Calibration of automatic gravimetric filling instruments in dynamic weighing

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Abstract: The project of traceable calibration of automatic weighing instruments operating in the dynamic mode, one of the EMPIR, focuses on the development of reproducible calibration methods and measurement uncertainty evaluation models for different groups of AWIs such as automatic catch weighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments. In this study details on the calibration of automatic gravimetric filling instrument, error model and uncertainty budget for the determination of the uncertainty of measurement of   in dynamic weighing have been mentioned by the calibration practice

 Keyword: dynamic weighing, traceable of dynamic weighing, error model, uncertainty of measurement and automatic gravimetric weighing instrument

1. Introduction

With the development of weighing technology, the number of Automatic Weighing Instruments (AWIs), which carry out measurements in a dynamic mode, has increased. Notwithstanding a generally higher purchase price than for Non-automatic Weighing Instruments (NAWIs), AWIs are more effective and efficient for their users in the long term. Improvements in the accuracy of AWIs mean that they are now used in an increasing number of applications from micro to macro weighing.

While NAWIs are routinely calibrated by accredited calibration laboratories according EURAMET

Calibration Guide cg-18, the calibration of AWIs is not as well defined as there is a significant difference between the static measurement mode of operation of NAWIs and the dynamic measurement mode of operation, which is typical for the majority of AWI applications.

There is also limited information about the uncertainties achievable using AWIs. There is therefore a need for validated reproducible calibration methods and measurement uncertainty evaluation models for different groups of AWIs operating in a dynamic measurement mode.

The EMPIR AWICAL Project " Traceable calibration of automatic weighing instruments operating in the dynamic mode" will develop calibration methods and uncertainty evaluation models for three categories of AWIs and these methods and models will be validated via on-site tests at end-users / manufacturers. Therefore draft calibration guides for the three categories of AWIs based on these calibration methods and uncertainty evaluation models will also be developed.

In this study details on the calibration of automatic gravimetric filling instrument, error model and uncertainty budget for the determination of the uncertainty of measurement of in dynamic weighing have been mentioned by the calibration practice.

2. The calibration of automatic gravimetric filling instrument

Automatic gravimetric filling instruments [1] are widely used to fill containers with predetermined and virtually constant mass of product from bulk by automatic weighing.

The calibration of the instruments in the static mode (non-automatic operation) in accordance with EURAMET Calibration Guide No. 18 [2] is not representative one for the actual operation of the instrument. The object of the calibration is the preset value [1], i.e. value, expressed in units of mass, preset by the operator, in order to define the nominal value of the fills. The actual value of the fill will be affected by dynamic effects, the load type and properties, the container properties, local gravity, the load temperature and density, and the temperature and density of the surrounding air.

Calibration consists of determining the conventional mass of the containers and applying material tests to the instrument under specified conditions and determining the preset value error at dynamic weighing and also estimating the uncertainty of measurement to be attributed to the results.

Unless requested otherwise by the client, the calibration extends over the range limited by the minimum nominal value of fills produced on-site Min' and the largest nominal value of fills produced on-site Max'.

The calibration is performed at the rate operation requested and specified in advance by the client. Normally these conditions are the same as conditions during the actual weighing process.

2.1. Test method

Tests are normally performed to determine the preset value error at different preset values. The test fills should be made of the type of product, which is normally weighed on the calibrated a control instrument. The test consists of repeated filling the fills with the same nominal value, and under constant test conditions.

The tests are carried out with k different preset values F_{Pj} , $1 \leq j \leq k$. Generally the preset value values are the minimum nominal value of fills produced on-site Min' and the largest nominal value of fills produced on-site Max' and near the a value between Min' and Max' according, especially if Min' is less than one third of Max'. The minimum number of individual test fills shall be as specified in the following table:

Table 1. Number of test fills

Preset value of the fills, F_p	Minimum number of test fills, n
$F_p \leq 1$ kg	60
1 kg < $F_p \leq 10$ kg	30
10 kg < $F_p \leq 25$ kg	20
25 kg < F_p	10

The control instrument and standard weights are used in testing. A control instrument is used to determine the conventional mass of test fills in containers and the conventional mass of empty containers.

Generally, the control instrument should have a resolution better than the calibrated instrument and, if applicable, ensure the determination of the conventional mass of each test load to an accuracy of at least one-third of appropriate tolerances for the calibrated instrument defined by client. The control instrument may be either separate or integral.

Standard OIML weights [3] directly applied on the instrument are not used for calibration of the instrument which are used for calibration of the control instrument.

The tare of empty containers, i.e. their conventional mass needs to be determined on the control instrument as a part of the calibration.

2.3. Measurement results

The preset value error E_{Pj} is calculated based on measurement of n test fills for j-th preset value F_{Pj}, and the reference values of mass of test fills $m_{ref,ij}$ as follows

$$E_{Pj} = \frac{1}{n}\sum_{i=1}^{n} m_{ref,ij} - F_{Pj} \qquad (1)$$

The repeatability error is calculated from the n fills F_{ij}, $i = 1, ..., n$, for a given j-th preset value F_{Pj}, the

standard deviation $s(F_j)$ is calculated by

$$s(F_j) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(F_{ij} - \overline{F_j})^2} \qquad (2)$$

2.4. Uncertainty of measurement

The basic formula for the calibration is (the same as (1), only the index j is omitted for the sake of simplicity)

$$E_P = \frac{1}{n}\sum_{i=1}^{n} m_{ref,ij} - F_P \qquad (3)$$

To account for sources of variability of the preset value error, (3) is amended by correction terms δX_{xx} such as δF_{rep}; the repeatability error of the preset value, δF_{repT}; the repeatability error of tare of the container, δm_{BTot}; the total buoyancy correction factor for preset value, δI_{dig} ; resolution of the device. The formula of sources of the preset value error is given

$$E_P = \frac{1}{n}\sum_{i=1}^{n} F_i + \delta F_{rep} + \delta F_{repT} + \delta m_{BTot} - F_P + \delta I_{dig} \qquad (3\text{-}1)$$

with standard uncertainty of the preset error[4].

$$u(E_P) = u^2(F_{rep}) + u^2(F_{repT})^2 + u^2(m_{BTot}) + u^2(\delta I_{dig}) \qquad (3\text{-}2)$$

3. A calibration example

The information of an automatic gravimetric filling instrument is given below.

Accuracy class X(x):1

Reference value Ref(x):1

Maxfill:2 kg

Minfill: 400 g

Scale interval d:1 g

Average number of loads/fill: 30 for 2 kg and 60 for 400 g.

Maximum rate operation (loads/munite): 10 second

Pneumatic/hydraulic pressure(bar): Pneumatic / 6 bar

Test Material: Water

Manufacture: Baykon Company

The control instrument information used as

Maximum capacity: 5 kg

Scale interval d: 0, 1 g

Manufacture: Kern

The gravimetric filling instrument was adjusted internally and the control instrument was adjusted externally before calibration. Also the control instrument was calibrated acc. Guidelines on the Calibration of Non-Automatic Weighing Instruments. For the device is used only at maxfill by the costumer, the calibration was carried out just at maxfill. The Table 2 summarizes dynamic calibration result at 2 kg of automatic gravimetric filling instrument.

Environmental condition during the calibration ;
Temperature value T: $(21,1 \pm 0,5)$ ^{0}C
Relative Humidity value RH: (55 ± 3)%

Table 2. Errors and related uncertainties

Quantity or influence	Load, indication and error in g Uncertainties in g
Preset value, Fp	2000
Av. Indication value of the control instrument, $I_{cont.}$	1998,98
Av. Indication value of the tare of container , I_{cont_tare}	115,06
Preset Error, E_p	-1,02
Repeatability value, $u(\delta F_{rep})$	0,79
Repeatability value, $u(\delta F_{repT})$	0,19
Total buoyancy correction, $u(\delta m_{BTot})$	Not relevant in this case
Resolution error $u(\delta I_{dig})$	0,29
Standard uncertainty of preset error, $u(E_p)$	0,9
Expanded uncertainty, U(E) (k=2)	1,8

4. References

[1].OIML R 61-1 Automatic gravimetric filling instruments, Part 1, 2004.

[2]. EURAMET cg-18 Version 4.0 Guidelines on the Calibration of Non-Automatic Weighing Instruments

[3]. OIML R 111-1 Weights of classes E1, E2, F1, F2, M1, M1–2, M2, M2–3 and M3, Part 1, 2004

[4].JCGM 100:2008 (GUM) Evaluation of measurement data-Guide to the expression of uncertainty in measurement, September 2008