

The Evaluation of the Weighing Instrument based on Information on Calibration

Certificate

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Abstract

As measurement instrument the weighing instrument has a very good measurement accuracy compared to some other measurements in processes. To know the characters of the weighing instrument the user must be able to evaluate it. The calibration is one method to show this working capacity of weighing instruments. The user must be able to define the values for permissible error of indication as well as the needed uncertainty of the calibration. The practice has shown that in the most cases it is adequate to indicate these values as scale intervals and it is as well a very pragmatic way to estimate the capability of weighing instruments. How can the user argue these values without careful analysis? The manufacturers give technical data of weighing instruments and the user can make good use of it. In most cases these values can be reached only in the best environmental circumstances even lower accuracy were sufficient. The analysis over some thousand-calibration results gives indication to evaluate the needed calibration uncertainty of weighing instruments in practice.

1.Verification for Weighing Instruments used in Legal Measurement

The regulations of legal measurement in most countries are founded on recommendations of OIML (Organisation Internationale Metrologie de Legale), directly or completed by own regulations. These recommendations give exactly maximum permissible errors for the initial verification and for the service the error limits are normally

twice. When the number of scale intervals for a weighing instrument as well as the class is known, the user knows exactly also the required performance of the weighing instrument. He knows that the weighing instrument has also a pattern approval and the error limits can be kept up also on the range of temperature $-10^{\circ}\text{C} \dots +40^{\circ}\text{C}$. Additionally the

accuracy can be reached in environmental circumstances with a certain electrical disturbances. Therefore it is very easy to define weighing instruments according OIML recommendation. The verification has some significant differences to calibration; there is no need to do any correction for the indication of the weighing instrument. The second difference is that the verification procedure does not contain any uncertainty calculation, but the development of the pattern approval with maximum permissible errors has a very long experience and the practice has shown as well the functioning of the limits. The user does not need to evaluate error limits or calibration intervals, they are all written in the recommendation of OIML or in local recommendations (verification interval). The one aim for the pattern approval is to confirm the long-term stability of the weighing instruments at least over verification period, which is not the case by calibration.

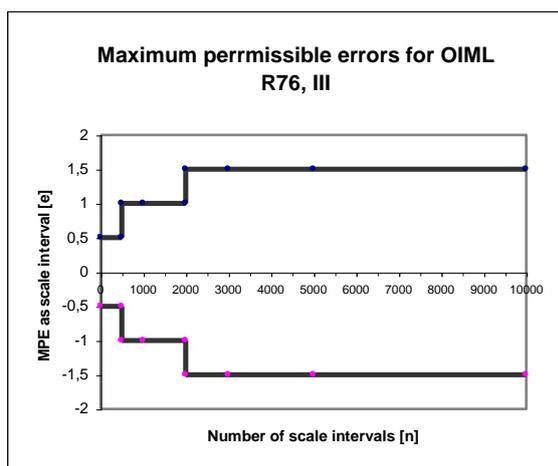


Figure 1. Maximum permissible errors according OIML R76 for class III for initial verification, in service verification they are usually twice (defined by local authority).

The verification regulations give exactly limits for permissible errors and the pattern approval confirms the reliability on the high level. However, there are no requirements for weighing instruments in use, which define the needed class or number of scale intervals. The user is responsible for selecting the accuracy class of the weighing instrument and he is as well responsible for the results of the measurement. In most cases the weighing instruments are used for selling material and the user has own interest to have the measurement capability. In other cases the user has to evaluate the needed accuracy and select the weighing instrument with adequate measurement capability

The classification of the weighing instruments is very clear with maximum permissible errors, however there are no requirements for the use of weighing instruments.

3. Evaluation of the Measurement Uncertainty by Weighing

Calibration gives the deviation between the value given by standards and the measured value. By giving the calibration certificate, especially according to EA roles (European cooperation for accreditation), the laboratory has to give uncertainty of the calibration. This uncertainty is given for the case, which is made by expert and it does not represent the normal situation in use. The practical measurement can have more factors, which are influencing the results. The quality assurance is requiring the uncertainty of the measurement

by production and the calibration of measurement instrument is only part of it. Therefore, the definition of the calibration uncertainty must be evaluated against this requirement, with condition of the production.

As example definition of the moisture content from a sample by a scale:

Percentage of the moisture can have a variation 5...15 %.

Size of a sample is 20...50 g.

Required uncertainty for the determination of the moisture content $< 2\%$.

The minimum difference to weight is 5 % and from minimum size of sample (20 g) it is 1 g.

Further 2 % from 1g gives **20 mg**.

This 20 mg is the needed uncertainty of the measurement. How small must the factor in the uncertainty for weighing instrument be to get for complete measurement the uncertainty $\leq 2\%$.

In the weighing technology it is a very common rule to have uncertainty of standards less than 1/3 of the required total uncertainty. With this rule 1/3 of the total uncertainty and by minimum size of sample 20 mg we get for the uncertainty of the weighing 6,7 mg.

This leads to scale interval **5 mg** and for the number of scale intervals $n \geq 10000$. That is only one factor of the total uncertainty of the measurement. The validation of the measurement gives indication for the other

factors of the measurement uncertainty like method of weighing, influence by measurer and object etc. The problematic of the sample, how well the sample represents the investigated material, is not included here. As validation method can be used statistical control, unidentified test piece, comparing between measurer etc. Practical validations have given as results for the measurements made by weighing instrument a total uncertainty 1,3 ... 1,6 times the uncertainty of the calibration of the weighing instruments itself.

To define the needed uncertainty for a weighing instrument you need to analyze the process and derive the uncertainty for calibration of weighing instrument from this evaluation.

4. The Aim of the Calibration of Weighing Instruments

It is very usual, that the necessity for calibration comes from the quality assurance. The system needs calibration certificate and in many cases the user is satisfied to get this paper. As in the previous chapter mentioned, the system needs the uncertainty of the measurement not the calibration of the measurement instrument. There can be also some other requirements for measuring if the production is working according to a written standard. The standard gives very often-needed accuracy for the measurement not an uncertainty and it can lead to some problem by the interpretation, how the uncertainty can be handled as accuracy. Unfortunately many

standards are not written with good manner regarding to metrology.

The calibration certificate is a tool to control the measurement process from correctness the results to final uncertainty of the measurement the product. Therefore the user must be capable to understand the information of a calibration certificate and the influence of different factors to measurement. This must be in correct relation to the needed accuracy of the measurement. The history of the calibrations and control of the essential factors like repeatability, hysteresis etc. needs monitoring in relation to the importance of them. All manufacturers give the technical information for the best behaviour. In the most cases it is not necessary to work with the best capability, satisfactory uncertainty can be reached with lower requirements and as benefit it means also lower costs.

The calibration certificate has to be used as tool for evaluation of the measurement system.

5. Evaluation of the Weighing Instrument with Calibration Certificate

Evaluation of the calibration certificates is the basement for final uncertainty and for maintenance of the measurement. The usability of the results is depending on the contents of calibration certificate and how they are indicated. The user has to distinguish very clear the correctness and the uncertainty, which has to be set for right importance in relation to the use of scale.

As contrary to verification, calibration gives always the difference between reference and measured value; it is called error of indication. The user should correct the result with the error of indication and this corrected measured value has limits according to uncertainty. However the users very seldom do this correction. One reason is, that it is time-consuming task and often the error of indication do not worsen the usability the weighing result. The users are trusting to the result without becoming worried about possible influence of the error. In the case that the error of measurement is less than uncertainty of the measurement, it does not lead to big problems. But if the error is significantly higher than uncertainty of the measurement, it should be taken into account by using the measured value.

Other way to realize this so called “bias-error” is to include the “bias-error” in to measurement uncertainty. Only the user normally does this calculation, because the calibration laboratory, if there is external calibrator, gives the poor measurement uncertainty for calibration.

In the case that bias-error is included in the calibration uncertainty it will be asymmetrical;

$$Y = y \begin{pmatrix} + 2 * u_{pos} \\ - 2 * u_{neg} \end{pmatrix} \quad (1)$$

Evaluation of the uncertainty of the calibration;

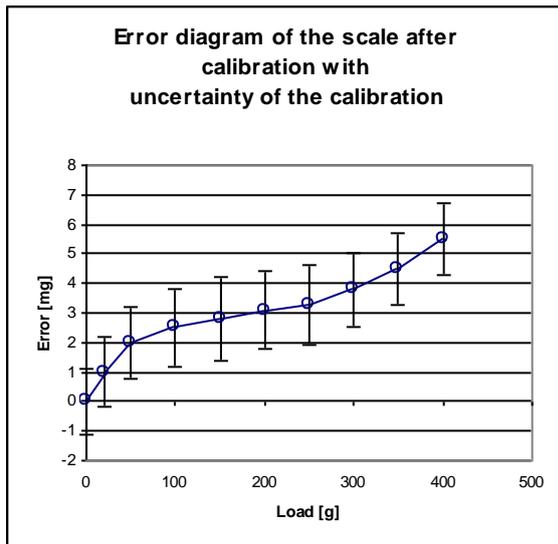


Figure 2. The error of the weighing instrument by calibration and uncertainties of the calibration

Only in the case where the number of uncertainty is significantly high, user can maybe ask the reason for that. Even very few of users are setting a limit for uncertainty for the calibration. However the user has to be able to understand the structure of uncertainty and he must be able to use it as tool for evaluation of condition of weighing instrument.

The user has to determine numerical value for the calibration uncertainty of weighing instrument and by exceeding this value the user must be able to analyze it.

One important criterion is the change of the level of uncertainty. If this is the case, the reason for the change is to make clear. In any case the calibration certificate should indicate the elements of the uncertainty calculation, in some cases all of them can have also numerical

values, not only the total measurement uncertainty. The main elements, which are indicating the condition of the weighing instrument, are normally repeatability, eccentric load, hysteresis and the scale interval. The maximum uncertainty of standards is normally in weighing technology 1/3 of the total determined uncertainty (error). Basically general elements to causing problems are repeatability, eccentric load and hysteresis.

Increasing of the repeatability is in most cases coming from change the mechanical construction of the scale or mechanical connection to the scale. Ability to show same result independently of the place of load on the load receptor, eccentric load, has as reason change of the transducers or load-transmitting mechanic. Higher hysteresis indicates the change of the mechanic or extraneous material or particles are creating higher friction.

The knowledge of calibration is fundamental element of the maintenance in weighing technology.

6. Information from the Analyze of Calibration Certificates

To get the real estimation from the approved uncertainty about thousand certificates evaluated and as result it shows the distribution related to classification of the weighing instrument. Two factors have been considered; the correctness and the uncertainty of the calibration.

The correctness of the indication is relatively easy to control. For a non-automatic weighing instrument in initial verification the error is maximal $\pm 1,5 e$ and in service $\pm 3 e$. The limit for correctness below $\pm 1,5 d$ is not realistic and $\pm 3 d$ is normally always to get. With these limits the calibration period will be reasonable and the range can also be wider, if the use of the weighing result is not exacting.

The uncertainty of the calibration is more difficult. Looking the technical data given by manufacturer, the calibration uncertainty could be $\pm 2 d$. Only in few cases the use and the location of the weighing instrument is supporting this kind of requirement. Especially weighing instruments in class I or II (according

OIML R76) show in practice wider distribution and the user are accepting it. The study of the calibration certificates has shown distribution for different weighing instruments as given in table 1.

It is more important to set as calibration uncertainty limits, which can be reached on the location of the weighing instrument assuming that the weighing instruments is working well and the user has to control the stability of the uncertainty from calibration to the next.

Type of weighing instrument	Scale interval	Distribution of the calibration uncertainty as scale interval
Verified weighing instruments		$\pm (1 \dots 3) e$
Weighing instruments for laboratory	$d = 0,1 \dots 1 \text{ g}$	$\pm (1 \dots 3) d$
Weighing instruments for laboratory	$d = 1 \dots 10 \text{ mg}$	$\pm (2 \dots 6) d$
Analyze weighing instruments	$d = 0,1 \dots 1 \text{ mg}$	$\pm (2 \dots 8) d$
Analyze weighing instruments	$d = 0,001 \dots 0,01 \text{ mg}$	$\pm (3 \dots 10) d$

Table 1. Calibration uncertainty as scale interval according analyze of the calibration certificates

7. References

- [1]. Non-automatic weighing instruments R76-1, OIML

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