Technical Protocol of the CIPM Key Comparison

CCAUV.V-K3

1 Task and Purpose 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 national NMIs. This is done by conducting key comparisons (KC) on different levels of the international metrological infrastructure. The previous top-level KC in the field of vibration metrology, CCAUV.V-K1, was completed in the year 2001 in the frequency range from 40 Hz to 5 kHz. The ongoing CCAUV.V-K2 is aimed at the frequency range from 10 Hz to 10 kHz.

However, recent developments in technology and improvements at the NMIs have extended the low-frequency vibration limit of calibration capabilities down to 0.4 Hz and even to 0.1 Hz and lower. Therefore during the meeting of CCAUV in 2012, the decision was taken to make preparations for a further comparison targeted at a low-frequency range.

In the field of vibration, this key comparison is organized in order to compare measurements of sinusoidal linear accelerations in the frequency range from 0.1 Hz to 40 Hz. Moreover, the complex sensitivity calibration and measurement capabilities (CMCs) of the participating laboratories for accelerometer calibration are to be examined and compared. It is the task of this comparison to measure the complex sensitivity of one accelerometer standard set (including a quartz-flexure servo-accelerometer of the single-ended type and a signal conditioner) at different frequencies with acceleration amplitudes as specified in section 3. The results of this key comparison will, after approval of equivalence, serve as the foundation at low vibration frequency for DoEs derived from three existing regional low-frequency supplementary comparisons and the registration of 'calibration and measurement capabilities' (CMC) in the framework of the CIPM MRA.

For the calibration of the accelerometer standard set, laser interferometry in compliance with method 1 or 3 of the international standard ISO 16063-11:1999 has to be applied, in order to cover the entire frequency range. Specifically, the magnitude of the complex voltage sensitivity shall be given in milli-volt per meter per second squared ($mV/(m/s^2)$) and phase shift in degrees for the different measurement conditions specified in section 4.

The reported complex sensitivities and associated uncertainties are then supposed to be used for the calculation of the DoE between the participating NMI and the key comparison reference value.

2 Pilot Laboratory

Pilot laboratory for this key comparison is

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Mechanics and Acoustics Metrology Division
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This is the delivery address for the set of artefacts and the written and signed reports.

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Co-Pilot laboratories for this key comparison are
Laboratoire national de metrologie et d'essais (LNE)
and
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3 Device under Test and Measurement Conditions

For the calibration task of this comparison, one quartz-flexure accelerometer set will be circulated between the participating laboratories. The accelerometer set is one 'single ended' (SE) type, namely SA 704 (SN: *to be confirmed*), with a signal conditioner, namely MSA-Ⅰ (SN: 02011001).

The accelerometer set is to be calibrated for its complex voltage sensitivity according to those procedures and conditions implemented by the laboratory in conformance with ISO 16063-11 which provides magnitude and phase shift information of the artefact. The complex sensitivities reported shall be for the accelerometer set, including all effects from the signal conditioner.

The frequency range of the measurements was agreed to be from 0.1 Hz to 40 Hz. Specifically, the laboratories are supposed to measure at the following frequencies (all values in Hz).

0.1, 0.125, 0.16, 0.2, 0.25, 0.315, 0.4, 0.5, 0.63, 0.8, 1, 1.25, 1.6, 2, 2.5, 3.15, 4, 5, 6.3, 8, 10, 12.5, 16, 20, 25, 31.5, 40.

The mandatory frequency range is from 0.4 Hz to 40 Hz. The measurement conditions should be kept according to the laboratory's standard conditions for calibration of customers' 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 [1,2,3], simultaneously.

Specific conditions for the measurements of this comparison are:

- acceleration amplitudes: a range of 0.05 m/s^2 to 30 m/s^2 is recommended.
- ambient temperature and accelerometer temperature during the calibration: (23 ± 2) ℃ (actual values to be stated within tolerances of ± 0.3 ℃).
- relative humidity: max. 75 % RH
- Mounting torque of the accelerometer: (2 ± 0.1) N.m

4 Circulation Type, Schedule and Transportation

The transducer set is circulated in two loops with a measurement period of two weeks provided for each participating laboratory and one week for the pilot. At the beginning and the end of the circulation as well as between certain subsequent measurements of participating laboratories, the transducer set is measured at the pilot laboratory in order to fix reference values and to monitor the stability of the transducer set.

The schedule is planned as follows:

Participant	Measurement (calendar week)	Transportation to next Participant (calendar week)
NIM	35/2014*	36/2014
LNE	37-38/2014	39/2014
PTB	40-41/2014	42/2014
BKSV-DPLA	43-44/2014	45/2014
GUM	46-47/2014	48/2014
METAS	49-50/2014	3/2015
NIM	4/2015	5/2015
A*STAR	6-7/2015	11/2015
NMISA	12-13/2015	14/2015
INMETRO	15-16/2015	17/2015
CENAM	18-19/2015	20/2015

NMIA	21-22/2015	23/2015
NMIJ	24-25/2015	26/2015
KRISS	27-28/2015	29/2015
VIINIM	30-31/2015	32/2015
NIM	33/2015	

* 35/2014 refers to the period from Monday, Aug 25th to Sunday, Aug 31st 2014

The cost of transportation to the next participating laboratory shall be covered by the participating laboratory. The transducer set has to be sent hand-carried with great caution. In case the transducer set gets damaged or lost during transportation, the participating laboratory for delivery should pay 4 000,- € to pilot laboratory for the set.

5 Measurement and Analysis Instructions

The participating laboratories have to observe the following instructions:

- The motion of the quartz-flexure accelerometer should be measured on the moving part of horizontal vibration exciter, close to the accelerometer's mounting surface, since the mounting (reference) surface is usually not directly accessible.
- The mounting surface of the accelerometer and the moving part of the exciter must be slightly lubricated before mounting.
- The cable between accelerometer and signal conditioner should be taken from the set delivered to the laboratory.
- It is advised that the measurement results should be compiled from complete measurement series carried out on different days under nominally the same conditions, except that the accelerometer is remounted and the cable re-attached. The standard deviation of the subsequent measurements should be included in the report.
- Participants should not perform any experiments other than comparison measurements stipulated in this protocol with the artifact.

6 Communication of the Results to Pilot Laboratory

Each participating laboratory will submit one printed and signed calibration report for the accelerometer set to the pilot laboratory including the following:

- a description of the calibration systems used for the comparison and the mounting techniques for the accelerometer
- a description of the calibration methods used
- a documented record of the ambient conditions during measurements
- the calibration results with a resolution of two decimal digits, including the relative expanded measurement uncertainty, and the applied coverage factor for each value. For example: sensitivity magnitude: XXX.XX mV/(m/s^2), phase shift: X.XX^o
- a detailed uncertainty budget for the system covering all components of measurement uncertainty (calculated according to the GUM [4,5]), including, among others, information on the type of uncertainty (A or B), assumed distribution function and

repeatability component.

In addition, the use of the electronic spreadsheets for reporting is mandatory. The format of the spreadsheet will be provided by the pilot in due course. 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 four weeks after the measurements have been completed.

The pilot laboratory will submit its set of results to the executive secretary of CCAUV in advance of the measurements of the first participating laboratory.

7 Remarks on post-processing

Presuming consistency of the results, the key comparison reference value and the unilateral degrees of equivalence will be calculated according to the established methods agreed upon already for CCAUV.V-K1.

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] ISO/IEC 17025:2005 ‘General requirements for the competence of testing and calibration laboratories’

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

[5] ISO/IEC Guide 98-3:2008/Suppl 1:2008 ‘Propagation of distributions using a Monte Carlo method’

Annex1：Low-frequency vibration comparison transfer standard

For the purpose of the low-frequency vibration comparison, the pilot laboratory will select one accelerometer for which monitoring data for at least 6 months will be available.

- One transfer standard accelerometer (single-ended), type SA704, S/N *to be decided* (manufacturer: NIM).
- One signal conditioner, type MSA-I, S/N 02011001 (manufacturer: NIM).

This transfer standard is of the same type as those used in APMP.AUV.V-S1, which are shown in Figure 1 and diagrammatically in Figure 2. There is a #10-32 UNF mounting thread in the middle of the installation surface of the SA704, the same as the B&K Type 8305 accelerometer. No special mechanical adaptor is needed. The other three holes of Φ3.5 mm are only for assembly purposes, not for installation. The cable between the accelerometer and signal conditioner is specially made and will be delivered together with the artefact. BNC output of the signal conditioner is available.

Figure 1: Two transfer standard accelerometers and the whole package

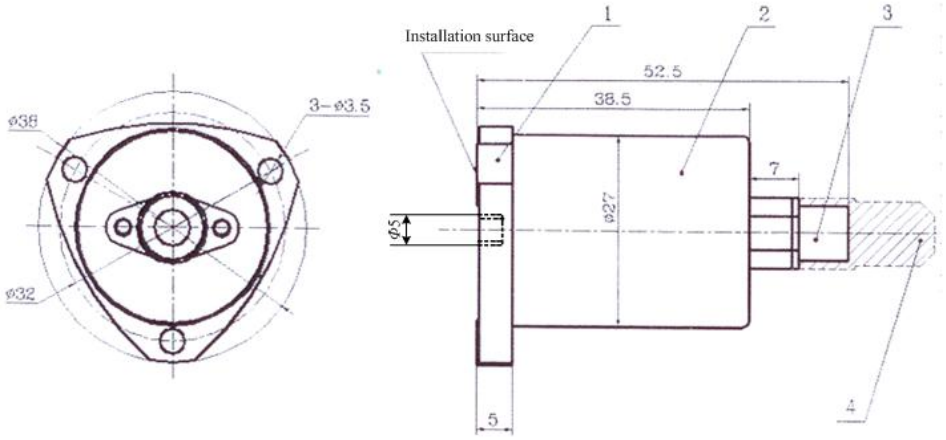

Figure 2: Outline drawing of quartz-flexure accelerometer

Specifications:

Intended application frequency range	0.1 Hz to 40 Hz
Input Range	$\pm 250 m/s^2$
Nominal sensitivity	124 mV/(m/s ²)
One-year composite repeatability	5×10^{-4}
Weight	122 ± 4 g
Power	±12 VDC or (110-220) VAC

The input range of SA-704 is (0 – 250) m/s^2 and the highest environment shock is 1000 m/s^2. Therefore, any violent drop may cause its sensitivity to change or even damage. For more information, please refer to:
http://www.bipm.org/utils/common/pdf/final_reports/AUV/V-S1/APMP.AUV.V-S1.pdf