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Technical protocol of a Bilateral EURAMET Comparison (*vibration acceleration*)

Swiss Federal Office of Metrology METAS

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1. Participants

The following 2 laboratories are participants in the proposed bilateral EURAMET comparison:

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2. Aim and task of the comparison

This bilateral EURAMET comparison of accelerometer calibration, is intended to disseminate the key comparison reference values, which were established in the CIPM key comparison CCAUV.V-K1, to METAS. The first key comparison in the area of vibration organized under the auspices of the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV) and piloted by the Physikalisch-Technische Bundesanstalt (PTB) was carried out between January 2000 and June 2001. Twelve National Metrology Institutes (NMIs) from the five Regional Metrology Organizations APMP, COOMET, EUROMET, SADCMET, and SIM participated. All NMIs used laser interferometry in compliance with the

International Standard ISO 16063-11:1999 to measure the charge sensitivity of two transfer standards from 40 Hz to 5 kHz at 22 frequencies (third-octave frequency series) with specified uncertainties. The "weighted mean method" was selected and used for calculating the key comparison reference values (KCRVs) and the degrees of equivalence relative to the KCRVs. The results of the CCAUV.V-K1 are a set of KCRVs, their uncertainties, and degrees of equivalence both for each laboratory with respect to the KCRV and between the laboratories. The results and conclusions of the key comparison CCAUV.V-K1 are specified in detail in *Metrologia* 40 Tech. Suppl. 09001, 2003.

In accordance with the procedures defined by the BIPM, the dissemination of the KCRVs established in CCAUV.V-K1 to the European countries (i.e. those within the EUROMET RMO) was provided by the four "linking laboratories" in the EUROMET.AUV.V-K1. One of these laboratories was the PTB, which had participated in both the CIPM key comparison and the EUROMET key comparison. METAS did participate in EUROMET.AUV.V-K1 with calibration facilities on the secondary level. Meanwhile, a set-up for primary calibration has been installed and its performance will be validated in this comparison.

The principal task of the comparison is the measurement of the charge sensitivity of two accelerometer standards (one of single-ended design and one of back-to-back design) at different frequencies and acceleration amplitudes specified in clause 3. The charge sensitivity shall be calculated as the ratio of the amplitude of the output charge of the accelerometer to the amplitude of the acceleration at its reference surface. The reference surface is the base or mounting surface of the accelerometer of single-ended design, and the top surface of the accelerometer of back-to-back design. The charge sensitivity shall be given in pico coulombs per metres per second squared: pC/(m/s^2), for the different measurement conditions specified below.

To calibrate two accelerometers, primary vibration calibration by laser interferometry in accordance with ISO 16063-11:1999 shall be used.

To measure the output charge of the accelerometer standards, a calibrated charge amplifier shall be used. For the calibration of the charge amplifier, see clause 5.

Note: The participating laboratory shall report the measurement results of the charge sensitivity and the associated uncertainties individually as they were calculated for any specified measurement condition (in particular, for a given frequency), without applying any curve fitting procedure which is frequently used to suppress deviations from a "flat" frequency response.

3. Conditions of measurement

- frequencies in Hz: 40 Hz, 80 Hz, 160 Hz, 800 Hz, 2 kHz and 5 kHz (160 Hz is reference frequency)
- Optionally the laboratories can measure at other frequencies (such as frequencies included in the third-octave frequency series)
- amplitudes: preferred value 100 m/s². A range of 10 m/s² to 200 m/s² should be complied with*. If needed, up to 300 m/s² will be accepted.*
- ambient temperature and accelerometer temperature during the calibration: 23 °C ± 3 K (actual values to be stated within tolerances of ±0,5 K).
- relative humidity: max. 75%.
- mounting torque of the accelerometer: (2 ± 0,1) N · m.

4. Transfer standards

As transfer standards, two types of piezoelectric accelerometers are to be used: standard accelerometer (single-ended), Brüel & Kjær type 8305 WH with serial number 2495771 (**Accelerometer A**), and standard accelerometer (back-to-back), Brüel & Kjær type 8305 with serial number 2456549 (**Accelerometer B**). The latter accelerometer will be provided by METAS with the top surface polished for sensing the motion without any additional reflector. The reflectivity of the polished top surface will be 80% or higher, and the flatness over the top surface in the order of 1 µm.

Specifications of Accelerometer A: transfer standard accelerometer (single ended), type 8305 WH (manufacturer Brüel & Kjær); weight: 26 grams, length: 22 mm, width over flats of hexagonal faces: 16 mm, mounting thread: 10-32 UNF-2B, electrical connector: coaxial 10-32 UNF-2A thread, accelerometer capacitance: ≈ 75 pF, sensitivity:≈ 0,13 pC/(m/s²), max. transverse sensitivity at 30 Hz: ≤ 1%,

Specifications of Accelerometer B: reference standard accelerometer (back-to-back) type 8305 (manufacturer Brüel & Kjær), weight: 40 grams, length: 29 mm, width over flats of hexagonal faces: 16 mm, mounting thread: 10 - 32 UNF - 2B, electrical connector: coaxial 10 – 32 UNF - 2A thread, accelerometer capacitance: ≈ 75 pF, sensitivity: ≈ 0,13 pC/(m/s²), max. transverse sensitivity at 30 Hz: ≤ 1%.

5. Measurement instructions

- The ***measurand*** is the magnitude of the complex charge sensitivity.
- ***Calibration of Accelerometer A by laser interferometry:***
- The reference surface for acceleration measurement is by definition the base or mounting surface of the accelerometer. If this surface is covered

during the calibration, the motion is to be sensed on the moving part close to the accelerometer. Alternatively, the motion can be sensed at the mounting surface of the accelerometer via longitudinal holes in the moving part of the vibration exciter. Requirements of ISO 16063-11:1999 standard have to be observed.

- ***Calibration of Accelerometer B by laser interferometry:***
- The motion is to be sensed at the top surface (polished) without any dummy mass; no reflector (e.g. corner cube) must be attached to the top surface.
- The **char*ge amplifier*** used in the laboratory should be calibrated using a standard capacitor and standard voltmeter both traceable to national standards. The calibration of the charge amplifier should be carried out shortly before the calibration, using values of the electrical quantities similar to those occurring in the accelerometer calibration.
- In order to suppress the effect of any non-rectilinear motion, the displacement should be measured at a minimum of three different points. These points should be equally spaced on the top surface of the back-to-back accelerometer or on the mounting surface of the single-ended accelerometer.
- The mounting surfaces of the accelerometer and the moving part of the vibration exciter shall slightly be lubricated before mounting.
- For each of the two accelerometers, the calibrations are to be carried out in accordance with the usual procedure of the corresponding laboratory.

6. Communication of the results

METAS will perform an initial calibration of the standards and submit the calibration results to the CCAUV secretary before sending the artefacts to the PTB.

PTB shall perform the calibration of the artefacts and submit its calibration report to the CCAUV secretary as well as the pilot laboratory within 6 weeks after the calibration

The calibration reports shall contain detailed descriptions of:

- the calibration equipment
- the calibration method(s) used
- the ambient conditions
- the mounting technique
- the calibration results including the relative expanded uncertainty

For reporting the calibration results, clause 10 of ISO 16063-11:1999 shall be taken into account. For uncertainty, the following instructions are given:

The list(s) of the principal components of the uncertainty budget shall be in accordance with ISO 16063-11:1999, Annex A for the primary calibration by laser interferometry, according to method 1 ("fringe-counting method"), method 2 ("minimum-point method") and/or method 3 ("sine-approximation method"). In each case, the uncertainties shall be determined in accordance with the Guide to the expression of uncertainty in measurement, which is adapted to the calibration of vibration and shock transducers in ISO 16063-1:1998, Annex A. Clause 10 and Annex A of ISO 16063-11:1999 and Annex A of ISO 16063-21 are formal parts of clause 6 of the technical protocol.

7. Circulation type

From METAS to PTB and back.

8. Time schedule

- **Calibration and transportation time period:**
  A total time period of 4 weeks is allocated for each laboratory covering both calibration and transportation
- **Total circulation period:**
  3 months
- **Preparatory stage:**
  Basic investigation, e.g. test of linearity and long-term stability of transfer standards. Jan 2008 to October 2008
- **Start of the circulation period:**
  October 2008
- **End of the circulation period:**
  January 2009 (or earlier if possible)
- **Draft report:**
  Feb 2009 (or earlier if possible)
- **Final report:**
  2009

9. Transportation

The transfer standards will be transported in a closed box by an international transportation agency (e.g. TNT, UPS, …).

10. Financial aspects

Each participating laboratory is responsible for its own costs for the measurements and liable for any damage to the artifacts while there are in the

respective laboratory. Costs of transportation and any customs charges as well as transportation insurance (if necessary) and overall costs of the organization of the comparison including the supply of the transfer devices are covered by METAS.

11. Insurance of transfer devices

Insurance of transfer devices is decided by agreement among the participants taking account of the responsibility of each participant for any damage in its country.