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New BIML conference facilities

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Editorial

Stephen Patoray
BIML Director

Another day at the BIML

As I sit at my desk in the Bureau on a stormy June morning in Paris, I reflect back on the past several months which have been hectic to say the least.

Since November we have seen a great deal of activity, which concluded in the BIML successfully hosting the JCGM/WG 1 *JCGM Working group on the Expression of uncertainty in measurement (GUM)* and the JCGM/WG 2 *JCGM Working group on the International vocabulary of basic and general terms in metrology (VIM)* in the brand new BIML conference room. From the comments we have received, all the participants were very pleased with the meeting facilities.

But of course that is not all that has been happening at the Bureau.

The BIML continues to work on the development of the new OIML website. The task has proven to be extremely challenging and is also turning out to be more time-intensive than we had initially anticipated (as these major projects often do!). However, we do plan to have the fundamental parts of the new site ready by the 48th CIML Meeting. We are confident that Members will appreciate the more modern design and functionalities it will provide.

Preparations for the CIML meeting are now well underway and the Viet Nam CIML website provides you with all the necessary information. It has been a pleasure to work with our hosts in Vietnam and we anticipate a very fruitful meeting.

"Measurements in daily life", the theme for World Metrology Day 2013, has most definitely brought out the best in many places. This year, Turkey took the lead in designing the poster for WMD. The events of some 29 countries have been registered on the "Events" page of the site and we were excited to discover that on May 20 itself there were over 49 000 hits to the WMD website, a new record by far. If you have not yet done so, please check out the links provided by several contributors to videos that they have produced on this year's theme.

The technical work continues with a number of TC/SC/PG meetings scheduled for the coming months. Incidentally, one of the main resources we are restructuring in the new website is the technical section, to align it with the new requirements of B 6 *Directives for OIML technical work*.

Based on resolution no. 1 of the 14th Conference, nine OIML publications have been translated into French since the Bucharest CIML meeting, and this work is ongoing.

The work on OIML B 7 *BIML Staff Regulations* is complete and this Basic Publication will be presented to the CIML this year for approval as planned.

The past few months have witnessed great progress at the Bureau, but work continues so that we may better serve our Members more efficiently and effectively.

As I finish writing the storm has passed, and the sun has come out. A sign that we are ever moving forward and taking things in our stride. Another day at the BIML. ■

WEIGHTS

Improvement of the calibration process for class E_1 weights using an adaptive subdivision method*

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Abstract

Taking into account the number and variety of measurements involved in scientific, industrial and legal activities that require traceability to the national mass standards of each country, it can be considered that mass standard calibration is one of the most important activities of the National Metrology Institutes (NMIs).

For the determination of the conventional mass, in the calibration of weights of the highest accuracy classes, the subdivision method and its variants are widely used. For the NMIs, it is very important to demonstrate and maintain their capability of applying such methods with good results. In this respect, a calibration procedure for the determination of conventional mass, called the "adaptive subdivision method" was developed in the Mass Laboratory of the Romanian National Institute of Metrology, which can lead to an improvement of CMCs (Calibration and Measurement Capabilities, approved and published in the BIPM database).

According to OIML R 111 [1], weights of nominal values greater than 1 g may have a cylindrical shape with a lifting knob. Considering this kind of shape and the use of an automatic comparator with a maximum capacity of 1 kg, the diameter of the weighing pan is too small to place a group of weights in the range of (500...100) g; therefore, the usual subdivision method cannot be applied for the calibration of weights.

The "adaptive subdivision method", presented in this paper, allows the cylindrical weights with a lifting knob with nominal values of (500...100) g, to be calibrated using an automatic comparator (which is not equipped with weight support plates). The method can be used for class E_1 weights, where the highest accuracy is required. In this case, the resulting calibration uncertainty for the unknown weights is better than that usually obtained for E_1 masses, being at the level of reference standards.

* *The content of this paper was presented at the "Fourth International Conference on Adaptive and Self-Adaptive Systems and Applications - ADAPTIVE 2012".*

1 Introduction

In 1889, at the First Conference on Weights and Measures (CGPM), the kilogram prototypes were shared - randomly - for each country. Romania received the "National kilogram Prototype No. 2" (NPK).

The NPK is a solid cylinder of Platinum-Iridium alloy (90 %, 10 %), having a height equal to its diameter (39 mm). Now, it is maintained by the National Institute of Metrology and serves as a reference for the entire dissemination of the mass unit in Romania.

The realization and dissemination of the unit of mass by the Mass Laboratory of the Romanian National Institute of Metrology starts from the reference stainless steel standards (a set of three 1 kg mass standards and two sets of disc weights from 50 g to 500 g), which are traceable to the International Prototype Kilogram through the mass of the Romanian Prototype Kilogram No. 2.

Starting from these stainless steel reference standards, submultiples and multiples of the unit are realized to permit the masses of additional bodies to be determined with traceability to the international standard. This takes place with the aid of several E_1 weight sets of suitable grading (in most cases 1, 2, 2, 5) which are determined "in themselves" according to proper weighing designs and by using a least squares analysis (with subdivision or multiplication methods).

In the calibration of class E_1 weights, when the highest accuracy is required, the subdivision method is mainly used. The subdivision weighing design has both advantages and disadvantages:

Advantages [2]:

a) minimizes handling (and hence wear) of standards;
b) produces a set of data providing important statistical information about the measurements and the daily performance of the individual balances;
c) offers a redundancy of data.

Disadvantages [2]:

a) requires a relatively complex algorithm to analyze the data (as compared with other methods, for example Borda [3]);
b) necessitates placing groups of weights on the balance pans (this can cause problems for instruments with poor eccentricity characteristics, or automatic comparators designed to compare single weights).

To apply the calibration by the subdivision method on the automatic comparator, a set of disc weights (reference standards) was used. These weights constitute both support plates and check standards.

The main objective in the search for better designs was to find a calibration scheme which can be performed considering the following factors: the automatic comparator, the diameter of the disc weights (so that a group of OIML weights can be placed over) and the efficiency of the design matrix.

This article is divided into 6 sections as follows: introduction, equipments and standards used in calibrations, statistical tools for evaluation of the measurement process and mass determination, analysis of uncertainties, quality assessment of the calibration, conclusions.

2 Equipments and standards used in calibration

The weighing system includes a proper balance (mass comparator) with a weights transporter, a system for monitoring environmental conditions and a MC Link software.

The mass comparator used was an automatic one, with the following specifications:

- maximum capacity: 1011 g;
- readability: 0.001 mg;
- pooled standard deviation: (0.4 to 2) µg (for nominal masses 100 g to 1 kg, respectively).

For accurate determination of the air density an environmental conditions monitoring system was used, consisting in a precise "climate station", model Klimet A30. The technical parameters for Klimet A30 are:

- temperature: readability: 0.001 °C;
  U (k=2): 0.03 °C;
- dew point: resolution: 0.01 °C;
  U (k=2): 0.05 °C;
- barometric pressure: resolution: 0.01 hPa;
  U (k=2): 0.03 hPa.

The mass standard used for the comparisons was a 1 kg reference standard, Ni 81 (see Figure 1).

Ni 81 was purchased by the National Institute of Metrology in 1981. This mass standard is the second in importance after the NPK. The data included in its calibration certificate are as follows:

m_{Ni81} = 1 kg + 0.130 mg, U = 0.028 mg , (k=2);

The weights involved in calibration are:

- unknown E_1 weights (from 500 g to 100 g, marked with A12…A9) of OIML shape (see Figure 2);
- disc weights (reference weights, marked with NA) (see Figure 3).

For all the weights, the volumes V and associated uncertainties $U_{(V)}$ are given in their calibration certificates. Table I shows these values.

Table I Volumes V and associated uncertainties $U(V)$ of the weights

Nominal mass g	Marking	V cm³	$U(V)$ cm³
1000 ref	Ni	127.7398	0.0012
500	NA	62.5480	0.0007
500	A12	62.266	0.032
200	A11	24.853	0.008
200	A10	24.853	0.008
100	NA	12.5083	0.0005
100	A9	12.456	0.004

Fig. 1 Reference standard of 1 kg, Ni81

Fig. 2 Weights of class E_1

Fig. 3 Reference disc weights

3 Statistical tools for evaluating the measurement process and mass determination

A. *Method used to evaluate the efficiency of the weighing design*

The dissemination of the mass scale to E_1 weights, using a single reference standard, requires mass comparisons between weights and groups of weights.

A mass calibration design (or design matrix) describes the general setup of these comparisons.

For a given number of mass comparisons, a criterion for the choice of a design matrix is that the variances of the estimates be as small as practicable [4].

For this reason, the idea of efficiency was introduced, to enable designs to be analyzed using this criterion, taking into account the variances of the weighing results.

The efficiency is very useful when comparing designs involving the same masses and balances, even if the number of mass comparisons differs. It is desirable that the efficiency of a design be large, as this would indicate that the variances are small [4].

Table II lists the mass comparisons possible for the 1 kg to 100 g decade, taking into account the following elements: the automatic comparator and the diameter of the disc weights (so that a group of OIML weights can be placed on it).

Table II Possible mass comparisons for the 1 kg to 100 g decade

Obs. No	Mass						
	Ni 81	500NA	500A12	200A11	200A10	100NA	100A9
1	-1	1	1	0	0	0	0
2	-1	1	0	1	1	1	0
3	-1	1	0	1	1	0	1
4	0	1	-1	0	0	0	0
5	0	1	0	-1	-1	-1	0
6	0	0	1	-1	-1	-1	0
7	0	0	0	1	-1	-1	1
8	0	0	0	-1	1	-1	1
9	0	0	0	1	-1	0	0
10	0	0	0	1	0	-1	-1
11	0	0	0	0	1	-1	-1
12	0	0	0	0	0	1	-1

To establish the design matrix "X" of the comparisons, several versions were performed, then the efficiency of the design was calculated for each of them. For example, using the notation of [4], for the design (2, 1, 1, 2, 0, 1, 1, 0, 1, 1, 2, 1) an efficiency of 0.38 was obtained, while for the design (1, 0, 1, 1, 1, 1, 1, 1, 1, 2, 2, 1) the efficiency obtained was 0.61.

Finally, the design (2, 1, 1, 2, 1, 1, 1, 1, 0, 1, 1, 1) was chosen, having 13 equations of condition, since the value for the efficiency was greater, namely 1.04.

The efficiency was calculated in the following manner. Once all weighings are completed, the first step is to form the design matrix, "X", which contains the information on the equations used (the weighing design).

Entries of the design matrix are +1, −1, and 0, according to the role played by each of the parameters (from the vector β) in each comparison. Symbols used:

X is the format for the matrix: $X = (x_{ij})$; i=1… n;

j = 1,…, k; x_{ij} = 1, −1 or 0;

β is the vector of unknown departures (β_j);

s is the vector containing the standard deviation of each comparison;

Y is the vector of the measured values "y_i", including buoyancy corrections according to (6).

$$X=\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 1 & 1 & 0 & 0 & 0 & 0 \\ -1 & 1 & 1 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 1 & 1 & 1 & 0 \\ -1 & 1 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 & -1 & -1 & 0 \\ 0 & 0 & 1 & -1 & -1 & -1 & 0 \\ 0 & 0 & 0 & 1 & -1 & -1 & 1 \\ 0 & 0 & 0 & -1 & 1 & -1 & 1 \\ 0 & 0 & 0 & 1 & 0 & -1 & -1 \\ 0 & 0 & 0 & 0 & 1 & -1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 1 & -1 \end{bmatrix} \quad s=\begin{bmatrix} 0.016 \\ 0.0013 \\ 0.0013 \\ 0.0009 \\ 0.0010 \\ 0.0017 \\ 0.0017 \\ 0.0004 \\ 0.0013 \\ 0.0006 \\ 0.0005 \\ 0.0005 \\ 0.0007 \\ 0.0009 \end{bmatrix} mg \quad Y=\begin{bmatrix} -3.1583 \\ 3.1896 \\ 3.1896 \\ 3.0994 \\ 3.0758 \\ 0.1001 \\ 0.1001 \\ 0.1796 \\ 0.0801 \\ -0.0052 \\ -0.0396 \\ -0.0414 \\ -0.0579 \\ 0.0225 \end{bmatrix} mg \quad \beta=\begin{bmatrix} Ni81 \\ 500NA \\ 500A12 \\ 200A11 \\ 200A10 \\ 100NA \\ 100A9 \end{bmatrix} \qquad (1)$$

where:

"Ni81" is the reference kilogram standard;

"NA" are the disc weights;

"A12, A11, A10, A9" are OIML weights of class E_1.

In Figure 4 a detailed weights combination can be seen: 500NA+200A12+200A11+100A9, part of determination "y_4".

Fig. 4 The combination of the weights from the 4th determination

The observations vector Y has a diagonal variance - covariance matrix G:

$$\boldsymbol{G} = \text{diag}\,(u_r^2, s_1^2, s_2^2, \ldots s_{n-1}{}^2) \qquad (2)$$

where u_r^2 is the square of the uncertainty of the reference standard, named Ni81, and s_j^2 (j= 1, . . . $\boldsymbol{n}$**-** 1) is the variance of the j-th comparison.

If G' is the same as $\boldsymbol{G}$ without the first row and column, the matrix $G'^{-1/2}$ can be calculated.

By denoting with $\boldsymbol{J}$ a $(n\text{-}1) \cdot (k\text{-}1)$ a sub-design matrix that would be used if the same mass comparisons are carried out, without the use of a reference mass, the matrix K can be defined:

$$K = G'^{-1/2} \cdot J \qquad (3)$$

Calculating K^T, which is a transpose of K, one can determine the inverse $(K^T \cdot K)^{-1}$:

$$\left(K^T \cdot K\right)^{-1} = \begin{bmatrix} \mathbf{0.120} & -0.011 & 0.016 & 0.019 & 0.019 & -0.001 \\ -0.011 & \mathbf{0.413} & 0.009 & 0.009 & 0.005 & 0.004 \\ 0.016 & 0.009 & \mathbf{0.059} & 0.001 & 0.009 & 0.014 \\ 0.019 & 0.009 & 0.001 & \mathbf{0.063} & 0.009 & -0.004 \\ 0.019 & 0.005 & 0.009 & 0.009 & \mathbf{0.054} & 0.003 \\ -0.001 & 0.004 & 0.014 & -0.004 & 0.003 & \mathbf{0.071} \end{bmatrix} \qquad (4)$$

If v_i are the diagonal elements of $(K^T \cdot K)^{-1}$ corresponding to the i^{th} mass, σ_m is the largest of the σ_i, then the efficiency of the design, represented by the matrix $\boldsymbol{X}$ is defined as [4]:

$$E = \sum v_i^{-1} \cdot h_i^2 \cdot \sigma_m^2 / (n-1) \qquad (5)$$

where:

n is the number of comparisons;

h_i is the ratio between the nominal values of the unknown weights and the reference.

In Tables III and IV, the calculation of the efficiency for different designs containing 13 equations of condition is presented.

Table III The calculation of efficiency for the design

(2, 1, 1, 2, 1, 1, 1, 1, 0, 1, 1, 1)

$1/v_i$	h	$h_i^2 \cdot 1/v_i$	n-1	σ^2_m	$(h_i^2 \cdot 1/v_i) \cdot \sigma^2_m/(n-1)$	Standard deviation (µg)
8.33	0.5	2.0819			0.501	0.35
2.42	0.5	0.606	12	2.89	0.146	0.64
16.80	0.2	0.672			0.162	0.24
15.82	0.2	0.633			0.152	0.25
18.55	0.1	0.185			0.045	0.23
14.07	0.1	0.141			0.034	0.27
					***E* = 1.04**	

Table IV The calculation of efficiency for the design

(2, 1, 1, 2, 0, 1, 1, 0,1, 1, 2, 1)

$1/v_i$	h	$h_i^2 \cdot 1/v_i$	n-1	σ^2_m	$(h_i^2 \cdot 1/v_i) \cdot \sigma^2_m/(n-1)$	Standard deviation (µg)
1.946	0.5	0.487			0,117	0,72
1.946	0.5	0.487	12	2,89	0,117	0,72
5.773	0.2	0.231			0,056	0,42
5.222	0.2	0.209			0,050	0,44
8.848	0.1	0.088			0,021	0,34
7.410	0.1	0.074			0,018	0,37
					***E* = 0.38**	

It can be seen that, in the first case (Table III), a higher efficiency was obtained, which indicates that the standard deviations are smaller. Therefore, this weighing design was finally chosen to calculate the mass of the unknown and the uncertainty of calibration.

B. Mass results obtained in the calibration of weights

If the weighing of the reference weight is denoted by (A) and the weighing of the test weight by (B), an ABBA weighing cycle represents the sequence in which the two weights are measured to determine the mass difference of a comparison in a design matrix.

The calibration data used are obtained from the weighing cycles ABBA for each y_i (which is the weighing comparison according to design matrix "X").

The general mathematical model for "y", corrected for air buoyancy is:

$$y = \Delta m + (\rho_a - \rho_o) \cdot (V_1 - V_2) \qquad (6)$$

where:

Δm is the difference of balance readings;

ρ_o is 1.2 kg · m^{-3} the reference air density;

ρ_a is air density at the time of the weighing;

V_1,V_2 are the volumes of the weights (or the total volume of each group of weights) involved in the measurement.

To estimate the unknown masses of the weights, the least square method was used [4, 5, 6].

The design matrix "X" and the vector of observations "Y " are transformed (to render them of equal variance) in U and W respectively, as follows [4]:

$$\boldsymbol{U} = \boldsymbol{G}^{-1/2} \cdot \boldsymbol{X} \text{ and } \boldsymbol{W} = \boldsymbol{G}^{-1/2} \cdot Y \qquad (7)$$

$$U=\begin{bmatrix} 0.0625 & 0 & 0 & 0 & 0 & 0 & 0 \\ -0.769 & 0.769 & 0,769 & 0 & 0 & 0 & 0 \\ -0.769 & 0.769 & 0,769 & 0 & 0 & 0 & 0 \\ -1.111 & 1.111 & 0 & 1,111 & 1,111 & 1,111 & 0 \\ -1 & 1 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0.588 & -0.588 & 0 & 0 & 0 & 0 \\ 0 & 0.588 & -0.588 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.769 & -0.769 & -0.769 & -0.769 & 0 \\ 0 & 2.50 & 0 & -2.5 & -2.5 & -2.5 & 0 \\ 0 & 0 & 0 & 1.667 & -1.667 & -1.667 & 1.667 \\ 0 & 0 & 0 & -2 & 2 & -2 & 2 \\ 0 & 0 & 0 & 2 & 0 & -2 & -2 \\ 0 & 0 & 0 & 0 & 1.429 & -1.429 & -1.429 \\ 0 & 0 & 0 & 0 & 0 & 1.111 & -1.111 \end{bmatrix} \quad W=\begin{bmatrix} -0.1974 \\ 2.4535 \\ 2.4535 \\ 3.4438 \\ 3.0758 \\ 0.0589 \\ 0.0589 \\ 0.0616 \\ 0.4490 \\ -0.0087 \\ -0.0792 \\ -0.0828 \\ -0.0827 \\ 0.0250 \end{bmatrix} mg \qquad (8)$$

The estimates β_j (conventional mass) and their variance-covariance matrix $V_{\beta j}$ are calculated as follows:

$$\langle \beta_j \rangle = (U^T \cdot U)^{-1} \cdot U^T \cdot W = \begin{bmatrix} \mathbf{Ni81} \\ 500NA \\ 500A12 \\ 200A11 \\ 200A10 \\ 100NA \\ 100A9 \end{bmatrix} = \begin{bmatrix} \mathbf{-3.158} \\ 0.0615 \\ -0.0345 \\ -0.0534 \\ -0.0704 \\ 0.0053 \\ -0.0175 \end{bmatrix} mg \qquad (9)$$

$$V_{\beta j} = \left(U^T \cdot U\right)^{-1} = \begin{bmatrix} \mathbf{256} & 128 & 128 & 51 & 51 & 26 & 26 \\ & \mathbf{64} & 64 & 26 & 26 & 13 & 13 \\ & & \mathbf{64} & 26 & 26 & 13 & 13 \\ & & & \mathbf{10} & 10 & 5 & 5 \\ & & & & \mathbf{10} & 5 & 5 \\ & & & & & \mathbf{3} & 3 \\ & & & & & & \mathbf{3} \end{bmatrix} \mu g^2 \qquad (10)$$

The diagonal elements V_{jj}, of the $V_{\beta j}$ represent the variance of the weights (which includes the type A variance combined with the variance associated to reference standard).

4 Analysis of uncertainties

A. Uncertainty of the weighing process, u_A

The variance V_j can also be expressed as [4]:

$V_{\beta j} = h\, h^T \cdot \sigma_r^2 + R$ with:

$$R = \left(0 \,\vdots\, \frac{0^T}{\left(K^T K\right)^{-1}} \right) \qquad (11)$$

The diagonal elements of $(K^T \cdot K)^{-1}$ represent the type A variance of the unknown weight. From here, the type A standard uncertainty can be obtained:

$$u_{A(\beta_j)} = \begin{bmatrix} 0.35 \\ 0.64 \\ 0.24 \\ 0.25 \\ 0.23 \\ 0.27 \end{bmatrix} \mu g \qquad (12)$$

B. Type B uncertainty

The components of type B uncertainties [1,9] are:

1) *The uncertainty associated with the reference standard, u_r for each weight is given by* [1]:

$$u_{r(\beta_j)} = h_j \cdot u_r = h_j \cdot \sqrt{u_{cert}^2 + u_{stab}^2} = \begin{bmatrix} 0.008 \\ 0.008 \\ 0.0032 \\ 0.0032 \\ 0.0016 \\ 0.0016 \end{bmatrix} mg \qquad (13)$$

where:

u_{cert} is the uncertainty of the reference standard from the calibration certificate;

u_{stab} is the uncertainty associated with stability of reference standard.

2) *The uncertainty associated with the air buoyancy corrections, u_b is given by* [1]:

$$u_{b\,(\beta j)}^2 = (V_j - V_r h_j)^2 u_{\rho a}^2 + (\rho_a - \rho_o)^2 u_{Vj}^2 + [(\rho_a - \rho_o)^2 -$$

$$- 2(\rho_a - \rho_o)(\rho_{a1} - \rho_o)] u_{Vr}^2 h_j \qquad (14)$$

where:

V_j, V_r is the volume of the test weight and the reference standard, respectively;

ρ_a is the air density at the time of the weighing;

$u_{\rho a}$ is the uncertainty for the air density determined at the time of the weighing, calculated according to the CIPM formula;

$\rho_o = 1.2\ \text{kg} \cdot \text{m}^{-3}$ is the reference air density;

u_{Vj}^2, u_{Vr}^2 is the uncertainty of the volume of the test weight and one of the reference standards, respectively;

ρ_{a1} is the air density determined from the previous calibration of the standard.

The uncertainty associated with the air buoyancy corrections, u_b, calculated for each weight is:

$$u_{b(\beta_j)} = \begin{bmatrix} 2.6 \cdot 10^{-4} \\ 4.5 \cdot 10^{-4} \\ 1.7 \cdot 10^{-4} \\ 1.7 \cdot 10^{-4} \\ 5.3 \cdot 10^{-5} \\ 7.7 \cdot 10^{-5} \end{bmatrix} mg \qquad (15)$$

3) *Uncertainty due to the sensitivity of the balance*

When the balance is calibrated with a sensitivity weight (or weights) of mass, m_s, and standard uncertainty, $u_{(ms)}$, the uncertainty contribution due to sensitivity is [1]:

$$u_s^2 = \Delta m_c^2 \times [u_{ms}^2 / m_s^2 + u_{(\Delta Is)}^2 / \Delta I_s^2] \qquad (16)$$

where:

ΔI_s is the change in the indication of the balance due to the sensitivity weight;

$u(\Delta I_s)$ is the uncertainty of ΔIs;

Δm_c is the average mass difference between the test weight and the reference weight.

Usually, the term in brackets is taken from the calibration certificate of the mass comparator.

The uncertainty associated with the sensitivity of the balance is calculated, giving:

$$u_s = \begin{bmatrix} 7\cdot10^{-7} \\ 7\cdot10^{-7} \\ 2\cdot10^{-7} \\ 2\cdot10^{-7} \\ 9\cdot10^{-8} \\ 9\cdot10^{-8} \end{bmatrix} mg \tag{17}$$

4) *The uncertainty associated with the display resolution of the balance,* u$_{rez}$, *(for electronic balances) is calculated according to formula* [1]:

$$u_{rez} = \left(\frac{d/2}{\sqrt{3}}\right) \times \sqrt{2} = 0.00041 mg \tag{18}$$

C. *Combined standard uncertainty*

The combined standard uncertainty of the conventional mass of the weight βj is given by [1]:

$$u_{c(\beta j)} = [(u_A^2(\beta j) + u_r^2(\beta j) + u_b^2(\beta j) + u_s^2 + u_{rez}^2]^{1/2} \tag{19}$$

D. *Expanded uncertainty*

The expanded uncertainty "*U*" of the conventional mass of the weights β_j is given by:

$$U_{(\beta j)} = 2\cdot u_c(\beta j) = \begin{bmatrix} 500NA \\ 500E_1 \\ 200NA \\ 200E_1 \\ 100NA \\ 100E_1 \end{bmatrix} = 2\cdot \begin{bmatrix} 0.0080 \\ 0.0080 \\ 0.0032 \\ 0.0032 \\ 0.0017 \\ 0.0017 \end{bmatrix} = \begin{bmatrix} 0.016 \\ 0.016 \\ 0.006 \\ 0.006 \\ 0.003 \\ 0.003 \end{bmatrix} mg \tag{20}$$

5 Quality assessment of the calibration

As shown, for the calibration of the E_1 weights, disc weights of 500 g and 100 g were used, having both the role of check standards and weight support plates for the whole determination.

To see if the mass values obtained for the disc weights are consistent with previous values, it is necessary to perform a statistical control. The purpose of the check standard is to assure the validity of individual calibrations. A history of values on the check standard is required for this purpose [1]. Considering that for the disc weights there are no sufficient calibration data to perform a statistical control according to [1], the method of normalized error E_n was chosen, which takes into account the result and its uncertainty from the last calibration.

The results obtained for the disc weights in this subdivision procedure are compared with data from their calibration certificates [7, 9]. The differences in values are normalized using formula [8]:

$$E_n = \frac{\delta_{subdiv} - \delta_{certif}}{\sqrt{U^2_{subdiv} + U^2_{certif}}} \tag{21}$$

where:

δ_{subdiv} is the mass error of the disc weight obtained by the subdivision method;

δ_{certif} is the mass error of the disc weight from the calibration certificate;

U_{subdiv} is the expanded uncertainty of the disc weight obtained in the subdivision method;

U_{certif} is the expanded uncertainty from the calibration certificate of the disc weight.

Using this formula, the measurement and the reported uncertainty are acceptable if the value of E_n, is between –1 and +1.

Table V presents the results obtained for the normalized errors, E_n.

Table V Comparison of measurement results of disc weights, obtained by the subdivision method and results from the calibration certificate

Nominal mass of disc weight	Subdivision		Calibration certificate		E_n
g	δ (mg)	U (mg)	δ (mg)	U (mg)	
500 NA	0.062	0.016	0.076	0.017	0.6
100 NA	0.005	0.003	0.008	0.004	0.5

6 Conclusions

An evaluation procedure has been presented, used for the calibration of a set of weights by subdivision (similar considerations were published by the author in [9]). This calibration procedure for the determination of the conventional mass of the weights was developed in the Mass Laboratory of the National Institute of Metrology, and can lead to an improvement of CMCs (Calibration and Measurement Capabilities), approved and published in the BIPM database.

The main feature of this kilogram subdivision method is represented by the fact that the calibration of the weights (whose shape is in accordance with OIML R 111) is performed using an automatic mass comparator. Uncertainties obtained using this method for the unknown weights are better than those usually occuring for E_1 (when only manual measurements are possible: 0.060 mg for the 500 g weight, 0.03 mg for the 200 g and 0.017 mg for the 100 g), being at the level obtained for reference standards (marked with NA).

The comparison of results obtained for the disc weights by the subdivision method with those from the calibration certificate using the normalized errors E_{n}, confirms the consistency of the results.

The method described in this paper for the calibration of E_1 weights can be used when the highest accuracy is required. ■

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TRUCK SCALES

Application of truck scales in the petroleum industry

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Abstract

In the petroleum industry, "products" are measured by two principles classified as dynamic and static measurements. Dynamic measurement involves quantities measured by means of a flowmeter. Static measurement involves quantities measured by means of a tank or weighing scales, here denominated as "truck scales."

The design, operation, calculation and calibration of dynamic measurement and tank gauging systems are well established by the petroleum industry, through the standardization performed by the American Petroleum Institute (API) and the International Organization for Standardization (ISO). Both organizations present specific chapters or standards for these subjects that are normally used in a contract between buyer and seller. API and ISO have no standards for truck scales. Standards and guidance documents for truck scales are available from the International Organization of Legal Metrology (OIML), the Gas Processors Association (GPA) and from the Energy Institute in the UK.

Truck scales are often used for weight accounting when loading certain products into road and rail tankers, such as liquefied petroleum gases (LPG), heated residual fuels, heated asphalt (bitumen), lubricating oils and special products such as petroleum coke and molten sulfur. Many operations are performed daily around the world, often involving large amounts of money – in custody transfer operations or for loss control of a company. This shows us the importance of this subject.

This paper will discuss and present an overview of the use of truck scales in the petroleum industry through the experience gained by the author during the specification development for truck scales. This includes: the type of weighbridge, type of load cell and the interface cables to the calculator/indicator device, accuracy class, mass calculation of the product, standards for type approval and design requirements. The paper will also present an estimate of the uncertainty of the measured values during the weighing operation of a product, as well as good practices to ensure scale operation is within the required error limits.

1 Introduction

Truck scales are used all over the world. In the petroleum industry these devices are often used for weight accounting when loading certain products into road and rail tankers, such as liquefied petroleum gases (LPG), heated residual fuels, heated asphalt (bitumen), lubricating oils and special products such as petroleum coke and molten sulfur.

They are used in the operation of custody transfer or for loss control of a company when a product is moved from one facility to another.

Truck scales are devices that weigh a volume of a matter. They are not affected by temperature profile variations, density profile variations or vapor/liquid phase separation in the volume of matter being weighed.

When a volume of matter is weighed in an open vessel, such as a road tanker or railcar at atmospheric pressure, the result is the "weight in air." For petroleum products this weight is less than the "weight in vacuum" (mass) value of the product owing to the buoyancy effect of air on the object being weighed. In some countries weight should be reported as "weight in vacuum," which may be obtained by applying a factor from API Table 56 to convert "weight in air" to "weight in vacuum" [1].

When a volume of matter, such as LPG, is weighed in a pressurized vessel with no venting, the result is approximately the "weight in vacuum". This is because in a closed vessel, the weight of air displaced by the container is effectively the same both before and after filling [2]. Therefore, the buoyancy effect is almost cancelled out when the tare weight is subtracted from the gross weight. A factor of 0.999 85 is applied to convert "weight in air" to "weight in vacuum".

2 Components of a truck scale

Most truck scales are located outdoors. That means they must be able to withstand all environmental challenges while working reliably and accurately. Depending on the environment and application, most truck scale owners expect a scale to last 10–20 years. The components of a truck scale are well defined – see below.

2.1 Foundation

A scale may be installed over an excavation (pit), allowing the driving surface to be flush with the ground (see Figure 1). At one time, all truck scales required deep pits because they needed to house large levers and suspension systems. Today, those mechanical scales are antiquated, making deep pits optional. The depth of a pit may be stipulated by local weights and measures authorities in some areas. They may also stipulate the size of manholes.

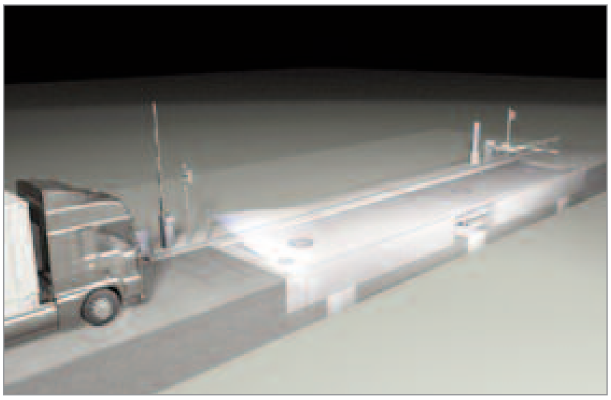

Figure 1 A pit mounted scale placed in an excavated foundation flush with the ground

A scale may also be installed in an above-ground (pitless) configuration with approaches allowing the truck to drive onto and off the scale (see Figure 2). It may have one or both sides open. Either way, permanent installations use a concrete foundation.

While the choice between a pit or pitless installation is often based on preference, there are a few instances that may require the use of a pit. One is when not enough physical space is available to build a ramp to the pitless scale's raised-deck surface while still allowing enough maneuvering space for the trucks once they exit the scale. Also, some industry safety requirements could make a pit scale more practical, because there is no possibility of the truck driving off the edge of the scale.

Another situation calling for a pit is when one is faced with height restrictions. Let's say, for instance, that a new scale will be used to control a bulk filling process. The overhead filling structures may already be in place and cannot be moved. The maximum allowable elevation of the scale's deck is at grade, and the only place to go is down.

Some site-owners find that pitless designs are easier for a number of reasons:

- **Access** – Pits require access points or "man holes" in the weighbridge or scale foundation for maintenance personnel to crawl beneath the scale and inspect critical components. On the other hand, most pitless scales only require the removal of a protective panel to access the scale's load cells and often do not require travelling under the scale deck.
- **Drainage** – A pit will require that drainage of water from rain or melting snow is considered in its design. Typically this will require the use of a drain and sump pump, which is one more system that will eventually require servicing or replacing. Pitless scales allow water to escape naturally.
- **Safety** – Depending on the safety requirements applicable for the facility, entering a pit for routine service may require special protocols to be followed. Because such a pit is often classified as a "confined space", safety requirements may include the use of harnesses, cable man-lifts, air-quality monitors and more. In some chemical plants, pits may collect heavier-than-air gases, posing a unique danger. Because open-sided scales typically do not require going under the scale, they allow for fewer safety preparations.
- **Other** – Pits have a tendency to collect debris, trash, spilled product and mud. They are difficult to clean, and can become the perfect home for pests and rodents.

Figure 2 A pitless mounting scale placed above ground [3]

2.2 Weighbridge

Also known as the scale deck, this is the structure that creates the driving surface for the trucks. The weighbridge is typically composed of modular sections that are placed together in a length long enough to accommodate the entire truck. This is the most common type of truck scale, because most "legal for trade" requirements specify that the entire truck must be weighed at once. Modules can be made entirely of steel with a steel tread plate as the driving surface. They also can be designed to be filled with concrete, creating a concrete driving surface.

Steel and concrete decks should provide equal weighing performance because both are built to the same design specifications. There are some differences that could make one deck type more advantageous for a site or application as presented below.

■ Steel deck

Steel decks are built in factories and are usually welded to an internal system of beams or structural components. Steel deck scales are ready for operation as soon as installation is complete (see Figure 3). Because they are fully built in factories, there are few variables to performance. Most steel decks use a diamond-pattern tread plate as the driving surface. This plate assists with traction when the scale is oily/wet. Some users prefer the traction of concrete in oily/wet/snowy environments, but in most cases driving traction with a patterned tread plate is comparable to concrete. Pedestrian traffic may experience better wet traction with a concrete deck as opposed to steel.

Figure 3 Steel deck [3]

■ Concrete deck

Concrete deck scales are steel structures into which concrete is poured during installation to create the driving surface (see Figure 4). The scale supplier builds in all the structural components and reinforcement needed, and the concrete is then typically poured by a third party contractor based on the scale supplier's specifications. The concrete requires up to 30 days to fully cure before trucks can drive on the scale.

Figure 4 Concrete deck [3]

When looking at the cost of a concrete deck scale, the cost of the concrete and pouring services should be considered. The concrete deck has a much higher static weight than steel, which may also require a more stout foundation, adding to the cost.

Some manufacturers will offer pre-fabricated concrete decks. This eliminates the need for curing time on site. These scales can be susceptible to concrete damage during transport. They are also vastly heavier than their counterparts, making them more expensive to transport – sometimes requiring two trucks as opposed to one. They also may require a larger crane to install.

Overall, a concrete deck can offer advantages, particularly for small truck scales. Because they have about four times the mass of steel, concrete decks are better able to resist the longitudinal forces caused by the truck's traction wheels during acceleration. The concrete deck also provides a uniformly strong surface for trailer-only use in bulk filling applications. The stationary wheels of a trailer can be lowered anywhere on a concrete deck and find all the support they need for high-point loadings.

Corrosion resistance is an issue for a steel deck when compared with the relatively small risk of corrosion in a concrete deck.

Generally speaking, and all issues considered, the prices of concrete deck scales and steel deck scales may be comparable.

2.3 Load cells

These are the sensors that measure the weight on the scale. Modern scales use load cells as integral structural components. In other words, the weighbridge is supported by the load cells themselves. They are typically positioned at the corners of each weighbridge module. There are two predominant geometries for load cell systems: compression type (vertical) and shear beam type (horizontal).

Load cells are the heart of any truck scale. They are the sensors that measure the weight of objects on the scale deck. Most truck scales require 6 – 12 load cells, which must all work together flawlessly to provide accurate weight readings.

The load cell system, consisting of the load cells, cables and connections, and possibly junction boxes, presents the most opportunities for a malfunction in a truck scale. Choosing the right load cell system can prevent these malfunctions.

To prevent damage, load cells can offer hermetic (air tight) seals. Additionally, load cells and cable connections can carry an Ingress Protection (IP) code rating to note their resistance to the ingress of dust and water. The level of protection is signified by a two-digit number code.

Normally, three predominant types of load cell systems are used in vehicle weighing applications: analog load cells, hybrid analog/digital systems and digital load cells.

■ Analog load cells

A precision shaped piece of metal, often steel or stainless steel, that changes its shape slightly as a force (weight) is applied. The change is monitored by electrical strain gauges. The result is an analog voltage signal that varies from the input signal based on the load. The analog signals from all the cells are summed in one or more junction boxes at the scale. The combined signal is then transmitted to the calculator/indicator device, where it is measured and converted to a digital signal that indicates the weight.

■ Analog/digital hybrid load cells

Analog load cells are connected to a junction box that converts the analog signal to digital. The combined signal is then transmitted to the calculator/indicator device. This configuration helps to protect the signal from interference, but only after it has reached the junction box.

■ Digital load cells

These are load cells that generate an analog voltage, which is converted into a digital signal within the load cell enclosure. The data from the cells is processed to determine the total weight. Utilizing a digital signal at the load cell and beyond provides advantages because the signal is not susceptible to interference like analog load cell signals. Also, this eliminates the need to use a junction box, which is the major component in the system that presents failure. Additionally, some digital load cell systems offer diagnostic features that can help and facilitate the operation and maintenance of the system.

Nowadays, the digital load cells can have a proprietary compensation algorithm that is built into the microprocessors in each load cell. Each cell is individually programmed during manufacturing based on its own individual characteristics. Once the cells are in use, each cell constantly measures variables, such as temperature, loading history and loading time. The built-in algorithms then neutralize the effect of those factors on the weight reading. The final results are consistent and accurate weight measurements, regardless of extreme or changing environmental conditions.

2.4 Calculator/indicator device

This is also known as a terminal. It is an electronic device that may perform the analog-to-digital (or digital-to-digital) conversion of the output signal of the load cell, and which further processes the data, and displays the weighing result in units of mass.

2.5 Cables

The signal from the load cells must be transmitted to the terminal. In most cases, this is done with cables.

2.6 Junction boxes

Many scales require numerous junction boxes as connection points for the load cell cables. The junction boxes combine the signals from the load cells and eventually connect to the terminal with a single cable. Some newer systems no longer require junction boxes. A typical truck scale using analog load cells will have 2 to 4 junction boxes.

2.7 Peripheral devices

Peripheral devices are additional devices which repeat or further process the weighing result and other primary indications from the calculator and indicator device, i.e. a printer and personal computer with its respective screen, keyboard and mouse.

3 Truck scales standardization in the petroleum industry

The design, operation, calculation and calibration of hydrocarbon measurement systems (meters and tanks) are well established by the petroleum industry, through

Table 1 – OIML maximum permissible error (mpe) - Class III

mpe	For loads, *m*, expressed in verification scale intervals, *e*
±0.5 *e*	$0 \leqq m \leqq 500\ e$
±1.0 *e*	$500\ e < m \leqq 2\ 000\ e$
±1.5 *e*	$2\ 000\ e < m \leqq 10\ 000\ e$

Table 2 – NIST maximum permissible error (mpe) - Class III

mpe	For loads, *m*, expressed in verification scale intervals, *e*
±0.5 *e*	$0 \leqq m \leqq 500\ e$
±1.0 *e*	$500e < m \leqq 2\ 000\ e$
±1.5 *e*	$2\ 000e < m \leqq 4\ 000\ e$
±2.5 *e*	$m > 4000\ e$

the standardization performed by the American Petroleum Institute (API) and the International Organization for Standardization (ISO). Both organizations present specific chapters or standards for these subjects that are normally used in a contract between buyer and seller. This greatly facilitates the management of discrepancies between parties in custody transfer and loss control. Next to nothing is mentioned in respect to truck scales by these institutions. The exceptions in the petroleum industry are the Gas Processors Association (GPA) standard [4] and the Energy Institute in the UK [2].

In many countries around the word, truck scales to be used in commercial transactions need to be "legal for trade". Normally, these "legal for trade" truck scales need to have a "type approval" for trade use.

In the European Union, type approval for truck scales is given by designated bodies (notified bodies) according to requirements in a European Directive (Non-automtaic weighing instruments Directive, or NAWI Directive). The technical and metrological requirements in the NAWI Directive are taken from Recommendations published by the OIML that provide the standards that the truck scales must meet for commercial applications. That includes vehicle scales and their components, such as load cells [5, 6, 7].

The OIML is an independent international organization that develops standards for adoption by individual countries. Its main task is harmonizing the regulations and metrological controls applied by the national metrological services in the countries that are OIML members. There are two main types of OIML publications:

- International Recommendations (OIML R) are model regulations that establish the metrological requirements for a measurement device, as well as requirements for specifying methods and equipment used to check measurement device's conformity. OIML Member States are responsible for implementing the Recommendations.
- International Documents (OIML D) provide information to help improve the work of the national metrological services.

In the United States, type approval is given by the National Type Evaluation Program (NTEP), which is administered by the National Conference on Weights and Measures (NCWM), an association of industry representatives and federal, state, and local officials. NTEP tests each model according to NCWM Publication 14 [10].

The National Institute of Standards and Technology (NIST) is part of the United States Department of Commerce and supports the NCWM. The NCWM adopts uniform laws and regulations recommended by its members, and NIST publishes those regulations in NIST Handbook 44 [9]. Adopted by most states and localities in the US, NIST Handbook 44 is the official listing of specifications, tolerances, and other technical requirements for weighing and measuring devices.

NIST Handbook 44 has its own set of accuracy classes and acceptance tolerances that differ from those of the OIML.

4 Truck scale accuracy

GPA [4] specifies an accuracy of ±0.1 % of applied load. Also, it establishes a limit of 9 kg for the scale division (or resolution), "*d*".

OIML and NIST define the accuracy of a scale based on the accuracy classes presented in References [5, 9]. For trade use, the accuracy class "III" is normally used. Tables 1 and 2 show, respectively, the maximum permissible error (mpe) defined by the OIML and NIST, as a function of the verification scale interval, "*e*".

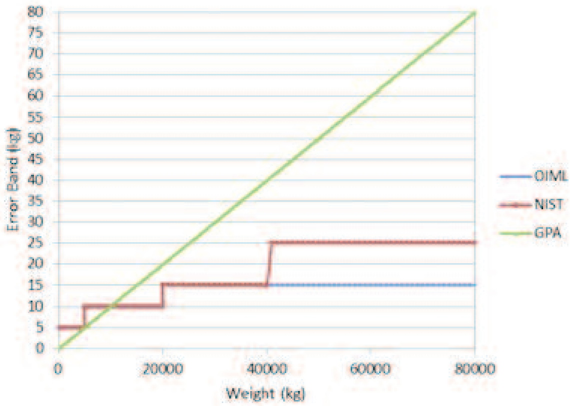

Figure 5 OIML/NIST/GPA accuracy comparison

The verification scale interval *"e"* is a value expressed in units of mass used for classification and verification of a scale. Normally, for truck scales this value is equal to the scale division *"d"*.

Figure 5 presents the comparison between GPA, OIML and NIST maximum permissible errors for a truck scale with a capacity of 80 000 kg, "Class III" and resolution *"d"* equal to 10 kg.

In Figure 5, the vertical axis represents the mpe in kg and the horizontal axis represents the actual weight on the scale in kg. Note that the OIML mpe are identical to those in NIST from 0 to 40 000 kg. At 40 000 kg, the NIST mpe increases from 15 kg to 25 kg, while the OIML mpe remains at 15 kg up to the maximum capacity of the truck scale. The GPA tolerances are smaller than OIML and NIST up to 10 000 kg. After this point, the tolerances become higher than OIML and NIST.

Finally, OIML and NIST specify that each scale must perform within the mpe over a temperature range of at least –10 to +40 °C to qualify for type approval.

5 Truck scale specification

This section presents the most important requirements to be considered in the specification development for truck scales to be used in the petroleum industry.

Based on the author's experience, the GPA standard, reference [4], has been used by the petroleum industry over the past few years because it is the only standard published by an institution belonging to the same sector. Despite it being an old document (1986), the GPA standard still contains relevant technical aspects which should be considered in a truck scale specification. To correct this delay and add metrological confidence for the weighing results, OIML R 76-1 [5] and NIST Handbook 44 [9] should be added to form the desired specification.

The minimum requirements to be considered for a specification are described below.

a) Scope of supply

- The vendor should supply a fully assembled permanent truck scale system.
- Type approval for trade use.
- OIML R 76-1, or
- NIST Handbook 44.
- Accuracy class: normally, class III.
- Repeatability: normally, within one scale division.
- Scale division: normally, 10 kg.

b) Design requirements

- Truck scale nominal capacity.
- Calculator/indicator device should be installed in such a manner that the operator has visual contact with the truck scale, when operating the device.
- Weighbridge should be fully supported by at least 6 load cells.
- Load cells should be supported by a rigid structure.
- The foundation and supports of a scale installed in a fixed location should be such as to provide strength, rigidity and permanence of all components.
- Clearance should be provided around all moving parts to the extent that no interference may result when the load-receiving element is unloaded, and throughout the weighing range of the scale.
- The foundation should be constructed to provide self-drainage away from its center.
- The size of the scale should be sufficient to accommodate the truck and its load.
- The design should take into consideration the accessibility to maintain and calibrate the weighing scale system.
- The truck scale should be constructed and installed such that it can function safely in a potentially hazardous area.
- A printer should be directly connected to the calculator/indicator device.

c) Electrical requirements

- The truck scale should present protection for: surge, short circuit, lightning, RFI and EMI.

d) Equipment requirements

Foundation/weighbridge

- Foundation type: pit or pitless.
- Weighbridge type: concrete deck.

Load cells

- Load cells should be of the compression type.
- Load cells with full temperature compensation should be used.
- Load cells should output only digital information to the calculator/indicator device.
- Load cells should be of stainless steel construction, hermetically sealed and operating continuously under the environmental conditions specified by the buyer.
- Load cells should have a positive lock quick connector integral to its housing for connecting and disconnecting the load cell with its interface cable. The connector should maintain a hermetic seal.

Interface cables

- The interface cables should be sheathed with braided cords made of stainless steel.

Calculator/indicator device

- The calculator/indicator device should have password protection.
- The calculator/indicator device should receive digital information from the load cells.
- The calculator/indicator device should communicate with each individual load cell and should display an error code immediately in the event of a load cell failure. The failed load cell should be identified by the calculator/indicator device.
- The calculator/indicator device should be equipped with a manual or semi-automatic zero-setting mechanism.
- The manual or semi-automatic zero-setting mechanism should be operable only when the indication is stable within plus or minus one scale division, and should not be operated during a weighing operation.
- The value of the scale division should be conspicuously marked adjacent to the calculator/indicator device display.
- The nominal capacity should be conspicuously marked adjacent to the calculator/indicator device display.
- Any printed ticket issued by the calculator/indicator device should have the following information: place, date, time, ticket number, I.D number, product, gross weight, tare weight, and net weight.
- The calculator/indicator device should have ports to communicate with peripheral devices such as the printer and a personal computer (PC).

6 Mass calculation of hydrocarbon product

In some countries weight should be reported as "weight in vacuum" (or mass), which may be obtained by applying a factor from API Table 56 to convert "weight in air" to "weight in vacuum" [1, 2].

6.1 Products loaded in opened containers

For products loaded into containers that are open to the atmosphere, the calculation procedures include:

a) Determine the tare weight (TW) in kg. The tare weight is here defined as the weight of the vehicle without a load.

b) Determine the gross weight (GW) in kg. The gross weight is here defined as the total weight of the vehicle loaded.

c) Calculate the net weight in air (NW) in kg by Eq. (1).

$$NW = GW - TW \qquad (1)$$

d) Obtain the product standard density (ρ_{ps}) in kg/m^3 at 15 °C and atmospheric pressure from the laboratory analysis report.

e) Obtain the air buoyancy correction factor (CBW) from Table 3 [1].

f) Calculate the net weight in vacuum (NWV) in kg by Eq. (2).

$$NWV = NW \times CBW \qquad (2)$$

6.2 LPG or other products loaded in closed containers

For LPG or other products that are loaded in closed containers, the calculation procedures include:

a) Determine the tare weight (TW) in kg.

b) Determine the gross weight (GW) in kg.

c) Calculate net weight in air (NW) in kg by Eq. (1).

Table 3 – Air buoyancy correction factor table

Density (ρ_{ps}) at 15 °C (kg/m^3)	**Air buoyancy factor (CBW)**
500.0 to 520.1	1.00225
520.2 to 543.2	1.00215
543.3 to 568.4	1.00205
568.5 to 596.0	1.00195
596.1 to 626.5	1.00185
626.6 to 660.3	1.00175
660.4 to 698.0	1.00165
698.1 to 740.2	1.00155
740.3 to 787.9	1.00145
788.0 to 842.1	1.00135
842.2 to 904.4	1.00125
904.5 to 976.6	1.00115
976.7 to 1061.4	1.00105
1061.5 to 1100.0	1.00095

Note: This table shall be entered with the product density at 15 °C

Calculate net weight in vacuum (NWV) in kg by Eq. (3), [2].

$$NWV = NW \times 0.999\ 85 \qquad (3)$$

7 Uncertainty analysis of the weight measured during the weighing of a product

7.1 Model formula for uncertainty analysis

The measurement uncertainty using the truck scale is estimated according to the *Guide to the Expression of Uncertainty in Measurement* (GUM) [11]. The model formula for uncertainty analysis of the mass accumulated in the truck is expressed by Eq. (2) or Eq. (3). Eq. (2) is used in this work, i.e., it considers a weighing operation of a product in a container that is open to the atmosphere. The combined standard uncertainty of the mass measurement is obtained applying Eq. (4) onto Eq. (2):

$$u_c^2(NWV) = \sum_{i=1}^{N}\left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) + 2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{\partial f}{\partial x_i}\frac{\partial f}{\partial x_j}u(x_i x_j) \qquad (4)$$

where N is the number of input estimates x_i, i = 1,..., N and $u(x_i)$ the standard uncertainty of input x_i.

The covariance term $u(x_i,x_j)$ is evaluated in association with input estimates that are correlated, according to [11, 12]. For two input quantities x_i and x_j, the covariance is given, by Eq. (5), as:

$$u(x_i,x_j) = u(x_i)u(x_j)r(x_i,x_j) \text{ with } (i \neq j) \qquad (5)$$

(where i ≠ j and |r ≤1|). The value of $r(x_i,x_j)$ may be determined by engineering judgment or based on simulations or experiments. The value is a number between –1 and 1, where $r(x_i,x_j) = 0$ represents uncorrelated quantities, and $|r(x_i,x_j)| = 1$ represents fully correlated quantities. In this work a value of $|r(x_i,x_j)| = 1$ is used for all correlated input quantities. This value has been validated by the author through the use of the Monte Carlo simulation technique.

The expanded uncertainty, U, is determined for a given coverage interval by multiplying the combined standard uncertainty, u_c, by the coverage factor, k, according Eq. (6).

$$U_{(NWV)} = k \times u_{c(NWV)} \qquad (6)$$

7.2 Truck scale calibration and its uncertainties

For truck loading operations analyzed in this work, the truck tare weight (TW) is around 20 000 kg (20 t) and the truck gross weight (GW) is around 40 000 kg (40 t). So, all the results presented in this work refer to one of these two load points. Also, this work considers a truck scale with a resolution of 10 kg and the use of compression type digital load cells with temperature compensation.

The influences to take into account in evaluating the measurement uncertainty during the truck scale calibration are scale resolution, scale repeatability, calibration of the standard weights and ambient temperature effect.

■ Scale repeatability and resolution

The uncertainty due the repeatability of the truck scale's indication is evaluated as being the maximum value between the truck scale repeatability test and the resolution of the weight indication.

The indication of the truck scale is set to be zero before measurement and then the indication is read at the measurement. The resolution of the weigh scale is 10 kg. The standard uncertainty due to the repeatability (u_R) is obtained by Eq. (7) and Eq. (8) when a rectangular distribution in the half width is used for the resolution of the scale.

$$u_R\,(20\,t) = \sqrt{2} \times \frac{10}{2\times\sqrt{3}} \approx 4.1\text{ kg} \quad (7)$$

$$u_R\,(40\,t) = \sqrt{2} \times \frac{10}{2\times\sqrt{3}} \approx 4.1\text{ kg} \quad (8)$$

■ Calibration of the standard weights

Normally, the standard weights used to calibrate the scale comply with the specification of OIML R 111 [13]. The truck scale is calibrated with a group of standard weights, each one with 2 000 kg, classified as class M_1. The standard uncertainty of standard weights, u_{ref}, is obtained by Eq. (9) and Eq. (10) when a rectangular distribution is used for the maximum permissible error (MPE) defined by Reference [13].

$$u_{ref}\,(20\,t) = \frac{\sum_1^{10} 0.1}{\sqrt{3}} \approx 0.60\text{ kg} \quad (9)$$

$$u_{ref}\,(40\,t) = \frac{\sum_1^{20} 0.1}{\sqrt{3}} \approx 1.2\text{ kg} \quad (10)$$

■ Temperature effect on truck scale

Some manufactures produce load cells with temperature compensation as presented by Reference [3]. In this case, the uncertainty of the temperature effect, (u_T), is considered insignificant when compared with the other sources.

■ Combined standard uncertainty associated with the determination of the indication error (E)

The basic formula for the truck scale calibration is defined by Eq. (11):

$$E = I - m_{ref} \quad (11)$$

where E is the error or scale non-linearity found during the calibration for a given load, represented by the standard weights, m_{ref}, and I is the indication of the truck scale for the given load.

The expression of uncertainty associated with the determination of the indication error, (u_E), is obtained by Eq. (12) and Eq. (13).

$$u_E(20\,t) = \sqrt{u_R^2 + u_{ref}^2 + u_T^2} \approx 4.1\text{ kg} \quad (12)$$

$$u_E(40\,t) = \sqrt{u_R^2 + u_{ref}^2 + u_T^2} \approx 4.2\text{ kg} \quad (13)$$

7.3 Measurement uncertainty of net weight in vacuum using truck scale

The standard uncertainties to take into account during the weighing operation are the uncertainties due to the scale nonlinearity, indication error determination, scale resolution, scale repeatability, scale eccentricity, ambient temperature and air buoyancy correction factor.

■ Scale non-linearity

During the calibration of truck scale, the instrument reading presented a difference, E (20 t), of 3 kg in relation to standard weights for a load TW of 20 000 kg and a difference, E (40 t), of 10 kg for a load GW of 40 000 kg.

When no correction is applied to the truck scale's indication, the standard uncertainty due to this non-linearity (u_L) is obtained by Eq. (14) and Eq. (15) when a rectangular distribution is assumed [14].

$$u_L\,(20\,t) = \frac{3}{\sqrt{3}} \approx 1.7\text{ kg} \quad (14)$$

$$u_L\,(40\,t) = \frac{10}{\sqrt{3}} \approx 5.8\text{ kg} \quad (15)$$

■ Indication error determination

The standard uncertainty due to the indication error determination, (u_E), is obtained by Eq. (12) and Eq. (13).

■ Scale resolution and repeatability

The standard uncertainty due to the scale resolution and repeatability, (u_R), is obtained by Eq. (7) and Eq. (8).

■ Scale eccentricity

To determine the effect of an eccentric load on the truck scale, the scale was loaded with the same load in different positions on the weighbridge during the eccentricity test. As a result the largest of the differences from that in the center position (Δ_{ecc}) is considered as the eccentricity. A value of 5 kg was found.

The standard uncertainty due to the effect of eccentric loading ($u_{\Delta ecc}$) is obtained by Eq. (16) and Eq. (17) when a rectangular distribution in the half width is used for the eccentricity value.

$$u_{\Delta ecc}\,(20\,t) = \frac{5}{2\times\sqrt{3}} \approx 1.4\text{ kg} \quad (16)$$

$$u_{\Delta ecc}\,(40\,t) = \frac{5}{2\times\sqrt{3}} \approx 1.4\text{ kg} \quad (17)$$

■ Temperature effect on truck scale

Some manufactures produce load cells with temperature compensation as presented by Reference [3]. In this case, the uncertainty of the temperature effect is considered insignificant when compared with the others sources.

■ Air buoyancy correction factor

The standard uncertainty for the "air buoyancy correction factor" (CBW), u_{CBW}, was assumed to be insignificant when compared with the other sources of uncertainty. A value of zero was used for the uncertainty of this factor.

■ Combined standard uncertainty associated with the measurement of gross weight (GW) and tare weight (TW)

When corrections are applied to the indication of the truck scale, the combined standard uncertainty, uc, for GW and TW, is defined by Eq. (18) and Eq. (19):

$$uc(GW) = \sqrt{u_E^2 + u_R^2 + u_{\Delta ecc}^2 + u_T^2 + u_{CBW}^2} \quad (18)$$

$$uc(TW) = \sqrt{u_E^2 + u_R^2 + u_{\Delta ecc}^2 + u_T^2 + u_{CBW}^2} \quad (19)$$

When no corrections are applied to the indication of the truck scale, the combined standard uncertainty, uc, for GW and TW, is defined by Eq. (20) and Eq. (21), [14]:

$$uc(GW) = \sqrt{u_L^2 + u_E^2 + u_R^2 + u_{\Delta ecc}^2 + u_T^2 + u_{CBW}^2} \quad (20)$$

$$uc(TW) = \sqrt{u_L^2 + u_E^2 + u_R^2 + u_{\Delta ecc}^2 + u_T^2 + u_{CBW}^2} \quad (21)$$

■ Expanded uncertainty associated with the measurement of net weight in vacuum (NWV)

The expanded uncertainty associated with the measurement of net weight in vacuum (NWV), U(NWV), is determined by applying Eq. (4) onto Eq. (2), Eq. (5), Eq. (18) or Eq. (20), Eq. (19) or Eq. (21) and Eq. (6).

7.4 Expanded uncertainty results for the net weight in vacuum (NWV)

The final results of the "net weight in vacuum" and their uncertainties are presented in Table 4 and Table 5 for the first and second scenarios, respectively. These results characterize a fuel oil truck loading operation with a density of 965.1 kg/m^3 at 15 °C. The uncertainty considers a coverage interval of 95 %, approximately. Two scenarios with two cases are considered:

Table 4 – Net weight in vacuum uncertainty – first scenario

Cases	CBW	TW (kg)	GW (kg)	NWV (kg)	*U* (kg)	*U* (%)
Case 1	1.00115	20 000	40 000	20 023	12	0.06
Case 2	1.0115	20 000	40 000	20 023	17	0.08

Table 5 – Net weight in vacuum uncertainty – second scenario

Cases	CBW	TW (kg)	GW (kg)	NWV (kg)	*U* (kg)	*U* (%)
Case 1	1.00115	20 000	40 000	20 023	17	0.08
Case 2	1.0115	20 000	40 000	20 023	21	0.10

First scenario: When corrections are applied to the indication of the truck scale, Eq. (18) and Eq. (19).

Second scenario: When no corrections are applied to the indication of the truck scale, Eq. (20) and Eq. (21).

Case 1: The "net weight in vacuum" was determined by the same truck scale, i.e., TW and GW was obtained by the same scale.

Case 2: The "net weight in vacuum" was determined by a different truck scale, i.e., TW and GW was obtained by different scales.

For case 1, the uncertainty of the NWV was evaluated considering the correlation (due to the same scale being utilized) between TW and GW for the uncertainty sources, u_E, $u_{\Delta ECC}$, u_T and u_{CBW}. Here, the same approach was used as that adopted by Reference [12].

For case 2, the uncertainty of the NWV was evaluated considering the non-correlation between TW and GW. So, the second term of Eq. (4) is not considered in the uncertainty analysis.

As can be seen in Tables 4 and 5, the first scenario presents the lowest uncertainty when compared with the second scenario. The average difference between these scenarios is ±4.5 kg. This difference shows us the importance of correcting the readings of the scale with the calibration result, *E*. As a worst case operation scenario, suppose the nonlinearity of the scale, *E*, for TW and GW is the MPE of 15 kg from Figure 5. For this worst case, the second scenario would present for cases 1 and 2, an uncertainty range from ±0.13 % to ±0.15 %, the average of which corresponds to double the average range presented in Table 4, directly impacting the revenue of a company.

In Tables 4 and 5, case 1 presented the smallest uncertainty. This represents for the first scenario a difference of ±5.0 kg per truck, for example. This means that we should use the same scale whenever possible to reduce product losses, during loading/unloading.

Comparing the uncertainty difference between case 1 of the first scenario and case 2 of the second scenario, a value of ±9.0 kg can be found. This represents the major difference between the cases and scenarios analyzed in this work.

Finally, the weighing result can show the importance to apply the air buoyancy correction factor, (CBW). Although its uncertainty is insignificant when compared with other uncertainty sources, its value is not. Its use represents a difference of +23 kg or (+0.12 %) between the net weight in vacuum (NWV) and the net weight in air (NW) obtained by the difference of the scale's readings, GW and TW. This positive difference is higher than the uncertainties presented in Tables 4 and 5.

Resuming, the truck scale's user should correct the readings of the scale with the calibration result, E, use the same truck scale whenever possible and correct the weighing result with the air buoyancy correction factor (CBW).

8 Truck scale operation within tolerance

After truck scale calibration, the second requirement in assuring the quality of the weighing results is in-service checks between calibrations. Normally, the companies define the time between calibrations based on their internal policies or on national regulations applicable where the truck scale is installed. GPA 8186 [4] defines a minimum frequency of six months.

These checks are used to confirm that the scale is performing with the required accuracy and identify any degradation in performance that might warrant action (such as servicing and re-calibration). The history of in-service checks can also be used to determine the re-calibration interval.

The simplest way to perform the in-service checks is to cross-check different scales at the same facility for a given load at least monthly. The cross-check should agree with the tolerance (*Tol*) defined by Eq. (22) or Eq. (23), in kg, with a confidence level of 99.73 % of probability.

$$Tol\,(GW) = 3 \times \sqrt{uc_{s1}^2(GW) + uc_{s2}^2(GW)} \tag{22}$$

$$Tol\,(TW) = 3 \times \sqrt{uc_{s1}^2(TW) + uc_{s2}^2(TW)} \tag{23}$$

where uc_{s1}^2 and uc_{s2}^2 are the combined standard uncertainties for the truck scale number 1 (s_1) and truck scale number 2 (s_2), respectively, defined by Eq. (18), Eq. (19), Eq. (20) and Eq. (21).

9 Conclusions and recommendations

This paper has discussed a number of issues associated with the application of truck scales in the petroleum industry, including:

- a description and comparison of truck scale components;
- truck scales standardization in the petroleum industry;
- a comparison of truck scale accuracy with different standards;
- a proposed a truck scale specification;
- how to correct the truck scale reading due the air buoyancy effect;
- calculation of the uncertainty of the net weight in vacuum (NWV); and
- best practice to ensure scale operation within tolerance.

Section 5 outlined the most important requirements to be considered in the development of the specification for truck scales in the petroleum industry. Despite the fact that the petroleum industry has a standard [4] to specify a truck scale system and having relevant technical aspects, it is necessary to include in the specification the use of scales with type approval for trade use that follows OIML R 76 [5] or NIST Handbook 44 [9]. Type approved scales offer scale buyers the confidence to acquire a product that has been tested with metrological bases to assure accurate and reliable results. Also, the proposed specification is expected to drastically reduce maintenance costs, truck scale downtime and mass measurement uncertainty.

Section 6 outlined the procedure to obtain the "weight in vacuum" (mass of product) through the indications displayed by the weighing scale. For products loaded into containers that are open to the atmosphere, the mass of product can be obtained through the use of the air buoyancy correction factor (CBW) defined by Table 56, Reference [1], which is a petroleum industry standard that was superseded by the 2004 edition, Reference [15]. The 2004 edition no longer consider Table 56 in its content.

Section 7 outlined the extreme importance of the use of CBW, the non-use of which can represent a loss of around +0.12 % for each truck loaded. For light hydrocarbon products with a density around of 500 kg/m^3, this value increases to +0.23 %. These values are higher than the uncertainty calculated in this work for the oil fuel mass loaded in a truck. It is known that this factor can be obtained by equations deducted from principles of physics. So, it is of extreme importance that the use of this factor through the equations or tables, such as Table 3, be standardized via the organizations belonging to the petroleum industry. The standardization will guide truck scale users and their clients in a contract of purchase and sale. From the scales manufacturers' side, they should provide to the oil market specific models for the indicator/calculator device. These models should have the capability to correct the net weight in air (NW) with the air buoyancy factor (CBW) in the same manner as presented in section 6. Also, this factor should be printed together with tare weight (TW), gross weight (GW) and net weight in vacuum (NWV) on the invoice ticket for auditing purposes.

Section 7 also outlined the procedures to calculate the expanded uncertainty of the net weight in vacuum (mass). It presented the expanded uncertainty results that characterize a fuel oil truck loading operation. The uncertainty results showed that truck scale user should operate truck scales in the following manner:

a) Correct the readings of the scale with the calibration result, E.
b) Use the same truck scale to measure the tare weight (TW) and the gross weight (GW), whenever possible.
c) Correct the net weight result with the air buoyancy correction factor (CBW).

Applying these procedures, the user will obtain the lowest measurement uncertainty when operating a truck scale.

Again, scale manufacturers should offer to the oil companies specific indicator/calculator devices that allow the scale operator to upload on it the calibration result, E, to automatically correct the scale's readings. This thought follows the same principle adopted by the flow computers to correct the meter's reading (by the meter factor) used for dynamic measurement system.

Finally, section 8 outlined a procedure to assure the quality of weighing results during the truck scale operation. The simplest way is to cross-check different scales at the same facility for a given load at least monthly. The cross-check should agree with the tolerance defined by Eq. (22) and Eq. (23) of this work. ■

10 References

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HISTORY OF SCALES

Part 9: Further details on strain-gauge load cells in the technology of scales and weighing

Ing. Wolfgang Euler, Hennef/Sieg and
Heinz Weisser, Balingen

Parts 7 and 8 of this series *Weights, scales and weighing through the ages* dealt with the subject of load cells as bending beams as well as strain-gauge technology (SGT).

By way of introduction, in Part 7 there was a simple but very important initial and basic examination of the subject: In the case of the mechanical beam balance, the weight of a known mass is the reference force.

When measuring force with a strain-gauge load cell as a bending beam, the change in electrical resistance, which is produced through the geometric change of a loaded metallic body, is the measure for the reference force.

The development from mass weighing (weight standards) to force measurement (strain-gauge load cells as bending beams) has to date represented the largest change ever in weighing technology, although the invention of the automatic Chronos scales (which however still work on the basis of mass weighing and do not require any of their own energy for automatic weighing) was also a revolutionary change in weighing technology.

In the OIML Bulletin, the development and the design for the application of strain-gauge load cells in weighing technology has been described in detail. The authors would therefore be very pleased if readers of this article would take the time to think about the pros and cons the two entirely different measurement methods have. There are some very big differences.

One essential question is: Are all scales with load cells, bending beams, glued-on resistors and a working range from –10 °C to +40 °C, really realistic and – in the long term – still suitable "scales" in this actual sense?

An advantage of load cells (which have become indispensable in many fields of life) is without doubt that their manufacture is more reasonably priced and the weighing performance is considerably higher than before (in certain fields of application this can, however, lead to weighing errors/conversion from mechanical to electronic scales). Nowadays, the consumer often hardly has a realistic chance of following the weighing process

Fig. 1: Mass and force details

On the left the weights can be seen (1.1) – shown as weight standards: from the top to the bottom we can see: old German weight (1.2), new uniform EU weight (1.3, the adjustment cavity is at the top), old Finnish weight (1.4, the adjustment cavity is at the front), old Belgian weight (1.5) etc. On the right strain-gauge load cells as bending beams as well as pressure load cells can be seen (2.2). In the case of the bending beams you can see the deformation areas of a piece of metal with ohmic resistors attached as a Wheatstone bridge as well as the bellows as protection, the load cell fastening and the force transmission "F".

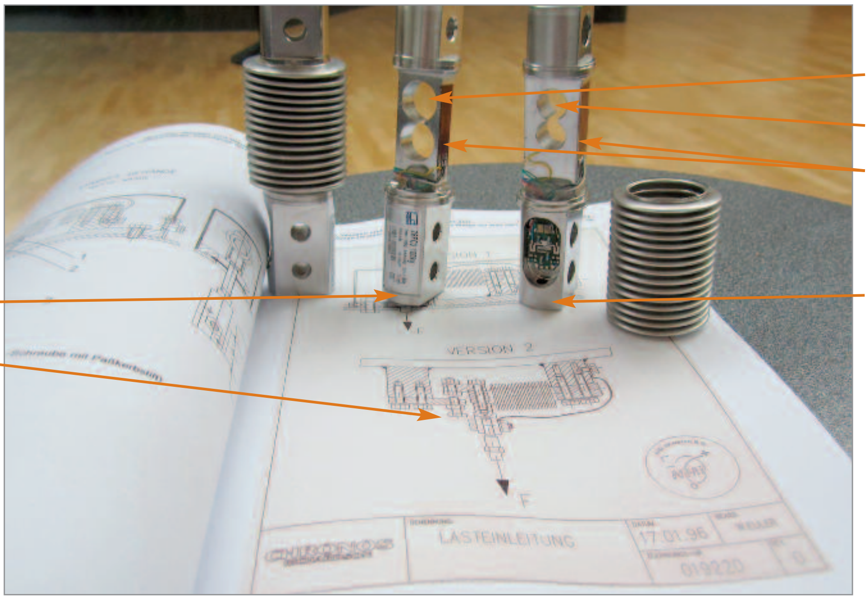


Fig. 2: Load cell and strain-gauge details: bending beams load cells

Bending beams from left to right: strain-gauge load cell as a bending beam with bellows as protection and load cell fastening as well as the load transmission "F". Strain-gauge load cell as a bending beam. Nominal load E_{max} = 100 kg, the glued-on Wheatstone bridge can be seen (centre right). Strain-gauge load cell as a bending beam. Nominal load E_{max} = 500 kg. The load cells with E_{max} = 100 kg and E_{max} = 500 kg are practically identical. Only the deformation area, or respectively, the straining area differ through the larger (E_{max} = 100 kg), or respectively, smaller holes (E_{max} = 500 kg).

compared to in the past. It does not even matter if scales are available for one's own checking purposes.

Who still knows and can recognize today that verified scales are integrated under the barcode scanner in a supermarket? In about three seconds – that is how long the weighing and price display cycle at the supermarket checkout takes today (the scales themselves cannot be seen) – not even an expert can see the weight and the price on the display of a weighing instrument that quickly. In the past every non-automatic weighing instrument (NAWI) had to display the weight for at least ten seconds.

This provision of display safety for the consumer was purely and simply reduced because otherwise, queuing at the checkouts would take too long. Electronic scales are as a rule replaced by more modern devices after about seven to ten years. Compared to this, for how many years do weighing scales, for instance in corner shops, remain fully functional? Besides this, these scales are or were much more simple to check for accuracy – even for the consumer.

Although the author, Wolfgang Euler, has had dealings with weighing scales as well as with load cells (force) for many decades throughout the world, metal deformations with glued-on resistors in load cells do not represent a means of measurement for the rest of eternity for him – unlike weighing scales. He is of the opinion that the manufacturers, developers and researchers of the future – for the protection of consumers all over the world as well as for handling food and other goods in ports – should invent still better, safer as well as more progressive measuring equipment and put it on the market.

Figures 1 and 2 present further illustrations to explain the details and to improve the reader's understanding.

The most important technical data on strain-gauge load cells with bending beams or similar equipment is presented below.

- Classification according to OIML R 60:

D 1:	nLC = 1000	E_{max} = 5 kg ... 1 t
C 3:	nLC = 3000	E_{max} = 10 kg ... 1 t
C 4:	nLC = 4000	E_{max} = 20 kg ... 500 kg
C 6:	nLC = 6000	E_{max} = 50 kg .. 200 kg

Where:

- D or C = the accuracy class,
- E_{max} = the maximum capacity of the load cell (kg),
- nLC = the maximum number of verification scale intervals for the load cell,

- v_{min} = the smallest verification scale interval of the load cell,

- Y = the ratio $Y = E_{max}/v_{min}$ (resolution of the load cell),
- Nominal (rated) sensitivity= 2 mV/V,
- Nominal range of supply voltage: 0.5 V – 12 V,
- Nominal temperature range: –10 °C to + 40 °C,
- Limit load: 150 % of E_{max},
- Breaking load: > 300 % of E_{max}
- Degree of protection (IP) as per EN 60529 (IEC 529), IP 68,
- Material: measuring body and bellows stainless steel,
- Cable inlet gland: stainless steel/viton,
- Cable sheath: PVC.

Not all the technical data is presented here, however, as the various values are almost identical to other similar strain-gauge load cells.

The authors think that – with this article on the history of scales – they have reached a certain conclusion. The next part is "Non-automatic weighing instruments (NAWI)", in accordance with OIML R 76 (EN 45 501).

After that the following will be discussed:

- discontinuous totalizing automatic weighing instruments (totalizing hopper weighers), in accordance with OIML R 107 – receiving/loading scales – bulk,
- automatic gravimetric filling instruments, in accordance with OIML R 61 – bagging,
- proportioning weighers for multiple ingredients,
- automatic catchweighers, in accordance with OIML R 51, and automatic checkweighers with price indication.

The Authors of the series
"Weights, scales and weighing through the ages"

Wolfgang Euler

Heinz Weisser

HISTORY OF SCALES

Part 10: The International Organization of Legal Metrology

ING. WOLFGANG EULER, HENNEF/SIEG and
HEINZ WEISSER, BALINGEN

As early as in the 1930's, considerable effort was made to establish an international organization of legal metrology. But it was not until 1950 that a provisional committee resumed these activities and prepared a convention on the creation of an International Organization of Legal Metrology in Paris. After several nations had signed this agreement, the Convention came into force in 1956.

The OIML elaborates and publishes international Recommendations on measuring instruments and their metrological and technical properties as well as their verification. After signing the agreement, the OIML Member States are morally bound to implement the Recommendations to the greatest extent possible when elaborating national provisions.

OIML Certificates of conformity are issued on request and upon examination, by national metrology and approval authorities. OIML Certificates are not approvals, however they make it considerably easier to obtain the corresponding national type approval certificates which are a precondition for national verifications of weighing instruments.

For gravimetric determinations, the following OIML publications are relevant:

Load cells:

OIML R 60

Weights:

OIML R 111

Weighing instruments:

OIML R 50	Continuous totalizing automatic weighing instruments (belt weighers)
OIML R 51	Automatic catchweighing instruments
OIML R 61	Automatic gravimetric filling instruments (AGFI)
OIML R 76	*Non-automatic weighing instruments* (NAWI) (the basis for EN 45501)
OIML R 106	Automatic rail-weighbridges
OIML R 107	Discontinuous totalizing automatic weighing instruments (totalizing hopper weighers)
OIML R 134	Automatic instruments for weighing road vehicles in motion. Total vehicle weighing

As soon as a new Recommendation has been elaborated and completed, it is assigned a number by the BIML. In the view of the authors, non-automatic weighing instruments (NAWI) are not only the oldest and most accurate, but also the most important weighing instruments of all times.

OIML R 76:1976 Non-automatic weighing instruments (NAWI). Part 1: Metrological and technical requirements – Tests Part 2: Test report format

A NAWI is an instrument that requires the intervention of an operator during the weighing process in order to decide whether the weighing result is acceptable (OIML R 76 T.1.2). The decision as to whether a weighing result is acceptable includes any intelligent action by the operator that affects the result. This may be an action (e.g. printing, taring or zeroing the weighing instrument) or it may also be the adjusting of the load of the product to be weighed and observing the indication at the same time.

OIML R 76 and EN 45501 are identical in substance. OIML R 76 is based on the former OIML Recommendations No. 3: Metrological Regulations and No. 28, Technical Regulations.

Non-automatic weighing instruments (NAWI) EN 45501

Specification for metrological aspects of non-automatic weighing instruments:

German version EN 45501:1992

Example of standards: BS EN 45501 for NAWI. All quoted technical regulations are compatible with each other.

BS = British Standard, DIN = Deutsches Institut für Normung, EN = European standard

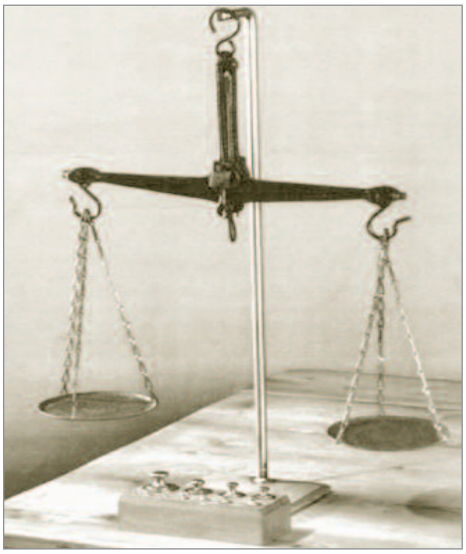


Fig. 1: Equal-arm beam balance, around 7000 BC

Fig. 2: Counter scales based on the principle of the equal-arm beam balance, around 1670

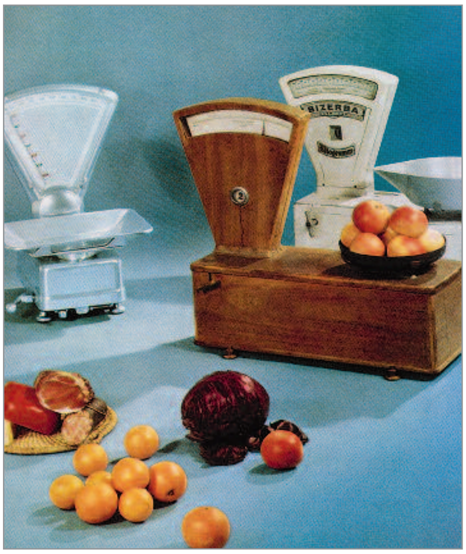


Fig. 3: Bizerba pendulum scales, approved for use in Germany for the first time in 1924

Fig. 4: Electronic commercial scales equipped with strain-gauge load cells, around 2002

Non-automatic weighing instruments through the ages (NAWI)

OIML R 76 – National and international maximum permissible errors on verification for non-automatic weighing instruments (NAWI) – Testing a weighing instrument submitted for verification

The dynamic testing of automatic weighing instruments will be dealt with in detail later when the technique of the relevant weighing instrument is dealt with. Today, in the European Union, the Measuring Instruments Directive (MID) 2004/22/EC applies to automatic weighing instruments.

The testing of a weighing instrument submitted for verification includes testing for compliance with the constructional requirements, the Verification Ordinance, and the type-approval certificate. In addition, a variation test as well as a metrological test are carried out in which compliance with the maximum permissible errors on verification is checked.

Fig. 5: "Weights, weighing instruments and weighing in the course of time" – Permanent exhibition on display in Meys Fabrik (kleine Stadthalle) in the town of Hennef a. d. Sieg – other "*non-automatic weighing instruments*" shown here: proportional-weight instrument (top left) Alois Quintenz, 1821. The proportional weights principle is such that 1/10 of the load to be weighed is put in the weighing pan in the form of weights. In order to weigh a 1 kg load, one no longer needs a counterweight of 1 kg – as is the case with the equal-arm beam balance – but only a 0.10 kg weight. The proportional-weight instrument depicted here is a masterpiece made by a Polish constructor of scales. Kazimierz Kacprzak gave the author these scales in Warsaw/Poland when he retired. Kacprzak was an executive at GUM (Glowny Urzad Miar) in Warsaw. Germany's oldest letter scales (top right), hand-made true to the 1851 original. Domestic spring scales are depicted just behind the letter scales. Domestic scales are scales with low accuracy for household use only.

Special	accuracy	I	Feinwaagen
High	accuracy	II	Präzisionswaagen
Medium	accuracy	III	Handelswaagen
Ordinary	accuracy	IIII	Grobwaagen

Fig. 6: Accuracy classes for NAWI

Non-automatic weighing instruments (NAWI) are tested according to "A"

For initial verification, automatic weighing instruments are also tested in static operation. Categorically, both authors presume there are two tests. These should be carried out at each verification:

A Static test with weights in non-automatic operation

For this purpose, the NAWI must comply with the maximum permissible errors on verification according to OIML R 76, Class III (medium accuracy) or EN 45501 when the load is increased and decreased with weights.

B Dynamic test with static weighing operation in automatic operation with product

Details are given when the corresponding weighing instruments are explained and described from a functional point of view and with regard to verification. See Table 1 for a practical example.

In the case of automatic weighing instruments (AGFI) used to weigh loose bulk products such as, e.g., flour/cereals, etc., the following example is used, as in the case of NAWI for the determination of the static maximum permissible errors on initial verification.

Table 1: Practical example

Maximum permissible error on initial verification according to OIML R 76 or, respectively, EN 45501				
Maximum permissible errors on initial verification	For loads (m) expressed in verification scale intervals (e) Class I	Class II	Class III	Class IV
± 0.5 e	$0 \le m \le 50\,000$	$0 \le m \le 5\,000$	$0 \le m \le 500$	$0 \le m \le 50$
± 1.0 e	$50\,000 < m \le 200\,000$	$5\,000 < m \le 20\,000$	$500 < m \le 2\,000$	$50 < m \le 200$
± 1.5 e	$200\,000 < m$ 20 000	$< m \le 100\,000$	$2\,000 < m \le 10\,000$	$200 < m \le 1\,000$

e = verification scale interval/increment of the weighing instrument
m = number of verification scale intervals of the weighing instrument
Max. = 52 kg
Verification scale interval: 1e = 1d = 0.02 kg
Verification scale intervals e = d = 52 kg: 0.02 kg = 2600 n/digits

Table 2: Maximum permissible error on initial verification for Class III

from 0 to 500 *e* × 0.02 kg = 10 kg, maximum permissible error ± 0.5 *e* = ± 0.01 kg
from >500 *e* to 2000 *e* × 0.02 kg = 40 kg, maximum permissible error ± 1.0 *e* = ± 0.02 kg
2000 *e*, e.g.: 2600 *e* × 0.02 kg = 52 kg, maximum permissible error ± 1.5 *e* = ± 0.03 kg

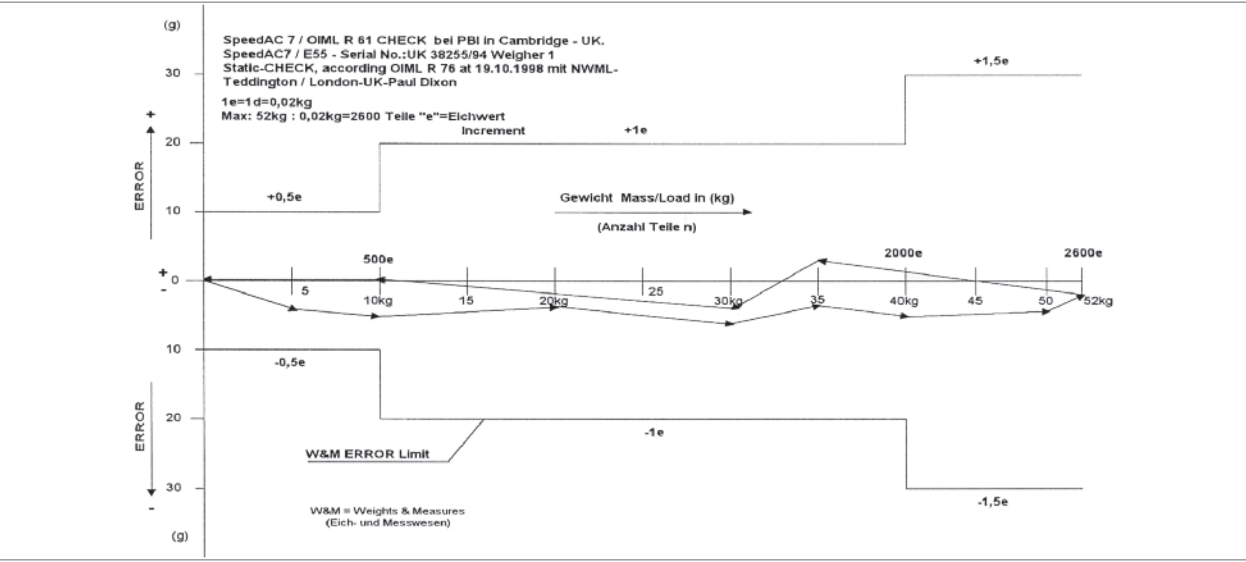


Fig. 7: Static maximum permissible errors on verification (W & M error limits) as a function of the number of verification scale intervals n and the actual errors on verification with regard to the relevant load

Figure 7 shows the static maximum permissible errors on verification (W & M error limits) as a function of the number of verification scale intervals n, and the actual errors on verification with regard to the relevant load. The static verification error curve was recorded by PBI Cambridge/UK with a bagging weigher BW/SWA test for SpeedAC (Speed: fast, AC: Accuracy/accurate = "SpeedAC") 7/E55 in order to obtain the OIML R 61 Certificate of conformity. (Paul Dixon (NWML) + Wolfgang Euler).

The maximum permissible errors in service are twice the maximum permissible errors on verification.

Description of the maximum permissible errors (mpe) on verification:

1. The scale towards Error+ is +10 g to +10 g.
2. The scale towards Error– is –10 g to –10 g.
3. Maximum permissible error on verification. Error+ or –10 g. Range up to 500 *e* × 0.02 g = 10 kg.
4. In this example, the mpe on verification up to 500 *e* or 10 kg amounts to + or –0.5 *e*.
5. From 500 *e* or 10 kg onwards, the mpe on verification amounts to 2000 *e* × 0.02 g = 40 kg.
6. In this case, the mpe on verification from 500 *e* or 10 kg up to 2000 *e* × 0.02 g = 40 kg + or –1.0 *e*.
7. From 2000 *e* or 40 kg onwards, the mpe on verification up to 2600 *e* × 0.02 g = 52 kg + or –1.5 *e*.
8. Load cells basically work like a spring balance. In this example, an HBM Hottinger bending beam of the type Z6FC3 – 100 kg was used. The spring effect of the load cell can be seen clearly. When applying the load, the verification error curve shows very good values, whereas when removing the load, a small return-stroke error (spring effect) of the load cell becomes clearly visible.

In the previous example, the maximum permissible errors on verification are perfectly met. The weighing instrument is therefore considered as "having passed verification".

The next part deals with automatic weighing instruments. First, OIML R 107:2007 *Discontinuous totalizing automatic weighing instruments (totalizing hopper weighers)*, also called "receiving and shipping weighers".

Sources

1 Haeberle, K. H.: 10000 Jahre Waage
2 Organisation Internationale de Métrologie Légale (OIML)
3 Manfred Kochsiek: Handbuch des Wägens.
4 Roman Schwartz, Panagiotis Zervos u.a.: Wägelexikon
5 Wikipedia (the free encyclopedia)

130 years of Chronos scales –

The world's first verifiable automatic weighing instrument

Carl Reuther and Eduard Reisert, the pioneers from Hennef, invented the "Chronos scales" which became the first weighing instrument in the world which was admitted for verification. It was approved for verification by the "Kaiserliche Normal-Aichungs-Commission" (Imperial Standard Verification Commission) in Berlin on 12 April 1883. In the same year, a notification was published in the "Deutscher Mühlen-Anzeiger" immediately after the "Kaiserliche Normal-Aichungs-Commission" in Berlin had given its verbal agreement with regard to the approval of the automatic weighing instrument for verification, i.e. even before the official notification was released. This approval meant the first ever legal recognition of an automatic weighing instrument as a standard of value worldwide.

The name "Chronos" (Greek for "time") was selected due to the factor of "time" as a name for the balance type – and later, as a company name. The reason for this is easy to explain. For approx. 10 000 years, bulk products were weighed manually with the aid of non-automatic weighing instruments. With the invention of the automatic Chronos scales, the weighing of loose bulk products was clearly faster, which left more time to make the weighing operation more accurate and the handling safer. One can now no longer imagine life without automatic industrial weighing instruments in modern industrial and computer-controlled weighing technologies.

In a short welcoming speech held on the occasion of the 120th anniversary, Prof. Dr. Manfred Kochsiek, then Vice-president of the Physikalisch-Technische Bundesanstalt (PTB) and Acting CIML President said:

"This balance, a worldwide ground-breaking invention, is much too fit and active to only gather dust in a museum! We are celebrating the anniversary of an instrument which is not just devoted to the past and only taking a trip down memory lane. It is still – admittedly with a more contemporary appearance – doing what it used to do in the past, namely weighing bulk products with great accuracy. Today, a piece of technology with 120 years' market expectation is hardly imaginable as we have become used to short-lived innovations – as in IT. To get a better picture of this duration, which is far longer in the technical sense than in the biological one, it might help to recall the following:

When the Chronos scales were built (back in 1883), the inventor Gottlieb Wilhelm Daimler was just experimenting with combustion engines – he had not yet invented his first automobile. This unique invention of the two great pioneers Carl Reuther and Eduard Reisert 130 years ago put an end to the manual weighing of loose bulk products and rang in the era of automatic weighing machines." ■

Manfred Kochsiek

OIML Systems

Basic and MAA Certificates registered 2013.03–2013.05

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

The OIML Basic Certificate System

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

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

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

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

The OIML MAA

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

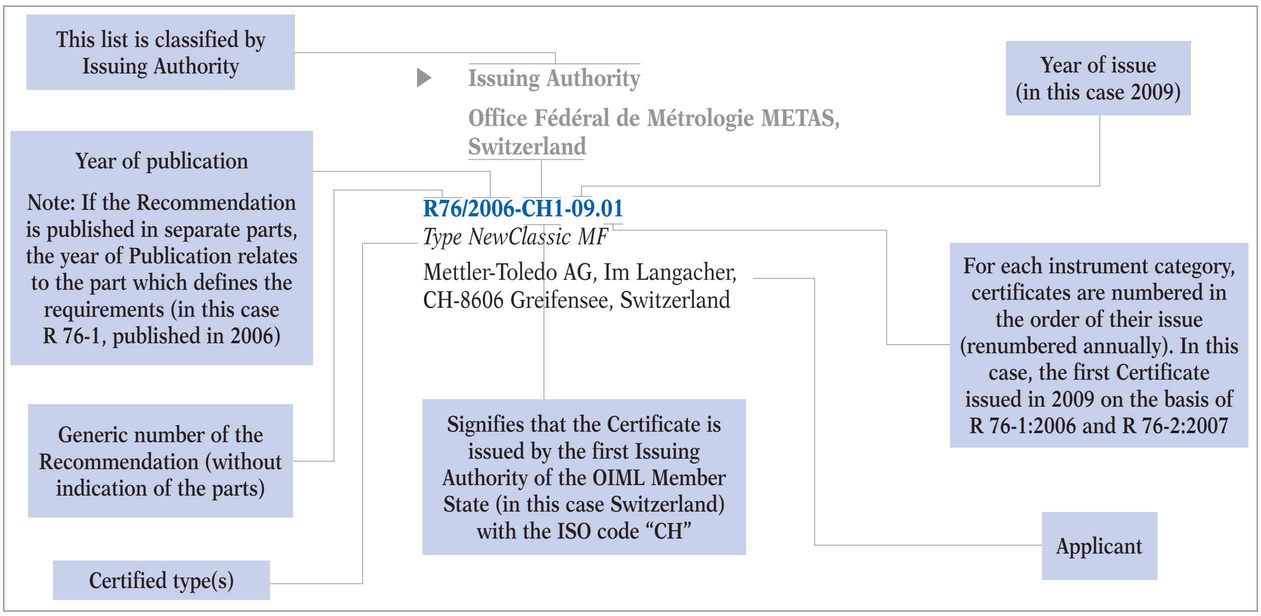
The OIML MAA is an additional tool to the OIML Basic Certificate System in particular to increase the existing mutual confidence through the System. It is still a voluntary system but with the following specific aspects:

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

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

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

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



INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

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

R 49 (2006)

▶ Issuing Authority / *Autorité de délivrance*

NMi Certin B.V.,
The Netherlands

R049/2006-NL1-2006.01 Rev. 2
Water meter - Type: OPTIFLUX x300C; OPTIFLUX x000F + IFC300y
Krohne Altometer, Kerkeplaat 12, NL-3313 LC Dordrecht, The Netherlands

R049/2006-NL1-2012.01 Rev. 2
Water meter - Type: WATERFLUX 3070
Krohne Altometer, Kerkeplaat 12, NL-3313 LC Dordrecht, The Netherlands

R049/2006-NL1-2013.01
Water meter - Type: OPTIFLUX x300C; OPTIFLUX x000F + IFC300y
Krohne Altometer, Kerkeplaat 12, NL-3313 LC Dordrecht, The Netherlands

▶ Issuing Authority / *Autorité de délivrance*

Physikalisch-Technische Bundesanstalt (PTB),
Germany

R049/2006-DE1-2008.02 Rev. 5
Water meter intended for the metering of cold potable water - Type: SM100, SM100E, SM100P or SM001, SM001E, SM001P, SM150, SM150E, SM150P, SM250, SM250E, SM250P, SM700, SM700E, SM700P
Elster Metering Ltd., 130 Camford Way, Sundon Park, GB-LU3 3AN Luton, Bedfordshire, United Kingdom

R049/2006-DE1-2010.03 Rev. 2
Water meter intended for the metering of cold potable water. Combination meter with mechanical register Type: C4000
Elster messtechnik GmbH, Otto-Hahn Strasse 25, DE-68623 Lampertheim, Germany

R049/2006-DE1-2013.01
Water meter intended for the metering of cold potable water and hot water. Rotating piston meter with mechanical indicating device 8R MD or 7R MD - Type: RTKD-S
Zenner International GmbH & Co. KG, Römerstadt 4, DE-66121 Saarbrücken, Germany

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

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

R 51 (2006)

▶ Issuing Authority / *Autorité de délivrance*

NMi Certin B.V.,
The Netherlands

R051/2006-NL1-2013.01
Automatic catchweighing instrument
Van Wouw Engineering, Koepelalle 5, NL-7722 KT Dalfsen, The Netherlands

R051/2006-NL1-2013.02
Automatic catchweighing instrument - Type: PR5410/xx (X3)
Sartorius Mechatronics T&H GmbH, Meiendorfer Strasse 205, DE-22145 Hambourg, Germany

▶ Issuing Authority / *Autorité de délivrance*

National Measurement Office (NMO),
United Kingdom

R051/2006-GB1-2008.01 Rev. 6
CW3 Checkweigher
Loma Systems Group and ITW Group, Southwood, Farnborough GU14 0NY, Hampshire, United Kingdom

R051/2006-GB1-2008.01 Rev. 7
CW3 Checkweigher
Loma Systems Group and ITW Group, Southwood, Farnborough GU14 0NY, Hampshire, United Kingdom

R051/2006-GB1-2013.01
L-Series 2180
Actronic Ltd., 45 Patike Road, Avondale, Auckland, New Zealand

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*

Centro Español de Metrologia, Spain

R060/2000-ES1-2013.01
Strain gauge compression load cell - Type: T34
Thames Side Sensors Ltd., Unit 10, io Trade Center, Deacon Way, Reading RG30 6AZ, United Kingdom

R060/2000-ES1-2013.02
Tension Load Cell - Type: T95
Thames Side Sensors Ltd., Unit 10, io Trade Center, Deacon Way, Reading RG30 6AZ, United Kingdom

▶ 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

R060/2000-JP1-2013.01 (MAA)
Universal (Tension/Compression) load cell - Type: U2S1-200K-C3, U2S1-250K-C3, U2S1-500K-C3, U2S1-1T-C3, U2S1-2T-C3,
Minebea Co. Ltd., 1-1-1 Katase Fujisawa-shi, JP-251-8531 Kanagawa-ken, Japan

▶ Issuing Authority / *Autorité de délivrance*

NMi Certin B.V., The Netherlands

R060/2000-NL1-2009.07 Rev. 1 (MAA)
Bending beam load cell, with strain gauges - Type: 0745A
Mettler-Toledo (Changzhou) Precision Instruments Ltd., 5, Middle HuaShan Road, Xinbei District, CN-213022 ChangZhou, Jiangsu, P.R. China

R060/2000-NL1-2009.07 Rev. 2 (MAA)
Bending beam load cell, with strain gauges - Type: 0745A
Mettler-Toledo (Changzhou) Precision Instruments Ltd., 5, Middle HuaShan Road, Xinbei District, CN-213022 ChangZhou, Jiangsu, P.R. China

R060/2000-NL1-2012.54 Rev. 1 (MAA)
*Compression load cell, with strain gauges - Type: CC010-**T-C3 (with ** the capacity in t)*
Minebea Co. Ltd., 1-1-1 Katase Fujisawa-shi, JP-251-8531 Kanagawa-ken, Japan

R060/2000-NL1-2013.05 (MAA)
Compression load cell, with strain gauges - Type: 160xx
Anyload Youngzon Transducer (Hangzhou) Co. Ltd., No. 160, South No. 11 Street, Hangzhou Economic & Technological Development Zone, CN-310018 Zhejiang, P.R. China

R060/2000-NL1-2013.06 (MAA)
Tension load cell - Type: SS300
Curiotec Co., Ltd., 581-1, Yougmi-ri, Goangtan-Mueon, Paju-si, 413-855 Cyenoggi-do, Korea (R.)

R060/2000-NL1-2013.08 (MAA)
Compression load cell, with strain gauges, equipped with electronics - Type: WBK-D
CAS Corporation, #19, Ganap-Ri, Gwangjuk-Myoun, Yangju-Si, KR-482-841 Kyunggi-Do, Korea (R.)

R060/2000-NL1-2013.09 (MAA)
Compression load cell, with strain gauges - Type: 106xx
Anyload Youngzon Transducer (Hangzhou) Co, Ltd., No. 160, South No. 11 Street, Hangzhou Economic & Technological Development Zone, CN-310018 Zhejiang, P.R. China

R060/2000-NL1-2013.10 (MAA)
Bending beam load cell, with strain gauges - Type: SLB215,SLB415
Mettler-Toledo (Changzhou) Precision Instruments Ltd., 5, Middle HuaShan Road, Xinbei District, CN-213022 ChangZhou, Jiangsu, P.R. China

▶ Issuing Authority / *Autorité de délivrance*

National Measurement Office (NMO), United Kingdom

R060/2000-GB1-2012.07 Rev. 1 (MAA)
SB6 stainless steel load cell
Flintec GmbH, Bemannsbruch 9, DE-74909 Meckesheim, Germany

R060/2000-GB1-2013.01 (MAA)
PC7 stainless steel load cell
Flintec UK Ltd., W4/5 Capital Point,
Capital Business Park, Wentloog Avenue,
Cardiff CF3 2PW, United Kingdom

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

R060/2000-DE1-2013.01 (MAA)
Strain gauge double bending beam load cell - Type: ERS
ELICOM electronic - Geoviev KD, 5th Saedienie sq.,
7500 Silsitra, Bulgaria

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*
NMi Certin B.V.,
The Netherlands

R076/1992-NL1-2013.10
Non automatic weighing instrument - Type: DPS-5600
Teraoka Seiko Co., Ltd., 13-12 Kugahara, 5-Chome,
Ohta-ku, JP-146-8580 Tokyo, Japan

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

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

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

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

R076/2006-DK3-2013.01
Non automatic weighing instrument - Type: CUC-Ex
Kosan Crisplant A/S, P.O. Pedersens Vej 22,
DK-8200 Aarhus N, Denmark

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

R076/2006-CN1-2013.03
Ultrasonic body height and weight of computer measuring instrument
BeiJing Haiborda Science and Tech Co., Ltd, Room 436,
4th floor, the GuangFang Building, No 18 ZhangHua
Road, Haidian District, 100097 Beijing, P.R. China

▸ Issuing Authority / *Autorité de délivrance*
NMi Certin B.V.,
The Netherlands

R076/2006-NL1-2012.32 (MAA)
Indicator - Type: LP-500
Dibal S.A, Astinze Kalea, 24-Pol. Ind. Neinver,
ES-48160 Derio (Bilbao-Vizcaya), Spain

R076/2006-NL1-2012.36 Rev. 1 (MAA)
Non automatic weighing instrument - Type: MP49
Mettler-Toledo Inc., 1150 Dearborn Drive, US-Ohio 43085
Worthington, United States

R076/2006-NL1-2012.40 (MAA)
Non-automatic weighing instrument - Type: DS-676 SS
Shanghai Teraoka Electronic Co., Ltd., Tinglin Industry
Developmental Zone, Jinshan District,
CN-201505 Shanghai, P.R. China

R076/2006-NL1-2012.42 Rev. 1
Non-automatic weighing instrument - Type: MP30
Mettler-Toledo Inc., 1150 Dearborn Drive, US-Ohio 43085
Worthington, United States

R076/2006-NL1-2013.03 (MAA)
Non-automatic weighing instrument - Type: LS2/LS4/CS2/LH1/LS6/LS2S series
Xiamen Pinnacle Electrical Co. Ltd., 4F Chambridge
Building, Torch High, Zone Xiamen, CN-361006 Fujian,
P.R. China

R076/2006-NL1-2013.05
Non-automatic weighing instrument - Type: DS-500 and DS-502
Shanghai Teraoka Electronic Co., Ltd., Tinglin Industry
Developmental Zone, Jinshan District,
CN-201505 Shanghai, P.R. China

R076/2006-NL1-2013.06 (MAA)
Indicator - Type: IND231 / IND236
Mettler-Toledo (Changzhou) Measurement Technology
Ltd., No. 111, West TaiHu Road, ChangZhou XinBei
District, CN-213125 Jiangsu, P.R. China

R076/2006-NL1-2013.07
Non-automatic weighing instrument
Type: IND211 / XIG / IND220 / IND221 / IND226 / IND226x / IND231 / IND236 / BBA211 / BBA220 / BBA221 / BBA226 / BBA226x / IND23X-YYYYYYYY

Mettler-Toledo (Changzhou) Measurement Technology Ltd., No. 111, West TaiHu Road, ChangZhou XinBei District, CN-213125 Jiangsu, P.R. China

R076/2006-NL1-2013.07 Rev. 1
Non-automatic weighing instrument Type: IND211 / XIG / IND220 / IND221 / IND226 / IND226x / IND231 / IND236 BBA211 / BBA220 / BBA221 / BBA226 / BBA226x / BBA23x-yyyyyyyyy

Mettler-Toledo (Changzhou) Measurement Technology Ltd., No. 111, West TaiHu Road, ChangZhou XinBei District, CN-213125 Jiangsu, P.R. China

R076/2006-NL1-2013.08 (MAA)
Non-automatic weighing instrument -
Type: DS-620, DS-620SS

Shanghai Teraoka Electronic Co., Ltd., Tinglin Industry Developmental Zone, Jinshan District, CN-201505 Shanghai, P.R. China

R076/2006-NL1-2013.09 (MAA)
Non-automatic weighing instrument -
Type: Valor 4000 V41...

Ohaus Corporation, 7, Campus Drive, Suite 310, US-NJ 07054 Parsippany, United States

R076/2006-NL1-2013.12 (MAA)
Non-automatic weighing instrument - Type: RM-60

Shanghai Teraoka Electronic Co., Ltd., Tinglin Industry Developmental Zone, Jinshan District, CN-201505 Shanghai, P.R. China

R076/2006-NL1-2013.13 (MAA)
Non-automatic weighing instrument - Type:

Xiamen Pinnacle Electrical Co. Ltd., 4F, Guangxia Building, North High-Tech Zone, Xiamen, CN-Fujian, P.R. China

R076/2006-NL1-2013.13 Rev. 1 (MAA)
Non-automatic weighing instrument -
Type: OS2 series - Brand: ACLAS or Arm Pos

Xiamen Pinnacle Electrical Co. Ltd., 4F, Guangxia Building, North High-Tech Zone, Xiamen, CN-Fujian, P.R. China

R076/2006-NL1-2013.17 (MAA)
Indicator - Type: CD-200D, CI-201D, CI-200SD, CI-200SCD, CI-201SD

CAS Corporation, #19, Ganap-Ri, Gwangjuk-Myoun, Yangju-Si, KR-482-841 Kyunggi-Do, Korea (R.)

▶ Issuing Authority / *Autorité de délivrance*

National Measurement Office (NMO), United Kingdom

R076/2006-GB1-2012.02 Rev. 2 (MAA)
DD1050, DD1050i, DD2050

Societa Cooperativa Bilanciai Campogalliano a.r.l, Via S. Ferrari, 16, IT-41011 Campogalliano (Modena), Italy

R076/2006-GB1-2012.14 Rev. 1 (MAA)
DD1010, DD1010IC, DD 1010I, DD1010H, DD1010ICH, DD1010IH

Societa Cooperativa Bilanciai Campogalliano a.r.l, Via S. Ferrari, 16, IT-41011, Campogalliano (Modena), Italy

R076/2006-GB1-2013.01 (MAA)
PR PLUS Series

CAS Corporation, #19, Ganap-Ri, Gwangjuk-Myoun, Yangju-Si, KR-482-841 Kyunggi-Do, Korea (R.)

▶ Issuing Authority / *Autorité de délivrance*

Physikalisch-Technische Bundesanstalt (PTB), Germany

R076/2006-DE1-2013.02
Non-automatic electromechanical baby weighing instrument - Type: BIS03A

Seca GmbH & Co. kg., Hammer Steindamm 9-25, DE-22089 Hamburg, Germany

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Automatic level gauges for fixed storage tanks
Jaugeurs automatiques pour les réservoirs de stockage fixes

R 85 (2008)

▶ Issuing Authority / *Autorité de délivrance*

NMi Certin B.V., The Netherlands

R085/2008-NL1-2013.01
Automatic level gauge for measuring the level of liquid in stationary storage tanks - Type: FMR530, FMR531, FMR532, FMR533

Endress + Hauser GmbH + Co., KG, Haupstrasse 1, DE-79689 Maulburg, Germany

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Discontinuous totalizing automatic weighing instruments
Instruments de pesage totalisateurs discontinus à fonctionnement automatique

R 107 (2007)

Issuing Authority / *Autorité de délivrance*

National Measurement Office (NMO), United Kingdom

R107/2007-GB1-2013.01
DDxxxxHS
Societa Cooperativa Bilanciai Campogalliano a.r.l, Via S. Ferrari, 16, IT-41011 Campogalliano (Modena), Italy

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

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

R 117 (1995) + R 118 (1995)

Issuing Authority / *Autorité de délivrance*

International Metrology Cooperation Office, National Metrology Institute of Japan (NMIJ) National Institute of Advanced Industrial Science and Technology (AIST), Japan

R117/1995-JP1-2011.01 Rev. 2
Fuel dispenser for motor vehicles, A series
Tokico Technology Ltd., 3-9-27 Tsurumi Chuo, Tsurumi-ku, Yokohama City, Kanagawa, Japan

Issuing Authority / *Autorité de délivrance*

NMi Certin B.V., The Netherlands

R117/1995-NL1-2009.01 Rev. 3
Fuel dispenser for motor vehicles -
Type: Quantium XXXX - Qmaz: 80 L/min resp. 130 L/min
Tokheim Sofitam Applications S.A.S., Immeuble le Cézanne, Paris Nord, 31-35 Allée des Impressionnistes, BP 45027 Villepinte, FR-95912 Roissy Charles de Gaulle Cedex, France

R117/1995-NL1-2009.01 Rev. 4
Fuel dispenser for motor vehicles - Type: Quantium XXXX
Tokheim Sofitam Applications S.A.S., Immeuble le Cézanne, Paris Nord, 31-35 Allée des Impressionnistes, BP 45027 Villepinte, FR-95912 Roissy Charles de Gaulle Cedex, France

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Automatic instruments for weighing road vehicles in motion and measuring axle loads
Instruments à fonctionnement automatique pour le pesage des véhicules routiers en mouvement et le mesurage des charges à l'essieu

R 134 (2006)

Issuing Authority / *Autorité de délivrance*

Office Fédéral de Métrologie METAS, Switzerland

R134/2006-CH1-2013.01
Automatic instrument for weighing road vehicles in motion and measuring axle loads - Type 5275A
Kistler Instrumente AG, Eulachstrasse 22, CH-8408 Winterthur, Switzerland

OIML CERTIFICATE SYSTEM

List of OIML Issuing Authorities

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		R 16	R 21	R 31	R 35	R 49	R 50	R 51	R 58	R 60	R 61	R 75	R 76	R 81	R 85	R 88	R 93	R 97	R 98	R 99	R 102	R 104	R 105	R 106	R 107	R 110	R 112	R 113	R 114	R 115	R 117/118	R 122	R 126	R 128	R 129	R 133	R 134	R 136
AT1	Bundesamt für Eich- und Vermessungswesen (BEV)						■	■	■		■		■		■	■		■	■		■	■		■	■	■			■	■	■							
AU1	National Measurement Institute (NMI)					■	■	■		■			■		■									■	■						■		■		■			
BE1	SPF Economie, PME, Classes Moyennes et Energie												■					■	■																			
BG1	State Agency for Metrology and Technical Surveillance (SAMTS)												■						■																			
BR1	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO)												■																									
CH1	Institut fédéral de métrologie (METAS)	■		■		■	■	■		■	■		■					■	■				■	■	■						■						■	
CN1	General Administration of Quality Supervision, Inspection and Quarantine of P. R. China (AQSIQ)			■			■	■		■	■		■					■	■						■						■						■	
CZ1	Czech Metrology Institute (CMI)					■							■	■	■								■								■						■	
DE1	Physikalisch-Technische Bundesanstalt (PTB)	■		■	■	■	■	■	■	■	■		■		■	■		■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■		■
DK1	The Danish Accreditation and Metrology Fund (DANAK)						■	■		■	■		■						■				■	■	■						■				■		■	
DK2	FORCE Certification A/S					■																																
DK3	Dansk Elektronik, Lys & Akustik (DELTA)						■	■		■	■		■											■	■										■		■	
ES1	Centro Español de Metrología (CEM)					■		■		■	■		■					■	■														■					
FI1	Inspecta Oy						■	■		■	■		■		■									■	■						■							
FR1	Ministère de l'Economie, de l'Industrie et de l'Emploi (MEIE)	*All activities and responsibilities were transferred to FR2 in 2003*																																				
FR2	Laboratoire National de Métrologie et d'Essais (LNE)		■	■		■	■	■	■	■	■		■	■	■	■		■	■	■	■		■	■	■	■			■	■	■		■		■		■	
GB1	National Measurement Office (NMO) - Formerly NWML		■		■	■	■	■		■	■	■	■		■				■				■	■	■						■				■		■	
GB2	National Physical Laboratory (NPL)																	■																				
HU1	Hungarian Trade Licensing Office (MKEH)												■																									
JP1	National Metrology Institute of Japan / National Institute of Advanced Industrial Science and Technology (NMIJ / AIST)									■			■																	■	■							
KR1	Metrology and Measurement Division (KATS)												■																									
NL1	NMi Certin B.V.		■	■		■	■	■		■	■		■	■	■			■		■			■	■	■						■		■	■	■		■	
NL2	KIWA Nederland B.V.					■																																
NO1	Norwegian Metrology Service (Justervesenet)						■	■			■		■										■	■	■						■				■			
NZ1	Measurement and Product Safety Service (MAPSS Wellington)												■																									
PL1	Central Office of Measures (GUM)												■						■		■																	
RO1	Bureau Roumain de Métrologie Légale (B.R.M.L.)																	■	■							■			■	■								
RU1	Russian Research Institute for Metrological Service (VNIIMS)			■		■	■	■	■	■	■		■		■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
SE1	Swedish National Testing and Research Institute AB (S.P.)						■	■		■	■		■		■				■					■	■						■							
SI1	Metrology Institute of the Republic of Slovenia (MIRS)												■																									
SK1	Slovak Legal Metrology					■							■																		■							
US1	NCWM, Inc.									■			■																									
VN1	Directorate for Standards and Quality (STAMEQ)												■																									

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The Congress is organized by the Collège Français de Metrologie in partnership with the BIPM, the OIML, Euramet, the NCSLi, the LNE, the NPL and METAS. The major industrial partners are Apave - A+ Métrologie and Carl Zeiss; Implex and Hexagon Metrology have also associated their names to the event.

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- Cyprus: Ms. Niki Pythara

Corresponding Member

- Rwanda

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OIML Meetings

16–18 July 2013

TC 7/SC 4/p3 Revision of R 91
(Radar equipment for the measurement of the speed of vehicles)

NIST, Gaithersburg, USA

23–25 July 2013

TC 17/SC 1/p1 Revision of R 59
(Moisture meters for cereal grains and oilseeds) and

TC 17/SC 8/p1 New Recommendation
(Protein measuring instruments for cereal grains and oilseeds)

NIST, Gaithersburg, USA

4–5 September 2013

TC 7 (Measuring instruments for length and associated quantities) and
R 35 (Material measures of length for general use)

NMO, Teddington, UK

23–27 September 2013

TC 6 (Prepackaged products)
METAS, Bern, Switzerland

7–11 October 2013

48th CIML Meeting and Associated Events
Ho Chi Minh City, Viet Nam

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Committee Drafts

Received by the BIML, 2013.04 – 2013.06

R 60-1 and -2: Metrological regulation for load cells Part 1: Metrological and technical requirements Part 2: Metrological controls and performance tests	E	2 CD	TC 9
R 137-3: Gas meters. Part 3: Report format for type evaluation	E	2 CD	TC 8/SC 7
Protein measuring instruments for cereal grain and oil seeds	E	4 CD	TC 17/SC 8

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- Announcements of forthcoming events, etc.

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

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