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World Metrology Day 2016:
Measurements in a dynamic world

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Willem KOOL

*** 12 October 1953 † 12 February 2016**

May we always be guided by your
wisdom, insight, logic, dedication
and your joy in accomplishment

Farewell our "brother in arms"

It is with great sadness that we inform you of the untimely passing of our colleague Willem Kool at his home in the Netherlands on Friday 12 February 2016 after a short but intense battle against cancer.

Willem was highly regarded by everyone who had the opportunity to work with him. Since he joined the BIML in 2007 he has represented our Organization at numerous international meetings, liaised with officials at the highest level and ensured the voice of the OIML was heard around the world. He also played a central role in the preparation of documents for CIML meetings and Conferences and provided support to a large number of technical committees, subcommittees and project groups.

Willem will be deeply missed by all his colleagues at the Bureau who respected him for his high degree of professionalism, work ethic, logic and efficiency. It was always a pleasure to work with Willem.

We at the BIML extend our most heartfelt condolences to his wife Mona, his sons Stephan and Thomas, and his daughter-in-law Diana.

The funeral took place at 11am on Wednesday 17 February in Dordrecht, the Netherlands in the presence of his family, friends and colleagues.

C'est avec une grande tristesse que nous vous informons de la disparition prématurée de notre collègue Willem Kool, chez lui aux Pays-Bas, le vendredi 12 février après une courte mais intense lutte contre le cancer.

Willem a gagné la plus haute considération de tous ceux qui ont eu l'opportunité de travailler avec lui. Depuis qu'il a rejoint le BIML en 2007 il a représenté notre Organisation dans de nombreuses réunions internationales, et a développé des liaisons avec des officiers au plus haut niveau en s'assurant que la voix de l'OIML soit entendue à travers le globe. Il a aussi joué un rôle central dans la préparation des documents pour les réunions du CIML et pour les Conférences, et il a fourni un soutien à un grand nombre de comités, sous-comités et groupes de projets techniques.

Willem manquera énormément à tous ses collègues du Bureau, qui le respectaient pour son très haut niveau de professionnalisme, son étique de travail, son sens de la logique et son efficacité. Ce fut toujours un plaisir de travailler avec Willem.

Au BIML nous présentons nos condoléances les plus sincères à son épouse Mona, ses fils Stephan et Thomas, et sa belle-fille Diana.

Les funérailles ont eu lieu à 11h le mercredi 17 février à Dordrecht, Pays-Bas, en présence de sa famille, ses amis et ses collègues.

BIML

CONFORMANCE ASSESSMENT

Conformance assessment of electrical energy meters investigated by risk analysis – a case study

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Abstract

This paper presents a case study of more effective decision rules for the conformance assessment of electrical energy meters in private households in Norway, and proposes how to use a specific risk analysis in order to set the time for the next meter test. The MID regulation today prescribes conformance assessment of electrical energy meters based on ISO standards for attribute sampling where decision rules are purely statistical decision rules and economic consequences are not explicitly taken into account. The risk analysis we introduce calculates the risks involved for erroneous decisions, either rejecting a conforming batch of meters (the producer risk) or accepting a non-conforming batch (the consumer risk). The consumer risk is sensitive to the period until the next test which becomes a quality characteristic of each batch. This time interval can be optimized by balancing the consumer risk against the producer risk. When the quality drops, the period until the next test will need to become shorter. But at a certain level of quality, the energy net supplier would rather replace the complete batch, than continue testing at such short intervals.

1 Introduction

In 2011, the Norwegian Ministry of Industry issued a press release stating that there would be no further replacement of electrical energy meters in private households in Norway until the introduction of smart meters for electrical energy. At the time, the transition to the modern instruments was scheduled to be completed by 2015, but this deadline was later extended to 2019. The practical implication of the press release was to suspend the testing regime of electrical energy meters, with the consequence that testing laboratories in Norway shut down their activities for these instruments.

The press release cited economic arguments for the decision, pointing out that the estimated replacement cost of a non-conforming instrument was around NOK 2 000. Since all instruments would be replaced within a few years anyway, this decision appeared to save money for the utility companies, and by extension the consumers of electrical power which would have faced a higher utility price when the companies recovered their costs. However, the Ministry of Industry appeared to neglect the possible costs associated with leaving non-conforming instruments on the market to measure consumption. In fact, by postponing the shift to smart meters, the accumulated cost from erroneous measurements potentially increased significantly. Indeed, if one considers the maximum permissible error (*MPE*) of the meter (see Figure 1), and multiplies this figure by a typical consumption level, the annual costs of measurement errors may be as large as NOK 600: extending the time in operation from 4 to 8 years would incur an additional cost of NOK 2400. A non-conforming instrument could represent an even higher cost.

While this simple cost estimate should act as a warning that the consumer costs can be significant, it does not accurately reflect realistic values. Firstly, the interplay between the failure modes of electrical utility meters, short-time fluctuations in the actual consumption, and short-term fluctuations in the pricing means it is difficult to quantify a "typical" consumption level and a "typical" utility price. Secondly, the test regime was based on grouping individual units in batches involving anything from a few tens of instruments to several thousands, sampling a subset of each batch for verification testing, and replacing the entire batch if a prescribed number of sampled units fail the test. Since it is exceedingly unlikely that every unit in a batch measures with the same large error, the batch average measurement error will almost always be smaller than the *MPE* even for rejected batches.

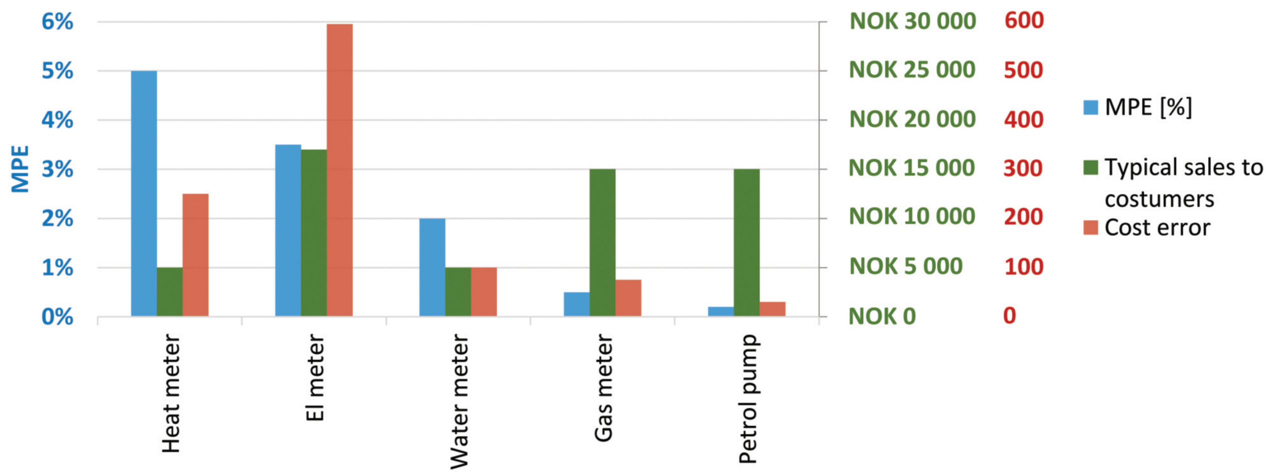

Figure 1: Blue bars: Maximum permissible error (*MPE*) defined in the MID for different types of meter.
Green bars: Estimate of typical annual consumption of a private household in NOK, green figures.
Red bars: "Maximum cost errors" for different types of utilities in NOK, red figures.

In this paper we present a much more detailed computation of the costs based on a large national database of test results. The database provides details about every sampled unit, such as its measurement errors at various loads, whether the unit failed the test, and whether the batch it belonged to failed the test. In addition we use detailed hourly data about the price of electrical power in Norway, typical hourly consumption profiles, and the actual distribution of household yearly consumption to compute a more realistic cost associated with erroneous measurements.

The consumer cost may then be directly compared with the producer cost (replacement of the entire batch). However, this direct comparison ignores the following issue: Since the verification was carried out using acceptance sampling, there is always a probability that the *actual* error rate (and therefore batch average measurement error) differs from the *observed* error rate. As a consequence the actual cost could have been higher or lower than observed. We propose here that a risk perspective is an attractive angle of attack on this issue. By multiplying the consumer cost with the probability that the actual error rate is greater than a tolerance, given the observed error rate, we obtain a *specific risk* value for the consumer, which may be compared with a corresponding producer risk.

The tolerance used in the probability calculation remains a free parameter. In fact, with acceptance sampling there are a number of parameters which need to be fixed, such as the sample size, acceptance and rejection thresholds, and the period between tests. Each of them affects the test performance, e.g. its cost, or the probabilities and consequences of wrong decisions. While typical acceptance sampling standards, often referred to in existing regulations, rely on probabilistic thresholds to fix these parameters, it is also possible to address the question within a risk analysis framework [1], [2], [3]. In our analysis we use the sample sizes given in the database, and acceptance and rejection thresholds from the Norwegian regulation and Welmec Guide 8.10 [4]. Interestingly, the two standards differ in the thresholds used, which also impacts the balance between specific risks.

The paper is structured as follows: The first part explains the test regime which electrical energy meters were subjected to in Norway, and shows how it compares with Welmec recommendations on an example dataset comprising almost 2 million instruments. The second part discusses how the cost of errors in metering electrical energy may be calculated, and shows how cost alone would affect accept/reject decisions of the dataset. The third part explains how to compute probabilities of non-conformity, and how the calculations may be combined to produce estimates of specific risks. The last part compares the different decision processes.

2 Statistical quality verification of electrical energy meters

The Norwegian regulation quite reasonably places the responsibility for quality assessment of electrical energy meters on the grid owners (producer side) rather than on the consumers. The typical consumer does not have the relevant knowledge or equipment to perform proper testing of their utility meter, and even if they did, they would have no incentive to report errors in their favour. The regulation prescribes statistical acceptance sampling of uniform batches, with tolerances directed both towards the performance of individual devices, and towards entire batches in terms of the proportion of non-conforming items in the batch. Batches are retested at predetermined intervals, which range from 3 to 10 years.

Sampling plans are chosen so that the Operational Characteristic (OC) curve for the test correctly passes beneath two critical points, the acceptance quality level (AQL) and the rejection quality level, also called the limiting quality level (LQL). AQL is a level of quality corresponding to a probability of acceptance of 95 %, with a non-conformity of less than 1 %: P_a (p < 1 %) = 95 %. LQL is a level of quality corresponding to a probability of acceptance of 5 %, with a non-conformity of less than 7 %: P_a (p < 7 %) = 5 %.

The MID Directive [6] is the basis for regulation of electrical energy meters in Norway. Normative documents EN 50470-1/-2/-3 [7] and OIML R 46-1/-2 [8] describe essential metrological requirements and tests. Taking into account measurement uncertainty [9] in each meter test result, each unit tested is declared to be inside or outside specifications (conforming or nonconforming) according to principles laid down in JCGM 106:2012 [10]. Accept or reject decisions, however, are made on the basis of statistical verification of homogeneous batches of meters rather than treating them as individual units, and statistical sampling uncertainties associated with limited sampling also needs to be accounted for. Requirements for statistical verification are described in Welmec 8.10 [4] and ISO 2859-1/-2 [11] using either a single sampling plan or a double sampling plan. When the number of non-conformances, M, is very small or very large, a double sampling plan is more efficient than a single sampling plan, because a conclusion is often clear already after the first part, effectively reducing the sample size, n. When the number of nonconforming units fall between critical values M_{Ac} and M_{Re}, the second part of the sampling plan is carried out. We will use index 1 or 2 for M, n and p to indicate the first or second part of a double sampling plan.

Table 1: Acceptance and rejection thresholds in the Norwegian regulation for verification of electrical energy meters. Indexes refer to the first and second part of the sampling plan.

Batch size	n_1	n_2	M_{Ac1}	M_{Re1}	M_{Ac2}	M_{Re2}
65 - 1200	32	64	0	2	1	2
1201 - 3200	50	100	1	4	4	5
3201 - 10000	80	160	2	5	6	7
10001 - 35000	125	250	5	9	12	13

Welmec Guide 8.10 [4] provides guidance to manufacturers of measuring instruments and to Notified Bodies responsible for conformity assessment of their products. The sampling plans chosen in the Norwegian regulation differ from examples given in the Guide as "best practice": The examples in Welmec Guide 8.10 are stricter than the sampling plans in the Norwegian regulation.

In order to illustrate the difference between the Welmec recommendation and the Norwegian regulation, we have analysed data in the national test result database. It contains values for more than 60 000 sampled electrical energy meters, representing roughly 2.2 million meters in Norway. We have limited our attention to batches of size $N \geq 200$, which comprise test results for 24 600 sampled mechanical type of electrical energy meters (divided into 502 batches, representing 910 933 devices), and 17 619 electronic type of electrical energy meters (sampled from 254 batches, representing 996 264 devices). The overall error rate ($\sum M_i / \sum n_i$) is 3.57 % for mechanical devices and 0.51 % for electronic devices.

For each batch we have extracted the number of tested units, the number of units in the batch, and the number of units which failed the test (i.e. exceeded the *MPE*). The numbers provide a best estimate of the failure rate in each batch. This estimate is then used to extrapolate the expected number of failing devices in a sample of a different size than that actually used: according to the Norwegian regulation on the one hand and the Welmec Guide on the other. The extrapolated number of failing devices is then compared with the prescribed threshold number for a rejection. Table 2 summarizes the results.

Table 2 illustrates how sensitive the test conclusions are with respect to the sampling scheme parameters. The Welmec recommendation results in many more rejections. The difference is particularly striking for electronic devices, where the number of rejected batches is significantly higher than the corresponding numbers using the sampling parameters from the Norwegian regulation.

Table 2: The number of failing batches, and the number of units they represent, for sampling parameters using Welmec Guide 8.10 and the Norwegian regulation. The average accumulated cost is the cost of the measurement errors for a batch if left to measure for 8 years, weighted by the size of the batches. See the cost section for more.

Observation	Welmec Guide	Norwegian regulation
Mechanical devices		
# batches accepted	360	383
# batches rejected	142	119
Failure rate, batches	28.3 %	23.7 %
# units in failing batches	48 483	36 791
# units per failing batch (average), *N*	341	309
Electronic devices		
# batches accepted	229	248
# batches rejected	25	6
Failure rate, batches	9.8 %	2.4 %
# units in failing batches	78 189	19 246
# units per failing batch (average), *N*	3 128	3 208

3 Cost of measurement errors

The cost errors of two different decisions

The cost of rejecting a batch and replacing the meters is the purchase of a new device, typically NOK 500, plus the cost of installation, typically NOK 1 500 (in 2011) multiplied by the number of items in the batch which are to be replaced. If this decision was an erroneous decision, this cost of replacement is the producer cost error, Δc_r.

If the decision is to accept the batch and continue to measure with these measurement errors, we calculate the accumulated consumer cost errors due to actual measurement errors for all units in the batch. The annual cost error for a utility meter is dependent on the measurement errors, as well as typical electrical power profiles of a household (frequency of use), and the actual price profile through the year, 8760 hours in one year (spot price and grid fee). The annual cost for instrument number i in the batch is calculated from equation 1:

$$c_i = c_i(W_i, P_i, e_i) = \sum_{q=1}^{8760} P_{iq}\left[W_{iq}\left(1 + \frac{e_{iq}}{100}\right)\right] \quad (1)$$

where:

W_q = the actual electric power during hour number q
e_q = measurement error in % during hour number q
P_q = price of electrical energy during hour number q

The annual cost error for instrument number i is given by Δc_i:

$$\Delta c_i = c_i(W_i, P_i, e_i) - c_i(W_i, P_i, 0) \quad (2)$$

We have calculated the annual cost error for a random meter in a particular batch with a Monte Carlo simulation for a large number of randomly selected sets of data. These sets of data are:

1) actual measurement errors for a randomly selected measuring device contained in the sample;
2) actual frequency of use, one hour resolution, randomly drawn from a set of typical power profiles (this curve is scaled to match a randomly drawn annual energy consumption from the distribution of annual consumptions of electric energy); and
3) price of utility during one year, one hour resolution.

Repeating calculations of equation (2) for $2{\times}10^6$ randomly selected triplets of data sets (measurement errors, scaled power profiles and price profiles) results in a distribution of the annual cost errors for a random meter in the batch. From Hafslund Energy, we have received 38 qualified power profiles for the period August 2011 – July 2012, and also the distribution of annual electrical energy consumption from more than 500 000 private households in eastern Norway, including Oslo. The Oslo spot price of electrical energy for the same period is taken from http://www.nordpoolspot.com.

This calculation treats negative and positive measurement errors within the same utility meter fairly; the costs cancel out depending on the size of measurement error, frequency of use and price. A positively signed error is to the benefit of the producer, a negatively signed error is to the benefit of the consumer. Both signs are equally important for *MPE* in the regulation, so this is also the case for cost errors. Independently of sign, the average annual cost error due to measurement errors for a randomly selected meter in the batch is calculated by equation (3):

$$\Delta c_m = \frac{1}{n}\sum_{i=1}^{n} |\Delta c_i| \tag{3}$$

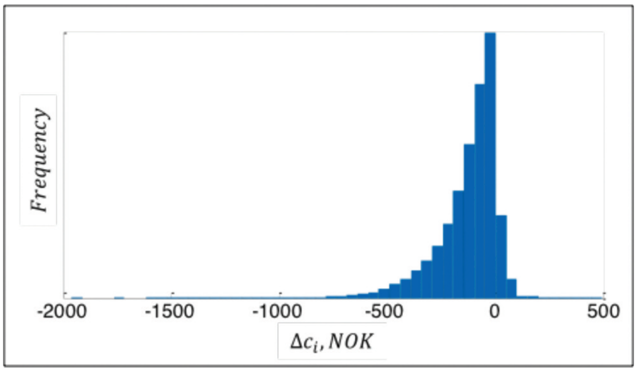

Figure 2: Results of a Monte Carlo simulation of cost errors, Δc_i, due to measurement errors in electric energy meters. A negative cost error is to the consumers benefit, positive cost error is to the producers benefit.

Figure 2 displays a typical result of a Monte Carlo simulation of annual cost errors for a random meter in a particular batch of meters. The distribution has a maximum close to zero, slightly on the negative side. It is also skewed to the negative side.

Taking only a cost perspective into consideration for the decision, a simple criterion for rejection of a batch is that the 8 year accumulated average excessive cost due to erroneous measurements is larger than the average cost of replacement, NOK 2 000 per item. Figure 3 and Table 3 summarize the results for mechanical and electronic electrical energy meters based on cost evaluation only.

We have so far considered the rejection ratio for essentially two separate methods: the traditional acceptance sampling method, which can be seen as a purely probabilistic approach, and a comparison between the cost of replacement on the producer side and the accumulated cost of measurement errors on the consumer side.

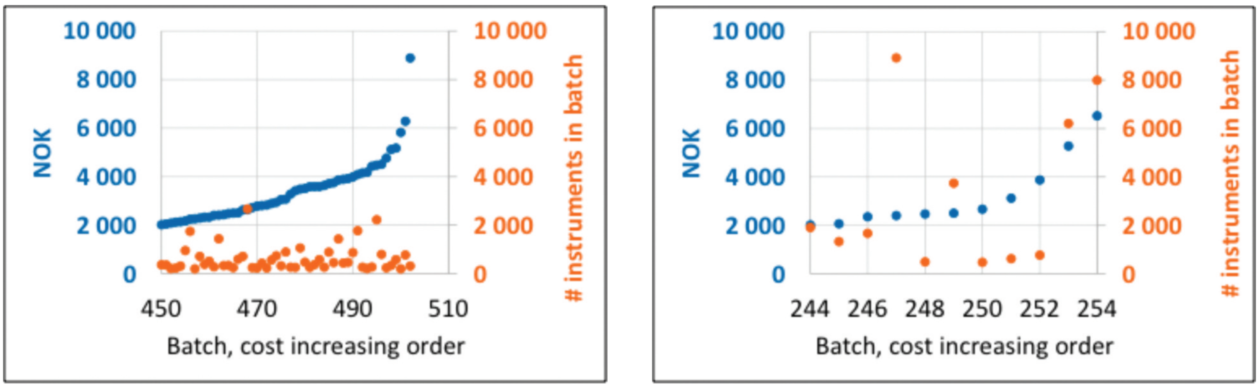

Figure 3: 8 year accumulated average cost for mechanical type (left) and electronic type (right) of electrical energy meter. 53 batches of mechanical meters and 11 batches of electronic meters have average cost error > NOK 2 000,-.

Table 3: Rejection of batches based on costs only.

'Cost only'	Mech.	Electr.
Number of batches with Cost, 8 years accumulated < NOK 2 000	449 batches	243 batches
Number of batches with Cost, 8 years accumulated > NOK 2 000	53 batches	11 batches
Fail rate, batches	10.6 %	4.3 %
Number of instruments in rejected batches	32 491	34 101
Average size of rejected batches, *N*	613	3 100

4 Specific risk analysis

The computed cost is an average whose value is based on the assumption that the observed measurement errors are representative of the actual performance of all units in the batch. We can relax this assumption by feeding the cost of measurement errors into a calculation of a specific consumer risk given the observations. A similar calculation of the specific producer risk allows a new rejection criterion based on a risk balance.

The specific risk of an erroneous decision from the producer point of view is the probability that a conforming batch is rejected multiplied by the error cost of replacing the entire batch with new electrical energy meters. The specific risk faced by the consumer is the probability that a non-conforming batch is accepted multiplied by the error cost of a continuation of erroneous measurements.

Computing the probabilities of conformance and non-conformance is non-trivial and explained below. We assume first that the probabilities are determined by the batch sampling, which appears to neglect the measurement uncertainty in the laboratory testing. However, because the measurement capability in the laboratories is high, at least greater than 10, we can safely ignore this contribution. The observed number of non-conforming units in a batch, M, and the sample size from the batch, n, provides an observed error rate $\hat{p} = M/n$. But the true error rate p could differ; in fact, given the observations the probability distribution of p is the normalized binomial distribution

$$f(p; n, M) = const \cdot p^M (1-p)^{n-M} = \frac{p^M (1-p)^{n-M}}{\int_0^1 u^M (1-u)^{n-M}\, du} \tag{4}$$

This expression is the beta-distribution with form factors α and β given by:

$$\alpha = M + 1 \tag{5}$$

$$\beta = n - M + 1 \tag{6}$$

A few examples of the shape of $f(p; n, M)$ are shown in Figure 5, in which two important features are highlighted. Firstly, the peak of the distribution is at $\hat{p}$ regardless of the sample size; secondly, for small $\hat{p}$ or small n the distribution is asymmetric with a long tail for high true rates p. The latter feature is particularly important in our case because small values of both $\hat{p}$ and n is a common scenario in assessing electrical energy meters.

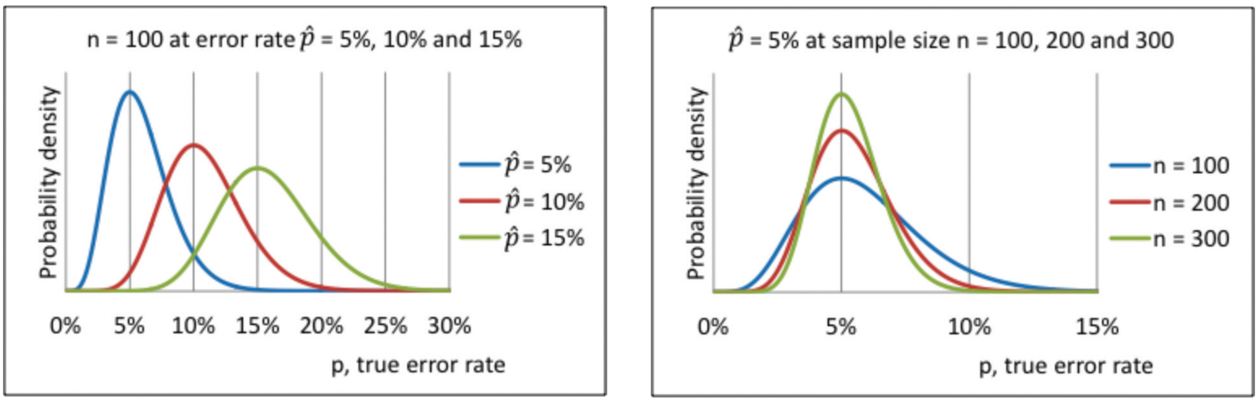

Figure 4: Left: Probability density distributions for the true error rate, p, at different observations of the error rate, $\hat{p}$ and sample sizes, n.

Finding the probability of conformance $P_C(\hat{p})$ and non-conformance $P_{NC}(\hat{p})$ is now straightforwardly achieved by integrating $f(p; n, M)$ between appropriate limits:

$$P_C(\hat{p}) = \int_0^{p_{Accept}} f(p;\hat{p})dp \quad (7)$$

$$P_{NC}(\hat{p}) = \int_{p_{Reject}}^{1} f(p;\hat{p})dp \quad (8)$$

The integration limits are in principle computed from the standardized values of rejection and acceptance thresholds as discussed in section 2. Figure 6 illustrates the integrals for a hypothetical case where the initial sample size is $n_1 = 50$ and the number of non-conforming units is $M_1 = 2$. The probabilities $P_C(\hat{p})$ and $P_{NC}(\hat{p})$ are shown as green and red areas, respectively, with the limits of integration taken from Table 4. The second part of the sampling plan is invoked in this case, with another two devices failing: the resulting integrals for $n_2 = 100$ and $M_2 = 4$ are also shown.

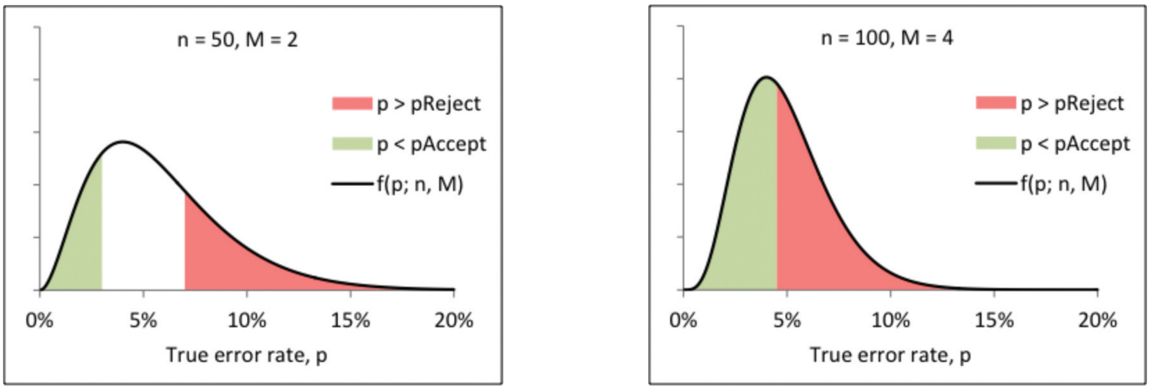

Figure 5: In this example $n_1 = 50$ and $M_1 = 2$, $\hat{p}_1 = M_1/n_1 = 4.0$ % in the first part of the sampling plan, and $n_2 = 100$ and $M_2 = 4$, $\hat{p}_2 = M_2/n_2 = 4.0$ % in the second part of the sampling plan. The probability of conformance, P_C, is indicated by the green area, and the probability for non-conformance, P_{NC}, is indicated by the red area.

The random sampling leads to a coarse resolution for the observed error rate of $1/n$. To adjust for the fact that the actual error rate can take on values also between adjacent values of observed error rates, we will use lower and upper watershed specification limits introduced by D.J. Wheeler [12]. The watershed specifications for p_{Ac} and p_{Re} are calculated from M_{AC} and M_{Re}:

$$p_{Ac} = (M_{AC} + 0.5)/n$$

$$p_{Re} = (M_{Re} + 0.5)/n$$

Transforming acceptance and rejection criteria for M in Table 1 into watershed specifications for p, rounded to two decimals, gives the following table for our sampling plans, see Table 2. There is no alternative to either accept or reject the batch after the second part of the sampling plan is finished, and this is seen in the table by the fact that $p_{Ac} = p_{Re}$ for the second part of the sampling plans.

We may now compute the probabilities $P_C(\hat{p})$ and $P_{NC}(\hat{p})$ for different values of observed M. Figure 6 shows an example for different values of the observed error rate, $\hat{p} = M/n$ for the same sample sizes as before ($n_1 = 50$ and $n_2 = 100$). As the observed error rate increases, the probability of conformance decreases while the probability of non-conformance increases. At some point the two curves intersect, providing a new, purely probabilistic batch rejection condition: $P_{NC}(\hat{p}) > P_C(\hat{p})$.

At the observed error rate $\hat{p}_1 = 2/50 = 4.0$ % and $\hat{p}_2 = 4/100 = 4.0$ %, the probability of non-conformance is higher than the probability of conformance. We would reject this batch at such observations of M. In contrast, the Norwegian regulation rejects the batch at $M_2 = 5$, ($\hat{p}_2 = 5$ %). In fact, we may perform a similar calculation for all batch sizes referred to in Table 4 and compare which method is more strict; the results are summarized in Table 5.

Table 4: Sampling plans in the Norwegian regulation with watershed specifications.

Batch size	n_1	n_2	M_{Ac1}	M_{Re1}	M_{Ac2}	M_{Re2}	p_{Ac1}	p_{Re1}	p_{Ac2}	p_{Re2}
65 - 1200	32	64	0	2	1	2	1.56 %	4.69 %	2.43 %	2.43 %
1201 - 3200	50	100	1	4	4	5	3.00 %	7.00 %	4.50 %	4.50 %
3201 - 10000	80	160	2	5	6	7	3.13 %	5.63 %	4.06 %	4.06 %
10001 - 35000	125	250	5	9	12	13	4.40 %	6.80 %	5.00 %	5.00 %

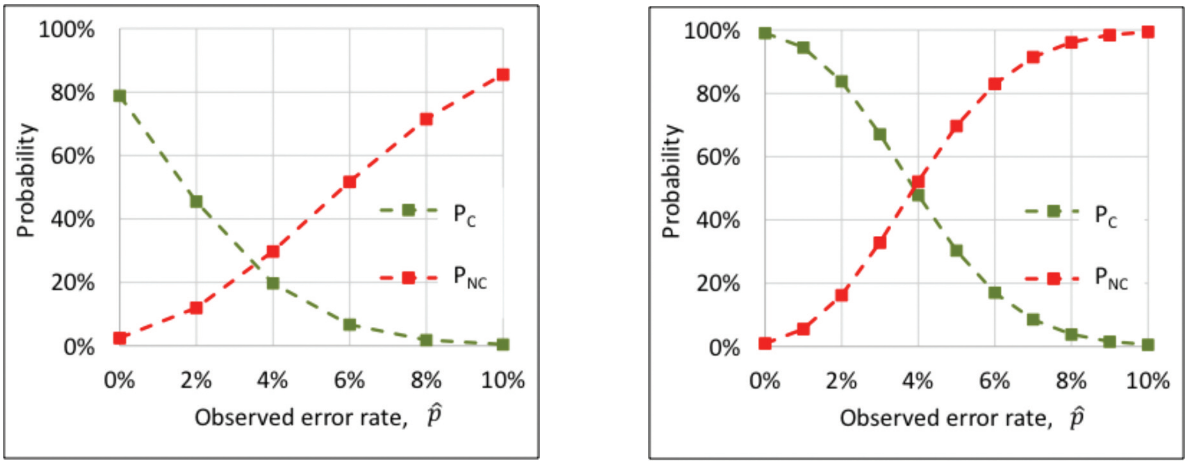

Figure 6: P_C (green curve) and P_{NC} (red curve) for different observations of the error rate, $\hat{p} = M/n$. Left: First part of the sampling plan, $n_1 = 50$. Right: Second part of the same sampling plan, $n_2 = 100$.

The Norwegian regulation allows more non-conforming units than a pure comparison of probabilities for conformance / non-conformance for all sampling plans, except for the second part of the smallest batch, where the Norwegian sampling plan is just slightly stricter than the probability perspective calculated from the observed error rate.

Table 6 summarizes the results for mechanical and electronic electrical energy meters based on probabilities only.

Table 5: Red colour: Norwegian regulation is stricter than the probability perspective.
Blue colour: Norwegian regulation is less strict than the probability perspective.
Green colour: Norwegian regulation is similar to the probability perspective.

Batch size	n_1	n_2	M_{Ac1}	M_{Re1}	M_{Ac2}	M_{Re2}
65 – 1 200	32	64	0	2	1	2
1 201 – 3 200	50	100	1	4	4	5
3 201 – 10 000	80	160	2	5	6	7
30 001 – 35 000	125	250	5	9	12	13

Table 6: Rejection of batches based on probabilities only.

'Pure probabilities'	Mech.	Electr.
Number of batches with $P_{NC} < P_C$ (accepted batches)	169 batches	131 batches
Number of batches with $P_{NC} > P_C$ (rejected batches)	333 batches	123 batches
Fail rate, batches	66.3 %	48.4 %
Number of instruments in rejected batches	352 506	206 256
Average size of rejected batches, N	1 059	1 677

Cost risk curves

The probability curves, as illustrated in Figure 6, can be used to compute corresponding risk curves. The probability of a conforming batch, given the observations, is multiplied with the cost of device replacement to give a producer side risk. Similarly the probability of a non-conforming batch is multiplied with the cost of measurement errors to give a consumer side risk. Figure 7 shows the risk curves for the same example as shown in Figure 6 assuming an annual consumer side cost of NOK 133 with 8 years continued operation (8 × NOK 133 = NOK 1 064). The observed error rate is a function of M, $\hat{p} = M/n$, and to emphasize that our cost risk curves are functions of the *observed* error rate, we display cost risk curves directly as functions of M, see Figure 7.

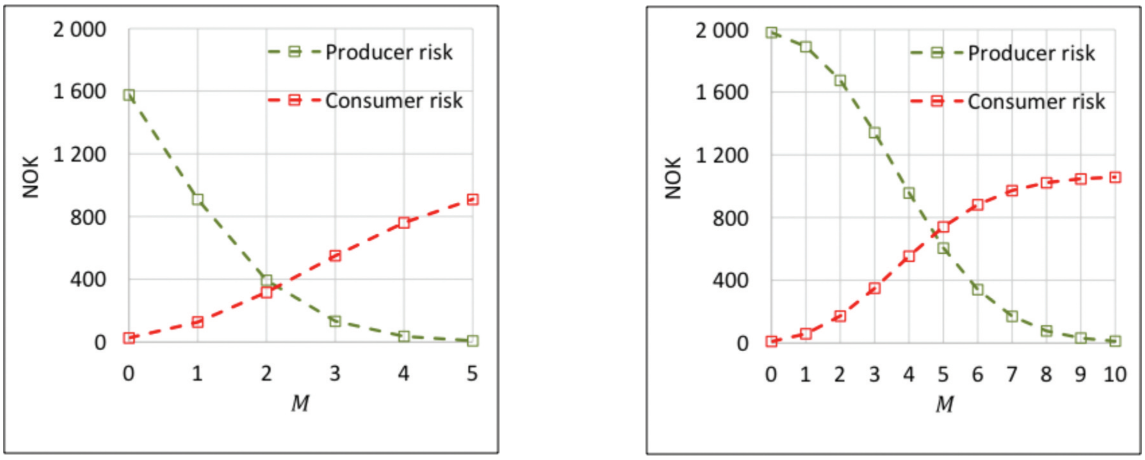

Figure 7: Average risk per instrument for producer (green curves) and consumer (red curves) for the first (n_1 = 50) and second (n_2 = 100) part of the sampling plan using watershed specifications. We have assumed average cost NOK 2 000 for replacing a meter, and average annual invoice error of NOK 133 and 8 years until next test.

We see that for our example of $n_1 = 50$ and $n_2 = 100$, the specific cost risk is higher for the producer than the consumer at $M_1 = 2$ ($\hat{p}_1 = 4$ %) and $M_2 = 4$ ($\hat{p}_2 = 4$ %). We avoid the higher risk if we decide to accept the batch at such observations of M: hence, adding in the cost modifies the test decision we would have taken from a purely probabilistic point of view.

Increasing the replacement cost shifts the producer risk curve upwards, reinforcing the decision to accept the batch. On the other hand, if the cost of measurement errors were higher (due to larger measurement errors, a higher utility price, or a longer time until the next test) the consumer risk might rise above the producer risk at $M_2 = 4$.
The probabilities P_C and P_{NC} are computed for each batch in the database using information on sample size n, number of rejections M, and which part of the sampling plan was used, 1 or 2. The consumer side cost is calculated for each batch individually based on the actual measurement errors registered for each sample, see Annex "The dataset, computation of costs". Table 7 summarizes the results for our data, which should be compared to the figures in Table 6. It is obvious that including the costs modifies the decisions significantly, and drastically decreases the number of rejected batches.

Table 7: Rejection of batches based on cost risk.

'Specific cost risk'	Mech.	Electr.
Number of batches with Cons cost risk < Prod cost risk (accepted)	326 batches	218 batches
Number of batches with Cons cost risk > Prod cost risk (rejected)	176 batches	36 batches
Fail rate, batches	35.1 %	14.2 %
Number of instruments in rejected batches	232 209	106 004
Average size of rejected batches, N	1 319	2 945

5 Discussion

The previous sections describe different ways to analyse the outcome of sampling. The standard recommendation in Welmec and the existing Norwegian regulation prescribe a certain statistical sample size and establish rejection rules by requiring tolerance thresholds for non-conforming units given certain %-confidence thresholds (expressed as the AQL and LQL levels described in section 2). The emphasis is placed on reducing the probability of an erroneous decision in favour of either side below certain limits. From the statistical sampling, one can use the prescribed sample sizes and the observed errors in sampled instruments to compute a cost associated with the measurement errors, as described in section 3. The emphasis is shifted to a purely economic analysis, completely disregarding the possibility that the sampled items do not accurately represent the batch. Finally, section 4 first describes a simple criterion based on the probability that the true error rate in the batch, given the observations, is smaller than or greater than a predefined value (in our case we use prescribed numbers from the Norwegian regulations). We then merge this probability perspective with the economic perspective by constructing a risk parameter as the product of the probability of an erroneous decision with the cost of the decision.

Figures 8 and 9 summarise the results in the preceding sections. The number of rejected batches (Figure 8) is strongly dependent on the analysis method, with a similar tendency for the number of units the batches represent (Figure 9). Regarding the two traditional sampling plans (left pane in both figures) the Welmec recommendations reject more batches (and units) than the Norwegian regulations. The difference arises from the fact that the Welmec recommendations require a very small error rate among units in operation (a 95 % or higher probability of accepting the batch if the actual error rate is below 1 %). The Norwegian regulations, on the other hand, emphasize a high probability of rejecting the batch above a certain error rate (5 % or lower probability of accepting the batch if the actual error rate is above 7 %).

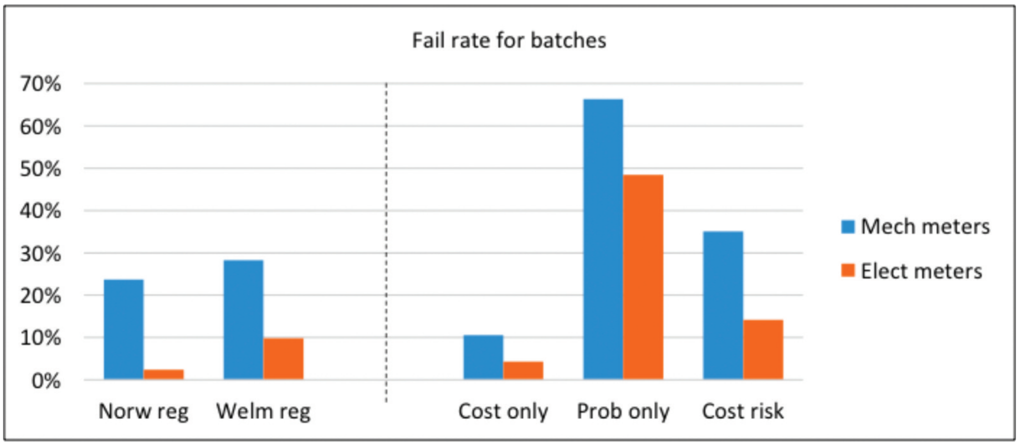

Figure 8: Proportion of batches failing the requirement according to different methods of analysis: Norwegian sampling plans, Welmec sampling plans, cost only, probability only and specific cost risk.

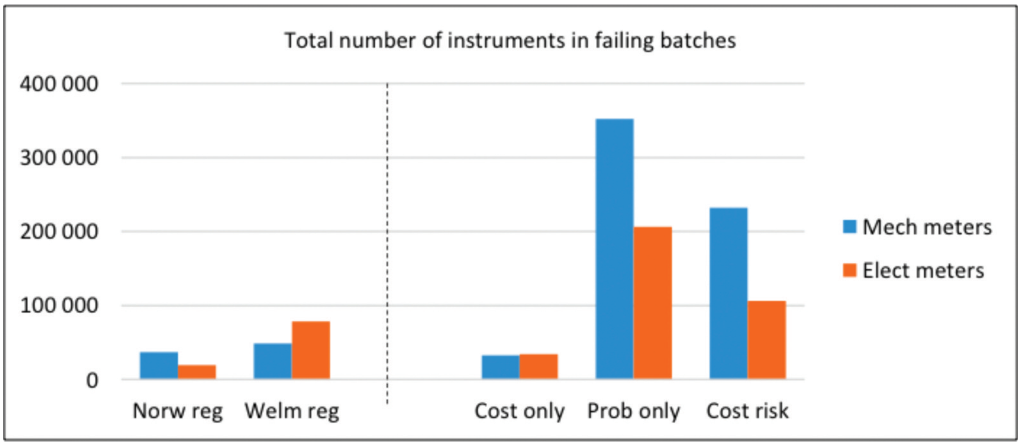

Figure 9: The total number of instruments in those batches which failed according to different methods of analysis: Norwegian sampling plans, Welmec sampling plans, cost only, probability only and specific cost risk.

It is conceivable that the cost calculation could have modified not only the number of failing batches, but also which batches were rejected. Figure 10 graphically represents the sets of rejected batches according to each method, where the overlap between methods is indicated by the common area of the geometric shapes, which represent each method. With a few exceptions a stricter method will just add more batches to the rejection list rather than select a completely different set. For example, using the risk balance method will reject more batches than the Welmec recommendation, but all the batches rejected by the latter are also rejected by the former. We can thus adequately characterize the methods according to the rejection ratio, which we will call *strictness*.

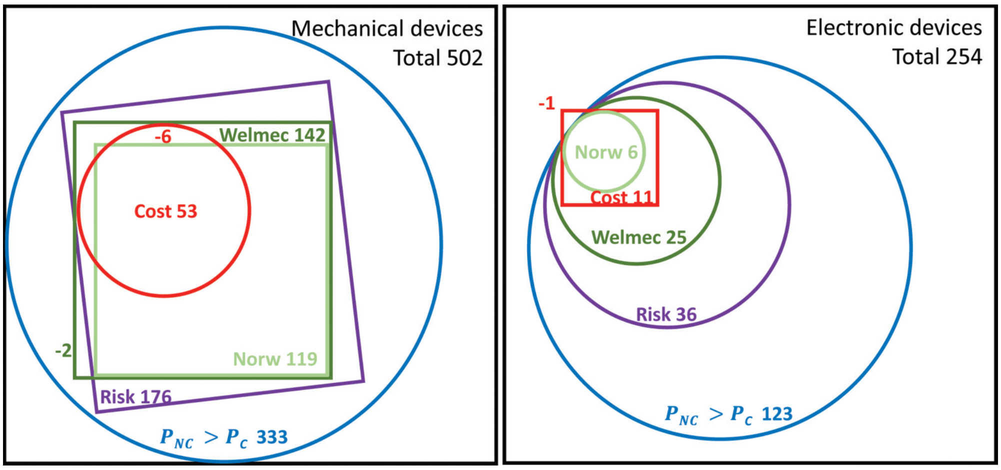

Figure 10: The number of rejected batches using different methods of analysis, mechanical devices on the left, and electronic devices on the right. Areas representing the number of rejected batches are drawn to proportional sizes. The overlap between different shapes indicates the set overlap between methods, so a smaller shape completely contained within a larger contains only batches common to both sets. Negative numbers indicate the number of failing batches *not* contained in the stricter method.
Light green: Norwegian regulation;
Green: Welmec sampling plans;
Red: Cost of 8 years continued use > NOK 2 000,-;
Blue: Probability, $P_{NC} > P_C$;
Purple: Risk analysis, consumer cost risk > producer cost risk;
Black: Total number of batches investigated.

The strictness clearly varies greatly between the rejection criteria, and yet the observations so far do not offer any guidance as to which method is most appropriate. In fact, there are a number of other parameters which could have been varied, such as the period between tests, the number of sampled units, the acceptance/rejection thresholds, and the error tolerance (*MPE*). Fixing these values requires a wider perspective, and the choices will place different emphasis on the grid owner or consumer protection. Traditional thinking tries to establish combinations of sample sizes and rejection limits from the probabilities of true error rate and desired confidence limits by phrasing the problem in terms of AQL and LQL levels (section 2). Pendrill ([1], [2], [3]) adopts a different approach by optimizing sample sizes with respect to a test cost and sampling uncertainty, thus bringing in yet another aspect of the verification assessment.

We would argue that once the measurement devices are put into operation, and the required sampling sizes for conformance assessment have been determined, the cost of replacement of units must impact the accept/reject decision. However, as shown by Figure 10 the two ways to include the cost (specific risk and pure cost) have very different strictness. In fact, it seems that the Norwegian regulation better matches a pure cost balance, while the Welmec recommendation better matches the method of risk balance. If one takes into account the probability that the true error rate differs from the observed error rate (essentially what the risk analysis does) we arrive at a practical rejection behaviour, which matches the Welmec recommendations best. However, with the sample sizes used, the authors of the Welmec Guide were forced to use values for M_{Ac} which imply a much smaller error rate than the AQL level of 1 %. This is appropriate in conformity assessment for type approval, but once the devices are in operation the additional cost represented by batch replacement requires a better producer side protection. The Norwegian regulations compensates this by relaxing the M_{Ac}; however, at the cost of consumer protection. A different strategy would be to ignore test costs and take larger samples in each test: while this would increase the test cost it would also decrease the probability of unwarranted batch replacement due to sampling uncertainty.

The calculation of consumer cost is tedious and demanding, and needs access to data other than the unit test measurements. Compiling a set of fixed rejection thresholds, as traditionally done, is a much simpler method to implement in a test laboratory. However, the biggest hurdle to basing the decision on a cost calculation is the sensitivity to the time to the next test. The consumer risk can be reduced simply by testing more frequently, and in an extreme case a grid owner could avoid unit replacements simply by deciding to perform another test within a short enough period of time. The risk analysis offers no guidance about how to handle this conundrum.

Rather than using a fixed period to the next test to provide the acceptance thresholds we could adopt the acceptance thresholds from elsewhere (e.g. Welmec) and compute the period until the next test instead. Such a test regime not only circumvents the test frequency conundrum, but would also retain the attractive ease of use in tabulated acceptance thresholds while also taking a cost perspective into account, which is updated according to the observations after a test. The time to the next test, τ, may be defined as the ratio between the producer risk and the *annual* consumer risk, (see section 4, with the annual cost of measurement errors in place of the accumulated cost of measurement errors):

$$\tau = \frac{P_{NC}}{P_C} \cdot \frac{\Delta c_r}{\Delta c_m} \quad (9)$$

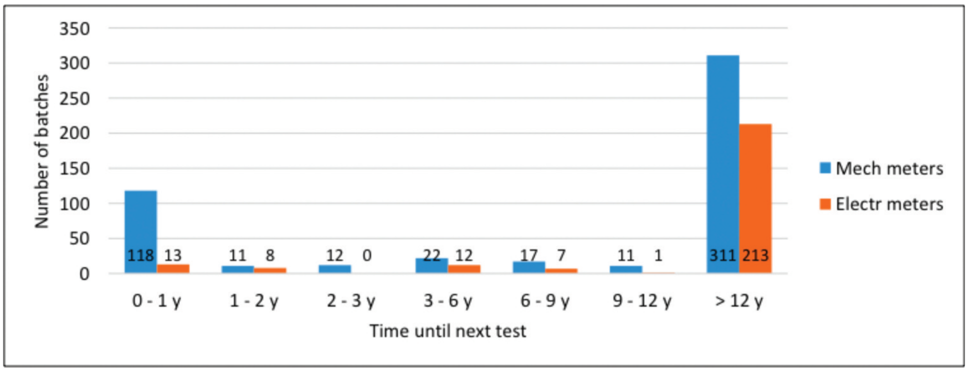

Figure 11: Time until the next test for each batch calculated from equation (9); acceptance criteria are from the Norwegian sampling plans.

We have computed τ for our data, and the results are shown in Figure 11. Most batches have $\tau > 12$ years. A smaller cluster of batches have a very short τ of less than a year, while a small, but significant number fall in between. While a very short period until the next test coincides with rejection, there can be cases where its value is unreasonably long. There is reason to expect units to have a finite lifetime, with a rapidly increasing error rate at the end of it. To avoid the situation where a batch undergoes accelerated failure rates long before its scheduled retest there should be an upper limit of τ fixed by other means, e.g. a knowledge of typical lifetimes of electricity meters.

The period until the next test can act as a quality indicator for each batch, which takes into account not only the measurement errors, but also their economic consequences. If the quality of a batch falls this might be seen as a decrease in τ, and could warn the net owner of an impending failure of the devices. A replacement of the batch could be planned a few years ahead based on actual measurements, which we hope could be a valuable asset to the utility companies. The quality feedback might also encourage utility companies to invest in better measurement devices in the first place, because they can reduce the workload associated with testing. In particular, since the majority of the cost associated with replacement stems from the installation work, it might even be possible to improve the device performance noticeably with a modest additional investment. Furthermore, as smart meters are introduced the grid owner might be able to exploit the measurements to purge poor individual units and thus extend the period until the next test, for instance by detecting unrealistic patterns in the consumption (e.g. a constant consumption for weeks, or suspiciously low values, or similar features).

The probability calculations we have carried out use the acceptance criteria from Table 4, which amounts to a sample size dependent tolerance level for the actual error rate. For the period until the next test computation one could perhaps favourably choose a fixed maximum tolerable error rate (typically 5 %). This would affect batches of small to moderate size by shifting the balance point between the consumer side risk and the producer side risk towards a higher value of observed error rate (section 4, in particular Figure 7), and hence increase τ. The large batches would be unaffected since the maximum tolerated error rate approaches 5 % with larger sample sizes.

Without regard to which method of analysis we choose (a pure cost analysis, a pure calculation of probabilities, or a combination of these two) we would argue that there are other important reasons for enforcing a test regime on measuring instruments. Firstly, there is a moral obligation to ensure a fair distribution of costs among consumers: measurement errors will shift costs between individuals in a completely arbitrary fashion. Secondly, correct measurements are the basis for levying taxes. Finally, correct measurement of consumption may induce consumers to act to conserve energy in the most cost effective way. Figure 1 actually suggests that electrical energy meters are already subject to rather wide tolerance levels, and any suspension of test regimes should be considered with much more diligent analysis than the press release indicated.

6 Conclusion

We propose to make accept/reject decisions for each individual batch after legal metrological testing is completed according to simple statistical rules described by the sampling plans in Welmec Guide 8.10 or similar plans modified in order to also provide better protection against false rejection (producer side risk). The Norwegian sampling plans provide such protection.

We further propose to use a risk analysis approach for those batches accepted by the rules of the regulation in order to calculate a period until the next test, which balances the consumer side risk with the producer side risk. A flat 5 % rate of non-conformances can be used for all sampling plans for this purpose. For each acceptance test which is carried out, the conditions for the risk analysis are updated with respect to actual measurement errors, varying price profiles through the year, typical consumption profiles, frequency of use and the cost of replacement of electrical energy meters.

The period until the next test acts as a quality characteristic of the batch, where a shorter period until the next test indicates degrading quality. By monitoring this quality characteristic it is possible to predict when each batch is expected to be replaced. At a short period until the next test, the net owner on their own initiative might choose to replace the batch, even though the batch was accepted according to the regulation.

7 Acknowledgements

The work on this paper is supported by the European Metrology Research Programme (2012–2015) in project NEW04 with a grant from the European Commission via EURAMET and which resulted in a Guide . We would like to express our gratitude to the stakeholder, Norsk Energi, who supported the initiative for this work, and especially to Håkon Jahr at Hafslund Fakturaservice who delivered a set of hour by hour profiles on electric power consumption as well as the distribution of annual energy consumption in eastern Norway. Henning Kolbjørnsen (JV) assisted the project by establishing contacts with Hafslund, and gave the project a good start. Kristian Ellingsberg (JV) has commented on differences in calculation of the power / energy measurements from 1-phase and 3-phase types of electrical energy meters. Hossein Piltan (JV) has contributed with the analysis of results stored in the database and many good discussions throughout the project. Nils Magnar Thomassen (JV), Eli Mogstad Ranger (JV) and Bjørn Fjeldstad (JV) have shown an interest in the results of the project and contributed with good discussions concerning the regulation. Stefan Svensson (SP) has commented on our calculations of excessive costs due to erroneous measurements, and Francesca Pennecchi (INRIM) has proof read and commented on parts of this paper in its various stages. ■

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Annex - The dataset, computation of costs

Figure A1 presents the measurement error curve for one particular electrical energy meter. We see that all the errors are negative, and that they lie within the specifications. When both positive and negative measurement errors are present they will to some extent cancel each other out when calculating the invoice error, depending on the frequency of use and the price of the utility. We have simplified the calculations of the calibration curve indicated in Figure A1, giving only rough estimates of the cost errors due to actual measurement errors.

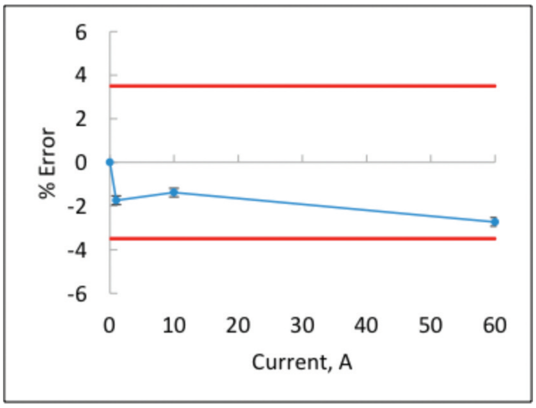

Figure A1: Calibration curve for a particular conforming meter in batch number 2783. The measurement errors are indicated with blue dots with measurement uncertainty bars. A stepwise linear interpolation is used to model errors between calibration points.

Figure A2 presents a typical power profile (frequency of use) for a private household. We have used only 38 such profiles from one vendor only. Some profiles received were excluded from this set of data because of strange behaviour, which was difficult to explain. For example, a variation period of 24 hours was expected, but we found a periodicity of ca. 32 hours. Also, some profiles showed constant power for several weeks.

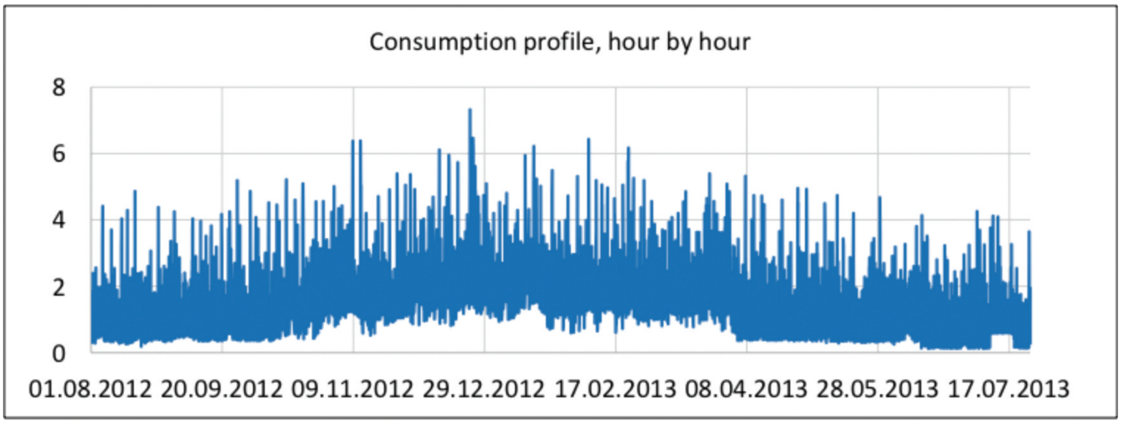

Figure A2: One example of a typical power profile for a private household in eastern Norway.

Figure A3 presents the distribution of the annual consumption of electrical energy for private households. The distribution of the annual consumption is highly skewed, with some excessively high consumptions. This curve is based on 500 000 electrical energy meters, all from one vendor, limited to eastern Norway, including Oslo. The annual energy consumption measured by our 38 typical power profiles in Figure A2 is marked with a blue "x" in Figure A3.

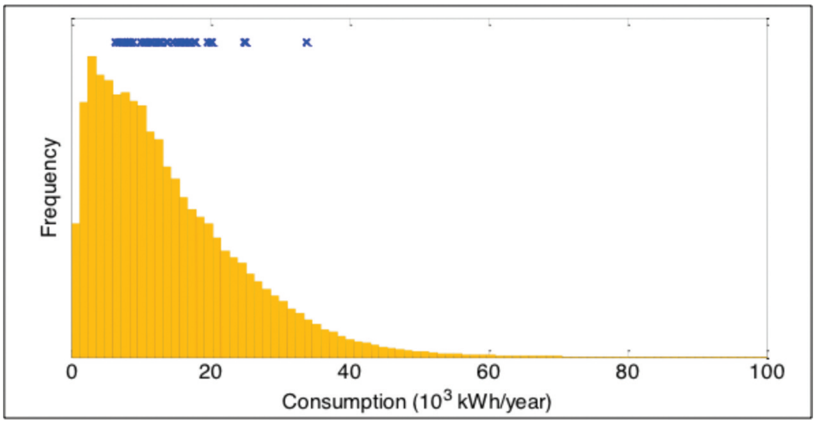

Figure A3: Annual electric energy consumption in private households in east part of Norway. Blue "x" indicate the annual electric energy consumption for our 38 available typical power profiles.

The scaling of each power profile by a randomly selected annual energy consumption is a rough way to simulate representative variations in actual power profiles. Our simulation might overstate the variation in power in some cases, or in other cases reduce variations. When variation in power exceeds I_{Max} these calculations have been deleted, effectively reducing the number of draws in the Monte Carlo simulation.

Figure A4 presents data for the price of electric power in the Oslo area. We have combined data sets for the same geographical area, and we have not simulated any variation between the different parts of Norway. Heating of private households in Norway is to great extent based on electricity, and there might be large variations in different parts of the country, especially during winter. Prices are highly correlated between different parts of Norway, but total energy consumption might have larger variations.

Figure A4: "Spot" price profile for electric power in the Oslo area. A grid fee of 390 NOK/MWh is added to this "spot" price.

The spikes on the spot price profile are of short duration, and have a small influence on the total annual cost. Many different price tariffs which avoid large spikes in the price profile are available. However, price tariffs which are different from the spot price tend to give higher annual prices on the annual energy consumption, as well as higher cost errors.

There are two shortcomings in our cost estimates: We have assumed a perfect power supply, measurement errors due to a phase difference between current and voltage are neglected, as well as measurement errors due to a voltage different from the standard value 230 V. Secondly, we have scaled a low number (38) of real example consumption profiles in a linear way to different yearly consumptions in order to simulate all the variations in yearly consumptions. This kind of scaling may not reflect fluctuations in real consumer profiles in a good way.

The probability density function for $\hat{p}$ was found using a binomial model for the sampling. For large batches, $n/N < 10$ %, this is a good approximation. Otherwise, a hypergeometric model for the sampling would be more accurate. We have limited our analysis to batch sizes $N \geq 200$, and also because of curtailment of the test, the requirement $n/N < 10$ % is not met for only 87 batches (total 756 batches), at a maximum value for $n/N = 30$ %.

We have presumed zero measurement errors for new electrical energy meters, which replace rejected electrical energy meters. This is a valid assumption when old mechanical meters with large measurement errors are replaced with electronic meters with low measurement errors. For electronic meters the distribution of measurement errors is narrower, but there may be a few meters with large measurement errors. When the electrical energy meter has very large measurement errors, it is possible to detect this by other means, and replacement of individual meters could be done without statistical sampling. ■

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HEAT METERS

Portable test equipment for residential utility meters

Part 2: Portable test equipment for residential gas meters

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YOUNG-MUN KWEON and SEUNG-JIN KIM, Metrology Industry Division, Korea Testing Certification (KTC), Republic of Korea

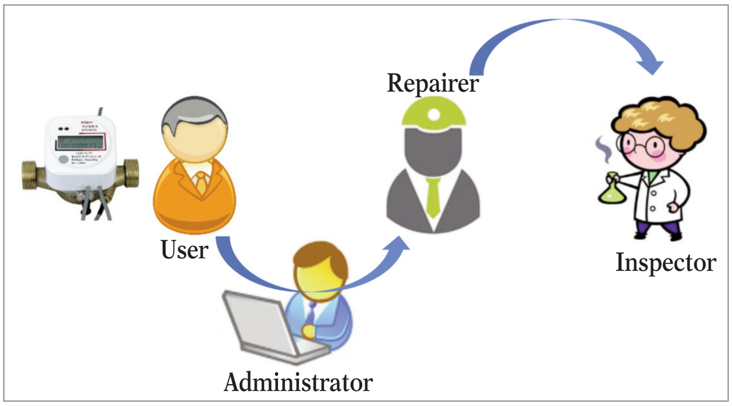

Figure 1: Procedure to resolve bill complaints

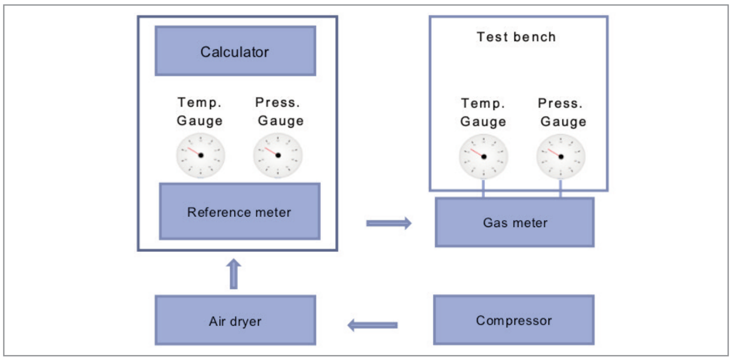

Figure 2: Portable gas meter test equipment components

1 General

Gas meters are measuring tools connecting gas providers to their consumers, and are considered to be fair only when their measured tolerances fall within an allowed range. The OIML has established R 31 to provide general requirements, type approval testing and verification requirements for gas meters.

When an abnormality occurs in a gas meter that is being operated on site, while the usability status can be determined by checking its performance, there are many restrictions on directly checking the operating conditions on site. Therefore, most performance tests have to be carried out in a laboratory.

To test gas meters, the pipes need to be disassembled and gas needs to flow while a reference flow meter is installed. But inspecting gas on site is not easy due to the risk of explosion.

In general, when abnormalities occur in a residential gas meter, the status of the abnormality can be checked using the procedure shown in Figure 1.

To summarize, when a user identifies an abnormality in the performance of a gas meter and requests a performance evaluation from the managing agency, the latter will have the gas meter separated from the piping by a repairman, and the meter is then sent to an inspection agency.

The gas meter then undergoes a process of measurement performance evaluation conducted at the inspection agency over a given period, following which the results are reported to the user.

In such cases and depending on the administrative procedures, significant time and cost may be incurred.

To reduce these inconveniences, an inspection device capable of carrying out on-site inspection of gas meters has been developed to address the problems that used to occur in the past, as well as to reduce distrust in gas meter related commercial transactions.

2 Application technique

The components of the portable test equipment for gas meters include: an air compressor (generating air as shown in Figure 2), an air dryer, a reference flow meter to measure flow, a calculator, and a test bench on which to place samples. The calculator converts the values of flow, temperature, and pressure of sample gases into the corresponding values according to the reference pressure state, and compares them with readouts of samples to determine errors.

The test equipment is divided into two different types: the sonic nozzle type and the rotary type depending on the reference flow meters. Tables 1 and 2 show the specifications of each type.

Table 1: Specifications of sonic nozzle type portable gas meter test equipment

Basic specifications	
Measuring range of flow rate	(0.3–6.0) m³/h
Accuracy	0.3 %
Size of gas meters	G1.6, G2.5, G4
Number of test gas meters	3

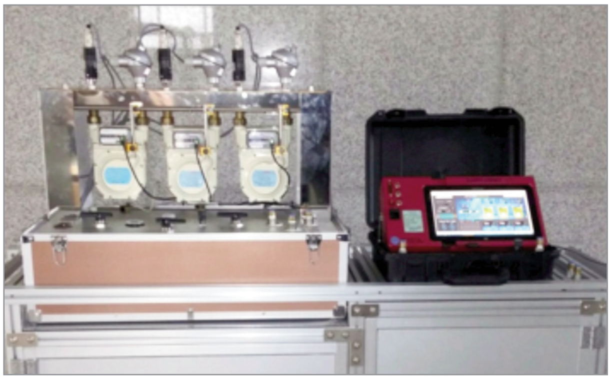

Figure 4: Portable gas meter test equipment

The sonic nozzle type uses sonic nozzles to measure flow, while rotary type utilizes rotary meters to measure flow.

The sonic nozzle type has a better flow rate range and is more accurate than the rotary type. Both types have a test bench that can examine three pieces of gas meters at the same time. They are both provided in different sizes of G1.6, G2.5, and G4.0, while offering testing for both left-handed and right-handed types. Although portability is important since they are not used in a laboratory, given the substantial sizes and weights of most gas meters and their components, such as compressors, filters, and dryers, convenience and accuracy are prioritized over portability.

Table 2: Specifications of rotary type portable gas meter test equipment

Basic specifications	
Measuring range of flow rate	(0.5–6.0) m³/h
Accuracy	0.5 %
Size of gas meters	G1.6, G2.5, G4
Number of test gas meters	3

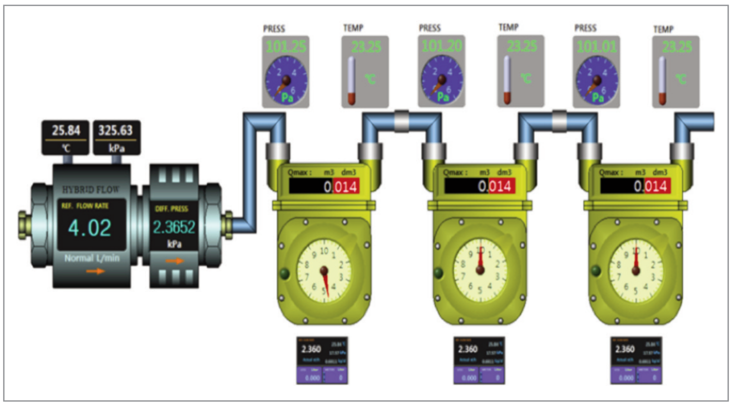

Figure 3: Display of portable gas meter test equipment

Figure 4 shows the whole test unit, which can be divided into a reference flow meter, a test bench, and a workbench on which the two previous apparatus can be placed for work. Figures 5 and 6 are the reference flow meters of the sonic nozzle and rotary types. The reference meter calculates reference flow rates based on temperature and pressure given from the reference flow meter, while the gas meter calculates its flow rates using temperature, pressure, and pulse from the test bench. The deviation values are calculated by comparing the two sets of information. Gas meters produce one pulse output per cycle and come in three different types: optical, mechanical, and zero pulse. For optical and mechanical contact outputs, the reference total flow is started and stopped by automatically receiving outputs from DAQ. However, in the case of a zero contact output, the operator should start and stop the reference total flow manually by observing the rotation of the gas meter.

The display is implemented via a tablet PC whose specifications are CPU Core i3, Memory 4 GB, HDD 128 GB, Touch SC, and an 11.4-inch LCD. The software is based on LabVIEW 2010 SP1 and the data processor is NI DAQ.

An evaluation of the on-site test devices conducted by the Korea Research Institute of Standards and Science (KRISS) has shown a maximum measurement deviation of 0.23 % for the sonic nozzle type and 0.36 % for the rotary type.

Figure 5: Reference flow meter part of sonic nozzle type portable gas meter test equipment

Figure 6: Reference flow meter part of rotary type portable gas meter test equipment

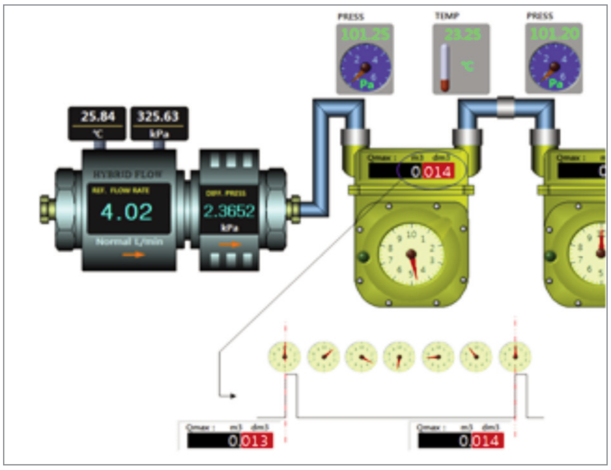

Figure 7: Start and stop of reference total flow

3 Discussion and concluding remarks

By utilizing this portable test equipment for gas meters, it is expected that the following problems experienced in laboratories can be solved:

- First, on-site civil complaints occurring between the administrator and the user are expected to be alleviated. This means that when disputes regarding gas meter bills occur, the inspection equipment is utilized; if inspection can be carried out through an on-site visit, time and financial savings can be made and consumer complaints can be promptly resolved as a result.
- Second, when the managing agency utilizes the present equipment, independent performance inspection can be conducted for the gas meter when the effective calibration period arrives, enabling accurate predictions to be made regarding the replacement of the measuring instrument.
- For a gas meter for which the effective verification period has expired, the economic burden the user incurs related to replacement can be reduced by avoiding unnecessary disposal from the inability to verify its performance.

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GAS METERING

The impact of the use of OIML R 137 ultrasonic gas meters of class 0.5 in the hydrocarbon industry

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Abstract

Different manufacturers specify different inlet requirements for custody transfer ultrasonic gas flow meters. Traditional designs usually require relatively long inlet piping and a flow conditioner. OIML R 137 [2] specifies a series of perturbation tests to be carried out with the manufacturer's recommended inlet piping. During these tests, the meter deviation shall be no more than 1/3 of the accuracy class. This means a maximum deviation of ±0.17 % for OIML R 137 class 0.5 approved meters. This deviation is almost half of the maximum allowable deviation of ±0.3 % required by AGA-9 and ISO 17089. This stringent requirement of OIML R 137 (class 0.5) is pushing ultrasonic meter manufacturers to develop more advanced meters and to pursue an optimal meter's path configuration. These newer state-of-the-art designs can usually operate with short inlet lengths and no longer need a flow conditioner. The immediate benefit of this approach is that the meter can be installed with a shorter inlet length thus saving space, weight and overall costs. The non-immediate benefit is that the pressure drop caused by the flow conditioners and their blockage over time is avoided. This paper will present the impact of the non-immediate benefit for different countries where metering stations are designed with ultrasonic meters and without flow conditioners. The benefits are reduced gas consumption by the gas turbines used to drive the pipeline's gas compressors, and the reduction of CO_2 emissions.

1 Introduction

Since the early 1990s, multipath ultrasonic flow meters have become the most used method for measuring flow in large pipelines, particularly for the purpose of custody transfer of natural gas. The reasons for this surge are many: excellent accuracy, high turn-down, good resistance to installation effects, and economical when compared to multiple runs of other kinds of meters such as orifice meters.

The following meter design parameters affect the ultrasonic flow measurement accuracy:

- number of paths;
- direct or reflective paths;
- path locations;
- paths in one or different planes;
- paths of different lengths;
- calculation method to obtain average flow velocity.

Normally, for custody transfer application the number of ultrasonic paths in a meter varies from four to eight, using reflective or direct paths in one or two planes.

The meter design can aim to achieve high accuracy, high tolerance to flow disturbances, the production of useful diagnostic data and a self-checking ability. The ideal situation would be to meet all these criteria, but this may not be possible and probably explains why such a large variety of meter designs exist.

Different approaches seem to have evolved [1]:

1 Installing a flow conditioner to establish a good flow profile and use the diagnostics to confirm the good profile, which then validates the meter accuracy. A reduced bore can also act as a flow conditioner.
2 Designing the meter to detect disturbances and be immune from them, to confirm the meter accuracy.
3 Designing the meter to measure profile factor, swirl, cross flow, distortion and turbulence to use them to correct the flow measurement.

The price for approach 1 is the cost of obstruction and pressure loss caused by the flow conditioner. If contamination is expected, the conditioner can become contaminated, which changes the flow profile and defeats the purpose of the conditioner. The advantage of approaches 2 and 3 would be the elimination of the flow conditioners, if they prove viable.

2 Performance testing required by the relevant standards/Recommendations

OIML R 137, AGA-9 and ISO 17089 specify a series of perturbation tests that must be carried out with the manufacturer's recommended inlet piping [2, 3, 4]. During these tests the flow meter is first calibrated with a long straight inlet run to establish a baseline.

Subsequently, the meter is calibrated with a number of perturbations that are installed directly in front of the manufacturer's recommended inlet piping to simulate the disturbance found in the field and obtain the maximum installation error. Figure 1 shows the tests to be performed as per OIML R 137 [2]. During these tests the meter shall not deviate more than ±0.3 % in the case of AGA-9 and ISO 17089 or more than 1/3 of the accuracy class in the case of OIML R 137. This means a maximum deviation of ±0.33 % for OIML R 137 class 1 approved meters and a maximum deviation of ±0.17 % for OIML R 137 class 0.5 approved meters. This is almost half of the maximum allowable deviation of ±0.3 % required by AGA-9 and ISO 17089.

The performance requirements established by OIML R 137 for meters of class 0.5 can be only achieved by the newer state-of-the-art ultrasonic gas flow meter designs [5, 6, 7]. Based on the author's experience, these meters are designed in line with the above approaches or in line with a combination of them, with six or more paths adopting reflective paths or direct paths in two planes.

Finally, some newer state-of-the-art ultrasonic gas flow meter designs can comply with the requirements of OIML R 137 class 0.5 using 10 D to 15 D without a flow conditioner. This shows the advanced degree achieved by manufacturers in the design of newer ultrasonic gas meters.

Test		Test conditions	Remarks	Turbine	Ultrasonic	Thermal mass	Vortex
a		Reference conditions	approx. 80 D straight line		×	×	×
			approx. 10 D straight line (see Note)	×			
b		A single 90° bend	radius elbow: 1.5 D	×	×	×	×
c		Double out-of-plane bend	rotating right; radius elbows: 1.5 D	×	×	×	×
d		Double out-of-plane bend	rotating left; radius elbows:1.5 D	×	×	×	×
e		Expander	one step difference of the pipe diameter is applied		×	×	×
f		Reducer	angle of expansion/reduction part: ≤ 15°		×	×	×
g		Diameter step on the upstream flange	approx. +3 % and –3 %	×	×		×
+		Half pipe area plate	image shows first bend in piping and mounting of half-moon plate.	×	×		

Note:
Any turbine meter will need to be equipped with a flow director (straightener and nose cone) in the upstream part. For this reason the influence of extending the upstream part with a straight line beyond the 10 D value will be negligible.

Figure 1: Piping configuration for flow disturbances [2]

3 Methodology

3.1 Flow conditioners

In the field of flow measurement it is often necessary to condition the flow upstream of a flow metering device so that the flow meter will register the flow with minimal error. Bends, valves, filters and other forms of pipeline components distort the flow velocity profile and by changing the flow direction they introduce non-axial velocity components or "swirl" in the flow stream. It is well known that the calibration or flow coefficients of certain types of flow meters are affected by distortions of the profile and/or by the presence of swirl.

Flow conditioners have been employed for many years to partially rectify distorted and swirling flows upstream of flow meters. The various devices deployed to date differ in design, with resulting differences in performance in terms of their ability to rectify flow versus the permanent pressure loss that they impose. Most conditioners have a single specified geometry or a constrained set of design parameters and cannot easily be adapted to suit the requirements of a particular situation.

More commonly used today are thick-plate type conditioners [8], also known in the hydrocarbon industry as "perforate plate" flow conditioners. In these designs a graded resistance to flow is achieved by making circular passages in a fairly thick plate. By varying the number, spacing and size of the circular passages, the desired graded resistance is achieved.

Examples of this type of conditioner include the Nova/CPA 50E and variants, Spearman, and Gallagher in addition to the thick plate version of the Zanker conditioner [8]. Common thick-plate conditioners are illustrated in Figure 2.

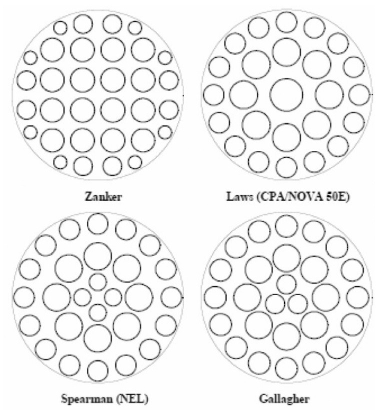

Figure 2: Typical thick-plate flow conditioner geometry [8]

These thick-plate conditioners with circular passages are considered to be the current state-of-the-art but still have certain deficiencies. Pressure loss coefficients are typically in the range of 2 to 5, greater than that available with a tube bundle. Attempts to produce plates of higher porosity and hence lower pressure loss have generally resulted in a reduction in flow conditioning performance [8].

3.2 Pressure loss coefficient

The pressure loss coefficient, k, for a flow conditioner can be calculated as per Eq.(1) [9]:

$$k = \frac{2 \times \Delta P_c}{\rho \times V^2} \qquad (1)$$

where:

ΔP_C is the pressure loss across the flow conditioner (Pa);

ρ is the density of the fluid in the pipe (kg/m^3);

V is the mean axial velocity of the fluid in the meter run (m/s).

Table 1 presents the pressure loss coefficients for the following flow conditioners: Sperman, Zanker, Gallangher and K-Lab Nova according to ISO 5167 [9, 10]. As can be seen, these flow conditioners are not patented and their designs are available in ISO 5167. Based on these factors, the skid manufactures prefer to select them to be part of the meter run to reduce the total price of the skid.

Table 1: Flow conditioner pressure loss coefficients

Type	Pressure loss (k)
Sperman	3.2
Zanker	3
Gallagher	2
K-Lab Nova	2
Nova 50E	2.6*

Note: * The k value for Nova 50E was obtained from [11].

An average value for k of 2.5 will be used in this work.

Daniel Measurement and Control [12] shows that most designers limit the normal operation of an ultrasonic gas meter to a velocity, V, in the range of 21 or 24 m/s. The average value of V = 22.5 m/s will be used in this work.

3.3 Power loss due to use of a flow conditioner

The power loss, P_c (kW) due to the pressure drop caused by the flow conditioner in the gas pipeline can be calculated by Eq.(2):

$$P_c = \frac{Q \times \Delta P_c}{1000} \qquad (2)$$

where Q is the actual flow rate of the fluid in the meter run (m^3/s).

The flow rate, Q, can be determined by Eq.(3):

$$Q = V \times A \qquad (3)$$

where A is the internal cross section area of the meter run (m^2).

The power, P_T (kW), necessary for the gas turbines to drive the pipeline's gas compressors to overcome the pressure drop caused by the flow conditioners can be calculated by Eq.(4):

$$P_T = \frac{N_m \times P_c}{\eta_c \times \eta_m \times \eta_T} \qquad (4)$$

where:

N_m is the number of natural gas meters used in the pipeline system;

η_c is the isentropic efficiency of the pipeline's gas compressors;

η_m is the mechanical efficiency of the pipeline's gas compressors;

η_T is the thermal efficiency of the pipeline's gas turbines.

Kurz [13] shows that the mechanical efficiency η_m for a centrifugal compressor, describing the friction losses in bearings and seals, as well as windage losses, is typically between 98 and 99 %. A value of 98 % will be used in this work. It also shows that the typical steady state pipeline operation will yield an isentropic efficiency η_c around 87 % for a centrifugal compressor. These figures are the results of evaluating the compressor efficiency along a pipeline steady state operating characteristic.

Ref. [14] shows that when the gas turbine is used solely for shaft power, its thermal efficiency η_T is around the 30 % mark.

Quantity and quality are both important aspects of gas transmission. Accordingly, the gas stream is measured as it enters the transmission line and again as it leaves the system. It may also be measured and sampled at various locations along its journey along the pipeline, but they will not be considered in the determination of N_m. So, N_m can be determined by Eq.(5):

$$N_m = 2 \times \frac{\left[Q_P \times \frac{P_b}{P_f} \times \frac{T_f}{T_b} \times \frac{Z_f}{Z_b}\right]}{[Q \times 3600 \times 24]} \qquad (5)$$

where:

Q_p is the flow rate of natural gas transported by the gas pipelines (standard m^3/day);

P_b is the base pressure, 101.325 kPa;
P_f is the absolute static pressure of gas at flowing conditions (kPa);
T_b is the absolute base temperature, 288.15 K;
T_f is the absolute temperature of gas at flowing conditions (K);
Z_b is the compressibility factor of gas at base conditions, per AGA Report No. 8 [15];
Z_f is the compressibility factor of gas at flowing conditions, per AGA Report No. 8.

3.4 Natural gas consumption by the gas turbine

The natural gas consumption, Q_T (standard m^3/s), by the gas turbine to drive the pipeline's gas compressors can be calculated by Eq.(6):

$$Q_T = \frac{P_T}{HHV} \qquad (6)$$

where HHV is the high heat value of natural gas consumed by the gas turbine (kJ/ standard m^3).

3.5 Natural gas cost due to the pressure drop caused by the flow conditioner

Once the consumption, Q_T (standard m^3/s), of natural gas by the gas turbine to drive the pipeline's gas compressors is determined by Eq.(6), the natural gas cost (USD/day) can be calculated by Eq.(7):

$$Cost = Q_T \times HHV \times Gas\ Price \times 3600 \times 24 \quad (7)$$

where *Gas Price* is the natural gas cost (USD/kJ).

3.6 CO_2 emissions by the gas turbine

Carbon dioxide emissions, also known as "Greenhouse gases", are produced during natural gas and distillate oil combustion in gas turbines. Nearly all of the fuel carbon is converted to CO_2 during the combustion process. This conversion is relatively independent of the firing configuration.

EPA [16] presents an emission factor (*EF*) for natural gas-fired turbines of 110 lb/MMBTU or 4.73×10^{-5} kg/kJ. The term "MMBTU" means millions of BTU or 10^6 BTU. This is the fuel energy input into the gas turbine.

The CO_2 emissions (kg/year) can be calculated using Eq.(8):

$$CO_2 = EF \times P_T \times 3600 \times 24 \times 365 \quad (8)$$

The number of trees (N_{trees}) necessary to capture the CO_2 emission by the gas turbine can be calculated by Eq.(9):

$$N_{trees} = \frac{CO_2}{ART} \qquad (9)$$

where ART is the CO_2 absorption rate of a tree (kg/year/tree).

According to [17, 18], a single tree can absorb CO_2 at a rate of 48 (lb/year/tree) or 22 (kg/year/tree).

4 Results

In addition to compressing natural gas to reduce its volume and push it through the pipe, metering stations are placed periodically along interstate natural gas pipelines. Quantity and quality are both important aspects of gas transmission. Accordingly, the gas stream is measured as it enters the transmission line and again as it leaves the system. It may also be measured and sampled at various locations along its journey along the pipeline. According to [19], gas pipelines are operated with a static gauge pressure in a range of 3447 kPa to 9653 kPa (500 to 1400 psig). Recently, the author has been working with many ultrasonic gas metering projects. The average pipe diameter is 500 mm (20"). The average design static gauge pressure and temperature of the gas used in these projects are 3450 kPa and 30 °C, respectively. These last three values will be used in this work.

Table 2 [20], shows the consumption of the 10 largest consumers of natural gas in the world. This data refers to 2014 and is in billions of standard cubic meters. These values will be used as the input for the flow rate of natural gas transported by gas pipelines, Q_P.

Table 2: Natural gas consumption by country

Country	Consumption (standard m^3) ($\times 10^9$)
United States	757
Russia	462
China	181
Iran	174
Japan	134
Canada	110
Saudi Arabia	87
Germany	81
Mexico	72
United Kingdom	70

Table 3 [15] presents a typical gas composition of the natural gas normally found in gas pipelines. This composition refers to the "Amarillo" composition retrieved from AGA-8. These compositions will be used in this paper.

Table 3: Amarillo gas composition

Component	Mole percent
Methane	90.6724
Nitrogen	3.1284
Carbon dioxide	0.4676
Ethane	4.5279
Propane	0.828
i-Butane	0.1037
n-Butane	0.1563
i-Pentane	0.0321
n-Pentane	0.0443
n-Hexane	0.0393
n-Heptane	0.0000
n-Octane	0.0000

For a gauge pressure of 3450 kPa, a temperature of 30 °C and the composition presented in Table 3, the compressibility factors Z_f and Z_b are determined as being 0.936094 and 0.997308, respectively. The gas density is 26.4813 kg/m^3. The high heat value of natural gas, *HHV*, has been calculated as per AGA-5 [21]. For the above composition, HHV is determined as being 38 555.3 (kJ/standard m^3).

Assuming a European international price for natural gas of USD 6/MMBTU (5.69 × 10^{-6} USD/kJ) [22] practiced in November 2015 when the oil price was around USD 40/barrel, Table 4 presents by country the results of the cost of natural gas consumed by the gas turbines, the CO_2 emission by the gas turbines and the number of trees necessary to capture the CO_2, due to the pressure drop caused by the flow conditioners installed in the pipeline metering systems. Also, Table 4 presents the gas cost, for a period of 25 years, due to the pressure drop of the flow conditioners. This number was selected assuming that 25 years is the useful lifetime of an ultrasonic meter.

The numbers presented in Table 4 represent a scenario that assumes the use of ultrasonic meters only *with flow conditioners*, or in other words, a scenario with the lowest pressure drop that can be produced with the actual technologies adopted in pipelines to measure the flow. In reality, the hydrocarbon industry applies a mix of the following technologies: ultrasonic meters with flow conditioners, orifice plates with flow conditioners, and turbine meters with flow conditioners. The last two methods produce a pressure drop which is worse than ultrasonic meters with flow conditioners. So, it is expected that the figures will be higher than those presented in Table 4.

Table 4: Cost and CO_2 emission due to the use of flow conditioners – gas price of USD 6/MMBTU

Country	Gas cost (USD/year) Eq.(7)	Gas cost (USD/25 years)	Number of meters (ID 500 mm) Eq.(5)	Number of trees per year Eq.(9)
United States	15 884 149	397 103 721	306	6 004 208
Russia	9 655 071	241 376 772	186	3 649 617
China	3 841 265	96 031 619	74	1 451 998
Iran	3 633 629	90 840 720	70	1 373 512
Japan	2 803 085	70 077 127	54	1 059 566
Canada	2 283 995	57 099 881	44	863 350
Saudi Arabia	1 868 723	46 718 085	36	706 377
Germany	1 661 087	41 527 187	32	627 891
Mexico	1 557 269	38 931 737	30	588 648
United Kingdom	1 453 452	36 336 288	28	549 405
Total	**44 641 725**	**1 116 043 137**	**860**	**16 874 572**

Analyzing the "Total" row of Table 4, we can see that globally the total gas cost for the 10 countries represents a value around USD 45 million per year or USD 1 billion over 25 years.

In terms of CO_2 emissions, the annual planting of 17 million trees, or a stunning 425 million trees over 25 years, is required to capture the CO_2.

For a single country, e.g. Germany, the gas cost represents almost USD 2 million per year or almost USD 42 million over 25 years. In terms of CO_2 emissions, almost 630 000 trees per year are necessary to capture the CO_2 emissions produced by the pressure drop of the flow conditioners. Over 25 years, this represents almost 16 million trees.

Finally, once applying the newer state-of-the-art ultrasonic meters without flow conditioners as per OIML R 137 class 0.5, at least the ciphers presented in Table 4 (or larger) can be avoided by pipeline operators.

The typical cost of a newer state-of-the-art ultrasonic meter is around USD 65 000, including the price of the meter's calibration in a high pressure gas lab. Assuming that all the countries in Table 4 change the 860 meters for newer ones without flow conditioners, the pay-back period would be 1.25 years.

Now, assuming an average European international price for natural gas of USD 11.62/MMBTU (1.10 × 10^{-5} USD/kJ) [22] practiced between October 2011 and October 2013 when the oil price was around USD 100/barrel, Table 5 presents by country the results of the cost of natural gas consumed by the gas turbines due to the pressure drop caused by the flow conditioners installed in the pipeline metering systems.

Analyzing the "Total" row of Table 5, we can see that globally the total gas cost for the 10 countries represents a value around USD 86 million per year or USD 2 billion over 25 years.

For a single country, e.g. Germany, the gas cost represents around USD 3 million per year or almost USD 80 million over 25 years.

Table 5: Cost due to the use of flow conditioners – gas price of USD 11.62/MMBTU

Country	Gas cost (USD/year) Eq.(7)	Gas cost (USD/25 years)	Number of meters (ID 500 mm) Eq.(5)
United States	30 762 302	769 057 540	306
Russia	18 698 654	467 466 348	186
China	7 439 249	185 981 235	74
Iran	7 037 128	175 928 195	70
Japan	5 428 641	135 716 036	54
Canada	4 423 337	110 583 437	44
Saudi Arabia	3 619 094	90 477 358	36
Germany	3 216 973	80 424 318	32
Mexico	3 015 912	75 397 798	30
United Kingdom	2 814 851	70 371 278	28
Total	**86 456 141**	**2 161 403 543**	**860**

Assuming that all the countries in Table 5 change the 860 meters for newer ones without flow conditioners, the pay-back period would be 0.65 years.

Another point to be highlighted for class 0.5 meters approved as per OIML R 137 is the maximum allowable deviation due to the installation error caused by flow disturbances in the field. As per Section 2 of this paper, the vendor shall demonstrate that the meter will not deviate by more than ±0.3 % in the case of AGA-9 and ISO 17089 or by more than ±0.17 % in the case of OIML R 137 class 0.5. This is an improvement of around ±0.1 % compared to the standards AGA-9 and ISO 17089. Tables 6 and 7 translate this improvement in terms of *"losses of potential revenue* or *financial exposure"* for pipeline operators if all the gas volumes of Table 2 were measured by the newer state-of-the-art ultrasonic meters according to OIML R 137 class 0.5.

Table 6: Loss of potential revenue due to the installation error – gas price of USD 6/MMBTU

Country	±0.1 % of Table 2 (standard m^3)	Loss of potential revenue (USD/year)	Loss of potential revenue (USD/25 years)
United States	757 000 000	165 979 979	4 149 499 472
Russia	462 000 000	101 298 217	2 532 455 424
China	181 000 000	39 686 098	992 152 450
Iran	174 000 000	38 151 277	953 781 913
Japan	134 000 000	29 380 868	734 521 703
Canada	110 000 000	24 118 623	602 965 577
Saudi Arabia	87 000 000	19 075 638	476 890 956
Germany	81 000 000	17 760 077	444 001 925
Mexico	72 000 000	15 786 735	394 668 378
United Kingdom	70 000 000	15 348 215	383 705 367
Total	**2 128 000 000**	**466 585 727**	**11 664 643 166**

Analyzing the "Total" row of Table 6, we can see globally that the *losses of potential revenue* for the 10 countries represent a value around USD 466 million per year or almost USD 12 billion in 25 years. These figures

Table 7: Loss of potential revenue due to the installation error – gas price of USD 11.62/MMBTU

Country	±0.1 % of Table 2 (standard m^3)	Loss of potential revenue (USD/year)	Loss of potential revenue (USD/25 years)
United States	757 000 000	321 447 892	8 036 197 311
Russia	462 000 000	196 180 880	4 904 522 005
China	181 000 000	76 858 743	1 921 468 578
Iran	174 000 000	73 886 306	1 847 157 638
Japan	134 000 000	56 900 948	1 422 523 698
Canada	110 000 000	46 709 733	1 167 743 334
Saudi Arabia	87 000 000	36 943 153	923 578 819
Germany	81 000 000	34 395 349	859 883 728
Mexico	72 000 000	30 573 644	764 341 092
United Kingdom	70 000 000	29 724 376	743 109 395
Total	**2 128 000 000**	**903 621 024**	**22 590 525 598**

are solely due to a reduction in the installation error of 0.1 % that newer state-of-the-art ultrasonic gas flow meters designs are capable of complying with.

For a single country such as Germany the *loss of potential revenue* represents almost USD 18 million per year or USD 444 million over 25 years.

Now, analyzing the "Total" row of Table 7 for a gas price of USD 11.62/MMBTU, we can see that the *losses of potential revenue* for the 10 countries represent a value around USD 904 million per year or USD 22.5 billion over 25 years.

For a single country, e.g. Germany, the *loss of potential revenue* represents around USD 34 million per year, or almost USD 900 million over 25 years.

Finally, the *financial exposure* can be double the figures presented in Tables 6 and 7 if we consider meters installed on both sides of a gas pipeline.

5 Conclusions

This paper has discussed a number of issues associated with the impact of the use of OIML R 137 class 0.5 ultrasonic gas meters in the hydrocarbon industry. These are:

- gas consumption of natural gas by the gas turbines to drive the pipeline gas compressors to overcome the pressure drop caused by the flow conditioners of metering systems;
- the associated gas cost of the additional gas consumption necessary to overcome the pressure drop caused by the flow conditioners of metering systems;
- the additional CO_2 emission by the gas turbines to drive the pipeline's gas compressors to overcome the pressure drop caused by the flow conditioners of metering systems;

- the number of trees necessary to capture the additional CO_2 emission by the gas turbines to drive the pipeline's gas compressors to overcome the pressure drop caused by the flow conditioners of metering systems; and
- the *losses of potential revenue* due to the non-use of ultrasonic gas meters approved as per OIML R 137 class 0.5.

Section 4 presented the results for the above points considering two gas prices (USD/MMBTU) or scenarios. They are:

i) Natural gas price of USD 6/MMBTU

We could see that globally the cost of gas consumed by the gas turbines due to the use of flow conditioners for the 10 countries represents a value around USD 45 million per year or USD 1 billion over 25 years.

Assuming that all the countries in Table 4 change the 860 meters for state-of-the-art ultrasonic meters without flow conditioners, the pay-back period would be 1.25 years.

In terms of additional CO_2 emissions produced by the pressure drop of the flow conditioners, each year it is necessary to plant around 17 million trees or 425 million trees over 25 years.

For a single country such as Germany the cost of gas represents almost USD 2 million per year or almost USD 42 million over 25 years. In terms of CO_2 emissions, almost 630 000 trees per year are necessary to capture the CO_2 emissions produced by the pressure drop of the flow conditioners. Over 25 years, this represents almost 16 million trees.

The *losses of potential revenue* due to the non-use of ultrasonic gas meters approved as per OIML R 137 class 0.5 for the 10 countries represents a value of around USD 466 million per year or almost USD 12 billion over 25 years. These figures are due to a reduction in the installation error of 0.1 % that newer state-of-the-art ultrasonic gas flow meter designs are capable of complying with. For this case the pay-back period would be 0.12 years.

For a single country, e.g. Germany, the *loss of potential revenue* represents almost USD 18 million per year or USD 444 million over 25 years.

ii) Natural gas price of USD 11.62/MMBTU

We could see that globally the cost of gas consumed by the gas turbines due to the use of flow conditioners for the 10 countries represents a value of around USD 86 million per year or USD 2 billion over 25 years.

Assuming that all the countries in Table 5 change the 860 meters for state-of-the-art ultrasonic meters without flow conditioners, the pay-back period would be 0.65 years.

For a single country, e.g. Germany, the cost of gas represents around USD 3 million per year or almost USD 80 million over 25 years.

The *loss of potential revenue* due to the non-use of ultrasonic gas meters approved as per OIML R 137 class 0.5 for the 10 countries represents a value around USD 904 million per year or USD 22.5 billion over 25 years. For this case the pay-back period would be 0.06 years.

For a single country, e.g. Germany, the *loss of potential revenue* represents around USD 34 million per year or almost USD 900 million over 25 years.

Finally, based on the numbers exposed in this section, the hydrocarbon industry should pay attention when selecting the meter technology and the standards (or Recommendations) to be applied when purchasing gas meters to be used in the field. The *financial exposure* can be double the figures presented above if we consider meters installed on both sides of a gas pipeline. ■

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MILK MEASUREMENT

UK legal metrology project on milk measurement processes from farm to dairy

Christine Munteanu, NMRO, UK

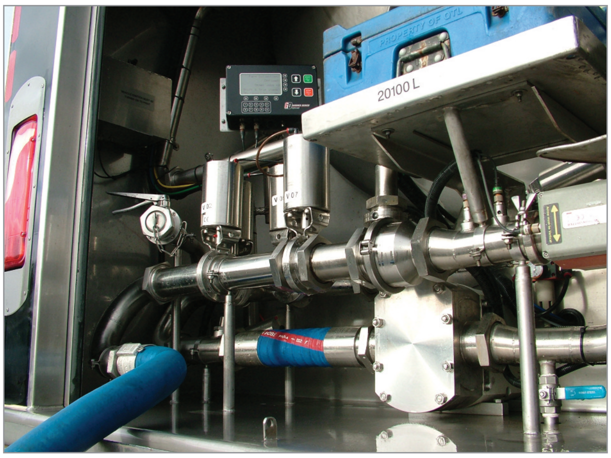
Tanker meter measuring systems for milk (2/4)

Following concerns raised by dairy farmers, the UK's legal metrology authorities carried out a fact-finding enquiry to establish whether a problem existed that was sufficient to warrant government intervention, new regulation, or further testing work to be carried out in the milk measurement process.

The investigation, which was a joint initiative involving both the then National Measurement and Regulation Office (NMRO) and Local Authority Trading Standards Departments, found no evidence of inaccuracies in milk measurements; however, it did conclude that the methods used varied considerably and could not be easily checked, leading to a lack of transparency in the process and giving rise to doubt and uncertainty.

As a result of follow-up work involving both farmers and the dairy industry, a new industry code of practice for milk measurement from farm to dairy is set to be introduced which should improve confidence in the milk measurement process.

Dairy farming is an important agricultural sector for the UK and in particular for many rural communities. It is the single largest agricultural sector in the UK,



Tanker meter measuring systems for milk (1/4)

accounting for around 17 % of agricultural production by value. For dairy farmers, the measurement of the milk they sell has become increasingly important as the margins on milk production have narrowed as a result of falling prices and oversupply in global markets.

Milk from cows produced by farmers is sold to dairies mainly on the basis of volume measurement, but measuring instruments used for this purpose are not regulated in the UK. They fall under the Measuring Instruments Directive (MID) which allows optionality for countries not to prescribe if they do not consider there is the need for prescription in their country.

Historically, the milk industry has regulated itself effectively in this area with no proven need for government intervention. However, NMRO received information from their Trading Standards Expert Panel and the Chartered Institute of Trading Standards Lead Officers for Metrology that complaints had been received from farmers across the country, particularly in Scotland, about the accuracy of milk measurement from farms to the dairies.

The farmers' concerns focussed on the lack of clarity in the measurements and the measuring process as they did not know whether the measurement of the milk was accurate or not as they did not have very effective means of checking what had been measured.

NMRO therefore initiated a fact-finding project in conjunction with a number of Local Authority Trading Standards Departments. The purpose of the project was to gather evidence and establish contacts with the parties concerned to ascertain whether there was a need for government intervention in this sector to ensure a competitive but fair trading environment.

Seventeen Local Weights and Measures Authorities from across the UK took part in the project and seventy-seven farms, twelve dairies and six tanker depots were visited. Nine tanker meter measuring systems were examined for evidence of measurement traceability.

Tanker meter measuring systems for milk (3/4)

Measurement methods, practices and records were examined, some calibrations were witnessed and feedback from all those involved and affected by the measurement process was gathered so that a number of different perspectives could be taken into account.

The examinations of the measurement methods, practices and records did not find any objective evidence showing that milk measurement is not accurate. The fact-finding project did not, therefore, uncover any evidence that warranted further detailed testing work being carried out, which would have been the necessary next step if formal regulation were to be considered.

However, what the project did find was that the process was not transparent and this was causing doubt and uncertainty for the farmers who were unable to check measurements themselves. Different methods are used by the different dairies to provide assurance to the farmers and this had contributed to a perceived lack of confidence by some farmers in the measurement process. In light of this it was suggested that the industry itself would benefit from better transparency and consistency in measurement of milk when collected from farms and that this would be best achieved through an industry code of practice for milk measurement which would standardise the process and provide the transparency that farmers need to have confidence that the measurement process is accurate and fair.


Tanker meter measuring systems for milk (4/4)

To follow this up, NMRO met with Dairy UK, the trade association representing the dairy industry, which agreed to produce an industry code of practice. NMRO and the TS Metrology Expert Panel have confirmed that they will provide support in preparing the code of practice and Dairy UK have agreed that a CTSI Lead Officer for Metrology should sit on the panel that produces the code. The expectation is that when the code of practice is finalised it will be endorsed by the legal metrology authorities, thus giving farmers the assurance they need that the milk measurement process continues to be fair and accurate.

The full project report is available from the NMRO website here:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/468644/National_Project_Milk_Measurement_from_Farm_to_Dairy_Final.pdf ■

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HISTORY OF SCALES

Part 18: Automatic checkweighers (ACWs) in accordance with OIML R 51

Wolfgang Euler, Hennef (Sieg), Germany, and
Bernd Zinke, Wipotec Wiege- und Positioniersysteme GmbH, Kaiserslautern, Germany

Background

Readers will recall that Part 17 of this series (published in the January 2016 OIML Bulletin) described in detail how an ACW is used to feed the item to be measured (such as packages or parts) to the load measuring device for weight control without the interaction of an operator, and to determine the deviation of the mass (m) (the package or part) from the target weight. For most applications, a downstream sorting device controlled by the ACW then rejects packages/ parts which exceed the set minus and/or plus limits or sorts the parts into classes.

The situation in Europe and in the United States

A large number of countries around the world currently use OIML R 51 as a guide for testing ACWs. For this reason, measurement data obtained in accordance with OIML R 51 in one country can generally be used in another country to issue national type approvals without additional laboratory testing.

However, in the United States OIML R 51 has not yet gained acceptance. Inspection specifications and requirements for ACWs in the United States are defined in NIST Handbook 44 (HB44) and in NCWM Publication 14 (Pub 14). HB44 Section 2.24 "Automatic Weighing Systems" (AWS) especially addresses ACWs (checkweighers).

With a view to the much-discussed transatlantic trade agreement (TTIP) currently being negotiated between the USA and the EU, important common features as well as differences in regulations which apply to ACWs are presented in this article, which includes a comparison between OIML R 51 and NIST Handbook 44, Section 2.24.

Accuracy classes

OIML R 51 classifies ACWs as Category X (checkweighers) and, on the basis of OIML R 76 (Non-automatic weighing instruments, NAWIs), has distinguished between four accuracy classes since 2006: XI, XII, XIII and XIIII. (Deviating from this, the European Measuring Instruments Directive 2004/22/EC (MID) mysteriously writes the fourth accuracy class as XIV.) This has been corrected in 2014/32/EU, which has to be applied from April 2016. Most of the ACWs used in the field are assigned to accuracy class XIII. NIST Handbook 44 uses only accuracy class III for ACWs.

Error types

OIML R 51 and HB44 distinguish between two independent error types:

- the mean (systematic) measurement error (often called mean value error), and
- the random measurement error, which refers to the spread of measurement errors and which is evaluated today in the form of the calculated standard deviation of the individual measurement errors. Previously, instead of the standard deviation, the range of uncertainty of the ACWs was used.

Systematic errors lead to a constant (correctable) **offset** of the measurement values from the true value (e.g. build-up/deposit of material or dirt on the weighing platform).

Random errors lead to a **scattering** of the measurement values around a mean value (e.g. unbalanced shaft of weighing conveyor) – see Figure 1.

Both types of errors are determined as statistical quantities from a specified minimum number of measurements, often 60. Here, the error regime of automatic checkweighers (ACWs) clearly differs from that of automatic catchweighers (ACIs, which are classified as

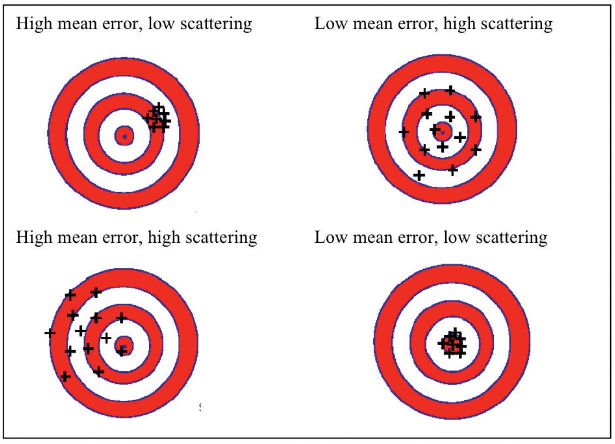


Figure 1: Scattering of the measurement values

Net load, *m*, expressed in verification scale intervals, *e*				Maximum permissible mean error for category X instruments	
XI	XII	XIII	XIIII	Initial verification	In-service inspection
$0 < m \leq 50\,000$	$0 < m \leq 5\,000$	$0 < m \leq 500$	$0 < m \leq 50$	±0.5 *e*	±1 *e*
$50\,000 < m \leq 200\,000$	$5\,000 < m \leq 20\,000$	$500 < m \leq 2\,000$	$50 < m \leq 200$	±1 *e*	±2 *e*
$200\,000 < m$	$20\,000 < m \leq 100\,000$	$2\,000 < m \leq 10\,000$	$200 < m \leq 1\,000$	±1.5 *e*	±3 *e*

Figure 2: OIML R 51, Table 3: Maximum permissible mean error (systematic error)

Table T.3. Class III - Tolerance in Divisions (e)		
Test Load in Divisions	**Tolerance in Divisions**	
Class III	**Acceptance**	**Maintenance**
0 - 500	± 0.5	± 1
501 - 2000	± 1.0	± 2
2001 - 4000	± 1.5	± 3
4001 +	± 2.5	± 5

Figure 3: HB44, Table T.3: Maximum permissible mean error (systematic error)

category Y); the latter type requires that the maximum permissible error (MPE) be complied with for every single measurement value, however only a minimum of 10 measurements has to be performed.

Maximum permissible errors

In R 51 Table 3 (see Figure 2), the mean systematic measurement error of the ACWs is divided into three load ranges and given as a function of the accuracy class. ACWs are tested against the error limit for initial verification.

NIST Handbook 44 gives the maximum permissible mean error in Table T.3 (see Figure 3). ACWs are tested against the Acceptance Tolerance.

Of note is the fourth weight range for loads above 4000 divisions (divisions are referred to in OIML publications as "verification scale intervals").

The maximum permissible standard deviation is defined in OIML R 51, Table 4 (see Figure 4). The numerical values are valid for the class designation factor (x) = 1. In the case of more accurate ACWs, the manufacturer selects a class designation factor which is smaller than (x) = 1, such as (x) = 0.5. This means that the standard deviation indicated in OIML R 51, Table 4 has to be multiplied by the class designation factor. Thus, for (x) = 0.5, the standard deviation is reduced by half.

Since the 2006 edition of OIML R 51, a correlation has been specified between the accuracy class and the class designation factor:

Value of the mass of the net load, *m* (g)	Maximum permissible standard deviation (as a percentage of *m* or in grams) for class designation factor, (x) = 1	
	Initial verification	In-service inspection
$m \leq 50$	0.48 %	0.6 %
$50 < m \leq 100$	0.24 g	0.3 g
$100 < m \leq 200$	0.24 %	0.3 %
$200 < m \leq 300$	0.48 g	0.6 g
$300 < m \leq 500$	0.16 %	0.2 %
$500 < m \leq 1\,000$	0.8 g	1.0 g
$1\,000 < m \leq 10\,000$	0.08 %	0.1 %
$10\,000 < m \leq 15\,000$	8 g	10 g
$15\,000 < m$	0.053 %	0.067 %

Figure 4: OIML R 51, Table 4: Maximum permissible standard deviation for class designation factor (x) = 1

- for classes XI and XII, (x) shall be less than 1;
- for class XIII, (x) shall be not greater than 1;
- for class XIIII, (x) shall be greater than 1.

In the 1996 edition of OIML R 51, ACW manufacturers were still free to choose the class designation factor as they wished.

Once again, ACWs are tested against the error limit for initial verification.

As the purpose of ACWs is to classify prepackaged goods of equal weight, the maximum permissible standard deviation of the ACWs was derived from the tolerable deficiencies of the package content (T) in accordance with OIML R 87 Table 2 (see Figure 5) by dividing its limiting values by 15 (5 × 3). The factor of 5 is derived from the T/5 requirement of OIML R 87. This requirement states that the overall error of the measuring instrument used may not exceed 0.2 T. The factor of 3 is based on the statistical assumption that,

Nominal quantity of product (Q_n) in g or mL	Tolerable deficiency *(T)* [a]	
	Percent of Q_n	g or mL
0 to 50	9	-
50 to 100	-	4.5
100 to 200	4.5	-
200 to 300	-	9
300 to 500	3	-
500 to 1 000	-	15
1 000 to 10 000	1.5	-
10 000 to 15 000	-	150
15 000 to 50 000	1	-

[a] *T* values are to be rounded up to the next 1/10 of a g or mL for $Q_n \leq 1\,000$ g or mL and to the next whole g or mL for $Q_n > 1\,000$ g or mL.

Figure 5: OIML R 87, Table 2: Tolerable deficiencies in actual content of prepackages

Table 2-5. Maximum Allowable Variations (MAVs) for Packages Labeled by Weight	
Labeled Quantity	Maximum Allowable Variations
Less than 36 g	10 % of labeled quantity
36 g or more to 54 g	3.6 g
More than 54 g to 81 g	5.4 g
More than 81 g to 117 g	7.2 g
More than 117 g to 154 g	9.0 g
More than 154 g to 208 g	10.8 g
More than 208 g to 263 g	12.7 g
More than 263 g to 317 g	14.5 g
More than 317 g to 381 g	16.3 g
More than 381 g to 426 g	18.1 g
More than 426 g to 489 g	19.9 g
More than 489 g to 571 g	21.7 g
More than 571 g to 635 g	23.5 g
More than 635 g to 698 g	25.4 g
More than 698 g to 771 g	27.2 g
More than 771 g to 852 g	29.0 g
More than 852 g to 970 g	31.7 g
More than 970 g to 1.12 kg	35.3 g
More than 1.12 kg to 1.25 kg	39.0 g
More than 1.25 kg to 1.45 kg	42.6 g
More than 1.45 kg to 1.76 kg	49 g
More than 1.76 kg to 2.13 kg	54 g
More than 2.13 kg to 2.63 kg	63 g
More than 2.63 kg to 3.08 kg	68 g
More than 3.08 kg to 3.58 kg	77 g
More than 3.58 kg to 4.26 kg	86 g
More than 4.26 kg to 5.30 kg	99 g
More than 5.30 kg to 6.48 kg	113 g
More than 6.48 kg to 8.02 kg	127 g
More than 8.02 kg to 10.52 kg	140 g
More than 10.52 kg to 14.33 kg	167 g
More than 14.33 kg to 19.23 kg	199 g
More than 19.23 kg to 24.67 kg	226 g
More than 24.67 kg	2 % of labeled quantity

Figure 6: NIST Handbook 133, Table 2-5: MAVs for packages labeled by weight

with a finite sample size of a test, 99.7 % of all measurement values are within a range of values between +3 s and –3 s, i.e. the scattering on each side of the Gaussian normal distribution curve corresponds to 3 times the standard deviation.

To proceed from the in-service maximum permissible standard deviation obtained in this way to the standard deviation which must be adhered to by the ACW during the initial verification, division by 1.25 (or multiplication by 0.8) is required.

In HB44, the maximum permissible standard deviation is specified in Section T.3.3.1.2 (b) for tests in automatic operation. Reference is made to the USA prepackaging ordinance, to NIST Handbook 133 (HB133, "Checking the Net Contents of Packaged Goods") and to the permissible underfill limit defined therein (MAV – Maximum Allowable Variation).

Table 2-5 (MAVs for Packages Labeled by Weight) of HB 133 deviates significantly from the specifications of OIML R 87 (Quantity of product in prepackages) (see Figure 6). Of note is the fact that deviating specifications are given for three areas of application for prepackages.

Number of weighings for automatic testing

During the type evaluation, the number of test weighings of HB44 corresponds to the 1996 version of OIML R 51. Therefore, the HB44 test is stricter, as the high number of 60 weighings is still to be used up to a load of 10 kg, whereas R 51 (2006) already reduces this number starting at 1 kg (see Figure 7).

Category	Load	Number of test weighings
X	$m \leq$ 1 kg	60
	1 kg < $m \leq$ 10 kg	30
	10 kg < $m \leq$ 20 kg	20
	20 kg < m	10
Y	Minimum of 10 for any load	

Figure 7: OIML R 51, Table 7: Number of test weighings

Table N.3.2. Number of Sample Weights per Test for Automatic Checkweighers		
Weighing Range m = mass of test load	Number of Sample Weights per Test	
	Field	Type Evaluation
20 divisions ≤ m ≤ 10 kg 20 divisions ≤ m ≤ 22 lb	30	60
10 kg < m ≤ 25 kg 22 lb < m ≤ 55 lb	16	32
25 kg < m ≤ 100 kg 55 lb < m ≤ 220 lb	10	20
100 kg (220 lb) < m	10	10

Figure 8: NIST HB44, Table N.3.2: Number of sample weights per test (referred to in OIML documents as "test weighings")

Special endurance tests for ACWs in the USA

Whereas for reasons of occupational safety OIML R 51 performs all influence factor tests in accordance with Chapter 6.4.5 only up to a maximum load of 20 kg in automatic operation (and permits static tests for loads in excess of 20 kg in non-automatic operation), all tests in the United States are performed with the entire weighing range in automatic operation.

This comparative strictness is due to other factors as well. In addition to HB44, ACWs in the United States also have to fulfill the requirements of NCWM Publication 14 (Pub 14) (see Figure 8). This publication includes a **permanence test**, an uninterrupted 100-hour endurance test in automatic operation without a single stop of the conveyor system. After this test is concluded, the accuracy of the ACW in automatic operation is checked again. During these 100 hours, the conveying speed is at least 80 % of the maximum speed. The packages moved across the conveyor belt and weighed dynamically have to weigh at least 75 % of the maximum capacity (Max) of the ACW. Furthermore, no large gap may be present between two successive packages, forcing the ACW to have weight applied to it as continuously as possible. In the case of fast ACWs, several hundred thousand packages are weighed during this test. Inferior conveyor systems which wear out quickly will not survive this endurance test.

All tests for the USA shall be carried out using a 60 Hz power supply.

Additional feature from NCWM Pub 14

The minimum acceptable indication of zero balance, according to Pub 14 Section 10.7, has to be in the same format as the decimal point of the verification scale interval (see Figure 9). Note: 00 g is not allowed according to OIML R 51.

Verification scale interval (e)	Minimum zero indication
0.01 g or 0.02 g or 0.05 g	0.00 g
0.1 g or 0.2 g or 0.5 g	0.0 g
1 g or 2 g or 5 g	0 g
10 g or 20 g or 50 g	00 g

Figure 9: Minimum acceptable indication of zero balance

Summary

ACWs which are type-approved in the United States need not shun competition with OIML R 51 ACWs. If anything, NTEP-certified ACWs are more robust and more reliable, as a complete examination is carried out over the entire approved weighing range. Only the EMC tests in Chapter T.8. of HB44 (Radio Frequency Interference (RFI) and Other Electromagnetic Interference Susceptibility) should be specified in greater detail.

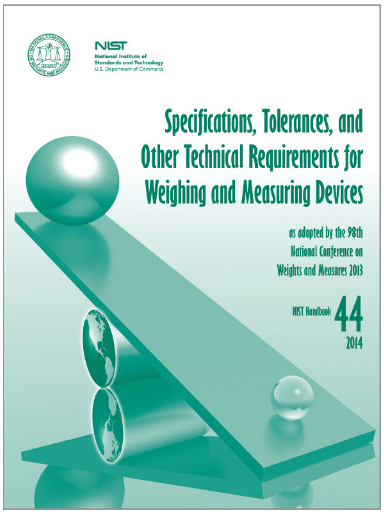
Acknowledgements

Bernd Zinke would like to extend his sincere gratitude to the Maryland Department of Agriculture, Weights and Measures Section, NTEP Program Weighing Devices in Annapolis, USA. Special thanks are due to Mrs. Andrea Buie and Mr. Edward Payne, who willingly imparted their profound knowledge of metrology and who were patient teachers.

About the authors

Wolfgang Euler, from Hennef (Sieg), Germany, a former employee of Chronos Richardson, and Bernd Zinke, of Wipotec Wiege- und Positioniersysteme GmbH in Kaiserslautern, Germany, can look back on many years of close and rich collaboration in the professional association of scales at VDMA in Frankfurt, as well as in CECIP, the European Association of Weighing Instruments Manufacturers. In their many specialized activities, both had a significant influence on a wide range of OIML International Recommendations, the European Measuring Instruments Directive (MID), the German Verification Ordinance and the DIN/EU standards.

Since 1992, Bernd Zinke has been responsible for legal metrology at Wipotec Wiege- und Positioniersysteme GmbH in Kaiserslautern, Germany, which also includes a distribution subsidiary, OCS Checkweighers. ■



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Bernd Zinke

OIML Systems

Basic and MAA Certificates registered 2015.12–2016.02

Information: www.oiml.org section "OIML Systems"

The OIML Basic Certificate System

The *OIML Basic Certificate System for Measuring Instruments* was introduced in 1991 to facilitate administrative procedures and lower the costs associated with the international trade of measuring instruments subject to legal requirements. The System, which was initially called "OIML Certificate System", is now called the "OIML Basic Certificate System". The aim is for "OIML Basic Certificates of Conformity" to be clearly distinguished from "OIML MAA Certificates".

The System provides the possibility for manufacturers to obtain an OIML Basic Certificate and an OIML Basic Evaluation Report (called "Test Report" in the appropriate OIML Recommendations) indicating that a given instrument type complies with the requirements of the relevant OIML International Recommendation.

An OIML Recommendation can automatically be included within the System as soon as all the parts - including the Evaluation Report Format - have been published. Consequently, OIML Issuing Authorities may issue OIML Certificates for the relevant category from the date on which the Evaluation Report Format was published; this date is now given in the column entitled "Uploaded" on the Publications Page.

Other information on the System, particularly concerning the rules and conditions for the application, issue, and use of OIML Certificates, may be found in OIML Publication B 3 *OIML Basic Certificate System for OIML Type Evaluation of Measuring Instruments* (Edition 2011) which may be downloaded from the Publications page of the OIML web site. ■

The OIML MAA

In addition to the Basic System, the OIML has developed a *Mutual Acceptance Arrangement* (MAA) which is related to OIML Type Evaluations. This Arrangement - and its framework - are defined in OIML B 10 (Edition 2011) *Framework for a Mutual Acceptance Arrangement on OIML Type Evaluations*.

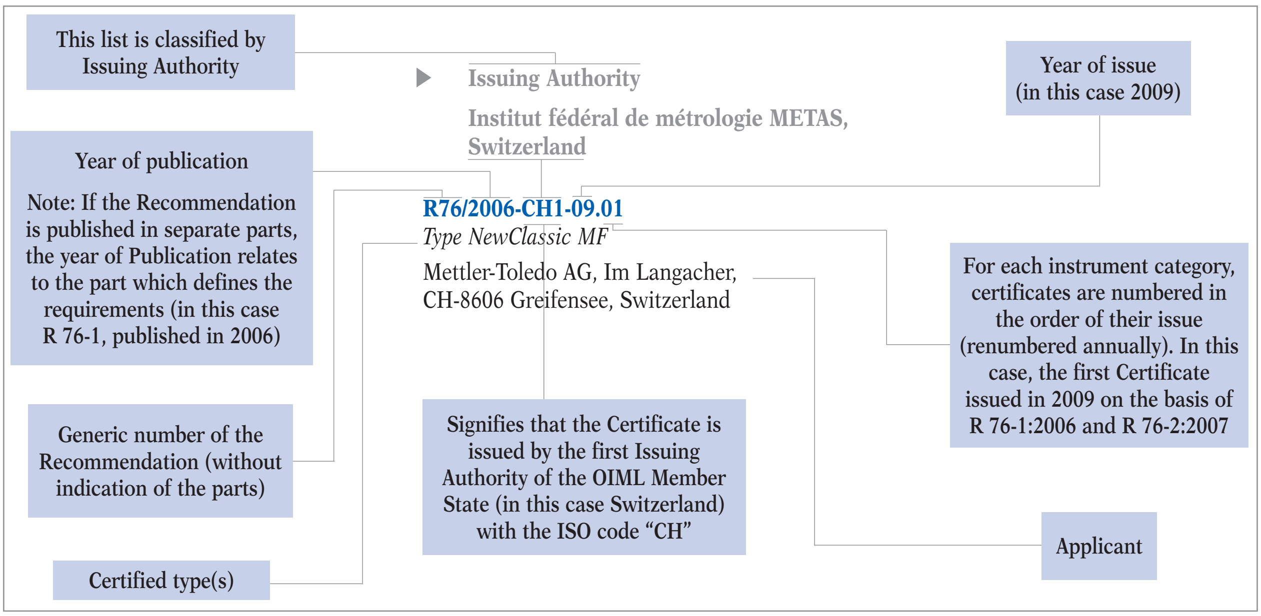
The OIML MAA is an additional tool to the OIML Basic Certificate System in particular to increase the existing mutual confidence through the System. It is still a voluntary system but with the following specific aspects:

- increase in confidence by setting up an evaluation of the Testing Laboratories involved in type testing,
- assistance to Member States who do not have their own test facilities,
- possibility to take into account (in a Declaration of Mutual Confidence, or DoMC) additional national requirements (to those of the relevant OIML Recommendation).

The aim of the MAA is for the participants to accept and utilize MAA Evaluation Reports validated by an OIML MAA Certificate of Conformity. To this end, participants in the MAA are either Issuing Participants or Utilizing Participants.

For manufacturers, it avoids duplication of tests for type approval in different countries.

Participants (Issuing and Utilizing) declare their participation by signing a Declaration of Mutual Confidence (Signed DoMCs). ■



INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Active electrical energy meters
Compteurs actifs d'énergie électrique

R 46 (2012)

▶ Issuing Authority / *Autorité de délivrance*

NMi Certin B.V.,
The Netherlands

R046/2012-NL1-2015.01
Measuring instrument - Type: 83334-1Mxxx or 83344-1Mxxx

Networked Energy Services, 550 Meridian Avenue, CA 95126 San Jose, California, United States

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Water meters intended for the metering of cold potable water and hot water
Compteurs d'eau pour le mesurage de l'eau potable froide et de l'eau chaude

R 49 (2006)

▶ Issuing Authority / *Autorité de délivrance*

Laboratoire National de Métrologie et d'Essais, Certification Instruments de Mesure, France

R049/2006-FR2-2009.06 Rev. 1
Single jet water meter ITRON - Type: TU1M DN25,32

Itron France, 11, Boulevard Pasteur, FR-67500 Haguenau, France

R049/2006-FR2-2011.02 Rev. 1
Water meter - Type: TU1 40F, TU1 50, TU1 65, TU1 80 and TU1 100

Itron France, 11, Boulevard Pasteur, FR-67500 Haguenau, France

R049/2006-FR2-2015.01
Water meter ITRON - Type: WOLTEX (WE)

Itron France, 11, Boulevard Pasteur, FR-67500 Haguenau, France

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Water meters for cold potable water and hot water
Compteurs d'eau potable froide et d'eau chaude

R 49 (2013)

▶ Issuing Authority / *Autorité de délivrance*

Czech Metrology Institute (CMI),
Czech Republic

R049/2013-CZ1-2015.01 Rev. 1
Water meter - Type: 280W/. . .

Spire Metering Technology, 15 Craig Road, MA 01720 Acton, Massachusetts, United States

▶ Issuing Authority / *Autorité de délivrance*

Physikalisch-Technische Bundesanstalt (PTB),
Germany

R049/2013-DE1-2016.01
Water meter intended for the metering of cold potable water and hot water. Woltman meter with mechanical indicating device - Type: WPD

Zenner International GmbH & Co. KG, Römerstadt 4, DE-66121 Saarbrücken, Germany

R049/2013-DE1-2016.02
Water meter intended for the metering of cold potable water and hot water. Woltman meter with mechanical indicating device - Type: WPHD

Zenner International GmbH & Co. KG, Römerstadt 4, DE-66121 Saarbrücken, Germany

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Continuous totalizing automatic weighing instruments (belt weighers)
Instruments de pesage totalisateurs continus à fonctionnement automatique (peseuses sur bande)

R 50 (2014)

Issuing Authority / *Autorité de délivrance*

NMRO Certification Services (NMRO), United Kingdom

R050/2014-GB1-2015.02
ICS-FH Series
Saimo Electric Co., Ltd., No.2, Loushan Road, Economic Development Zone, Xuzhou, Jiangsu, P.R. China

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Automatic catchweighing instruments
Instruments de pesage trieurs-étiqueteurs à fonctionnement automatique

R 51 (2006)

Issuing Authority / *Autorité de délivrance*

NMRO Certification Services (NMRO), United Kingdom

R051/2006-GB1-2009.03 Rev. 4
9000 Series Checkweigher / Weigh or Weight-Price labeller
Marel Ltd., Wyncolls Road, Severalls Industrial Park, Colchester CO4 9HW, United Kingdom

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Metrological regulation for load cells (applicable to analog and/or digital load cells)
Réglementation métrologique des cellules de pesée (applicable aux cellules de pesée à affichage analogique et/ou numérique)

R 60 (2000)

Issuing Authority / *Autorité de délivrance*

NMi Certin B.V., The Netherlands

R060/2000-NL1-2015.15 Rev. 1 (MAA)
Bending beam load cell, with strain gauges - Type: CZL601
Guangdong South China Sea Electronic Measuring Technology Co. Ltd., Dasheng Industrial Park, Machong, 523136 Guangdong Province, Dongguan, P.R. China

R060/2000-NL1-2015.17 Rev. 2 (MAA)
Compression load cell, with strain gauges - Type: CZL425
Guangdong South China Sea Electronic Measuring Technology Co. Ltd., Dasheng Industrial Park, Machong, 523136 Guangdong Province, Dongguan, P.R. China

R060/2000-NL1-2015.19 (MAA)
Tension load cell, with strain gauges - Type: STC
Vishay Transducers Celtron/Technologies Inc., Binguan Nan Dao Youyi Road, Hexi District, CN-300061 Tianjin, P.R. China

R060/2000-NL1-2015.20 (MAA)
Single point load cell, with strain gauges, equipped with electronics - Type: FIT7
Hottinger Baldwin Messtechnik GmbH, Im Tiefen See 45, DE-64293 Darmstadt, Germany

R060/2000-NL1-2015.25 (MAA)
Shear beam load cell, with strain gauges - Type: ILGBC-ASS
Zaklad Elektroniki Cyfrowej LABTRONIK Tomasz Zajas, ul. Romanowicza 2, 30-702 Krakow, Poland

R060/2000-NL1-2016.02 (MAA)
Compression load cell, with strain gauges - Type: MSB
Medeni Baskul San.Tic.Ltd.Sti, Gokceler Mah. T. Cemal Beriker Bulv. No:719/A, Mersin Karayolu 19. km Cukobirlik civari, Seyhan, Adana, Turkey

R060/2000-NL1-2016.03 (MAA)
Compression load cell, with strain gauges - Type: UZE-L 01
Uzay Baskul Endustriyel Tartim Sistemleri San.Tic.A.S., Ornek Sanayi Sitesi 1356 Sokak No:6, Bandirma, Balikesir, 10200 Turkey

▶ Issuing Authority / *Autorité de délivrance*

NMRO Certification Services (NMRO), United Kingdom

R060/2000-GB1-2016.01 (MAA)
QL-1x family
Hanzhong Quanyuan Electronic Co., Ltd, No 1032, Xinghan Road, Hantai District, Hanzhong, Shaanxi, P.R. China

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Nonautomatic weighing instruments
Instruments de pesage à fonctionnement non automatique

R 76-1 (1992), R 76-2 (1993)

▶ Issuing Authority / *Autorité de délivrance*

NMRO Certification Services (NMRO), United Kingdom

R076/1992-GB1-2015.04 (MAA)
CL5000J Series
CAS Corporation, #262, Geurugogae-ro, Gwangjeok-myeon, Yangju-si, Gyenonggi-do, Korea (R.)

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Non-automatic weighing instruments
Instruments de pesage à fonctionnement non automatique

R 76-1 (2006), R 76-2 (2007)

▶ Issuing Authority / *Autorité de délivrance*

Dansk Elektronik, Lys & Akustik (DELTA), Denmark

R076/2006-DK3-2015.09
Non-automatic weighing system - Type: 825
Cardinal Scale Manufacturing Co., 203 East Daugherty Street, P.O. Box 151, US-64870 Webb City, Missouri, United States

▶ Issuing Authority / *Autorité de délivrance*

Laboratoire National de Métrologie et d'Essais, Certification Instruments de Mesure, France

R076/2006-FR2-2012.01 Rev. 2 (MAA)
Indicator for non-automatic weighing instruments - Type: IDL
Arpege Master K, 15 rue de Dauphine, Bat 6 CS40216, FR-69800 Saint Priest, France

R076/2006-FR2-2015.01 Rev. 2 (MAA)
Indicator - Type IDL for non-automatic weighing instruments
Arpege Master K, 15 rue de Dauphine, Bat 6 CS40216, FR-69800 Saint Priest, France

R076/2006-FR2-2016.01 Rev. 0 (MAA)
Module Indicator - Type: MicroPACK'R
Pack Realisations S.A, 2 rue de la Caillarderiere, Zone Industrielle, FR-49070 Beaucouze, France

▶ Issuing Authority / *Autorité de délivrance*

NMi Certin B.V., The Netherlands

R076/2006-NL1-2014.11 Rev. 2 (MAA)
Indicator or Digital Data Processing Device - Type: EDI-2200
Yamato Scale Co., Ltd., 5-22 Saenba-cho, JP-673-8688 Akashi, Hyogo, Japan

R076/2006-NL1-2015.27 (MAA)
Non-automatic weighing instrument - Type: BagDrop V8 Unit
Bagdrop Systems B.V., Haringvliet 100, NL-3011 TH Rotterdam, Netherlands

R076/2006-NL1-2015.53 (MAA)
Non-automatic weighing instrument - Type: SS1X Series - Brand: ACLAS or Arm Pos
Xiamen Pinnacle Electrical Co., Ltd., 4F, Guangxia Building, North High-Tech Zone, Xiamen, CN-Fujian, P.R. China

R076/2006-NL1-2015.54 (MAA)
Non-automatic weighing instrument - Type: AB, RJ
Shinko Denshi Co., Ltd, 3-9-11 Yushima, Bunkyo-ku, JP-113-0034 Tokyo, Japan

R076/2006-NL1-2016.01 (MAA)
Non-automatic weighing instrument - Type: BW-0365
Nagata Scale Co. Ltd., No. 3, Lane 404, Chung Chen S. Rd., Yung Kand Dist., Tainan City, Chinese Taipei

R076/2006-NL1-2016.02 (MAA)
Indicator - Type: BW-8300
Nagata Scale Co. Ltd., No. 3, Lane 404, Chung Chen S. Rd., Yung Kand Dist., Tainan City, Chinese Taipei

R076/2006-NL1-2016.03 (MAA)
Non-automatic weighing instrument - Type: DS-983, DS-984 - Variants: ES, FS, BF, BC, RL, SA, SB, SC, RA, RB, PS, CD, C
Shanghai Teraoka Electronic Co., Ltd., Tinglin Industry Developmental Zone, Jin Shan District, CN-201505 Shanghai, P.R. China

R076/2006-NL1-2016.06 (MAA)
Indicator - Type: Ai5, Ai7 or Ai8
Hao Han Industry Company, 1F, No.8, Alley 10, Lane 114, Sec. 2, Xingnan Road, Zhonghe Dist., New Taipei City 235, Taiwan, Chinese Taipei

▶ **Issuing Authority /** ***Autorité de délivrance***
NMRO Certification Services (NMRO), United Kingdom

R076/2006-GB1-2013.03 Rev. 2 (MAA)
C510, C520, C530
Rinstrum Pty. Ltd., 41 Success Street, QLD 4110 Acacia Ridge, Australia

R076/2006-GB1-2015.04 Rev. 1 (MAA)
Type: ZP900 series
Avery Weigh-Tronix, Foundry Lane, Smethwick B66 2LP, United Kingdom

▶ **Issuing Authority /** ***Autorité de délivrance***
Physikalisch-Technische Bundesanstalt (PTB), Germany

R076/2006-DE1-2008.05 Rev. 2
Non-automatic price-computing weighing instrument - Type: K. . .
Bizerba GmbH & Co. KG, Wilhelm-Kraut-Strasse 65, DE-72336 Balingen, Germany

R076/2006-DE1-2012.02 Rev. 1
Non-automatic electromechanical price-computing weighing instrument for direct sales to public - Type: XC. . .
Bizerba GmbH & Co. KG, Wilhelm-Kraut-Strasse 65, DE-72336 Balingen, Germany

R076/2006-DE1-2013.05 Rev. 1
Non-automatic electromechanical weighing instrument - Type: es. . . /iS1. . ./iS2. . .
Bizerba GmbH & Co. KG, Wilhelm-Kraut-Strasse 65, DE-72336 Balingen, Germany

R076/2006-DE1-2015.04
Non-automatic electromechanical weighing instrument with or without lever - Type: SIWAREX WP231 NAWI
Siemens AG, Östliche Rheinbrücken Strasse 50, DE-76187 Karlsruhe, Germany

R076/2006-DE1-2016.01 (MAA)
Non-automatic price-computing weighing instrument for direct sales to the public - Type: MC . . .
Bizerba GmbH & Co. KG, Wilhelm-Kraut-Strasse 65, DE-72336 Balingen, Germany

▶ **Issuing Authority /** ***Autorité de délivrance***
Dansk Elektronik, Lys & Akustik (DELTA), Denmark

R076/2006-DK3-2016.03
Non-automatic weighing instrument - Type: PT252 / PT 253
PT Limited, Glenfield, Auckland, New Zealand

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Fuel dispensers for motor vehicles
Distributeurs de carburant pour véhicules à moteur

R 117 (1995) + R 118 (1995)

▶ **Issuing Authority /** ***Autorité de délivrance***
International Metrology Cooperation Office, National Metrology Institute of Japan (NMIJ) National Institute of Advanced Industrial Science and Technology (AIST), Japan

R117/1995-JP1-2013.01 Rev. 2
Fuel dispenser for motor vehicles, HA / HI series
Tominaga Mfg. Co., 88 Nishinokyo-Minamiryomachi, Nakagyo-ku, JP-604-8493, Kyoto, Japan

▶ **Issuing Authority /** ***Autorité de délivrance***
SP Technical Research Institute of Sweden, Sweden

R117/1995-SE1-2013.01 Rev. 1
One or two sided fuel/pump dispenser for motor vehicles - Type: Wayne Helix 1000, 2000, 4000, 5000, 6000
Wayne Fueling System Sweden AB, Hanogatan 10, SE-211 24 Malmo, Sweden

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Multi-dimensional measuring instruments
Instruments de mesure multidimensionnels

R 129 (2000)

Issuing Authority / *Autorité de délivrance*

NMi Certin B.V.,
The Netherlands

R129/2000-NL1-2015.01
Multi-Dimensional Measuring Instrument - Type: DM3610
Datalogic Automation Srl, Via Lavino no. 265,
IT-40050 Monte San Pietro, Italy

Database of all
OIML Certificates:

www.oiml.org/en/certificates/registered-certificates

info

The OIML is pleased to welcome the new

CIML Members

for Australia (Interim CIML Member): Mr. Anthony Donellan

for Denmark: Mrs. Hanne Scherrebeck

for Portugal: Mrs. Susana Santos

for Spain: Mrs. Belén Martin Blasco

Calendar of OIML meetings

OIML TC 8/SC 1

Revisions of R 71, R 80 and R 85
June 2016 (exact dates to be advised)
Göteborg, Sweden

OIML TC 8/SC 3/p 4

Revision of R 117
4–6 July 2016
Delft, The Netherlands

Committee Drafts received by the BIML

R 85: Automatic level gauges for measuring the level of liquid in stationary storage tanks

1 CD	TC 8/SC 1/p 10	USA	Received on 2016-03-02

R 71: Fixed storage tanks. General requirements

1 CD	TC 8/SC 1/p 9	USA	Received on 2016-03-02

R 126: Evidential breath alcohol analyzers

1 CD	TC 17/SC 7/p 3	DE+FR	Received on 2015-12-21

TC/SC NEWS

Reconciliation meeting of OIML TC 6 *Prepackaged products*

OIML R 87 *Quantity of product in prepackages*

27–29 January 2016 Rio De Janeiro, Brazil

The CIML preliminary ballot on the revision of OIML R 87 *Quantity of product in prepackages* closed on 24 September 2015. The result was that a sufficient majority of CIML Members supported the Draft Recommendation; however, two issues concerning sample sizes and the statistical requirements for sampling were identified that needed to be resolved before the Final Draft Recommendation could be submitted to the CIML for final approval.

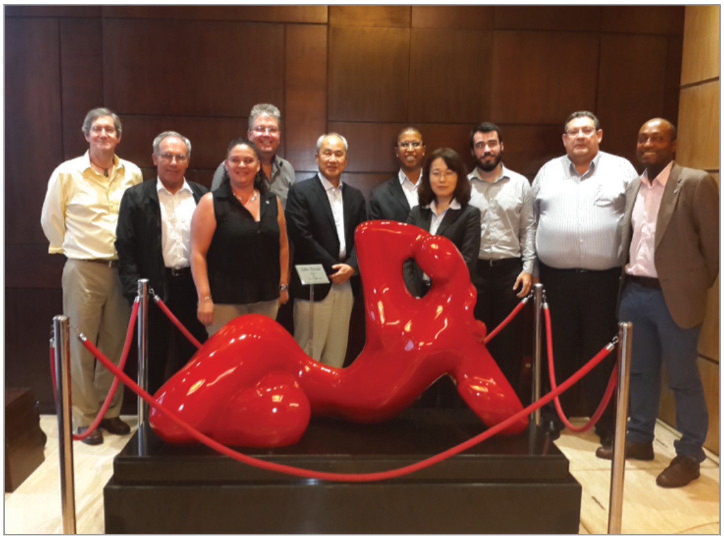
The BIML discussed this matter with both the CIML Member for South Africa, Mr. T. Madzivhe and the Convener of the Project Group, Mr Jaco Marneweck, at the time of the 50th CIML Meeting in Arcachon and it was proposed that the Secretariat arrange a "reconciliation meeting" with experts from those countries that brought up these issues (Brazil and Switzerland) and also Japan, which proposed new tables and sample sizes.

The meeting was intentionally limited in scope and focused only on the statistical issues. It was important to resolve the problems with the statistical issues to ensure that R 87 can be used for enforcement of the accuracies of measurements made under legal metrology legislation. Previously, OIML R 87 had been criticized for inaccuracies in the statistical model employed in the Recommendation by various experts such as Messrs. Willink and Field.

Although it had been extremely difficult for the BIML to organize such a reconciliation meeting at very short notice, after discussions with the project group members, who would provide statistical expertise, it was decided to hold the meeting in Brazil from 27 to 29 January 2016 at the offices of the Brazilian Society of Metrology.

The President of INMETRO welcomed participants to Brazil and wished them well with their endeavours to successfully address concerns regarding the statistical matters. The Secretariat then provided background information to explain the importance of the meeting and what was expected of the participants to ensure the final draft of OIML R 87 could be finalised. The main focus of the meeting was to ensure an appropriate sampling plan which would meet the statistical requirements laid down in the final Draft Recommendation.

The outcome of the meeting was very successful in that the Secretariat could report that all concerns regarding the statistical sampling plans were addressed as well as all the other comments of a general nature that had been received from CIML Members. Work plans were also set to ensure that the Recommendation could be approved by the CIML during its 51st meeting in 2016. ■



CEEMS

Analysis of CIML Resolution 2015/10

Peter Mason, CIML President

Introduction

In the January Edition of the Bulletin we published an account of the second Seminar held in 2015 concerning Countries and Economies with Emerging Metrology Systems (CEEMS) and the subsequent discussion during the 50th CIML meeting which resulted in the adoption of Resolution 2015/10.

This resolution is a very important milestone in the OIML's approach to what used to be called "Developing Country" issues and represents a substantial number of measures to be implemented over the next few years. However, it is long and complicated – but that is traditionally how the CIML does its work! The intention of this article is to re-order and explain the 17 key paragraphs so that they can be better understood.

In the preamble there is a key phrase:

Recognizing the continued efforts that are needed to assist in building the capacity of legal metrology institutions and their staff in countries and economies with emerging metrology systems (CEEMS)

which confirms the CIML's commitment to taking action in this area. However, it is the 16 other paragraphs in which the CIML *instructs*, *requests* and *urges* which represent the substance of the package put forward. These can be grouped into three categories:

1 Instructions to the BIML and CIML Office Holders;

2 Direction of Technical Work; and

3 Recommendations to Member States and other organisations.

1 Instructions to the BIML and CIML office holders

There are seven paragraphs which are directed primarily at the BIML:

Instructs the Bureau to continue its efforts to participate in capacity building activities through training courses and other regional activities organized by other organizations,

Instructs the Bureau to continue to work with the constituent bodies of the DCMAS Network, in particular the BIPM, in identifying new initiatives where the OIML can make a direct contribution,

Instructs the Bureau to further develop the OIML website such that it may be used as a source of up-to-date information on capacity-building initiatives, including training materials and, if feasible, a database of experts available to contribute to such work,

Instructs the Bureau to take account of the need for greater involvement of CEEMS in OIML technical work when further developing the OIML website's functionality in supporting the technical work,

Instructs the Bureau to pay particular attention to the role of the OIML Bulletin and the OIML website in facilitating the exchange of new ideas, and in particular new approaches to legal metrology,

Notes the particular contribution that research can play in promoting and evaluating new approaches to legal metrology, and instructs the Director to take this into account when considering projects which can be supported by the special fund created by the 14th Conference,

Requests its President, Vice Presidents and the Bureau to take particular account of the needs of CEEMS when involved in activities related to Objective 5 in the OIML Strategy (OIML B 15:2011).

The significance of some of these items – for instance the support for Bureau staff to participate in training courses organised by others (such as the AFRIMETS Metrology Schools), co-operation within the DCMAS Network, promotion of the case for better metrology at the highest levels of government within Member States – is that they endorse current activities without proposing a significant change in the amount of activity. Work on some of the other items – development of the OIML website as a resource to be used by everyone with an interest in CEEMS issues, use of the Bulletin as well as the website to share new ideas more widely and use of the Special Fund approved in 2012 to promote relevant research – has also already started, but the resolution makes it clear that there is scope to do more, even within the resources currently available. Finally, there is one specific proposal – the creation of a public database of experts available to work with the CEEMS community – which is entirely new, but which is something that has been widely requested.

2 Direction of technical work

Four paragraphs in the resolution directly relate to how technical work, one of the core OIML activities, is conducted:

> Requests relevant Technical Committees and Subcommittees to take note of the demand from CEEMS to ensure Recommendations take more account of the needs of CEEMS,
>
> Instructs the Certificate System Project Group (CSPG), established by Resolution 2015/18, to ensure that the needs of CEEMS are addressed in the OIML Certificate System,
>
> Instructs the Project Group for the revision of OIML B 6:2013 *Directives for OIML technical work* (see Resolution no. 2015/13) to take account of the need for greater involvement of CEEMS in OIML technical work when drafting the revision of B 6,
>
> Urges the conveners of project groups TC 3/SC 6/p 1 *Premarket surveillance activities* and TC 6/p 5 *Guidance for defining the system requirements for a certification system for prepackages* to bring their work to a conclusion as soon as possible.

Two of these concern Project Groups – one developing the new OIML Certificate System and the other undertaking the revision of B 6:2013 – set up at the same CIML meeting; these paragraphs will be built into the work of those groups from the beginning. A third relates to two projects, a guide on *Premarket surveillance activities* (often called "Conformity to Type") and Guidance on the *certification system for prepackages*, which have from the beginning been recognised as important to the CEEMS community and which are both nearing completion. Perhaps the most significant, however, is the paragraph asking Technical Committees and Subcommittees to take note of the demand that Recommendations take more account of the needs of CEEMS. One particular area in which this might be followed up is for OIML Recommendations on specific types of instrument to contain provisions that are relevant to verification activities as well as type approval applications, which is where the main emphasis tends to be at the moment.

3 Recommendations to Member States and other organisations

The remaining paragraphs of the resolution are more varied as they are directed at several different audiences:

> Expresses its support for the work of the DCMAS Network,
>
> Endorses the proposal of the advisory group, set up by Resolution no. 2013/9, to establish a "pilot training center" and encourages the authorities in P.R. China to give their full support to this initiative,
>
> Urges other Member States to study the results of this first pilot and to consider, in the light of an evaluation of the pilot, whether they are able to initiate something similar,
>
> Urges Member States to be ready to propose conveners for projects to produce other documents proposed during the two seminars organized in 2015,
>
> Urges both Member States and Corresponding Members to consider opportunities to second staff to the Bureau in order to develop the skills and experience of appropriate individuals.

Along with the two paragraphs instructing the Bureau to work with other organisations involved in capacity building activities, directly or through DCMAS, the paragraph expressing support for the work of the DCMAS Network, represent encouragement to those organisations to continue and indeed extend their work. A further paragraph is particularly addressed to the authorities in China, encouraging them to support the "pilot training center" which has been proposed by the Advisory Group; another is addressed to Member States in a position to do something similar to ask them to study the results of this pilot to see if they wish to make a similar iniative. Harnessing the resources of Member States who have their own development programmes and forging closer links between the OIML and these programmes is likely to enhance the effectiveness of both.

More generally, the resolution asks Member States to volunteer conveners to produce other documents proposed during the 2015 seminars. This is important because producing more documents will inevitably result in an increase in technical work and this will be feasible only if there are sufficient numbers of conveners available to take these projects forward.

Finally, there is one part of the resolution directly addressed to the CEEMS among OIML Membership – this is to ask them to look for opportunities to second staff to the Bureau in order to develop their skills and experience. In itself, the small size of the Bureau means that this will be a limited opportunity, but if the arrangement proves successful we hope that individual Member states will also set up similar schemes.

At the Presidential Council meeting in March it was agreed that the above framework would be used to monitor progress in all the various areas covered by Resolution 2015/10. We will therefore be looking to use it for the report to be provided at the CIML meeting to be held in October. ■

OIML CERTIFICATE SYSTEM

List of OIML Issuing Authorities

The list of OIML Issuing Authorities is published in each issue of the OIML Bulletin. For more details, please refer to our web site: www.oiml.org
There are no changes since the last issue of the Bulletin.

		R 16	R 21	R 31	R 35	R 46	R 49	R 50	R 51	R 58	R 60	R 61	R 75	R 76	R 81	R 85	R 88	R 93	R 97	R 98	R 99
AT1	Bundesamt für Eich- und Vermessungswesen (BEV)							■	■	■		■		■		■	■		■	■	
AU1	National Measurement Institute (NMI)						■	■	■		■			■		■					
BE1	SPF Economie, PME, Classes Moyennes et Energie													■					■	■	
BG1	State Agency for Metrology and Technical Surveillance (SAMTS)													■						■	
BR1	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO)													■							
CH1	Institut fédéral de métrologie METAS	■		■			■	■	■		■	■		■					■	■	
CN1	General Administration of Quality Supervision, Inspection and Quarantine of P. R. China (AQSIQ)			■		■		■	■		■	■		■					■	■	
CZ1	Czech Metrology Institute (CMI)						■							■	■	■					
DE1	Physikalisch-Technische Bundesanstalt (PTB)			■	■		■	■	■	■	■	■		■		■	■		■	■	■
DK1	The Danish Accreditation and Metrology Fund (DANAK)							■	■		■	■		■						■	
DK2	FORCE Certification A/S						■														
DK3	Dansk Elektronik, Lys & Akustik (DELTA)							■	■		■	■		■							
ES1	Centro Español de Metrología (CEM)						■		■		■	■		■					■	■	
FI1	Inspecta Oy							■	■		■	■		■		■					
FR1	Ministère de l'Economie, de l'Industrie et de l'Emploi (MEIE)	*All activities and responsibilities were transferred to FR2 in 2003*																			
FR2	Laboratoire National de Métrologie et d'Essais (LNE)		■	■			■	■	■	■	■	■		■	■	■	■		■	■	■
GB1	NMRO Certification Services (NMRO)		■		■		■	■	■		■	■	■	■		■				■	
HU1	Hungarian Trade Licensing Office (MKEH)													■							
IT1	Ministero dello sviluppo economico - Direzione generale mercato, concorrenza, consumatori, vigilanza e normativa tecnica						■														
JP1	National Metrology Institute of Japan / National Institute of Advanced Industrial Science and Technology (NMIJ / AIST)						■				■			■							
KR1	Metrology and Measurement Division (KATS)													■							
NL1	NMi Certin B.V.		■	■		■	■	■	■		■	■		■	■	■			■		■
NL2	KIWA Nederland B.V.						■														
NO1	Norwegian Metrology Service (Justervesenet)							■	■			■		■							
NZ1	Measurement and Product Safety Service (MAPSS Wellington)													■							
PL1	Central Office of Measures (GUM)													■						■	
RO1	Bureau Roumain de Métrologie Légale (B.R.M.L.)																		■	■	
RU1	Russian Research Institute for Metrological Service (VNIIMS)			■			■	■	■	■	■	■		■		■	■	■	■	■	
SE1	Swedish National Testing and Research Institute AB (S.P.)							■	■		■	■		■		■				■	
SI1	Metrology Institute of the Republic of Slovenia (MIRS)													■							
SK1	Slovak Legal Metrology						■							■							
US1	NCWM, Inc.										■			■							
VN1	Directorate for Standards and Quality (STAMEQ)													■							

	R 102	R 104	R 105	R 106	R 107	R 110	R 112	R 113	R 114	R 115	R 117/118	R 122	R 126	R 128	R 129	R 133	R 134	R 136	R 137	R 139
AT1	■	■		■	■	■			■	■	■									
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BG1																				
BR1																				
CH1			■	■	■						■						■			
CN1					■						■						■			
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IT1																				
JP1										■	■									
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NZ1																				
PL1	■																			
RO1						■			■	■										
RU1	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	
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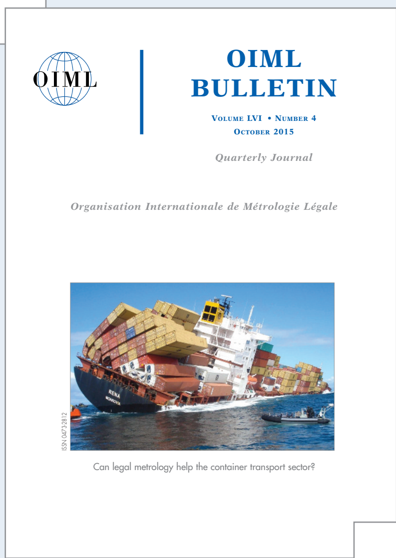
SI1																				
SK1											■									
US1																				
VN1																				

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.;
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