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Guidelines on the Calibration of Automatic Catchweighing Instruments

CONTENTS

1 INTRODUCTION

Automatic catchweighing instruments [1] are widely used to determine the value of a load in terms of mass. While for some applications specified by law, automatic catchweighing instruments are subject to legal metrological control, there is a growing need for confirmation of their metrological characteristics by calibration, eg. where required by EN ISO 9001 or EN ISO/IEC 17025 standards.

2 SCOPE

This document contains guidance for the calibration of automatic catchweighing instruments (hereafter called "instrument"), in particular for

1. determination the mass of test loads,
2. measurements to be performed,
3. calculation of the measuring results,
4. evaluation of the uncertainty of measurement,
5. contents of the calibration certificates.

The guide refers to automatic operation of the instrument [1]. The guide deals with the instruments that weighs dynamically [1], but it could be as well used for the instruments that weighs statically [1].

The guide doesn't cover calibration of vehicle incorporated instruments [1] and vehicle mounted instruments [1].

The calibration of the instruments in the static mode (non-automatc operation) [1] 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 indication provided by the instrument in response to an applied load. The results are expressed in units of mass. The value of the load indicated by the instrument will be affected by dynamic effects, speed of the load transport system [1], the load dimensions, local gravity, the load temperature and density, and the temperature and density of the surrounding air.

The uncertainty of measurement depends significantly on properties of the calibrated instrument itself, the control instrument, the characteristics of the test loads, not only on the equipment of the calibrating laboratory; it can to some extent be reduced by increasing the number of measurements performed for a calibration. This guideline does not specify lower or upper boundaries for the uncertainty of measurement.

It is up to the calibrating laboratory and the client to agree on the anticipated value of the uncertainty of measurement, which is appropriate in view of the use of the instrument and in view of the cost of the calibration.

While it is not intended to present one or few uniform procedures the use of which would be obligatory, this document gives general guidance for establishing of calibration procedures the results of which may be considered as equivalent within the EURAMET Member Organisations.

Any such procedure must include, for a limited number of test loads, the determination of the error of indication and of the uncertainty of measurement assigned to these errors. The test procedure should as closely as possible resemble the weighing operations that are routinely being performed by the user – e.g. weighing articles, which are actually weighed on the instrument by client.

The calibration can only deliver a measurement error in comparison to a reference at the time of calibration and under the conditions of the calibration. Any transfer of this information to other conditions or an extrapolation of the results into the future requires additional succeeding calibrations or a priori information and the respective extrapolation of the uncertainty based on the knowledge about the behaviour of the instrument.

The information presented in this guideline is intended to serve, and should be observed by

1. bodies accrediting laboratories for the calibration of automatic catchweighing instruments,
2. laboratories accredited for the calibration of automatic catchweighing instruments,
3. manufacturers and other users using calibrated automatic catchweighing instruments for measurements relevant for the quality of production subject to QM requirements (e.g. EN ISO 9000 series, EN ISO 10012, EN ISO/IEC 17025).

3 TERMINOLOGY AND SYMBOLS

The terminology used in this document is mainly based on existing documents

- OIML R51 [1] for terms related to the operation, construction and metrological characterization of automatic catchweighing instruments
- EURAMET Calibration Guide No. 18 [2] for terms related with the static weighing and calibration of control instrument,

Such terms are not explained in this document, but where they first appear, references will be indicated.

Symbols whose meanings are not self-evident, will be explained where they are first used. Those that are used in more than one section are collected in Activity 1.3.2.

4 GENERAL ASPECTS OF THE CALIBRATION

4.1 Elements of the calibration

Calibration consists of

1. determining the conventional mass of the test loads,
2. applying test loads to the instrument under specified conditions,
3. determining the mean error of the indications, and
4. evaluating the uncertainty of measurement to be attributed to the results.

4.1.1 Range of calibration

In agreement with the client, the calibration is performed at individual nominal values, which are defined by mass of the test loads, and it is only valid for the specified test loads (with a small bandwidth for mass, volume and shape). It will usually not be possible to calibrate a "range" for such instruments, because of the dynamic behaviour.

On a multiple range instrument [1], the client should identify which range(s) shall be calibrated. The paragraph above may be applied to each range separately.

On a multilane instrument (the instrument with several load receptors and a single terminal), the client should identify which lane(s) shall be calibrated. The paragraph above may be applied to each lane separately.

The calibration is performed at speed(s) of load transport system and rate(s) of operation [1] requested and specified in advance by the client. Normally these conditions are the same as conditions during the actual weighing process.

The calibration it is only valid for these conditions.

4.1.2 Place of calibration

Calibration is performed in the location where the instrument is being installed. The calibration is valid for the place of installation.

4.1.3 Preconditions, preparations

The calibration should be done under normal conditions of use (air flow, vibrations, stability of the weighing site etc.) of the instrument. The calibration should not be performed unless

1. the instrument can be readily identified,
2. all functions of the instrument are free from effects of contamination or damage, and functions essential for the calibration operate as intended,
3. presentation of weight values is unambiguous and indications, where given, are easily readable,
4. the instrument is energized prior to calibration for an appropriate period, e.g. as long as the warm-up time specified for the instrument, or as set by the user,
5. the instrument is levelled, if applicable,
6. the instrument has been several times exercised in the automatic weighing mode with the largest test load.

If the instrument is fitted with the dynamic setting facility [1], which is regularly used by the user, the dynamic setting is executed for each test load value before commencing the calibration. Such setting should be made with the means normally used by the client and following the manufacturer's instructions when available.

If agreed with the client, the instrument could be statically adjusted before the calibration. Adjustment should be performed with the means that are normally applied by the client, and following the manufacturer’s instructions where available.

Instruments fitted with an automatic zero-setting device or a zero-tracking device [1] should be calibrated with the device operative or not, as set by the client.

The user of the instrument should be asked to ensure that the normal conditions of use prevail during the calibration. In this way disturbing effects such as air flow, vibrations, or inclination of the measuring platform will, so far as is possible, be inherent in the measured values and will therefore be included in the determined uncertainty of measurement.

4.2 Control instrument

A control instrument [1] is used to determine the conventional mass of the test loads.

The control instrument may be either separate (a weighing instrument other than the instrument being calibrated) or integral (when a static weighing mode is provided by the instrument being calibrated).

The control instrument, whether separate or integral, should ensure the determination of the mass of each test load to an accuracy, which is appropriate to the expected uncertainty of calibration of the calibrated instrument.

As a recommendation it can be taken that the control instrument should have a resolution better than or equal to that of 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.

Details on determination of the conventional mass of the test load and its uncertainty on the control instrument are given in the section 4.3 and 7.1.2, respectively.

4.3 Test loads

The test loads should preferably be the type of article(s), which are normally weighed on the calibrated instrument. For the purpose of calibration, their traceability to the SI unit of mass shall be demonstrated.

A selection of the test loads requires due consideration of the following:

1. appropriatness for the intended use of the instrument (if not exactly article(s), which are usually weighed on the calibrated instrument)

2. shape, material, composition should allow easy handling,

3. shape, material, composition should allow easily estimate the position of center of gravity,

4. their mass must remain constant throughout the period in which they are used for calibration,

5. non-hygroscopic, non-electrostatic, non-magnetic material.

The mass of the test loads shall be normally determined at the time and place of calibration of the instrument. If their conventional mass is not determined at the time and place of calibration of the instrument, but elsewhere (e.g. in a permanent laboratory[1]):

6. their density should be easy to estimate and reported on the calibration report,

7. the test loads of low density (e.g. cardboard boxes filled with material, paper, etc.) may require special attention due to buoyancy. Monitoring of the temperature and the atmospheric pressure may be necessary throughout the period of use of the loads during the calibration.

The necessary measurements to determine the mass and uncertainty of the test loads are performed on the control instrument. The procedure could be based either on OIML R 111 [3] or EURAMET Calibration Guide No. 18. The section 4.3.1 deals with the case where the control instrument is used as a mass comparator and the mass of the test load is obtained by its calibration with a reference standard weight. The section 4.3.2 deals with the case where the test load is weighed on the calibrated control instrument.

[1] A calibration laboratories may prepare in advance in a permanent laboratory standard articles, like boxes with defined weight. This makes sense, for instance, when the instrument is used to weight parcels of different sizes and weight (packaging or transport companies).

These two approaches for determining the mass of the test load are further discussed in the section 4.5 in order to determine the reference value of mass.

For dynamic tests where no errors of indication are determined, i.e. for eccentricity test, it is not essential that the mass of the test load is known. Requirements for the test loads, which are given above, are applicable.

4.3.1 Determination of the mass of the test load based on OIML R111

If the procedure for determination of the mass and uncertainty of the test load is based on OIML R111, the control instrument is used as a mass comparator and the conventional mass of the test load m_{cTL} is obtained by its calibration with a reference standard weight. In general, the relation is the following:

$$m_{cTL} = m_{cR}(1 + C) + \overline{\Delta m_c} \quad (4.3.1\text{-}1)$$

where

$$C = (\rho_{aCI} - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_R}\right) \quad (4.3.1\text{-}2)$$

$$\overline{\Delta m_c} = \frac{1}{n}\sum_{i=1}^{n} \Delta m_{ci} \quad (4.3.1\text{-}3)$$

$$\Delta m_{ci} = I(m_{cTL}) - I(m_{cR}) \quad (4.3.1\text{-}4)$$

with
m_{cR} – conventional mass of the standard weights used for calibration of the test load on the control instrument,
C – air bouynacy correction contribution
$\overline{\Delta m_c}$ – average measured difference between the test load and standard weights
ρ_{aCI} - air density at the time of calibration of the test load on the control instrument,
ρ_0 - reference air density, 1,2 kg/m^3,
ρ_{TL} - density of the test load,
ρ_R - density of standard weights used for calibration of the test load on the control instrument,
n – number of calibration comparison cycles,
$I(m_{cTL})$, $I(m_{cR})$ – indication of m_{cTL} and m_{cR}, respectively, on the control instrument

4.3.2 Determination of the mass of the test load based on EURAMET Calibration Guide No. 18

If the procedure for determination of the mass and uncertainty of the test load is based on EURAMET Calibration Guide No. 18, the test load is weighed on the calibrated control instrument. The conventional mass of the test load m_{cT} is proportional to the weighing result of the control instrument W_{CI}. The relation is the following [2]:

$$m_{cTL} = W_{CI}\left[1 + \left(\rho_{aCI} - \rho_0\right)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_{sCI}}\right)\right] \quad (4.3.2\text{-}1)$$

where

$$W_{CI} = R_{CI} - E_{CI} \quad (4.3.2\text{-}2)$$

$$R_{CI} = R_{LCI} - R_{0CI} \quad (4.3.2\text{-}3)$$

$$E_{CI} = I_{CI} - m_{refCI} \quad (4.3.2\text{-}4)$$

$$I_{CI} = I_{LCI} - I_{0CI} \quad (4.3.2\text{-}5)$$

$$m_{refCI} = m_{cCalCI} + \delta m_{BCI} \tag{4.3.2-6}$$

$$\delta m_{BCI} = -m_{cCalCI}\left[(\rho_{aCalCI} - \rho_0)\left(\frac{1}{\rho_{CalCI}} - \frac{1}{\rho_{sCI}}\right)\right] \tag{4.3.2-7}$$

with
R_{CI} – reading of the test load on the control instrument corrected for zero reading
R_{LCI} – reading of the test load on the control instrument (loaded)
R_{0CI} - reading of the test load on the control instrument (unloaded)
E_{CI} – eror of the control instrument
I_{CI} – indication of the standard weights on the control instrument corrected for zero indication
I_{LCI} – indication of the standard weights on the control instrument (loaded)
I_{0CI} - indication of the standard weights on the control instrument (unloaded)
m_{refCI} – reference value of mass of standard weights used for calibration of the control instrument,
m_{cCalCI} - conventional mass of the standard weights used for calibration of the control instrument,
δm_{BCI} – air bouyancy correction for the standard weights used for calibration of the control instrument,
ρ_{aCI} - air density at the time of weighing of the test load on the control instrument,
ρ_{aCalCI} - air density at the time of calibration of the control instrument with mass,
ρ_{sCI} - density of standard weights used for adjustment of the control instrument,
ρ_{CalCI} - density of standard weights used for calibration of the control instrument,
ρ_{TL} - density of the test load,
ρ_0 - reference air density, 1,2 kg/m^3,

4.3.3 Standard weights

Standard OIML weights directly applied on the load transport system are not used for calibration of the instrument.

Specially designed standard weights or special test loads assembled using packing with standard OIML weights inside could be used only if comparable dynamic propeties to the articles, which are actualty weighed on the instrument by client, are ensured. The requirements for the standard weights are given in [2].

The requirements for the standard weights, which are used for calibration of the control instrument or calibration of the test loads using the control instrument as a comparator are given in [2] and [3], respectively.

4.3.4 Effects of convection

The test loads may not be at the same temperature as the instrument and its environment. The temperature difference ΔT is defined as the difference between the temperature of the test load and the temperature of the surrounding air. Two phenomena should be noted in this case:

- An initial temperature difference ΔT_0 may be reduced to a smaller value ΔT by acclimatisation over a time Δt.
- When the test load is put on the load receptor, the actual difference ΔT will produce an air flow about the test load leading to parasitic forces which result in an apparent change Δm_{conv} on its mass. The sign of Δm_{conv} is normally opposite to the sign of ΔT, its value being greater for large test loads than for small ones.

The effect of convection should be minimized allowing the test loads to reach the temperature of the environment, i.e. to the extent that the remaining change Δm_{conv} is negligible in view of the uncertainty of the calibration required by the client.

4.4 Indications

4.4.1 General

An automatic weighing instrument shall be capable of performing consecutive weighing cycles without any intervention of an operator [4]. Unlike for non-automatic weighing instrument, the automatic weighing instrument operator is niether capable nor expected to make a correction of the indication under load with the indication at no load.

Consequently, for the purpose of calibration of automatic catchweighing instrument, only the test load indications I_{TL} are taken into account, and they are not corrected for the no load indications I_0.

$$I = I_{TL} \tag{4.4.1-1}$$

During calibration tests, the original indications should be recorded, not errors or variations of the indication.

Instead of the visualy observed indications, the indications stored electronically and displayed on demand or printed by the calibrated instrument may be equivalently used by the calibration laboratory.

4.4.2 Resolution

Indications are normally obtained as integer multiples of the scale interval d.

At the discretion of the calibration laboratory and with the consent of the client, means to obtain indications in higher resolution than in d may be applied, e.g. where compliance to a specification is checked and smallest uncertainty is desired. Such means may be switching the indicating device to a smaller scale interval $d_T < d$ ("service mode"). In this case, the indications are obtained as integer multiple of d_T.

4.5 Reference value of mass

To determine the errors of indication of an instrument, test loads are applied. Their conventional value of mass m_{cTL} is a priori not known, their density ρ_{TL} is normally significantly different from the reference value ρ_c and the air density ρ_a at the time of calibration is normally different from ρ_0.

The error of indication E is

$$E = I - I_{ref} \tag{4.5-1}$$

where I_{ref} is the reference value of the indication of the instrument, further called reference value of mass, m_{ref}. Due to effects of air buoyancy, convection, drift and others which may lead to minor correction terms δm_x, m_{ref} is not exactly equal to m_{cTL}, the conventional mass value of the load

$$m_{ref} = m_{cTL} + \delta m_B + \delta m_D + \delta m_{conv} + \delta m \dots \tag{4.5-2}$$

with
δm_B – air bouyancy correction for the test load used for calibration of the catchweigher,
δm_D – correction due to possible drift of the test load of since its last calibration,
δm_{conv} – correction due to convection effects on the test load.

δm – further corrections that it may be necessary to apply under special conditions, these are not considered hereafter.

Oposite to calibration of NAWI, density of the test load used for calibration of the catchweigher may significantly differ from reference density of a weight ρ_s, i.e. 8 000 kg/m^3 [5]. Consequently, air bouyancy corection could be significant. If conventional mass of the test load is determined at air density, which is diferent from air density at the time of calibration of catchweigher, the density of the test load need to be known with relevant accuracy/uncertainty. On the other hand, if conventional mass of the test load is determined at the time and place of calibration of the catchweigher there is no difference in the air density. It will be shown that the density of the test load doesn't need to be known in such a case.

m_{ref} could be determined in various ways as it is summarised in the table below.

Section	Principle of calibration of test load	Time of calibration	Remarks
4.5.1	Test load with calibration certificate	Test load calibrated previously.	Test load needs to have calibration certificate. Drift of test load is relevant. Significant air bouyancy correction / Density of test load needs to be known.
4.5.2	Test load calibrated on the control instrument used as comparator (calibration based on OIML R111)	Test load calibrated at the time and place of calibration of AWI	No significant drift of test load. Small air bouyancy correction. No need to know density of test load.
4.5.3	Test load weighed on the calibrated control instrument	Control instrument calibrated at time and place of calibration of AWI Test load weighed at the time and place of calibration of AWI	No drift of test load Small air bouyancy correction. No need to know density of test load
4.5.4	Test load weighed on the calibrated control instrument	Control instrument calibrated previously. Test load weighed at the time and place of calibration of AWI	Control instrument needs to have calibration certificate. Uncertainty of control instrument in use needs to be taken into account. No significant drift of test load Small air bouyancy correction. No need to know density of test load.
4.5.5	Test load weighed on the verified control instrument	Control instrument verified previously. Test load weighed at the time of calibration of AWI.	No significant drift of test load. Small air bouyancy correction. No need to know density of test load. Traceability of the verification needs to be demonstrated. Uncertainty of control instrument in use needs to be taken into account.

Sections 4.5.1 to 4.5.5 provide examples of determination of reference value of mass m_{ref} based on determination of the conventional mass of test load m_{cTL} and the air bouyancy correction for test load δm_B considering the principle and time of calibration of the test load

$$m_{ref} = m_{cTL} + \delta m_B. \tag{4.5-3}$$

For δm_D and δm_{conv} it is assumed, that δm_D=0 and $\delta m_{conv} = 0$. In general, however, their uncertainties may need to be taken into account.

4.5.1 Test load with the calibration certificate. Test load calibrated previously.

If it is justified that the test load is calibrated prior to the calibration of the instrument, then it is accompanied with calibration certificate, which states its conventional mass m_{cTL} with uncertainty and density with uncertainty.

The air bouyancy correction for the test load used for calibration of the catchweigher δm_B is affected by air density at the time of calibration of the catchweigher ρ_a, density of the test load ρ_{TL} and density of standard weights used for adjustment of the catchweigher ρ_s

$$\delta m_B = -m_{cTL}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_s}\right)\right] \qquad (4.5.1\text{-}1)$$

with reference air density $\rho_0 = 1{,}2\ kg/m^3$.

4.5.2 Test load calibrated on the control instrument used as comparator (calibration based on OIML R111) at the time and place of calibration of the catchweigher

Based on (4.3.1-1) and (4.3.1-2) for the conventional mass of the test load and (4.5.1-1) for the air bouyancy correction, and under the condition that $m_{cTL} \cong m_{cR}$ the reference value of mass m_{ref} is determined by

$$m_{ref} = m_{cR}\left[1 + (\rho_{aCI} - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_R}\right)\right] + \overline{\Delta m_c} - m_{cR}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_s}\right)\right] \qquad (4.5.2\text{-}1)$$

Since the mass of the test load is determined at the same time and place as the calibration of catchweigher, $\rho_{aCI} = \rho_a$, (4.5.2-1) consequently simplifies to

$$m_{ref} = m_{cR} + m_{cR}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_s} - \frac{1}{\rho_R}\right)\right] + \overline{\Delta m_c} \qquad (4.5.2\text{-}2)$$

If the total contribution of the correction for air buoyancy to m_{ref} in (4.5.2-2) is called δm_{BTot} then

$$\delta m_{BTot} = -m_{cR}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_R} - \frac{1}{\rho_s}\right)\right] \qquad (4.5.2\text{-}3)$$

and

$$m_{ref} = m_{cR} + \delta m_{BTot} + \overline{\Delta m_c} \qquad (4.5.2\text{-}4)$$

4.5.3 Test load weighed on the control instrument calibrated at time and place of calibration of the catchweigher. Test load weighed at the time and place of calibration of the catchweigher.

The control instrument should be calibrated in calibration points close to nominal masses of the test loads and the error of indication of the control instrument is taken into account.

Based on (4.3.2-1) to (4.3.2-7) for the conventional mass of the test load and (4.5.1-1) for the air bouyancy correction we get the following general expression for m_{ref}:

(4.5.3-1)

$$\begin{aligned} m_{ref} = \Big\{ & (R_{LCI} - R_{0CI}) - (I_{LCI} - I_{0CI}) + m_{cCalCI} \\ & - m_{cCalCI}\left[(\rho_{aCalCI} - \rho_0)\left(\frac{1}{\rho_{CalCI}} - \frac{1}{\rho_{sCI}}\right)\right]\Big\}\left[1 + (\rho_{aCI} - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_{sCI}}\right)\right] \\ & - m_{cTL}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_s}\right)\right] \end{aligned}$$

It is necessary that $(R_{LCI}-R_{0CI})-(I_{LCI}-I_{0CI})\ -m_{cCalCI}\left[(\rho_{aCalCI}-\rho_0)\left(\frac{1}{\rho_{CalCI}}-\frac{1}{\rho_{sCI}}\right)\right]\ll m_{cCalCI}$ and $m_{cTL}\approx m_{cCalCI}$, then (4.5.3-1) simplifies to

$$m_{ref}=(R_{LCI}-R_{0CI})-(I_{LCI}-I_{0CI})+m_{cCalCI}-m_{cCalCI}\left[(\rho_{aCalCI}-\rho_0)\left(\frac{1}{\rho_{CalCI}}-\frac{1}{\rho_{sCI}}\right)\right] +m_{cCalCI}\left[(\rho_{aCI}-\rho_0)\left(\frac{1}{\rho_{TL}}-\frac{1}{\rho_{sCI}}\right)\right]-m_{cCalCI}\left[(\rho_a-\rho_0)\left(\frac{1}{\rho_{TL}}-\frac{1}{\rho_s}\right)\right] \quad (4.5.3\text{-}2)$$

Since the mass of the test load is determined at the same time and place as the calibration of control instrument and catchweigher, then $\rho_{aCI}=\rho_{aCalCI}=\rho_a$, and

$$m_{ref}=(R_{LCI}-R_{0CI})-(I_{LCI}-I_{0CI})+m_{cCalCI}\left[1-(\rho_a-\rho_0)\left(\frac{1}{\rho_{CalCI}}-\frac{1}{\rho_s}\right)\right] \quad (4.5.3\text{-}3)$$

The total contribution of the air buoyancy correction δm_{BTot} to m_{ref} in (4.5.3-3) equals

$$\delta m_{BTot}=-m_{cCalCI}\left[(\rho_a-\rho_0)\left(\frac{1}{\rho_{CalCI}}-\frac{1}{\rho_s}\right)\right] \quad (4.5.3\text{-}4)$$

and

$$m_{ref}=(R_{LCI}-R_{0CI})-(I_{LCI}-I_{0CI})+m_{cCalCI}+\delta m_{BTot} \quad (4.5.3\text{-}5)$$

4.5.4 Test load weighed on the previously calibrated control instrument. Test load weighed at the time and place of calibration of the catchweigher

The mass of test load is determined by its weighing on the control instrument, which has been calibrated previously. The calibration certificate for the control instrument is on a disposal. However, the same approach could be used also in a case when the instrument is calibrated immediatelly prior to determination of the mass of test load.

If the conventional mass of test load is close to the calibration point in which the error of control instrument was determined, then the weighing result W_{CI} could be determined based on the reading of the test load R_{CI} corrected for the error of the control instrument E_{CI} as given by (4.3.2-2). The error of the control instrument is reported in its calibration certificate.

$$W_{CI}=R_{CI}-E_{CI}$$

If this is not the case (e.g. when the conventional mass of test load is not close to the calibration point in which the error of control instrument was determined, or if so decided by the calibration laboratory), no correction is applied to the reading

$$W_{CI}=R_{CI} \quad (4.5.4\text{-}1)$$

but errors of the control instrument need to be included in an uncertainty (i.e. a "global uncertainty" $U_{gl}(W_{CI})$, which includes the errors of indication such that no corrections have to be applied to the readings in use).

For a reading taken under the same conditions as those prevailing at calibration of the control instrument (e.g. immediatelly after its adjustment), the result may be denominated as the weighing result under conditions of the calibration W^*_{CI}.

Based on (4.3.2-1) for the conventional mass of the test load and (4.5.1-1) for the air bouyancy correction, we get the following general expression for m_{ref}:

$$m_{ref} = W_{CI}\left[1 + (\rho_{aCI} - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_{sCI}}\right)\right] - m_{cTL}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_s}\right)\right] \qquad (4.5.4\text{-}2)$$

If $m_{cTL} \approx W_{CI}$, then

$$m_{ref} = W_{CI}\left[1 + (\rho_{aCI} - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_{sCI}}\right) - (\rho_a - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_s}\right)\right] \qquad (4.5.4\text{-}3)$$

Since the mass of the test load is determined at the same time and place as calibration of the catchweigher, $\rho_{aCI} = \rho_a$, and (4.5.4-3) consequntly simplifies to

$$m_{ref} = W_{CI}\left[1 + (\rho_a - \rho_0)\left(\frac{1}{\rho_s} - \frac{1}{\rho_{sCI}}\right)\right] \qquad (4.5.4\text{-}4)$$

The total contribution of the air buoyancy correction δm_{BTot} to m_{ref} in (4.5.4-4) equals

$$\delta m_{BTot} = -W_{CI}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_{sCI}} - \frac{1}{\rho_s}\right)\right] \qquad (4.5.4\text{-}5)$$

and

$$m_{ref} = W_{CI} + \delta m_{BTot} \qquad (4.5.4\text{-}6)$$

4.5.5 Test load weighed on the previously verified control instrument. Test load weighed at the time and place of calibration of the catchweigher

The mass of test load is determined by its weighing on the control instrument, which has been calibrated verified. Traceability of the verification needs to be demonstrated.

In general, no correction is applied to the reading (as in (4.5.4-1))

$$W_{CI} = R_{CI}$$

but errors of the verified control instrument need to be included in an uncertainty (i.e. a “global uncertainty” $U_{gl}(W_{CI})$, which includes the errors of indication such that no corrections have to be applied to the readings in use).

Since the mass of the test load is determined at the same time and place as calibration of the catchweigher, $\rho_{aCI} = \rho_a$, m_{ref} and δm_{BTot} are determined in the same way as in the section 4.5.4, i.e. using (4.5.4-6) and (4.5.4-5).

4.6 Operating parameters

Article dimensions, the length of the platform and load transport system speed (belt speed) must be determined, and the speed setting (indicated belt speed and/or rate of operation, or position of speed setting switch) recorded for each case.

Based on the belt speed v, and the distance between the centres of articles S, maximum rate c_{max} is calculated according to the following expression:

$$c_{max} = v/S \qquad (4.6\text{-}1)$$

The distance S is equal or larger than the length of the platform.

The dimensions of the article are given in the following standardized form $a \times b \times c$, being

- *a*, length in the forward direction of the belt,
- *b*, width, perpendicular to the length in the plane of the belt,
- *c*, height, perpendicular to the plane of the belt.

5 MEASUREMENT METHODS

Tests are normally performed to determine:

- the errors and repeatability of indications, and
- the effect of eccentric application of a load on the indication.

The calibration laboratory deciding on the number of measurements for its routine calibration procedure should consider that, in general, a larger number of measurements tends to reduce the uncertainty of measurement but increase the cost.

Details of the tests performed for an individual calibration may be fixed by agreement of the client and the calibration Laboratory, in view of the normal use of the instrument. The parties may also agree on further tests or checks, which may assist in evaluating the performance of the instrument under special conditions of use. Any such agreement should be consistent with the minimum numbers of tests as specified in the following sections.

The general test procedure for the test specified in the following sections shall be as follows:

1) Select the test loads as specified in the section 4.3 with the test load values as specified in the sections 5.1 and 5.2 for the test for errors and repeatability of indication and eccentricity test, respectively. Determine the reference value of mass of each test load on the control instrument as specified in the section 4.5.

2) The instrument should be tested in its normal mode of automatic operation (with the consent of the client, indications in higher resolution may be obtained, see section 4.4.2). Start the automatic weighing system, including the surrounding equipment, which is normally operational when the instrument is in use.

3) Set the load transport system to the speed agreed with the client. Normally this is the speed used for weighing articles by the client. The speed may vary depending on the mass of the test load.

4) The number of consecutive test weighings for each test load depends on the nominal mass of the test load as specified in the sections 5.1 and 5.2 for the test for errors and repeatability of indication and eccentricity test, respectively..

5) Where applicable before commencing the tests select the corresponding dynamic setting factor, or carry out the dynamic setting for each test load value if the client regularly uses this facility.

6) Zero shall be set at the start of each test at a given load value and not readjusted at any time during the test. It has to be allowed that automatic adjustment of zero is operational during the tests.

7) Enable the test loads to be automatically weighed for the specified number of times and record each indication. The test load is introduced to the load transport system and the load receptor preferably using the load conveyor of the instrument.

8) The status of dynamic adjustment and automatic zeroing facilities shall be recorded for each individual test.

5.1 Test for errors and repeatability of indication

The test consists of the passing repeatedly the same load over the middle of the load receptor, under identical conditions of handling the load and the instrument, and under constant test conditions. The purpose of this test is an appraisal of the accuracy and repeatability of the instrument at least in some points of usual application of the instrument if not over the whole weighing range. Each test point is characterized by its own repeatability.

The test is performed with k different test loads L_{Tj}, $1 \leq j \leq k$.

Examples for the test load target values:
- the minimum nominal load of weighed articles available on-site *Min'*,
- the largest nominal load of weighed articles available on-site *Max'*,
- one/two or more test points equally distributed between *Min'* and *Max'* according to use of the instrument and depending on articles available on-site.

Details about the test load target values need to be agreed with the client to represent usual use of the calibrated instrument.

The minimum number of consecutive test weighings shall be as specified in the following table:

Nominal mass m of the test load	Minimum number of repetitions
m ≤ 10 kg	30
10 kg < m ≤ 20 kg	20
20 kg < m	10

If the instrument is used to determine the net values of the weighed articles and one of available tare devices (static or dynamic tare device, preset tare device) is used to take into account the tare value of the packing of weighed article, this may be taken into account during the test for errors and repatability of indication. The (preset) tare value(s) shall be agreed with the client.
- For the static taring, place the tare load on the load receptor and allow the tare function to operate (refer to the manufacturer's instructions).
- For the dynamic taring, pass the load to be tared over the load receptor to allow the tare function to operate (refer to manufacturer's instructions).
- For the preset tare, determine the tare value in the same way as the load value and introduce it into the instrument (refer to the manufacturer's instructions).

5.2 Eccentricity test

The effect of the eccentric application of the load on the indication is tested when applicable. The test is not applicable when the test load can not be applied eccentrically on the load receptor due to nature and shape of the article or the design of the load receptor, for example due to existence of mechanical guides, adapted to the width of the article.

The test load L_{ecc} should be the heaviest one from those used in 5.1, and which can be at the same time easily accommodated on a halfwide (1/2 *W*) of availbale portion of the load transport system.

The effect of eccentric loading shall be determined using the selected test load using the middle of load transport system (if the test load L_{ecc} is one of the test loads from 5.1, it is not necessary to repeat measurements in the middle but results from 5.1 could be utilised), the portion of the load transport system that is halfway between the center and the back, and repeated with the same test load using the portion of the load transport system that is halfway between the center and the front as shown in figure 5.2-1.

Figure 5.2-1: Positions of load for test of eccentricity.

In figure 5.2-1 *W* represents the width of the load transport system if there are no guides or width between guides where they exist.

The minimum number of consecutive test weighings shall be as specified in the following table:

Nominal mass *m* of the test load	Minimum number of repetitions
$m \leq 10$ kg	10
10 kg < $m \leq 20$ kg	6
20 kg < m	3

5.3 Auxiliary measurements

The following additional measurements or recordings are recommended, in particular where a calibration is intended to be performed with the lowest possible uncertainty.

The air temperature in reasonable vicinity to the instrument should be measured, at least once during the calibration. Where an instrument is used in a controlled environment, the span of the temperature variation should be noted, e.g. from a thermograph, from the settings of the control device etc.

Barometric pressure or, by default, the altitude above sea-level of the site may also be useful.

Special care should be taken to prevent excessive convection effects, by observing a limiting value for the temperature difference between the test loads and instrument, and/or recording an acclimatisation time that has been executed.

6 MEASUREMENT RESULTS

The procedures and formulae in the chapters 6 and 7 provide the basis for the evaluation of the results of the calibration tests and therefore require no further description on a calibration certificate. If the procedures and formulae used deviate from those given in the guide, additional information may need to be provided in the certificate.

It is not intended that all of the formulae, symbols and/or indices are used for presentation of the results in the calibration certificate.

The definition of an indication I as given in 4.4.1 is used in this section.

6.1 Repeatability

From the n indications I_{ij} for a given test load L_{Tj}, the standard deviation $s(I_j)$ is calculated

$$s(I_j) = \sqrt{\frac{1}{n-1}\sum_{1=1}^{n}\left(I_{ij} - \bar{I}_j\right)^2} \qquad (6.1\text{-}1)$$

with

$$\bar{I}_j = \frac{1}{n}\sum_{1=1}^{n} I_{ij}. \tag{6.1-2}$$

6.2 Errors of indication

For each test load L_{Tj}, the mean error of indication E_j is calculated as follows

$$E_j = \overline{I_j} - m_{ref,j} \tag{6.2-1}$$

where the mean of several readings, $\overline{I_j}$, is calculated as per (6.1-2) and $m_{ref,j}$ is the value obtained according to the section 4.5.

6.3 Effect of eccentric loading

For each tested band k of the load transport system, the average difference $\Delta I_{ecc,k}$ is calculated as follows:

$$\Delta I_{ecc,k} = \bar{I}_k - \bar{I}_m \tag{6.3-1}$$

$\bar{I}_k$ being the average of the indications of the test load L_{ecc} on k-th of the tested bands, k being 1 or 2, and $\bar{I}_m$ the average of the indications of the test load L_{ecc} in the middle of the load transport system.

7 UNCERTAINTY OF MEASUREMENT

In this and the following sections, there are uncertainty terms assigned to small corrections. For the quotient of such an uncertainty divided by the related value of mass or indication, the abbreviated notation u_{rel} will be used.

Example: let

$$u(\delta m_{corr}) = m \cdot u(corr) \tag{7-1}$$

with the dimensionless term $u(corr)$, then

$$u_{rel}(\delta m_{corr}) = u(corr) \tag{7-2}$$

Accordingly, the related variance will be denoted by $u_{rel}^2(\delta m_{corr})$ and the related expanded uncertainty by $U_{rel}(\delta m_{corr})$.

For the determination of uncertainty, second order terms have been considered negligible, but when first order contributions cancel out, second order contributions should be taken into account (see JCGM 101 [6], 9.3.2.6).

7.1 Standard uncertainty of the error

The basic formula for the calibration is

$$E = \bar{I} - m_{ref} \tag{7.1-1}$$

with standard uncertainty of the error

$$u(E) = \sqrt{u^2(\bar{I}) + u^2(m_{ref})} \tag{7.1-2}$$

All input quantities are considered to be uncorrelated, therefore covariances are not considered.

The terms are further expanded hereafter.

7.1.1 Standard uncertainty of the indication of the catchweigher

To account for sources of variability of the indication, (4.4.1-1) is amended by correction terms δI_{xx} as follows

$$\bar{I} = \bar{I}_{TL} + \delta I_{digTL} + \delta I_{rep} + \delta I_{ecc} \tag{7.1.1-1}$$

Further correction terms may be applied in special conditions (temperature effects, drift, hysteresis,..), which are not considered hereafter.

For the purpose of calibration of automatic catchweighing instrument, the load indications I_{TL} are not corrected for the no load indications I_0.

All these corrections have the expectation value zero. Their standard uncertainties are

7.1.1.1 δI_{digTL} accounts for the effect of the resolution of indication at load. Limits are $\pm d/2$ or $\pm d_T/2$ as applicable; rectangular distribution to be assumed, therefore

$$u(\delta I_{digTL}) = d/2\sqrt{3} \tag{7.1.1-2a}$$

or

$$u(\delta I_{digTL}) = d_T/2\sqrt{3} \tag{7.1.1-2b}$$

respectively.

Note: on a multi-interval instrument, d varies with I.

7.1.1.2 δI_{rep} accounts for the repeatability of the instrument; normal distribution is assumed, estimated as

$$u(\delta I_{rep}) = s(I_j)/\sqrt{n} \tag{7.1.1-3}$$

where $s(I_j)$ is determined in 6.1 and n is number of repeated weighings for the given test load.

$s(I_j)$ is determined for each given test load L_{Tj} and it is considered as representative only for the respective test load.

Note: For a standard deviation reported in a calibration certificate, it should be clear whether it is related to a single indication or to the mean of n indications.

7.1.1.3 δI_{ecc} accounts for the error due to off-centre position of the centre of gravity of a test load. This effect may occur where the instrument does not have guides to center the articles or where the guides are not suitable to this article. Where this effect can not be neglected, an estimate of its magnitude may be based on these assumptions:

- the average differences ΔI_{ecc} determined by (6.3-1) are proportional to the orthogonal distance of the load from the centre of the load receptor in respect of direction of travel of the load,
- the average differences ΔI_{ecc} determined by (6.3-1) are proportional to the value of the load,
- the effective centre of gravity of the test loads during the test for errors of indication and repeatability test is not further from the centre of the load receptor

than half the orthogonal distance between the load receptor centre and the eccentricity load positions in respect of direction of travel of the load (i.e. ¼ W), as per figure 5.2-1.

Based on the largest of the differences determined as per 6.3, δI_{ecc} is estimated to be

$$\delta I_{ecc} \leq I\left|\Delta I_{ecc,k}\right|_{max}/(2L_{ecc}) \tag{7.1.1-4}$$

Rectangular distribution is assumed, so the standard uncertainty is

$$u(\delta I_{ecc}) \leq I\left|\Delta I_{ecc,k}\right|_{max}/\left(2L_{ecc}\sqrt{3}\right) \tag{7.1.1-5}$$

or, in relative notation

$$u_{rel}(\delta I_{ecc}) \leq \left|\Delta I_{ecc,k}\right|_{max}/\left(2L_{ecc}\sqrt{3}\right) \tag{7.1.1-6}$$

7.1.1.4 The standard uncertainty of the indication is normally obtained by

$$u^2(\bar{I}) = d^2/12 + s^2\left(I_j\right)/n + u_{rel}^2(\delta I_{ecc})I^2 \tag{7.1.1-7}$$

Note 1: In general it is not expected that the uncertainty $u(I)$ is constant over the instrument's weiging range.

Note 2: The first term on the right hand side may have to be modified in special cases as mentioned in 7.1.1.1.

7.1.2 Standard uncertainty of the reference mass

Taken into account the content of table in Section 4.5, the following frequent cases are treated in this section:

A. Test load with calibration certificate
B. Test load calibrated on the control instrument
C. Test load weighed on the simultaneoulsy calibrated control instrument
D. Test load weighed on the previously calibrated control instrument
E. Test load weighed on the previously verified control instrument

In general, uncertainty of reference mass gets larger from procedure B to procedure E.

7.1.2.A Test load with calibration certificate

From (4.5-2) the reference value of mass is

$$m_{ref} = m_{cTL} + \delta m_B + \delta m_D + \delta m_{conv} \tag{7.1.2-1}$$

The corrections and their standard uncertainties are

7.1.2.1 m_{cTL} is the conventional mass of the test load given in the calibration certificate for the test load, together with the uncertainty of calibration U and the coverage factor k. The standard uncertainty is

$$u(m_{cTL}) = U/k \tag{7.1.2-2}$$

Where the test load has been calibrated to specified tolerances Tol, e.g. to the mpe given in OIML R111 [3], and where its nominal value m_N is used, rectangular distribution is assumed, therefore

$$u(m_{cTL}) = Tol/\sqrt{3} \tag{7.1.2-3}$$

Where a test load consists of more than one test piece, the standard uncertainties are summed arithmetically not by a sum of squares, to account for assumed correlation.

7.1.2.2 δm_B is the correction for air buoyancy as introduced in [2]. The value depends on the density of the test load ρ_{TL}, density of standard weights used for adjustment of the catchweigher ρ_s and air density at the time of calibration of the catchweigher ρ_a.

$$\delta m_B = -m_{cTL}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_{TL}} - \frac{1}{\rho_s}\right)\right] \tag{7.1.2-4}$$

with relative standard uncertainty

$$u_{rel}^2(\delta m_B) = u^2(\rho_a)(1/\rho_{TL} - 1/\rho_s)^2 + (\rho_a - \rho_0)^2 u^2(\rho_s)/\rho_s^4 + (\rho_a - \rho_0)^2 u^2(\rho_{TL})/\rho_{TL}^4 \tag{7.1.2-5}$$

As far as values for ρ_{TL}, $u(\rho_{TL})$, ρ_s, $u(\rho_s)$, ρ_a and $u(\rho_a)$, are known, these values should be used to determine $u_{rel}(\delta m_B)$.

The calibration certificate for test load needs to provide information about the density of the test load with uncertainty or the density ρ_{TL} (as well as the density ρ_s) and its standard uncertainty may be estimated according to the state of the art or based on information available. Appendix E1 in [2] offers internationally recognized values only for common materials used for standard weights.

The air density ρ_a and its standard uncertainty can be calculated from temperature and barometric pressure if available (the relative humidity being of minor influence), or may be estimated from the altitude above sea-level. Appendix A in [2] gives further information on air density calculation.

Only if the density of test load equals to that of a certain accuracy class of the standard OIML weights, recourse may be taken to section 10 of OIML R111 [3]. No correction is applied, and the relative uncertainties are:

If the instrument is adjusted immediately before the calibration

$$u_{rel}(\delta m_B) \approx mpe/\left(4m_N\sqrt{3}\right) \tag{7.1.2-6}$$

If the instrument is not adjusted before the calibration

$$u_{rel}(\delta m_B) \approx (0{,}1\rho_0/\rho_c + mpe/(4m_N))/\sqrt{3} \tag{7.1.2-7}$$

If some information can be assumed for the temperature variation at the location of the instrument, equation (7.1.2-7) can be substituted by:

$$u_{rel}(\delta m_B) \approx \sqrt{1{,}07 \cdot 10^{-4} + 1{,}33 \cdot 10^{-6} K^{-2} \Delta T^2 \cdot}\, \rho_0/\rho_c + mpe/\left(4m_N\sqrt{3}\right) \tag{7.1.2-8}$$

where ΔT is the maximum variation of environmental temperature that can be assumed for the location (see appendixes A2.2 and A3 in [2] for details).

7.1.2.3 δm_D corresponds to the possible drift of m_{cTL} since the last calibration. A limiting value D is best assumed, based on the difference in m_{cTL} evident from consecutive calibration certificates of the test load. D could be also estimated as the maximum allowed drift of the test load between its recalibrations, or the maximum drift expected in the medium term, when the calibration of test load has been performed for a particular use, but not immediately prior to the calibration of catchweigher.

It is not advised to apply a correction but to assume even distribution within $\pm D$ (rectangular distribution). The standard uncertainty is then

$$u(\delta m_D) = D/\sqrt{3} \qquad (7.1.2\text{-}9)$$

7.1.2.4 δm_{conv} corresponds to the convection effects. It is not advised to apply a correction but to assume an even distribution within $\pm\Delta m_{conv}$. The standard uncertainty is then

$$u(\delta m_{conv}) = \Delta m_{conv}/\sqrt{3} \qquad (7.1.2\text{-}10)$$

There are no studies available, which would give a simple elaboration of the convection effects for a general case. It appears that this effect is only relevant for uncertainties of calibration comparable to uncertainties for weights of class F_1 or better [2]. In such a case, a suitable temperature equilibrium need to be reached between the test load and surroundig air at loaction of calibration of the catchweigher.

7.1.2.5 When the test load with calibration certificate is used, the standard uncertainty of the reference mass is obtained from – cf. (7.1.2-1)

$$u^2(m_{ref}) = u^2(m_{cTL}) + u^2(\delta m_B) + u^2(\delta m_D) + u^2(\delta m_{conv}) \qquad (7.1.2\text{-}11)$$

with the contributions from 7.1.2.1 to 7.1.2.4.

7.1.2.B Test load calibrated on the control instrument

To account for sources of variability of the reference value of mass, when the test load is calibrated on the control instrument, (4.5-2) is amended by corrections terms δX_{xx} as follows

$$m_{ref} = m_{cR} + \delta m_{BTot} + \overline{\Delta m_c} + \delta m_{ba} + \delta m_D + \delta m_{conv} \qquad (7.1.2\text{-}12)$$

7.1.2.6 m_{cR} is the conventional mass of the standard weights used for calibration of the test load on the control instrument. Its standard uncertainty $u(m_{cR})$ should be evaluated according to Section C.6.2 of OIML R111 [3].

7.1.2.7 δm_{BTot} is the correction for air buoyancy as introduced in 4.5.2, equation (4.5.2-3). The value depends on the density ρ_R of the standard weights used for calibration of the test load on the control instrument, density ρ_s of standard weights used for adjustment of the catchweigher and air density ρ_a at the time of calibration of the catchweigher.

$$\delta m_{BTot} = -m_{cR}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_R} - \frac{1}{\rho_s}\right)\right]$$

Where a simple comparison of expected values of δm_{BTot} with the resolution of the instrument d shows that the air buoyancy correction is small enough, a more elaborate calculation of the correction and its uncertainty component based on actual data may be superfluous. Consequently, no correction is applied, i.e. δm_{BTot}=0. If conformity of the standard weights used for adjustment of the catchweigher and calibration of the test load to OIML R111 [3] is established and if the catchweigher is not adjusted before the calibration, the relative uncertainty is evaluated in the same way as in (7.1.2-7)

$$u_{rel}(\delta m_{BTot}) \approx (0{,}1\,\rho_0/\rho_c + mpe/(4m_N))/\sqrt{3}$$

For smaller uncertainties, e.g. if air buoyancy correction is taken into account according to (4.5.2-3) or the catchweigher is adjusted immediately before calibration, the standard uncertainties could be evaluated according Section 7.1.2.1 of cg-18 [2].

7.1.2.8 $\overline{\Delta m_c}$ is the corrected measured difference between the test load and standard weights as introduced in 4.3.1, equation (4.3.1-3). Its standard uncertainty $u(\overline{\Delta m_c})$ should be evaluated according to Section C.6.1 of OIML R111 [3].

7.1.2.9 δm_{ba} corresponds to the influences of the control instrument used for calibration of the test load. No corrections are apllied and their standard uncertainties $u(\delta m_{ba})$ should be evaluated according to Section C.6.4 of OIML R111 [3].

7.1.2.10 δm_D corresponds to the drift of the test load. Since the test load is calibrated at the time of calibration of the catchweigher, it is with negligible uncertainty, $\delta m_D \approx 0$, assumed that no correction is necessary.

7.1.2.11 δm_{conv} corresponds to the to the convection effects. If the test load is calibrated at the time and place of calibration of the catchweigher and if the test loads are kept at the temperature conditions prevailed during the calibration for longer time before the calibration, it is with negligible uncertainty, $\delta m_{conv} \approx 0$, assumed that no correction is necessary.

7.1.2.12 When the test load calibrated on the control instrument is used, the standard uncertainty of the reference mass is obtained from – cf. (7.1.2-12)

$$u^2(m_{ref}) = u^2(m_{cTL}) + u^2(\delta m_B) + u^2(\overline{\Delta m_c}) + u^2(\delta m_{ba}) \qquad (7.1.2\text{-}13)$$

with the contributions from 7.1.2.6 to 7.1.2.9.

7.1.2.C Test load weighed on the simultaneoulsy calibrated control instrument

To account for sources of variability of the reference value of mass when the test load is determined by weighing on the control instrument, which was calibrated immediately before the weighing took place, (4.5-2) is amended by corrections terms δX_{xx} as follows

$$m_{ref} = R_{CI} - I_{CI} + m_{CalCI} + \delta m_{BTot} + \delta m_D + \delta m_{conv} \qquad (7.1.2\text{-}14)$$

The first three terms (R_{CI}, I_{CI} and m_{CalCI}) of the right hand side of (7.1.2-16) are further amended by correction terms

(7.1.2-15)

$$\begin{aligned} m_{ref} = &\left(R_{LCI} + \delta R_{digLCI} + \delta R_{repCI} + \delta R_{eccCI} - (R_{0CI} + \delta R_{0CI})\right) \\ &- \left(I_{LCI} + \delta I_{digLCI} + \delta I_{repCI} + \delta I_{eccCI} - \left(I_{0CI} + \delta I_{dig0CI}\right)\right) \\ &+ (m_{NCalCI} + \delta m_{cCalCI} + \delta m_{DCalCI} + \delta m_{convCalCI}) + \delta m_{BTot} + \delta m_D \\ &+ \delta m_{conv} \end{aligned}$$

7.1.2.13 R_{CI} is the reading of the test load on the control instrument. Its standard uncertainty $u(R_{CI})$ should be evaluated according to Section 7.4.1 of cg-18 [2].

7.1.2.14 I_{CI} is indication of the standard weights on the control instrument. Its standard uncertainty $u(I_{CI})$ should be evaluated according to Section 7.1.1 of cg-18 [2].

7.1.2.15 m_{CalCI} is the reference mass value of standard weights used for calibration of the control instrument, without taking into account the correction term for air buoyancy. Its standard uncertainty $u(m_{CalCI})$ should be evaluated according to Section 7.1.2 of cg-18 [2], but not taking into account the standard uncertainty of the air bouyancy correction. The standard uncertainty of the air bouyancy correction is treated separately according the following paragraph.

7.1.2.16 δm_{BTot} is the correction for air buoyancy as introduced in 4.5.3, equation (4.5.3-4). The value depends on the density ρ_{CalCI} of the standard weights used for calibration of the test load on the control instrument, density ρ_s of standard weights used for adjustment of the catchweigher and air density ρ_a at the time of calibration of the catchweigher.

$$\delta m_{BTot} = -m_{cCalCI}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_{CalCI}} - \frac{1}{\rho_s}\right)\right]$$

Where a simple comparison of expected values of δm_{BTot} with the resolution of the instrument d shows that the air buoyancy correction is small enough, a more elaborate calculation of the correction and its uncertainty component based on actual data may be superfluous. Consequently, no correction is applied, i.e. δm_{BTot}=0. If conformity of the standard weights used for adjustment of the catchweigher and calibration of the test load on the control instrument to OIML R111 [3] is established and if the catchweigher is not adjusted before calibration, the relative uncertainty is evaluated in the same way as in (7.1.2-7)

$$u_{rel}(\delta m_{BTot}) \approx (0{,}1\,\rho_0/\rho_c + mpe/(4m_N))/\sqrt{3}$$

For smaller uncertainties, e.g. if air buoyancy correction is taken into account according to (4.5.3-4) or catchweigher is adjusted immediately before calibration, the standard uncertainties could be evaluated according Section 7.1.2.1 of cg-18 [2].

7.1.2.17 δm_D corresponds to the drift of the test load. Since the test load is calibrated at the time of calibration of the catchweigher, it is with negligible uncertainty, $\delta m_D \approx 0$, assumed that no correction is necessary.

7.1.2.18 δm_{conv} corresponds to the to the convection effects. If the test load is calibrated at the time and place of calibration of the catchweigher and if the test loads are kept at the temperature conditions prevailed during the calibration for longer time before the calibration, it is with negligible uncertainty, $\delta m_{conv} \approx 0$, assumed that no correction is necessary.

7.1.2.19 When the test load load weighed on the simultaneulsy calibrated control instrument is used, the standard uncertainty of the reference mass is obtained from – cf. 7.1.2.C

$$u^2(m_{ref}) = u^2(R_{CI}) + u^2(I_{CI}) + u^2(m_{CalCI}) + u^2(\delta m_{BTot}) \qquad (7.1.2\text{-}16)$$

with the contributions from 7.1.2.13 to 7.1.2.16.

7.1.2.D Test load weighed on the previously calibrated control instrument

To account for sources of variability of the reference value of mass when the test load is determined by weighing on the control instrument, which was calibrated previously and separately from the weighing of test load, (4.5-2) is amended by corrections terms δX_{xx} as follows

$$m_{ref} = W_{CI} + \delta m_{BTot} + \delta m_D + \delta m_{conv} \qquad (7.1.2\text{-}17)$$

7.1.2.20 W_{CI} is the weighing result of the control intrument. W_{CI} is determined according to Section 4.5.4. Its standard uncertainty $u(W_{CI})$ should be evaluated according to Sections 7.4.5 or 7.5.2 of cg-18 [2] for a case when errors of the control instrument are accounted by correction or included in a "global" uncertainty $U_{gl}(W_{CI})$, respectively.

According to cg-18 [2], standard uncertainty for the weighing result under conditions of the calibration $u(W_{CI}^*)$ could be used instead of $u(W_{CI})$ if the control instrument was calibrated right before its use. Similar can be assumed if the control instrument was adjusted right before its use and uncertainty contributions resulting from the opration of the control instrument (as defined in Section 7.4.4 of cg-18 [2]) are negligable.

The control instruments needs to have the calibration certificate. If the certificate states uncertainty of the instrument in use, this is non-acredited value. The laboratory needs to independently evaluate uncertainty in use based on actual conditions valid in a period since the last calibration of control instrument.

7.1.2.21 δm_{BTot} is the correction for air buoyancy as introduced in 4.5.4, equation (4.5.4-5). The value depends on the density ρ_{sCI} of the standard weights used for adjustment of the catchweigher, density ρ_s of standard weights used for adjustment of the catchweigher and air density ρ_a at the time of calibration of the catchweigher.

$$\delta m_{BTot} = -m_{cR}\left[(\rho_a - \rho_0)\left(\frac{1}{\rho_{sCI}} - \frac{1}{\rho_s}\right)\right]$$

Where a simple comparison of expected values of δm_{BTot} with the resolution of the instrument d shows that the air buoyancy correction is small enough, a more elaborate calculation of the correction and its uncertainty component based on actual data may be superfluous. Consequently, no correction is applied, i.e. δm_{BTot}=0. Where conformity of the standard weights used for adjustment of the catchweigher and control instrument to OIML R111 [3] is established and if the catchweigher is not adjusted before calibration, the relative uncertainty is evaluated in the same way as in (7.1.2-7)

$$u_{rel}(\delta m_{BTot}) \approx (0{,}1\,\rho_0/\rho_c + mpe/(4m_N))/\sqrt{3}$$

For smaller uncertainties, e.g. if air buoyancy correction is taken into account according to (4.5.4-5) or catchweigher is adjusted immediately before calibration, the standard uncertainties could be evaluated according Section 7.1.2.1 of cg-18 [2].

7.1.2.22 δm_D corresponds to the drift of the test load. Since the test load is calibrated at the time of calibration of the catchweigher, it is with negligible uncertainty, $\delta m_D \approx 0$, assumed that no correction is necessary.

7.1.2.23 δm_{conv} corresponds to the to the convection effects. If the test load is calibrated at the time and place of calibration of the catchweigher and if the test loads are kept at the temperature conditions prevailed during the calibration for longer time before the calibration, it is with negligible uncertainty, $\delta m_{conv} \approx 0$, assumed that no correction is necessary.

7.1.2.24 When the test load load weighed on the previously calibrated control instrument is used, the standard uncertainty of the reference mass is obtained from – cf. (7.1.2-17)

$$u^2(m_{ref}) = u^2(W_{CI}) + u^2(\delta m_{BTot}) \qquad (7.1.2\text{-}18)$$

with the contributions from 7.1.2.20 and to 7.1.2.21.

7.1.2.E Test load weighed on the previously verified control instrument

To account for sources of variability of the reference value of mass when the test load is determined by weighing on the control instrument, which was verified previously and separately from the weighing of test load, (4.5-2) is amended by corrections terms δX_{xx} in the same was as in Section 7.1.2.D, (7.1.2-17):

$$m_{ref} = W_{CI} + \delta m_{BTot} + \delta m_D + \delta m_{conv}$$

7.1.2.25 W_{CI} is the weighing result of the control intrument. W_{CI} is determined according to Section 4.5.5. Its standard uncertainty $u(W_{CI})$ should be evaluated according to Section 7.5.2 of cg-18 [2] for a case when errors of the control instrument are included in a "global" uncertainty $U_{gl}(W)$. In general, errors of the control instrument are not know, but durinq the verificiation they were smaller or equal to the maximum permissible error of the weighing instrument mpe_{R76}[7,8]. It can be assumed that errors of the control instrument are evenly distributed in the range defined by mpe_{R76}.

The stadard global uncertainty of the verified control instrument $u_{gl}(W_{CI})$ can be estimated by:

$$u_{gl}^2(W_{CI}) = u^2(W_{CI}) + \left(\frac{mpe_{R76}}{\sqrt{3}}\right)^2 \tag{7.1.2-19}$$

with

$$u(W_{CI}) = \sqrt{u^2(W_{CI}^*) + u^2(\delta R_{inst}) + u^2(\delta R_{proc})} \tag{7.1.2-20}$$

$$u^2(W_{CI}^*) = u^2(E) + u^2(\delta R_{dig0}) + u^2(\delta R_{digL}) + u^2(\delta R_{rep}) + u^2(\delta R_{ecc}) \tag{7.1.2-21}$$

$$u^2(\delta R_{inst}) = u^2(\delta R_{temp}) + u^2(\delta R_{bouy}) + u^2(\delta R_{adj}) \tag{7.1.2-22}$$

$$u^2(\delta R_{proc}) = u^2(\delta R_{Tare}) + u^2(\delta R_{time}) + u^2(\delta R_{ecc}) \tag{7.1.2-23}$$

Approximate relation between standard uncertainties of above mentioned influencing parameters and mpe_{R76} is summarised in the table below.

$u(W_{CI}^*)$	$u(E)$	$u(\delta I_{dig0})$	$d/(2\sqrt{3})$, $d \le e/5 \cong mpe_{R76}/(10\sqrt{3}) \cong 0$
		$u(\delta I_{digL})$	$d/(2\sqrt{3})$, $d \le e/5 \cong mpe_{R76}/(10\sqrt{3}) \cong 0$
		$u(\delta I_{rep})$	$mpe_{R76}/(2\sqrt{3})$
		$u(\delta I_{ecc})$	0
		$u(\delta m_c)$	$(mpe_{R76}/3)/\sqrt{3}$
		$u(\delta m_B)$	$(0{,}000015/\sqrt{3})R + (mpe_{R76}/3)/(4\sqrt{3})$
			for class (II), 20.000 e: R=20.000 mpe
			$0{,}3mpe_{R76}/\sqrt{3} + (mpe_{R76}/3)/(4\sqrt{3}) \le mpe_{R76}/5$
		$u(\delta m_D)$	$(mpe_{R76}/3)/\sqrt{3}$
		$u(\delta m_{conv})$	0
	$u(\delta R_{dig0})$		$d/(2\sqrt{3}) \le mpe_{R76}/(4\sqrt{3})$
	$u(\delta R_{digL})$		$d/(2\sqrt{3}) \le mpe_{R76}/(2\sqrt{3})$
	$u(\delta R_{rep})$		$mpe_{R76}/(2\sqrt{3})$
	$u(\delta R_{ecc})$		$mpe_{R76}/(2\sqrt{3})$
$u(\delta R_{inst})$	$u(\delta R_{temp})$		$mpe_{R76}/\sqrt{12}$
	$u(\delta R_{bouy})$		$(0{,}000015/\sqrt{3})R$
			for class (II), 20.000 e: R=20.000 mpe
			$0{,}3mpe_{R76}/\sqrt{3} \le mpe_{R76}/5$
	$u(\delta R_{adj})$		$mpe_{R76}/\sqrt{3}$
	$u(\delta R_{Tare})$		0

$u(\delta R_{proc})$	$u(\delta R_{time})$	0
	$u(\delta R_{ecc})$	evaluated and taken into account above

$$u_{gl}(W_{CI}) = \sqrt{mpe_{R76}{}^2 + \left(\frac{mpe_{R76}}{\sqrt{3}}\right)^2} \cong 1{,}15 mpe_{R76} \tag{7.1.2-24}$$

7.1.2.26 When the test load load weighed on the previously verified control instrument is used, the standard uncertainty of the reference mass is obtained from

$$u^2(m_{ref}) = u_{gl}^2(W_{CI}) + u^2(\delta m_{BTot}) \tag{7.1.2-25}$$

with the contributions from 7.1.2.25 and to 7.1.2.21.

7.2 Expanded uncertainty at calibration

The expanded uncertainty of the error $U(E)$ is

$$U(E) = ku(E) \tag{7.2-1}$$

where standard uncertainty of the error $u(E)$ is defined by (7.1-2) and k is the coverage factor.

The coverage factor $k = 2$ is chosen such that the expanded uncertainty corresponds to a coverage probability of 95,45 %.

8 REFERENCES

[1] *OIML R 51-1: Automatic catchweighing instruments. Part 1: Metrological and technical requirements – Tests*, Edition 2006 (E)

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[3] *OIML R111, Weights of Classes E1, E2, F1, F2, M1, M1-2, M2, M2-3, M3,* Edition 2004 (E)

[4] *Welmec 2, Directive 2009/23/EC: Common application non-automatic weighing instruments*, 2015

[5] *OIML D 28: Conventional value of the result of weighing in air*, Edition 2004 (E)

[6] *JCGM 101:2008, Evaluation of Measurement Data – Supplement 1 to the "Guide to the expression of uncertainty in measurement" – Propagation of Distributions using a Monte Carlo method,* 1st edition, 2008

[7] *OIML R 761-1: Non-automatic weighing instruments. Part 1: Metrological and technical requirements – Tests*, Edition 2006 (E)

[8] EN 45501:2015 Metrological aspects of non-automatic weighing instruments