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Use of Balance Calibration Certificate to Calculate the Errors of Indication and Measurement Uncertainty in Mass Determinations Performed in Medical Laboratories

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Abstract: Based on the reference document [1], the article proposes the way to calculate the errors of indication and associated measurement uncertainties, by resorting to the general information provided by the calibration certificate of a balance (non-automatic weighing instruments, shortly NAWI) used in medical field.

The paper may be also considered a useful guideline for:
- operators working in laboratories accredited in medical (or other various fields) where the weighing operations are part of their testing activities;
- test houses, laboratories, or manufacturers using calibrated non-automatic weighing instruments for measurements relevant for the quality of production subject to QM requirements (e.g. ISO 9000 series, ISO 10012, ISO/IEC 17025);
- bodies accrediting laboratories;
- accredited laboratories for the calibration of NAWI.

Article refers only to electronic weighing instruments having maximum capacity up to 30 kg.

Starting from the results provided by a calibration certificate it is presented an example of calculation.

Keywords: Calibration of weighing instrument, Error of indication, Regression.

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1. Introduction

Weighing is a common task in any laboratory (either chemical, medical or pharmaceutical) and its results may determine the acceptability of a products or the outcome of a test [2].

Also, the weighing is an important step in an experiment and its results, resulted from an electronic balance (or other weighing instruments) are often of critical importance for next steps of an analysis.

Electronic balances have become so sophisticated that many calibrate themselves and appear to provide "error free" measurements [3]. However, things are not quite so.

All measurements have error which cannot be known exactly. In principle, the value of a known error can be applied as a correction to the result.

The error creates an uncertainty about the quality of the measured value. On the other hand the uncertainty’s value cannot be used to correct a measurement result.

Considering these aspects, in an analysis it is very important to know the error of indication and the associated measurement uncertainty to determine the weighing results.

The calibration certificate of a weighing instrument provides only generic information.

This turns over to the laboratory the responsibility of estimating weighing uncertainty for specific applications.

Since the implementation of quality management systems, measuring uncertainty became a key-element in demonstrating the laboratory's capability to provide reliable services and products that would meet the customer's demands [4].

The paper is intended for operators laboratories accredited for relevant measurements in medical field and shows how it can be obtained from the discrete values resulted at calibration and/or presented in a calibration certificate, errors and assigned uncertainties for any other reading within the calibrated weighing range.

2. Calibration Certificate

A calibration certificate is released by accredited calibration laboratories that follow the guidelines of [1] and is intended to be consistent with the requirements of ISO/IEC 17025 which take precedence.

The basic information provided by a certificate, elaborated according to [1] contains:
- general information (identification of the calibration laboratory, identification of the certificate, reference to the accreditation, signature(s), identification of the client, information regarding the weighing instrument, etc);
- information about the calibration procedure;
- results of measurement (errors of indications, repeatability of indications, effect of eccentric application of a load, on the indication).

3. The Error of Indication and Associated Measurement Uncertainty for any Indication within the Weighing Calibrated Range (A Review of the Regression Concept and Approximation Model of Experimental Data)

The regression function means a mathematical expression, deduced from experimental data processing, which approximates (estimates) dependency between two or more variables of a system or process.

In statistics, regression analysis includes any techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps to understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed.

Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships.

One can starts from the analysis of any phenomenon whose actual evolution is not known, more exactly the dependence $y = f(x)$ is not known.

All we know is that the measurements can be made for different values of the current variable x. More specifically, at points x_0, $x_1 \ldots x_n$ can be determined the corresponding values y_0, $y_1, \ldots y_n$. Practically, it results "$n+1$" pairs: (x_0, y_0), (x_1, y_1), ... (x_n, y_n). Usually, the points x_0, $x_1 \ldots x_n$ are called "nodes", and the values $y_0, y_1, \ldots y_n$ are called "data" and it is obvious that there is the mathematical relation:

$$y_k = f(x_k),\ k = \overline{0,n} \tag{1}$$

There are several known ways of approximating the experimental data; it is practically about the following types of approximations [5]:

A) continuous approximation (interpolation). In this case, the approximation function ***must*** pass through the known points. In interpolation, is assumed that the interpolation nodes are exactly known, being not affected by errors;

B) direct approximation, when the approximation function ***must not*** pass through the points known, but approximate better the known values (this is a typical situation of approximation of experimental data affected by inherent errors).

3.1. Continuous Approximation (Interpolation)

3.1.1. Interpolation by Polynomials

Interpolation by polynomials consists in determining a polynomial that has the following characteristics:

▪ has degree n (which is a unit less than the number of nodes);
▪ obligatorily, passes through the "cloud" of data, so check the equalities:

$$P_n(x_k) = y_k,\ k = \overline{0,n} \tag{2}$$

In the nodes, takes exactly known values from the measurements, but otherwise there is no guarantee that describe the evolution of the phenomenon studied.

In other words, in the intervals (x_0, y_0), (x_1, y_1), ... (x_n, y_n) it is possible that the graph of polynomial curve have a deviation from the graph curve of the analyzed phenomenon evolution [5].

There are known several types of interpolation polynomials, the most common type is the so-called Lagrange polynomials (which are used more often because they have an easier formula):

$$P_n(x) = \sum_{k=0}^{n} y_k \cdot L_k(x) \text{ ,} \tag{3}$$

where

$$L_k(x) = \frac{(x - x_0)(x - x_1)\ldots(x - x_{k-1})(x - x_{k+1})\ldots(x - x_n)}{(x_k - x_0)(x_k - x_1)\ldots(x_k - x_{k-1})(x_k - x_{k+1})\ldots(x_k - x_n)} \tag{4}$$

One advantage of representation by Lagrange polynomials is the fact that the polynomials L_k depend only by the choice of interpolation nodes, but, adding new nodes, the calculation of L_k must be done again, which is a defect.

The polynomial L_k depends on x, as the polynomial P_n(x), and therefore the approximation function is a polynomial of x, which can then calculate any point x, not only in the nodes, but also between them, thus justifying the term "interpolation".

3.1.2. Linear Interpolation between Two Adjacent Points

Often, in the interpolation problems, data to be interpolated are obtained so that, the considered independent variable, x, corresponds to equidistant values: $x_{k+1} - x_k = h = \text{constant, with } k = \overline{0, n}$ where h is often called the interpolation step [6].

In this case, a simple form of interpolation (linear interpolation) can be used.

Practically, the linear interpolation involves estimating a new value by connecting two adjacent known values with a straight line.

For example, if the two known points are given by the coordinates (x_0, y_0) and (x_1, y_1), then, the y value for some point x is given from the equation:

$$\frac{y - y_0}{x - x_0} = \frac{y_1 - y_0}{x_1 - x_0} \tag{5}$$

Solving this equation for y, that is the unknown value at x, results:

$$y = y_0 + (x - x_0) \cdot \frac{y_1 - y_0}{x_1 - x_0} \tag{6}$$

3.1.3. Applications of the Interpolation Methods in Determining the Error of Indication for any Reading in a Calibrated Weighing Range

Taking into account that, in the calibration of weighing instrument the test for determination of indications errors is performed with $k_L \geq 5$ different test loads L_{Tj} , $1 \leq j \leq k_L$ (distributed fairly evenly over the normal weighing range), the calibration certificate will contain only results for these points. When another reading R corresponds to an indication I reported in the calibration certificate, the error $E(R)$ and the corresponding measurement uncertainty $U(R)$, may be taken from there.

To obtain an error of indication for another reading R, different from that of the calibration certificate, in the calibrated weighing range, can be used either an interpolation formula or an approximation function.

If the applied test loads are chosen equidistant as nominal value, a linear interpolation can be used. For a reading R with $I_k < R < I_{k+1}$, the above formula (6) become [1]:

$$E(R) = E(I_k) + (R - I_k)(E_{k+1} - E_k)/(I_{k+1} - I_k) \tag{7}$$

Expanded uncertainty associated to this error is calculated as follows:

$$U(R) = U(I_k) + (R - I_k)(U_{k+1} - U_k)/(I_{k+1} - I_k) \tag{8}$$

However, in many cases, the test loads applied may not be equidistant. In this case, it can be used one of the known interpolation formulas (for example Newton, or Lagrange - which is shortly described above, at A.1).

After determining the polynomial interpolation, the error of indication for any reading in the calibrated range can be calculated.

3.2. Direct Approximation

3.2.1. General Considerations Regarding the Direct Approximation

For a certain approximation be considered the "best", the sum of squares of distances from each point to the approximated curve should be minimal.

With this condition, it is possible that no point of the dataset not find on the approximate curve, which clearly distinguishes the approximation and interpolation.

The basis of most methods of approximation is the method of least squares, which considers that, the best approximation is that, for which, the sum of squares errors is minimal. This can be written in general form as follows:

$$\varphi(x) = \sum \left(x_{i,g} - x_{i,c}\right)^2 = \text{minimum} \tag{9}$$

where:
x_{ig} are the given values (or observed values);
x_{ic} the calculated values.

The polynomial regression is an approximation of a data set by a polynomial which has the form:

$$P_n(x) = a_0 + a_1 x + a_2 x^2 + \ldots + a_n x^n \tag{10}$$

If the data set has m elements, all data are on the "approximation" curve.

The approximation is better if the polynomial degree, n, is closer to the number of data.

If it uses a polynomial approximation having a higher degree that the number of data set, one can obtain significant errors in approximation.

3.2.2. Applications of the Approximation Methods in Determining the Error of Indication for any Reading in the Calibrated Weighing Range

In addition, or as an alternative to the discrete values obtained at calibration, I_j, E_j , a characteristic, or calibration curve may be determined for the weighing range, which allows to estimate the error of indication for any indication I within the weighing range.

A function $E_{\text{appr}}=f(I)$ may be generated by an appropriate approximation (that should take into account the uncertainties $u(E_j)$, of the errors) which should in general, be based on the "least squares" approach [1].

According to formula (9) and using the symbols from [1], we can write:

$$\sum v_j^2 = \sum \left(f\left(I_j\right) - E_j \right)^2 = \text{minimum} \tag{11}$$

The calculations should also include a check whether the model function is mathematically consistent with the data sets, E_j, I_j, $u(E_j)$.

For approximations, the "min χ^2" approach (which is similar to the least squares approach) is proposed:

$$\chi^2 = \sum w_j v_j^2 = \sum w_j \left(f\left(I_j\right) - E_j \right)^2 = \text{minimum} \tag{12}$$

where:

v_j is the residual;

f is approximation function containing n_{par} parameters ($n_{\text{par}} \leq n/2$);

E_j error of indication;

$w_j = \dfrac{1}{u_j^2}$ is the weighting factor.

To check the validity of the approximation, the following condition should be met [1]:

$$\left| \min \chi^2 - \upsilon \right| \leq \beta \sqrt{(2\upsilon)} \tag{13}$$

with:

$\upsilon = n - n_{par}$ are the degrees of freedom;

β a factor chosen to be 1, 2 or 3.

If the condition (13) is met, the form of the model function $E(I)$ can be considered to be mathematically consistent with the data underlying the approximation.

3.2.2.1. Preliminary Steps in Regression Analysis Using Polynomial Functions

As it was shown, a polynomial is a function that can be written in the form:

$$P_n(x) = a_0 + a_1x + a_2x^2 + ... + a_nx^n \tag{14}$$

for some coefficients $a_0,…, a_n$. If $a_n \neq 0$, then the polynomial is said to be of order n. A first - order (linear) polynomial is just the equation of a straight line, while a second-order (quadratic) polynomial describes a parabola.

A preliminary estimation of the polynomial used in the analysis can be done as follows:
1) the graphic representation *XY* (scatter plot) for the data set is achieved.
2) if the graph shows a straight line, we can try a polynomial of the first degree, written in general form as follows:

$$y = a_0 + a_1x \tag{15}$$

3) if the graph is as close to that of a parabola, we can try a polynomial of second degree written in general form as follows:

$$y = a_0 + a_1x + a_2x^2 \tag{16}$$

4) if the graph is more complex shape than a parabola, we can try a polynomial of third degree written in general form as follows:

$$y = a_0 + a_1x + a_2x^2 + a_3x^3 \tag{17}$$

5) if the polynomials of smaller degree didn't give satisfactory results, we can try a polynomial of fourth degree written in general form as follows:

$$y = a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4 \tag{18}$$

3.2.2.2. Approximation by a Straight Line

Suppose that the graphic representation *XY* (scatter plot) for the data set shows a straight line.
If the polynomial (14) is written for non-automatic weighing instruments we can write [1]:

$$E(R) = f(R) = a_0 + a_1R + a_2R^2 + ... + a_{n_a}R^{n_a}, \tag{19}$$

where:
R is any other reading within the calibrated weighing range;
n_a the degree of the polynomial which should be chosen such that:

$$n_a = n_{par} - 1 \tag{20}$$

For $n_a = 1$, the polynomial from (19) becomes a linear function:

$$E(R) = f(R) = a_0 + a_1 R \tag{21}$$

This simple linear model and its least squares estimates can be represented in matrix notation as follows:

$$\underset{\text{nx1}}{Y} = \begin{bmatrix} E_1 \\ E_2 \\ \vdots \\ E_n \end{bmatrix} ; \ \underset{\text{nx1}}{a} = \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} ; \ \underset{\text{n x 2}}{X} = \begin{bmatrix} 1 & I_1 \\ 1 & I_2 \\ \vdots & \vdots \\ 1 & I_n \end{bmatrix} \ \underset{\text{n x n}}{U(Y)} = \begin{bmatrix} u_{E_1}^2 & 0 & 0 & 0 \\ 0 & u_{E_2}^2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & u_{E_n}^2 \end{bmatrix}, \tag{22}$$

where:

Y is a column vector whose components are the errors E_j;

a a column vector whose components are the coefficients of the approximation (a_0, a_1);

X a matrix with two columns, whose first rows is (1, I_1); I is the indication of the weighing instrument (considered to be equal to nominal mass applied);

U(Y) the variance - covariance matrix of Y.

The coefficients a (a_0 and a_1) can be determined as follows [1]:

$$a = (X^{\mathrm{T}}WX)^{-1} X^{\mathrm{T}}WY \tag{23}$$

where:

X^{T} is the transpose of X;

$W = U(Y)^{-1}$ the weighting matrix (being the inverse matrix of $U(Y)$).

To check the validity of the approximation, according to (13), the "minimum χ^2" is calculated using the next formula [1]:

$$\min \chi^2 = v^T W v \tag{24}$$

with v_j the residual

$$v = Xa - Y \tag{25}$$

If the condition (13) is met, the variance covariance matrix for the coefficients a can be calculated as follows:

$$U(a) = (X^{\mathrm{T}}WX)^{-1} \tag{26}$$

If the condition (13) is not met, it should be repeated the approximation with an approximating polynomial of higher degree.

Having the values for a and *U(a),* the error and associated uncertainty for any reading R (obtained after the calibration, in the weighing calibrated range), can be calculated as follows [1]:

$$E_{\text{appr}}(R) = r^T a \tag{27}$$

$$U(E_{\text{appr}}) = 2\sqrt{u^2(E_{\text{appr}})} = 2\sqrt{\left(r'^{\mathrm{T}}a\right)U(R)(r'^{\mathrm{T}}a)^{\mathrm{T}} + r^{\mathrm{T}}U(a)r} \tag{28}$$

with:
r a column vector whose elements are $(1, R)^{T}$;
r' a column vector whose elements are the derivates of *r*: $(0, 1)^{T}$.
U(R) represents the expanded uncertainty of the reading calculated according to the formula:

$$U(R) = 2\sqrt{\frac{d_0^2}{12} + \frac{d_R^2}{12} + s^2(I)} \tag{29}$$

d_0 is the resolution of the weighing instruments at no-load indication;
d_R the resolution of the weighing instruments at load;
s (I) the standard deviation associated to the repeatability.

Where only one repeatability test has been performed, this standard deviation may be considered as being representative for all indications of the instrument.

When several standard deviations are determined for different test loads, the greater value of s_j, for the two test points enclosing the indication whose error has been determined, should be used [1]. Also, when the balance has two scale intervals and the standard deviation is determined for each range, it will be used in the formula (29) the corresponding standard deviation of the respective range.

The uncertainty from (29) is constant when s = constant.

If the eccentricity error has to be considered, the term containing uncertainty associated to this effect should be added to the formula (29).

3.2.2.3. Particular Case

It was presented a restriction of the polynomial (19) to a linear function, provided it is sufficient in view of condition (13).

A particular case is represented by the fact when, in the formula (21) it can be considered $a_0 = 0$, taking into account that, due to zero-setting of the weighing instrument (at least for increasing loads), the error $E(R) = 0$

The formula (21) becomes:

$$E_{\text{appr}}(R) = f(R) = a_1 R \tag{30}$$

The coefficient a_1 and associated expanded uncertainty can be calculated as follows:

$$a_1 = \sum wIE / \sum wI^2 \tag{31}$$

$$U(a_1) = 2\sqrt{u^2(a_1)} = 2\sqrt{1/\sum wI^2} \tag{32}$$

The "*w*" term was explained at formula (12).

To check the validity of the approximation, according to (13), the "minimum χ^2" is calculated using the next formula [1]:

$$\min\chi^2 = \sum w\left(a_1 I - E\right)^2 \tag{33}$$

In this formula, I and E represent the mean of the indications and that of the errors respectively.

From (30), the expanded uncertainty of the approximation U (E $_{\text{appr}}$) can be obtained:

$$U\left(E_{\text{appr}}\right) = 2\sqrt{u^2\left(E_{\text{appr}}\right)} = 2\sqrt{a_1^2 u^2\left(R\right) + R^2 u^2\left(a_1\right)} \tag{34}$$

4. Calculation Example

In order to better illustrate the above explained ideas, we can resort to an example. The chosen instrument is a frequently used type of electronic balance (non-automatic weighing instrument) having maximum capacity, Max 81g /220g and the scale interval "*d* ": 0.01 mg / 0.1 mg.

Usually, a calibration certificate gives the next results of measurement: errors of indications, repeatability of indications, effect of eccentric application of a load on the indication and also the measurement uncertainty for each of them.

The Table 1 shows what is expected to be found in a calibration certificate related to the type of the instrument described above:

Table 1. Results from the calibration certificate.

The error of indication for the balance charged to load *L*:		**Uncertainty of calibration U**
L = 0.010 g	E = 0.00 mg	0.03 mg
L = 0.10 g	E = -0.05 mg	0.03 mg
L = 1 g	E = 0.00 mg	0.03 mg
L = 10 g	E = 0.06 mg	0.04 mg
L = 20 g	E = 0.14 mg	0.04 mg
L = 50 g	E = 0.23 mg	0.05 mg
L = 70 g	E = 0.26 mg	0.07 mg
L = 100 g	E = 0.4 mg	0.2 mg
L = 120 g	E = 0.4 mg	0.2 mg
L = 150 g	E = 0.3 mg	0.2 mg
L = 170 g	E = 0.3 mg	0.2 mg
L = 200 g	E = 0.3 mg	0.2 mg
L = 210 g	E = 0.2 mg	0.2 mg
The repeatability error for the balance charged to load L:		
L = 70 g:	s = 0.016 mg	
L = 200 g:	s = 0.08 mg	
The repeatability error is expressed as standard deviation, obtained from 10 determinations of the same load.		

The error for a load L eccentric placed:		Uncertainty of calibration U
L = 70 g	E = 0.00 mg	0.07 mg

For simplicity the nominal indication was considered to be $I_{Nj} = m_{Nj}$ where m_N is the nominal conventional value of mass of a standard weight.

Firstly, a preliminary estimation of the polynomial is made, using the graphic representation *XY* (scatter plot) of the data set (Fig. 1):

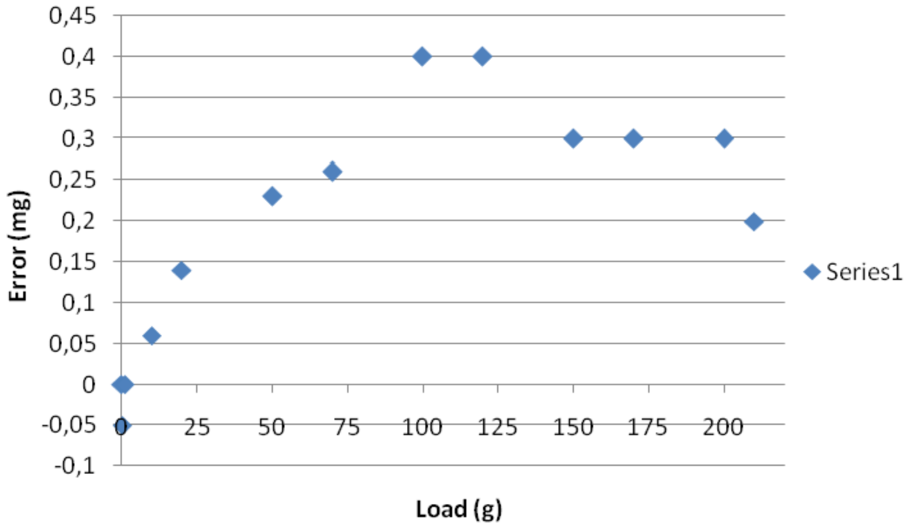

Fig. 1. Representation *XY* (scatter plot) of the data set.

The graph does not show a straight line, so, we can begin by trying a polynomial of second degree having the form: $Y = a_0 + a_1R + a_2R_2^2$.

For this model, the least squares estimates can be represented in matrix notation as follows:

$$\underset{13\text{x}1}{Y} = \begin{bmatrix} 0 \\ -0.05 \\ \vdots \\ 0.2 \end{bmatrix};\quad \underset{3\text{x}1}{a} = \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix};\quad \underset{13\text{ x }2}{X} = \begin{bmatrix} 1 & 0.01 \\ 1 & 0.1 \\ \vdots & \vdots \\ 1 & 210 \end{bmatrix} \qquad \underset{13\text{ x }13}{U(Y)} = \begin{bmatrix} 2.7\cdot10^{-4} & 0 & 0 & 0 \\ 0 & 2.7\cdot10^{-4} & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & 0.01 \end{bmatrix}$$

The coefficients *a* (a_0, a_1 and a_2) can be determined according to formula (23):

$$a = \begin{bmatrix} -0.012 \\ 6.2\cdot10^{-6} \\ -2.5\cdot10^{-11} \end{bmatrix}$$

The variance covariance matrix for the coefficients *a* is calculated using the formula (26):

$$U(a) = (X^TWX)^{-1} = \begin{bmatrix} 7.7\cdot10^{-5} & -2.4\cdot10^{-9} & 1.1\cdot10^{-14} \\ -2.4\cdot10^{-9} & 2.6\cdot10^{-13} & -1.5\cdot10^{-18} \\ 1.1\cdot10^{-14} & -1.5\cdot10^{-18} & 1.0\cdot10^{-23} \end{bmatrix}$$

To check the validity of the approximation, the "minimum χ^2" is determined:

$$\min \chi^2 = 12.36$$

If $\upsilon = n - n_{par} = 10$, according to formula (13), it's obtained:

$$2.4 < 8.9$$

The condition (13) is met and the form of the model function *E(I)* can be considered to be mathematically consistent with the data underlying the approximation.

Suppose that we need to calculate the error of indication and the associated uncertainty for the reading $R = 190$ g.

If the vectors *r* and *r'* are:

$$r = \begin{bmatrix} 1 \\ 190 \\ 190^2 \end{bmatrix} g \text{ and } r' = \begin{bmatrix} 0 \\ 1 \\ 380 \end{bmatrix} g$$

The approximated error, according to formula (27) is: $E_{\text{appr}}(190) = 0.3$ mg.

Taking into account that the weighing range has two scale intervals, the expanded uncertainty of the reading, *U(R)*, calculated according to formula (29) gives:

$$U(\mathrm{R}) = 0.17 \text{ mg}$$

The formula (28) can be now calculated, obtaining the next value for $U(\mathrm{E}_{\text{appr}})$:

$$U(E_{\text{appr}}) = 0.1 \text{ mg}$$

The certificate may give the advice to the user that the standard uncertainty to the error of any reading *R*, obtained after the calibration, is increased by uncertainty of the reading [1], $u(\mathrm{R}) = 0.085$ mg.

5. Conclusions

Starting from a calibration certificate of a NAWI, the article proposes the way to calculate the errors of indication and associated measurement uncertainties within the calibrated weighing range, for others readings, different from those stated in the calibration certificate.

Based on information from the calibration certificate, laboratories may create their own specific formula, (depending on the conditions they have complied with), in order to obtain a more complete uncertainty.
A laboratory should not attempt to make measurements with an uncertainty of "x" using an instrument that has the readability "x". If the user wishes to apply no corrections, to obtain an uncertainty of "x", he should have a balance with a readability of "0.1x", to be sure that are no gross errors present.

When a calibrated weighing instrument is used, the calibration uncertainty stated in the calibration certificate of that instrument has to be taken into account when reporting the measurement uncertainty associated with any measurement results, but it should be remembered that the calibration uncertainty represents only one part of the measurement uncertainty stated in current applications of the laboratory.

Other contributions to the measurement uncertainty that have to be taken into account are the influence of the buoyancy correction, the influence of the properties of the product that is weighed (evaporation, hygroscopic behavior, electrostatic charging, etc). Other possible causes include (for example): container or sample is magnetic, gravitational acceleration and fluctuations in temperature.

As the analysis of the influences upon the measurement process and their reflection in the measurement uncertainty associated with the results is a very specific topic for medical field, the paper does not go into details.

The medical laboratory may use the measurement results provided by the certificate in order to create its own formula, adapted to its working conditions.

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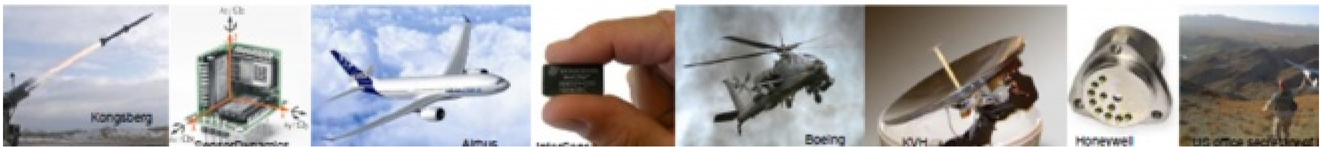

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http://www.sensorsportal.com/HTML/CMOS_Image_Sensors.htm

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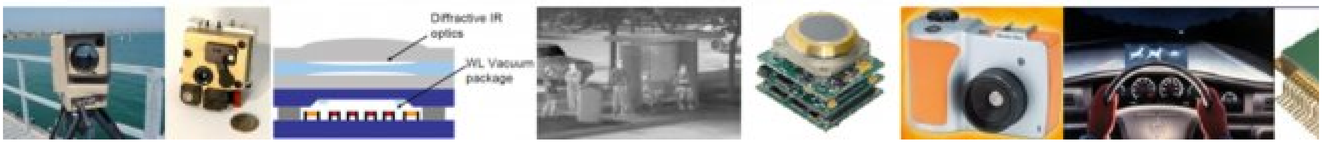

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

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Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm Authors must follow the instructions strictly when submitting their manuscripts.

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