MIKES
29.1.2010
Jussi Hämäläinen

Technical protocol of the Bilateral EURAMET Comparison – DRAFT

(Vibration & acceleration)

EURAMET Project Ref.-no. ??

1 Participants

The following two laboratories will participate in the project:

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MIKES / Finland	Hämäläinen, Jussi: Tel: +358 10 605 4404 E-mail: jussi.hamalainen@mikes.fi

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2 Aim and task of the comparison

The principal task of the comparison is the measurement of the complex 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 magnitude of complex charge sensitivity shall be given in pico coulombs per metres per second squared: pC/(m/s²) and the phase shift of complex charge sensitivity shall be given in degrees: °. 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 shall be used. The latter method shall only be applied if the participating laboratory is supplied with traceability by primary calibration of reference accelerometers.
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 for magnitude, if laser interferometry is used,
- 1 % to 3 % or smaller for magnitude, if the comparison method is used,
- 1 ° or smaller for phase shift.

Note: The participating laboratory shall report the measurement results of the complex 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: 10, 12.5, 16, 20, 40, 80, 160, 315, 630, 800, 1250, 2000, 2500, 3150, 4000, 5000, 6300, 8000 and 10000 Hz
- amplitudes: preferred value 10 m/s². A range of 5 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 ± 1 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 used: standard accelerometer (single-ended), type 4366, manufacturer Brüel & Kjær (**Accelerometer A**), and standard accelerometer (back-to-back), type 2270, manufacturer Endevco (**Accelerometer B**).

Accelerometer A is provided by SP and accelerometer B by MIKES. Both accelerometers have been measured over a longer period for stability data.

In addition a dummy mass for calibrating accelerometer B by laser interferometry is provided by MIKES.

Specifications of Accelerometer A: Accelerometer (single ended) type 4366, manufacturer Brüel & Kjær. Weight: 28 grams. Length: 19 mm. Width over flats of hexagonal faces: 16 mm. Mounting thread: 10-32 UNF. Electrical connector: coaxial 10-32 UNF. Accelerometer capacitance: ≈ 1.1 nF. Sensitivity:≈ 5 pC/(m/s²). Max. transverse sensitivity: ≤ 2%.

Specifications of Accelerometer B: Accelerometer (back-to-back) type 2270 (manufacturer Endevco). Weight: 40 grams. Length: 28 mm. Width over flats of hexagonal faces: 16 mm. Mounting thread: 1/4-28 UNF. Electrical connector: coaxial 10 – 32. Accelerometer capacitance: ≈ 1.6 nF. Sensitivity: ≈ 0.22 pC/(m/s²). Max. transverse sensitivity: ≤ 3%.

Specifications of Dummy mass: Dummy mass made of steel. Weight: 50 grams. Dummy mass has three equally spaced longitudinal holes on its circumference and one center hole for mounting it on top of an accelerometer.

5 Measurement instructions

- The ***measurand*** is the magnitude and phase shift 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 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. ISO 16063-11:1999 is to be observed.
    - ***Calibration of <u>Accelerometer B</u> by <u>laser interferometry</u>:***

      A dummy mass provided by the pilot laboratory shall be mounted on the top surface of the accelerometer B. The reference surface for acceleration measurement is by definition the top surface of the back-to-back accelerometer B. The motion is to be sensed at the polished top surface of accelerometer B via longitudinal holes in the dummy mass. ISO 16063-11:1999 is to be observed.
    - In order to suppress the effect of any non-rectilinear motion in laser-interferometric calibrations, the displacement should be measured at a minimum of three different points. These points should be equally spaced on the mounting surface of the accelerometer.
    - ***Calibration of <u>Accelerometer A</u> by <u>comparison</u>:***

      The accelerometer is to be calibrated according to ISO 16063-21 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.
    - ***Calibration of <u>Accelerometer B</u> by <u>comparison</u>:***

      Accelerometer B is calibrated by using a single-ended transfer standard accelerometer mounted on top of it as a reference. The transfer standard accelerometer is to be calibrated according to ISO 16063-21 by comparison to a reference accelerometer calibrated by laser interferometry in accordance with ISO 16063-11:1999. The weight of the transfer standard accelerometer should be the same as the weight of the dummy mass.
- The ***charge amplifier*** used in the laboratory should be calibrated. The calibration of the charge amplifier should be carried out using values of the electrical quantities similar to those occurring in the accelerometer calibration.
- 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

MIKES and SP will calibrate both accelerometers without any information from the other participant. Both participants will send the calibration results to the TC-AUV SC Acceleration and vibration convenor Thomas Bruns independently. After both participants have performed their calibrations and Thomas Bruns has received both calibration results, he will send the calibration results to MIKES.

The calibration results will be submitted to Thomas Bruns within 6 weeks after performing the calibration. The calibration report will 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 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

Only one link between SP and MIKES exists.

SP will send the accelerometer A to MIKES. MIKES calibrates the accelerometer and sends it back to SP, which will perform its own calibration of accelerometer A.

MIKES will send the accelerometer B to SP. SP calibrates the accelerometer and sends it back to MIKES, which will perform its own calibration of accelerometer B.

8 Time schedule

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

A total time period of 6 weeks is allocated for each laboratory covering both calibration and transportation.

- ***Total circulation period*:**
  3 months
- ***Start of the circulation period*:**
  March 2010
- ***End of the circulation period*:**
  May 2010 (or earlier if possible)
- ***Draft report*:**
  July 2010 (or earlier if possible)
- ***Final report*:**
  2010

9 Transportation

The transfer standards will be transported in a closed box by an international transportation agency (e.g. UPS) or directly from one laboratory to another by a car.

10 Financial aspects

Each participating laboratory is responsible for its own costs for the measurements as well as any damage that may occur within its country. Pilot laboratory is responsible for transportation, any customs charges and overall costs of the organization of the comparison.

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.

ANNEX A: Agreed EUROMET Project Ref.-No ???

EURAMET Project Form "Proposal"

Status: ☐ proposed ☒ agreed

1. Ref. No.: (*please leave blank*)	2. Subject Field: Acoustics, ultrasound and vibration
3. Type of collaboration: Comparison of measurement standards	
3A. In the case of a comparison: Registered as Key comparison (KC) or Supplementary Comparison (SC) in the KCDB: ☒no ☐ yes If yes: No. of KC/SC:	
4. Participating Partners: 4A EURAMET members or associates (Institute's standard acronym with country code in brackets) as registered on EURAMET website. SP (SE), MIKES(FI) 4B Institutes not being EURAMET members or associates (Institute's full name and name the of country in brackets)	
5. Title: Bilateral Comparison of Accelerometer Calibration	
6. Description: MIKES has been building a vibration transducer calibration facility on a secondary level. Now, when the calibration facility is ready to be used, MIKES is motivated to carry out a bilateral comparison to validate it. The task is to compare measurements of sinusoidal linear accelerations and piezoelectric accelerometer calibration in the frequency range from 10 Hz to 10 kHz. Two accelerometers, one provided by each laboratory, will be used during the comparison. The calibration is accomplished by primary method according to ISO 16063-11 or by secondary method according to ISO 16063-21. The result of the calibration is the magnitude and phase shift of the complex charge sensitivity. The results of comparison will be used as an evidence for MIKES CMCs for secondary calibration of vibration transducers. MIKES will act as a pilot in the comparison.	
7. Additional remarks: (e.g. external funding available etc.)	
8. Proposer´s name:Jussi Hämäläinen Address: MIKES, Tekniikantie 1, 02150 Espoo, Finland Telephone: +358 10 6054 404 Fax: E-mail: jussi.hamalainen@mikes.fi	
9. Date: 29.1.2010	10. Proposed starting date: -

Only for agreed projects:

11. Date project agreed:------ Ref.No. of proposal: ------	12. Starting Date: 1.3.2010	13. Expected completion date: 2010 Only for permanent agreements: ☐ On-Going

Notes for completion of the form overleaf