
Publishable Summary for 14RPT02 AWICaI

Traceable calibration of automatic weighing instruments operating in the dynamic mode

Overview

While non-automatic weighing instruments (NAWIs) are routinely calibrated by accredited calibration laboratories based on the Guidelines on the Calibration of Non-Automatic Weighing Instruments EURAMET/cg-18, the calibration of automatic weighing instruments (AWIs) was not as well defined and only little documented guidance was available. The project was focused on the development of reproducible calibration methods and measurement uncertainty evaluation models for different groups of AWIs, which operate in a dynamic mode. The project was also aimed to increase expertise among EURAMET members in the provision of reliable traceability of AWIs. The calibration guides developed for AWIs were submitted to EURAMET for further approval as EURAMET Calibration Guides. The guides will be directly used by calibration laboratories, which will assure traceability of measurements performed by AWIs operating in the dynamic mode.

Need

With the development of weighing technology, the number of AWIs, which carry out measurements in a dynamic mode, has increased. In the dynamic measurement mode of operation the instruments operate with a non-stable equilibrium based measuring system during the mass determining process while the load is in motion. Notwithstanding a generally higher purchase price than for Non-automatic Weighing Instruments (NAWIs), AWIs are more effective and efficient for their users in the long term. Improvements in the accuracy of AWIs mean that they are now used in an increasing number of applications from micro to macro weighing.

While NAWIs are routinely calibrated by accredited calibration laboratories according to EURAMET Calibration Guide cg-18, the calibration of AWIs is not as well defined, as there is a significant difference between the static measurement mode of operation of NAWIs and the dynamic measurement mode of operation, which is typical for the majority of AWI applications. There is also limited information about the uncertainties achievable using AWIs and little documented guidance available. There is therefore a need for validated reproducible calibration methods and measurement uncertainty evaluation models for different groups of AWIs operating in a dynamic measurement mode, this project focuses on three groups of AWIs: automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments.

In parallel, integration of emerging EURAMET member countries in the research and development of methods for the calibration of automatic weighing instruments operating in the dynamic mode is necessary to bridge an existing gap in the level of metrology expertise between EURAMET member countries. In particular countries with an association agreement with the EU need to develop their conformity assessment competence in order to support the implementation of the Measuring Instruments Directive (MID) and the Pre-packages Directive.

Objectives

The project has been focused on the development of reproducible calibration methods and measurement uncertainty evaluation models for different groups of automatic weighing instruments, which operate in a dynamic mode. The project has also been aimed to increase expertise among EURAMET members in the provision of reliable traceability of automatic weighing instruments.

The specific technical objectives of the project were to:

1. **Develop and validate appropriate measurement methods for the calibration of selected AWIs** (automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments). The results obtained using the new methods for calibration of AWIs operating in the dynamic mode will be compared with static weighing of objects. The relevant specific

content of a calibration certificate for calibration of an AWI will be defined. The reproducibility of methods developed will be confirmed by comparison of dynamic weighing measurements by the partners.

2. **Develop and validate error models for the dynamic weighing process** for these three groups of automatic weighing instruments and to determine the potential sources of measurement uncertainty for these instruments.
3. **Develop uncertainty budgets for the determination of the uncertainty of measurement for the calibration of AWIs and for the determination of the uncertainty of a weighing result.** The uncertainty budgets will be validated by comparisons and cross-checked with static methods.
4. **Develop 3 draft calibration guides for automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments** respectively and to submit them to EURAMET for approval either as three separate EURAMET Calibration Guides or as one combined Guide.
5. **Develop individual strategies for the long-term development of research capabilities in dynamic mass metrology** including priorities for collaborations with the research community in the partners' country, the establishment of appropriate quality schemes and accreditation (including participation in comparisons and submission of CMCs either to the KCDB or an accreditation body as appropriate). The internal funded partners will also develop a strategy for offering calibration services from established facilities to their own country and neighbouring countries. The individual strategies will be discussed within the consortium and with other EURAMET NMIs/DIs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Progress beyond the state of the art

The project developed calibration methods and uncertainty evaluation models for three categories of AWIs. These methods and models were validated via on-site tests at end-users/manufacturers. Draft calibration guides for the three categories of AWIs based on these calibration methods and uncertainty evaluation models were developed, providing the first guides available for these instruments/application.

The draft calibration guides for the three categories of AWIs will be directly used by calibration laboratories, which will assure traceability of measurements performed by AWIs operating in the dynamic mode. In addition the guides may serve as harmonised standard documents. The measurement uncertainty evaluation models will also be of benefit to the conformity decision process for AWIs used for legal metrology purposes, which are subject to the requirements of the MID. These draft calibration guides for automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments were submitted as three separate guides to EURAMET for further approval as EURAMET Calibration Guides.

The project increased metrology research capabilities and expertise of emerging EURAMET member countries in the provision of reliable traceability of dynamic mass measurements. This will also assist countries with an association agreement with the EU in developing their conformity assessment competence in order to support the implementation of the MID and the Pre-packages Directives.

Results

The project developed **three draft calibration guides for AWIs** (Objective 4), one guide for each instrument group respectively. The documents were submitted to EURAMET for subsequent approval and publication. For the selected groups of AWIs, i.e. for automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments, the structure of the guide is basically the same and comparable to that of EURAMET calibration guide for non-automatic weighing instruments. The guides contain measurement methods with calculation of the measuring results; error models for the dynamic weighing process; potential sources of measurement uncertainty and measurement uncertainty budgets for the determination of the uncertainty of measurement for the calibration of AWIs and for the determination of the uncertainty of weighing results; methods for determination of the reference value of mass of test loads; contents of the calibration certificates, and calibration examples. During their preparation, the draft guides were publically available at the project website www.awical.eu. The draft calibration guides were presented to a wider audience of technical experts from EURAMET TC-M NMIs/DIs and members of the Stakeholder Committee in April 2018 during EURAMET TC-M meeting in Dublin at AWICaI workshop. After submitting the

final version documents to EURAMET, the final versions are available at the project webpage, too. The project objectives to develop appropriate measurement methods, error models and uncertainty budgets for the dynamic weighing process, and to develop three draft calibration guides for automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments were fully achieved.

Based on a general validation plan for the **validation of developed calibration methods** (Objective 1), **error models** (Objective 2) and **uncertainty budgets** (Objective 3), and several additional proposals of what to include in the validation, instrument specific detailed validation plans and templates of validation reports were developed. The project partners have liaised with the collaborators and obtained confirmation from them that their AWI facilities are available for the on-site validation activities. All planned validation measurements have been executed by the partners. Based on reported results of validation, the validation reports and analyses were prepared. Outcomes of the validation were used to improve content of the draft calibration guides. The project objectives to validate error models for the dynamic weighing process for automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments and cross-checking them with static methods were fully achieved.

For the interlaboratory comparison of calibration of AWIs based on the draft calibration guides, the technical protocols were prepared and access to facilities with instruments ensured and agreed with the project collaborators. The comparison measurements for the automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments were carried out at three different locations. One instrument was provided by a producer Mettler Toledo Garvens, Germany, which were also the project partner. The other two instruments were provided by the project collaborators Tensovahy, Czech Republic, and Esit, Turkey. The planned comparison measurements were executed by the partners. Based on reported comparison results, the comparison reports and analyses were prepared. During the AWICaI workshop at EURAMET TC-M meeting in Dublin in April 2018, the intercomparison results for the select three groups of AWIs were presented and discussed by other partners and workshop participants. After that, agreed comparison reports for the interlaboratory comparisons were prepared. Outcomes of the intercomparisons were used also to improve content of the draft calibration guides. The project objectives to confirm reproducibility of methods and uncertainty budgets developed by comparison of dynamic weighing measurements by the partners were fully achieved.

As a result of the project, **individual strategies for each NMI partner for the long-term development of their research capability in dynamic mass metrology** (Objective 5) and a strategy for the provision of calibration services from established facilities in their own country and/or neighbouring or other countries were developed. Based on the agreed action plan the process of preparation of individual strategies involved also interviews with various national stakeholders. The strategies took into account requirements for international cooperation and smart specialisation, including priorities for collaborations with the research community in the partners' countries. The strategies aim at sustainability of the project achievements. The presentation of the research strategies took place in April 2018 during EURAMET TC-M in Dublin at AWICaI workshop. The workshop was well attended by the project partners and other experts from EURAMET TC-M NMIs/DIs and members of the Stakeholder Committee. The project objective to develop individual strategies of internal partners for the long-term development of research capabilities in dynamic mass metrology was fully achieved.

Impact

A Stakeholder Committee was established for the duration of the project. It consisted of 16 members representing end-users of AWIs, calibration laboratories in the field of weighing instruments, AWI manufacturers, and conformity assessment bodies of AWIs and legal metrology bodies. The committee has been regularly updated on the project progress. Some committee members have provided their comments of the draft calibration method, which are available on the project web page. During 2016 GUM carried out three training sessions for Polish stakeholders from industry and then in 2017 a further three training sessions for Polish end-users of WIM instruments. In January 2016, 2017 and 2018, PTB held a presentation about the project for national stakeholders from industry. In September 2016 CECIP and AWI producer representatives took part at the consortium meeting in Göttingen. Stakeholder forums were carried out also by MIRS, IMBiH and Metrosert during 2017, while other partners will organise similar activities during the end of the year. The project partners have closely cooperated with collaborators from industry, which provided access to automatic weighing instruments for the purpose of validation of developed calibration methods. During second half of

2017 and May 2018 also other project partners (MIRS, CMI, DMDM, TUBITAK and Metroser) organised and held national workshops at their locations. The outputs of the project were presented there including the draft calibration guides for AWIs. In addition, AWICaI workshop took place on 19 April 2018 during EURAMET TC-M in Dublin. The workshop was attended by the project partners and other experts from EURAMET TC-M NMIs/DIs and members of the Stakeholder Committee. Results of the AWI intercomparisons and draft guides were presented and discussed between the project partners and auditorium of mass experts.

The EURAMET TC-M was informed during its annual meetings in May 2016, April 2017 and April 2018 about the progress achieved in the project. The committee was further invited to be actively involved in the development of the calibration guides. The project was presented also at the COOMET annual mass group meeting in October 2016.

WELMEC WG2 considers and provides guidance on the MID with regard to AWIs to facilitate its implementation and WELMEC WG6 considers issues related to the EU prepacked product legislation. The partners involved in the WGs disseminated the outputs of the project results among the WG members. During the meetings of WELMEC WG2 in Bratislava, Slovakia in October 2015 and in Göttingen, Sweden in September 2016, the project was presented to the group by BEV and MIRS, respectively. CMI presented the project to WG6 in Paris in June 2016 and MIRS presented the final project results to WELMEC Committee meeting in Sarajevo in April 2018. Positive feedback on the project goals and results was received from all above mentioned WELMEC groups.

OIML recommendations R51, R61 and R134 define conformity assessment procedures of AWIs, and R51 and R61 are normative documents for the MID Directive. Their future revisions will need to implement the OIML Document on the measurement uncertainty in conformity assessment in legal metrology. In February 2016 the project partners BEV/PTP, GUM, CMI, DMDM and PTB were involved in a web discussion related to the revision of OIML R61 for automatic gravimetric filling instruments within the TC9/SC2 "Automatic weighing instruments". The involved project partners disseminating information about the project and its outputs to this group.

At XXI IMEKO World Congress in September 2015 PTB and MGRT presented challenges for the calibration of automatic weighing instruments in dynamic operation to a scientific and industrial audience. Three peer reviewed conference papers summarising the mid-term project results were presented at IMEKO TC3, TC5 and TC22 International Conference 2017 by MIRS and TUBITAK. MIRS gave a presentation about traceable calibration of AWIs at CIM2017 congress in September 2017. Another paper has been accepted for a presentation at IMEKO XXII Wold Congress in September 2018 and two papers about calibration methods for AWIs were published in OIML Bulletin in July 2018.

Impact on relevant standards

The EURAMET TC-M was briefed on the developments and results of the project during a May 2016 meeting in Budva, Montenegro, an April 2017 meeting in Espoo, Finland and an April 2018 meeting in Dublin, Ireland. Some members of EURAMET TC-M also provided their input to the draft guides. The final versions of calibration guides for automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments were finalised in May 2018 and submitted to EURAMET TC-M for further approvals as EURAMET Calibration Guides.

Impact on industrial and other user communities

The main stakeholder groups, which directly benefit from the outcomes of the project, are calibration laboratories, accreditation bodies, producers of AWIs and conformity assessment bodies.

- The validated calibration techniques, associated uncertainty formulation and new and harmonised calibration guides on AWIs developed by the project will be directly used by calibration laboratories, which will assure traceability of measurements performed by dynamically operated AWIs. Harmonised and traceable calibration based on accreditation is a basic requirement for mutual recognition of calibration results, offering a cost saving to European exporters. The recognised traceability of calibration results will also provide an important contribution to consumer protection.
- Accreditation bodies accrediting laboratories for the calibration of AWIs according to EN ISO/IEC 17025 and laboratories calibrating AWIs will benefit from the project outcomes as the calibration methods and

guides developed will assure harmonised methods for calibration of the instruments and harmonised accreditation scopes of commercial calibration laboratories across Europe.

- Manufacturers of AWIs cooperate closely with the end users of these instruments. The project will enable important improvements in the quality of information on the performance of three different categories of AWIs. With the information provided by an accredited calibration certificate, the producer will be able to better meet the requirements of their clients. This will provide increased reliability and confidence in the performance of instruments for the end-user community.
- The conformity assessment bodies for instruments covered by the MID are usually accredited according to EN ISO/IEC 17025 for the testing of AWIs within the type evaluation or verification procedure. The guides on the calibration of AWIs operating in the dynamic mode will provide harmonised uncertainty evaluation procedures, which will provide supporting information to those bodies with respect to the requirements of the standard related to uncertainty evaluation.

Until now, five companies (from Turkey, Croatia, Estonia, Germany and Slovenia) expressed their intention to implement one or two of calibration guides into practice and later ask for the accreditation of their laboratory in offering a calibration service (based on customer's demands).

During preparation of the research strategies it came clear that the calibration guides, developed by the project, would have their highest value when adopted as the EURAMET calibration guides. There exist a larger number of calibration laboratories, which will approach their partners, end users of AWIs, offering calibration of AWIs in the dynamic mode of operation, after the EURAMET calibration guides for AWIs are formally adopted.

Impact on the metrological and scientific communities

The project will have impact on development of Calibration and Measurement Capabilities (CMCs) of laboratories which calibrate AWIs, through the provision of harmonised calibration methods. The accredited CMCs are proof of competence of calibration laboratories and the guide will ensure harmonised accreditation scopes among calibration laboratories and accreditation bodies.

Longer-term economic, social and environmental impacts

The individual strategies developed by the partners for the long-term development of their research capability in dynamic mass metrology were discussed within the consortium and with other EURAMET NMIs/DIs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole. The strategies aim at sustainability of the project achievements. The presentation of the research strategies took place in April 2018 during EURAMET TC-M in Dublin at AWICal workshop. The strategies are published on the project website.

List of publications

1. O Mack, T Klein, C Schlegel, M Grum, *Challenges for the calibration of automatic weighing instruments in dynamic operation*, Proceedings of XXI IMEKO World Congress, 2015
2. M Grum, G Grgić, *Test Load Reference Mass Value for AWI Calibration*, Proceedings of IMEKO TC3, TC5 and TC22 International Conference 2017
3. M Grum, G Grgić, *Two Model Functions for Calibration of Automatic Gravimetric Filling Instruments*, Proceedings of IMEKO TC3, TC5 and TC22 International Conference 2017
4. S Kaçmaz, C Yılmaz, L Kangı, M Telli, S Yelekcı, *Calibration of automatic gravimetric filling instruments in dynamic weighing*, Proceedings of IMEKO TC3, TC5 and TC22 International Conference 2017
5. M Grum, *Traceable calibration of automatic weighing instruments in dynamic operation*, Proceedings of CIM2017 18th International Metrology Congress, 2017
6. M Grum, *Traceable calibration of automatic weighing instruments operating in dynamic mode*, OIML Bulletin, Volume LIX, Number 3, July 2018
7. S Kaçmaz, *The role of control instruments in the calibration of automatic gravimetric filling instruments in dynamic mode*, OIML Bulletin, Volume LIX, Number 3, July 2018

8. M Grum, *Calibration of automatic catchweighing instruments in dynamic mode of operation*, Proceedings of XXII IMEKO World Congress, 2018

Project start date and duration:		1 June 2015, 36 months
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Internal Funded Partners: Partner 1 MIRS, Slovenia Partner 2 BEV-PTP, Austria Partner 3 CMI, Czech Republic Partner 4 GUM, Poland Partner 5 IMBiH, Bosnia and Herzegovina Partner 6 Metroserf, Estonia Partner 7 DMDM, Serbia Partner 8 PTB, Germany Partner 9 TUBITAK, Turkey	External Funded Partners: Partner 10 MT, Germany	Unfunded Partners: