Guidelines on the Calibration of Automatic Instruments for Weighing Road Vehicles in Motion and Measuring Axle Loads

AWICal WIM Guide

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1 INTRODUCTION

Automatic instruments for weighing road vehicles in motion [1], hereinafter referred to as “WIM instruments” these are the bridging measuring instruments widely used to determine the, the axle loads, if applicable the axle-group and vehicle mass of road vehicles when the vehicles are weighed in motion. For WIM there may be a growing need to have their metrological quality confirmed by calibration, e.g. where required by EN ISO 9001 or EN ISO/IEC 17025 standards.

2 SCOPE

This document contains guidance for the calibration of WIM instruments, in particular for:

1. measuring equipment and the 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 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 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.
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 vehicles that represent various vehicle types usually weighed in the place of application.

The procedure may further include rules how to derive from the results advice to the user of the instrument with regard to the errors, and assigned uncertainty of measurement, of indications which may occur under normal conditions of use 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 WIM instruments,
2. laboratories accredited for the calibration of WIM instruments,
3. manufacturers and other users using calibrated WIM 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

a) OIML R 76-1 (or EN ISO/IEC 45501) for terms related to the functioning, to the construction, and to the metrological characterization of non-automatic weighing instruments,

b) OIML R 134 [1] for terms related to the operation, construction and metrological characterization of WIM instruments,

c) 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.

4 GENERAL ASPECTS OF THE CALIBRATION

4.1 Elements of the calibration

Calibration consists of:

a) applying test loads to the instrument under specified conditions,

b) determining the total weight and axle load of control vehicles constituting the test load,

c) determining the indication errors of WIM instrument,

d) evaluating the uncertainty of measurement to be attributed to the results.

4.2 Weighing range

Unless requested otherwise by the client the weighing range is given by the values Max and Min, and must conform to the values listed in Table 1.

Table 1 – Weighing range

Weighing range	*Min* [kg]	*Max* [kg]
Axle load	1000	20000
Vehicle mass	3500	≤ 48000 or as specified by special legislation

4.3 Place of calibration

Calibration of the complete WIM instrument is performed in the conditions of its use in a location agreed with the client.

Before the application of the test procedure, extreme caution and safety in the dock entrance road and the weighing area should be guaranteed and provided.

4.4 Preconditions

The calibration should be done under normal conditions of use (air currents, vibrations, stability of the weighing site, normal configuration, in the temperature range specified by the producer etc.) of the instrument.
The calibration may be perform if:

a) the instrument can be readily identified,

b) all functions of the instrument are free from effects of contamination or damage, and functions essential for the calibration operate as intended,

c) presentation of weight values is unambiguous and indications, where given, are easily readable, 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,

d) the instrument is levelled, if applicable.

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.

4.5 Measuring equipment

4.5.1. Basic informations

For a complete test of a WIM instrument at the point of installation the following aspects shall be considered and applied before testing::

a) use a standard weights that are traceable to the SI unit of mass should be used. Weights that comply with the relevant specifications of [3] are assumed to be appropriate. The appropriate class of accuracy depends on the indication of the WIM system working on NAWI mode (scale interval d) to determine the Ax_{ref} and the needs of the client with regard to the uncertainty of the calibration of the instrument,

b) a set of additional weights (10 pcs.) weighing each $0.1d$ (as described in [4] point A.4.4.3), if the meter device does not have the possibility of extending the digit d, where necessary or if applicable,

c) the relevant vehicles should be available and represent the various types, which are normally used with consideration of the client's needs,

d) if not otherwise requested by the client, the set of vehicles needs to represent:

   – a rigit 2-axle vehicle and

   other vehicles, preferably where necessary adapted to allocate weight. The set of other vehicle may include

   – 3- or 4-axle,
   – 5- or 6-axle articulated 3-axle semi-trailer,
   – 2- or 3-axle and 2- or 3-axle trailer towed.

   Vehicles should be loaded by weights to the appropriate useful reference mass a value close to the maximum load calibrated WIM used by the customer or to the load most recently used by a customer. Should be described in the certificate the kinds of used vehicles.

e) the type and mass of vehicle on customer request may be given in the calibration certificate as additional information,

f) the mass of the vehicle should be constant during the calibration,

g) control NAWI, hereinafter referred to "separate NAWI", which is used to determine the static total weight VM_{ref} of 2-axle and multi-axle vehicle,

h) a substitution material (ballast) shall be available, which can be used for the study of static and dynamic weight of the absence of sufficient mass standards. A change in mass (due to the material characteristics of the ballast) should be avoided during the calibration,

i) measuring instruments for monitoring environmental conditions (such as temperature measuring instruments).

4.5.2. Requirements for control NAWI

The control NAWI is used to determine the total weight of the control vehicle used during the calibration of the WIM instrument.

The control NAWI should be calibrated by a calibration laboratory competent for NAWI calibration using appropriate mass standards, and if not owned laboratory should be calibrated before use. The scope of the calibration should cover the load corresponding to all control vehicles used in the calibration process and ballast (if used).

5. MEASUREMENT METHODS

5.1 Basic information

Meaning of symbols used is as follows:

Ax_i	–	value of the mass of the control vehicle axle load during the biaxial static weighing
VM_{ref}	–	value of the total reference mass of the control biaxial vehicle obtained by weighing the vehicle on control NAWI
VM_i	–	value of the total mass of the control biaxial vehicle
Ax_{ref}	–	the value of the load reference axis of the control vehicle during the weighing on the static mode
E_{Axi}	–	error of the value of the mass of the control vehicle axle load during the biaxial WIM weighing
E_{VMi}	–	error of the value of the total mass of the control vehicle during biaxial WIM weighing
Ax_j	–	value of the mass of a single axle load control vehicle other than a two-axis during the WIM weighing
Gr_g	–	value of the mass of a multiple axis load of the vehicle during the WIM weighing
VM_n	–	value of the total mass of the control vehicle other than biaxial obtained by the WIM weighing
$Corr\,\overline{Ax}_j$	–	corrected value of the axle load obtained by multiplying the average mass of a single axle load of control vehicle other than a two-axis by the correction factor k
$Corr\,\overline{Gr}_g$	–	corrected value of the axle load obtained by multiplying the average mass of multiple axis load of control vehicle other than a two-axis by the correction factor k
EAx_j	–	error of the value of the load of a single-axis of the control vehicle other than a two-axis during the WIM weighing
EGr_g	–	error of the value of the load of a multiple axis of the control vehicle other than a two-axis during the WIM weighing
E_{VMn}	–	error of the value of the total mass of the control vehicle other than a two-axis during the WIM weighing

Calibration of the complete WIM instrument include:

- Checking how to install, signs and security in the dock entrance road and the weighing area.
- Static load test to determine the axle load Ax_{ref} of the control vehicle - if the scale is calibrated in such a function and the importance of working as a function of the static weighing it will be used as a internal control instrument.
- Test dynamic mode (dynamic loads).

5.2 Determining the error of indications when operating the WIM instrument as non-automatic weighing instrument (using mass standards)

Calibration of the WIM instrument as NAWI to determining static axle load of the control vehicle can be carried out in accordance with the EURAMET Calibration Guide No. 18: *Guidelines on the Calibration of Non-Automatic Weighing Instruments* [2]. Load range of calibration should correspond to the estimated axle load of the control vehicle.

5.3 Determining the axle load Ax_{ref} of control vehicle

a) The mass Ax_{refi} determined two axle vehicle i = 2:

b) Perform at least 10 load static measurements of Ax_i for the setting direction of the vehicle.

c) loads shall be determined in practice, at least two different loads: vehicle unloaded and the most loaded with standard weights or ballast.

d) Calculates the average value Ax_i for each axis of a 2-axle vehicle representing the value Ax_{ref}

$$Ax_{refi} = A\overline{x}_i = \frac{\sum_{1}^{10} Ax_i}{10} \tag{5.3-1}$$

e) Calculated the total mass of the vehicle VM_i:

$$VM_i = \overline{VM}_i = \sum A\overline{x}_i \tag{5.3-2}$$

5.4 Method of calibration the WIM instrument of the dynamic loading

a) A complete WIM instrument is checked using control vehicle and other measuring equipment at rated operating conditions of WIM instrument, according to its characteristics.

b) The mass of control vehicle should be such that it can be as close as possible to the maximum measuring range of the WIM instrument. The mass of control vehicle may be less adapted to customer needs. This should be agreed before starting the measuring procedure.

c) Vehicles carrying liquids or other materials, which means harder-bones moves during the weighing may be used as a control vehicle only in duly substantiated cases (eg. customer needing, special application of WIM instrument).

d) Speed of vehicles while checking should be fixed, without acceleration and braking, and should include the full speed range, including the minimum speed V_{min}, and the speed of a typical usable of WIM instrument. If necessary (eg. according to the customer needing), the speed can be different(higher or lower than V_{max}), but only with the acceptance of the customer and printing such information on the calibration certificate.

e) For each of vehicle control, and for each set of the weight and speed and specified driving directions (with customer consent) as in point. d, takes at least n = 5 passages:

- 3 runs down over the center of the load receptor,
- 1 ride left side of the load receptor,
- 1 ride right side of the load receptor.

f) The change in mass of control vehicles (eg. fuel consumption) on the route of the control instrument to the tested WIM instrument is adjusted if has a significant influence on the result, eg. after completion of series trips a given vehicle type.

6 MEASUREMENT RESULTS

6.1 Test of WIM instrument with 2-axles control vehicle dynamic loading

a) The measurement shall be performed in accordance with paragraph 5.4.

b) Determines the error of axle E_{Axi} and vehicle total mass E_{VMi} from every passage of the individual vehicle and:

$$E_{Axi} = Ax_i - Ax_{refi} \tag{6.1-1}$$

$$E_{VMi} = VM_i - VM_{ref} \tag{6.1-2}$$

6.2 Test of WIM instrument with dynamic loading using the vehicle on the number of axes greater than 2

a) Determines the mass of the control vehicle VM_{ref} using separately control instrument.

b) The measurement with the dynamic load is carried out in accordance with paragraph 5.4.

c) Determines the average axle load of each j[th] axle $\overline{Ax}_j$ and g[th] multi-axles $\overline{Gr}_g$ of the vehicle for trip series and the total mass of the vehicle VM_n and average total mass of the vehicle for trip series $\overline{VM}_n$:

$$\overline{Ax}_j = \sum_1^j \frac{Ax_j}{5} \tag{6.2-1}$$

$$\overline{Gr}_g = \sum_1^g \frac{Gr_g}{5} \tag{6.2-2}$$

$$VM_n = \sum_1^j Ax_j + \sum_1^g Gr_g \quad \text{when } n \text{ – number of axles} \tag{6.2-3}$$

$$\overline{VM}_n = \sum \frac{VM_n}{5} \tag{6.2-4}$$

d) Sets a correction factor k:

$$k = \frac{VM_{ref}}{\overline{VM}_n} \tag{6.2-5}$$

e) Calculate the average value of corrected axle load $Corr\overline{Ax}_j$ and multi-axes $Corr\overline{Gr}_g$:

$$Corr\overline{Ax}_j = k \cdot \overline{Ax}_j \tag{6.2-6}$$

$$Corr\overline{Gr}_g = k \cdot \overline{Gr}_g \tag{6.2-7}$$

f) Determines the error of every axle load EAx_j and multi-axes $EGr_g$the axis of the corrected axle load $\mathrm{Corr}Ax_j$ and multi-axes $\mathrm{Corr}\ Gr_g$:

$$EAx_j = Ax_j - Corr\overline{Ax}_j \tag{6.2-8}$$

$$EGr_g = Gr_g - Corr\overline{Gr}_g \tag{6.2-9}$$

g) Determines the error of control vehicle mass E_{VMn} of each 5th driving trip:

$$E_{VMn} = VM_n - VM_{ref} \tag{6.2-10}$$

7 UNCERTAINTY BUDGET

7.1 Standard uncertainty of discrete values

General equation for error calculation is:

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

Where I is the value indicated by the instrument in the certain entity (gross mass or axle load) m_{ref} is reference load.

Variances are:

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

In case of automatic weighing instruments, m_{ref} is replaced by a value of control instrument.

E represents an error calculated from above values.

$$E = I - R_K \tag{7.1-2}$$

where R_K is value from the control instrument and

$$R_K = I_K - E_K \tag{7.1-4}$$

where E_K is the error of the control instrument which means

$$E = I - (I_K - E_K) \tag{7.1-5}$$

Variances are:

$$u^2(E) = u^2(I) + u^2(R_K) \tag{7.1-6}$$

where $u(I)$ is the uncertainty of teh indication and
$u(R_K)$ is the uncertainty of the value from the control instrument

7.2 Standard uncertainty of indication

$$I = I_L + \delta I_{digL} + \delta I_{rep} - I_0 - \delta I_{dig0} \tag{7.2-1}$$

All these correction have expected value of zero. Their standard uncertainties are:

δI_{dig0} stands for the rounding error at zero loading

$$u(\delta I_{dig0}) = \frac{d_0}{2\sqrt{3}} \tag{7.2-2}$$

or

$$u(\delta I_{dig0}) = \frac{d_T}{2\sqrt{3}} \tag{7.2-3}$$

δI_{digL} stands for the rounding error of indication at a load

$$u(\delta I_{digL}) = \frac{d_I}{2\sqrt{3}} \tag{7.2-4}$$

or

$$u(\delta I_{digL}) = \frac{d_T}{2\sqrt{3}} \tag{7.2-5}$$

δI_{rep} stands for the error of repeatability

$$u(\delta I_{rep}) = s(I_j) \tag{7.2-6}$$

Standard deviation calculation is carried out form a series of calculated errors for each entity (gross mass or axle load).

7.3 Standard uncertainty of a value from the control instrument $u(R_K)$

$$u(R_K)^2 = u^2_{opak} + u^2_{d0} + u^2_{dI} + u^2_{EI} \tag{7.3-1}$$

where $u(R_K)$ is equal to the uncertainty of the instrument in use. The uncertainty of the control instrument value u_{EI} for the given load (the value is obtained from the control instrument calibration certificate) is expanded by an uncertainty of indication.

The value of the uncertainty taken from a calibration certificate is valid only for a control instrument intended for weighing the gross mass of a reference vehicle.

The uncertainty of a control instrument for weighing axle load shall be obtained as followes.

$$u_n^2 = (\frac{\text{mpe}}{\sqrt{3}})^2 + (0{,}005 \times I)^2 \tag{7.3-2}$$

where: mpe is the maximum permissible error for the given load in service;
0,005 is the value resulting from external effects;

I is the indication.

The individual results of measurement are considered to be as correlated quantities (coefficient: r = 1) and summing the uncertainties of individual axles shall be as follows:

$$u_C = u_1 + u_2 + \ldots + u_n$$

The expanded uncertainty:

$$U = 2 \times u_C$$

7.4 Combined standard uncertainty

$$u(E_I)^2 = u^2_{opak} + u^2_{d0} + u^2_{dI} + (u^2_{opak} + u^2_{d0} + u^2_{dI} + u^2_{EI} + u(m_T)^2) \qquad (7.4\text{-}1)$$

where items in brackets represent an uncertainty of the control instrument.

8. CALIBRATION CERTIFICATE

This section contains advice what information may be useful to be given in a calibration certificate. It is intended to be consistent with the requirements of ISO/IEC 17025 which take precedence.

8.1 General information

Identification of the calibration laboratory, reference to the accreditation (accreditation body, number of the accreditation), identification of the certificate (number, date of issue, number of pages), signature(s) of authorised person(s).

Identification of the client.

Identification of the calibrated automatic instruments for weighing road vehicles in motion, information about the instrument (manufacturer, type, serial number, weighing range, Max, d, v_{max}, A_{max}, restrictions of use (if any).

Warning that the certificate may be reproduced only in full unless the calibration laboratory permits otherwise in writing.

8.2 Information about the calibration procedure

Date of measurements (calibration),
site of calibration - place of installation,
conditions of environment and/or use that may affect the results of the calibration.

Information about the instrument operation for each measurement/test (adjustment performed, dynamic setting performed, setting of software as far as relevant for the calibration, speed of vehicle, minimum and maximum speed, zero settings, tare settings), any anomalies of functions, purpose of use of the instrument as far as relevant for the calibration etc..

Information if the indications were obtained as integer multiple of d_T.

Reference to, or description of the applied procedure for calibration of the instrument.

Reference to, or description of the applied procedure for determination of the reference mass of the test load(s).

Description of the test load(s) (e.g. number of axles, mass, vehicle type, vehicle ID-number plate, shape or other applicable information, including drawing or photo, if applicable).

Agreements with the client e.g. over metrological specifications to which conformity is declared.

Information about the traceability of the measuring results.

8.3 Results of measurement

Mean reference value of mass (total and by axles), mean value of indications and mean errors of indication for applied test loads, as discrete values; number of repetitions, for each measurement/test; speed of vehicle if relevant for the understanding of the above, standard deviation(s) determined, identified as related to the mean of indications, for each measurement/test; information about the eccentricity test (if applicable), indicating effect of eccentric loading, as well as position and direction of the vehicle, where the max eccentricity was determined, for each measurement/test; expanded uncertainty of measurement for the reported results.

Indication of the coverage factor, with comment on coverage probability.

Where the indications/errors have not been determined by normal readings - single readings with the normal resolution of the instrument - a warning should be given that the reported uncertainty is smaller than would be found with normal readings.

9 REFERENCES

[1] *OIML R 134-1: Automatic instruments for weighing road vehicles in motion and measuring axle loads. Part 1: Metrological and Technical Requirements – Tests,* Edition 2006 (E)

[2] *EURAMET Calibration Guide No. 18: Guidelines on the Calibration of Non-Automatic Weighing Instruments*, Version 4.0 (1/2015)

[3] *OIML R 111-1: Weights of classes E_1, E_2, F_1, F_2, M_1, M_{1-2}, M_2, M_{2-3} and M_3. Part 1: Metrological and Technical Requirements,* Edition 2004 (E)

[4] *OIML R 76-1: Non-automatic weighing instruments. Part 1: Metrological and Technical Requirements – Tests,* Edition 2006 (E)

APPENDIX A: EXAMPLE

A1 Automatic instrument for weighing road vehicles Max = 20 000 kg, d = 50 kg

Note: The example is demonstrated on the 2 Axle vehicle data.

A1.1 Conditions specific for the calibration

Instrument:	**Automatic instrument for weighing road vehicles**
Max	20 000 kg
Min	500 g
d	50 kg
d_T	5 kg
Installation	outside
Type designation/manufacturer	DFW
Last calibration	-
Temperature during calibration	25,0 °C to 29,0 °C
Barometric pressure during calibration:	1018 hPa ± 2 hPa
Test vehicle	2 axle vehicle
Control instrument	Separate simultaneously calibrated

A1.2 Tests and results

Reference values of the test vehicle	Reference value of Axle 1 = 1558,9 kg Reference value of Axle 2 = 1884,1 kg Vmref = 3443 kg VM = 3435,5 kg Corr = 1,002183
The error of axle E_{Axi} and vehicle total mass E_{VMi}	$Ax_{refi} = A\bar{x}_i = \frac{\sum_1^{10} Ax_i}{10}$ = 1550 kg $Ax_{refi} = A\bar{x}_i = \frac{\sum_1^{10} Ax_i}{10}$ = 1900 kg $E_{Axi} = Ax_i - Ax_{refi} = -8{,}9$ kg

	$E_{Axi} = Ax_i - Ax_{refi} = 15{,}9\ kg$ $E_{VMi} = VM_i - VM_{ref} = 7\ kg$
Eccentricity	$\delta I_{ecc} = 0\ kg$

A1.3 Uncertainty of measurements

Standard uncertainty of indication	$I = I_L + \delta I_{digL} + \delta I_{rep} - I_0 - \delta I_{dig0}$ $u(\delta I_{dig0}) = \frac{d_T}{2\sqrt{3}}$ = 1,4 kg $u(\delta I_{digL}) = \frac{d_T}{2\sqrt{3}}$ = 1,4 kg $u(\delta I_{rep}) = s(I_j) = 0$ kg u $(\delta I_{ecc}) = 0\ kg$ **u(I) = 2 kg**
Standard uncertainty of the control instrument	**u(R_K) = 5,5 kg**
Standard uncertainty of the error	**u(E) = 5,8 kg**
Expanded uncertainty at calibration	$U(E) = ku(E)$ $\boldsymbol{U(E)}$ = **11,7 kg** The coverage factor $k = 2$ is chosen such that the expanded uncertainty corresponds to a coverage probability of 95,45 %.

A1.4 Standard uncertainty of a weighing results

Standard uncertainty of weighing result	$u(\delta I_{dig0}) = \frac{d_0}{2\sqrt{3}}$ = 14,4 kg $u(\delta I_{digL}) = \frac{d_I}{2\sqrt{3}}$ = 14,4 kg $u(\delta I_{rep}) = s(I_j) = 0$ kg u $(\delta I_{ecc}) = 1{,}4\ kg$ **u(R) = 20,5 kg**
Standard uncertainty of reading in use	**u(R) = 20,5 kg**
Standard uncertainty of weighing result	**U(W) = 21,3 kg**
Expanded uncertainty of a weighing result	$\boldsymbol{U(W) = ku(W)}$**= 42,3 kg** The coverage factor $k = 2$