

THE NATIONAL PHYSICAL LABORATORY

# TECHNICAL PROTOCOL FOR KEY COMPARISON CCAUV.A-K5

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Richard Barham  
National Physical Laboratory  
Teddington  
United Kingdom

Tel +44 20 8943 6725

Fax +44 20 8943 6717

Email: [richard.barham@npl.co.uk](mailto:richard.barham@npl.co.uk)

# TECHNICAL PROTOCOL FOR KEY COMPARISON CCAUV.A-K5

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## BACKGROUND

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The first key comparison of microphone calibration CCAUV.A-K1, concerning the pressure calibration laboratory standard microphones type LS1P, was completed in August 2003. At the sixth meeting of CCAUV in 2008 it was noted that the nominal seven year cycle for carrying out a key comparison would be approaching by the time of the seventh meeting in 2010. At the same meeting the need to maintain a KCRV for the calibration of this type of microphone was affirmed. It was therefore agreed that preparations for repeating the key comparison would be initiated and that NPL would be the pilot laboratory. It was also agreed that the scope should be expanded significantly to reflect recent developments and experience that has been attained since CCAUV.A-K1 was first proposed.

The key comparison has been denoted CCAUV.A-K5.

A draft protocol was presented for discussion at CCAUV-7 and confirmed subject to inclusion of the comments received. This document defines the agreed protocol for the comparison. It should be read in conjunction with the 'Guidelines for key comparisons carried out by Consultative Committees' by T J Quinn which includes more details on the purpose and conduct of key comparisons in general. The purpose of this document is to "specify the procedures necessary for the comparison, but not the procedures used for the realization of the standards being compared."

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## PARTICIPANTS

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Given the large number of institutes expressing interest in taking part in this key comparison, a questionnaire was circulated to assess the scope of the key comparison and the range of capability of potential participants. The responses to the questionnaire survey and the criteria used to select the participants listed below, can be found in Annex A.

The following laboratories have been selected based on the questionnaire responses and their participation agreed at CCAUV-7

- |                      |                   |                    |
|----------------------|-------------------|--------------------|
| ◆ CENAM, Mexico      | ◆ INMETRO, Brazil | ◆ NMIJ, Japan      |
| ◆ CSIR, South Africa | ◆ INRIM, Italy    | ◆ NPL, UK          |
| ◆ DPLA, Denmark      | ◆ KRISS, Korea    | ◆ NRC, Canada      |
| ◆ GUM, Poland        | ◆ NIM, China      | ◆ VNIIFTRI, Russia |

Contact details can be found in Annex A.

These participating laboratories provide representation for the following RMOs in this key comparison:

AFRIMETS (1 participant), APMP (3 participants), COOMET (1 participant), Euramet (e.V.) (3 participants, plus the pilot laboratory) and SIM (3 participants).

In addition a further bi-lateral comparison between NPL and NIST has been proposed, using this protocol as the basis, to be carried out following the measurement phase of CCAUV.A-K5, which is planned to end in March 2012.

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### MICROPHONES TO BE CIRCULATED

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Two LS1P microphones have been selected for this comparison. The microphones are Brüel & Kjær type 4160 serial numbers 811012 and 2652754†. These microphones are referred to as the reference microphones in the remainder of this document. Additional microphones will be maintained by the pilot laboratory should any reference microphone fail during the key comparison.

Each participant is responsible for transporting the reference microphones to the laboratory scheduled to next receive them. Local customs formalities must be observed and if the participating laboratory requires NPL to supply an ATA carnet (or any other documentation) for this purpose, they must inform NPL, using the 'agreement to participate form' shown in Annex A. In this regard, please bear in mind that the reference microphones may come to you directly from another participant (see Timetable in Annex A).

The reference microphones will be packaged in a suitable form for transportation by courier. It is essential that this packaging is used when using air or land couriers to transport the microphones between participating laboratories. The microphones may also be hand carried, but it is recommended that the same packaging be used. The microphones shall be stored appropriately while in the possession of the participating laboratory. Ideally this should be in temperature controlled environment maintained at the reference temperature of 23°C. Any protection grid fitted to the microphones for transportation, shall be removed before conducting measurements.

The microphone cases will be marked as key comparison reference standards and the microphones must not be used for any purpose other than that associated with their calibration for this comparison. Sudden shocks can be caused by applying sound calibrators, pistonphones or dehumidifiers to the microphones and these actions should also be avoided.

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### MEASUREMENTS

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This key comparison is concerned only with **primary methods** of calibration and will only consider results from such methods.

The microphones require a polarising voltage of 200 V. Any protection grid fitted to the microphone shall be removed before conducting measurements.

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† Brüel & Kjær have kindly provided microphones for this KC and retain ownership of these devices.

Table 1. Scope of key comparison

Frequency range	Sensitivity level	Sensitivity phase
2 Hz - 20 Hz (1/3-octave)	Optional	Optional
20 Hz – 10 kHz (1/12-octave)	Mandatory	Optional

Table 1 shows the measurands and frequency ranges within the scope of this key comparison. Participants shall complete the mandatory elements and at least one optional element of the scope, unless agreed in advance with the pilot laboratory. Each laboratory is to determine the open-circuit pressure sensitivity level of each reference microphone, and optionally the open-circuit pressure sensitivity phase.

The open-circuit pressure sensitivity level shall be reported in decibels with a reference value of 1V/Pa.

The convention to be used for reporting the sensitivity phase is that it approaches 180° at low frequency and is 90° at the resonance frequency of the microphone, i.e. the sensitivity phase shall be reported as positive values.

It is IEC TC29 policy that specifications referring to frequency in all new or revised standards, use the base 10 system of frequencies specified in IEC 61260. It is therefore appropriate to adopt this policy for CCAUV.A key comparisons. Accordingly measurements shall be carried out and reported at frequencies generated by the formulae given below. In all calculations, the reference frequency  $f_r$  is 1000 Hz (NB. the octave frequency ratio of  $G = 10^{(3/10)}$  described in IEC 61260, is implicit in these equations).

In the optional low frequency region, the third-octave calibration frequencies  $f_n$  between 2 Hz to 20 Hz shall be calculated from:

$$f_n = f_r 10^{n/10} \quad (1)$$

where  $n$  is an integer between  $-27$  and  $-17$ .

In the mandatory frequency region the twelfth-octave calibration frequencies  $f_n$  between 20 Hz to 10 kHz shall be calculated from‡:

$$f_n = f_r 10^{n/40} \quad (2)$$

where  $n$  is an integer between  $-68$  and  $40$ .

The actual frequency than can be set during a measurement will be determined by the particular equipment used. The effect of any significant variation in the set frequency from that calculated above, on the measured sensitivity level shall be accounted for in the uncertainty analysis.

Any other frequencies (for example, preferred nominal frequencies) reported by the participants will not be collated by the pilot laboratory.

The frequency range of any calibration and measurement capability (CMC) that the laboratory has declared or intends to declare under the MRA, as being supported by this key comparison, must correspond or fall within the range where data is reported.

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‡ The twelfth-octave frequencies calculated according to IEC 61260 correspond to the centre frequencies of band-pass filters. However these frequencies do not coincide with the third-octave frequencies normally used in acoustic measurement. In order to maintain consistency with existing data in the KCDB and with laboratories who perform their calibrations at only third-octave frequencies, Eq. (2) specifies lower band edge frequencies of twelfth-octave bands, which do periodically coincide with third-octave frequencies.

It is expected that most laboratories will fulfil the measurement requirements by implementing reciprocity calibration. Where reciprocity calibration is to be used, this shall be according to IEC 61094-2:2009.

The reference microphones will have suitably flat front surface to make the use of grease on the contact surface unnecessary for couplers filled with air.

The use of hydrogen-filled couplers is not recommended, but where a participating laboratory intends to use such a method, the reference microphones shall only be used as receivers. This intention must be stated on the 'agreement to participate' form.

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#### PRE-PARTICIPATION

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The key comparison is scheduled to begin on **10 January 2011**, when the pilot laboratory will start their measurements. The reference microphones will then be circulated to other participants for the first time.

Prior to the circulation of the microphones, participants shall complete the 'Agreement to participate form' shown in Annex A. This includes a statement of the measurements they expect to carry out and report. An electronic version of this form has been circulated with this protocol.

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#### REPORTING RESULTS

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Each laboratory shall report their results using the standard certificate that they would normally issue to a customer. However results shall also be reported in the pilot laboratory's proforma spreadsheet, that has been circulated with this protocol. Please remember to **check the box confirming that the data reported in the proforma spreadsheet is consistent with that reported in the certificates**, as the spreadsheet data will be used as the basis for the analysis.

Results shall be corrected to the reference environmental conditions given in IEC 61094-2.

Results shall be accompanied by a statement of the associated measurement uncertainty, estimated for a confidence probability of 95%.

Where necessary an additional covering letter or report shall be provided to include any details not covered in the certificate, including:

- Details of any deviations from the recommendations in IEC 61094-2 and an estimate of the affect this has on the reported results.
- The values of the front cavity volume, cavity depth, and microphone acoustic impedance parameters used in the calculation, where appropriate.
- Values of the temperature and static pressure coefficients of the microphones used in the calculations.
- A summary of the uncertainty calculation, listing and quantifying each of the components considered, and indicating the method used to produce the overall estimate of measurement uncertainty. Where a frequency dependent analysis is carried out, this summary should cover the whole frequency range, but be limited to the third-octave frequencies only for brevity.

The final results and the accompanying information should be received at NPL within **four weeks** of the end of the scheduled measurement period. Dated deadlines can be found in the schedule shown in Annex A. A reminder will be sent by email one week before the due date and this deadline shall be strictly enforced: failure to submit results by the deadline may result in the exclusion of the participant laboratory. An email to the pilot laboratory should be sent to announce that the results have been despatched. The completed proforma spreadsheet should be attached to this email. It is also acceptable to send all other material by email to meet the deadline, but hardcopies of calibration certificates should follow in the post.

The pilot laboratory will carry out their measurements at the start of the circulation period and the results lodged with the CCAUV secretariat.

When all participants have completed the measurements, the data will be analysed by the pilot laboratory. If a result is found to be anomalous the laboratory in question will be notified and given **three weeks** to respond. A Draft A report will then be prepared.

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## FINANCE

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Participants are responsible for their own costs, the cost of delivering the microphones to the next recipient, any ATA carnet required and for any damage to the microphones while they are in their possession.

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## TIMETABLE

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The timetable is given in Annex A.

**The timetable must be followed regardless of any delays caused by customs irregularities and this could cause a laboratory to lose the opportunity to participate in the comparison.**

Each participating laboratory has been allocated a 4-week period in the schedule. The first three weeks should be used to acclimatise the reference microphones to their laboratory environment and to carry out measurements. During the fourth week, the participating laboratory must finalise their measurements and despatched the microphones to the next participant or back to NPL, so that they are received by the start date assigned to the next laboratory, as indicated in the timetable.

It is essential that the microphones are passed on to the next participating laboratory or back to NPL on time even if measurements are not complete. If an individual laboratory has difficulty with their allocated time, it may be possible for two participants to exchange their place in the timetable.

The microphones will return to NPL for an interim calibration, typically after calibration by two participating laboratories. This is so that the stability of the devices can be monitored and so that results from different laboratories can still be compared should a change occur.

In the event of one of the microphones failing then NPL will find a substitute, though this may make the analysis of the results more complicated.

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## KEY COMPARISON REFERENCE VALUE

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The determination of the Key Comparison Reference Values (KCRV) is an important outcome of this key comparison. These may be determined from the overall *grand mean* with no weighting. This is fine for normally distributed data where individual estimates of overall uncertainty are very similar, but there may be problems with anomalous results from one participant. It is the responsibility of the pilot laboratory to identify anomalous results and notify the participant according to CIPM Guidelines. The criteria that will be used for this purpose is the use of figures of merit.

There are various approaches to deal with this situation including using weights according to the reciprocal of the estimated uncertainty (or its square) or even using a 'Median' approach. The relative merits of these approaches depend on the statistics of the distribution of results and their uncertainties. It is expected that the ratio of the largest and smallest uncertainty reported by the laboratories is less than two and thus the 'Median' approach will be used initially, but the approach may change depending on the statistical nature of the data.

The guidelines for key comparisons deal with the principles of this issue and sets out useful procedures but does not provide a solution if anomalies remain. The BIPM guidelines will be followed initially but if a problem remains, the participants will decide how to deal with this situation prior to completing the final report.

The pilot laboratory also intends to investigate the use of Reference Curves in reporting the results of this key comparison.

## ANNEX A – PARTICIPANTS

A questionnaire was circulated ahead of preparing this protocol to gauge interest in participation and help formulate a realistic but challenging scope.

The questionnaire was circulated by CCAUV to 26 nations, and 18 responses were received. In addition the questionnaire was circulated independently in the APMP region, producing a response to CMS (ITRI), Chinese Taipei. The responses received are summarised in Table A1. No responses were received from Austria, Belarus, Czech Rep., France, the Netherlands, Romania and Singapore.

Table A1 – Summary of responses from questionnaire

Responding NMI	Country	RMO	Frequency step				Phase	Selected	
			1/3	1/6	1/12	LF			
CEM	Spain	Euramet	●	●	●	●			
CENAM	Mexico	SIM	●	●	●	●	●	●	
DPLA	Denmark	Euramet	●	●	●	●	●	●	
GUM	Poland	Euramet	●	●	●	●	●	●	
INMETRO	Brazil	SIM	●	●	●	●	●	●	
INRIM	Italy	Euramet	●	●	●		●	○	
KRISS	Korea	APMP	●	●		●	●	○	
METAS	Switzerland	Euramet	●	●	●				
NIM	China	APMP	●	●	●	●	●	●	
NIST	USA	SIM	●	●		●			
NMIJ	Japan	APMP	●	●	●	●	●	●	
NMI-ZA	South Africa	AFRIMET	●	●	●			○	
NPL	UK	Euramet	●	●	●	●	●	●	
NPLI	India	APMP	●						
NRC	Canada	SIM	●	●	●			○	
PTB	Germany	Euramet	●						
UME	Turkey	Euramet	●	●	●				
VNIIFTRI	Russia	COOMET	●	●		●		○	
CMS/(ITRI)	Chinese Taipei	APMP	●	●	●	●			
NMIA	Australia	APMP	Declined participation						

● preferred frequency resolution      ● Participation in full scope  
● acceptable frequency resolution      ○ Participation in partial scope

In order to constrain the duration of the key comparison, it is proposed that the maximum number of participants should be limited to 12, with no more than 3 from any given RMO, and to have all RMOs represented. The number of responding laboratories therefore meant that some degree of selection was necessary.

Using the information provided in the questionnaire, the following criteria were therefore used in addition to the above, to select the final list of participants:

1. Participant expects to be able to perform full proposed scope
2. Participant expects to be able to perform mandatory element of scope
3. Participant expects to be able to perform phase calibration
4. Participant expects to be able to perform low frequency calibration
5. Participant implements a unique or distinctive measurement system

The outcome of the selection process is indicated in Table A1. It can be seen that APMP, EURAMET and SIM each have 3 participants (excluding the pilot laboratory), while AFRIMETS and COOMET have one participant each.



## List of contact persons

<p><b>CENAM:</b>          Andrés E. Pérez Matzumoto          Centro Nacional de Metrología          Vibration and Acoustics Division          Km 4,5 Carretera a Los Cués, Municipio El Marqués          76241 Querétaro          Mexico          Tel: -52 442 211 0551          Email: <a href="mailto:eperez@cenam.mx">eperez@cenam.mx</a></p>	<p><b>NMIJ:</b>          Ryuzo Horiuchi          National Metrology Institute of Japan, AIST          Acoustics and Vibration Metrology Division          Tsukuba Central 3          Tsubuka 305-8563          Japan          Tel: +81 298 61 5585          Email: <a href="mailto:ryuzo.horiuchi@aist.go.jp">mailto:ryuzo.horiuchi@aist.go.jp</a></p>
<p><b>NMISA:</b>          Ian Veldman          National Metrology Institute of South Africa          Building 7          Private Bag X34          Lynnwood Ridge          0040 Pretoria          South Africa          Tel: +27 12 841 4008          Email: <a href="mailto:csveldman@nmisa.org">csveldman@nmisa.org</a></p>	<p><b>NPL:</b>          Richard Barham          National Physical Laboratory          F10-A3          Teddington          Middlesex TW11 0LW          United Kingdom          Tel: +44 208 943 6725          Fax: +44 208 943 6217          Email: <a href="mailto:richard.barham@npl.co.uk">richard.barham@npl.co.uk</a></p>
<p><b>DPLA:</b>          Salvador Barrera-Figueroa          Danish Primary Laboratory of Acoustics          Acoustic Technology          Oersted Institute, DTU          Building 352          2800 Kgs. Lyngby          Denmark          Tel: +45 4525 3937          Email: <a href="mailto:sbf@dfm.dtu.dk">sbf@dfm.dtu.dk</a></p>	<p><b>NRC:</b>          Peter Hanes          National Research Council of Canada          Institute for National Measurement Standards          Mechanical Metrology Group          Building M-36          1200 Montreal Road          Ottawa, Ontario          Canada K1A 0R6          Tel: +1 613-998-1282          Email: <a href="mailto:Peter.Hanes@nrc-cnrc.gc.ca">Peter.Hanes@nrc-cnrc.gc.ca</a></p>
<p><b>GUM:</b>          Danuta Dobrowolska          Central Office of Measures, Sound and Vibration Division          UI Elekoralna 2          PO Box P-10          PL 00-950 Warszawa          Poland          Tel: +48 22 620 4259          Email: <a href="mailto:d.dobrowolska@gum.gov.pl">d.dobrowolska@gum.gov.pl</a></p>	<p><b>VNFIITRI:</b>          Anatolij Konkov          Institute for Physical-Technical and Radiotechnical          Measurements          Laboratory for Acoustics          141570 Mendeleevo,          Moscow Region          Russian Federation          Tel: +7 495 744 8128          Email: <a href="mailto:akustika@vniiftri.ru">akustika@vniiftri.ru</a></p>
<p><b>INMETRO:</b>          Zemar M. Defilippo Soares          INMETRO – Instituto Nacional de Metrologia, Normalização e          Qualidade Industrial          Laboratório de Eletroacústica          Av. N. Sra Das Gracas, 50          25250-020 Duque de Caxias, RJ          Brazil          Tel: +21 2679 9192          Email: <a href="mailto:zmsoares@inmetro.gov.br">zmsoares@inmetro.gov.br</a></p>	<p><b>NIM:</b>          He Longbiao          National Institute of Metrology          Acoustical Laboratory          No 18, Bei San Huan Dong Lu          100013 Beijing          China          Tel: +86 10 6429 1900          Email: <a href="mailto:helb@nim.ac.cn">helb@nim.ac.cn</a></p>
<p><b>KRISS:</b>          Sang Joon Suh          Korea Research Institute of Standards and Science          Acoustics and Vibration Group          Division of Physical Metrology          1 Doryong-Dong, Yuseong          305-340 Daejeon          Republic of Korea,          Tel: +82 42 868 5300          Email: <a href="mailto:sis@kriss.re.kr">sis@kriss.re.kr</a></p>	<p><b>INRIM:</b>          Claudio Gugliemone          Istituto Nazionale di Ricerca Metrologica          Strada delle Cacce, 91          10135 Torino          Italy          Tel +39 011 3919626          Email: <a href="mailto:c.gugliemone@inrim.it">c.gugliemone@inrim.it</a></p>



## Agreement to participate

### Agreement to participate in CCAUV.A-K5

Name and address of laboratory

Contact person

Name:	
E-mail:	
Phone:	

Methodology

IEC 61094-2:2009

Other (please give details in Additional Information below)

Scope

Frequency range	Sensitivity level	Sensitivity phase
2 Hz - 20 Hz (N3)		
20 Hz – 10 kHz (N12)		

Will you require an ATA Carnet?      Yes       No

The proposed date for participation is acceptable     

Additional information (please mention any planned use of gas other than air)

[Please return this form to richard.barham@npl.co.uk](mailto:richard.barham@npl.co.uk)

The pilot laboratory has distributed this form electronically to participating laboratories. A further copy is available by contacting [richard.barham@npl.co.uk](mailto:richard.barham@npl.co.uk)

The completed form shall be returned to the pilot laboratory by 28 January 2011.