BUREAU INTERNATIONAL DES POIDS ET MESURES

Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV)

Report of the 7th meeting
(20 - 21 October 2010)
to the International Committee for Weights and Measures

Comité international des poids et mesures

Note:

Following a decision of the International Committee for Weights and Measures at its 92nd meeting (October 2003), reports of meetings of the Consultative Committees are now published only on the BIPM website and in the form presented here.

Full bilingual versions in French and English are no longer published.

Working documents for the meetings are listed at the end of the report and those which the Consultative Committee decides are for public use are also available on the website.

M. Kühne,
Director BIPM

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

as of 20 October 2010

President

J. Valdés, member of the International Committee for Weights and Measures

Executive Secretary

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

Members

Central Office of Measures/Glówny Urzad Miar [GUM], Warsaw.

Centro Nacional de Metrología [CENAM], Querétaro.

Laboratoire National de Métrologie et d'Essais [LNE], Paris.

D.I. Mendeleyev Institute for Metrology [VNIIM], Rostekhregulirovaniye of Russia, St Petersburg.

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

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

Istituto Nazionale di Ricerca Metrologica [INRIM], 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], Lindfield.

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

National Metrology Institute of South Africa [NMISA], Pretoria.

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

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

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

Observers

Agency for Science, Technology and Research [A*STAR], Singapore.

Bulgarian Institute of Metrology [BIM], Sofia.

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

Centro Español de Metrología [CEM], Madrid.

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

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

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

Instituto Português da Qualidade [IPQ], Lisbon.

Institutul National de Metrologie [INM], Bucharest.

International Electrotechnical Commission [IEC], Geneva.

International Organization for Standardization [ISO], Geneva 20.

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

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

VSL [VSL], Delft.

1 OPENING OF THE MEETING: APPOINTMENT OF A RAPPORTEUR APPROVAL OF THE AGENDA

The Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV)* held its 7th meeting at the International Bureau of Weights and Measures (BIPM) in Sèvres on Wednesday 20 and Thursday 21 October 2010.

The following delegates and experts were present: Ph. Averlant (LNE), R. Barham (NPL), T. Bruns (PTB), W.S. Chung (KRISS), Z.M. Defilippo Soares (INMETRO), J.N. Durocher (LNE), D. Dobrowolska (GUM), J.S. Echeverría-Villagómez (CENAM), S. Barrera-Figueroa (DFM), C. Guglielmone (INRIM), T. Kikuchi (NMIJ/AIST), C. Koch (PTB), J. Kolasa (GUM), T.R. Licht (DPLA), A.L. Lopez-Sanchez (CENAM), V. Nedzelnitsky (NIST), R. Nel (NMISA), A. Paolero (NIST-USRD), K. Rasmussen (DFM/DPLA), G. Ripper (INMETRO), S. Robinson (NPL), D. Rodrigues (LNE), E. Sadikoglu (UME), A. Scott (NMIA), G. Silva-Pineda (CENAM), Q. Sun (NIM), T. Usuda (NMIJ/AIST), J. Valdés (President of the CCAUV), C.S. Veldman (NMISA), A.J. Wallard (Director of the BIPM), L. Wu (NRC-INMS), P. Yang (NIM), B. Zeqiri (NPL).

Observers: H.A. Chua (A*STAR), I. Godinho (IPQ), C. Hof (METAS), A.E. Isaev (VNIIFTRI), A. Konkov (VNIIFTRI), M.N. Medina (CEM).

Participants from the BIPM were: P.J. Allisy-Roberts (Executive Secretary), M. Kühne (Deputy Director of the BIPM), S. Picard (future Executive Secretary), C. Thomas (Coordinator of the BIPM KCDB).

Apologies were received from: M. Blabla (CMI), A. Enyakov (VNIIFTRI), R. Koops (VSL), A. Leitner (BEV), A. Pepelyshev (VNIIM), V. Pozdeeva (BelGIM), E. Sandermann-Olsen (BKSV-DPLA), S. Van den Berg (VSL), H.-J. von Martens (ISO TC108).

The Director of the BIPM, Prof. Wallard, welcomed the delegates to the 7th meeting of the CCAUV, noting that this would be his last meeting before retiring as Director. He explained that his successor, Prof. Kühne, was attending a parallel meeting but would join the CCAUV meeting later. He reminded delegates of the BIPM's safety rules.

The President of the CCAUV, Dr Valdés, added his welcome and commented that there were more than 29 documents listed in the agenda for discussion. Dr Valdés stated that the CCAUV has linked together seven key comparisons, in acoustics and for vibration, and noted that the CCAUV is the first CC to have achieved this. He presented a diagram illustrating the seven linked KCs and regional key comparisons for the pressure sensitivity of LS1P microphones at 1 kHz, commenting that this demonstrates the CIPM MRA in action and represents 10 years of work. A similar diagram of the calibration of back-to-back accelerometers at 160 Hz was also shown. Altogether, five such groups have now been completed in different metrological fields, of which two are from the CCAUV.

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* For a list of acronyms, click here.

Dr Valdés summarized the results of two CCAUV working group meetings which took place in the days before the CCAUV meeting. The Strategic Planning Working Group (SPWG) reached a consensus on the format and terms of reference for their activities. The Regional Metrology Organizations Working Group (RMOWG) reviewed material and guidance published by the JCRB, CMCs and considered corrections to lists of services. Further details of these meetings are given in Section 6.

Dr Valdés reported that at the 99th meeting of the CIPM, which had taken place the week before the CCAUV meeting, the definition of the base units of the SI were discussed and discussions are under way on the redefinition of the kilogram, the mole, the ampere and the kelvin. A re-determination of the Boltzmann constant will be required for the redefinitions and measurements of the speed of sound will play a central part. Research in this area is presented in Section 7.2.

Dr Valdés mentioned a recently published special issue of *Metrologia* on the topic of materials metrology. The special issue included contributions from the AUV field. He asked delegates to prepare research highlights on real achievements that could be collated and presented to the CGPM meeting in 2011 as part of the President's report.

The delegates were invited to introduce themselves.

The Director Designate of the BIPM, Prof. Kühne, joined the meeting on the second day. He provided a short account of his career in metrology, from his time at the PTB, beginning in 1977, through to his work establishing EURAMET as a legal entity. Prof. Kühne joined the BIPM as deputy director in 2009. He will take up his position as Director in January 2011.

Dr Allisy-Roberts announced that she will be stepping down as Executive Secretary of the CCAUV. Dr Susanne Picard, BIPM, will take over from the 1 January 2011. Dr Valdés noted that Dr Allisy-Roberts had provided excellent service to the CCAUV. Later in the meeting, a special certificate endorsed by all the CCAUV participants was presented to Dr Allisy-Roberts, commending her efforts and contributions.

Dr Valdés reported that CCAUV member Dr George Wong had died since the last meeting. Dr Wong was an original member of CCAUV and a lively contributor to its work. A one-minute silence was observed in his memory.

Dr Allisy-Roberts and Dr Valdés proposed Dr Barham as rapporteur of the meeting, and this was approved.

The agenda was adopted without any changes or additions, noting the recent inclusion of two documents generated in the RMOWG meeting.

2 REPORT OF THE 6TH MEETING OF CCAUV, 2008

Dr Valdés invited comments on the report of the 6th meeting of the CCAUV. There were no comments and the report was confirmed. Dr Valdés and Dr Allisy-Roberts thanked Dr Echeverría-Villagómez for his efforts as Rapporteur over the last two years.

3 CCAUV KEY COMPARISONS

Dr Allisy-Roberts gave an overview of the status of CCAUV key comparisons. Three key comparisons have been completed since the last meeting of the CCAUV, two are in progress, and one new future key comparison is for discussion.

3.1 Published comparisons

Dr Allisy-Roberts gave an overview of the status of the comparisons in the key comparison database (KCDB), highlighting the following:

- CCAUV.A-K2: Final report, KCRV and results available (2009);
- CCAUV.A-K4: Final report, KCRV and results available (2010);
- CCAUV.V-K1.1: Final report, links and results available (2010).

3.2 Reports of comparisons in progress

3.2.1 CCAUV.U-K3

Dr Koch explained that there had been some problems with the CCAUV.U-K3 comparison but these have now been resolved. This key comparison was suggested at the 5th meeting of the CCAUV and was formally agreed at the 6th meeting. Measurements began in 2008, with the original intention of having the Draft A report available in 2011. However, progress was delayed by technical problems at the third participant NMI.

The problem was found to be a broken connection in the reference transducer. It was promptly repaired by the pilot laboratory and returned to the first participant for re-measurement. However, a further problem with water ingress was discovered and the transducer was returned to the PTB. A second more extensive repair was made and the transducer was placed in a dryer to remove the remaining water. The repaired device was subjected to soak-testing and the effectiveness of the final repairs was confirmed. The PTB carried out further measurements on the repaired device and the results showed only a small increase in response, with a slightly larger deviation above 15 MHz, relative to measurements before the repairs. It was further shown that variations in the response of the device were not significant with respect to the measurement uncertainties. The PTB therefore proposed to continue using the repaired transducer and the participants agreed. The results from the PTB before and after the repair were used to correct the results from the first, second and fourth participant NMIs.

The project is now following a revised schedule where the last participant is due to complete its measurements in August 2011. The Draft A report is expected in December 2011 after which the next hydrophone key comparison will begin.

Dr Koch thanked the participants for their patience and support while investigating the problems.

A question was raised regarding the magnitude of the deviation in the transducer performance in the context of medical applications. The deviations are smaller than the measurement uncertainty which itself is one order of magnitude smaller than the typical uncertainties achieved in medical applications (around 1 % compared to 20 % or 30 %).

3.2.2 CCAUV.V-K2

Dr Bruns reviewed progress on the CCAUV.V-K2 key comparison which is piloted by the PTB. It involves the magnitude and phase charge-sensitivity calibration of two types of artefacts; one single-ended and one back-to-back accelerometer in the frequency range from 10 Hz to 10 kHz.

The measurement schedule is in progress. However, because of the high ambient temperatures recorded during the measurements made at the UME, these measurements will be repeated at the end of the key comparison.

Dr Bruns stated that the measurements show some 'peculiarities'.

(a) PTB measurements on the single-ended accelerometers indicate a systematic difference, which is apparent above 3 kHz, mostly dependent on the exciter armature material (these are either made in beryllium or ceramic). Back-to-back devices are not affected. Possible solutions include requesting participants to state their armature material, especially for the bespoke exciter, and to split the analysis into two groups, e.g. considering results above 3 kHz separately.

(b) The single-ended transducers appear to be very stable. The PTB has records covering more than 800 days before the start of the key comparison to 300 days after. However, the stability of back-to-back devices, which were initially satisfactory, subsequently showed a linear increase in sensitivity. The pattern is evident in the PTB data and in the data from participants and will therefore need to be taken into account during the analysis.

Dr Bruns described a potential anomaly with the phase convention used for back-to-back accelerometers. On an upright device, the output voltage is in phase with the applied acceleration but when the device is inverted, as in the back-to-back configuration, the phase also inverts and some correction is necessary to restore the correct time convention.

3.3 Future comparison proposals

3.3.1 CCAUV.A-K5

Dr Barham presented a recently circulated draft protocol for a new key comparison, CCAUV.A-K5, on the pressure calibration of type LS1P microphones. The key comparison was proposed at CCAUV-6 in 2008 where it was suggested that the scope should be as challenging as possible. The pilot laboratory, NPL, carried out a survey by questionnaire to identify the capabilities of potential participants. A set of objective selection criteria was used to select the final participants. These participants were confirmed during the meeting. Dr Barham described the scope, which implies measurements covering the frequency range from 2 Hz to 10 kHz, including both magnitude and phase calibration.

The key comparison is scheduled to begin in January 2011, with measurements completed by March 2012. The schedule has been arranged with the intention that the pilot laboratory can be in a position to seek approval of a Draft A report at the next CCAUV meeting (assuming that the meeting takes place around October 2012).

A few comments were received following circulation of the draft and these were summarized in the presentation. There was a discussion to clarify certain details, including the frequency resolution in the lower frequency range and the precision to which the frequency should be set.

Dr Barham confirmed that the comments received would be incorporated into the final protocol.

NIST raised the issue of the inclusion of phase calibration. It was argued that in some cases, the magnitude calibration uncertainty can be compromised by facilitating phase measurement. Systems designed to optimize magnitude performance might not be able to measure the phase response sufficiently well. However, those participants present at the meeting did not regard this as a problem with their particular systems. It was therefore agreed that a bilateral comparison would be organized with NIST, following completion of the measurements for this key comparison.

3.3.2 Other proposals

A new key comparison in the field of underwater acoustics has been proposed. This concerns pressure calibration of hydrophones using the coupler reciprocity method. It is expected that there will be fewer participants compared to free-field comparisons (CCAUV.W-K1). The key comparison will cover the frequency range from 20 Hz to 1 kHz. The pilot laboratory is the NPL and the participants currently include the NIST-USRD and the VNIIFTRI. However, Mr Robinson requested that other potential participants contact him, as a key comparison with only three participants is hardly viable. The meeting discussed potential additional participants: China (the delegates from the NIM need to discuss participation with the relevant institute) and India. Ukraine has expressed an interest in participating but it presently has the status of Associate Member of the CGPM. A draft protocol will be prepared based on initial participation of the six NMIs noted above.

Dr Zeqiri presented an update on the agreed future key comparison CCAUV.U-K4 concerning the primary calibration of hydrophones in the frequency range from 1 MHz to 20 MHz. The pilot laboratory is the NPL and the key comparison was due to begin around April 2010. However, problems at the NPL prevented the key comparison from starting. These have now been resolved, but a further six months is needed to fully validate the system and the reference standards at the NPL. A new start date of spring 2011 was proposed. A request was made to update the list of interested participants with the following institutes: The NPL (pilot), INMETRO, NIM, NMIJ/AIST, PTB and (possibly) KRISS are interested in participating; the INRIM and UME are not able to participate at the present time.

4 REGIONAL KEY COMPARISONS

4.1 Published results

Dr Allisy-Roberts summarized the regional comparisons that had been completed since the 6th meeting of the CCAUV. These include:

- APMP.AUV.A-K1.1, report published 2009;
- APMP.AUV.V-K1.2, report published 2010;
- COOMET.AUV.A-K1, report published 2009;
- COOMET.AUV.A-K1.1, report published 2009;
- EURAMET.AUV.V-K1.1, report published 2010;
- SIM.AUV.V-K1, report published 2009.

4.2 Reports for approval

4.2.1 COOMET.AUV.A-K2

The bilateral key comparison COOMET.AUV.A-K2, between DP NDI 'Systema' and the VNIIFTRI concerning low frequency pressure calibration of type LS1P microphones, links to CCAUV.A-K2 via the VNIIFTRI. Measurements have been carried out in the frequency range from 2 Hz to 250 Hz, with typical measurement uncertainties between 0.1 dB and 0.14 dB. The reference standard exhibited good stability during the 2-month measurement period. The degrees of equivalence have been calculated and agreement between the results was identified as being consistent with the declared uncertainty.

The final report was presented for approval, which was granted without comment.

4.2.2 APMP.AUV.A-K3.1

The bilateral key comparison APMP.AUV.A-K3.1, between KRISS and KIM-LIPI, on the pressure calibration of type LS2P microphones, links to CCAUV.A-K3 via KRISS. Results were presented illustrating a high degree of compatibility between the two participating laboratories. Degrees of equivalence were calculated and the difference was identified as being consistent with the declared uncertainty.

The final report was presented for approval, and approval was granted without comment.

4.3 Measurements in progress

4.3.1 APMP.AUV.V-K1.1

Key comparison APMP.AUV.V-K1.1 is intended to link with CCAUV.V-K1 and was originally scheduled for completion in 2009. Dr Usuda reported that there had been some communication problems which resulted in delays, but the measurements were finally completed in March 2010. The Draft A report will be prepared for the next APMP AUV meeting.

4.3.2 EURAMET.AUV.U-K2

It was decided (subsequent to the meeting), that there is no longer a need to conduct key comparison EURAMET.AUV.U-K2, since all the potential participants are involved in CCAUV key comparisons.

4.3.3 EURAMET.AUV.V-K1.2

EURAMET.AUV.V-K1.2 is a bilateral key comparison between METAS and the PTB concerning the calibration of single-ended and back-to-back accelerometers. METAS participated in an earlier EURAMET key comparison using equipment that has subsequently been replaced. This bilateral key comparison aims to establish the new facility following the same procedure as in the original key comparison. METAS carried out its measurements in October 2008 and the PTB in March 2009. Both types of device showed very favourable results that were consistent with the measurement uncertainties, apart from one value at 8.5 kHz. At this frequency, the results showed a high standard deviation for different interferometry measurement locations on the surface of the transducer. This known problem due to resonances will, once properly accounted for in the measurement uncertainty, result in better consistency between the participants. A Draft B report will be circulated.

4.4 Reports in progress

4.4.1 SIM.AUV.V-K1.1

There has been no further progress on the Draft B report for SIM.AUV.V-K1.1. It is not expected to be finished before 2011.

4.5 Proposals for future comparisons

The NIM presented a proposal for a new regional key comparison on low-frequency vibration measurements. The driver for this key comparison was the major earthquake in 2008 in southern China. Since the devastation caused by the earthquake, the area has been regenerated with new buildings and infrastructure. New regulations introduced since the earthquake, required the installation of on-site advanced sensors, including low-frequency vibration sensors, for detecting

earthquake susceptibility. Therefore, the APMP was given the task of proposing and piloting a key comparison on low-frequency vibration measurement.

An initial survey among the APMP members, conducted by questionnaire, found seven interested participants. Further support for the project objectives came from member states which do not have this measurement capability. A lower frequency limit for the comparison at 0.5 Hz appears realistic with the present general capabilities, but the NIM would like to see an even lower limit of 0.1 Hz.

A second survey investigated which types of transducer would be suitable for such a key comparison. Quartz flexure servo accelerometers have been identified as having a suitably flat frequency response over the proposed range of the comparison. Furthermore, the NIM has investigated the magnitude and phase stability of such a device and identified that both parameters appear to be stable. The traceability of a.c. voltage measurements in this frequency range is another issue. However, it appears that suitable traceability is available.

A video clip of the operation of a driver system and the associated equipment operated at 0.1 Hz was shown during the presentation. During the NIM presentation a question was raised about whether a regional key comparison can be run before a CC key comparison. In principle this did not present a problem because many participants in the regional key comparison are also members of the CCAUV. However, a problem was identified with assigning a code number to the regional key comparison when there is no corresponding CCAUV key comparison registered. The solution will be to designate it as a supplementary comparison.

Dr Bruns reported that EURAMET plans to run a similar comparison on low frequency calibration, but it is not yet in a position to propose a CCAUV key comparison.

Dr Valdés commented that it was encouraging to see links being made between fundamental metrology and the needs of society.

4.6 Linking regional comparisons

4.6.1 APMP.AUV.A-K3

The Draft B report for key comparison APMP.AUV.A-K3 was completed in 2007 and the results are pending linkage to the CCAUV.A-K3 comparison. The pilot laboratory sought advice from the CCAUV-KCWG, and the task of carrying out the linking was assigned to a member of the BEV. This staff member has now left the CCAUV and the task remains incomplete. The KCWG is now tasked with completing this linking exercise as a matter of priority.

5 SUPPLEMENTARY COMPARISONS

5.1 Measurements in progress

5.1.1 APMP.AUV.A-S1

The measurements for supplementary comparison APMP.AUV.A-S1 were completed in March 2010 and the Draft A report will be discussed at the APMP meeting in November 2010.

5.1.2 EURAMET.AUV.A-S1

Measurements for EURAMET.AUV.A-S1 were completed in 2010, and a Draft A report is in preparation. The KCDB was updated during the meeting to reflect this status.

5.2 Reports in progress

5.2.1 COOMET.AUV.A-S1

The Draft A report is in preparation.

5.2.2 SIM.AUV.A-S1

The Draft A report is under discussion.

5.2.3 COOMET 473/RU/09

The pilot study COOMET 473/RU/09 on free-field calibration of hydrophones is in the frequency range from 250 Hz to 250 kHz. The participants in the project are the HAARI (pilot) and the VNIIFTRI. The objectives of the study are to:

- determine the consistency in the free-field sensitivity obtained from measurements in a reverberation tank;
- extend the calibration range to low frequencies;
- prepare for a key comparison on low frequency calibration.

Traditional free-field calibration has a lower limiting frequency of between 1 kHz and 3 kHz; pressure calibrations are typically applied at lower frequencies.

The HAARI uses a vibrating liquid column method to determine the pressure sensitivity below 1 kHz and free-field calibration above this frequency.

The VNIIFTRI uses only free-field calibration using a large water tank. However, different techniques are used in different parts of the frequency range.

Results from the two laboratories were presented. For a Brüel and Kjær hydrophone the results showed an almost constant small difference of approximately 0.28 dB across the frequency range with the VNIIFTRI's free-field sensitivity typically exceeding the HAARI's pressure sensitivity. Typical measurement uncertainties are approximately 0.6 dB.

For a type TC 4032 hydrophone, results from the VNIIFTRI were typically lower than those of the HAARI.

Sources of uncertainty in both pressure and free-field calibration need further investigation to facilitate a better comparison of measurements. In particular, it is noted that the uncertainty in pressure calibration increases significantly above 500 Hz.

6 REPORTS FROM WORKING GROUPS

6.1 AUV metrology for materials

Although no formal working group on materials metrology has been set up, the CCAUV contributed to a special issue of *Metrologia* covering the subject. It was edited by Dr Valdés and Dr Seton-Bennett[1] of the NPL. It included contributions from a wide range of disciplines including a paper prepared jointly by the NPL and the PTB. Dr Valdés encouraged the CCAUV to pursue activities in this field. He noted that this topic has so far only been covered briefly and he raised the possibility of producing a second special edition of *Metrologia* on the subject.

6.2 AUV strategic planning working group (CCAUV-SPWG)

The chairman of the AUV strategic planning working group (CCAUV-SPWG), Dr Zeqiri, reported on the meeting held on 18 October 2010. He thanked the working group members for their constructive contributions. The two main tasks considered in the meeting were to define terms of reference for the working group and to initiate a process for updating the document on 'Future needs in AUV metrology'.

A key outcome of the meeting was an agreement on the terms of reference of the working group, which are to:

- establish a view on the emerging metrology requirements for AUV and the way that these are driven by societal and industrial needs of stakeholders;
- provide input within the area of AUV into the CIPM "Future Needs in Metrology" documents;

[1] Also member of the CIPM.

- advise the CCAUV on the optimal operating structure e.g. for information gathering, collation and dissemination;
- share information on national priorities (road mapping etc.) for emerging metrology, helping NMIs to formulate improved metrological programmes;
- identify areas suitable for collaboration, thereby allowing impact to be accelerated;
- monitor and respond to developments within other CCs (including the future of the SI) which might impact the CCAUV;
- identify developments needed for AUV measurement of properties relevant to "Materials Metrology".

The terms of reference were reviewed by the CCAUV and it was suggested that an additional point addressing 'key technologies that may provide solutions to the highlighted challenges' should be included.

A discussion followed on whether the documents that are considered and produced by this working group should be made available to all members of the CCAUV. In general it was felt that the CCAUV should have access to the SPWG documents as they are likely to have an impact on the operation and future work priorities of the CCAUV.

The CCAUV pioneered the approach to strategic planning by producing a document highlighting future needs for metrology. This document has been available for some time and now needs to be updated. The working group agreed to approach this task with a questionnaire survey. The survey will revisit existing topics to identify who is active in research in the particular areas of interest and will identify emerging areas. The responses to the questionnaires will be gathered before August 2011, and will then be compiled into an updated report that Dr Valdés can use to report to the meeting of the CGPM in October 2011. The updated report will be available on the CCAUV website.

A discussion considered the topic of physiological quantities and effects on the human body. A meeting on this topic was held at the BIPM in November 2009, and the report of the meeting prompted some questions. The CCAUV will consider whether a response is warranted. Prof. Kühne invited the CCAUV to provide input to the next SI brochure which will include physiological parameters. It was noted that such input had been provided for a previous issue of the brochure, but that the contribution was not included in the final version. If this activity goes ahead it was proposed that this should be a matter for the CCAUV rather than the SPWG alone.

6.3 Key comparisons working group (CCAUV-KCWG)

Dr Allisy-Roberts reported that there had not been much activity in the Key comparisons working group (CCAUV-KCWG) to date, but noted the action to establish a linking mechanism for the APMP.AUV.A-K3 comparison. Membership of the working group was reviewed and requests were received by INMETRO, NPL and NMIJ/AIST to nominate additional delegates to the working group, bringing the total number to seven. The NPL suggested that in their case it would be more appropriate for a colleague from the mathematical support group, rather than an AUV specialist, to participate.

6.4 Regional metrology organization working group (CCAUV-RMOWG)

A report on the Regional metrology organization working group (CCAUV-RMOWG) is given in section 8.2.

7 CONTRIBUTIONS FROM PARTICIPANTS

7.1 Status of national standards

7.1.1 NMIA

Dr Scott gave a presentation on activities at the NMIA. Rather than focus on calibration techniques in development as in past presentations, Dr Scott provided an overview of the group noting that Dr Narang has now left the NMIA.

Industry and society are the drivers in deciding the scope and depth of services offered. Around 150 calibrations per year are provided, and with just two staff members, this occupies most of the time available. Approximately 50 % are microphone calibrations, 20 % are accelerometer calibrations and 17 % sound calibrators. A third staff member recently joined the group and will be responsible primarily for vibration activities.

The group implements microphone reciprocity calibrations, mostly for internal use, and offers comparison calibrations to clients. A three-port reciprocity coupler is still used and demonstrates excellent stability. The group also implements low-frequency calibration of microphones using a large volume sealed chamber. Calibrations from 1 Hz are possible with a measurement uncertainty of 0.4 dB. Free-field substitution comparison calibrations on microphones are also carried out. These mostly come from environmental monitoring applications.

Primary calibration of reference grade accelerometers is possible for vibration measurements, but calibrations for customers are typically carried out by comparison.

The group has a primary standard radiation force balance for the measurement of ultrasonic power. The related uncertainty budget is currently under review with the intention of seeking ISO 17025 accreditation. A new facility for the calibration of mechanical couplers (artificial mastoids) is also being established.

7.1.2 DFM

Dr Barrera-Figueroa gave a brief summary of the activities at the DFM. He reported that new topics of research include:

- optical methods of acoustic calibration (a significant new area of research);
- continued efforts on low-frequency calibration of microphones;

- calibration of microphones in the extended high-frequency range addressing requirements of airborne ultrasound measurement;
- ear simulator calibration for audiometry applications;
- quantification of accelerometer calibration rigs.

Dr Barrera-Figueroa reported that one institute working in the field of ultrasound is awaiting a formal announcement as a newly Designated Institute (DI).

A question was raised about the distinction between DPLA and DFM. It was explained that DPLA is an instrument used within the Danish metrology infrastructure but does not exist as a legal entity. In fact, the DPLA is a cooperation between the DFM with BKSV (Brüel and Kjær), the latter being a DI. Calibration responsibilities are shared between these two organizations depending on the service required. For example, requirements for free-field calibration are dealt with at the DFM and pressure calibration by the BKSV-DPLA. Both institutes maintain CMCs but in different areas.

7.1.3 NMIJ/AIST

Dr Kikuchi gave a presentation on recent developments in acoustics and ultrasound at NMIJ/AIST.

He reviewed the calibration capabilities and facilities for microphones, sound calibrators and sound level meters. In particular, a new capability to calibrate WS3 (quarter-inch) microphones was described. A compact free-field chamber is being used to deal with requirements from industry for measurement standards for sound-in-air in the ultrasound region (20 kHz to 100 kHz). The measurement uncertainty is typically 1 dB.

There are plans to establish new standards in the infrasound region using a laser pistonphone. A prototype facility was shown and further developments are scheduled for 2011.

A new facility for sound power measurements using a hemispherical array of microphones is scheduled for development around 2014.

A similar outline of capabilities for ultrasound measurement was described, including:

- ultrasound power standards using the radiation force balance;
- hydrophones calibrated using laser interferometry;
- measurement of ultrasound field parameters.

A new ultrasound calibration facility using an acoustically transparent pellicle was reported. However, this suffers from a requirement to be close to the source to avoid the impact of absorption to the medium. A focused optical beam is used for this purpose, but this gives rise to problematic acousto-optic effects. To overcome these problems, an air pellicle was developed that has the advantage of no acousto-optic interactions. The setup process is the same as for conventional pellicles, and the signal-to-noise ratio is improved by virtue of a doubling in vibration amplitude.

Further new techniques in development include:

- high power ultrasound measurement in the range up to 500 W using a water calorimeter;

- calibration of cavitation sensors following NPL's lead, including a comparison with chemical indicator methods;
- robust hydrophones for high-intensity focused ultrasound (HIFU) applications.

Dr Usuda described four vibration measurement facilities, which together cover the frequency range from 0.1 Hz upwards. In addition, a shock exciter system capable of generating accelerations up to 5 000 m s^{-2} was presented, and issues on longitudinal resonances and corresponding accelerometer frequency responses were discussed.

7.1.4 INRIM

Dr Guglielmone reported the establishment of a Centre for Ultrasound to provide better characterization of medical ultrasound devices and support for hospitals.

He reported that the responsibility for accreditation is no longer covered by the INRIM, although technical assessors are still provided by the laboratory.

Dr Guglielmone described new measurement capabilities including:

- extension in ultrasonic power standards to 100 W with corresponding changes to CMCs;
- new services relating to the use of ultrasound in medicine including verification of physiotherapy devices;
- material testing for building acoustics to comply with new regulations, including noise isolation performance.

Work in the field of vibration is currently limited to delivery of services and support for accredited laboratories. Continued work in this area is under review.

7.1.5 PTB

Dr Koch reported on two recent activities in acoustics and ultrasound at the PTB.

A recent question on whether vibration affects the performance of sound level meters prompted the PTB to carry out a study. A comparison method was used whereby two sound level meters were exposed to the same sound pressure level, with the device under test being attached to a vibration exciter. The study concluded that vibration effectively reduces the noise floor of sound level meters and therefore:

- manufacturers of sound level meters should state the vibration sensitivity of their instruments in the instrument manual;
- users should be made aware that sound level meters are sensitive to vibration;
- local levels of vibration should be known when sound level meters are used.

Interferometer systems used for sound pressure measurements (in water) are critically dependent on the characteristics of the photodiode used to decode the information in the light signal. Information is therefore needed on the transfer function between the optical input and the electrical output. A series of measurements to investigate these characteristics has led to the realization of a simple calibration set-up employing difference-frequency servo control to ensure stability and enable fine tuning. The set-up was used to calibrate photodetectors up to 450 MHz

with sufficient measurement uncertainty, enabling traceability for direct measurements of sound pressure to be realized.

The PTB's activities in the field of vibration are reported in section 7.2.2.

7.1.6 GUM

Mrs Dobrowolska reported that the reciprocity calibration system at the GUM was upgraded after 10 years in service. The upgrade to the original system, provided by the NPL, removed reliance on an obsolete software platform, improved the runtime, and provides compliance with IEC 61094-2:2009. Critically, the upgrade enables core elements of the system to be retained ensuring continuity of historical data. The upgrade included new hardware and software enabling an expanded functionality of the system including:

- low-frequency calibration to 2 Hz;
- phase calibration;
- multi-coupler calibration and data optimization.

The new system was validated by calibrating retained standards and the results showed no significant changes in performance.

Systems for vibration calibration have been described previously. These cover the range from 1 Hz to 10 kHz and use exciters in both horizontal and vertical orientations. The scope of vibration measurements was extended in 2008 to include phase calibration. In 2009, the frequency range was extended to 5 kHz to comply with requirements for calibrating human vibration meters according to ISO 8041: 2005.

The presentation on the facilities at the GUM led to a discussion on potential traceability issues when commercial vibrometers are used for calibration. In summary, it was generally agreed that:

- the use of an analogue output can be problematic;
- digital demodulation (using the digital output) presents no real issues in the frequency range of interest.

Later in the meeting, Dr Bruns presented a reference from *Metrologia* confirming these observations.[2]

7.1.7 NIM

Dr Yang gave a presentation on the organizational structure of the ten staff working in the field of acoustics, ultrasound (including acoustic emission) and audiometry at NIM. Recent developments include:

- coupler reciprocity extended to low frequencies;
- a new facility for free-field reciprocity calibration;

[2] *Metrologia* **46** (2009) 11-18

- a sound power calibration facility with a hemi-spherical array of microphones for the calibration of medium and large scale instruments;
- ultrasound power standards;
- high frequency hydrophone calibration using the two-transducer reciprocity method in the frequency range 0.5 MHz to 15 MHz;
- acoustic emission sensor calibration using both reciprocity and face-to-face comparison calibration in the frequency range 100 kHz to 1 MHz;
- ear simulator calibration.

New research topics include:

- optical calibration at low and very low frequencies;
- high-frequency calibration of hydrophones up to 60 MHz;
- measurement of HIFU fields;
- optical calibration methods of acoustic emission sensors;
- calibration methods for opto-acoustic emission and auditory brainstem response systems used in audiometry;

The NIM operates four facilities for vibration measurement covering the ultra-low frequency range (from 0.01 Hz) to the high-frequency range (50 kHz), as well as two shock acceleration facilities. Recent developments include the addition of phase calibration, an extended frequency range of magnitude calibration, and improved uncertainty for shock calibration.

The NIM has participated in some applied research projects in addition to its metrology activities.

A new research campus has been established in an area where the presence of vibration in the environment was known to exist. Limits for vibration were therefore established, and tests have been carried out across the campus to demonstrate that actual vibration levels are well below this limit, except at very low frequencies.

Other research was carried out to characterize the performance of vibration damping materials. Such materials are commonly used to isolate equipment. Tests have been developed to determine vibration attenuation ratios and shock attenuation. Further research was carried out on non-linear transfer characteristics.

7.1.8 LNE

Dr Rodrigues described the facilities available at the LNE. These include:

- primary pressure and free-field reciprocity calibration;
- type approval of sound level meters and sound calibrators;
- primary calibration of accelerometers;
- a range of consultancy activities.

Research activities underpin the operation of these facilities. In acoustics, research is focused on microphones, acoustics of cavities, free-field propagation and the acoustic behaviour of small

components. The research makes use of numerical and analytical modelling, signal processing and experimentation as appropriate. Ongoing research activities include:

- optical velocity profile measurements on the diaphragm of microphones;
- a new analytical model of a microphone taking into account thermo-viscous effects;
- numerical modelling of ear simulators, also accounting for thermo-viscous effects especially close to boundaries.

Recent developments in the systems for vibration measurements include:

- a new digital system for analysis;
- a change to the vibration exciter system now employing vertical orientation.

7.1.9 NMISA

Mr Veldman explained that the laboratory was re-accredited in 2009 with minor changes to scope and staff competency. A programme of upgrading ageing equipment is underway, balanced against the availability of funding and manpower. Revised CMCs have recently been submitted for inter-RMO review. Recent developments include:

- vibration measurements extended to the low-frequency range of 0.4 Hz, incorporating a bilateral comparison with INMETRO;
- development of mechanical shock calibration using comparison techniques following a demand from industry for dynamic force measurements. While traceability is currently imported, there are plans to establish primary mechanical shock capability in the future. The necessary equipment is already available but procedures need to be developed.

7.1.10 CENAM

Dr Echeverría-Villagómez described the industrial and social drivers for work at CENAM in the areas of acoustics, ultrasound and vibration, that have been identified through a series of workshops. These are broadly represented by industrial hygiene for acoustics, healthcare for ultrasound and the automotive industry for vibration. These sectors are supported by a range of standards, measurement services, new technologies and knowledge transfer arising from each of these fields.

An action plan was described for strengthening the quality management system (with respect to ISO 9001 and ISO 17025) within CENAM. This includes a series of internal audits by experts from related fields (e.g. voltage and frequency), and consultation with international experts.

Improvements to facilities for vibration measurements were described. A number of facilities exist, each covering different parts of the frequency range. Low frequency measurements begin at 0.4 Hz using a Michelson interferometer-based system. Facilities covering the medium and high frequency ranges use a range of vibration exciters with recent improvements to the suspension mechanisms. The importance of establishing traceability for vibrometers operating in the kilohertz frequency range was highlighted. Other topics under investigation include:

- the use of the coincidence method at very high frequencies;
- calibration of rotational vibrometers for use in shock testing in the automotive industry;

- calibration of laser vibrometers using shock shape excitation where two different types of interferometer have been used to validate the method, in the absence of opportunities for external comparisons;
- secondary calibration of accelerometers;
- research on micro-electro-mechanical-systems (MEMS) accelerometers, including issues with long-term stability;
- development of an exciter system with six degrees of freedom for the calibration of inertial sensors used in the aerospace industry.

In the field of acoustics, research is focused on:

- low-frequency reciprocity calibration of microphones to 2 Hz;
- static pressure coefficients of microphones (this is important because of the altitude at which the CENAM is located), derived from pressure reciprocity calibration and applied in free-field calibration;
- measurement of the sound isolation of buildings and building elements, but without a transmission suite and using external facilities;
- verification of noise dose measurements to fulfil legal requirements.

7.1.11 NIST-USRD

Mr Paolero provided the first coverage of the field of underwater acoustics in the meeting by giving an overview of the facilities available at the Underwater Sound Research Division (USRD) of NIST. The work in underwater acoustics is a devolved NIST activity and its facilities include:

- an open tank facility for the calibration of standards and prototype transducer testing;
- an open water facility for larger transducers and lower frequency calibration, featuring constant temperature and depths to 2 m;
- a pressure vessel for simulated ocean conditions, simulating depths up to 2 000 m, used for example, to evaluate properties of materials such as rubber, ceramics and particulates at simulated ocean depths;
- a low-frequency calibration vessel with an operating range between –4° C and 40° C, and up to 7 000 m simulated depth;
- a transducer standards laboratory.

Ongoing research activities at USRD include:

- development and maintenance of around forty reference transducer types, covering the frequency range from 10 Hz to 2 MHz;
- development of low noise preamplifiers, including the use of surface mount components for a reduced form factor, with a consequent reduction in acoustic scattering, and the search for new materials to replace lithium sulphate, which is becoming ever more difficult to source;

- development of constant beam width transducers;
- provision of a high frequency measurement system, employing a high-precision positioning system and a new data acquisition system, providing the basis for calibration services;
- an electrical transducer simulator used to verify measurement and data acquisition systems;
- development of calibration capabilities, including couplers for primary and secondary calibration and optimization of measurement uncertainties using the GUM approach to identify significant components.

7.1.12 UME

Mr Sadikoglu summarized the highlights from his submitted report CCAUV/10-29. The UME is active in the sound-in-air, ultrasound and vibration fields. UME recently considered starting work in underwater acoustics, but this activity has been assigned to another laboratory which is not a metrology laboratory and unlikely to become a DI.

Recent improvements in facilities include:

- implementation of the sine approximation method (SAM) in the vibration field;
- extending the range of ultrasound power measurement up to 30 W.

The UME is taking part in the external beam cancer therapy project funded by the European Commission for which it modified its radiation force balance to operate up to 150 W.

Finally, it was noted that the number of accredited laboratories in Turkey is growing, increasing the pressure on the UME to organize a comparison among them.

7.1.13 KRISS

Dr Wan-Sup Cheung reported that former CCAUV delegate Dr Sang Joon Suh is due to retire, but before doing so will complete his final research project to prepare a new calculation programme for reciprocity calibration using MATLAB. There is currently a discrepancy of around 0.02 dB but further work should reduce this difference.

Other research activities include:

- development of a small water tank to establish an underwater acoustic free-field calibration capability;
- hardware improvement for the ultrasound power facilities which are twenty years old;
- expansion of vibration measurement facilities to include phase calibration and a low-frequency calibration system for seismic applications;
- establishment of a primary calibration system for angular vibration and the commercial development of suitable exciters for laboratory and field use.

7.2 Research

7.2.1 Speed of sound measurements for the determination of the Boltzmann constant

Dr Valdés commented that it is exceptional for base units of the SI to be redefined. At the moment a redefinition of the kilogram is under discussion, as well as a new realization of the ampere in terms of the basic electronic charge, the mole linked to an exact value of the Avogadro constant and the kelvin in terms of the Boltzman constant. In this last respect, research is currently in progress on a re-determination of the Boltzmann constant, where one of the key approaches under investigation involves the determination of the *speed of sound*. In this context, before the meeting, Dr Valdés welcomed a presentation on the progress in this subject.

Dr Guglielmone presented the work carried out mainly by Dr R. Gavioso at the INRIM, on "Speed of sound measurement for the determination of the Boltzmann constant, k_B". Recent work on acoustic thermometry began in 1998 with the development of an acoustic resonator system. This work enabled the INRIM to join a project on the re-determination of the Boltzmann constant in 2004. The basic principle of the approach is that an analysis is made of the resonance frequencies of the acoustic modes within a spherical resonator. The geometry of the resonator allows a determination of the Boltzmann constant via the speed of sound. The main challenge is to determine the geometric parameters with sufficient accuracy. One solution is to excite the cavity with microwaves, yielding a second set of resonant frequencies which can be used together with the acoustic data to derive the unknown geometry factors.

Dr Guglielmone showed photographs of the facilities at the INRIM and of similar spherical resonators developed at NIST and the LNE-INM. Data showed the present level of agreement in the determination of k_B using five different existing facilities. Three of the five results showed a high degree of consistency.

7.2.2 Reports from NMIs – INMETRO

Dr Ripper presented research highlights from the acoustics and vibration fields. These included:

- improvements in free-field reciprocity calibration of microphones where the effects of cross-talk have been corrected, based on data obtained from measurements on a microphone used without polarizing voltage;
- the adoption of impulse response techniques developed for free-field calibration in pressure calibrations;
- application of digital signal processing (DSP) techniques in impedance tube measurements, enabling time-domain studies of reflection coefficients;
- the development of a new low frequency acceleration system utilizing a new shaker system and a LabView software platform;
- reconfiguration of an optical 2-reflector system for the calibration of laser vibrometers;
- homodyne and heterodyne quadrature interferometric systems for shock calibrations;
- rocking motion compensation using an auxiliary counter actuator, which has led to higher measurement repeatability especially at higher frequencies.

Dr Soares completed the INMETRO presentation by providing an overview of time-selective techniques. These have been developed to take account of the effects of reflections and cross-talk in free-field reciprocity calibration, but have been applied in other reciprocity applications. This enabled the IMETRO to take part in CCAUV.A-K4.

7.2.3 Reports from NMIs – NPL

NPL presented a three-part report covering its activities in sound-in-air, underwater acoustics and ultrasonics.

Dr Barham listed some research highlights covering:

- developments in both primary and secondary microphone calibrations extending to phase calibration, quarter-inch microphone calibrations and multi-channel simultaneous calibration;
- participation in a EURAMET project to verify a new method of determining the free-field correction of standard laboratory microphones (SLMs) under development in IEC TC29;
- support for IEC standards for ear simulators including a novel optical scanning method for characterizing complex 3D shapes of artificial pinnae;
- developments in optical calibration techniques to measure acoustic particle velocity.

Dr Barham gave an update on the NPL's research aimed at establishing MEMS microphones as measurement devices. He concluded that the NPL has demonstrated proof-of-concept using the system named DREAMSys that it has developed.

Mr Robinson gave a brief overview of the underwater acoustics facilities at the NPL and discussed the drivers for the research projects on marine environmental noise. He explained that the two significant sources of marine noise are:

- low frequency noise from shipping, where the number of ships is leading to a significant problem. Mr Robinson noted that the IEC is planning to address this issue, by following the ANSI's lead to produce a new standard;
- noise from piling operations, e.g. in relation to off-shore wind turbine installations, which presents a basic metrological challenge to identify (and then standardize) a meaningful metric. Mr Robinson described an approach to quantify the noise as a function of distance from the source and then to use energy summation to characterize that particular source. Impact on marine life is being assessed using hearing weighting functions for different species, in the same way as is done for humans. However, the effects of vibration also need to be taken into account because these are often more significant than sound pressure.

Dr Zeqiri presented novel NPL research in medical and industrial ultrasound addressing a diverse range of applications. These include:

- exploitation of the pyro-electric effect, where materials produce electric potentials as a result of a temperature change on exposure to ultrasound, for the measurement of ultrasonic power. The systems are able to detect temperature changes of the order of 1 mK and are therefore more sensitive than conventional radiation force balance

approaches. The principle forms the basis of new instrumentation developments at the NPL for measuring the output power of medical diagnostic equipment;

- investigation of thermo-chromic materials to assess intensity distributions in ultrasonic beams. Dr Zeqiri discussed a tile-based device that was used at the NPL to image a transducer;
- the development and commercialization of the NPL Cavimeter, for use in the sono-processing (ultrasonic cleaning) industry as a means of quantifying the level and distribution of cavitation which governs process effectiveness. This research has forged close links with industry users;
- sensors for the micro world, where micro-sized bubbles are used as sensors in a variety of applications such as contrast agents in medical imaging, drug delivery, food processing and microfluidics.

Dr Valdés commended the NPL for maintaining their excellent standard of research, and for the high quality of their presentation.

7.2.4 Reports from NMIs – PTB

Dr Koch presented four research topics on sound in air and ultrasound:

- distortion-product otoacoustic emissions (DPOAE) stimulated by means of bone-conduction stimulation was recorded in the ears of all test subjects for at least one frequency. With respect to the calibration of the stimuli, this kind of stimulation has the advantage that simple microphone probes can be employed to detect the emission.
- the determination of sound pressure in high-intensity therapeutic ultrasound (HITU) fields using a fibre-optic sensor. Comparing HITU for different sound field configurations demonstrates that the fibre-optic device allows a reliable determination of sound velocity. Using the complex valued frequency response of the sensor, previously determined in a calibration procedure, sound field pressure can also be established precisely.
- new concepts for economic calibration techniques applied to objective audiometry. Scientists and engineers have requested a calibration scheme that produces reference values which have an adequate physiological relation to the hearing threshold. The PTB has taken a first step in that direction by simplifying the procedure, assigning equal reference values to signals of identical amplitude magnitude spectra by integrating them into signal classes.
- the development of sound insulation screens for musicians in a symphony orchestra, mounted between rows of musicians, in particular in front of the brass section. This disposition reduces the loudness of the most emitting instruments without changing the sound of the music. Sound level reductions from 8 to 12 dB(A) were obtained.

Dr Bruns presented two areas of research at the PTB in the vibration field.

The first concerned a recent observation that the armature material of a vibration exciter appears to influence the frequency response of certain kinds of accelerometers. The PTB has studied

possible causes, including mechanical resonances and deformations of the driver systems, the influence of the accelerometer housing, and coupling between the exciter and accelerometer.

The main conclusions were that:

- only results above 5 kHz are influenced;
- the behaviour appears to originate at the contacting surfaces and is not due to mechanical deformations;
- the consequences for traceability established through single-ended devices and for the CCAUV.V-K2 comparison need to be assessed.[3]

The second topic presented was the primary calibration of laser vibrometers. Dr Bruns presented an alternative calibration configuration that eliminates the need for a second reference laser, and the associated misalignment problems, by introducing so-called 'beam recycling'. The original purpose of the investigation was to establish a possibility for phase calibration, but it was realized that the arrangement could be readily extended to full magnitude calibration.[4]

7.2.5 Physiotherapy machine output power – CENAM

Dr Lopez-Sanchez presented the results of a study on ultrasonic power measurements of physiotherapy devices used in clinical environments, including physiotherapy rehabilitation centres. The objective was to ascertain the operational status of equipment using its emitted acoustic power as an indicator of operating effectiveness and safety.

The results revealed that one-in-four devices gave an output power higher than expected and between 12 % and 19 % of the devices showed deviations in output power at 3 MHz of more than 40 %, which is twice the IEC 61689 tolerance. These discrepancies were present despite the fact that the equipment was generally well maintained and correctly used.

It was concluded that there is:

- a strong case for having physiotherapy devices calibrated at regular intervals;
- a need for international guidance on maintenance procedures.

[3] Further details can be found in *Metrologia* **47** (2010) 58-64.

[4] Use of the optical set-up for phase is described in *Metrologia* **46** (2009) 489-495.

8 REGIONAL METROLOGY ORGANIZATIONS

8.1 Reports from regional representatives

8.1.1 AFRIMETS

Mr Veldman gave an overview of the developments within the RMOs, in the AUV field in particular. Altogether there are 368 CMC entries across all fields. NMIs in Kenya (KEBS), Egypt (NIS) and South Africa have active work programmes in the AUV field. The quality systems in the NIS and KEBS are established, with the former gaining acceptance in EURAMET and the latter under review in AFRIMETS.

Workshops have been held on metrology related topics such as CMC processes and CIPM MRA matters. The 4th AFRIMETS General Assembly was held in Egypt in 2010, and in 2011 a Metrology School, similar to the BIPM Summer Schools, will be held at the KEBS in Kenya.

Mr Maina from the KEBS was appointed vice-chair of the AFRIMETS AUV working group, following technical training at the NMISA and time spent in accredited laboratories studying measurement practices and quality processes.

8.1.2 APMP

Dr Usuda reported on activities in the APMP region.

The APMP General Assembly was held in Malaysia in December 2009, together with the TC-AUV meeting, where 15 NMIs were represented.

Dr Usuda summarized the regional and supplementary comparisons, noting in particular, a requirement to complete the linking process in APMP.AUV.A-K3, which KRISS will action. He noted that 10 members have published CMCs, new CMCs are being prepared by Hong Kong and the Republic of Korea. India has CMCs in the vibration field awaiting support from the associated key comparison. The APMP operates a policy to review and re-assess CMCs every 5 years. A programme of peer reviews to support CMCs is underway.

A TC meeting was planned to take place in Thailand in November 2010, in connection with an IMEKO conference, providing an opportunity to discuss the topic of materials measurement. A further metrology workshop is planned on practical issues associated with vibration measurement and calibration.

8.1.3 COOMET

Mr Veldman presented the material prepared by the COOMET delegate in their absence.

COOMET consists of 15 economies and a diagram illustrating how the COOMET laboratories interact with other RMOs and NMIs was presented.

A list of TC meetings was presented. The 2010 meeting took place in the Ukraine. A review of past and present projects was undertaken, demonstrating a focus on establishing and supporting CMCs.

An update on the CMCs was provided, noting that there were no entries presently under review within COOMET, but some are currently under inter-regional review. A schedule for the periodic review of quality systems has been established.

8.1.4 EURAMET

Dr Figueroa summarized EURAMET's activities. He stated that TC-AUV has three sub-committees covering the fields of: sound-in-air; ultrasound and underwater acoustics; and vibration and acceleration. The TC has twenty-five members in total, with Greece and Hungary re-establishing their participation. The TC-AUV is currently involved in two CCAUV comparisons, two EURAMET and two COOMET comparisons, and a further three bilateral comparisons. EURAMET has 505 CMC entries in the KCDB.

The 2010 TC-AUV meeting was held in Sweden.

EURAMET has prepared roadmaps to address the key scientific challenges that have been identified for collaborative research. These are:

- characterization of non-rigid calibration rigs for acceleration and other structural effect;
- optical methods for acoustic calibration;
- full range traceability;
- new transducer technologies;
- characterization of HIFU devices.

Statistics were presented for the complete set of TC-AUV projects, categorizing them as either comparison, co-operation, traceability or consultation projects. EURAMET currently has nine active projects registered, which include collaborative research as well as those addressing CIPM MRA matters. Brief details were given on a selected project from each of the three sub-committees, together with an outline of future project proposals. Dr Figueroa encouraged members of other RMOs to review details of the active projects and new proposals on the EURAMET website, as participation from outside EURAMET is welcomed.

8.1.5 SIM

Dr Ripper reported on the activities of the SIM metrology working group MWG-9, which has six members active in the fields of AUV, following the recent inclusion of Peru. Five members have registered CMCs, with three of the members active in all fields. All members have had quality management systems approved by the SIM quality task force, with self-declaration supported by onsite peer review being the most popular approach.

SIM organized a metrology school in December 2009. The event took place at INMETRO and focused on the development of young researchers and fostering links with other RMOs. The metrology school attracted fifty participants from SIM and a further six from other regions, and included lectures and practical sessions making use of facilities at the host laboratory.

Reports of such events from many of the RMOs were well received by the CCAUV President, who commented that teaching and training activities should be specifically featured in the agenda of future meetings.

8.2 Working Group on CMCs

Mr Veldman reported on the meeting held on 19 October 2010, involving 17 participants representing all five RMOs. The following points were discussed:

- A review of previous actions noted that all actions had been completed or were dealt with during the meeting.
- The current status of CMC reviews was discussed. There are currently no issues, but three batches are under review (from the APMP, AFRIMETS and the EURAMET).
- Increasing requirements for technical assessors to peer review quality systems led to the suggestion that a database of experts should be created. The RMO TC chairpersons would then be responsible for populating the database, and the NMIs requiring assessment would have access to the data via a restricted login to the BIPM webpage. Data protection considerations were raised during the discussions.
- A common format for CMC reviews was discussed, after which the adoption of an existing EURAMET form with minor changes was agreed.
- Secondary laboratories reporting uncertainties comparable or smaller than some NMIs need to be assessed to examine the validity of their claims. Any issues would then need to be raised with ILAC via CCAUV.

Mr Veldman was re-elected as the WG chair, and the next meeting will be in conjunction with CCAUV-8.

The issue relating to secondary laboratories led to a discussion in the CCAUV meeting, and the following points were noted:

- national accreditation bodies have the responsibility for assuring the performance of secondary laboratories. If there is evidence of failure in this process, the BIPM Director should be asked to raise the issue with the JCRB;
- it does not seem viable for secondary laboratories to exceed the performance of the NMIs without the research investment that the NMIs are likely to have made;
- a statement from the ILAC may be required to warn national accreditation bodies of this possible issue;
- more information on specific cases is needed (an example in the SIM was mentioned) before taking action;
- a general observation was made that there is no mechanism for national accreditation bodies to verify the consistency of accreditation processes of other bodies. Much depends on the expertise of individual assessors but such information is not easily accessible. The ILAC should have a role in facilitating consistency across the accreditation bodies.

8.3 JCRB matters

Mr Mussio (ex-JCRB Executive Secretary) gave a report on the meetings of the JCRB that took place in 2010. The JCRB recommendations on the following topics were presented:

- the DIs should take direct responsibility for initial and periodic reviews of their quality systems and not work through their NMIs, and every participating institute should be present at the RMO quality meetings;
- pilot studies should not be subject to the same processes and guidelines as comparisons, but be given separate consideration (see CIPM MRA-D-05);
- a new traceability policy for CMCs relating to primary standards now requires traceability to be established directly with an NMI rather than via accredited laboratories (see CIPM MRA-D-04);
- new policies for the periodic review of quality systems have been added to guidelines for monitoring and reporting by RMOs (see CIPM MRA-D-02).

A list of agreed actions and resolutions of the JCRB was reviewed. Key points included:

- review and reporting of quality systems to oversee key changes, to cover laboratory buildings, personnel, instruments, etc. and a form for reporting to be prepared by the JCRB secretariat;
- greyed-out CMCs will be deleted after 5 years, after a 2-stage procedure of issuing reminders to the RMO and the NMI concerned has been followed;
- for those NMIs that have achieved ILAC accreditation, peer review requirements related to the CIPM MRA should not duplicate efforts;
- the BIPM is preparing the scope for a workshop on inter-RMO review of CMCs advocating a harmonized international approach;
- the growing number of DIs, many declaring a relatively small number of CMCs, is placing an increasing load on peer reviewers. New criteria for DIs is under development.

9 REPORTS FROM INTERNATIONAL MEETINGS

9.1 IMEKO TC 22 activities

Dr Bruns gave a short report on the activities of IMEKO TC22 on vibration measurements.

The IMEKO 19th World Congress was held in Lisbon, Portugal, in 2009 with fifteen contributions. Access to the proceedings is available at www.IMEKO.org.

The next meeting will be held in Thailand in November 2010, and the next world congress is planned for the Republic of Korea in 2012, where all the TCs will meet.

9.2 Others

Dr Barrera-Figueroa reported that the session on metrology and measurement at InterNoise 2010 in Lisbon, Portugal, was well-attended and announced that a similar session will be organized for InterNoise 2011, which will be held in Ōsaka, Japan.

10 REPORTS FROM INTERNATIONAL OBSERVERS

10.1 IEC TC 87

Dr Zeqiri provided a summary of IEC TC 87 (Ultrasonics).

A meeting of the TC was held in Seattle in October 2010.

There are nine standards currently under development or review, covering HIFU and physiotherapy output measurements. Dr Zeqiri has taken over as the convenor of WG3 covering ultrasonic test methods.

10.2 IEC TC 29

Dr Barham presented a report prepared by Mrs Dowson, the new Chair of IEC TC 29 (Electroacoustics). TC 29 produces standards relating to the specification, calibration and test methods for electroacoustic measurement instrumentation such as microphones, sound level meters, sound calibrators, filters, audiological equipment, hearing aids and ear simulators, including the recent addition of instrumentation for the measurement of aircraft noise.

The IEC TC 29 and each of its WGs met in Tokyo, Japan, in November 2009. Progress and status of all the documents in preparation or under review can be found at www.iec.ch (TC Dashboard).

An important development at the 2009 TC meeting was that all the IEC TCs have been asked to produce a statement on strategic policy (cf. CCAUV-SPWG terms of reference), covering objectives and strategy from 3 years to 5 years. Two points in the TC 29 action plan which have particular synergies with the CCAUV are:

- the investigation of emerging technologies and their impact on IEC TC 29;
- the preparation of guidance on implementing uncertainty analysis in IEC documents.

The next meeting of IEC TC 29 will be held in London in March 2011.

10.3 ISO TC 108

Mr Veldman presented the report on ISO TC 108 (Mechanical vibration, shock and condition monitoring) which was prepared by Dr von Martens. It provides an overview of the TC activities, including:

- an update on the ISO 5347 and ISO 16063 series of standards, including the status of each of the document parts, noting that these documents are under continuous development;
- illustrations showing equipment and new challenges to be addressed by WGs;
- calibration of laser vibrometers;
- acknowledgement of the role of the CCAUV and the impact of KCs on the ISO 16063 series.

It was noted that TC 108 assembles renowned experts from industry and the world's metrology institutes.

11 PUBLICATIONS

11.1 CCAUV Web pages and links

Dr Allisy-Roberts reminded participants that the search facility on the BIPM website allows searching on NMI websites, as well as on the BIPM web pages. The website also includes the publication lists and bibliographies prepared by CCAUV members.

It was proposed that all reports submitted to this CCAUV meeting have open access unless there are plans to publish the material elsewhere. The delegates confirmed that documents can have open-access status.

11.2 CCAUV members' bibliographies

Dr Allisy-Roberts noted that a few bibliographies remain to be submitted and will follow this up with the NMIs concerned.

12 MEMBERSHIP OF THE CCAUV

12.1 Criteria for membership

Dr Allisy-Roberts reviewed the criteria for membership and reported that the UME is now a full member of the CCAUV.

A question was asked regarding the Russian membership on why it is that the VNIIM is the registered member, when most the CCAUV activity, including participation in KCs and meetings is carried out by the VNIIFTRI. It was noted that both of these institutes are DIs of the Russian Federation but only one can be a full member of the CCAUV. The Russian Federation decided that this should be the VNIIM.

12.2 Proposals for new members and observers

No new requests have been received regarding member or observer status.

Dr Allisy-Roberts asked if anyone had information or proposals about any such requests, but none were reported.

13 OTHER ITEMS

Dr Bruns reported the details of a *Metrologia* paper, mentioned earlier in the meeting, on the use of He-Ne lasers as standards for wavelength[5]. He noted that the paper recommends that for applications where a 1.5×10^{-6} uncertainty is acceptable, there is essentially no value in having the laser frequency/vacuum wavelength measured via heterodyne comparison with an iodine-stabilized laser, because such a comparison would provide no further useful information.

14 DATE OF NEXT MEETING

The date of the next meeting was not confirmed, other than it would be in 2012.

A proposal to hold the meeting in May 2012 was made to coincide with the CIPM meeting. It was pointed out that May is a very busy month for international meetings.

The alternative would be to maintain the current practice of holding meetings in October.

Nevertheless, two requests regarding future meetings were raised:

[5] *Metrologia* **46** (2009) 11-18

1) to change the meeting times to 09:30–18:00 on day 1 and 08:30 onwards on day 2, to minimize the need for some delegates to miss parts of the meeting because of their return travel arrangements;
2) to bring the research element forward in the programme to allow more time for discussion both during the meeting, and during the social hours.

Delegates welcomed these suggestions.

The meeting closed at 18:00.

APPENDIX 1.
WORKING DOCUMENTS SUBMITTED TO THE CCAUV AT ITS 7TH 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

Documents restricted to Committee members can be accessed on the restricted-access CCAUV website.

Document CCAUV/	
10-00	Draft agenda – updated, P. Allisy, 3pp.
10-01	The BIPM key comparison database, C. Thomas, 16pp.
10-02	Draft B report for the COOMET.AUV.A-K2 comparison, V. Chalyy, 20pp.
10-03	Report of the ISO International Observer, H.-J. von Martens, 20pp.
10-04	Draft technical protocol for CCAUV.A-K5, R. Barham, 10pp.
10-05	CCAUV comparison status, P. Allisy, 3pp.
10-06	Status of RMO AUV comparisons, P. Allisy, 5pp.
10-07	Draft B report of the APMP.AUV.A-K3.1 comparison, S.J. Suh, 15pp.
10-08	Current status of the ultrasound comparison CCAUV.U-K3, C. Koch, 8pp.
10-09	Brief report from the NMIA, D.A. Scott, 4pp.
10-10	Recent research activities at the INMETRO, G. Ripper, 4pp.
10-11	Report from the SIM, G. Ripper, 3pp.
10-12	Overview of acoustic metrology research at the NPL, B. Zeqiri, 22pp.
10-13	IEC/TC 29 Electroacoustics report for 2010, S. Dowson, 6pp.
10-14	Short report of DPLA activities in AUV, S. B.-Figueroa, 6pp.
10-15	EURAMET TC AUV report, S. B.-Figueroa, 3pp.
10-16	The current status of AUV in NMIJ, T. Kikuchi, 13pp.
10-17	Short report on INRiM activities in Acoustics, Ultrasound and Vibration, C. Guglielmone, 4pp.
10-18	Report of the COOMET TC AUV, V. Pozdeeva, 4pp.
10-19	Short report from the PTB, C. Koch, 6pp.
10-20	Report on the COOMET Pilot Comparison - Calibration of hydrophones from 250 Hz to 200 kHz, A. Isaev, 17pp.
10-21	Report from APMP TC for AUV, T. Usuda, 2pp.
10-22	Brief report on primary standards for acoustics and vibration at the GUM, D. Dobrowolska, 3pp.
10-23	Status report in AUV at the NIM, Sun Qiao, 13pp.
10-24	Primary metrology in France in acoustics and vibration, D. Rodrigues, 6pp.
10-25	Brief report to the CCAUV from the NMISA, C.S. Veldman, 3pp.
10-26	Status report on AUV from the CENAM, Mexico, S. Echeverria, 17pp.
10-27	On-site measurement study of ultrasonic power from physiotherapy devices, A. L. López Sánchez, 7pp.
10-28	Short report from the NIST, V. Nedzelnitsky, 2pp.
10-29	Short report on acoustical metrology from the UME, E. Sadikoglu, 3pp.
10-30	Draft CCAUV rules and guidelines for intra-regional review of CMCs, I. Veldman, 1p.
10-31	CCAUV Instructions for completing CMC entries, CCAUV-RMOWG, 2pp.

10-32 APMP TCAUV Report, T. Usuda, 12pp.
10-33 JCRB Report to the CIPM, L. Mussio, 4pp.
10-34 EURAMET-AUV.V-K1.2, C. Hof, 17pp.
10-35 Primary Microphone Calibration in Free Field using a Time Selective technique, Z. Soares, 14pp.
10-36 Primary metrology in France in Acoustic and Vibration Fields, LNE, 15pp.
10-42 NIST-USRD Underwater Sound Reference, A. Paolero, 11pp.
10-43 The current status of vibration measurement standards at the AIST/NMIJ, T. Usuda, 18pp.
10-44 Recent activities in AUV for KRISS, W-S. Cheung, 9pp.
10-45 National Standards and Research Activities at the NMIJ: Short Report on Acoustics and Ultrasonics, T. Kikuchi, 31pp.
10-46 Short Report on IMEKO TC22 2010, T. Bruns, 12pp.
10-47 Influence of Vibration Exciters, T. Bruns, 13pp.
10-48 Laser Vibrometer calibration, T. Bruns, 13pp.
10-49 NPL Report, NPL, 37pp.
10-50 CCAUV SPWG report 2010, B. Zeqiri, 3pp.
10-51 Report of the SIM MWG-9 to the CCAUV, G. Ripper, 11pp.
10-52 AFRIMETS feedback report, I. Veldman, 6pp.
10-53 CCAUV RMOWG Report, I. Veldman, 3pp.
10-54 NMISA Status Report, I. Veldman, 4pp.
10-55 Brief Report on Primary AUV Standards at the GUM, D. Dobrowolska, 13pp.
10-56 Current Status of CCAUV-U.K3, C. Koch, 12pp.
10-57 Recent Research Topics at the PTB, C. Koch, 34pp.
10-58 Recent Development of Standards at the PTB, C. Koch, 20pp.
10-59 Laboratory Report from NIM,China, Yang Ping, 27pp.
10-60 Report of the ISO International Observer to the 7th CCAUV, H.-J. von Martens, 12pp.
10-61 CCAUV-SPWG/10-01: Industrial ultrasound Road map, E. Sadikoglu, 1p.
10-62 CCAUV-SPWG/10-02: Medical ultrasound roadmap, E. Sadikoglu, 1p.
10-63 CCAUV-SPWG/10-03: Sound in Air Roadmap 1, E. Sadikoglu, 1p.
10-64 CCAUV-SPWG/10-04: Sound in Air Roadmap 2, E. Sadikoglu, 1p.
10-65 CCAUV-SPWG/10-05: Underwater acoustics Roadmap, E. Sadikoglu, 1p.
10-66 CCAUV-SPWG/10-06: Vibration Roadmap, E. Sadikoglu, 1p.
10-67 CCAUV-SPWG/10-07: Strategic Planning Document (CCEM/09-06), CCEM, 17pp.
10-68 CCAUV-SPWG/10-08: Explanatory notes for the industrial ultrasound roadmap, E. Sadikoglu, 2pp.
10-69 CCAUV-SPWG/10-09: Explanatory notes for the medical ultrasound roadmap, E. Sadikoglu, 2pp.
10-70 CCAUV-SPWG/10-10: Explanatory notes for the sound in air roadmap, E. Sadikoglu, 3pp.
10-71 CCAUV-SPWG/10-11: Explanatory notes for the underwater acoustics roadmap, E. Sadikoglu, 3pp.
10-72 CCAUV-SPWG/10-12: Explanatory notes for the vibration roadmap, E. Sadikoglu, 3pp.
10-73 CCAUV-SPWG/10-13: Japanese Strategic Technology Roadmap, AIST/T. Usuda, 3pp.