Technical Protocol of the APMP Key Comparison

APMP.AUV.V-K5

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 NMIs. This is done by conducting Key Comparisons (KCs) on different levels of the international metrological infrastructure.

The CCAUV.V-K5 forms the new basis for DoE. It will be then derived in subsequent RMO KCs and therefore serve as the foundation for the registration of "calibration and measurement capabilities" (CMC) in the framework of the CIPM MRA.

The specific task of this APMP KC is to measure the complex charge sensitivity of two different accelerometers at specified frequencies with primary means *i.e.* according to [1] and [2].

The reported 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 Values (KCRVs) of CCAUV.V-K5 through a linking procedure based on the results of the linking laboratories.

2 Pilot Laboratory

Pilot laboratory for this APMP KC is

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3 Terms of participation

As the number of participants to CCAUV.V-K5 was limited to four NMIs for APMP, all laboratories from APMP (and other RMOs) can participate in this APMP KC.

Following this recommendation, the questionnaire of this APMP KC was distributed to the technical committees of Acoustics, Ultrasound and Vibration of AFRIMETS, COOMET and APMP.

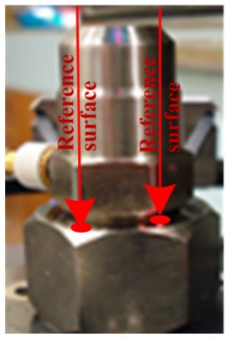
4 Device under Test and Measurement Conditions

For the calibration task of this APMP KC a set of two piezoelectric accelerometers will be circulated among the participating laboratories. The individual accelerometers being

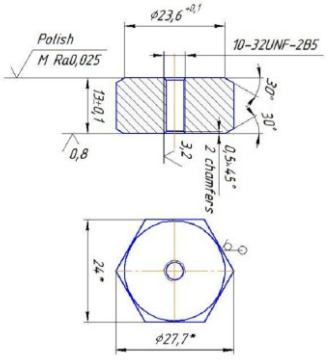
• a Brüel & Kjar 8305-001 (SN: ...) “single ended” (SE) type

• an ENDEVCO 2270 (SN: ...) “back to back” (BB) type.

ENDEVCO 2270



Brüel & Kjar 8305-001with adapter



A special adapter for the SE-type accelerometer (supplied by NIM) will also be used during this APMP KC. The adapter is made of stainless steel 1.4404 (AISI 316L) and has a weight (calculated) of about 40 g. Its hardened top surface is polished in order to provide mirror-like reflectivity for the laser beam.

The accelerometers are to be calibrated for magnitude and phase of their complex charge sensitivity according to those procedures and conditions implemented by the NMI in conformance with ISO 16063-11 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 10 Hz to 20 kHz and will be linked to CCAUV.V-K5. Specifically, the laboratories are supposed to measure at the following frequencies (all values in Hz).

10, 12.5, 16, 20, 25, 31.5, 40, 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, 10 500 11 000, 11 500, 12 000, 12 500, 13 000, 13 500, 14 000, 14 500, 15 000, 15 500, 16 000, 16 500, 17 000, 17 500, 18 000, 18 500, 19 000, 19 500, 20 000.

Note: this set does deviate from the standard frequencies of ISO 266, however, it coincides with the frequencies from 10 Hz to 20 kHz of the CCAUV.V-K5.

The participating laboratories will provide magnitude and phase results for the range from 10 Hz to 20 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 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 KC are:

- acceleration amplitudes:
  preferably 50 m/s² to 100 m/s², a range of 2 m/s^2 to 200 m/s^2 is admissible.
- ambient temperature and accelerometer temperature during the calibration:
  (23 ± 2) ºC (actual values to be stated within tolerances of ± 0.3 ºC).
  The accelerometer temperature should be measured and reported.
- relative humidity: max. 75 % RH
- Mounting torque of the accelerometer: (2.0 ± 0.1) N·m

4 Circulation Type, Schedule and Transportation

The accelerometers are circulated in a star type fashion with a measurement period of three weeks provided for each participating laboratory. At the beginning and the end of the circulation as well as between certain subsequent measurements of participating laboratories, the accelerometers are measured at the pilot laboratory in order to monitor the stability of the accelerometers.

The schedule is planned as follows (confirm email should be sent before delivery though the recipients' information for each participant is given in annex):

Participant	Measurement (calendar week)	Transportation to next Participant (calendar week)
NIM	20-22/2022	23-24/2022
SCL	25-27/2022	28-29/2022
NIMT	30-32/2022	33-34/2022
VMI	35-37/2022	38-39/2022
NMC	40-42/2022	43-44/2022
CMS	45-47/2022	48-49/2022
NIM	50-52/2022	01-02/2023
NMIJ	03-05/2023	06-07/2023
NMIA	08-10/2023	11-12/2023
KRISS	13-15/2023	16-17/2023
VNIIM	18-20/2023	21-22/2023
Ukrmetrteststandart	23-25/2023	26-27/2023
NIM	28-30/2023	

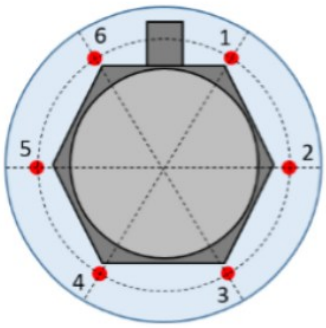
The cost of transportation to the next participating laboratory shall be covered by the participating laboratory. The accelerometers have to be sent by an international logistic service providing a tracking system. The transportation has to include an insurance covering a total value of 12 000€ in case 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.

5 Handling, Measurement and Analysis Instructions

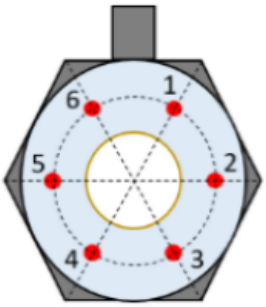
The participating laboratories have to observe the following instructions:

- 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 accelerometer **without any additional reflector, mirror or dummy mass** (c.f. picture on page 2).
- The SE accelerometer shall be mounted together with the mounting adapter, which 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 accelerometer shall be measured on the top surface of the polished mounting adapter**, close to the accelerometer's housing (c.f. picture on page 2). **The measurand of the SE accelerometer should be considered as the combined mechanical response of the mounting adapter and accelerometer**.
- The mounting surface of the BB accelerometer or the adapter in case of the SE accelerometer and the moving part of the exciter must be slightly lubricated before mounting.
- The cable between accelerometer and charge amplifier should only be taken from the set of DUT delivered to the laboratory. It is a B&K, 10-32 UNF (M) to 10-32 UNF (M), 1.2 m cable.
- In order to reduce the influence of non-rectilinear motion, the measurements (on both BB and SE accelerometers) should be performed as the simple average of response for six different laser point locations which are rotationally equal-spaced distributed over the respective measurement surface, with any systematic variations between individual laser point locations ignored in the uncertainty estimation.



Brüel & Kjar 8305-001with adapter
(Top view)



ENDEVCO 2270
(Top view)

- 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 or adapter in case of an SE accelerometer is remounted and the cable reattached. The standard deviation of the subsequent measurements should be included in the report.
- For acceleration signals $a(t)$ of the form

  $$a(t) = \hat{a} \cdot \cos(\omega t + \varphi_a)$$

  and the respective charge output of signal of the accelerometer $q(t)$ of the form

  $$q(t) = \hat{q} \cdot \cos(\omega t + \varphi_q)$$

  The phase is defined according to ISO 16063-1 as

  $$\Delta\varphi = \varphi_q - \varphi_a$$
- For the measurement of the phase of the sensitivity, the delay or phase characteristics of the interferometer channel(s) has to be taken into account, since the photo-diode-amplifier-system typically has a non-negligible influence on the results. The used delay and the type of interferometer system should be reported.

6 Communication of the Results to Pilot Laboratory

Each participating laboratory will submit one printed and signed calibration report (a scanned copy sent by email to the pilot laboratory) for each accelerometer including the following:

- a description of the calibration systems used for the comparison and the mounting techniques for the accelerometer, which will be included in the comparison report,
- a description of the calibration methods used, including information about the demodulation scheme,
- a record of the ambient conditions during measurements,
- the calibration results, including the relative expanded measurement uncertainty, and the applied coverage factor for each value,
- a detailed uncertainty budget for the system covering all components of measurement uncertainty (calculated according to GUM [4,5]). Including, among others, information on the type of uncertainty (A or B), assumed distribution function and repeatability component.

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 its set of results to the executive secretary of CCAUV in advance to the first measurement of the participating laboratory.

7 Remarks on post processing

The results of the participants will be scaled to the level of KCRVs of CCAUV.V-K5. The scaling factor will be determined via the results of the linking laboratories which are taking part in both comparisons.

The report will include the results of all the participants and their degrees of equivalence respectively to the KCRVs of the CCAUV.V-K5.

In case of damage or loss of any of the artefacts, this regional key comparison will be evaluated as far in the schedule as possible, all further action concerning continuation will be decided in coordination with the participants.

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

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