scopes is published in each issue of the OIML Bulletin and can be downloaded at www.oiml.org/oiml-cs/utilizers-and-associates

Updated: 2021-04-19

1 = Scheme A only **5 = Scheme B only**
2 = Scheme A and MAA
3 = Scheme A and B
4 = Scheme A, B and MAA

		R 21:2007	R 35:2007	R 46:2012	R 49:2006	R 49:2013	R 50:2014	R 51:2006	R 58:1998	R 59:2016	R 60:2000	R 60:2017	R 61:2004	R 61:2017	R 75:2002	R 76:1992	R 76:2006	R 81:1998	R 85:2008	R 88:1998	R 93:1999	R 99:2008	R 102:1992	R 104:1993	R 106:2011
AU	National Measurement Institute, Australia (NMIA)				1	1					1					1	1								
BE	Federal Public Service Economy	3		3		3	3	3			1		3		3		1		3			3			3
CA	Measurement Canada										2	1			1		2								
CH	Federal Institute of Metrology (METAS)			1	2	2	1	1			2		1		1		2								1
CN	State Administration for Market Regulation (SAMR)							1			2	1	1	1		2	2								
CO	Superintendencia de Industria y Comercio (SIC)	3		3	4	4	3	3			2		3		3	2	2		3			3			3
CU	Oficina Nacional de Normalizacion (NC)	3	3	1		1	3	1	3	3	1	1	3	3	3		1	3	3	3	3	3	3	3	3
CZ	Czech Metrology Institute (CMI)					1		1						1			1								
DE	Physikalisch-Technische Bundesanstalt (PTB)	5		3	3	4	3	3			2		3		3		2					5			1
DK	FORCE Certification A/S				2	2	1	1			2	1	1	1			2								1
FR	Laboratoire National de Métrologie et d'Essais (LNE)	1		1	1	1	1	1			1		1		1	1	1		1			1			1
GB	NMO Certification	3			4	4	3	3			2		3			2	2		3						3
IN	Legal Metrology Division, Department of Consumer Affairs	3		3		4	3	3			2		3		3		2		3						1
IR	Institute of Standards and Industrial Research of Iran (ISIRI)				4	4					2	1				2	2								
JP	NMIJ/AIST										2	1				2	2								
KE	Weights and Measures Department		3	3	4	4		3			4	4	3	3		4	4		3						3
KH	National Metrology Centre (NMC)	3		3	3	3	3	3			1		3		3	1	1		3			3			3
KI	Ministry of Commerce, Industry and Cooperatives	5	5	5	1	1	5	1		5	1	1	5	5	5	1	1	5	5						5
KR	Korea Testing Certification (KTC)															2	2								
LV	LNMC Ltd. Metrology Bureau																								
NA	Namibian Standards Institution			3	4	4	3	3			2		3			2	2		3						3
NL	NMi Certin B.V.	3		3	3	4	3	3			2	1	3	3	3	1	2		3			3			3
NZ	Trading Standards (Ministry of Business, Innovation and Employment) (MBIE)				4	4	3	3			2					2	2		3						3
RU	VNIIMS																								
RW	Rwanda Standards Board	3	3	3	3	3		3	3	3	1	1	3	3		1	1					3	3	3	3
SA	SASO (Saudi Standards, Metrology and Quality Organization)			3		1						1					1								
SE	RISE Research Institutes of Sweden AB							3			2	1	3				2		3						
SK	Slovak Legal Metrology (SLM)				2	2											2								
TN	National Agency of Metrology (ANM)	3		3	2	2	3	3			2		3				2		3			3			3
UG	Uganda National Bureau of Standards (UNBS)			3	1	3					1	1				1	1								
US	National Conference on Weights and Measures (NCWM)										2														
ZA	NRCS: Legal Metrology				3	3		3			1					1	1		3						3
ZM	Zambia Metrology Agency	3		3	3	3	3	3			1		3		3	1	1		3			3			3

OIML Certification System (OIML-CS)

List of Utilizers, Associates and their scopes (Cont'd)

The list of Utilizer and Associate scopes is published in each issue of the OIML Bulletin and can be downloaded at www.oiml.org/oiml-cs/utilizers-and-associates

Updated: 2021-04-19

1 = Scheme A only
2 = Scheme A and MAA
3 = Scheme A and B
4 = Scheme A, B and MAA
5 = Scheme B only

		R 107:2007	R 110:1994	R 117:1995	R 117:2007	R 117:2019	R 122:1996	R 126:1998	R 128:2000	R 129:2000	R 129:2020	R 133:2002	R 134:2006	R 136:2004	R 137:2012	R 139:2014	R 139:2018	R 143:2009	R 144:2013	R 145:2015	R 146:2016	R 148:2020	R 149:2020	R 150:2020
AU	National Measurement Institute, Australia (NMIA)																							
BE	Federal Public Service Economy	3			3					3					3	3								
CA	Measurement Canada																							
CH	Federal Institute of Metrology (METAS)	1						1		1			1		1									
CN	State Administration for Market Regulation (SAMR)																							
CO	Superintendencia de Industria y Comercio (SIC)	3		3	3			3		3			3		3	3								
CU	Oficina Nacional de Normalizacion (NC)	3	3		3		3	3	3	3		3	3	3	3	3	3	3	3	3	3			
CZ	Czech Metrology Institute (CMI)				1	1									1									
DE	Physikalisch-Technische Bundesanstalt (PTB)	3			3	1				3			1	5	3									
DK	FORCE Certification A/S	1			1	1				1	1		3		1									
FR	Laboratoire National de Métrologie et d'Essais (LNE)	1			1			1		1			1		1	1								
GB	NMO Certification	3		3	3					3			3											
IN	Legal Metrology Division, Department of Consumer Affairs	3			3					3			1		3	3								
IR	Institute of Standards and Industrial Research of Iran (ISIRI)																							
JP	NMIJ/AIST																							
KE	Weights and Measures Department			3	3			3					3	3	3	3	3							
KH	National Metrology Centre (NMC)	3		3	3			3		3			3		3	3								
KI	Ministry of Commerce, Industry and Cooperatives		5	1	1							5	5		5	5	5							
KR	Korea Testing Certification (KTC)																							
LV	LNMC Ltd. Metrology Bureau							3					3											
NA	Namibian Standards Institution	3		3	3			3		3			3											
NL	NMi Certin B.V.	3		3	3	1		3		3			3		3	3	3							
NZ	Trading Standards (Ministry of Business, Innovation and Employment) (MBIE)	3		3	3					3			3											
RU	VNIIMS			3	3																			
RW	Rwanda Standards Board		3	3	3		3	3		3		3	3		3			3	3		3			
SA	SASO (Saudi Standards, Metrology and Quality Organization)				3																			
SE	RISE Research Institutes of Sweden AB			3	3																			
SK	Slovak Legal Metrology (SLM)																							
TN	National Agency of Metrology (ANM)	3		3	3			3		3			3		3	3								
UG	Uganda National Bureau of Standards			1	1	1							3		3									
US	National Conference on Weights and Measures (NCWM)																							
ZA	NRCS: Legal Metrology	3		3	3			3		3			3		3	3								
ZM	Zambia Metrology Agency	3		3	3			3		3			3		3	3								

Countries and Economies with Emerging Metrology Systems (CEEMS)

2021 OIML CEEMS AWARD

Background

Many countries and economies with emerging metrology systems suffer from a lack of resources for the operation of a sound legal metrology system. Although these resources cannot be provided by the OIML, the Organisation supports initiatives for the development of legal metrology. To highlight the importance of metrology activities in CEEMS, and to provide an incentive for their improvement, in 2009 the OIML established an Award for "*Excellent achievements in legal metrology in Developing Countries*".

Following the establishment of the Advisory Group on matters of Countries and Economies with Emerging Metrology Systems (CEEMS), and an increased focus on OIML activities in this area, it was decided to rename the Award the "OIML CEEMS Award" from 2018.

The OIML CEEMS Award is intended to raise the awareness of, and create a more favourable environment for legal metrology and to promote the work of the OIML. The Award intends: "*to acknowledge and honour new and outstanding activities achieved by individuals, national services or regional legal metrology organisations contributing significantly to legal metrology objectives on national or regional levels.*"

Selection criteria and procedure

The criteria which will be used to assess the candidates' contribution or achievement will include:

- its significance and importance;
- its novelty;
- its attractiveness and adaptability for other legal metrology services.

The BIML will prepare a list of candidates highlighting the importance of the achievements. The Award winner will be selected by the CIML President and announced at the 56th CIML Meeting in October 2021.

The Award

The Award will consist of:

- a Certificate of Appreciation signed by the CIML President;
- a token of appreciation, such as an invitation to make a presentation of the Award-winning achievement at the next CIML Meeting or OIML Conference at the OIML's expense;
- an engraved Award trophy.

How can candidates be proposed?

Nominations may be made by any individuals or organisations concerned with legal metrology, including the individual or organisation seeking the Award.

Nominations should be sent to Ian Dunmill at the BIML and must contain facts, documents and arguments explaining why the candidate deserves the Award. The closing date is 31 August 2021.

Past Awards

2020 - Agus Suparmanto, Minister of Trade of the Republic of Indonesia
- Veri Anggriono Sutiarto, S.E., M.Si., Director General of Consumer Protection and Trade Compliance, Ministry of Trade, Republic of Indonesia
- Dr. Rusmin Amin, S.Si, MT, Director of Metrology, Republic of Indonesia

2019 - No Award was made in 2019

2018 - Prof. Carlos Augusto de Azevedo, Ministerio Da Industria, Comercio Exterior e Serviços, Instituto Nacional De Metrologia, Qualidade E Tecnologia – INMETRO, Brazil

2017 - Superintendencia de Industria y Comercio, Colombia
- Dr. Osman Bin Zakaria, Senior Director, National Metrology Institute of Malaysia (NMIM)
- Dato' Roslan Bin Mahayudin, Director of Enforcement Division, Ministry of Domestic Trade, Co-operatives and Consumerism
- Haji Ibrahim Bin Hamzah, Chairman Executive, Metrology Corp. Malaysia Sdn. Bhd.

2016 - Institute of Trade Standards Administration, Kenya

2015 - Mr. Nam Hyuk Lim, Director of Korea Testing Certification
- The Metrology Department, Saint Lucia Bureau of Standards

2014 - Serbian National Metrology Institute (DMGM)

2013 - Weights and Measures Agency, Tanzania

2012 - Loukoumanou Osséni, Benin

2011 - José Antonio Dajes, Peru and Juan Carlos Castillo, Bolivia

2010 - Thai Legal Metrology Service

2009 - Mr. Osama Melhem, Jordan

For more details, please contact:

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Promotion of the OIML Bulletin: Become a Mentor

The OIML Bulletin is one, if not the only, international publication dedicated to legal metrology topics.

In accordance with CIML Resolutions 2019/30 and 2020/21, there is a clear desire for the Bulletin to be an attractive publication for legal metrology worldwide, and for it to be an excellent advertisement for our Organisation.

This can be achieved through long-term planning of the future editions and identification of key topics of high interest, for instance, legal control of measuring instruments in the fields of energy, health and the environment, where important aspects such as new technology, legal requirements, or test/verification procedures will be addressed.

In addition, support is sought from CIML Members and Corresponding Member Representatives who are ready to take on the responsibility of acting as "**Mentors**" for certain key topics / editions and technical articles. These are not necessarily expected to be written by the "**Mentors**" themselves, but by experts that a "**Mentor**" has identified and contacted.

In order to identify key topics of significant interest and "**Mentors**" to lead them, it was proposed by the CIML President that the BIML prepares, and makes publicly available on the OIML website, a plan for the upcoming eight to ten editions of the Bulletin.

The table on the following page is intended to be "dynamic", i.e. proposed key topics may be moved to other editions depending on available "**Mentors**" and authors for technical articles. The table can also be found at www.oiml.org/en/publications/bulletin/future-editions.

All CIML Members and Corresponding Member Representatives are encouraged to support the OIML Bulletin, to share their legal metrology experiences with the legal metrology community worldwide, and to take responsibility either as a "**Mentor**" for one of the next editions of the Bulletin, or by promoting it at TC/SC/Project Group meetings, RLMO meetings, CEEMS AG meetings, and other opportunities.

CIML Members and Corresponding Member Representatives who would like to be a "**Mentor**" for a specific edition / key topic, or who would like to suggest that a new key topic be added to the list, are asked to contact the BIML (chris.pulham@oiml.org).

Edition	General key topic	Mentor	Article submission #1	Article submission #2	Article submission #3	Other
July 2021	Digital transformation		May 2021 Workshop paper #1	May 2021 Workshop paper #2	May 2021 Workshop paper #3	Update on priority projects
October 2021	Health		Medical instruments / devices with metrological functions			
2022	(Metrology for protecting the) Environment					
	National / Regional Metrology Systems					
	Measurement related to traffic	PTB/ METAS	Speed meters (overview of current technologies)	Soot particle measurement	Smart metering, e-vehicle charging	
	Training of inspectors / verification officers		E-Learning material already available	Revised OIML D 14		
	Pre-packages / Statistical control	Some RLMOs?	Theoretical principles / basics	Various systems in different regions	Report on OTE 2022 in Bad Reichenhall (DE)	
	Intellectual property		Role of patents in legal metrology			

info

The OIML is pleased to welcome the following new

CIML Members

- **Bulgaria:**
  Mrs. Snezhana Spasova
- **Kazakhstan:**
  Mr. Arman Abenov
- **Kenya:**
  Mr. John Ngugi Mwaura
- **Israel:**
  Eng. Tomy Glantz
- **Pakistan:**
  Dr. Abdul Aleem Memon

Corresponding Members:

- **Gabon:**
  Readmission
- **Guyana:**
  New Corresponding Member

Committee Draft

Received by the BIML, 2021.02 – 2021.04

New Document: Traceability of electrolytic conductivity measurement results	1 CD	TC 17/SC 4/p1	RU	2021-02-16

OIML meetings

20-21 April 2021
TC 9/SC 2/p 11: Revision of R 134:2006

5 May 2021
Workshop: Digital Transformation in Legal Metrology

10-12 May 2021
TC 5/SC 2/p 4: Revision of D 31

28 September 2021
CEEMS AG meeting

30 September 2021
RLMO Round Table meeting

18-22 October 2021
16th International Conference on Legal Metrology and 56th CIML Meeting

www.worldmetrologyday.org
World Metrology Day Website

Bulletin online

Download the OIML Bulletin free of charge

www.oiml.org/en/publications/bulletin

Call for papers

OIML Members
RLMOs
Liaison Institutions
Manufacturers' Associations
Consumers' & Users' Groups, etc.

- Technical articles on legal metrology related subjects
- Features on metrology in your country
- Accounts of Seminars, Meetings, Conferences
- Announcements of forthcoming events, etc.

The **OIML Bulletin** is a forum for the publication of technical papers and diverse articles addressing metrological advances in trade, health, the environment and safety - fields in which the credibility of measurement remains a challenging priority. The Editors of the Bulletin encourage the submission of articles covering topics such as national, regional and international activities in legal metrology and related fields, evaluation procedures, accreditation and certification, and measuring techniques and instrumentation. Authors are requested to submit:

- a titled, typed manuscript in Word or WordPerfect either on disk or (preferably) by e-mail;
- the paper originals of any relevant photos, illustrations, diagrams, etc.;
- a photograph of the author(s) suitable for publication together with full contact details: name, position, institution, address, telephone, fax and e-mail.

Note: Electronic images should be minimum 150 dpi, preferably 300 dpi.

Technical articles selected for publication will be remunerated at the rate of 23 € per printed page, provided that they have not already been published in other journals. The Editors reserve the right to edit contributions for style, space and linguistic reasons and author approval is always obtained prior to publication. The Editors decline responsibility for any claims made in articles, which are the sole responsibility of the authors concerned. Please send submissions to:

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