

Bureau International des Poids et Mesures

Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV)

Report of the 4th meeting
(27-28 September 2004)
to the International Committee for Weights and Measures



Comité international des poids et mesures

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Note:

Following a decision made by the International Committee for Weights and Measures at its 92nd meeting in October 2003, Reports of meetings of Consultative Committees will henceforth be published only on the BIPM website in the form presented here.

Full bilingual printed versions in French and English will no longer appear.

T.J. Quinn,
Director BIPM,
November 2003.

**LIST OF MEMBERS OF THE
CONSULTATIVE COMMITTEE
FOR ACOUSTICS,
ULTRASOUND AND VIBRATION**

as of 27 September 2004

President

Dr J. Valdés, member of the International Committee for Weights and Measures, Instituto Nacional de Tecnología Industrial, San Martín.

Executive Secretary

Dr P.J. Allisy-Roberts, International Bureau of Weights and Measures [BIPM], Sèvres.

Members

Bureau National de Métrologie, Institut National de Métrologie [BNM-INM], Paris.

Centro Nacional de Metrología [CENAM], Querétaro.

CSIR, National Measurement Laboratory [CSIR-NML], Pretoria.

D.I. Mendeleev Institute for Metrology [VNIIM], Gosstandart of Russia, St Petersburg.

Danish Institute of Fundamental Metrology [DFM], Danish Primary Laboratory for Acoustics [DPLA], Naerum.

Instituto Nacional de Metrologia, Normalização e Qualidade Industrial [INMETRO], Rio de Janeiro.

Istituto Elettrotecnico Nazionale Galileo Ferraris [IEN], Turin/Istituto di Metrologia Gustavo Colonnetti del Consiglio Nazionale delle Ricerche [IMGC-CNR], Turin.

Korea Research Institute of Standards and Science [KRISS], Daejeon.

National Institute of Metrology [NIM], Beijing.

National Institute of Standards and Technology [NIST], Gaithersburg.

National Measurement Institute of Australia [NMIA], West Lindfield.

National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology [NMIJ/AIST], Tsukuba.

National Physical Laboratory [NPL], Teddington.

National Physical Laboratory of India [NPLI], New Delhi.

National Research Council of Canada [NRC], Ottawa.

Nederlands Meetinstituut, Van Swinden Laboratorium [NMI VSL], Delft.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Swiss Federal Office of Metrology and Accreditation [METAS], Bern-Wabern.

The Director of the International Bureau of Weights and Measures [BIPM], Sèvres.

Observers

Bundesamt für Eich- und Vermessungswesen [BEV], Vienna.

Český Metrologický Institut/Czech Metrological Institute [CMI], Prague.

Główny Urząd Miar/Central Office of Measures [GUM], Warsaw.

Institute for Physical, Technical and Radiophysical Measurements [VNIIFTRI], Gosstandart of Russia, Moscow.

Instituto Português da Qualidade [IPQ]/Laboratório Nacional de Engenharia Civil [LNEC], Lisbon.

International Electrotechnical Commission [IEC].

International Organization for Standardization [ISO].

Slovenský Metrologický Ústav/Slovak Institute of Metrology [SMU], Bratislava.

Standards, Productivity and Innovation Board [SPRING Singapore], Singapore.

State Agency for Metrology and Technical Surveillance [SAMTS], Sofia.

Ulusal Metroloji Enstitüsü/National Metrology Institute [UME], Gebze-Kocaeli.

1 **OPENING OF THE MEETING; APPOINTMENT OF THE RAPPORTEUR; APPROVAL OF THE AGENDA**

The Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV) held its fourth meeting at the International Bureau of Weights and Measures (BIPM) Sèvres, on Monday 27 and Tuesday 28 September 2004.

The following were present: F. Berthod (METAS), W.S. Cheung (KRISS), V. Cutanda-Henriquez (CENAM), J.N. Durocher (BNM-INM), J.S. Echeverría-Villagómez (CENAM), E. Frederiksen (DPLA), C. Koch (PTB), A. Konkov (VNIIFTRI, representing the VNIIM), M. Lecollinet (BNM-INM), G. Mana (IMGC-CNR), P. Narang (NMIA), V. Nedzelnitsky (NIST), K. Rasmussen (DPLA), G. Ripper (INMETRO), S. Robinson (NPL), S. Sato (NMIJ/AIST), G. Silva-Pineda (CENAM), S.J. Suh (KRISS), J. Valdés (President of the CCAUV), P. van Kan (NMI VSL), C.S. Veldman (CSIR-NML), H.-J. von Martens (PTB and ISO TC108), Qiao Sun (NIM), U. Takashi (NMIJ/AIST), A.J. Wallard (Director of the BIPM), G. Wong (NRC), J.F. Zalesak (NIST and IEC TC 87), B. Zeqiri (NPL), Yue Zhang (NIM).

Observers: A. Enyakov (VNIIFTRI), A.E. Isaev (VNIIFTRI), M. Prasil (CMI), E. Sadikoglu (UME), M. Sinojmeri (BEV), M. Szlag (GUM).

Guests: C. Casal (CEM), V. Pozdeeva (BelGIM for COOMET), A. Elías-Juarez (CENAM for SIM).

Also attending the meeting: T.J. Quinn (Emeritus Director of the BIPM), P.J. Allisy-Roberts (Executive Secretary, BIPM), C. Thomas (Coordinator of the BIPM key comparison database).

Apologies were received from: I. Botkova (SMU), C. Guglielmone (IEN), V. Mohanan (NPLI), V. Smirnov (VNIIM).

The Director of the BIPM, Professor Wallard, welcomed the members to the fourth meeting of the CCAUV held at the BIPM. He noted that the meeting was the first in a full series over the following two weeks at the BIPM.

The President, Dr Valdés, formally opened the meeting and welcomed all the participants explaining that all the meeting documents has been issued electronically. He invited the participants to stand in silence for one minute in respect for Dr Suzanne Thwaites (NMIA) who had died tragically while on mission to Canada. Dr Valdés summarised the agenda, giving a brief overview of the objectives of the meeting. Apologies were noted from members unable to attend, followed by a brief introduction by each of the participants, observers and guests. Dr Koch (PTB) presented the best wishes of Dr Reibold to the participants.

Mr Veldman (CSIR-NML) was thanked for all his work as the previous *Rapporteur* and Dr Bajram Zeqiri (NPL) was appointed as the new *Rapporteur* of the CCAUV.

The topics of the SI brochure proposals and of the report on acoustics, ultrasound and vibration (AUV) needs were added to the agenda (Item 9). The agenda (CCAUV/04-00) was then accepted.

2 REPORT OF THE THIRD MEETING OF THE CCAUV 2002

The President, Dr Valdés, provided a summary of the key features of the third meeting which appear in the [Consultative Committee \(CC\) report](#). This included an up-date of CCAUV and regional key comparisons, and emphasised the fact that comparison results were now published in the *Metrologia Technical Supplement*. At the previous meeting, it had been decided that certain documents with the nomenclature CCAUV-02, as generated by the CCAUV, should be made available for free access by the general community. The status of the dB as a dimensionless SI unit had been discussed, with the decision made to maintain the *status quo*. Developments and improvements in national standards by member national metrology institutes (NMIs) had been presented. The meeting had been presented with a draft of a document providing an analysis of future requirements for metrology in the area acoustics, ultrasound and vibration. Dr Valdés regarded this as an important document that could provide a template for other CCs. He recommended that this document be up-dated and published as soon as possible. He also commended the [Kaarls' Report](#) to the CC, as it provided a basis for the future planning at NMIs.

3 CCAUV KEY COMPARISONS

3.1 Published comparisons: [CCAUV.A-K1](#); [CCAUV.U-K1](#); [CCAUV.V-K1](#)

The three published key comparisons were reviewed to establish whether there were any lessons to be learnt regarding their completion. On behalf of Dr Beißner (PTB), Dr Koch stated that CCAUV.U-K1 had been completed two years ago and no problems had been encountered, the procedures for the comparison and the derivation of the key comparison reference values (KCRVs) and degrees of equivalence were very clear. Mr Robinson (NPL), for CCAUV.A-K1, said that Dr Barham had been very happy with the procedure. For CCAUV.V-K1, Dr von Martens indicated that the whole report had been published as a *Metrologia Technical Supplement*, and acknowledged the excellent support of Dr Allisy-Roberts and Dr Thomas of the BIPM.

3.2 Reports in progress

CCAUV.A-K3 (K. Rasmussen)

The [CCAUV.A-K3](#) comparison was completed by the end of October 2003. In an introduction, Professor Rasmussen referred to his previous results on monitoring the stability of the sensitivities of a large number of microphones. All the microphones demonstrated changes in sensitivity, which were either abrupt changes of 0.03 dB, or drifts of up to 0.02 dB per year over a ten-year period. The

reasons for the drifts were not known but they illustrated the need to carry out comparisons in as short a time interval as possible.

Professor Rasmussen described how the circulation of the microphones for the comparison, involving fifteen participants, had been completed over a ten month period. He thanked all of the participants for keeping to the tight schedule. Due to the need to complete the comparison in a reasonable time, it was undertaken in two circles, with all the laboratories measuring two microphones, and only two laboratories measuring all four. This complicated the procedure of linking, and Dr Cutanda-Henriquez (CENAM) presented a proposal for the analysis, based on the linear least-squares analysis method that is presented in the Draft A report produced in September 2004. Progress of the report was now dependent on the participants agreeing to the method of analysis and, in particular, the assumptions made regarding correlations between participants' results. Dr Nedzelnitsky (NIST) expressed concerns regarding whether it could be assumed that there were no correlations, especially as the equipment used by laboratories was very similar. He indicated that specifying air-filled couplers, rather than hydrogen filled, was one way in which some correlation between participants could be forced. He indicated that there needed to be evidence to support the assumption of zero correlations. There ensued a discussion between Dr Wong (NRC) and Professor Rasmussen related to the relative stabilities of the measurement system and the measurement device, and how it was difficult to separate the two. Professor Rasmussen indicated that short-term (day-to-day) stability for the microphones used was generally better than medium term, over a period of three weeks or so. He also indicated that, unsurprisingly, microphones kept within a laboratory environment were more stable than those kept in the field.

With regard to the analysis of key comparison data, Professor Wallard pointed to a special seminar covering this topic at the [Software for Metrology](#) meeting at NMIJ/AIST (Japan), to be held in May 2005.

CCAUV.W-K1 (S. Robinson)

Mr Robinson (NPL) described the [CCAUV.W-K1](#) comparison, which covered the free-field calibration of underwater acoustic hydrophones in the frequency range 1 kHz to 500 kHz. In total, seven countries participated in the comparison from Canada, China, Germany, Russian Federation, South Africa, United Kingdom and the United States. Mr Robinson summarised the influences in calibrations; highlighting variations in environmental conditions, such as the depth used and the temperature range over which the calibrations were undertaken. Calibrations at NPL, during the process of the key comparison, had verified the stability of the devices used. A weighted-mean analysis was used to derive the KCRV, although the value was actually insensitive to the type of estimator used. One particular problem arising from this comparison was the treatment of the overlap frequencies. Mr Robinson described how this analysis had been made in the Draft B report. In total, 94 frequencies were measured, and it was considered to be more practical for a selection of these to be chosen for display in the database. Assuming it was acceptable to the CC and the participants, the aim was to publish the results of the key comparison in an acoustic's journal. One interesting observation was that, although the uncertainties quoted by different countries were very similar, estimates for identical components quoted by the laboratories differed wildly. Mr Robinson suggested that this indicated the need for further work. In addition, he proposed that future key

comparisons should aim for better control of temperature, include target frequencies below 1 kHz, and perhaps circulate a mount with the hydrophones to standardise on the mounting configuration. Dr Valdés questioned whether this was the most appropriate approach. Mr Robinson stated that cases could be made both for and against providing a mount. It really depended on whether the aim of the key comparison was to compare between participants, or to establish the ‘true’ sensitivity of a hydrophone. The Draft B for CCAUV.W-K1 as submitted for approval was duly approved by the Consultative Committee.

CCAUV.U-K2 (B. Zeqiri)

Dr Zeqiri (NPL) gave a summary of the key comparison [CCAUV.U-K2](#), which covered the calibration of 1 mm active element ultrasonic hydrophones over the frequency range 1 MHz to 15 MHz. For a variety of reasons, only four laboratories (the NPL, PTB, NIM and the TNO) were able to complete absolute calibrations, while one other laboratory submitted a secondary calibration result (DFI). The Draft A report was completed in February 2002, and was presented to the CCAUV meeting in 2002. In the analysis, one of the laboratories was identified as being discrepant at the two higher frequencies, 10 MHz and 15 MHz. At the last CC meeting, it was agreed that there should be a bilateral comparison between NPL and the laboratory in question. This was duly completed, a process which resolved the differences in line with the calibrations of the remaining laboratories. The Draft B report was published as an NPL report in August 2004, and included the required KCRV and degrees of equivalence analysis. The Draft B report was submitted to the CC and was duly approved.

3.3 Comparisons in progress

CCAUV.A-K2 (M. Sinojmeri)

Mrs Sinojmeri (BEV) described a draft of the technical protocol for the key comparison [CCAUV.A-K2](#) which would be undertaken using LS1P microphones over the frequency range 2 Hz to 125 Hz. The original aim was to use the two microphones (owned by the NPL) which had been used in the previous key comparison, CCAUV.A-K1, thus establishing a link with this comparison. Unfortunately, Mrs Sinojmeri indicated that one of the microphones had changed in terms of its sensitivity, and as a consequence, two BEV microphones had been used. Professor Rasmussen (DPLA) suggested including frequencies of 12.5 Hz, 16 Hz and 250 Hz. Despite the inability to use the NPL microphones, Dr Allisy-Roberts stated that links could still be made with CCAUV.A-K1 through laboratories which have undertaken calibrations at the same frequencies within the two comparisons. There were a number of comments from participants related to scheduling of the work, and it was agreed that this should be resolved during the two days of the CCAUV meeting.

CCAUV.A-K4 (K. Rasmussen)

Professor Rasmussen explained that originally this key comparison labelled [CCAUV.A-K4](#) was designed to be a pressure and free-field comparison, to be carried out on the same microphones.

However, the scope had changed and Professor Rasmussen's basic question was whether there was sufficient interest in a key comparison that concentrated on free-field reciprocity. This would relate to the use of LS2 microphones, covering the frequency range of 2 kHz or 3 kHz, up to 50 kHz. There was considerable interest from the CC in participating in the key comparison, although a recurrent theme from the NMIs was that they were not in a position to participate until, typically, the second half of 2005. Dr Echeverría-Villagómez also indicated an interest in the key comparison and raised the possibility of repeating the joint collaboration with DPLA which had worked successfully under CCAUV.A-K3. Professor Rasmussen indicated that within the key comparison, courier transport of the devices would be used rather than reliance on hand-delivery, as the mode of delivery seemed to have only a small impact on the stability of the devices. Additionally, the microphones would be provided with a thermal jacket to protect them from variations in temperature. As a useful piece of advice, he said that the microphones were best sent on a Monday. If sent on a Friday, then they were likely to be kept in a cold warehouse or distribution centre over the weekend. Dr Allisy-Roberts summarised the situation, with eight laboratories expressing an interest in taking part in the key comparison (the BNM-LNE, CENAM, DPLA, KRIS, NIST, NMIJ/AIST, NPL, PTB). She stated that this comparison could be crucial to supporting future calibration and measurement capabilities (CMCs).

3.4 Future comparisons

CCAUV.W-K2 (low frequency)

Dr Enyakov (VNIIFTRI) gave an interesting presentation which described a [Russian-Chinese comparison](#). The Chinese partner in the comparison was HAARI. Four types of hydrophone were used during the comparison, two Russian and two Chinese. A method of hydrostatic excitation was used for the very low frequency range 0.01 Hz to 1 Hz. For the various hydrophone types, the agreement between the two institutions was very good, being typically within 0.45 dB, and the results have been published in a Russian Journal which has been translated into English. The potential for extending participation as a CCAUV.W-K2 comparison was then discussed. Mr Robinson indicated that NPL were willing to take part and, below 1 kHz, they would apply coupler reciprocity. Dr Koch indicated that the PTB has no facilities to perform calibrations in this frequency range. Calibrations carried out under the [CCAUV.W-K1](#), were carried out by an institution which was part of the German Army although they could no longer take part in key comparisons due to their inability to institute a Quality System. The PTB's current lower frequency limit for hydrophone calibrations was 200 kHz. Dr Nedzelitsky indicated that the NIST had no service, and that within the United States calibrations of this type were the responsibility of the U.S. Naval Research Laboratory. On behalf of the NRL, Mr Zalesak, stated that the laboratory did not operate in this frequency range and had no funding to carry out such calibrations.

4 REGIONAL KEY COMPARISONS AND LINKS

4.1 Reports in progress

EUROMET.AUV.A-K1 (Draft B and links for approval)

On behalf of Dr Barham, Mr Robinson (NPL) provided a status report on the project [EUROMET.AUV.A-K1](#), presenting the Draft B and links for approval. This report described an exercise which had been completed over two years ago, and related to the primary calibration of laboratory standard microphones (both LS1P and LS2a). In total, thirteen and nine laboratories had completed calibrations on the LS1P and LS2a microphones, respectively. Completion of the progress on the report had been delayed to enable links to be made with the key comparison CCAUV.A-K1 (LS1P microphones). Three laboratories had provided the links (DPLA, NPL and PTB) for LS1P microphones. The results had been discussed at the last CCAUV meeting and, subsequently, the results of a non-NMI participant from Spain had been omitted at the request of the Spanish NMI, CEM. Once CCAUV.A-K3 has been completed, links to this comparison will be made using the results of the DPLA, GUM, NPL and the PTB. In general, agreement between the different laboratories was good, with the spread in values for LS2a microphones, being less than those for LS1P microphones. This was tentatively ascribed to the fact that fewer, more experienced laboratories had completed calibration on the half-inch devices. The final draft of the report would be submitted directly after the CCAUV meeting. The Draft B and links were duly approved by the CCAUV.

SIM.AUV.A-K1 (Draft B and links for approval)

Dr Elías-Juarez (CENAM) provided an interesting critique of various methods of analysis of key comparison (KC) data, primarily using the papers of Cox (2002), Elster (2003) and Sutton (2004), comparing how they dealt with various issues. These included their ability to handle: correlations; instabilities in the standards used within the KC; several standards; linkages and whether or not they provide a single value of the KCRV. For [SIM.AUV.A-K1](#), Dr Elías-Juarez had applied four methods but as the procedures of Sutton (2004) are able to handle all the situations listed above, he proposed that this method be used. He suggested further that if additional care is taken when setting the measurement protocols, this would simplify the final analysis and make the link between comparisons easier. Dr Thomas (BIPM) confirmed that the Sutton method had been used within a recent mass comparison, and had been approved for forming regional linkages to key comparisons. Dr Ripper (INMETRO) expressed a concern about the clarity of the linkages that had been made through the pilot laboratory, in contrast to the way EUROMET.AUV.A-K1 had been linked to CCAUV.A-K1. Dr Nedzelnitsky (NIST) stated that Dr Elías-Juarez's paper was interesting and there was a need to look at the various methods. Through discussion, Dr Wong (NRC) established a suitable timetable that involved studying Dr Elías-Juarez's analysis, circulating the Draft B and links to participants for comment with a view to getting the Draft B and links approved by the end of 2004. Dr Allisy-Roberts (BIPM) emphasised the importance of establishing links for INMETRO and INTI, in order to support their CMCs.

SIM.AUV.V-K1 (Draft B and links for approval)

A report on [SIM.AUV.V-K1](#) was given by Dr Nedzelnitsky (NIST) on behalf of his colleague Dr D.J. Evans. A meeting had been held at NIST of the five participating NMIs in April 2004. No progress had been made in completing the Draft B as full uncertainty budgets had not been received from all the participants. Dr Nedzelnitsky stated that such information was crucial in unravelling any correlations and in deciding which of the methodologies was most appropriate in generating the degrees of equivalence. The problem was that this comparison had been initiated pre-MRA, and there had been no stipulation that full uncertainty budgets should be reported. The results had been reported with combined uncertainties only. Dr Nedzelnitsky agreed with Dr Valdés that the status of the comparison had not moved on since the last CCAUV meeting, two years ago. It was agreed that the full uncertainty budgets may never be forthcoming, and the suggestion was made to publish the Draft B, declaring “provisional equivalence” as the guidelines were not in place when the SIM.AUV.V-K1 comparison had started.

This discussion spilled into the second day. The decision taken was that the agreed draft report should be published as a provisional report without making any link to the CCAUV.V-K1 which would allow the INMETRO and the INTI to have a comparison to support their CMCs in this field.

Dr von Martens stated that there was a precedent for dealing with this type of situation, as a previous regional vibration comparison, APMP.AUV.V-K1 had no detailed budgets but there were no problems in forming links with the CCAUV.V-K1 comparison.

APMP.AUV.V-K1 (H.-J. von Martens)

Dr von Martens described the comparison [APMP.AUV.V-K1](#) which had been conferred the status of a regional key comparison that had run over the period (1996–1997). This had involved eight NMIs in an accelerometer comparison with links formed to the CIPM key comparison CCAUV.V-K1. Dr von Martens described the method of linking, underlining its quality, and stated that the link had only been made at 160 Hz. The links to the CCAUV.V-K1 were then approved by the CCAUV.

COOMET.AUV.A-K1 (T. Fedtke)

On behalf of Dr Fedtke, Dr Koch of PTB, described the current status of the regional key comparison [COOMET.AUV.A-K1](#). A first version of the Draft A had been prepared and the comparison had identified some discrepant results. Although discussed amongst the comparison team, the most appropriate method of establishing whether or not results are discrepant had still to be decided. Dr Koch asked whether or not there was an agreed policy for deciding this issue. Dr Allisy-Roberts said that every comparison is slightly different and no specific protocols existed. The best approach was for the group of laboratories to reach agreement. She then made the following points, which are essentially comments taken from experience with other comparisons:

- a value could be considered as discrepant, if it differed from the mean by more than 4 standard deviations (σ). In which case it could justifiably not be included in the KCRV if this is based on an arithmetic mean;

- in borderline cases, where there are significant differences (but not quite 4σ), then the participant is invited to withdraw from the KCRV calculation;
- when there are discrepant results that cannot be resolved and need to be included in the KCRV, the median might be deemed to be more appropriate for the KCRV than the weighted mean.

Dr Koch outlined the timetable for a finalised Draft A to be ready in 2005. His timetable was accepted by the CCAUV.

4.2 Measurements in progress

APMP.AUV.A-K1 (S. Sato)

Dr Sato explained the progress made with this regional key comparison [APMP.AUV.A-K1](#), which had been approved at the last CCAUV meeting. The technical protocol had been circulated to the participants by e-mail in April 2004. The artefacts and the measurement frequencies were consistent with previous CCAUV comparisons. The regional comparison would involve nine laboratories and two LS1P microphones. An itinerary was described, including the methods of transportation that included a special box allowing pressure equalisation. Permission to link with the key comparison CCAUV.A.K1 would be sought in the future.

During the discussion, an issue was raised regarding laboratories whose measurement and calibration capability has actually improved. Dr Allisy-Roberts stated that such laboratories could ask for a bilateral comparison to establish whether they have actually improved. Any consequent changes to their claimed CMCs would need to be reviewed by the Regional Metrology Organizations (RMO).

EUROMET.AUV.A-K3 (C. Gugliemone)

On behalf of Dr Gugliemone, Dr Rasmussen described progress under the regional key comparison [EUROMET.AUV.A-K3](#). Nine laboratories are involved in the comparison, with DPLA providing the link with the relevant CCAUV comparison. The microphones used were two of the four LS2P microphones chosen for CCAUV.A-K3. The Draft A would be completed in November 2004 and, currently, one set of data was still missing. It was considered too early to estimate the completion date for the Draft B.

EUROMET.AUV.V-K1 (H.-J. von Martens)

Good progress under this regional key comparison [EUROMET.AUV.V-K1](#) for vibration and shock was reported by Dr von Martens (PTB). Since the last CCAUV meeting, the technical protocol had been prepared, investigations of the long-term stability of the transfer standards had been made and the schedule describing the circulation of the transfer standards, which would be undertaken as a modified star-type comparison had been determined. The comparison had been running since 2003, involving fourteen participants from fourteen countries. The schedule had been maintained and the

measurements were expected to be finished in December 2004, with the final report being issued in 2006.

4.3 Future comparisons

EUROMET.AUV.U-K2 (B. Zeqiri)

This regional key comparison [EUROMET.AUV.U-K2](#) involved only the NPL and the PTB. It dealt with the calibration of ultrasonic hydrophones at frequencies up to 40 MHz. Dr Zeqiri (NPL), reported that two hydrophones had been circulated by NPL and calibrations of hydrophone sensitivity had been completed by PTB, along with ancillary measurements of directional response. The hydrophones were currently with NPL, who would endeavour to complete their calibrations by the end of October 2004.

5 SUPPLEMENTARY COMPARISONS: PROGRESS AND REPORTS

5.1 [SIM.AUV.A-S1](#) (A. Elías-Juarez)

Dr Elías-Juarez described the report submitted on the supplementary comparison [SIM.AUV.A-S1](#) which dealt with piston-phone acoustical calibrators. The Draft A report had been released to and agreed by the participants so the Draft B was currently in the process of being written. The comparison dealt with sound pressure level (in dB re: 20 μ Pa) and total harmonic distortion measurements. There was a desire to link the results of this supplementary comparison to the results of SIM.AUV.A-K1, although Dr Elías-Juarez commented that this comparison determined pressure level sensitivities, expressed in dB re: 1 V Pa⁻¹, so this was a different quantity. He acknowledged that this supplementary comparison has raised the issue of linking to a comparison where the measurands were not the same, and he requested permission for this linking. Dr Thomas (BIPM) stated that normally it was not possible to perform linking when the measurand in the key and regional comparisons are not the same. It was noted that a regional supplementary comparison normally exists on its own merits and does not need to be linked to any other comparison. Dr Elías-Juarez accepted that a link was not actually necessary in this case.

5.2 [SADCMET.AUV.V-S1](#) (C.S. Veldman)

Dr Veldman described the comparison [SADCMET.AUV.V-S1](#) which had been conferred supplementary status by the SADCMET. Dealing with acceleration by laser interferometry over the frequency range 10 Hz to 10 kHz, calibrations of both magnitude and phase had been undertaken, and Dr Veldman provided the uncertainties for these quantities. It was noted that the B&K

accelerometer was not appropriate for use above 5 kHz, especially for phase calibration. The results had been published in the [Metrologia Technical Supplement](#) and were submitted to the CCAUV for information. In response to a question from the President, it was commented that degrees rather than radians were in common usage for phase calibrations.

5.3 Proposal for a SIM acceleration comparison (G. Silva-Pineda)

Dr G. Silva-Pineda (CENAM) described the draft technical protocol for SIM.AUV.V-S1 involving the measurement of the charge and voltage sensitivities of two standard accelerometers covering the frequency range 2 Hz to 160 Hz. The relative merits of standard devices which could be used was discussed by the CCAUV. This supplementary comparison would involve five laboratories in the SIM: CENAM, INMETRO, INTI, NIST and the NRC. The comparison was required to support CMC declarations. The SIM was keen to involve other participants and Dr Silva-Pineda cited China, Japan and Korea as being interested. Dr Allisy-Roberts confirmed that for a regional supplementary comparison, any laboratory from another region may be invited to participate. Dr von Martens underlined the amount of effort involved in the comparison, and stated that it was highly unlikely that PTB could find the funding to take part. Dr Suh (KRISS) indicated that there were still technical issues to resolve regarding the most appropriate choice of transfer standards, citing issues of electrical stability. Dr Echeverría (CENAM) indicated that the comparison could wait until these issues are resolved, or until other laboratories are ready to participate. On the other hand, it could proceed with only the SIM participants. Dr Sun (NIM), indicated that the comparison should be extended down to even lower frequencies, down to 0.4 Hz (as specified in ISO). Dr von Martens indicated that there would be some value in doing this, as 0.4 Hz was a reference frequency regarding the human response to vibration.

6 PUBLICATIONS

6.1 CCAUV web-page and links

Dr Allisy-Roberts gave a description and working demonstration of how to use the [CCAUV web-page](#) and access the documents. She emphasised that it had been agreed at the last CCAUV meeting that there should be open access to CCAUV reports, and to CCAUV working documents whenever possible. The numbering system used for the CCAUV documents was explained in that the “04” in CCAUV-04, referred to the year, and not that this was coincidentally the fourth CCAUV meeting. It was noted that as electronic documents were not available for the first meeting, the printed versions can be obtained on request from the BIPM.

6.2 CCAUV members bibliographies

Dr Allisy-Roberts emphasised the importance of participants providing an up-to-date listing of [publications](#) to demonstrate their current and active participation in the field of AUV. It was noted that for the current CCAUV meeting, not all the participants had provided renewed listings. A simple list or references or a web-link could be provided. Dr Wong asked whether these should be only the most recent, or all publications. It was indicated that generally the most recent were the most valuable but that each NMI needs to use some judgement on the key publications, perhaps picking out a few key older works. Professor Wallard encouraged participants to work on their bibliographies, as this was a way of extending international confidence in the work of each NMI which is an obligation under the CIPM Mutual Recognition Arrangement (MRA).

6.3 Future needs of NMIs working in AUV

Dr Zeqiri described the current status of the document [CCAUV/02-33](#), which had not moved on since the last CCAUV meeting. He felt that the document had been the subject of insufficient scrutiny and comment from the CCAUV, and that it provided a very Euro-centric view, gathered from the IEN, NPL and the PTB. Participants were asked to feed comments back to Dr Zeqiri by the end of October 2004. It was felt useful to publish an up-dated version of the report as a BIPM report. Professor Wallard agreed that this would be possible.

6.4 SI Brochure: Chapter on units for quantities that describe biological effects

Prior to the meeting, a draft had been circulated to participants which described quantities having biological effects, including acoustic quantities. The [draft document](#) was to be presented to the Consultative Committee for Units (CCU) the following week. The draft generated considerable discussion, which revolved around two main issues. The first related to the use of *rms* values of pressure, whereas it was well established that peak or impulsive values play the significant role in hearing damage. The second, and major point, concerned the use of the non-SI unit, the dB. Whilst the use of the dB was ingrained in industrial practice, the CIPM promotes the use of SI units wherever possible. The appropriate quantities defining biological effects are the acoustic pressure, in pascals, and acoustic power, in watts. Dr Zeqiri stated that the SI is used in the medical ultrasound area and yet this field was not mentioned at all in the draft chapter. The wording of a recommendation to be presented to the CCU was discussed as:

1. The CCAUV supports
 - a) the proposal to remove the bel and the neper from Table 6 to Table 8 for “non SI units”;
 - b) the statement that the reference value of the quantity should always be stated in SI units whenever the decibel is used.

2. The CCAUV proposes that the new Chapter 4

- a) should refer to peak values as well as rms values of acoustic pressure both of which are important for damage risk criteria for human hearing;
- b) should encourage the use of the SI in preference to the decibel;
- c) should include the quantities power and pressure with the SI units watt and pascal, respectively as used in medical ultrasound applications.

Although the wording of this recommendation to the CCU was agreed, there was a consensus that it would be extremely difficult to change long-standing habits relating to the use of the dB.

7 CONTRIBUTIONS FROM THE PARTICIPANTS

A series of presentations was given describing the status of the national standards.

7.1 Status of national standards

Dr Koch (PTB) described the [primary standard calibration](#) of microphones for sound in air, at frequencies up to 150 kHz. Airborne ultrasound, generated in applications such as ultrasonic cleaning, for example, was a technical area in which there are no regulatory limits, and for which no measurement standards or protocols exist. He also described the water-borne calibration of ultrasonic hydrophones, determining both the magnitude and phase response, thereby allowing the application of deconvolution methods. The final area described was the development of a portable power standard for use in calibrating ultrasound power balances. The details of the system, developed as an [EU-funded project](#) in collaboration with the NMIA (Australia), was described by Dr Zeqiri (NPL). Dr Valdés commented that this was an excellent example of international collaboration.

Mr Veldman (CSIR), reported on the technical areas of vibration and acoustics in his laboratory. In the vibration field, the scope of accreditation has been extended over the frequency range 10 Hz to 10 kHz. In the acoustics area, reciprocity techniques have been established to enable calibrations of one-inch and half-inch microphones and CSIR are looking at the development of a laser-piston-phone. The anechoic chamber is currently being re-furbished, with the aim of developing a free-field capability.

Dr Enyakov (VNIIFTRI) gave an interesting [presentation](#) which outlined the requirements for the development of medical ultrasound standards within Russia. Requirements related to: the development of hydrophones; a diagnostic performance phantom (no domestic phantoms exist) and a flow phantom for testing Doppler devices. These test devices are needed in order to support the development of a manufacturing industry in Russia.

As part of his presentation describing progress at the NRC, Dr Wong raised the issue of the calibration status of physiotherapy equipment, and the fact that there was no regulatory requirement to have this type of equipment calibrated, despite the fact that the equipment was used on humans. Dr Allisy-Roberts stated that, should the CCAUV be so inclined, it could recommend to the CIPM who could put a resolution to the CGPM that this equipment be subject to mandatory calibrations.

The current status of standards at NMIJ/AIST was described by Dr Sato. He explained that calibration standards in the medical ultrasound area were currently under development. Dr Usuda then described the current status of work in the vibration area, outlining the published CMCs. In 2005, this capability would be extended down to a frequency of 0.1 Hz.

Ms Szelag (GUM) described activities ([CCAUV-04/33](#)) in the Sound, Vibration and Optical Division of the GUM. She listed the services provided in the acoustics and vibration laboratories and the key comparisons in which the GUM had participated. Dr Valdés asked about the GUM history of publications, with nine papers published over the last three years. Ms Szelag indicated that acoustics was an active field in Poland and these papers had been presented to the Polish Academy of Sciences and the Polish Acoustical Society. There is an annual conference with international participants and parts of the conference are in English.

Dr Echeverría-Villagomez detailed the advances made by the CENAM in the two years since the last CCAUV meeting, providing a *résumé* of the organisational changes. In the vibration area, there are two secondary laboratories and the CENAM provides five calibration and measurement services. In acoustics, there is currently only a single secondary laboratory. At the primary level, Dr Echeverría-Villagomez felt there were still scientific advances to be made, although over recent years a large proportion of the available effort had been devoted to international key comparisons. He felt that there was a need to strike a balance. His vision involved devolving measurement services to secondary laboratories, allowing the CENAM to concentrate on the delivery of value-added services. In the ultrasound area, take up of the services had been strengthened by a new written standard requiring the calibration of diagnostic ultrasound equipment. Other activities in the ultrasound area were the characterisation of transducers used for NDT and the characterisation of a force balance. An acoustic pressure measurement system was currently being developed, and Dr Echeverría-Villagomez acknowledged the role of the NPL in providing staff training and support.

7.2 Presentations on research areas

Dr Koch described four new areas of research at PTB related to the assessment of auditory brainstem response; a 2-D camera which was made from a multi-layer optically scanned hydrophone; the application of deconvolution methods to improve the uncertainty of hydrophone measurements and limitations of the simplified (exponential) relationship of the absorption of sound in air or water.

An illuminating treatise of the uncertainties associated with free-field, air-borne calibration methods was presented by Professor Rasmussen (DPLA). A first principle analysis was used to assess the contribution of various sources of uncertainty on the measurement: cross-talk, ground-loops, band-filtering, measurement distance and the nonlinear distortion. He considered the impulse response of the set-up, and demonstrated the effect of mounting and clamping. With careful control and

correction for the experimental conditions, differences between equivalent runs can be reduced to as little as 0.03 dB. Mr Robinson asked how the distance between the acoustic centres was determined. Professor Rasmussen said that this was done by careful alignment and repeated measurements at various distances. He raised the interesting question of whether the acoustic centre for the phase response of the microphone was the same as its magnitude response. A reliable determination of the separation was an issue affecting the most accurate measurements.

Dr Zeqiri gave an outline of the new three-year acoustical metrology programme at NPL, which started on 1 October 2004. He described the balance between the three areas: sound in air, underwater acoustics and medical and industrial ultrasound. A particular feature of the new programme was the high level of research for the development of new measurement standards, which comprised 40 % of the overall programme activity. Dr Zeqiri described a selection of these new areas, such as: measurements under simulated ocean conditions, the development of optical methods for calibration in underwater acoustics and the investigation of measurement techniques for characterising cavitation in high-power ultrasonic fields. One particularly exciting area was the intended development of a new type of microphone for air-borne sound measurement that is based on silicon MEMS technology.

Dr Wong raised the issue of the IEC TC 61672-1 document concerning the A-weighted tolerance limits that have been changed for sound level meters. After some discussion, he agreed to send a short paper explaining the problem to the CCAUV participants so that they could each take it up at a national level.

8 REGIONAL METROLOGY ORGANIZATIONS

8.1 Reports from regional representatives

The representatives of the regional metrology organisations gave a series of presentations. More extended descriptions may be found within their reports which had been written for the CCAUV meeting.

8.1.1 APMP

Dr Sato, the Chair of the APMP Technical Committee for AUV presented the [report for the APMP](#), which now comprised eleven member economies. One regional comparison (APMP.AUV.V-K1) had been completed with links established. Linking for APMP.AUV.A-K1 was currently in progress.

8.1.2 COOMET

Dr Enyakov described the [current position in the COOMET](#) on behalf of Dr Podzeeva. This RMO had recently been enlarged by the accession of North Korea and Uzbekistan. The current status of member CMCs was reviewed. The third Technical Committee meeting was held in Lvov (Ukraine) in September 2004, with the participation of experts in airborne acoustical measurements from NPL and DPLA.

8.1.3 EUROMET

Ms Szelag (GUM) gave a presentation which described [current activities within the EUROMET](#). The Technical Committee consists of four sub-committees each of which was coordinated by a permanent convenor: sound in air, underwater acoustics, ultrasonics, and acceleration and vibration. The report included a description of measurement trends.

8.1.4 SIM

The RMO report for SIM was presented by Dr Elias (CENAM). The status of the AUV comparisons was described; in particular, the low frequency accelerometer calibration, which involved five SIM NMIs, with the possible participation of two organisations from the APMP.

8.1.5 SADC MET

An [extensive report of the current status of SADC MET](#) was given by Mr Veldman (CSIR), covering an up-date of RMO membership and the Quality System status review. He acknowledged the support of Europe and the Americas in providing training for the African countries.

8.2 CCAUV Working Group on CMCs

It was noted that this WG would meet on the day following the CCAUV. It was for this reason that some participants had been invited to observe the CCAUV meeting. The JCRB matters would also be discussed during the WG meeting.

9 REPORTS FROM INTERNATIONAL OBSERVERS

9.1 IEC

9.1.1 TC 87

Dr Zeqiri gave a brief report on the activities of TC 87 “Ultrasonics”, where the major changes had been the accession of new Officers, with both the Chairman and Secretary being replaced. Progress on a number of documents had been prevented due to the long-standing difficulty in resolving the issue of the Chairman. The IEC TC 87 meeting had been held in Hangzhou (China) during the week prior to the CCAUV meeting.

9.1.2 TC 29

Professor Rasmussen presented the [TC 29 report](#), providing information on the standards currently at the final draft of the international standard (FDIS) stage, with the relevant voting dates.

9.1.3 IEC 565 UAT

On behalf of Dr van Buren, Dr J. Zalesak up-dated the CC on the progress on IEC 565. This had also been discussed at the Hangzhou TC 87 meeting, and the latest draft of the proposed revision has now been prepared as a Committee draft for vote (CDV).

9.2 ISO

Dr von Martens gave the [report from the ISO](#); in particular, the progress made by TC 108/SC 3 towards key comparisons and traceability of vibration and shock.

10 MEMBERSHIP OF THE CCAUV

10.1 Criteria for membership

Professor Wallard detailed the requirements for membership of the CIPM Consultative Committees. He explained that, after the General Conference which is held every four years, the members of each Consultative Committee are scrutinised to ensure their continued validity. The CIPM believes that the Consultative Committees are becoming too large, and that the criteria should be applied more strictly so that there are fewer full members and perhaps more with observer status. He outlined the

criteria for full membership: that they should be a recognised institute at national level, taking part in comparisons, undertaking research and publishing in peer-reviewed international journals. Another key requirement that he emphasised was the need to participate actively in the meetings.

10.2 Proposals for future CCAUV membership

Professor Wallard was disappointed to note that eight laboratories had not submitted reports covering their research activities. Whilst the final decision was in the hands of the President, Dr Valdés, Professor Wallard offered some other personal observations on the way forward for the CCAUV. He recommended that: for Italy, IEN should retain “member” status, with IMGc acquiring “observer” status; the NMI (Netherlands), the NPLI (India) and METAS (Switzerland) should become observers; the GUM (Poland) should become a full member; the CEM (Spain) should be invited to become an observer until they have developed sufficient expertise to become a full member.

The CCAUV noted the criteria and the recommendations of the Director. The GUM had indeed submitted a written request to the Director with documentary support to become a full member.

11 PROPOSALS FOR CCAUV WORKING GROUPS

There were no proposals to form a CCAUV working group other than the RMO WG.

12 CCAUV OPEN DOCUMENTS

The concept of making the CCAUV working documents available with open access was approved on condition that they were: not confidential; not reports in draft form and not papers for publication elsewhere. The Executive Secretary would confirm the status with the authors before making the documents open access.

16 DATE OF NEXT MEETING

The CCAUV agreed that the next meeting should be held in the autumn of 2006.

B. Zequiri, *Rapporteur*

December 2004

Appendix A 1. WORKING DOCUMENTS SUBMITTED TO THE CCAUV AT ITS 4TH MEETING

Open working documents of the CCAUV can be obtained from the BIPM in their original version, or can be accessed on the BIPM website:

(<http://www.bipm.org/cc/AllowedDocuments.jsp?cc=CCAUV>).

Document
CCAUV/

- 04-00 BIPM. — Draft agenda, P.J. Allisy-Roberts, 3 pp. (not open access)
- 04-01 BEV (Germany). — Draft technical protocol for CCAUV comparison CCAUV.A-K2; see CCAUV/04-34, M. Sinojmeri, 7 pp. (not open access)
- 04-02 PTB (Germany). — Update for the COOMET.AUV.A-K1 comparison, R. Reibold, 1 p. (not open access)
- [04-03](#) PTB (Germany). — Report on the PTB national standards, R. Reibold, 3 pp.
- [04-04](#) PTB (Germany). — Research areas at the PTB, R. Reibold, 4 pp.
- [04-05](#) PTB (Germany). — Progress in the EUROMET.AUV.V-K1 regional key comparison, H.-J. von Martens, 9 pp.
- [04-06](#) ISO, PTB (Germany). — Report of the ISO international observer, H.-J. von Martens, 5 pp.
- 04-07 PTB (Germany). — Linking the results of the regional key comparison APMP.AUV.V-K1 to those of the CIPM key comparison CCAUV.V-K1 (draft final report), H.-J. von Martens, C. Elster, A. Link, W. Wöger and P.J. Allisy-Roberts, 9 pp. (not open access)
- [04-08](#) CSIR-NML (South Africa). — CSIR-NML Report to the CCAUV, C.S. Veldman, 3 pp.
- [04-09](#) SADC MET, CSIR-NML (South Africa). — SADC MET regional activities, C.S. Veldman, 4 pp.
- 04-10 DPLA (Denmark), IEN (Italy). — Progress in the EUROMET.AUV.A-K3 regional key comparison, K. Rasmussen and C. Gugliemone, 1 p. (not open access)
- [04-11](#) IEC, NUWC (United States). — Report from the Working Group 8 of IEC TC87 (Ultrasonics), A.L. Van Buren, 1 p. (not open access)
- 04-12 CENAM (Mexico), DPLA (Denmark) — International comparison CCAUV.A-K3, progress report, V. Cutanda Henríquez and K. Rasmussen, 1 p. (not open access)

Document
CCAUV/

- [04-13](#) IEC, DS and DTU (Denmark)— Report from IEC TC 29: Electroacoustics, L. Nielsen and K. Rasmussen, 4 pp.
- [04-14](#) VNIIFTRI (Russian Fed.), HAARI (China).— A Russian-Chinese comparison of hydrophone calibrations methods in the low-frequency range, A.M. Enyakov, S.M. Likhachev, Yuan Wenjun and Chen Yi, 9 pp.
- [04-15](#) VNIIFTRI (Russian Fed.).— Current status and prospects for development in Russia of underwater acoustics in the MHz frequency range, A.M. Enyakov, 18 pp.
- 04-16 CENAM (Mexico)— Progress Report on SIM.AUV.A-S1, pistonphone acoustical calibrators, A. Elias, 1 p. (not open access)
- 04-17 SIM, CENAM (Mexico)— Draft technical protocol for SIM comparison on acceleration at low frequencies, G. Silva, 8 pp. (not open access)
- [04-18](#) SIM.— SIM Acoustics & Vibration Report, A. Elias, 2 pp.
- [04-19](#) NRC (Canada).— INMS-NRC Status report of acoustical standards, G.S.K. Wong, 2 pp.
- 04-20 NPL (United Kingdom).— Draft B report for CIPM key comparison CCAUV.U-K2, B. Zeqiri, 37 pp. (not open access)
- [04-21](#) DPLA (Denmark).— Short report on DPLA activities, K. Rasmussen, 2 pp.
- 04-22 NPL (United Kingdom).— Final report on the EUROMET.AUV.A-K1 comparison of sound pressure standards (EUROMET Project 399) for CCAUV approval, R. Barham, 22 pp. (not open access)
- [04-23](#) NPL (United Kingdom).— The acoustical metrology programme at the NPL, B. Zeqiri, 23 pp.
- 04-24 NPL (United Kingdom).— Provisional draft B report on key comparison CCAUV.W-K1, S. Robinson, 80 pp. (not open access)
- 04-25 NMIJ/AIST (Japan).— Progress report on regional key comparison APMP.AUV.A-K1, S. Sato, 2 pp. (not open access)
- [04-26](#) APMP.— Report from APMP, S. Sato, 2 pp.
- [04-27](#) BIPM.— Brief guidelines for linking RMO key comparisons to the CIPM KCRV, P.J. Allisy-Roberts, 2 pp.
- 04-28 CCU.— Units for quantities that describe biological effects, I. Mills, 4 pp. (not open access)
- [04-29](#) COOMET.— Report from the COOMET, V. Pozdeeva, 6 pp.
- [04-30](#) EUROMET.— AUV annual report from the EUROMET, M. Szelag, 6 pp.

Document
CCAUV/

- 04-31 NIST (United States).— Progress report on key comparison SIM.AUV.V-K1, D.J. Evans, 1 p. (not open access)
- 04-32 SIM.— On the linking of SIM.AUV.A-K1 comparison to CCAUV.A-K1, A. Elias, 17 pp. (not open access)
- [04-33](#) GUM (Poland).— Brief report on acoustics and vibration from the GUM, M. Szelag, 3 pp.
- 04-34 BEV (Germany).— Technical protocol for key comparison CCAUV.A-K2, M. Sinojmeri, 10 pp. (not open access)
- [04-35](#) NRC (Canada).— The A-weighting tolerance limits of current sound level meters, G.S.K. Wong, 3 pp.