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Progress in the EUROMET.AUV.V-K1 Regional Key Comparison

(cf. Draft Agenda of 20/04/04, item 7.1 of 4th Meeting of the CCAUV

at the BIPM in Sèvres in Sept. 2004)

Survey of activities since the 3rd meeting of the CCAUV (BIPM, October 2002)

The first European (RMO EUROMET) key comparison in the field of vibration and shock (physical quantity of acceleration) has progressed in accordance with document CCAUV/02-09 which was presented at the 3rd CCAUV meeting. The main steps taken since that time have covered the following:

- Preparation, discussion and completion of the Technical Protocol
- Continuation of the investigations into the long-term stability of the transfer standards
- Circulation of the transfer standards according to schedule (starting in July 2003, to be finished by December 2004)

In CCAUV/02-09, 14 participating laboratories from 14 countries were named. In addition, the Bundesamt für Eich- und Vermessungswesen (BEV), Austria, is participating as the 15th laboratory. Recently, the Spanish Centre of Metrology (CEM) decided to represent Spain as participant, demanding exclusion of activities of the Institute of Acoustics (CSIC-IA) from EUROMET. Accordingly, the coordinator of the Agreed EUROMET Project Ref.-No. 579 European comparison in accelerometer calibration (EUROMET AUV.V.K1) has updated the project description. This version dated 5th July 2004 was submitted to the EUROMET Secretary.

The updated Technical Protocol of the RMO key comparison EUROMET.AUV.V-K1 is given in the ANNEX. In the Technical Protocol, several annexe are mentioned, which are not attached to this report.

The Final report of EUROMET AUV.V.K1 is scheduled for 2006.

ANNEX

Physikalisch-Technische Bundesanstalt (PTB)
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Technical protocol of the Key Comparison EUROMET.AUV.V-K1 (*vibration acceleration*)

Agreed EUROMET Project Ref.-no. 579
Updated version of 6th July, 2004

1 Participants

The following 15 laboratories (NMIs or Institutes authorized by the respective NMI to represent the country in this comparison) are participants in the a greed EUROMET Project Ref.-no. 579 (RMO Key Comparison EUROMET.AUV.V-K1); contact persons see below:

BEV / Austria	(Sinojmeri, Merita: Fax: +43 1 492 0875 (3901) E-mail: m.sinojmeri@metrologie.at)
BNM/CESTA / France	(Barreau, Christian, Fax: +33 5 57 04 54 28 E-mail: Christian.Barreau@ANTIGONE.CEA.FR)
CEM / Spain	(Casal, Carmen: Fax: +34 91 807 2807 E-mail: ccasal@mfom.es)
CMI / Czech Republic	(Prasil, Milan, Fax: +420 2 5732 8077 E-mail: mprasil@cmi.cz)
CNR-IGMC / Italy	(Mana, Giovanni, Fax: +39 011 3977 426 E-mail: g.mana@igmc.to.cnr.it)
DPLA / Denmark	(Licht, Torben, Fax: +45 7741 2014 E-mail: TRLicht@bksv.com)
GBARL / Hungary	(Istvan, Daniel, Fax: 36 1 309 2616, E-mail: daniel@sparc.core.hu)
GUM / Poland	(Kolasa, Joanna: Fax: +48 22 620 83 78 E-mail: acoustcs@gum.gov.pl)

INETI / Portugal	(Nunes, Mário, Fax: +351 217 143 997 E- mail: mario.nunes@ineti.pt
METAS / Switzerland	(Berthod, Fabienne, Fax: +41 31 32 33210 E-mail: fabienne.berthod@metas.ch)
NMi-VSL / Netherlands	(van Kan, Paul: Fax: +31 15261 2971 E-mail: pvankan@nmi.nl)
PTB / Germany	(***pilot laboratory***, Hans-Jürgen v. Martens, contact details see below)
SIRA/United Kingdom	(Hewett, Ray, Fax: +4420 8295 3005 E-mail: rahewett@siratc.co.uk)
SP / Sweden	(Andersson, Hakan: Fax: +46 33 13 83 81 E-mail: hakan.andersson@sp.se
UME / Turkey	(Bilgic, Eyup: Fax: +90 262 646 5914 E-mail: eyup.bilgic@ume.tubitak.gov.tr)

Contact details of pilot laboratory/coordinator:

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2 Aim and task of the comparison

The EUROMET key comparison of accelerometer calibration, EUROMET.AUV.V-K1, is intended to disseminate the key comparison reference values, which were established in the CIPM key comparison CCAUV.V-K1, within the EUROMET Regional Metrology Organization. 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 computing 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) is to be provided by the four "linking laboratories". These are laboratories, which have participated in both the CIPM key comparison and will participate in the EUROMET key comparison (i.e. the NMIs: BNM-CESTA, CMI, NMi-VSL and PTB).

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 or Secondary vibration calibration by the comparison method in accordance with ISO 16063-21 (to be issued) shall be used. The latter method shall only be applied if the participating laboratory is supplied with traceability by primary calibration of reference accelerometers at the PTB on the basis of the agreed EUROMET project ref. No. 198.

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.

Recommendation: expanded uncertainty of measurement (coverage factor $k = 2$) determined by the participating laboratories should be in the approximate range of

- 0,5 % to 1 % or smaller, if laser interferometry is used,
- 1 % to 2 % or smaller, if the comparison method is used.

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 all the laboratories can measure at other frequencies provided they are 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.

The laboratories can measure within their capabilities but they should be aware of the fact that the restrictions regarding the CCAUV.V-K1 will be mentioned.

4 Transfer standards

As transfer standards, two types of piezoelectric accelerometers are to be used: standard accelerometer (single-ended), type 8305 WH 2335 (**Accelerometer A**), and standard accelerometer (back-to-back), type 8305 (**Accelerometer B and C**, respectively) (manufacturer Brüel & Kjær).

The latter accelerometer will be provided by the PTB pilot laboratory in two versions: For primary vibration calibration, the participating laboratory will obtain an accelerometer type 8305 (**Accelerometer B**) 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. For comparison, the participating laboratory will obtain a usual version (**Accelerometer C**) allowing the reference accelerometer of the respective laboratory to be mounted on the top surface of Accelerometer C.

Specifications of Accelerometer A: transfer standard accelerometer (single ended), type 8305 WH 2335 (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 and Accelerometer C: 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 <u>Accelerometer A</u> by <u>laser interferometry</u>:***

  The reference surface for acceleration measurement is by definition the baseor 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. ISO 16063-11:1999 is to be observed.

- ***Calibration of <u>Accelerometer A</u> by <u>comparison</u>:***

  The accelerometer is to be calibrated according to ISO 16063-21 (current stage FDIS) by comparison to a reference accelerometer calibrated by laser interferometry in accordance with ISO 16063-11:1999. The reference accelerometer of the calibrating laboratory may be of the so-called back-to-back type meant for direct mounting of the transducer to be calibrated (i.e. Accelerometer A) on top of it in a so-called back-to-back configuration. It may also be a reference accelerometer with normal mounting provisions used underneath a fixture in line with Accelerometer A. It is not recommended to mount the two transducers side by side as rocking motion will often be present, causing large errors in many circumstances. For calibrators, the reference transducer may be an integral part of a moving element.

- In ***calibration of <u>Accelerometer B</u> (by laser interferometry only!)***, 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.
- In ***calibration of <u>Accelerometer C</u> (by comparison only)***, the arrangements given above for Accelerometer A are possible. However, the single-ended accelerometer mounted on the top surface of the back-to-back Accelerometer C must be the reference accelerometer of the calibrating laboratory.
- The **charge *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. For the four linking laboratories contributing to the EUROMET Key Comparison Reference Value (cf. section 2), this is a requirement. For the other participating laboratories using laser interferometry, this is a recommendation.
- 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, carry out the calibration in accordance with the usual procedure of your laboratory.

6 Communication of the results to the pilot laboratory

The calibration report shall be submitted to the pilot laboratory within 6 weeks after the calibration and contain detailed descriptions of:

- the calibration equipment
- the calibration method(s) used
- the ambient conditions
- the mounting technique
- the calibration results
- the uncertainty budget(s)

In addition to the calibration report, the measurement results should be submitted to the pilot laboratory on a diskette formatted to be compatible with a 3.5 inch PC disk drive or on a CD, and in advance by electronic mail, with the data in *Excel* or ASCII text format.

For reporting the calibration results, clause 10 of ISO 16063-11:1999 and clause 7 of ISO 16063-21, respectively, 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"). For vibration calibration by comparison to a reference accelerometer, Annex A of ISO 16063-21 shall be taken into account. 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

Modified star type, loops through 2 to 3 participating laboratories and the pilot laboratory.

8 Time schedule

- ***Calibration and transportation time period:***

  A total time period of 3 weeks is allocated for each laboratory covering both

calibration and transportation (cf. Annex D).

- ***Total circulation period*:**

  Max. 18 months

- ***Preparatory stage*:**

  Basic investigation, e.g. test of linearity and long-term stability of transfer standards. July 2002 to June 2003

- ***Start of the circulation period*:**

  July 2003

- ***End of the circulation period*:**

  December 2004 (or earlier if possible)

- ***Draft report*:**

  2005

- ***Final report*:**

  2006

- ***Detailed timetable***

  See Annex D

9 Transportation

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

10 Financial aspects

Each participating laboratory is responsible for its own costs for the measurements, transportation and any customs charges as well as any damage that may occur within its country. Overall costs of the organization of the comparison including the supply of the transfer devices are born by the pilot laboratory.

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.