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Editorial

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OIML cooperation with ILAC and the IAF

The implementation of the OIML Mutual Acceptance Arrangement (MAA) has reinforced existing cooperation between ILAC (the Inter Laboratory Accreditation Cooperation) and the OIML. Within the scope of the MAA, accreditation is one option to evaluate the competence of testing laboratories on the basis of ISO/IEC 17025 *General requirements for the competence of testing and calibration laboratories*.

This cooperation was confirmed by the signing of a Memorandum of Understanding (MoU) between the two Organizations in Cancun, Mexico in November 2006 on the occasion of the ILAC General Assembly. The scope of the MoU is not limited to the MAA but also includes cooperation in conformity assessment in the field of legal metrology, in particular to improve confidence in type evaluation test results performed on the basis of OIML Recommendations.

A joint ILAC/OIML Working Program has been developed for 2007 and 2008 to implement this MoU. One of the main issues will be to develop lists of assessors and technical and metrological experts who could be employed either by ILAC, or by the OIML, to guarantee harmonization in ILAC and OIML processes and to increase confidence in accreditation in the field of legal metrology.

Conformity assessment in the field of legal metrology is not limited solely to testing, but may also include other activities such as product certification, quality management system certification, and inspection (which are also covered by ISO and IEC Standards).

Therefore, ILAC and the OIML have mutually decided to further extend the MoU to include the IAF (International Accreditation Forum) which has set up Multilateral Recognition Arrangements among National Accreditation Bodies responsible for accrediting product and quality management system certification bodies. It is planned to implement this extension by the end of 2007.

Such arrangements, together with the ILAC Mutual Recognition Arrangement among National Accreditation bodies responsible for accrediting calibration and testing laboratories through a close cooperation between ILAC, IAF and the OIML, are certainly a precious tool when considering accreditation processes in the field of legal metrology.

In addition, cooperation with international organizations for standardization (ISO and the IEC) and participation in their respective technical work will contribute to promoting legal metrology aspects in the field of testing, certification and inspection. ■

GAMING

Mathematical control of the randomness of gambling devices II

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Abstract

Three topics are discussed in this paper.

In order to determine the precision of the χ^2 test, the changes caused in the expectation and in the standard deviation of the random variable:

$$\chi^2 \equiv \sum_{j=1}^{v} \frac{(k_j - Np_j)^2}{Np_j}$$

are examined by substituting the supposed, expected or prescribed probabilities q_j in place of the real, true probabilities p_j into the above formula.

For specific "gambling" purposes, in order to exclude unnaturally small deviations it is suggested to use the χ^2 criteria in the form $\boxed{A \le \chi^2 \le A + W}$ *instead of the classical criteria* $\boxed{\chi^2 \le \chi^2_{crit}}$.

In the October 1999 OIML Bulletin the author published a paper entitled "Mathematical control of the randomness of gambling devices" [1]. This study is expanded in the present paper. In [1] the method of modulated differences was suggested for testing the randomness of roulette-type gambling games. In this paper an appropriate test is adapted for lottery-type games as well.

1 Accuracy of the χ^2 test

In order to control the randomness of gambling devices the 3σ test and the χ^2 test are most often used. The latter serves as a basis for almost all hypothesis tests on probability distributions, including certain normality tests. In the case of gambling games, the following are examined:

- whether the supposed probabilities of given events can be equal to the real probabilities of the events, and
- in the case of roulette wheels, for instance, whether the chances of spinning any number are the same (i.e. whether the hypothesis on uniform distribution is true).

As a reminder the so called χ^2 theorem is cited which forms the basis of the χ^2 tests.

If the random events $A_1, A_2, \ldots, A_j, \ldots, A_v$ with probabilities $p_1, p_2, \ldots, p_j, \ldots, p_v$ mutually exclude each other and constitute a complete system of events, i.e. if $\sum_{j=1}^{v} p_j = 1$, then the distribution of the random variable:

$$\chi^2 \equiv \sum_{j=1}^{v} \frac{(k_j - Np_j)^2}{Np_j} \tag{1}$$

formed from the frequencies $k_1, k_2, \ldots, k_j, \ldots, k_v$, extends to an χ^2 distribution with $r = v - 1$ degree of freedom if $N \to \infty$. Here the frequencies k_j show how many times the events A_j occurred during N independent experiments. In proving this theorem, use is made of the fact that the common distribution of the frequencies k_j is a v-variable Bernoulli distribution.

Since the expectation of the random variable Y following an χ^2 distribution with r degree of freedom is:

$\mu(Y) \equiv \langle Y \rangle = r$ and its variance is:

$$\sigma^2(Y) \equiv \langle Y^2 \rangle - \langle Y \rangle^2 = 2r$$

the standard deviation of the above random variable χ^2 extends to the finite constant $\sqrt{2(v-1)}$, independent of N and of the probabilities p_j, while its expectation equals exactly $v - 1$.

In the case of roulette wheels with a single zero ($v = 37$) the expectation of the above random variable χ^2 equals 36 and its standard deviation extends to $\sqrt{72}$, despite the fact that in the definition of the variable and during its practical calculation the number of experiments N is used, which can be arbitrarily large.

The random variable in equation (1) is a theoretical construction in the sense that in the formula the *true, real-life* probabilities p_j occur. When the theorem is used in practice the existing (but not exactly known) probabilities are substituted by the supposed, expected or prescribed ones. When the formula is not used with the real probabilities the above theorem can no longer be used.

Below we will examine how the characteristics of the random variable χ^2 change when the true probabilities p_j are substituted into equation (1) by the supposed probabilities q_j, which are not necessarily equal to true probabilities, while the values of the true probabilities remain p_j.

$$\chi^2 \equiv \sum_{j=1}^{v} \frac{(k_j - Nq_j)^2}{Nq_j} \tag{1*}$$

where: $\sum_{j=1}^{v} k_j = N$, and $\sum_{j=1}^{v} q_j = 1$

If for the simple numbers $x_1, x_2, \ldots, x_j, \ldots, x_v$ (which do not necessarily represent the possible values of a real random variable) we use the usual symbolism related to the expectation and variance of a real random variable, i.e. if we introduce the following notations:

$$\langle x \rangle \equiv \sum_{j=1}^{v} p_j x_j \text{ and}$$

$$\sigma^2(x) \equiv \langle x^2 \rangle - \langle x \rangle^2$$

then for the expectation of the random variable χ^2 according to (1*):

$$\mu \equiv \mu(\chi^2) \equiv \langle \chi^2 \rangle = N \left\langle \frac{p-q}{q} \right\rangle + \left\langle \frac{1-p}{q} \right\rangle \tag{2}$$

can be given, where:

$$\left\langle \frac{p-q}{q} \right\rangle \equiv \sum_{j=1}^{v} p_j \frac{p_j - q_j}{q_j} \text{ and}$$

$$\left\langle \frac{1-p}{q} \right\rangle \equiv \sum_{j=1}^{v} p_j \frac{1-p_j}{q_j}$$

Equation (2) returns the value $v - 1$ only in the case when each supposed q_j exactly equals the real probability p_j, i.e. when the hypothesis on the probability distribution is true. In this case the quantity $\left\langle \frac{p-q}{q} \right\rangle$ occurring in the above formula evidently equals zero, while the value of the quantity $\left\langle \frac{1-p}{q} \right\rangle$ is:

$$\left\langle \frac{1-p}{q} \right\rangle \equiv \sum_{j=1}^{v} p_j \frac{1-p_j}{q_j} = \sum_{j=1}^{v} p_j \frac{1-p_j}{p_j} = \sum_{j=1}^{v} (1-p_j) = v - 1$$

Otherwise the quantity $\left\langle \frac{p-q}{q} \right\rangle$ is always positive, so the expectation of the random variable χ^2 according to (1*) reaches infinity in the case of $N \to \infty$ instead of being equal to the finite constant $v - 1$. It can also be deduced from equation (2) that this "reaching infinity" occurs faster when the number N of experiments is high and the differences $p_j - q_j$ are large. For the sake of completeness the variance of the random variable χ^2 according to (1*) is also given:

$$\sigma^2 \equiv \sigma^2(\chi^2) \equiv \langle \chi^4 \rangle - \langle \chi^2 \rangle^2 =$$

$$= 2\frac{N-1}{N}\left[2(N-2)\sigma^2\left(\frac{p}{q}\right) + 3\left\langle \frac{p}{q^2} \right\rangle - \left\langle \frac{p}{q} \right\rangle^2 - 2\left\langle \frac{1}{q} \right\rangle \left\langle \frac{p}{q} \right\rangle\right] + \frac{1}{N}\sigma^2\left(\frac{1}{q}\right) \tag{3}$$

where:

$$\left\langle \frac{p}{q} \right\rangle \equiv \sum_{j=1}^{v} p_j \frac{p_j}{q_j} \equiv \sum_{j=1}^{v} \frac{p_j^2}{q_j}$$

$$\sigma^2\left(\frac{p}{q}\right) \equiv \left\langle \frac{p^2}{q^2} \right\rangle - \left\langle \frac{p}{q} \right\rangle^2 \equiv \sum_{j=1}^{v} p_j \frac{p_j^2}{q_j^2} - \left\langle \frac{p}{q} \right\rangle^2 \equiv \sum_{j=1}^{v} \frac{p_j^3}{q_j^2} - \left\langle \frac{p}{q} \right\rangle^2$$

$$\left\langle \frac{p}{q^2} \right\rangle \equiv \sum_{j=1}^{v} p_j \frac{p_j}{q_j^2} \equiv \sum_{j=1}^{v} \frac{p_j^2}{q_j^2}$$

$$\left\langle \frac{1}{q} \right\rangle \equiv \sum_{j=1}^{v} p_j \frac{1}{q_j} \equiv \sum_{j=1}^{v} \frac{p_j}{q_j} \text{ and}$$

$$\sigma^2\left(\frac{1}{q}\right) \equiv \left\langle \frac{1}{q^2} \right\rangle - \left\langle \frac{1}{q} \right\rangle^2 \equiv \sum_{j=1}^{v} p_j \frac{1}{q_j^2} - \left\langle \frac{1}{q} \right\rangle^2 \equiv \sum_{j=1}^{v} \frac{p_j}{q_j^2} - \left\langle \frac{1}{q} \right\rangle^2$$

The quantity $\sigma^2\left(\frac{p}{q}\right)$ in equation (3), determining the highest power of N, equals zero only when each quotient p_j / q_j is equal, i.e. when $p_j = q_j$ for all j, otherwise $\sigma^2\left(\frac{p}{q}\right)$ is always positive. The only point worth bearing in mind in equation (3) is that $\sigma(\chi^2)$ is proportional to $\sqrt{N}$, and is larger when the differences $p_j - q_j$ are also large.

So the random variable χ^2 of finite expectation and of finite standard deviation in the case of the true hypothesis becomes of infinite (proportionally to N) expectation and of infinite (proportionally to $\sqrt{N}$) standard deviation, if the hypothesis is not true and the number N of experiments extends to infinity.

Table 1 relates to single zero roulette wheels used in Hungary, and illustrates the foregoing. The Table is compiled considering the following suppositions and conditions:

- Every supposed probability q_j is equal:

  $q_j = \frac{1}{v} = \frac{1}{37} = 0.027027$. In the case of roulette wheels this supposition is quite logical; the test is even performed in order to check whether this condition is fulfilled.
- It is supposed in this simple model that out of the 37 real probabilities p_j:

  18 values p_j equal $\frac{1}{37} - \varepsilon$,

Table 1 Expectation and standard deviation of the random variable χ^2 as a function of the number of experiments N and of the deviation ε

N \ ε	0.001		0.002		0.003		0.004		0.005		0.006	
	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ
10	6	8	36	8	36	8	36	8	36	8	36	8
100	36	8	37	9	37	9	38	9	39	9	41	10
1000	37	9	41	10	48	11*	57	13*	69	14**	84	16***
10000	49	11*	89	17***	156	23***	249	30***	369	37***	515	44***
100000	169	25***	569	47***	1235	69***	2167	92***	3366	114***	4831	135***

18 values p_j equal $\frac{1}{37} + \varepsilon$, and the remaining

one value p_j equals $\frac{1}{37}$ exactly.

By this supposition the condition $\sum_{j=0}^{36} p_j = 1$ is fulfilled.

This probability distribution is not a real-life one, but is very simple and is suited to demonstrating the effect of the deviations.

- The value of ε changes from 0.001 to 0.006 uniformly, in steps of 0.001.
- The number of experiments N changes from 10 to 100 000 exponentially.
- The table contains data rounded to the nearest integer.

The columns headed μ give the expectations $\langle\chi^2\rangle$ according to equation (2), and the columns headed σ give the theoretical standard deviations $\sigma\langle\chi^2\rangle$ calculated on the basis of equation (3) as a function of the number of experiments N and of the deviation ε.

In Table 1 the pairs μ, σ are marked by * for which $\mu - 2\sigma < 36 \le \mu - \sigma$, by ** for which $\mu - 3\sigma < 36 \le \mu - 2\sigma$ and by *** for which the inequality $\mu - 3\sigma \ge 36$ is true. In the latter case the number N of experiments and the value of ε characterizing the deviation from reality are big enough for the density functions of χ^2 according to (1) and of χ^2 according to (1*) to be separated clearly enough, so the test will result in a rejection with a high probability.

The foregoing proves exactly that the χ^2 test is indeed suitable for checking the hypothesis on probability distributions and is clear-cut when the number of experiments N is large enough.

For a fixed number N of experiments the hypothesis can definitely be rejected when the difference between the hypothesis and reality is large; to ascertain the smaller deviations (see the first column in Table 1, for example), sometimes a huge number of experiments N is necessary.

2 "Confidence interval" for the random variable χ^2

Considering that the random variable χ^2 according to (1*) is "small" with a high probability if the hypothesis is true and is "large" if not, the test is usually performed by calculating an upper limit χ^2_{crit} on the basis of the theorem above, from the condition $P = F_{v\text{-}1}(\chi^2_{crit})$ using the χ^2 distribution with $r = v - 1$ degree of freedom. The value of χ^2, determined experimentally, must be less than χ^2_{crit}, with a (high, prescribed) probability P if the hypothesis is true, i.e. the hypothesis will be retained when the condition

$$\boxed{\chi^2 \le \chi^2_{crit}} \tag{4}$$

is fulfilled, and rejected otherwise.

Considering that the natural lower limit of χ^2 equals zero, the use of the above procedure is similar to when a measurement result is given by a confidence interval $[0, \chi^2_{crit}]$ of a confidence level P.

Despite the doubtless analogy there are two conspicuous differences between the confidence intervals usual in metrology and the above intervals $[0, \chi^2_{crit}]$:

- Giving a measurement result in the form of a confidence interval is indeed the *estimate* of the true value, while the interval $[0, \chi^2_{crit}]$ is a *prognosis* of the future value of a random variable: χ^2 will fall into this interval with the prescribed probability P, if the hypothesis is true;
- The metrological confidence interval is created around the measurement result (symmetrically or sometimes asymmetrically), the interval $[0, \chi^2_{crit}]$ is the choice from the infinite possible intervals belonging to the given P, whose lower limit equals zero. Perhaps there is no example of such a practice in metrology.

Why is the interval $[0, \chi^2_{crit}]$ still used in statistics? Because the upper limit of all the other possible intervals belonging to the given P is greater than χ^2_{crit}, and to obtain a clear decision it is evidently necessary for the upper limit to be small. However, the issue (which is unusual in statistics but logical in metrology) should be raised of how the interval will be changed, if the condition lower limit = 0 were to be replaced by the condition: for the interval belonging to the given P to have a minimal width. To answer this question a simple theorem (not found in any literature) related to the intervals of minimal width will be proved. The general theorem is valid not only in the concrete situation:

- Let Y be a continuous random variable having the distribution function $\Phi_Y(x)$ and the density function $\varphi_Y(x)$ with a single maximum, where of course: $\frac{d\Phi_Y(x)}{dx}=\varphi_Y(x)$. It follows from the definition

of the distribution functions that the equation $P = \Phi_Y(A + W) - \Phi_Y(A)$ is true for the confidence interval having a lower limit A, a width W (consequently an upper limit $A+W$) and a confidence level P. For the arbitrary but ***fixed*** P and Φ_Y the above formula can be considered as being an implicit function giving the dependence of the width W of the lower limit A.

Let us derive both sides of the above equation according to A.

$$0=\varphi_Y(A+W)\left(1+\frac{dW}{dA}\right)-\varphi_Y(A)$$

The width W, as a function of the lower limit A, can only be minimal if the relationship $\frac{dW}{dA}$ is fulfilled. So in the general case as the condition of the confidence interval having a minimal width we obtain:

$$\varphi_Y(A) = \varphi_Y(A + W) \tag{5}$$

The above relationship can be illustrated as follows. Let the curve of the density function $\varphi_Y(x)$ be sectioned by a parallel in line with the X-axis. The intersections of the curve and the straight line determine the two limits of a confidence interval of minimal width.

In the case of density functions having a single maximum, such as the normal or the χ^2 distributions, for instance, equation (5) evidently gives the necessary and sufficient condition of the confidence interval with a minimal length.

Let us apply (5) for the density function:

$$f_r(x)=\frac{1}{2\Gamma\left(\frac{r}{2}\right)}\left(\frac{x}{2}\right)^{\frac{r-2}{2}}e^{-\frac{x}{2}}$$

of the χ^2 distribution with r degree of freedom:

$$A^{\frac{r-2}{2}}e^{-\frac{A}{2}}=(A+W)^{\frac{r-2}{2}}e^{-\frac{A+W}{2}}$$

In the actual case from here

$$A=\frac{W}{e^{\frac{W}{r-2}}-1} \text{ and } A+W=\frac{W}{1-e^{-\frac{W}{r-2}}}\equiv Ae^{\frac{W}{r-2}} \tag{6}$$

can be given for the lower and upper limits of the "confidence interval" of minimal length in function of the width W of the interval. Now the width W of the interval can be determined from the condition:

$$P=F_r(A+W)-F_r(A)=F_r\left(\frac{W}{1-e^{-\frac{W}{r-2}}}\right)-F_r\left(\frac{W}{e^{\frac{W}{r-2}}-1}\right) \tag{7}$$

where:

$$F_r(x)\equiv\int_0^x f_r(y)dy=e^{-\frac{x}{2}}\sum_{k=1}^{\infty}\frac{1}{\Gamma\left(k+\frac{r}{2}\right)}\left(\frac{x}{2}\right)^{k+\frac{r-2}{2}}$$

is the distribution function of the χ^2 distribution with r degree of freedom, and the Γ function is defined as:

$$\Gamma(x)\equiv\int_0^\infty y^{x-1}e^{-y}dy$$

Applying the lower limit A and the upper limit $A+W$, determined on the basis of the relationships (7) and (6), the criteria of acceptance (4) can implicitly be modified as follows: the hypothesis will be retained if for the quantity χ^2, determined experimentally, the condition:

$$\boxed{A\le\chi^2\le A+W} \tag{8}$$

is true, otherwise the hypothesis will be rejected.

If the degree of freedom is large enough, about the interval $[A,\ A + W]$ of minimal width, having a "confidence level" P, the following can be stated:

- $A >> 0$, i.e. the lower limit of the interval is much larger than zero. This fact is not unexpected at all, since the density function $f_r(x)$ of the χ^2 distribution is negligibly small at values x close to zero. At the 90/5 lottery, for example, where $v = 90$ and the degree of freedom $r = 89$, the density function $f_{89}(x)$ "behaves" like the function $Bx^{\frac{89-2}{2}}=Bx^{43,5}$, so the area under the density function is negligibly small on the interval $[0, A]$; the ***random*** occurrence of too small values χ^2 is a very improbable event!
- The width W is much less than χ^2_{crit}, consequently the interval $[A,\ A + W]$ is much shorter than the interval $[0,\ \chi^2_{crit}]$. This fact is a straight consequence of minimizing.
- The upper limit $A+W$ is only "just" bigger than χ^2_{crit}, so the use of criteria (8) instead of criteria (4) does not considerably decrease the "resolution" of the χ^2 test!

It is important to note that in the case of draw games used in Hungary (perhaps the only exception is the game "Joker", where the value of v only equals 10) the degrees of freedom can be considered as being large enough for the above statements to be valid, which is also proved by Tables 2 and 3 in which the following data are given:

- the denomination of the draw game,
- the number v of the numbers participating in the draw,
- the degree of freedom $r = v - 2$ or $r = v - 1$ (see sections 3.2 and 3.6),
- for the probability of acceptance $P = 0.9545$ (according to 2σ) and $P = 0.9973$ (according to 3σ), necessary for giving the criteria $\boxed{A \le \chi^2 \le A + W}$,
- the lower limit A of the interval,
- the width W of the interval,
- the upper limit $A+W$ of the interval, and
- the threshold value χ^2_{crit}, necessary for the use of the criteria $\boxed{\chi^2 \le \chi^2_{crit}}$.

Table 2 The parameters of acceptance for different draw games, determined from the conditions $\boxed{F_r(A+W) - F_r(A) = P}$ or $\boxed{F_r(\chi^2_{crit}) = P}$

P = 0.9545 (2σ)	v	r	A	W	χ^2_{crit}	$A+W$
Joker (10/6)	10	9	1.84	15.83	17.21	17.67
Putto (20/8 + 4/1)	20	18	7.11	23.19	29.24	30.30
		19	7.78	23.87	30.52	31.64
Scandinavian lottery (35/7)	35	33	17.74	31.89	47.87	49.63
		34	18.49	32.39	49.08	50.88
Roulette	37	36	20.00	33.37	51.48	53.37
45/6 lottery	45	43	25.40	36.57	59.82	61.97
		44	26.18	37.00	61.01	63.18
Luxor	75	73	49.71	47.93	94.60	97.64
		74	50.55	48.26	95.73	98.81
Keno (80/20)	80	78	53.89	49.57	100.28	103.46
		79	54.73	49.89	101.42	104.62
90/5 lottery	90	88	62.33	52.70	111.60	115.02
		89	63.17	53.00	112.73	116.17

Table 3 The parameters of acceptance for different draw games, determined from the conditions $\boxed{F_r(A+W) - F_r(A) = P}$ or $\boxed{F_r(\chi^2_{crit}) = P}$

P = 0.9973 (3σ)	v	r	A	W	χ^2_{crit}	$A+W$
Joker (10/6)	10	9	0.75	24.68	25.26	25.43
Putto (20/8 + 4/1)	20	18	4.35	35.39	39.17	39.74
		19	4.85	36.39	40.63	41.24
Scandinavian lottery (35/7)	35	33	12.89	48.27	60.10	61.16
		34	13.52	49.01	61.44	62.53
Roulette	37	36	14.79	50.46	64.10	65.25
45/6 lottery	45	43	19.41	55.22	73.30	74.63
		44	20.08	55.87	74.60	75.95
Luxor	75	73	40.92	72.17	111.12	113.10
		74	41.68	72.67	112.35	114.35
Keno (80/20)	80	78	44.70	74.62	117.25	119.32
		79	45.46	75.11	118.47	120.56
90/5 lottery	90	88	52.36	79.30	129.41	131.66
		89	53.13	79.75	130.62	132.89

What advantages can the interval $[A, A + W]$ of minimal width have compared to the interval $[0, \chi^2_{crit}]$, which is moreover more "elegant" due to its shortness?

The fact that the use of the criteria $\boxed{A \le \chi^2 \le A+W}$ excludes the values of χ^2 that are too small! The values of χ^2 according to (1*) can only be very small when the scatter of the frequencies k_j around their expectation is too small, which is worthy of note considering that gambling devices are concerned. Nature cannot *spontaneously* produce such phenomena. A random quantity *must* fluctuate, within limits, of course. The *absence* of the expected scatter should be rejected but conversely too *large* a scatter should also be rejected: for example, let us suppose that $N = 3700$ exactly. In this case the **expectation** of each frequency k_j equals $3700/37 = 100$. The game is acceptable if each k_j takes a value between 70 and 130 (3σ). If one or more frequency k_j is less than 70 or bigger than 130 the game cannot be accepted since the scatter is too wide, i.e. the deviation is significantly greater than the expectation. It is not acceptable either if each frequency k_j equals exactly 100 or falls, for instance, between 99 and 101 only.

In reference [1] the extreme example of the roulette wheel was introduced, which would spin the numbers in increasing order, so that each number is one higher than the previous and the number 36 is followed by the number zero (for example: 35, 36, 0, 1, ...). For such a roulette wheel the frequencies k_j of all the $\nu = 37$ numbers would be very close to their common expected value $\langle k_j \rangle = \dfrac{N}{\nu}$ (in the case of a number N of experiments divisible by 37, they would equal it exactly), consequently the value of χ^2 would be very close to zero (or would equal zero exactly). Checking the original data of this unacceptable roulette wheel either by the 3σ or by the usual χ^2 test, the decision would be acceptance, despite the fact that the actual "operation" of the roulette wheel is extremely predictable and not random at all. Because in this case χ^2 would be smaller then A, the χ^2 test using the suggested criteria $\boxed{A \le \chi^2 \le A+W}$ instead of the criteria $\boxed{\chi^2 \le \chi^2_{crit}}$ would evidently result in a rejection!

3 Testing the randomness of the sequence of numbers drawn for lottery-type games

The game of roulette is played in the presence of the players, who would be in a privileged position if they could identify any form of regular pattern in the sequence of the numbers spun. This is why in [1] it was suggested to test not only the uniformity of distribution of the numbers spun but also the randomness of the sequence of the numbers spun. The following possible test method was suggested:

- On the basis of the list of numbers available to be spun x_i ($i = 1,2,\dots,N$; $x_i = 0,1,2,\dots,36$) in sequential order, let us take the differences of the m^{th} neighbors ($m = 1,2,\dots$):

  $$y_i^{(m)} \equiv x_{i+m} - x_i \qquad (i = 1,2,\dots,N - m)$$

  (The upper index m refers to the m^{th} neighbors, and the quantity $y_i^{(m)}$ was signed by $y_{i,m}$ in [1]).
- Considering that the above differences can be a negative number or zero, let us form the following non-negative so-called modulated differences $z_i^{(m)}$:

  $$z_i^{(m)} \equiv \begin{cases} y_i^{(m)}, & \text{if } y_i^{(m)} \ge 0 \\ y_i^{(m)} + \nu, & \text{if } y_i^{(m)} < 0 \end{cases}$$

  (The quantity $z_i^{(m)}$ was signed by $z_{i,m}$ in [1]).
- In the case of a roulette wheel the modulated differences $z_i^{(m)}$ can take values from 0 to 36, the same as the original data x_i, and among the values $z_i^{(m)}$ all 37 numbers have to occur almost the same number of times if the roulette wheel operates randomly (i.e. fairly) so the 3σ and/or the χ^2 test also have to be performed on the modulated differences $z_i^{(m)}$, using the value $N - m$ instead of N.

In reference [1] the author wrote:

> "Because in the case of lottery-type games the order in which the numbers are drawn is not of any significance, here it is not reasonable to perform the χ^2 test on the modulated differences too. The sequence of the results of lottery draws has not been recorded statistically for several decades; the numbers drawn are reported only in increasing order."

This former opinion has to be reconsidered.

In Hungary the game of bingo used to be authorized (but was prohibited in 1998). Bingo is evidently a lottery-type game, since the balls drawn are not returned to the pot during one drawing process. The number of balls drawn changes from game to game, since the game continues until the first player shouts "BINGO!". It is important to note that to win, at least two conditions have to be fulfilled. Firstly the player must indeed have a winning coupon, and secondly it is also necessary for the player to actually notice *in time* that he won, otherwise the draw will continue until the first person shouts "BINGO!". Similarly to roulette, also in bingo the players are present during the draws. From the above bingo game rule it follows that the players would have an advantage if they were able to find any regularity in the sequence of the numbers drawn.

In the case of computer programs, drawing game prizes or winning numbers, the possibility of failure of the random generator or bad programming can arise.

So there are draw-based, lottery-type games where it can be reasonable to test the randomness of the sequence of numbers drawn within one drawing process.

For the case of draws with "balls and pot" the quite logical requirement of randomness means that each ball still in the pot could be drawn with the same probability independently of the numbers already drawn. The above requirement can be generalized for all lottery-type games, and evidently does not depend on the concrete realization of the game.

Before the method "with modulated differences" (calculated for testing the randomness of roulette-type "with return" games) can be adapted to lottery-type "without return" games, the differences between both types of game have to be taken into account:

- According to present practice for lottery-type games, the draw is performed out of the numbers $1,2,\ldots,v$, so the number 0 cannot occur among the numbers drawn.
- At lottery-type games more than one number is always drawn during one game, but in roulette, only one number is ever spun at one time. (This statement is not valid for all roulette-type games: at the Joker game, which is evidently of the roulette-type, $n = 6$ numbers are drawn out of $v = 10$, "with return").
- At lottery-type games all the numbers drawn on one occasion are different, so when choosing any two of them the difference between them cannot be zero.
- At roulette-type games the list containing the original data provided by the client for the tests consists of the numbers x_i, which can be arranged into a column, while the list of the original data of lottery-type games is a matrix, consisting of the numbers drawn $x_{i,l}$, where $x_{i,l}$ signifies the l^{th} number drawn (l^{th} in time, and not l^{th} in line arranged in increasing order!) during the i^{th} draw. Here $x_{i,l} = 1,2,\ldots,v$; $i = 1,2,\ldots,N$ and $l = 1,2,\ldots,n$. In bingo and Luxor the number of numbers drawn "without return" is not constant, but there exists a theoretical limit, so that bingo or Luxor cannot be achieved if the number of numbers drawn is less than this theoretical limit. In these cases it is practical to choose this theoretical limit as a value n, and the lists have to be truncated, for instance so that the first n numbers of every line are kept and the remaining numbers are discarded.

For lottery-type games, in order to test the randomness of the sequence of the numbers drawn in one game, the following procedure is suggested:

- On the basis of the list available for the tests containing the original data $x_{i,l}$, let us take the differences $y_{i,l}^{(m)}$ of the m^{th} neighbors belonging to the same draw:

$$y_{i,l}^{(m)} \equiv x_{i,l+m} - x_{i,l}$$

Here: $m = 1,2,\ldots,m_{\max}$, $i = 1,2,\ldots,N$ and $l = 1,2,\ldots,n-m$.

- Considering that the above differences can be negative, but that the zero cannot occur among them, let us constitute from them the following positive modulated differences $z_{i,l}^{(m)}$:

$$z_{i,l}^{(m)} \equiv \begin{cases} y_{i,l}^{(m)}, & \text{if } y_{i,l}^{(m)} > 0 \\ y_{i,l}^{(m)} + v, & \text{if } y_{i,l}^{(m)} < 0 \end{cases}$$

- The modulated differences $z_{i,l}^{(m)}$, which are termed *derived data* in order to distinguish them from the *original data*, can take values 1 to $v - 1$, and among them the $v - 1$ possible different numbers have to occur almost as many times. So the 3σ and the χ^2 test have to be performed on the modulated differences $z_{i,l}^{(m)}$ as well.
- The first step of both tests is the determination of the frequencies $k_j^{(m)}$, where the frequency $k_j^{(m)}$ shows how many times the number j ($j = 1,2,\ldots,v - 1$) occurred among the modulated differences $z_{i,l}^{(m)}$.

At roulette-type games the evaluation of both the original and derived data is performed in the same way using either the 3σ or χ^2 test, because both the original and derived data are of roulette-type ("with return"). At lottery-type games the original data and the derived data have to be evaluated in a significantly different way, because the original data, of course, are of lottery-type ("without return") but the derived data are of roulette-type. Therefore hereinafter the tests suggested for the case of lottery-type games will be reviewed, and hence both the original and derived data can be evaluated. For the sake of better transparency certain parts will be repeated.

At lottery-type games during one draw out of the numbers 1 to $\boldsymbol{v}$, $\boldsymbol{n}$ different numbers are drawn with the same required probability, and for the evaluation the results of $\boldsymbol{N}$ drawing processes are available. These notations will be used consistently.

3.1 Evaluating the original data for lottery-type games

- For the evaluation the list is available containing the original data $x_{i,l}$, where $x_{i,l} = 1,2,\ldots,v$; $i = 1,2,\ldots,N$ and $l = 1,2,\ldots,n$. The number of the data in the list equals Nn.

- The frequency k_j shows how many times the number j occurred among the original data $x_{i,l}$. Here: $j = 1,2,\ldots,\nu$.
- Since in the case of lottery-type games any number j can be drawn at most once during one game, it is true that $k_j = 0,1,2,\ldots,N$ (i.e. any number can occur at most N times in the list containing the result of N drawings), and $\sum_{j=1}^{\nu} k_j = Nn$.
- For one drawing act the required probability p_o of drawing any number j is $p_o = \frac{n}{\nu}$,

  since on one occasion n different numbers are drawn out of ν. (The index o refers to the *o*riginal data).

3.2 Evaluating the original data by the 3σ test for lottery-type games

Each frequency k_j, in itself, is of Bernoulli distribution, with the expectation:

$\mu_o = \langle k_j \rangle = Np_o = N\frac{n}{\nu}$ and with the standard deviation:

$$\sigma_o = +\sqrt{\langle k_j^2 \rangle - \mu_o^2} = +\sqrt{Np_o(1-p_o)} = +\sqrt{\frac{Nn}{\nu}\left(1-\frac{n}{\nu}\right)}$$

On the basis of the evaluation of the original data the device under control can be accepted, and the draw of all ν numbers can be considered as being of the same probability, if for all frequencies k_j the conditions:

$$\boxed{\mu_o - 3\sigma_o \le k_j \le \mu_o + 3\sigma_o}$$

are fulfilled.

3.3 Evaluating the original data by the χ² test for lottery-type games

In paper [1] it was proved that for lottery-type games the random variable:

$$\chi_o^2 \equiv \frac{\nu - 1}{\nu - n}\sum_{j=1}^{\nu}\frac{(k_j - Np_o)^2}{Np_o} \qquad (9)$$

consisting of the above frequencies k_j, follows an χ^2 distribution with $r = \nu - 1$ degree of freedom in the case of $N \to \infty$, that is:

$\Phi_{\chi_o^2}(x) = F_{\nu-1}(x)$, if $N \to \infty$,

where: $\Phi_{\chi_o^2}(x)$ is the distribution function of the random variable χ_o^2, and

$F_{\nu-1}(x)$ is the distribution function of the χ^2 distribution with $r = \nu - 1$ degree of freedom.

This statement does not follow on from the χ^2 theorem, cited above, since the set of the frequencies k_j does not follow a multivariable Bernoulli distribution, though each frequency k_j, in itself, is of a simple Bernoulli distribution.

So the procedure of evaluation is:

- Let us determine the value of χ^2 on the basis of equation (9).
- For an arbitrary probability P of acceptance (whose suggested value equals $P = 0.9973$, belonging to 3σ, in order to synchronize this test with the 3σ test), on the basis of the relationship $P = \Phi_{\chi_o^2}(x = \chi_{crit}^2)$, let us determine the threshold value χ_{crit}^2.
- On the basis of the evaluation of the original data, the operation of the device can be considered as being random at "confidence level" P, all the numbers drawn can be considered as being of the same probability, the device under control can be accepted, if the condition

  $$\boxed{\chi_o^2 \le \chi_{crit}^2}$$

  is fulfilled. (If the Reader accepts the suggestion explained in section 2, he or she can also choose the criteria $\boxed{A \le \chi_o^2 \le A + W}$ as well as or instead of the criteria $\boxed{\chi_o^2 \le \chi_{crit}^2}$ above).

3.4 Evaluating the derived data for lottery-type games

- For the evaluation the list containing the modulated differences $z_{i,l}^{(m)}$ is available, derived from the m^{th} neighbors drawn during one game, by the method shown above, where $z_{i,l}^{(m)} = 1,2,\ldots,\nu - 1$; $i = 1,2,\ldots,N$ and $l = 1,2,\ldots,n - m$.
- A separate list belongs to each value m, and the evaluation has to be performed for each m separately.
- The possible values of m are $m = 1,2,\ldots,m_{max}$.
- The maximal value m_{max} of m can be chosen arbitrarily, depending on the farthest neighbors whose differences it is necessary to examine. The relationship $m_{max} \le n - 1$ evidently gives an upper limit; in the case of n objects located in one line, the "distance" (even of the farthest neighbors) cannot be larger than $n - 1$.
- The list belonging to a given m contains N lines and $n - m$ numbers in every line. Consequently the total number of the data in the list equals $N(n - m)$.

- The frequency $k_j^{(m)}$ shows how many times the number j occurred among the derived data $z_{i,l}^{(m)}$. Here $j = 1,2,\ldots,v - 1$, because between the numbers $1,2,\ldots,v$ the largest possible (modulated) difference equals $v - 1$.
- The number j can occur several times in the lines of the list containing the modulated differences $z_{i,l}^{(m)}$, in contrast to the list containing the original data! It is possible for a line to contain the same numbers only, and it cannot be excluded either, at least in principle, for the whole matrix to consist of the same numbers j. (If the lottery numbers of a week were 5, 12, 19, 26, 33, drawn in this order exactly, the number 7 would occur only in the line of the list containing the differences of the adjacent numbers, while in the list of second neighbors the number 14 would occur only). Consequently for the frequencies $k_j^{(m)}$ the relationships

  $k_j^{(m)} = 0,1,2,\ldots,N(n - m)$ and $\sum_{j=1}^{v-1} k_j^{(m)} = N(n-m)$ are valid.
- In the case of a device drawing randomly, all the probabilities p_j must be the same:

  $$p_j = p_d = \frac{1}{v-1}$$

  where p_j signifies the probability of the event that for an element chosen randomly in the matrix $z_{i,l}^{(m)}$, to be equal to the number j. (The index d refers to *d*erived data).

3.5 Evaluating the derived data by the 3σ test for lottery-type games

In the case of a device drawing randomly, the set of frequencies $k_j^{(m)}$, determined on the basis of matrices $z_{i,l}^{(m)}$, follows a $(v - 1)$-variable Bernoulli distribution, where the expectation of all frequencies is:

$$\mu_d = \left\langle k_j^{(m)} \right\rangle = N(n-m)p_d = N\frac{n-m}{v-1}$$ and their common standard deviation is:

$$\sigma_d = +\sqrt{\left\langle \left(k_j^{(m)} - \mu_d\right)^2 \right\rangle} = +\sqrt{N(n-m)p_d(1-p_d)} = +\sqrt{N\frac{n-m}{v-1}\left(1-\frac{1}{v-1}\right)}$$

On the basis of evaluating the m^{th} modulated differences, the sequence of the numbers drawn by the device can be considered as being random, and the device can be accepted, if for all frequencies $k_j^{(m)}$ ($j = 1,2,\ldots,v - 1$) the conditions:

$$\boxed{\mu_d - 3\sigma_d \le k_j^{(m)} \le \mu_d + 3\sigma_d}$$

are fulfilled.

3.6 Evaluating the derived data by the χ^2 test for lottery-type games

The random variable:

$$\chi_d^2 \equiv \sum_{j=1}^{v-1} \frac{\left[k_j^{(m)} - N(n-m)p_d\right]^2}{N(n-m)p_d} = \sum_{j=1}^{v-1} \frac{\left(k_j^{(m)} - N\frac{n-m}{v-1}\right)^2}{N\frac{n-m}{v-1}} \qquad (10)$$

consisting of the frequencies $k_j^{(m)}$ follows an χ^2 distribution with $r = v - 2$ (!) degree of freedom in the case of $N \to \infty$, i.e.:

$$\Phi_{\chi_d^2}(x) = F_{v-2}(x) \text{ , if } N \to \infty$$

where: $\Phi_{\chi_d^2}(x)$ is the distribution function of the random variable χ_d^2, and

$F_{v-2}(x)$ is the distribution function of the χ^2 distribution with $r = v - 2$ degree of freedom.

This statement is a direct consequence of the χ^2 theorem cited above.

Because of the conditions $\sum_{j=1}^{v} k_j = Nn$ for the original data, and $\sum_{j=1}^{v-1} k_j^{(m)} = N(n-m)$ for the derived data, the degree of freedom is one less than the number of the possible values of j. When the draw is performed out of the numbers $1,2,\ldots,v$, i.e. when the number of possible values equals v, the degree of freedom equals: $r = v - 1$. Among the derived data only the numbers $1,2,\ldots,v - 1$ can occur, so the degree of freedom equals: $r = v - 2$.

The evaluation procedure is:

- On the basis of equation (10) let us determine the value of χ_d^2.
- For an arbitrarily chosen probability P of acceptance, (it is useful to choose the same value as in the case of the original data, in order to ensure uniform handling), on the basis of the relationship $P = \Phi_{\chi_d^2}\left(x = \chi_{crit}^2\right)$ let us determine the threshold value χ_{crit}^2 of the acceptance.
- On the basis of the evaluation of m^{th} modulated differences the sequence of the numbers drawn by the given device can be considered as being random at a "confidence" level P, and the device is acceptable, if the condition

  $$\boxed{\chi_d^2 \le \chi_{crit}^2}$$

  is fulfilled.

4 Summary

All three topics discussed in this paper belong to the field of mathematical statistics. The three problems are inter-connected by the use of the χ^2 distribution and by examining their applicability focusing on gambling games.

It was examined how the expectation and the standard deviation of the random variable $\chi^2 \equiv \sum_{j=1}^{v} \frac{(k_j - Np_j)^2}{Np_j}$ change, if the supposed, expected or prescribed probabilities q_j, different from the probabilities p_j, are substituted into the formula instead of the real probabilities p_j. By means of a simple model, elaborated in this case for roulette wheels, the well-known fact was demonstrated and also proved in an exact way, that for a fixed number N of experiments the χ^2 test results in a rejection with a high probability, when the differences between the supposed and the real probabilities are large. If these differences are relatively small, the number N of experiments must be large.

To check the hypothesis on a given probability distribution the χ^2 test is usually used so that it is examined whether the inequality $\boxed{\chi^2 \le \chi^2_{crit}}$ is fulfilled between the quantities χ^2 determined experimentally, and χ^2_{crit} calculated theoretically. Considering the idiosyncrasies of gambling games, i.e. that persons contribute during certain draws or presentation of the draw lists, it may be practical to exclude the too "regular" lists at which the fluctuations are too small. Therefore instead of or as well as the above criteria, the criteria $\boxed{A \le \chi^2 \le A + W}$ is suggested, which is based on the interval of minimal width. If the degrees of freedom are big enough, the latter criteria excludes the too small values of χ^2 so that the sharpness of the test does not decrease to a significant extent.

In the case of certain lottery-type ("without return") games it also may be reasonable to check whether the sequence of the numbers drawn can be considered as being random. The simple, demonstrative method, previously elaborated for roulette-type games, was adapted for lottery-type games as well. The original data of the lottery-type games are, of course, of lottery-type while the derived data are of roulette-type, so the original data and the derived data have to be evaluated in a different way. In this paper the 3σ and the χ^2 tests were introduced for both the original and the derived data of lottery-type games.

Reference

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BREATH TESTING

Traceability of breath alcohol concentrations in Romania

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Abstract

The aim of this article is to provide results obtained by specialists from the Romanian National Institute of Metrology (INM) in their attempt to ensure traceability of breath alcohol measurement in Romania.

The Gas Concentration Group of the INM is prepared, from a technical and theoretical point of view, to provide support to National Authorities (Police Departments) with reference materials (RM) and traceable measurements of breath alcohol concentrations in Romania. The key quality parameters are the uncertainties associated with the certified values and the reliability of the uncertainty estimate. Depending on the different sources of uncertainty, an estimation of the uncertainties is presented regarding the generated alcohol concentration used for calibrating breath alcohol analyzers. The uncertainty budgets were calculated using the ISO approach [1,2]. Breath alcohol measurements are presented in this article together with the expanded uncertainty, U, using a coverage factor k=2 which gives a degree of confidence of approximately 95 %.

The tests and measurements were performed over two years in the Gas Concentration Laboratory of the INM using breath alcohol analyzers, breath alcohol simulators and pure ethanol. The results of the measurements, covering the entire range of concentration of breath alcohol analyzers, are summarized in tables.

Keywords: Traceability; reference materials; breath alcohol concentration; metrology

0 Introduction

The alcohol concentration is measured using air from the lungs or blood from the veins.

Over the years, breath testing has become a widely used method for the qualitative and quantitative determination of the alcohol level of persons suspected of driving while under the influence of alcohol. After recognizing the need for a quantitative assessment of intoxications, blood alcohol concentration was considered as the single most important variable. However, concern about the inconvenience of drawing a blood sample led to the development of the breath test as a non-invasive means of assessing the level of intoxication.

Scientists all over the world have started to look for new non-invasive methods to determine the alcohol concentration in the human body. Depending on the accuracy, specifically alcohol-related, cross sensitivity, long term stability, etc. a number of measuring principles are used for breath alcohol determination: chemical, bio-chemical (system based on oral fluids), physical (semiconductor cell - surface reaction), electrochemical (fuel cell), infrared spectroscopy, and gas chromatography.

Breath-alcohol testing methods have changed over the years from chemical oxidation and calorimetric procedures to physico-chemical techniques such as gas-chromatography, electrochemical oxidation and multiple wavelength infrared spectrophotometers.

1 Basics in breath alcohol concentration measurements

Breath alcohol measurements are based on Henry's law: "When an aqueous mixture of a volatile substance reaches equilibrium in air, there will be a fixed ratio between the concentration of the substance in the air and its concentration in the solution".

It is well known that water and alcohol can be mixed in any ratio, resulting in a homogeneous mixture. Both liquids have a tendency to evaporate, but alcohol has a greater tendency to do so. If an alcohol-water mixture of this type is kept in a partly filled and sealed system, the concentration of gaseous alcohol in the air above the liquid will increase until a certain concentration is reached. At this stage, there is a defined ratio between the alcohol concentration in the liquid and that in the air. Scientists all over the world accept the value of this ratio as having a value of between 2000:1 to 2300:1.

The concentration of alcohol in the vapor phase above the liquid alcohol-water mixture depends on two factors: the temperature of the mixture, and the alcohol concentration of the liquid (Dubowsky formula):

$$C_{air} = 0.041445 \times 10^{-3}\, C_{H_2O} \times e^{0.06583\, t}$$

where t is the solution temperature in °C.

If t = 34.0 ± 0.1 °C, $C_{air} = 0.38866 \times 10^{-3}\ C_{H_2O}$

Henry's law applies to the exchange processes in the human body, especially in the lungs. The balance between the alcohol in the blood and in the breath is created in the lungs in the same way as described for alcohol in an aqueous solution and air in a semi-closed system.

In accordance with this law, the diffusion processes (which are also what cause oxygen to be taken up in the lungs) achieve a balance between the alcohol concentration in the blood and that in the air in the lungs. Thus, the breath alcohol measurement involves directly determining this concentration.

Evidential breath analyzers are instruments that automatically measure the mass concentration of alcohol in exhaled breath that originates from the alveoli of the lungs.

Although the relationship between the breath and blood alcohol concentrations is still uncertain, evidential breath-alcohol instruments are used in many countries to determine the alcohol concentration level for prosecution purposes.

National authorities may require a specific conversion device that converts the measurement result obtained in terms of ethanol content and that can approve evidential breath analyzers for law enforcement purposes with a threshold limit of breath-alcohol concentration alongside the existing statutory blood-alcohol concentration limits.

Quality assurance has become an indispensable accompaniment to forensic breath-alcohol analysis.

The INM Gas Concentration Laboratory is prepared to provide the following control procedures:

- type approval;
- initial and periodic verification of new evidential breath analyzers; and
- performance tests and calibrations.

It focuses on the development, implementation and use of such quality assurance programs for breath-alcohol testing.

An evidential breath analyzer is an instrument which accurately measures the concentration of alcohol in "end-expiratory" air to provide a result which can be used as evidence in drink-driving offences. End-expiratory air is a breath sample containing air from the end of a forced expiration from the lungs. An evidential breath analyzer, once type approved and having undergone independent official verification, ensures that the measurement results attain the extremely high level of reliability that European and national standards demand.

Traceability of breath alcohol concentration is a new field of interest in Romania. About 1700 breath alcohol analyzers were purchased by the Ministry of the Interior (Police Department) a few years ago following a European project to equip East-European Police Departments. Since then, the traceability of measurements performed by such instruments was a priority in order to ensure accurate measurements and especially acceptance in court. Measurements made at different times or in different places are thus directly related to a common reference. Applying the concept of traceability to breath alcohol measurements is not easy, but traceability has to provide qualitative results using analytical techniques used in calibration laboratories.

Specialists from the INM have started to prepare the basis necessary to transmit the specific measuring units from high level standards (reference materials) to the working level measurements.

The measurements and tests were performed using the following equipment, in order to deliver test gases having ethanol concentrations analogous to those theoretically calculated and to those which evolve during a real exhalation.

- Evidential breath alcohol analyzer Alcotest 7110 MK III, manufactured by Dräger Safety AG & Co., KgaA, Germany, serial numbers: ARNC-0145, with Calibration Certificate no. 0347/14.10.2005 and ARND-0145, with Calibration Certificate no. 2040/14.10.2005, issued by EDN (Eichdirection Nord), Germany and traceable to the PTB's standards;
- Ethanol purity 99.8 %, manufactured by Merck, code K 22707783 608, batch 200-578-6;
- Wet bath simulator for testing and calibrating breath alcohol analyzers, type Mark II, serial no. DDSE P 0003 and DDSE P 0006, manufactured by Dräger Safety AG, Germany;
- Wet bath simulator for testing and calibrating breath alcohol analyzers, manufactured by ICIA - Cluj, Romania;
- Syringe, (10.0 ± 0.2) mL;
- Analytical balance, type XS 205 manufactured by Mettler Toledo; and
- Distilled water.

The evidential breath alcohol analyzers Alcotest 7110 MK III satisfy the requirements of DIN VDE 0405 and OIML R 126 and were approved by the PTB and also by the Romanian INM following a series of tests according to the above Standard/Recommendation. This kind of measuring system can be used for breath alcohol concentration measurements either in Germany or in Romania [4-7].

2 Preparation of calibration standards

Traceability is defined as the property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties.

It is known that traceability requires an 'unbroken chain of comparisons' between a measurement and the 'stated references'.

The first step in this project was preparing standard mixtures. Table 1 presents alcohol concentrations, expressed in ‰ (promile) and mg/L (milligram alcohol in a liter of air) obtained by mixing certain quantities of pure alcohol (ethanol) in distilled water.

Table 1 Alcohol concentrations obtained by mixing certain quantities of pure alcohol (ethanol) in distilled water

No.	$C_{C2H5\text{-}OH}$ mL	C_{H2O} g	C_{air} ‰	C_{air} mg/L
1	0.31	0.245	0.2	0.0952
2	0.62	0.490	0.4	0.1905
3	0.93	0.735	0.6	0.2857
4	1.24	0.980	0.8	0.3810
5	1.56	1.225	1.0	0.4762
6	2.33	1.838	1.5	0.7143
7	3.12	2.450	2.0	0.9524
8	3.90	3.063	2.5	1.1905
9	4.68	3.676	3.0	1.4286

3 Quantifying the uncertainty components

In order to estimate the associated uncertainty for each prepared concentration, all the possible sources of uncertainties were taken into consideration. The influence quantities that can affect the measurement result are generated by the following devices: syringe, recipient, purity of the ethanol, and the temperature established by the simulator's thermostat.

3.1 Uncertainty due to the syringe

One important source of uncertainty is related to the syringe, which has a nominal range of (0...10) mL. To establish this contribution to the final uncertainty budget, ten weighings were performed of 4.60 mL H_2O distilled water with a Mettler Toledo precision balance. The results are presented in Table 2.

Table 2 Result of 10 weighings (uncertainty related to the syringe)

Conventional value of distilled water g	Measured mass of distilled water g	Average value g	Standard experimental deviation, s g
4.60	4.59318; 4.57837; 4.61531; 4.59736; 4.59305; 4.59063; 4.61904; 4.63416; 4.61148; 4.57626	4.60088	0.01859

The associated uncertainty was estimated according to [1,2]. The combined standard uncertainty is:

$$u_{C\_seringa} = \sqrt{s^2 + u_{s1}^2 + u_{s2}^2} = \sqrt{0.00035^2 + 0.00816^2 + 0.00121^2} = 0.020336$$

where:

- s is the standard deviation for 10 measurements of the weight of 4.60 mL H_2O distilled water;
- $u_{s1} = \dfrac{0.02}{\sqrt{6}} = 0.00816$ is the standard uncertainty, calculated assuming a triangular distribution, as stated by the syringe manufacturer;
- $u_{s2} = 10\,(\mathrm{mL}) \cdot \dfrac{2.1}{10^{-4}} \cdot \dfrac{1\,(°\mathrm{C})}{\sqrt{3}} = 0.00121$ is the standard uncertainty, calculated assuming a rectangular distribution for a temperature variation and the coefficient of the volume expansion.

The expanded uncertainty is obtained by multiplying the combined standard uncertainty with a coverage factor of 2, giving:

$U_{C\_seringa}$ = 0.002 × 2 = 0.004 mL;

Thus, the volume of the syringe is:

$V_{\_seringa}$ = (4.60 ± 0.04) mL

3.2 Uncertainty due to the recipient

The standard uncertainty specified by the manufacturer in the recipient's Calibration Certificate, calculated assuming a rectangular distribution, is:

$$u_{V1} = \frac{1}{\sqrt{3}} = 0.57735$$

The standard uncertainty, calculated assuming a rectangular distribution for the coefficient of the volume expansion, has the value:

$$u_{V2} = 1000\,(\mathrm{mL}) \cdot \frac{2.1}{10^{-4}} \cdot \frac{1\,(°\mathrm{C})}{\sqrt{3}} = 0.12124$$

The combined standard uncertainty is:

$$u_{C\ \ Volum} = \sqrt{{u_{V1}}^2 + {u_{V2}}^2} = \sqrt{0.57735^2 + 0.12124^2} = 0.589944$$

which gives the following value for the volume of the recipient used for preparing the standard mixture:

$V_{\_volum}$ = (1.000.00 ± 0.59) mL

3.3 Uncertainty due to the purity of the ethanol

The ethanol used for the preparation of the various standards was 99.8 % by volume. The standard uncertainty has the value:

$$u_{etalon} = \sqrt{\left(\frac{1-0.998}{\sqrt{3}}\right)^2} = 0.001155$$

3.4 Uncertainty due to the temperature established by the simulator's thermostat

The simulator's thermostat was set to (34.0 ± 0.2) °C during the experiments. The standard uncertainty, calculated assuming a rectangular distribution for the variation of the thermostat's temperature, has the value:

$$u_{thermostat} = \sqrt{\left(\frac{0.2}{\sqrt{3}}\right)^2} = 0.011547$$

4 Example of a total uncertainty budget calculation for a concentration of 0.8 ‰ corresponding to a concentration of 0.381 mg/L (alcohol in a liter of air)

For the uncertainty of the alcohol concentration in air generated by the temperature:

Table 3 Spreadsheet showing the uncertainty calculation

$C_{ethanol}$	0.98625	$u_{ethanol,\ g}$	0.016045		1.00230	0.98625	0.98625
Purity	0.998	u_p	0.001155		0.998	0.991955	0.998
Volume	1	u_V	0.00059		1	1	1.00059
$C_{0(ethanol/L)}$	0.984278	$u_{(ethanol/L)}$	0.016013	$C_{i(ethanol/L)}$	1.000291	0.978315	0.983697
				C_0-C_i	0.016013	-0.00596	-0.00058
				$(C_0$-$C_i)^2$	0.000256	3.55E-05	3.37E-07
				$\Sigma(C_0$-$C_i)^2$			0.000256

$$u_{(e\tan ol/L)} = \sqrt{(C_0 - C_i)^2} = \sqrt{0.000256} = 0.016013$$

Table 4 Uncertainty calculation for a temperature value *t* = 34 °C

$C_{0(ethanol/L)}$	0.984278	$u_{solution}$	0.016013		1.000291	0.984278
t, °C	34	$u_{temperature}$	0.011547		34	34.01155
$C_{0(ethanol/L\ air)}$	0.38255	$u_{ethanol/L\ air}$	0.006230	$C_{i(ethanol/L\ air)}$	0.388774	0.382841
‰	0.80	Index, %	1.63	C_0-C_i	0.006224	0.000291
				$(C_0$-$C_i)^2$	3.87E-05	8.46E-08
				$(C_0$-$C_i)^2$		3.88E-05
				Index, %	99.78	0.22

$$u_{(ethanol/L\,air)} = \sqrt{(C_0 - C_i)^2} = \sqrt{3.88 \cdot e^{-5}} = 0.006230$$

The simulator's temperature was set to (34.0 ± 0.2) °C

$$u_{termostat} = \sqrt{\left(\frac{0,2}{\sqrt{3}}\right)^2} = 0.011547$$

according to the Dubowsky formula:

$C_{air} = 0.041445 \times 10^{-3}\, C_{H_2O} \times e^{0.06583\, t}$

where t represents the solution temperature, expressed in °C.

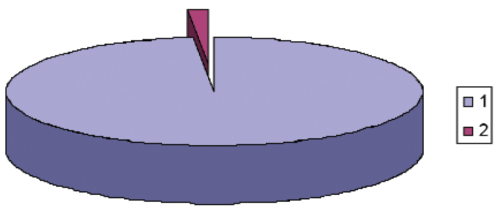
The corresponding spreadsheet uncertainty calculation for a temperature value t = 34 °C is shown in Table 4.

The alcohol concentration, expressed as mg in a litre of air, is then:

C_{air} = (0.382550 ± 0.006230) mg/L

or taking into account the number of digits available on the breath alcohol analyzers:

C_{air} = (0.382 ± 0.006) mg/L



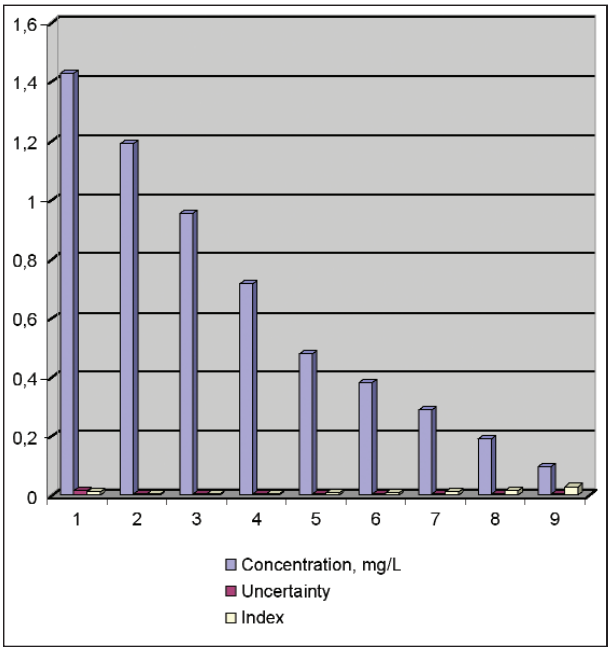
1 Alcohol concentration in air

2 Associated uncertainty

Table 5 and its associated graph present the alcohol concentration prepared according to the Dubowsky formula and the associated uncertainties calculated according to the most recent edition of the Guide to the expression of Uncertainty in Measurement (GUM) [1,2].

Table 5 Alcohol concentration prepared according to the Dubowsky formula and the associated uncertainties

Alcohol concentration ‰	Calculated alcohol concentration mg/L	Calculated uncertainty mg/L	Index %
3.0	1.425861	0.012274	0.86
2.5	1.188088	0.002685	0.23
2.0	0.950315	0.002630	0.28
1.5	0.712930	0.002586	0.36
1.0	0.475158	0.002554	0.54
0.8	0.380126	0.002545	0.67
0.6	0.285095	0.002538	0.89
0.4	0.190063	0.002533	1.33
0.2	0.095032	0.002529	2.66



Using the equipment in the INM Gas Concentration Laboratory the ethanol concentrations presented in Table 6 were prepared.

Table 6 Ethanol concentrations

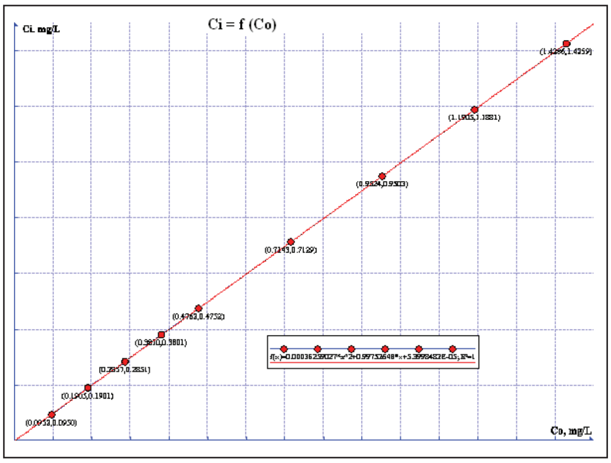
Alcohol concentration ‰	C_0 mg/L	C_i mg/L
3.0	1.4286	1.4259
2.5	1.1905	1.1881
2.0	0.9524	0.9503
1.5	0.7143	0.7129
1.0	0.4762	0.4752
0.8	0.3810	0.3801
0.6	0.2857	0.2851
0.4	0.1905	0.1901
0.2	0.0952	0.0950

C_0 Conventional true value of alcohol concentration, mg/L

C_i Prepared alcohol concentration, mg/L

The graph presents the final alcohol concentrations prepared in the laboratory (C_i, mg/L) against the theoretical concentrations (C_0, mg/L) calculated according to the Dubowsky formula.

The differences between the desired and the prepared concentrations are very small; this means that from the theoretical and practical point of view the INM laboratory is prepared to ensure traceability to the existing measuring analyzers of breath alcohol concentration.



Conclusion

Breath alcohol analyzers are widely accepted as legal measuring instruments used for determining the mass concentration of alcohol in exhaled breath. Nowadays, the Road and Traffic Department of the Romanian Ministry of the Interior uses some one thousand several hundred electronic devices for testing breath alcohol concentration.

The INM Gas Concentration Laboratory has started a project to prepare standards for ethanol in air in order to provide the following control procedures:

- initial verification of new evidential breath analyzers;
- periodic verification; and
- performance tests and calibrations.

During two years of sustained research activity different alcohol concentrations were prepared; their associated uncertainties were evaluated according to the most recent standards [1,2].

The results obtained show that the INM standards, prepared according to the European and International Standards and with the knowledge and equipment in existence in the INM laboratory, are of the required accuracy and can be used to transmit the measuring unit, mg/L, to breath alcohol analyzers.

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INTERVIEW by Valérie Dobigny, "Contrôles-Essais-Mesures" Journal, 04/2007:

Jean-François Magana, BIML Director

Round Table, Congrès International de Métrologie — Lille, France — 06/2007

Metrology helps in improving road safety

According to the World Health Organization and the World Bank, every year in the world road accidents lead to some 1.2 million deaths and 50 million injuries. The challenge facing metrologists is to contribute to improving road safety, and a *Round Table on Metrology and Road Safety*, presided by Jean-François Magaña, BIML Director, opened up the International Metrology Congress in Lille (France) this June.

La métrologie fait avancer la fiabilité au volant

Selon l'Organisation Mondiale de la Santé et la Banque Mondiale, les accidents de la route occasionnent 1,2 millions de tués et 50 millions de blessés dans le monde chaque année. Le défi de la métrologie est d'augmenter la sécurité sur les routes, et une Table Ronde sur *La Sécurité Routière et la Métrologie* a fait l'ouverture du Congrès International de Métrologie, animé par Jean-François Magaña, Directeur du BIML, en juin dernier.

- *Valérie Dobigny:* **What is the present role of metrology in road safety?**

Jean-François Magaña: Metrology plays an essential role in road safety. To the public, this role can either be visible (for example radars) or invisible, but nevertheless important – for example, antilock braking systems or trajectory control both involve sophisticated measurements and rely on metrology to ensure their accuracy.

Metrology contributes to the safety of vehicles, it plays a role in civil engineering during road design, it plays a role in police checks, and can even be found in the technology used in navigational satellite equipment.

A vehicle is a complex but coherent system including a number of sensors and signal processing devices which allow the onboard computer to manage the operation and performance of the vehicle, and also the anti-pollution, safety and preventive maintenance features. A defective ABS sensor or an incorrectly processed ABS signal represent risks for safety. The same applies to pressure sensors for tyres or for the braking circuits.

- *Valérie Dobigny:* **Quelle est la place actuelle de la métrologie dans la sécurité routière ?**

Jean-François Magaña: La métrologie a une place essentielle pour la sécurité routière. Pour le public, elle peut être très visible (les radars) ou invisible, mais elle est très importante (systèmes antiblocage ou contrôle de trajectoire).

La métrologie contribue à la sécurité routière dans nos véhicules, sur les routes ou les ouvrages d'art, dans les contrôles des forces de l'ordre, et même dans l'utilisation des satellites GPS.

Une voiture est un système extrêmement complexe de capteurs et de traitement de signaux grâce auxquels l'ordinateur de bord gère le fonctionnement et les performances du véhicule, mais aussi l'anti-pollution, la sécurité et la maintenance préventive. Un capteur d'ABS défaillant ou un signal d'ABS mal traité est un risque pour la sécurité. De même qu'un capteur de pression de pneus ou de circuit de freins.

Measurements are also used in the design and evaluation of vehicles. This includes for example the measurement of headlight luminance, braking efficiency, shock absorber testing, etc.

The development of safer road infrastructures also calls for measurements. Tyre road-holding on different surface coatings is an important element for road safety, as are the detection and indication of rain, fog, snow, or road accidents.

Systems designed to help drivers require advanced measuring systems such as anti-collision radars.

Checks carried out by enforcement officers on the behavior and alcohol intake of drivers are also based on measurements such as the speed the vehicle is traveling at, whether safety distances were respected, measurement of the breath alcohol level, etc.

Lastly, when an accident unfortunately does occur, the airbags are activated by a deceleration sensor and the satellite navigation system may be programmed to alert the rescue services.

■ *Valérie Dobigny:* **How can metrology reduce the number and gravity of accidents?**

Jean-François Magaña: Metrology provides tools to ensure that the technologies used are indeed reliable. It ensures that the measurements used to control a system are representative, reproducible, reliable and accurate enough. Without metrology one cannot fully rely on the safety devices present.

Therefore, it is not metrology itself which reduces the number of accidents and their gravity, but the contribution metrology makes to the reliability and efficiency of these technologies.

The development of metrology allows designers to access parameters which were previously inaccessible. Before laser telemetry existed, it was not possible for vehicles to measure the distance and speed of the preceding vehicle and for automated devices to detect a danger of collision and activate an emergency braking system. The global progress made in measurement and in metrology opens up new possibilities to designers to invent modern security devices. Satellite navigation systems were initially designed to respond to military needs; today they save lives in the sea, in the mountains and on the road.

It is important to establish a dialog between industrial designers, metrologists, researchers and practitioners. Designers must express their needs, for instance:

On recourt également à la mesure dans la conception et l'évaluation des véhicules. Cela va de la mesure d'éclairement des phares à la mesure de l'efficacité du freinage en passant par l'essai des amortisseurs.

Le développement d'infrastructures routières plus sûres recourt aussi à la mesure. L'adhérence des revêtements des routes est un élément important pour la sécurité routière, de même que la détection et la signalisation de pluie, de brouillard, de neige ou d'accidents.

Les systèmes d'aide à la conduite nécessitent des systèmes de mesure avancés comme les radars anti-collision.

Les contrôles par les forces de l'ordre du comportement et de l'état des conducteurs font aussi l'objet de mesures (mesures de vitesse des véhicules, respect des distances de sécurité, mesures d'alcoolémie).

Enfin lorsque malheureusement un accident intervient, c'est le capteur de décélération qui déclenche l'airbag et ce peut être le navigateur GPS qui alerte les secours.

■ *Valérie Dobigny:* **Comment la métrologie peut-elle agir pour réduire le nombre d'accidents et leur gravité?**

Jean-François Magaña: La métrologie fournit les moyens pour que les technologies utilisées soient fiables. Elle garantit que les mesures servant à commander ou à contrôler un système soient représentatives, reproductibles, sûres et suffisamment exactes. Sans métrologie on ne peut totalement se fier aux dispositifs de sécurité mis en place.

Ce n'est donc pas la métrologie elle-même qui réduit le nombre d'accidents et leur gravité, mais les technologies auxquelles elle apporte fiabilité et efficacité.

Le développement de la métrologie permet aux concepteurs un accès à des paramètres auparavant inaccessibles. Lorsque la télémétrie laser n'existait pas, il n'était pas envisageable pour les véhicules de mesurer la distance et la vitesse de celui qui les précède, et que des dispositifs automatiques détectent un danger de collision et déclenchent un freinage d'urgence. L'ensemble des progrès de la mesure et de la métrologie ouvre des possibilités nouvelles aux concepteurs pour imaginer de nouveaux dispositifs de sécurité. Le GPS a été conçu pour des besoins militaires. Aujourd'hui il sauve des vies en mer, en montagne ou au bord de la route.

Ce qui est important, c'est qu'un dialogue s'instaure entre les développeurs industriels et les métrologues, aussi bien chercheurs que praticiens. Les développeurs

"I would like to measure such a quantity or such a phenomena, with so much uncertainty, under such conditions, do you know how to do that?". This dialog allows the needs of the designers to be better identified, and helps them to better understand what must be measured. In parallel, metrologists may suggest alternative approaches, and may in return inform designers about measurement technologies and the performances that can reasonably be expected.

Some years ago I participated in a discussion related to the measurement of the distance between vehicles. The risks of a distance unsuited to speed are well known: the accident in the Mont Blanc tunnel in France dramatically illustrated this. The first questions I raised were: "Do you want to measure the gap in seconds or in metres?", "Do you want to establish a relationship between the distance, the size and the speed of the vehicles?" and "Do you want to measure the distance between the fronts of the two vehicles or between the back and front of the respective vehicles?". These questions - which seem obvious - have grave consequences on the phenomena that are intended to be measured, on the most appropriate techniques, on the interpretation of measurement results and on the resulting actions.

■ *Valérie Dobigny:* **What are the needs of the key players in the field of road safety as regards metrology?**

Jean-François Magaña: Metrologists form part of a scientific and technical community serving science, technology and society as a whole. What these different players lack is knowledge of the stakes of metrology, what metrology can provide, how and where to find advice related to measurements, how to express their needs, and where to find solutions to their problems. A simple informal discussion with a metrologist may, at no cost, offer a valuable perspective to those involved in road safety.

It is therefore necessary for metrologists to make their field of expertise and the services they can provide better known. Metrologists are often consulted too late, when a system is at the industrialization stage. At this point, the metrologist can only help to stabilize the production process of a system whose design may not fully answer the initial needs.

doivent exprimer leurs besoins, par exemple : "Je voudrais mesurer telle grandeur ou tel phénomène, avec telle incertitude, dans telles ou telles conditions, savez-vous faire ?". Ce dialogue permet de mieux cerner la question du développeur, de l'aider à mieux savoir ce qu'il veut mesurer. Dans le même temps, il lui suggère des approches alternatives, il l'informe des technologies de mesure et des performances qu'il peut en attendre.

Il y a quelques années, j'ai participé à une discussion concernant la mesure d'interdistance des véhicules. On sait le risque que représente une distance inadaptée à la vitesse. L'accident du tunnel du Mont Blanc l'a dramatiquement rappelé. Les premières questions que j'ai posées étaient : "Voulez-vous mesurer l'écart entre deux véhicules en secondes ou en mètres ?", "Voulez-vous faire une relation entre interdistance, gabarit et vitesse des véhicules" et "Voulez-vous mesurer l'écart entre les pare-chocs avant des deux véhicules ou entre les pare-chocs respectifs avant et arrière des véhicules ?". Ces questions, qui semblent triviales, ont des conséquences importantes sur les phénomènes que l'on veut mesurer, les techniques les mieux adaptées, l'interprétation des résultats et les actions qui en résultent.

■ *Valérie Dobigny:* **Quels sont les besoins des acteurs de la sécurité routière en matière de métrologie ?**

Jean-François Magaña: Les métrologues sont une communauté scientifique et technique au service de la science, de la technologie et de la société entière. Ce qui manque aux différents acteurs, c'est de connaître les enjeux de la métrologie, de savoir ce qu'elle peut leur apporter, comment et où trouver un conseil en matière de mesure, comment et où s'adresser pour exprimer leurs besoins et connaître les réponses existantes. Un simple entretien informel avec un métrologue peut, sans coût, apporter un éclairage précieux pour les acteurs de la sécurité routière.

Il faut donc que les métrologues fassent mieux connaître leur spécialité et les services qu'ils peuvent rendre. Trop souvent on ne consulte un métrologue qu'en aval, lorsqu'un système est au stade de l'industrialisation. À ce stade, tout ce que peut faire le métrologue, c'est aider à stabiliser le processus de production d'un système qui ne répond peut-être pas exactement aux attentes initiales.

What the metrology world most needs is knowledge of the needs, questions and challenges to meet. Many skills exist among metrologists: if the needs are better matched to the skills, solutions can more easily be found.

Ce dont les acteurs de la métrologie ont surtout besoin, c'est la connaissance des besoins, un dialogue, des questions et des défis à relever. Les compétences existent chez les métrologues. Si les besoins se rapprochent des compétences, les solutions seront facilement trouvées.

■ *Valérie Dobigny:* **How will these practices develop in the coming years?**

Jean-François Magaña: Road safety is a major issue at the global level, and awareness of what is at stake will continue to increase in the coming years. During the Round Table, road safety specialists will be telling us what the main themes will be for the development of road safety in the foreseeable future.

The technologies needed to actively ensure vehicle safety already exist. They will develop and will become more widely available, from bottom-of-the-range vehicles through to top-of-the-range ones. Metrology is no longer a limiting factor in this domain.

The present trend is to render roads "intelligent", to develop human-vehicle interfaces and to provide assistance to drivers, since the human factor is most definitely the major risk factor as far as road safety is concerned.

Metrology can offer solutions to detect the risk of driver "failure" including alcohol consumption, drowsiness, etc. so long as the risk factors are correctly identified in the first place.

Metrology can also reduce the risks caused by the environment of the vehicle, such as glare from headlights.

In addition, the progress of metrology may prevent or at least reduce drivers' errors of appreciation: safe distances for overtaking, crossing a white line, etc.

Lastly, with the rapid development of road and vehicle equipment, the movies in which the driver simply dictates his destination to the on-board computer and selects automatic cruise are no longer science-fiction, they are merely anticipation! ■

■ *Valérie Dobigny:* **Quelle sera l'évolution de cette pratique dans les prochaines années ?**

Jean-François Magaña: La sécurité routière est un sujet majeur au niveau mondial. La prise de conscience de cet enjeu augmentera sans cesse dans les années à venir. Les spécialistes de la sécurité routière nous diront lors de la table ronde du 18 juin quels sont les axes de développement de la sécurité routière.

Les technologies de sécurité active des véhicules existent. Elles se démocratiseront et seront appliquées aussi bien sur les véhicules de bas de gamme que sur les véhicules de haut de gamme. La métrologie n'est déjà plus un facteur limitant dans ce domaine.

La tendance actuelle est de rendre les routes intelligentes, de développer les interfaces homme-véhicule et l'assistance à la conduite. Le facteur humain est certainement le principal facteur de risque en matière de sécurité routière.

La métrologie peut apporter des solutions pour détecter les risques de défaillance du conducteur, imprégnation alcoolique, assoupissement… pour autant que les facteurs de risque soient correctement identifiés.

La métrologie peut également réduire les risques dûs à l'environnement du véhicule tel que l'éblouissement.

Par ailleurs, les progrès de la métrologie peuvent prévenir et réduire les erreurs d'appréciation des conducteurs : distances libres pour le dépassement, franchissement de lignes…

Enfin grâce à l'instrumentation des routes et des véhicules, les films dans lesquels le conducteur donne sa destination à l'ordinateur de bord et se place en pilotage automatique ne sont déjà plus de la science-fiction. Tout au plus de l'anticipation. ■

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PREPACKAGES

The benefits of a dual legislative system for prepackages

JEROEN ROMMERTS, NMi, The Netherlands

Abstract

This document, which is intended as a discussion document for anyone interested in prepackaging legislation, considers the *minimum principle* as an addition to the *average principle* in prepackages as implemented in OIML R 87 in Europe and in most other countries.

It sets out ideas of how the minimum principle could be added to prepackaging legislation, alongside the average principle.

The aim is to decrease the burden on small packers and packers with low-cost product, to facilitate market surveillance by national authorities, and to provide for easier access to external markets.

If implemented, it could create a legal system with more choice for packers; it could decrease the burden on small packers and packers with low-cost product, facilitate trade of prepacked products between the various economical free trade zones in the world, and provide assistance in market surveillance activities by authorities.

1.1 Summary

European e-marking legislation [1] allows for and OIML R 87 [2] recommends the **average principle** for prepackages, whereby the average quantity may not be less than the nominal quantity indicated on the label, only a small number of prepackages may contain less product than the T1-error and no prepackages may contain less product than the T2-error. However, it is almost impossible to enforce the average principle during market surveillance as the required number of prepackages is usually not available.

For this reason, in Europe enforcement relies on judgment and on various forms of recognition of the packer's filling procedures by governments. OIML TC 6 is developing a similar system in its proposal for the IQ mark system.

Small packers and packers who pack cheap product do not benefit from the average principle. In practice they often use the minimum principle, whereby the actual quantity of product in all prepackages is at least equal to the nominal quantity indicated on the label. For packers who use the minimum principle, a judgment of their filling procedures by the authorities is a waste of time and leads to higher costs for the packer as well as for the authorities.

Enforcement of prepackages filled according to the minimum principle can take place through market surveillance. Therefore there is no need for recognition of filling procedures.

It should be possible to distinguish prepackages filled according to the minimum principle from those filled according to the average principle. The best solution is through a mark identifying the average filled prepackages (in Europe: the 'e'-mark) while minimum principle prepackages do not bear a mark. The second best solution is to identify prepackages filled according to the minimum principle by using words such as 'min' or 'minimum' preceding the nominal quantity.

Small packers and packers with cheap product who choose to apply the minimum principle do not need cumbersome and recognized quantity control systems and their prepackages are checked easy through market surveillance. Market surveillance authorities may instruct the packer not to put non-conforming prepackages on the market in the future.

Larger packers and packers with more expensive products, who choose to invest in more stringent and recognized quantity control systems, can apply the average principle. Enforcement relies mainly on recognition of procedures instead of on market surveillance.

1.2 Definitions

average principle

The specifications for the quantity of product in prepackages are as laid down in current EU legislation and in OIML R 87:

- the average quantity must not be less than the nominal quantity that is indicated on the label;
- a small number of prepackages may contain less product than the T1-error; and
- no prepackages may contain less product than the T2-error.

minimum principle

The actual quantity of product in all prepackages must not be less than the nominal quantity indicated on the label.

e-mark

Small 'e' printed on the packing material to indicate that the prepackage complies with the current European e-marking legislation.

market surveillance

For the purpose of this document 'market surveillance' is referred to as shop checks.

packer

Person who measures and fills product in prepackages.

importer

Person established in a market who places prepackages originating from a third country on the market he is established in.

2.1 Current EU legislation

Currently, European legislation allows for three ways (explained in 3.1, 3.2 and 3.3 below) to bring e-marked prepackages to the market. All three ways are laid down in Annex I of 75/106/EEC and 76/211/EEC. Some Member States allow other ways, according to national legislation; others have harmonized their national legislation with European legislation without an e-mark.

To check whether prepackages of average filled prepackages in a batch meet the requirements, a *reference test* is used (see 76/211/EEC Annex I.5, which is more or less equal to OIML R 87, clause 4). For a non-destructive check, a batch should contain at least 100 prepackages. This number is usually not available during shop-checks. Therefore, it is almost impossible to enforce a system of average filled prepackages through shop-checks. For this reason, European enforcement (i.e. the combination of recognized procedures and the reference test) is transferred from the shops to the premises of the packer.

Shop-checks are important because they can spot imported prepackages that the authorities were unaware of and help to identify packers and importers unknown to the authorities.

Prepackages that bear the e-mark comply with European legislation.

2.2 Measuring the actual quantity of product in prepackages

The quantity of product contained in a prepackage ..., shall be measured ... by weight or volume under the responsibility of the packer and/or importer. The measurement ... shall be carried out by means of a legal measuring instrument suitable for effecting the necessary operations. (See 76/211/EEC Annex I.4, second paragraph. Note: Measuring may be carried out by using measuring container bottles).

This possibility offers four practical solutions:

- Hand measuring the product with the aid of a non-automatic weighing instrument, with the weight of the individual packing material tarred or measuring a liquid using a verified capacity (volume) measure. When no records are kept, the only practical way requires each prepackage to contain the quantity of product indicated on the label.
- Measuring (while dosing) the product with a gravimetric filling instrument.
- Measuring (while dosing) the product with a volumetric filling instrument. This option is currently not used, although manufacturers are developing it.
- Weighing of the product with an automatic weighing instrument between measuring and packing. This is only possible for a limited number of products.

Options 2, 3 and 4 are not possible in countries where the software used in the machine is not included in the type approval and verification of the machine itself.

2.3 Production checks in accordance with recognized procedures

The check may be carried out by sampling. (Note: The check may be carried out by using measuring container bottles).

Where the actual contents are not measured, the check carried out by the packer shall be so organized that the quantity of the contents is effectively ensured.

This condition is fulfilled if the packer carries out production checks in accordance with procedures recognized by the competent departments in the Member

Note: Text in italics is copied from legislation.

State and if he holds at the disposal of those departments the documents containing the results of such checks, in order to certify that these checks, together with any corrections and adjustments which they have shown to be necessary, have been properly and accurately carried out. (See 76/211/EEC Annex I.4 third, fourth and fifth paragraphs).

Most packers in Europe use this option. This provision (recognition of procedures by competent departments) is currently under discussion in Europe as implementation in different Member States in Europe varies considerably since some countries do not recognize the procedures of **explicit recognition**, **recognition through codes of practice** and **implicit recognition** as described in 1.1 above.

2.4 Imports: provide evidence

In the case of imports from non-EEC countries, the importer may instead of measuring and checking provide evidence that he is in possession of all the necessary guarantees enabling him to assume responsibility. (See 76/211/EEC Annex I.4 sixth paragraph).

There is no harmonization about what evidence is supposed to be provided. In the future, such evidence may consist of an OIML *Certificate of conformity* according to the possible future Framework For a Mutual Acceptance Arrangement on an OIML IQ Mark Scheme.

2.5 National legislation in The Netherlands: Minimum principle

According to Dutch legislation, in The Netherlands the quantity of product in prepackages has to be at least equal to the nominal quantity, except when prepackages meet the requirements of the European legislation (have their procedures recognized) and bear the e-mark [3].

Although minimum filled prepackages will probably meet the requirements of the average principle laid down in European legislation, it is not allowed to apply the e-mark because the procedures of the 'minimum principle packer' have not been recognized by the competent department.

This minimum principle rule also applied to prepackages originating from other countries (both within and outside the EU) until the system of mutual recognition was implemented in Europe. Mutual recognition means that EU Member States must accept product that is legally on the market in another Member State, even if it does not comply with legislation in the receiving Member State. One exception is when consumers are not protected properly. The Dutch interpretation of mutual recognition is currently under debate and the question is being posed "are consumers protected when average filled prepackages without an e-mark from outside The Netherlands are placed on the Dutch market?" If not, then the mutual recognition principle does not apply and these prepackages could be prevented from being placed on the Dutch market.

Compared to the reference test it is relatively easy to check whether or not prepackages filled according to the minimum principle comply. Contrary to the average principle system, a legal system based on the minimum principle can be enforced through shop-checks.

3 The minimum principle in co-existence with the average principle

3.1 How the two systems co-exist

Packers that apply the minimum principle may do so without permission from the authorities. Small packers and packers packing cheap product will probably choose this option.

Packers that want to apply the average principle do so because they want to fill less product. In order to do that, their filling procedures have to be better developed. These are larger packers, who already implemented quality systems and packers of expensive product, who benefit more.

3.2 Enforcement

3.2.1 Minimum principle

Authorities can enforce prepackages packed according to the minimum principle through an easy check in the shop.

More details about the practical application of this test as well as the statistical background are currently under development by Dr. Alain Duran[1].

[1] Inspector in charge of quality statistical tests within the Direction Générale de la Concurrence, de la Consommation et de la Répression des Fraudes (Ministère de l'Économie, des Finances et de l'Industrie (alain.duran@dgccrf.finances.gouv.fr)

Prepackages that fail the check have to be removed from the market. Authorities may investigate at the packers' premises to ascertain whether the rejection is caused by a structural problem. In this case, market surveillance authorities may instruct the packer to prevent the placing on the market of non-compliant prepackages in the future. Packers can be forced to apply the average principle in future.

The existence of prepackages packed according to the minimum principle brings enforcement authorities to the shops. Because of that, they will have a better knowledge of the market. They will find fraudulent packers and imported product.

3.2.2 Average principle

Authorities cannot enforce average filled prepackages during shop-checks, because the required batch size is usually not available. Enforcement is transferred to the reference test and recognition of the filling procedures of the packer.

The placing on the market of batches that fail the reference test can be prevented.

The permission to pack according to the average principle can be withdrawn, forcing the packer to use the minimum principle.

3.3 Packers can choose

It is up to the packer to choose to apply the minimum principle or the average principle.

Before the average principle may be used, permission must be obtained, and the filling and measuring procedures of the packer have to be verified and recognized by the metrological authorities.

Packers who choose to apply the minimum principle may do so without permission or judgment of their filling and measuring procedures. However, some countries may have legal requirements for filling prepackages, for instance the obligation to use verified measuring instruments.

3.4 Labelling

For consumer information as well as market surveillance it is necessary that prepackages from either system can be distinguished. But, both are better served with different labelling.

3.4.1 For consumer information

In Europe, very few consumers understand the meaning of the e-mark.; consumers receive better information when minimum filled prepackages are marked (for example: 'minimum 200 g' or 'min 750 ml').

Marking the product with 'minimum' or similar will inform the consumer and extend their options. They can make the choice as to whether they want a minimum amount, or an average amount.

3.4.2 For enforcement

Enforcement is easier when the average filled prepackages are marked. This mark can consist of a general mark (IQ-mark or e-mark) or a mark identifying the authority that gave permission to the packer to use the average system.

While performing shop-checks, authorities can verify in a database whether or not the packer is allowed to use the average system and concentrate on the minimum principle prepackages.

When legislation requires a mark on prepackages filled according to the minimum principle (for example 'minimum 200 g' or 'min 750 ml'), packers are encouraged to not mark their minimum filled prepackages as such, to avoid rejection during shop-checks (as authorities will treat those prepackages as average filled).

3.5 How imported prepackages fit in

For imported prepackages the importer is responsible.

3.5.1 Minimum principle prepackages

The importer can place prepackages packed according to the minimum principle on the market without permission and without having to notify the authorities.

3.5.2 Average principle prepackages

For average filled prepackages the importer can assume responsibility in two ways:

- by checking the batches by himself and according to procedures recognized by the authorities, or
- by providing evidence that he is able to assume his

responsibility. The acceptable evidence needs to be developed and could, among others, consist of the OIML Certificate of Conformity (from the IQ mark proposal).

3.6 Consumer protection and fair competition

To facilitate fair competition, the consumer needs to be accurately informed about the quantity of product in prepackages. For that, the relationship between the actual quantity and the nominal quantity has to be ensured.

Similar to the sale of product that is not prepacked, the relation between the actual (measured) quantity and the claimed (labelled) quantity may never become part of the competition. It is the responsibility of authorities to ensure that this is never the case.

With a dual legislative system for prepackages as described in this paper, the author concludes that the packer has more options to choose from, the consumer is better informed and fair competition is better facilitated. ■

References

[1] 75/106/EEC (on the approximation of the laws of the Member States relating to the making-up by volume of certain prepackaged liquids) and 76/211/EEC (on the approximation of the laws of the Member States relating to the making-up by weight or by volume of certain prepackaged products)

[2] OIML R 87: Quantity of product in prepackages, Edition 2004 (E), OIML

[3] Warenwetbesluit Etikettering van Levensmiddelen, Articles 11.1 and 11.3 and Hoeveelheidsaanduidingenbesluit, Article 28

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Certificates registered 2007.02–2007.04

Up to date information (including B 3): www.oiml.org

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Issuing Authority / *Autorité de délivrance*

Netherlands Measurement Institute (NMi)
Certin B.V., The Netherlands

R60/2000-NL1-02.02
Type 0765 (Class C)
Mettler-Toledo Inc., 150 Accurate Way,
Inman, SC 29349, USA

For each instrument category, certificates are numbered in the order of their issue (renumbered annually).

Pour chaque catégorie d'instrument, les certificats sont numérotés par ordre de délivrance (cette numérotation est annuelle).

OIML Recommendation applicable within the System / Year of publication

Recommandation OIML applicable dans le cadre du Système / Année d'édition

The code (ISO) of the Member State in which the certificate was issued, with the Issuing Authority's serial number in that Member State.

Le code (ISO) indicatif de l'État Membre ayant délivré le certificat, avec le numéro de série de l'Autorité de Délivrance dans cet État Membre.

Year of issue

Année de délivrance

Certified type(s)

Type(s) certifié(s)

Applicant

Demandeur

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Certificats enregistrés 2007.02–2007.04

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Les certificats sont délivrés par les États Membres de l'OIML, qui ont établi une ou plusieurs autorités de délivrance responsables du traitement des demandes présentées par des constructeurs souhaitant voir certifier leurs types d'instruments.

Les règles et conditions pour la demande, la délivrance et l'utilisation de Certificats OIML sont définies dans l'édition 2003 de la Publication B 3 *Système de Certificats OIML pour les Instruments de Mesure.*

Les services nationaux de métrologie légale peuvent accepter les certificats sur une base volontaire; avec le développement entre Membres OIML d'un climat de confiance mutuelle et de reconnaissance des résultats d'essais, le Système simplifie les processus d'approbation de type pour les constructeurs et les autorités métrologiques par l'élimination des répétitions coûteuses dans les procédures de demande et d'essai.

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Diaphragm gas meters
Compteurs de gaz à parois déformables

R 31 (1995)

- **Issuing Authority / *Autorité de délivrance***

  Netherlands Measurement Institute (NMi) Certin B.V., The Netherlands

R031/1995-NL1-2007.01
Diaphragm gas meter
Ecometros S.L., C/Urgel, 240 2 °C, E-08036 Barcelona, Spain

R031/1995-NL1-2007.02
Diaphragm gas meter
Siame, Z.I. 8030, Grombalia, Nabeul, Tunisia

R031/1995-NL1-2007.03
Diaphragm gas meter
iMeter B.V, Snelliustraat 24, NL-7102 RD Winterwijk, The Netherlands

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

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

R 51 (1996)

- **Issuing Authority / *Autorité de délivrance***

  Netherlands Measurement Institute (NMi) Certin B.V., The Netherlands

R051/1996-NL1-2006.03
Automatic catchweighing instrument. Type: LS-3000, CW-3000 and GW-3000
DIBAL S.A., c/ Astintze Kalea, 24, Poligono Industrial Neinver, E-48016 Derio (Bilbao-Vizcaya), Spain

R051/1996-NL1-2006.04
Automatic catchweighing instrument. Type: LS-3000, CW-3000 and GW-3000
Avery Weigh-Tronix, Foundry Lane, Smethwick B66 2LP, West Midlands, 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 (1991)

- **Issuing Authority / *Autorité de délivrance***

  National Weights and Measures Laboratory (NWML), United Kingdom

R060/1991-GB1-2000.05 Rev. 1
Model TB5
Lahti Precision Oy, Ahjokatu 4 A, FIN-15800 Lahti, Finland

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***

  National Weights and Measures Laboratory (NWML), United Kingdom

R060/2000-GB1-2006.03
Aluminium compression (beam) strain gauge load cell
CAS Corporation, CAS Factory # 19 Kanap-ri, Gwangjuk-Myoun, Yangju-SI, 482-841 Gyeonggi-Do, Korea (R.)

and

Shanghai CAS Electronics Co. Ltd., No. 448 Maixin Road, Xingiao Zhen Songjiang Qu, 2016012 Shanghai, P.R. China

R060/2000-GB1-2006.04
Aluminium compression (beam) strain gauge load cell
CAS Corporation, CAS Factory # 19 Kanap-ri, Gwangjuk-Myoun, Yangju-SI, 482-841 Gyeonggi-Do, Korea (R.)

Issuing Authority / *Autorité de délivrance*

Netherlands Measurement Institute (NMi) Certin B.V., The Netherlands

R060/2000-NL1-2005.06 Rev. 1
Single point bending beam load cell: Type: C2G1
Minebea Co. Ltd., Kuruizawa Factory Miyota-Machi, Kitasakugun, 4106-73 Nagano-Ken, Japan

R060/2000-NL1-2006.19
Digital compression load cell. Type: CB50X-DL......
Scaime S.A., Z.I. de Juvigny, B.P. 501, F-74105 Annemasse Cedex, France

R060/2000-NL1-2006.20
Shear-beam load cell. Type: SBC and SBCS
Mettler-Toledo (Changzhou) Precision Instruments Ltd., 5 Middel HuaShan Road, Sanjing Industry Park, XinBei District, 213022 ChangZhou, JiangSu, P.R. China

R060/2000-NL1-2006.21 Rev. 1
Tension, S-type load cell, Type: S510T
Balea, 8, avenue du Grand Chêne, Z.A. Les Avants, F-34270 Saint-Mathieu de Tréviers, France

R060/2000-NL1-2006.22
Single point load cell. Type: PW6.../.., PW6K.../.., PW6C.../.. And PW6D.../..
Hottinger Baldwin Messtechnik GmbH, Im Tiefen See 45, D-64293 Darmstadt, Germany

R060/2000-NL1-2007.01
Single point load cell: Type: PW16A...
Hottinger Baldwin Messtechnik GmbH, Im Tiefen See 45, D-64293 Darmstadt, Germany

R060/2000-NL1-2007.02
Shear beam load cell
Lahti Precision Oy, Ahjokatu 4 A, FIN-15800 Lahti, Finland

R060/2000-NL1-2007.03
Single point load cell. Type: 1028
Vishay-Transducers, 5 Hazoran Street, New Industrial, IL-42506 Netanya, Israel

R060/2000-NL1-2007.05
Compression load cell: Type: COKL... and COK...
Laumas S.r.l., via 1° Maggio n.6, I-43030 Basilcanova Parma, Italy

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*

Measurement and Product Safety Service, New Zealand

R076/1992-NZ1-2007.01 Rev. 1 [MAA Certificate]
A & D Mercury Model FS-30Ki - Non-Automatic Weighing Instrument
A & D Mercury Ltd., 32 Dew Street, SA 5031 Thebarton, Australia

Issuing Authority / *Autorité de délivrance*

National Measurement Institute (NMI), Australia

R076/1992-AU1-2002.01 Rev. 2
Datalogic Scanning Model Magellan 8502 and 9502 Weighing Instruments
Datalogic Scanning, Inc., 959 Terry Street,, Eugene, Oregon 97402, Eugene, United States

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

R076/1992-JP1-2007.01 [MAA Certificate]
Type AD-6121 A
A&D Company Ltd., 3-23-14 Higashi-Ikebukuro, Toshima-Ku, 170-0013 Tokyo, Japan

Issuing Authority / *Autorité de délivrance*

National Weights and Measures Laboratory (NWML), United Kingdom

R076/1992-GB1-2007.01
Torrey LSQ-20 and LSQ-40
Fabricantes De Basculas Torrey S.A. De C.V., Los Andes 605, Col. Coyoacan, Monterrey, N.L., C.P. 64510, Mexico

R076/1992-GB1-2007.03
NCR 7878-2000 Non-Automatic weighing instrument
NCR Corporation, 2651 Satellite Blvd, 30136 Georgia, Duluth, Georgia, United States

R076/1992-GB1-2007.04
Charder DP-2400V5, DP-2701, DP-3100, DP-3300 indicating devices
Charder Electronic Co., Ltd., 103, Kuo Chung Road, Dah Li City, Taichung Hsien 412, Chinese Taipei

Issuing Authority / *Autorité de délivrance*

Netherlands Measurement Institute (NMi) Certin B.V., The Netherlands

R076/1992-NL1-2006.39 Rev. 1
Non-automatic weighing instrument. Type: FM-123SL, FMM-TPRO3100
Fook Tin Technologies Ltd., 4/F Eastern Center, 1065 King's Road, Quarry Bay, Hong Kong China

R076/1992-NL1-2006.40
Non-automatic weighing instrument. Type: Azextra
ADAM Equipment Co. Ltd., Bond Avenue, Denbigh East Industrial Estate, Milton Keynes MK1 1SW, United Kingdom

R076/1992-NL1-2006.41
Non-automatic weighing instrument. Type: CGC-…M
ADAM Equipment Co. Ltd., Bond Avenue, Denbigh East Industrial Estate, Milton Keynes MK1 1SW, United Kingdom

R076/1992-NL1-2007.02
Non-automatic weighing instrument. Type: FM-604, FMM-TPRO3500, FM-605, FMM-TPRO3300
Fook Tin Technologies Ltd., 4/F Eastern Center, 1065 King's Road, Quarry Bay, Hong Kong China

R076/1992-NL1-2007.03
Non-automatic weighing instrument. Type: SM-100..
Shanghai Teraoka Electronic Co. Ltd., Ting Lin Industry Development Zone, Jinshan District, Shanghai 201505, P.R. China

R076/1992-NL1-2007.05
Non-automatic weighing instrument. Type: PC-100
Acom Inc., #679-1, Yugyo-ri, Gunnae-Myun, Pocheon-Gun, Kyunggi-Do, Korea (R.)

R076/1992-NL1-2007.06
Non-automatic weighing instrument. Type: 420, 420 Plus, 420 HE
Rice Lake Weighing Systems, 230 West Coleman Street, 54868 Wisconsin, Rice Lake, Wisconsin, United States

R076/1992-NL1-2007.07
Non-automatic weighing instrument. Type: DS-162, DS-162SS, DS-162C
Shanghai Teraoka Electronic Co., Ltd., Ting Lin Industry Development Zone, Jinshan District, Shanghai 201505, P.R. China

R076/1992-NL1-2007.08
Non-automatic weighing instrument. Type: SM-4600…
Teraoka Weigh-System PTE Ltd., 4 Leng Kee Road, #06-01 SIS Building, 159088 Singapore, Singapore

R076/1992-NL1-2007.09
Non-automatic weighing instrument. Type: T31xx
Ohaus Corporation, 19A Chapin Road, NJ 07058-9878 New Jersey, Pine Brook, New Jersey, United States

R076/1992-NL1-2007.10
Non-automatic weighing instrument. Type: DPS-4600…
Teraoka Seiko Co. Ltd., 13-12 Kugahara, 5-Chome, Ohta-ku, 146-8580 Tokyo, Japan

Issuing Authority / *Autorité de délivrance*

Physikalisch-Technische Bundesanstalt (PTB), Germany

R076/1992-DE1-2005.09 Rev. 2
Non-automatic electromechanical weighing instrument with or without lever works. Type: AV…-C, AC…-C
Ohaus Corporation, 19A Chapin Road, NJ 07058-9878 New Jersey, Pine Brook, New Jersey, United States

R076/1992-DE1-2007.01
Nonautomatic electromechanical weighing instrument. Type: CS300…
Bizerba GmbH & Co. KG, Wilhelm-Kraut-Straße 65, D-72336 Balingen, Germany

R076/1992-DE1-2007.02
Nonautomatic electromechanical weighing instrument. Type: ECII…
Bizerba GmbH & Co. KG, Wilhelm-Kraut-Straße 65, D-72336 Balingen, Germany

Issuing Authority / *Autorité de délivrance*
OIML Chinese Secretariat, State General Administration for Quality Supervision and Inspection and Quarantine (AQSIQ), China

R076/1992-CN1-2002.01
Electronic Price Computing Scale
Zhejiang Kaifeng Group Co. Ltd., Huku Industrial Zone, Zhejiang Province, Yongkang City, P.R. China

R076/1992-CN1-2004.04
Price Computing Instrument
W & P Scales Mfg. (Kunshan) Co., Ltd., N° 99 Shunchang Rd., Jiangsu Province, 215337 Kunshan, P.R. China

R076/1992-CN1-2004.05
Weighing Indicator KW
W & P Scales Mfg. (Kunshan) Co., Ltd., N° 99 Shunchang Rd., Jiangsu Province, 215337 Kunshan, P.R. China

R076/1992-CN1-2005.05
Bar Code Printing Scale, Type:TM-Aa
Shanghai Dahua Scale factory, 1488 Jinqiao Road, Pudong, 201206 Shanghai, P.R. China

Issuing Authority / *Autorité de délivrance*
Swedish National Testing and Research Institute AB, Sweden

R076/1992-SE1-2006.02
Graduated, self-indicating, electronic, non-automatic weighing instrument.
Flintab AB, Kabelvägen 4, SE-553 02 Jönköping, Sweden

R076/1992-SE1-2007.01
Graduated, self-indicating, electronic, multi-interval non-automatic weighing instrument.
Ishida Co., Ltd., 44, Sanno-cho, Shogoin, Sakyo-ku, 606-8392 Kyoto-city, Japan

Issuing Authority / *Autorité de délivrance*
DANAK The Danish Accreditation and Metrology Fund, Denmark

R076/1992-DK1-2001.02 Rev. 1
Non-automatic weighing instrument. Type: 200, 205, 210, 215, or 220
Cardinal Scale Manufacturing Co., 203 East Daugherty St., Webb City, 64870 Missouri, United States

R076/1992-DK1-2006.01 Rev. 1
Non-automatic weighing instrument. Type: Load Line-3
Tunaylar Baskül Sanayi ve Ticaret A.S., Beylikdüzü N°:6, TR-34520 Büyükçekmece, Istanbul, Turkey

R076/1992-DK1-2007.01
Non-automatic weighing instrument. Type: 180EU
Cardinal Scale Manufacturing Co., 203 East Daugherty St., Webb City, 64870 Missouri, United States

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*
Czech Metrology Institute (CMI), Czech Republic

R117/1995-CZ1-2007.01
Fuel dispenser for motor vehicles. Type: CFS Fuel Star Series
Chen Fuel Systems LTD, Industrial Zone No. 5, P.O.B. 262, IL-21071 Maalot, Israel

R117/1995-CZ1-2007.02
Fuel dispenser for motor vehicles. Type: CFS Fuel Star Series
Chen Fuel Systems LTD, Holtmeulen 34, NL-1083 CH Amsterdam, The Netherlands

Issuing Authority / *Autorité de délivrance*
Netherlands Measurement Institute (NMi) Certin B.V., The Netherlands

R117/1995-NL1-2007.01
Fuel dispenser for Motor Vehicles, model Quantium with a Q_{max} of 80 L/min.
Tokheim Netherlands B. V., Touwslagerstrat 17, NL-2984 AW Ridderkerk, The Netherlands

and

Tokheim-Hengshan Technologies, 66 Nanxiang Yi Lu, S10663 Science Town of Guangzhou, P.R. China

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Multi-dimensional measuring instruments
Instruments de mesure multidimensionnels

R 129 (2000)

▶ Issuing Authority / *Autorité de délivrance*

Netherlands Measurement Institute (NMi) Certin B.V., The Netherlands

R129/2000-NL1-2006.01 Rev. 1
Multi-dimensional measuring instrument for measuring cubic and rectangular, non-irregular shaped, non reflective and opaque boxes. Type: VMS 510

SICK AG., Nimburger Strasse 11, D-79276 Reute, Germany

R129/2000-NL1-2007.01
Multi-dimensional measuring instrument for measuring rectangular, non-rectangular, non-irregular shaped, non-reflective and opaque boxes. Type: VMS 520

SICK AG., Nimburger Strasse 11, D-79276 Reute, Germany

▶ Issuing Authority / *Autorité de délivrance*

Norwegian Metrology Service, Norway

R129/2000-NO1-2007.01
Type: Dimensioner: Cargoscanner CSN810 (also sold under the name CNS810). Display: Cargoscanner CS2200

Mettler-Toledo Cargoscan AS, Grenseveien 65/67, N-0663 Oslo, Norway

R129/2000-NO1-2007.02
Type: Dimensioner: Cargoscanner CSN910 (also sold under the name CND910) Display: Cargoscanner CS2200

Mettler-Toledo Cargoscan AS, Grenseveien 65/67, N-0663 Oslo, Norway

R129/2000-NO1-2007.03
Type: Dimensioner: Cargoscanner CSN840 Pallet (also sold under the name CND840.3 Pallet Dimensioner). Display: Cargoscanner CS2200

Mettler-Toledo Cargoscan AS, Grenseveien 65/67, N-0663 Oslo, Norway

OIML CERTIFICATE SYSTEM

List of OIML Issuing Authorities (by Country)

*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/certificates. There are two changes since the April 2007 issue of the Bulletin, marked in **red**.*

AUSTRALIA

AU1 - National Measurement Institute	**R 49**	R 50	R 51	R 60	R 76	R 85
	R 106	R 107	R 117/118	R 126	R 129	

AUSTRIA

AT1 - Bundesamt für Eich- und Vermessungswesen	R 50	R 51	R 58	R 61	R 76	R 85
	R 88	R 97	R 98	R 102	R 104	R 106
	R 107	R 110	R 114	R 115	R 117/118	

BELGIUM

BE1 - Metrology Division	R 76	R 97	R 98

BRAZIL

BR1 - Instituto Nacional de Metrologia, Normalização e Qualidade Industrial	R 76

BULGARIA

BG1 - State Agency for Metrology and Technical Surveillance	R 76	R 98

CHINA

CN1 - State General Administration for Quality Supervision and Inspection and Quarantine	R 60	R 76	R 97	R 98

CZECH REPUBLIC

CZ1 - Czech Metrology Institute	R 49	R 76	R 81	R 85	R 105	R 117/118

DENMARK

DK1 - The Danish Accreditation and Metrology Fund	R 50	R 51	R 60	R 61	R 76	R 98
	R 105	R 106	R 107	R 117/118	R 129	
DK2 - FORCE Technology, FORCE-Dantest CERT	R 49					

FINLAND

FI1 - Inspecta Oy	R 50	R 51	R 60	R 61	R 76	R 85
	R 106	R 107	R 117/118			

FRANCE

FR1 - Bureau de la Métrologie	*All activities and responsibilities were transferred to FR2 in 2003*				
FR2 - Laboratoire National de Métrologie et d'Essais	R 31	R 49	R 50	R 51	R 58
	R 60	R 61	R 76	R 85	R 88
	R 97	R 98	R 102	R 105	R 106
	R 107	R 110	R 114	R 115	R 117/118
	R 126	R 129			

GERMANY

DE1 - Physikalisch-Technische Bundesanstalt (PTB)	R 16	R 31	R 49	R 50	R 51
	R 58	R 60	R 61	R 76	R 88
	R 97	R 98	R 102	R 104	R 105
	R 106	R 107	R 110	R 114	R 115
	R 117/118	R 128	R 129	R 133	

HUNGARY

HU1 - Országos Mérésügyi Hivatal	R 76

JAPAN

JP1 - National Metrology Institute of Japan	R 60	R 76	R 115	R 117/118

KOREA (R.)

KR1 - Korean Agency for Technology and Standards	R 76

THE NETHERLANDS

NL1 - NMi Certin B.V.	R 31	R 49	R 50	R 51	R 60
	R 61	R 76	R 81	R 85	R 97
	R 105	R 106	R 107	R 117/118	R 126
	R 129	R 134			

NEW ZEALAND

NZ1 - Ministry of Consumer Affairs, Measurement and Product Safety Service	R 76

NORWAY

NO1 - Norwegian Metrology Service	R 50	R 51	R 61	R 76	R 105
	R 106	R 107	R 117/118	R 129	

POLAND

PL1 - Central Office of Measures	R 76	R 98	R 102

ROMANIA

RO1 - Romanian Bureau of Legal Metrology	R 97	R 98	R 110	R 114	R 115

RUSSIAN FEDERATION

RU1 - Russian Research Institute for Metrological Service	R 31	R 50	R 51	R 58	R 60
	R 61	R 76	R 85	R 88	R 93
	R 97	R 98	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		

SLOVAKIA

SK1 - Slovak Legal Metrology (Banska Bystrica)	**R 49**	R 76	R 117/118		

SLOVENIA

SI1 - Metrology Institute of the Republic of Slovenia	R 76				

SPAIN

ES1 - Centro Español de Metrología	R 51	R 60	R 61	R 76	R 97
	R 98	R 126			

SWEDEN

SE1 - Swedish National Testing and Research Institute AB	R 50	R 51	R 60	R 61	R 76
	R 85	R 98	R 106	R 107	R 117/118

SWITZERLAND

CH1 - Swiss Federal Office of Metrology and Accreditation	R 16	R 31	R 50	R 51	R 60
	R 61	R 76	R 97	R 98	R 105
	R 106	R 107	R 117/118		

UNITED KINGDOM

GB1 - National Weights and Measures Laboratory	R 49	R 50	R 51	R 60	R 61
	R 76	R 85	R 98	R 105	R 106
	R 107	R 117/118	R 129	R 134	
GB2 - National Physical Laboratory	R 97				

UNITED STATES

US1 - NCWM, Inc.	R 60	R 76			

VIETNAM

VN1 - Directorate for Standards and Quality (STAMEQ)	R 76				

MAA IMPLEMENTATION: WATER METERS

First R 49 CPR Meeting

Brøndby, Denmark

Régine Gaucher - MAA Project leader - BIML
Samuel Just - R 49 CPR Secretariat - BIML

The R 49 CPR held its first meeting on 24-25 May 2007 in Brøndby, Denmark at the FORCE Technology premises.

Eight countries applied for participation in the R 49 Declaration of Mutual Confidence (DoMC), among which three applied to participate as Issuing Participants.

Four of the eight CPR representatives who were appointed attended the meeting, thus the quorum was reached (as defined in the Amendment - approved in October 2006 - to OIML B 10-1 *Framework for a Mutual Acceptance Arrangement on OIML Type Evaluations*).

OIML TC 3/SC 5 *Conformity assessment* and OIML TC 8/SC 5 *Water meters* were also represented in the meeting.

The CPR discussed in particular the following issues:

- The scope of the DoMC and notably those requirements in OIML R 49 to be excluded from the scope of the R 49 DoMC;
- The additional national requirements to be included in the scope of the DoMC;
- The validation of technical and metrological experts proposed by Member States in the field of water meter testing; and
- The acceptance of potential Participants who applied for participation.

The R 49 CPR Members drew up the R 49 CPR Report according to the requirements of OIML B 10-1. This report will be circulated among potential Participants for final acceptance of each Participant by all the others.

Considering the time schedule, it is expected that the R 49 DoMC will be signed in December 2007.

FORUM: METROLOGY - TRADE FACILITATOR?

Second hand equipment used again

EBERHARD SEILER
Chairman, OIML Permanent Working Group on Developing Countries (PWGDC)

1 Introduction

From time to time equipment is replaced, even though it still functions correctly; indeed, this happened with measurement standards used by certain German Verification Authorities. During the Forum entitled *Metrology - Trade Facilitator* held in Berlin in conjunction with the 2004 OIML Conference and CIML Meeting, such used equipment was offered during the poster exhibition *What is offered, what is needed*.

The need for equipment was expressed by many representatives from legal metrology services of Developing Countries and Countries in Transition but demand was much greater than what was on offer. The selection of recipient countries was based on the analysis of a questionnaire which had to be submitted to the Chairman of the OIML Permanent Working Group on Developing Countries (PWGDC).

The feedback to the German Verification Authorities about this high demand, and the dispatch of the second hand measuring instruments, resulted in an offer for some more equipment. The BIML published a list of available equipment on its web site together with the application procedure. A second round of shipments was started and completed and a summary of these activities is given below.

2 Equipment donated and recipient countries

The list of second hand equipment shipped to selected countries is given below:

- 6 scales
- 20 sets of weights (1 kg to 10 kg)
- 300 pieces of 50 kg weights
- 10 testing devices for petrol pumps
- 11 volume standards (2 to 200 L)
- 2 oval gear meters for water
- 2 dip tapes (20 m)

The equipment was shipped to the following countries:

Albania	Guinea
Angola	Jordan
Benin	Madagascar
Burkina Faso	Mali
Bolivia	Niger
Cameroon	Peru
Ecuador	Togo
Ethiopia	Ukraine

The 50 kg weights were adjusted to class M_1 (with a few exceptions) for those countries able to carry out the adjustment themselves. The scales were checked by the manufacturer (Mettler Toledo) prior to shipment. The volume standards and the oval gear meters were delivered with a calibration certificate issued by a German Verification Office.

The recipient countries paid for the transportation of the equipment. Some metrology services could not mobilize the necessary funds, but fortunately the PTB was able to bear the costs out of its Technical Cooperation Projects budget. The PTB also financed the packaging and preparation of the shipment.

3 Responses from recipient countries

One of the questions on the application for equipment was:

> "Would you agree to deliver a report on verification activities carried out with the equipment indicating the number of verifications (e.g. per month) and the results (positive, if the tolerable error limits are respected, negative, if not). Note: This information will be needed as feedback to the donors and the OIML."

Only those applicants who were willing to deliver such a report were selected; later on they were asked to provide the information as promised. Eleven out of sixteen countries sent back an answer. Most confirmed that the equipment would be used for legal metrology purposes. Only a few answers contained information about the number of verifications carried out and the results. Nevertheless, there is evidence that the equipment donated through this action broadened the verification possibilities and activities of the various legal metrology services concerned. The 50 kg weights in particular opened up the possibility to extend the mass capability up to 1000 kg in many countries. As a consequence, high capacity weighing instruments could be verified.

A high degree of interest was shown in the equipment for verifying petrol pumps. For many countries the donation offered the first and only possibility to carry out such checks.

4 Concluding remarks

The dispatch of second hand equipment to countries in need of measuring instruments requires a lot of logistics work and the active support of an organization or institute ready to facilitate the shipment. The transportation costs are fairly high in the case of landlocked countries. In some cases customs created problems, despite the equipment having been declared a donation.

Some reports sent in showed that the preparation of the verification work with the new equipment was underestimated in terms of time and additional resources needed. This might be one reason why mainly qualitative statements were received with regard to the results. Perhaps more time is needed before detailed reports can be expected. Hopefully, such reports will be published by some of the countries concerned in the future. This would be helpful in taking the decision as to whether the efforts of mobilizing second hand equipment to be used again should be envisaged in the future.

Acknowledgements

I would like to take this opportunity to express my thanks to the Verification Authorities of Baden-Württemberg, Berlin, Mecklenburg-Vorpommern and Nord for providing equipment and calibrations, and to Mettler Toledo for checking the scales. Thanks also to the PTB for facilitating the shipment; without this support I would not have been able to carry out this work. ■

Volume standards, polished and assembled on a trolley by the receiving metrology service for the checking of petrol stations

New web site of special interest to Developing Countries

From the PWGDC Chairman — Portal - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://workgroups.oiml.org/developing_countries/from-the-pwgdc-chairman

OIML

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- Packaging Seminar

From the PWGDC Chairman

last modified 2007-05-23 12:54

Welcome to the web site of special interest to Developing Countries:

http://workgroups.oiml.org/developing_countries

Dear Readers,

You may have read the article *Modern BIML communication methods: Information Technology at the Service of OIML Members* published in the October 2006 OIML Bulletin. As mentioned by the authors, Jean-Francois Magana, BIML Director and Chris Pulham, Editor and WebMaster, the BIML's main priority for a number of years has been to improve communication with Members.

I am pleased to inform you that part of this initiative is the new **Virtual Forum** on Developing Countries. It is our aim to provide a platform for the exchange of ideas, for questions and answers and for news of special interest and importance to Developing Countries.

In addition to what has been published so far on this brand new web site, further possibilities for dynamic interaction will be available, which means you may (after receiving the necessary access rights) upload your comments or files.

We anticipate a more vivid exchange of communication on subjects of high interest. The success of course will depend on your contributions and on your readiness to use the information available for your legal metrology activities.

Eberhard Seiler

Chairman, OIML Permanent Working Group on Developing Countries (PWGDC)

LIAISONS

UNIDO Meeting with the BIPM, ILAC and the OIML

12 March 2007

On the occasion of the annual JCDCMAS meeting held in Vienna in March 2007, Messrs. Alan Johnston, CIML President, Andrew Wallard, Director of the BIPM and Mike Peet, Immediate Past-Chair of ILAC, Liaisons of international Metrology and Accreditation Organizations to UNIDO, met with the UNIDO Director-General Mr. Kandeh Yumkella.

Messrs. Pedro Espina, Executive Secretary of the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) and Ian Dunmill, Assistant Director of the BIML, accompanied them.

Messrs. Lalith Goonatilake, PTC/TCB/OD and Otto Loesener, PTC/TCB/TAC attended the meeting.

The Director-General welcomed the delegations from the BIPM, ILAC and OIML as key partners of the Trade Capacity Building Programme of UNIDO.

He highlighted the importance of joint activities between the international technical organizations and UNIDO with a view to contributing to the sustainable industrial development of emerging economies.

He also informed of his intention to explore possibilities of organizing joint awareness raising events in Geneva, Brussels, New York, Vienna or in the field, taking into consideration:

i) that UNIDO has a strong partnership with the World Trade Organization (MOU/new cotton initiative) and other Geneva based organizations,

ii) that he recently took the initiative to open a new Liaison Office in Brussels, so as to cooperate closer with the EU, and

iii) the presence of decision makers at political level/Representatives from Permanent Missions from developing countries at various UN meetings regularly held in New York and Vienna.

The Delegation expressed its satisfaction with the cooperation between UNIDO and BIPM/OIML/ILAC in terms of their involvement in UNIDO activities in developing countries.

It expressed its appreciation to the Director-General for hosting the bilateral consultation meetings between UNIDO and the International Organizations as well as for taking the leadership in the activities of the Joint Committee on Coordination of Technical Assistance for Developing Countries in Metrology, Accreditation and Standardization (JCDCMAS).

The representatives of the BIPM requested support from UNIDO in relation to their future involvement in the Committee on Technical Barriers to Trade of the World Trade Organization. ■

JCGM: NEWS & UPDATE

Joint Committee for Guides in Metrology (JCGM)

Willem Kool, BIML

1 Introduction

The Joint Committee for Guides in Metrology (JCGM) was established in 1997 by seven international organizations that had previously participated in the work of ISO/TAG4, publishing the *"Guide to the Expression of Uncertainty in Measurement"* (GUM) and the *"International Vocabulary of Basic and General terms in Metrology"* (VIM). The JCGM took over the responsibility for these documents.

The current version of the GUM is the 1995 edition [2] and the current version of the VIM was published in 1993 [3]. The VIM is being revised, and for the GUM a number of supplementing documents are in preparation.

Currently, the following organizations are members of the JCGM:

- The International Bureau of Weights and Measures (BIPM);
- The International Organization of Legal Metrology (OIML);
- The International Organization for Standardization (ISO);
- The International Electrotechnical Committee (IEC);
- The International Union of Pure and Applied Chemistry (IUPAC);
- The International Union of Pure and Applied Physics (IUPAP);
- The International Federation of Clinical Chemistry and Laboratory Medicine (IFCC); and
- The International Laboratory Accreditation Organization (ILAC).

The JCGM recently adopted a new text for its charter, which was published in the April 2007 issue of the OIML Bulletin [1].

This article aims to provide the OIML community with some up-to-date general information about the structure and activities of the JCGM and the state of progress of the JCGM documents. The impact of the JCGM activities on OIML work is also considered.

2 JCGM operational structure

The JCGM consists of a committee, acting as a steering committee, and two Working Groups. The chairman of the JCGM is appointed by its members. Currently the JCGM chairman is Prof. Andrew Wallard, Director of the BIPM. The committee meets once a year, the next meeting being scheduled for 7 December 2007 [1].

Working Group 1, "Expression of uncertainty in measurement" has the task of promoting the use of the GUM and its supplements to ensure its widespread application. Working Group 2 "International Vocabulary of Metrology" has the task of revising and promoting the use of the VIM.

WG1 is chaired by Dr. Walter Bich of the Italian National Metrology Research Institute (INMRS). The OIML is represented by Charles Ehrlich (OIML Vice-president) and Willem Kool (BIML), who has succeeded Attila Szilvássy. WG1 has a considerable workload (see 3, below) and meets twice a year. The last meeting took place in April 2007 and the next meeting is scheduled for 27-30 December 2007.

WG2 is chaired by Prof. Pierre Giacomo, formerly Director of the BIPM. OIML representatives in WG2 are Charles Ehrlich, Jerzy Borzyminski (Secretariat of OIML TC 1) and Willem Kool. WG2 met twice this year to finalize the revision of the VIM (see 4, below). No further meetings of WG2 have been scheduled.

3 WG1: the GUM and supplementary documents

The Guide for the Expression of Uncertainty in Measurement (GUM) was developed on the basis of Recommendation INC-1 (1980), "Expression of Experimental Uncertainties" [4] of the Working Group on the Statement of Uncertainties, convened by the BIPM. The Recommendation was approved by the CIPM in 1981.

Following the publication of the GUM, many organizations have felt the need to develop guidance documents to facilitate the proper implementation of the principles of the GUM in their respective fields of application, such as:

- "Guidelines for evaluating and expressing the uncertainty of NIST measurement results" [5];

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[1] For general information about the JCGM see: http://www.bipm.org/en/committees/jc/jcgm/

- "The expression of uncertainty and confidence in measurement" (UKAS Guide) [6];
- "Quantifying uncertainty in analytical measurement" (EURACHEM/CITEC) [7];
- "Expression of the Uncertainty of Measurement in Calibration" (EA Guide) [8].

Considering the experiences in the implementation of the GUM, the JCGM has felt it appropriate to supplement the Guide with a number of documents, some of which may be considered as extensions, others as guidance documents. The proposed documents are:

- **An introduction to the GUM and related documents**. This document is intended to provide a brief introduction to the GUM, indicating its relevance and promotion of its use. It will also outline the related supplements and guidance documents;

- **Concepts and basic principles**. This document will present the fundamental concepts and principles underlying the GUM and related documents, including the concepts of Bayesian probability theory, which provide a method for treating non-linear measurement models, which cannot validly be linearized. The evaluation methods in the GUM are applicable only to linear or linearized models.

- **Propagation of distributions using a Monte Carlo method (Supplement 1)** [2]. The GUM is founded on probability theory. Because of difficulties, at the time of the GUM's development, in evaluating uncertainty for general models using general distributions, the GUM provides a simplified approach, the so-called GUM uncertainty framework, in which the uncertainty intervals are characterized by Gaussian distributions. For some measurement models, this approach may be inappropriate. Supplement 1 describes a general numerical implementation of the propagation of distributions, using a Monte Carlo method. It also provides examples of the application of MCM and the validation procedure.

- **Models with any number of output quantities (Supplement 2)**. The GUM and Supplement 1 concentrate on measurement models with one single output quantity (measurement result). However, many measurement problems are described in so-called multivariate models (having more than one output quantity), such as complex quantities (represented in terms of their real and imaginary components, or their magnitude and phase) and the coefficients of a calibration curve. Supplement 2 extends the application of the GUM to multivariate models.

- **Modelling (Supplement 3)**. This document will provide guidance on developing and working with a model of measurement (construction, classification and computation). The Supplement will include examples from a range of metrology disciplines as well as guidance on numerical analysis issues.

- **The role of measurement uncertainty in deciding conformance to specified requirements**. As in the case of type approval and verification of measuring instruments, measurement is often used as the basis for deciding whether a quantity (the measurand) falls within a specified interval of permissible values. Because of the uncertainty, there is a risk of error: to accept a quantity as conforming, although it may actually be non-conforming, or *vice versa*. This document addresses the problem of calculating the conformance probability and the probabilities of the two types of error, the specification limits and the limits of the acceptance zone. The choice of acceptance zone limits as such depends on the implications of the accept/reject decision errors, and is not the subject of this document.

- **Application of the least-squares method** [3]. This document will provide guidance on the application of the least-squares method, or least-squares adjustment to data evaluation problems in metrology.

Supplement 1 is now in the final stage of preparation and will be published shortly. The introductory document and the concepts and principles documents are also at an advanced stage and are expected to be published in the coming year. Following discussions in the JCGM on the importance of the document on the role of measurement uncertainty in deciding conformance to specified requirements, which is of particular interest to the OIML, this document now has a very high priority.

For more information about the documents that WG1 is preparing, see the article "Evolution of the Guide to the Expression of Uncertainty in Measurment" by Bich, et.al. [9].

[2] A Monte Carlo method or MCM is an algorithm for simulating the behaviour of physical or mathematical systems. For more information, see: http://en.wikipedia.org/wiki/Monte_carlo_method

[3] For explanation, see: http://en.wikipedia.org/wiki/Least-squares_method

4 WG2: Revision of the VIM

Working Group 2 has completed the revision of the VIM. The document is now being edited for publication. The title will change to "International Vocabulary of Metrology – Basic and General Concepts and Associated Terms" (VIM, 3rd edition).

The following text is from the introduction to the final draft of the revised VIM:

"The 2nd edition of the International Vocabulary of Basic and General Terms in Metrology was published in 1993. The need to cover measurements in chemistry and laboratory medicine for the first time, as well as to incorporate concepts such as those that relate to metrological traceability, measurement uncertainty, and nominal properties, led to this 3rd edition. Its title is now International Vocabulary of Metrology – Basic and General Concepts and Associated Terms, (VIM), in order to emphasize the primary role of concepts in developing a vocabulary.

In this Vocabulary, it is taken for granted that there is no fundamental difference in the basic principles of measurement in physics, chemistry, laboratory medicine, biology, or engineering. Furthermore, an attempt has been made to meet conceptual needs of measurement in fields such as biochemistry, food science, forensic science, and molecular biology. [,,,]

The change of the treatment of measurement uncertainty from an Error Approach (sometimes called Traditional Approach or True Value Approach) to an Uncertainty Approach necessitated reconsideration of some of the related concepts appearing in the 2nd edition of the VIM. The objective of measurement in the Error Approach is to determine an estimate of the true value that is as close as possible to that single true value. The deviation from the true value is composed of random and systematic errors. The two kinds of error, assumed to be always distinguishable, have to be treated differently. No rule can be derived on how they combine to form the total error of any given measurement result, usually taken as the estimate. Usually, only an upper limit of the absolute value of the total error is estimated, sometimes loosely named "uncertainty". […]

The objective of measurement in the Uncertainty Approach is not to determine a true value as closely as possible. Rather, it is assumed that the information from measurement only permits assignment of an interval of reasonable values to the measurand, based on the assumption that no mistakes have been made in performing the measurement. Additional relevant information may reduce the range of the interval of values that can reasonably be attributed to the measurand. However, even the most refined measurement cannot reduce the interval to a single value because of the finite amount of detail in the definition of a measurand. The definitional uncertainty, therefore, sets a minimum limit to any measurement uncertainty. The interval can be represented by one of its values, called a "measured quantity value".

In the GUM, the definitional uncertainty is considered to be negligible with respect to the other components of measurement uncertainty. The objective of measurement is then to establish a probability that this essentially unique value lies within an interval of measured quantity values, based on the information available from measurement.

The IEC scenario focuses on measurements with single readings, permitting the investigation of whether quantities vary in time by demonstrating whether measurement results are compatible. The IEC view also allows non-negligible definitional uncertainties. The validity of the measurement results is highly dependent on the metrological properties of the instrument as demonstrated by its calibration. The interval of values offered to describe the measurand is the interval of values of measurement standards that would have given the same indications.

In the GUM, the concept of true value is kept for describing the objective of measurement, but the adjective "true" is considered to be redundant. The IEC does not use the concept to describe this objective. In this Vocabulary the concept and term are retained because of common usage and the importance of the concept".

For more information about the evolution of the philosophy and approaches in the VIM, see the article "Evolution of philosophy and description of measurement (preliminary rationale for VIM3)" by Charles Ehrlich in the April 2007 issue of the OIML Bulletin [10].

5 Distribution of JCGM Guides

The current versions of the GUM and the VIM are available as printed documents only and are distributed exclusively by ISO for a charge.

All future JCGM publications may be published by each of the members of the JCGM in electronic format on their respective web sites, free of charge. ISO will continue to produce and sell paper documents.

The GUM will be made available free of charge on a web site in HTML format; this site is currently being developed by ISO.

6 Impact on OIML work

The new edition of the VIM will require a review and revision of the VIML (International Vocabulary of Terms in Legal Metrology) [11]. This work will be undertaken by OIML TC 1 (Terminology), for which Poland holds the Secretariat, and will start within the next few months.

The document on the role of measurement uncertainty in deciding conformance to specified requirements, now being prepared by JCGM-WG1, is of major importance to most of the OIML TCs and SCs and has considerable impact on the specification of metrological requirements and test procedures for measuring instruments. OIML Secretariats will be asked to comment on draft version of the document and may contribute to its development by providing WG1 with examples of practical problems in the application of the GUM uncertainty framework to measurements performed in the context of type evaluation and verification of measuring instruments. A first draft for comment may be distributed in 2008. ■

7 References

[1] OIML Bulletin – Volume XLVIII, number 2, April 2007, pp. 41-44.

[2] "Guide to the Expression of Uncertainty in Measurement" (GUM), 1st edition, *International Organization for Standardization (ISO)*, 1993; corrected and reprinted, 1995.

[3] "International Vocabulary of Basic and General Terms in Metrology" (VIM), 2nd edition, *International Organization for Standardization (ISO)*, 1993.

[4] Kaarls, R., 1981, *BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 49, A1-12 (in French).

[5] "Guidelines for evaluating and expressing the uncertainty of NIST measurement results", Technical Report TN1297, *National Institute of Standards and Technology (NIST, Gaithersburg, MD, USA)*, 1994.

[6] "The expression of uncertainty and confidence in measurement", Guide M3003, *United Kingdom Accreditation Service (UKAS)*, 1997.

[7] "Quantifying uncertainty in analytical measurement". Guide CG4, 2nd edition, *EURACHEM/ CITEC*, 2000.

[8] "Expression of the Uncertainty of Measurement in Calibration", Guide EA-4/02, *European Co-operation for Accreditation (EA)*, 1999.

[9] Metrologia, 43 (2006), pp. S161-166.

[10] OIML Bulletin – Volume XLVIII, number 2, April 2007, pp. 23-35.

[11] "International Vocabulary of Terms in Legal Metrology", *OIML*, edition 2000.

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TC 17/SC 1 Humidity

15-16 November 2007 - Hamburg, Germany (To be confirmed)
TC 8/SC 1 Static volume and mass measurement

22–26 October 2007 - Shanghai, P.R. China
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Received by the BIML, 2007.03 – 2007.04

Revision D 16: "Principles of assurance of metrological control"	E	1 CD	TC 3/SC 2	CZ
New OIML Draft Recommendation: "Measuring systems for gaseous fuel"	E	DR	TC 8/SC 7	BE/FR
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