Technical protocol of the Key Comparison EURAMET.AUV.V-K5.1 (INRiM, Italy – CSIR-NPL, India – LNE France)

1. Participants

The following laboratories have indicated interest as participants in the agreed Key Comparison (ILC): INRiM, CSIR-NPL, LNE.

Contact details of participating laboratory representatives:

For **INRiM** / Italy
National Institute of Metrological Research
Applied Metrology and Engineering Division
Vibration Laboratory
Str. delle Cacce, 91
10135 Torino
ITALY

Contact: Dr. Alessandro Schiavi
E-mail: a.schiavi@inrim.it
Phone: 0039-011-3919396

For **CSIR-NPL** / India
CSIR-National Physical Laboratory
Physico Mechanical Metrology Division & Acoustics and Vibration Standards
New Delhi - 110 012, India.

Contact: Dr. Naveen Garg
E-mail: ngarg@nplindia.org
Phone: 011-45609386, 9868377370 (M)

For **LNE** / France
Laboratorie Nationale de Métrologie et d'Essai (France)
29 Av. Roger Hennequin,
78190 Trappes,
France

Contact: M. Adrien Canu
E-mail: adrien.canu@lne.fr
Phone: +33 1 30691200

2. Task and Aim of the Comparison

According to the rules set up by the CIPM MRA, the consultative committees of the CIPM have the responsibility to establish "degrees of equivalence" (DoE) between the different measurement standards operated by the NMIs. This is done by conducting key comparisons (KC) on different levels of the international metrological infrastructure.

The current Key Comparison in which INRiM (Italy), CSIR-NPL (India) and LNE (France) will participate aim to provide proper supporting evidences for the registration of "calibration and measurement capabilities" (CMC) in the framework of the CIPM MRA.

The specific task of this comparison is to measure the magnitude of the charge sensitivity of two accelerometers ("back-to-back" type and "single ended" type) at specified frequencies with primary means i.e. according to pertinent standards [1, 2].

The sensitivities of the piezoelectric accelerometer BK 8305 (SN: 705519) "back to back" (BB) type and BK 4382 (SN:1671819) "single ended" (SE) type supplied by INRiM, are to be reported by each participant at agreed frequencies and acceleration amplitudes. The sensitivity reported will exclude effects from the applicable conditioning amplifier/power supply unit (PSU) used. For all instances, the participating laboratory shall provide the amplifier to be used.

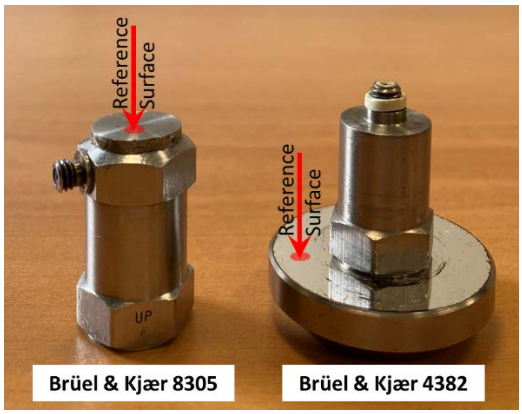
No amplifier/PSU will accompany the circulation of the transfer transducer.

The reported sensitivities and associated uncertainties are then supposed to be used for linking this RMO KC to the CIPM KC CCAUV.V-K5 and the calculation of the unilateral DoE between the participating NMIs and the KCRVs. The weighted mean of the calibration values (with the associated uncertainty of measurement (UoM)) submitted by the participants will be used for the linking process.

3. Devices under Test and Measurement Conditions

For the calibration task of this KC a piezoelectric accelerometer will be circulated between the participating laboratories. The individual transducer is:

- BK 8305 (SN: 705519) "back to back" (BB) type supplied by INRIM.
- BK 4382 (SN:1671819) "single ended" (SE) type supplied by INRIM.



A special adapter for the SE-type transducer developed (supplied by DPLA) and used during the CCAUV Key Comparison will also be used during this comparison. The adapter is made of stainless steel and has a weight (measured) of 22.6 g. Its hardened top surface is polished in order to provide mirror-like reflectivity for the laser.

We are aware that it doesn't correspond to the usual way of calibration of the participants; but this is the only way to reduce or avoid the material dependency to the moving element described in [3] and [4].

The accelerometers are to be calibrated for magnitude of the charge sensitivity according to those procedures and conditions implemented by the NMI in conformance with ISO 16063-11 [2] which provide magnitude (and phase) information of the artefact.

The sensitivities reported shall be for the accelerometers alone, excluding any effects from the charge amplifier. The frequency range of the measurements was agreed to be from 5 Hz to 10 kHz. Specifically, the laboratories are supposed to measure at the following frequencies (all values in Hz).

5, 6.3, 8, 10, 12.5, 16, 20, 25, 31.5, 40, 50, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1 000, 1 250, 1 500, 1 600, 2 000, 2 500, 3 000, 3 150, 3 500, 4 000, 4 500, 5 000, 5 500, 6 000, 6 300, 6 500, 7 000, 7 500, 8 000, 8 500, 9 000, 9 500, 10 000.

Note: this set does deviate from the standard frequencies of ISO 266 and include some extra frequencies (5, 6.3, and 8 Hz), which were not included in the scope of the former KCs CCAUV.V-K5 and EURAMET.AUV.V-K5.

The participating laboratories will provide magnitude results at least for the range from 5 Hz to 10 kHz. Laboratories with existing CMCs registered in the KCDB of BIPM in the scope of this comparison shall provide results covering their CMCs.

The charge amplifier (CA) used for the calibration is not provided within the set of the artefacts, it must therefore be provided by the individual participant. By this measure, the capability of the participating laboratory to calibrate charge amplifiers is implicitly verified.

The measurement condition should be kept according to the laboratory's standard conditions for calibration of customer accelerometers for claiming their best measurement capability or CMC where applicable. This presumes that these conditions comply with those defined by the applicable ISO documentary standards [2, 5], simultaneously.

Specific conditions for the measurements of this comparison are:

- Acceleration amplitudes: preferably 50 m/s^2 to 100 m/s^2, a range of 2 m/s^2 to 200 m/s^2 is admissible.
- Ambient temperature and accelerometer temperature during the calibration: (23 ± 2) °C (actual values to be stated within tolerances of ± 0.3 °C).

The accelerometer temperature should be measured and reported.

- Relative humidity: max. 75 %
- Mounting torque of the accelerometer: (2.0 ± 0.1) N·m

4. Circulation Type, Schedule and Transportation

The transducers are circulated from INRiM (pilot) to CSIR-NPL, to LNE, and then back to INRiM, with a measurement period of three weeks provided for each participant. The schedule is planned as follows (the full delivery address for each participant is given in annex).

The accelerometers have to be sent by an international logistic service providing a tracking system. The transportation has to include an insurance covering a total value of 12 000 € in case the set of accelerometers gets damaged or lost during transportation. As an alternative the artefact may be hand carried by a member of the participating laboratory.

Participant	ISO country code	Participant Duration in weeks (measurement + transportation)	Week number
INRiM (Pilot)	**IT**	**6+1**	To be defined
CSIR-NPL	**IN**	**3**	To be defined
LNE	**FR**	**3**	To be defined

5. Handling, Measurement and Analysis Instructions

The participating laboratories must observe the following instructions:

- The charge amplifier used for the measurement of the accelerometer's response has to be calibrated with equipment traceable to national measurement standards.
- The motion of the BB accelerometer should be measured with the laser directly on the (polished) reference surface of the transducer without any additional reflector or dummy mass (c.f. picture on page 2).
- The SE accelerometer shall be mounted together with the mounting adapter, that comes attached to it. The combined SE accelerometer with adapter shall be handled as a single mechanical unit for mounting. The mounting adapter must not be adjusted, loosened or removed. The mounting or dismounting torque between the adapter and the shaker shall be applied only to the mounting adapter. An appropriate crowfoot wrench with 3/8" square drive adaptation and 18 mm span is provided within the set.
- The motion of the SE accelerometers shall be measured on the top surface of the polished mounting adapter that comes attached to each, close to the accelerometer's housing (c.f. picture on page 2) and at the same distance for all the measurement points.
- The mounting surface of the BB accelerometer or the adapters in case of the SE accelerometers, and the moving part of the exciter must be slightly lubricated before mounting.
- The cable between accelerometer and charge amplifier should be taken from the set of DUT delivered to the laboratory.

- In order to reduce the influence of non-rectilinear motion, the measurements should be performed for at least three different laser positions which are symmetrically distributed over the respective measurement surface.
- It is advised that the measurement results should be compiled from complete measurement series carried out at different days under nominally the same conditions, except that the BB accelerometer is remounted and the cable reattached. The standard deviation of the subsequent measurements should be included in the report.
- The report will be provided by each laboratories in the following form (example):

Frequency	Acceleration magnitude	Charge sensitivity	Relative expanded uncertainty on charge sensitivity
[Hz]	[m/s^2]	[$pC/(m/s^2)$]	[%]
10,0	10	0,13090	0,4
12,5	14	0,13076	0,4
16,0	20	0,13077	0,4
20,0	20	0,13082	0,4
25,0	20	0,13078	0,4
31,5	20	0,13086	0,4
40,0	20	0,13085	0,4
63,0	20	0,13082	0,4

6. Communication of the Results to the Pilot Laboratory

Each participating laboratory will submit one printed and signed calibration report (sent by post-mail or email to Alessandro Schiavi, a.schiavi@inrim.it) including the following:

- Description of the calibration systems used and the mounting techniques for the accelerometer,
- Description of the calibration methods used, including information about the demodulation scheme,
- Record of the ambient conditions during measurements,
- Calibration results, including the relative expanded measurement uncertainty, and the applied coverage factor for each value,
- Detailed uncertainty budget for the system covering all components of measurement uncertainty (calculated according to GUM [6, 7]). Including among others information on the type of uncertainty (A or B), assumed distribution function and repeatability component. (This information is necessary for the evaluation and linking of subsequent RMO KC).

In addition, each participating laboratory will receive two electronic spreadsheets prepared by the pilot laboratory, where the calibration results have to be filled in following the structure given in the files. The use of the electronic spreadsheets for reporting is mandatory. The consistency between the

results in electronic form and the printed and signed calibration report is the responsibility of the participating laboratory. The data submitted in the electronic spreadsheet shall be deemed the official results submitted for the comparison.

The results have to be submitted to the pilot laboratory within six weeks after the measurements. The pilot laboratory will submit it's set of results to the executive secretary of CCAUV in advance to the first measurement of a participating laboratory

References

[1] ISO 16063-1:1998 “Methods for the calibration of vibration and shock transducers, Part 1: Basic concepts

[2] ISO 16063-11:1999 “Methods for the calibration of vibration and shock transducers, Part 11: Primary vibration calibration by laser interferometry”

[3] The influence of different vibration exciter systems on high frequency primary calibration of single-ended accelerometers, A. Täubner, H Schlaak, M Brucke and Th Bruns, Metrologia, Volume 47, Number 1

[4] The influence of different vibration exciter systems on high frequency primary calibration of single-ended accelerometers: II, Th Bruns, A Link and A Täubner, Metrologia, Volume 49, Number 1

[5] ISO/IEC 17025:2005/2017 “General requirements for the competence of testing and calibration laboratories”

[6] ISO/IEC Guide 98-3:2008 “Uncertainty of measurement, Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)

[7] ISO/IEC Guide 98-3:2008/Suppl 1:2008 “Propagation of distributions using a Monte Carlo method”