Bureau International des Poids et Mesures

General Conference on Weights and Measures

22nd Meeting (October 2003)

Note on the use of the English text

To make its work more widely accessible the International Committee for Weights and Measures publishes an English version of its reports.

Readers should note that the official record is always that of the French text. This must be used when an authoritative reference is required or when there is doubt about the interpretation of the text.

Contents

Proceedings
of the 22nd General Conference
on Weights and Measures
13-17 October 2003

Agenda

The provisional agenda of the 22nd General Conference (see Appendix A page 389) is adopted as the final agenda.

1 Opening of the Conference

Professor Étienne-Émile Baulieu, President of the French Academy of Sciences of the Institut de France and President of the 22nd General Conference on Weights and Measures (CGPM), opened the Conference by inviting Mr Gilles Barrier, representing the French Minister for Foreign Affairs, to address the Conference.

2 Address on behalf of the Ministre des Affaires Étrangères de la République Française

Mr Barrier, French Ministry of Foreign Affairs, Department of the United Nations and international organizations, gave the following speech:

"Mr President, Ladies and Gentlemen, Delegates,

M. Dominique de Villepin, Minister for Foreign Affairs, has asked me to represent him here today as he is, unfortunately, unable to be present. In his name and in the name of the Government of the French Republic, I have the great honour and pleasure of welcoming you today and to open the 22nd General Conference on Weights and Measures.

It was 128 years ago, on the 20th May 1875 to be precise, that the Metre Convention was signed, which lead to the creation of the International Bureau of Weights and Measures, the International Committee for Weights and Measures, and instigated the General Conference on Weights and Measures, for which we are here assembled today.

There has been considerable evolution since then, marked by technological progress and, in parallel, by the multiplication and diversification of the needs of users of metrology services. These needs are increasingly manifest through international institutions, which are not only increasing in number but also becoming more varied. This evolution accompanies the continuous development of the metrological activities of the International Bureau of Weights and Measures, at the scientific level – and we know the immensity of this domain of activity – and at the level of international cooperation, for the sake of an increasing number of countries, and in closer partnership with many international organizations.

Since the last General Conference, in particular, there has been a great deal of tangible progress. It is appropriate at this point to mention the Mutual Recognition Arrangement, which assists the establishment of international exchange, and which can be seen in the important service represented by the BIPM Key Comparison Database on the website of the International Bureau of Weights and Measures.

We owe this development to the guiding personalities of the International Bureau of Weights and Measures, who I would like to congratulate. In particular, I would like to pay tribute to Dr Terry Quinn, who will this year come to the end of his period as Director of the International Bureau of Weights and Measures after a brilliant career in international metrology. I will also take this opportunity to send my best wishes to his co-director, Professor Andrew Wallard, who

will succeed him at the beginning of next year as Director of the International Bureau of Weights and Measures. I wish him well.

New pages in the history of the institutions of weights and measures remain to be written, and I know that the discussions, animated by the International Committee, on the future orientations of the International Bureau of Weights and Measures to be discussed at this General Conference will be fundamental. This is why I am sure that this Conference will be a huge success, which is what I wish with all my heart

I thank you for your attention."

3 Reply by the President of the International Committee

Professor Kovalevsky, President of the International Committee for Weights and Measures (CIPM), thanked the representative of the Minister of Foreign Affairs for hosting the CGPM in the Centre de Conférences Internationales, and complimented the Centre on the modern, well-equipped conference room.

Following on from the words of Mr Barrier, he drew attention to the increasing needs for precise measurements in more and more fields, some of which had not even been anticipated a few years ago. Metrology, he said, is now an essential basis not only for industry and commerce, but also for health and the environment, which means that the traditional fields of study must be extended to cover a whole range of new areas, such as inorganic and organic chemistry, medical analyses (including *in vitro* testing), the monitoring of air, water and ground pollution, pharmacology, the food industry, and anti-doping testing. In all these subjects we increasingly need high-quality references and absolute measurements of the best possible precision, and need to deal with their application to day-to-day measurements.

The diversification of these fields has led and will continue to lead to an inescapable increase in new activities in the BIPM and the National Metrology Institutes (NMIs). These developments cannot be undertaken entirely at the expense of existing activities, and one of the key issues to be resolved by this Conference will be to decide to what extent the budget of the BIPM should be increased to meet these needs.

Professor Kovalevsky noted that Mr Barrier had drawn attention to the extension of the cooperation between an increasing number of States and Economies. This situation is an important development, due in part to internationalization, and in part to the needs of developing countries for techniques to demonstrate the coherence of their measurements with those carried out elsewhere. Resolution 3 of the 21st General Conference introduced the notion of Associates of the CGPM. This has opened up the work of the BIPM – including, but not limited to, the CIPM Mutual Recognition Arrangement – to fifteen additional States or Economies. This number is expected to continue to increase over the coming years.

France, the initiator of the Metre Convention, has always strongly supported the BIPM and Mr Barrier's talk proved this continues to be the case. Professor Kovalevsky concluded by expressing his confidence that the Minister's wishes would be fulfilled, and expressed his thanks again to the French Minister for Foreign Affairs for his support of the Conference.

4 Address by the President ofthe Académie des Sciences, President of the Conference

Professor Étienne-Émile Baulieu, President of the French Academy of Sciences, opened the 22nd General Conference on Weights and Measures with the following address:

"Ladies and Gentlemen, Delegates, Mr Barrier, President of the CIPM Jean Kovalevsky, Dr Quinn, Professor Wallard, Dear Colleagues.

In the name of the Academy of Sciences, I have pleasure in saluting you and to thank you for your work. Our Academy of Sciences is, as always, pleased and honoured to have the opportunity of attending the General Conference every four years.

For us scientists, an event such as the General Conference is one of the best examples, perhaps the best example, of the process of globalization. Such activities with their interactions between international experts represent the positive side of human progress. This is particularly important at the moment because, as everyone is aware, the rapid evolution of modern science has meant that the majority of people do not understand what science means today and have, as a consequence, a certain fear of what it might imply.

I praise the remarkable breadth of your activities. In particular, I see from the documents for the General Conference that you have created a working group on the expression of uncertainty in measurement. This is a particularly useful development, as it is important to attempt to communicate what modern science has and is able to give us. Scientific progress needs to be understood widely and used wisely.

The problems you are addressing cover a wide range of domains. As a biomedical scientist, I notice with interest that problems as fundamental as the redefinition of the metre, the redefinition of the kilogram, the study of electrical units, indeed, all that has to do with the field of nanotechnology, including the biomedical sciences, are in the list of topics for your studies. Consequently, I wish you well and thank you. Your interests are in the *avant-garde* of what is happening in science today and what will arrive tomorrow.

It is perhaps surprising for someone, who like the majority of us, undertook his studies some time ago, to find himself talking to a group who are looking again at Avogadro's number, the definition of the electron volt, the curie, and Planck's constant. This work is important in demonstrating how the human spirit is forever continuing to search, to perfect, and to invent.

As a bio-medical scientist, I would like to make a few simple observations. Like all of you, in the course of my research I am confronted by a variety of measurements; measurements on living systems which must be considered in terms of their scale or dimension. The dimensions found in living systems cover a range of scales. Starting, of course, at the level of organic molecules composed of chemical bonds (e.g. carbon-carbon bonds), which have a length scale of about one and a half ångstroms, but one rapidly encounters larger-scale dimensions such as small energy-supplying molecules, proteins where there are small structural elements that constitute protein ensembles, which give us a dimension scale of about 30 nm. After this, one passes into living organisms such as bacteria, where the dimension scale increases to a level of about a micrometre. We are all composed of billions and billions of cells which range in size from a micrometre to tens of micrometres; for example, a red blood cell typically has a diameter of seven micrometres. An understanding of these small scales is essential to comprehending the various phenomena found in living systems.

A study of the speed of chemical reactions, or of how things vary with time, is also fundamental for the study of living systems. The primary events of the process of vision involve reactions that occur in tens of picoseconds, which is all together difficult to comprehend on the usual scale of human reflexes. However, it is by investigating the picosecond domain that we can begin to understand the world around us. In the unwinding of the double helix strands of DNA, the dynamics takes microseconds, whereas the dynamics of proteins may take much longer, of order, a second – a difference of a million fold. To have a coherent picture of living systems, we must learn to manipulate all these events. Of course, the gestation of living organisms takes time; for example, the simple bacterium reproduces in about 30 minutes. However, considering the time life has been evolving on this planet, one has the time for such studies.

For the moment, I wish to consider measurements made at the dimensions of genes, which I mentioned earlier, and which will allow me to remind you of the extraordinary diversity of ranges of size which such measurements involve. There are the very smallest viruses; organisms that are not truly living but which survive and sometimes have a deleterious effect on the survival of cells. For example, a virus like SV40 or the Polio virus are barely a micrometer in length and contain only 5000 nucleic acid base pairs. From this scale one passes to the scale of a bacterium, such as *Escherichia coli*, where the strand of nucleic acid is, of order, a millimetre in length; a molecule of nucleic acid which can code the production of a number of protein molecules, of order, 3000 to 5000 per bacterium. In man, we each have billions upon billions of cells, each containing a strand of nucleic acid (DNA) which is upwards of a metre in length, and which allows us to generate hundreds of thousands of different protein. Interestingly, man contains about 30 000 different genes, which is only ten times more than the microbe.

An understanding of these different levels of complexity is fundamental, because it is here that the quantitative mixes with the qualitative; that is to say, that at a first glance these are single chemical entities, but they also contain an efficient mechanism of transcription and other parts which are there to regulate the ensemble. There are different scales of quantitative complexity, which have not yet been fully explored and which we now know to be essential in fully understanding the relationship between the qualitative and the quantitative. That is to say that beyond the genes, that code for proteins, which have a well-understood structure with few variants, there are modifications possible through single nucleotide polymorphisms; that is, variations in the structures which regulate the function of the genes. Thus, everything in life happens over a range of differing scale. At a simplistic level, we can talk of life and death, but there exists a huge range of fine structure in functionality. At a variety of levels of scale there are different, but linked functionalities which are not only linked in the scale over which the function operates but also the degree to which it operates.

I am particularly impressed by the international efforts to create, through an international arrangement which is referred to as the Mutual Recognition Arrangement of the CIPM (CIPM MRA), a validated list of reference materials and procedures of measurement, particularly for medical laboratories, and the Joint Committee for Traceability in Laboratory Medicine (JCTLM) demonstrating that the BIPM is the main actor in questions of the traceability of measurements. In this context, the word traceability has become widely used in both the technical and general press, and figures in the thoughts and worries of the general public; it is particularly important in relation to the quality of foodstuffs and medications where it plays a large part in all aspects of human health, and also in questions of terrorism and criminality. I congratulate Joseph Thijssen, Willie May and Terry Quinn for having set up this committee, which has already met three times this year and established a list of hundreds of materials and about a hundred methods of

reference measurements. This is all together a remarkable achievement, one that is not only important from the point of view of technology but also from an ethical viewpoint.

It is with this consideration that I wish to conclude this short introduction. With the extraordinary progress of modern science in the fields of matter, in the understanding of the phenomena of energy and in the control of the difficult, which all rest on the idea of human society. Measurements are essential; they assist in our understanding. As we have seen, there must always be ever greater degrees of precision. There must also be rapidity of execution, which is particularly essential when it involves the wider community such as those involved in justice, politics and medicine. One must have an idea of the importance of the spirit of community of the scientific enterprise. It is this that I sensed when I read the papers relating to the work of this General Conference. You are not simply applying methodologies but are also innovating and honing new technology, evaluating such advances with judgement and responsibility, which is fundamental. I thank you for demonstrating that the close relationship between the countries and between the scientific disciplines make of your work a humanistic activity.

I thank you."

Professor Baulieu then announced that, due to other commitments, he was obliged to leave the Conference, and Prof. Christian Bordé, a physicist, corresponding member of the French Academy of Sciences and scientific advisor to the Bureau National de Métrologie, would replace him for the remainder of the meeting.

Professor Christian Bordé then gave the following address:

"It is a great pleasure for me to meet you again after these four years, which I hope have been happy and productive for all of you. It has been a time when I have been thinking a lot about the International System of Units (SI) and I would like to share with you some ideas that have come out of this reflection. We know that the SI is not fixed, but necessarily evolves with our increasing understanding of the physical world and rapid progress in technology. It is our duty to guide and work with this evolution so that it moves in the right direction: that of a greater coherence and a greater universality, to make the SI benefit from the richness of today's science.

An important step was taken in 1983 when we linked the metre to the second by fixing the fundamental constant the speed of light c. We should now look to see whether this step can and should be followed with other fundamental constants, such as the Planck constant h, the Boltzmann constant k_B, and the mass of the electron m_e.

I will mention two examples:

- At the quantum level, the quantity mass is indissolubly linked to the Planck constant. All of the equations of quantum mechanics bring in mass only in the ratio h/m_e. How can we translate this link to the macroscopic level? The watt balance gives a very elegant solution to this question, in giving us a method, absolutely ideal and well adapted, of linking the de Broglie wavelength, and therefore the ratio h/m_e for a macroscopic mass such as a kilogram standard, uniquely by measurements of frequency. Should we redefine the unit of mass by fixing the Planck constant? In a few years there will be a crucial choice to be made for the future of the SI and perhaps a unique opportunity to go in the right direction.

- In the same way, we can today measure the Boltzmann constant k_B, or rather k_B/h, by means of a frequency measurement, the measurements of the Doppler width, and perhaps in due course we may imagine the redefinition of the unit of temperature by fixing the Boltzmann constant.

One can see that the majority of the base units at present, like the metre, could be attached to the second. The definition of the second itself could perhaps evolve in the future, taking into account of the developments of optical clocks and femtosecond lasers; for example, using the spectrum of hydrogen.

At the dynamic level it is necessary that the system of units should integrate the consequences of the unified vision of fundamental interactions that comes from the standard model of physics. This standard model treats fundamental interactions as gauge fields coupled to matter by a set of fundamental constants without dimension. For example, we know that all of electromagnetism is described by a single fundamental coupling constant without dimension, the fine-structure constant α. At the microscopic level this vision is now very well established. How can we transfer this to the macroscopic level?

In general, we are seeing the emergence of a quantum metrology. For example, in electricity with the Josephson effect, the quantum Hall effect and the electron tunnelling effect of an electron; or in the domain of atomic physics with the use of cold atoms in atom interferometry. This quantum metrology allows the linking of the microscopic to the macroscopic world. We must close the metrological triangle at a level of accuracy sufficient to give us full confidence in the accuracy of these measurements. We should also pursue the determination of the fine structure constant by atomic interferometry.

These are marvellous tools that we have been offered, and it is our historic responsibility to use them well. Of course, it is also necessary to better understand these fundamental constants, their origin, and their possible variations in space and time.

The present SI is just one step towards a more unified, more coherent system. With all the prudence that is necessary, it is up to us to pursue this effort to find the right direction that will also assure the continuity and renewal of our system of units, while at the same time maintaining traceability and continuing to listen to the needs of society.

We have set up a working group at the French Academy of Sciences that is studying this question in close cooperation with the BIPM. I would imagine that this sort of work is being carried out in a number of countries, and the BIPM will of course be the crossroads and perhaps the focal point of all these thoughts.

As a particularly successful example of the spreading of the scientific word, the BIPM organized in July this year a summer school at which I had the great pleasure of participating. It had some eighty students from National Metrology Institutes from twenty-two countries, and it was a great success in terms of scientific communication as well as human contact. This was an occasion where we were all able to understand how much the BIPM is important in its role of driving and coordinating metrological science at the world level.

This is only possible if the BIPM has among its staff people at the highest level, and to attract such people at this level we all know it is necessary to have an experimental laboratory activity which is also of the highest level. We should therefore be very careful this week to maintain this critical mass, which itself is the only way of giving scientific credibility to the BIPM.

Finally, on the occasion of the reports of the Presidents of the Consultative Committees, I would like us to take up some of these points concerning the possible evolution and definitions of the base units as I have mentioned here very briefly."

5 Presentation of credentials by delegates

The Convocation required that details of the composition of each delegation be sent to the BIPM at least two weeks before the opening of the Conference. On arrival, delegates were required to present their credentials from their Government.

6 Nomination of the Secretary of the Conference

Professor Bordé, the new President of the Conference, proposed Dr R. Kaarls, Secretary of the CIPM, as Secretary of the Conference; this proposal was adopted.

7 Establishment of the list of delegates entitled to vote

The Secretary, having examined the credentials of the delegates, proceeded to the establishment of a list, by Member State, of those delegates eligible to vote on behalf of their Government. The list, in alphabetical order, was as follows:

Argentina	J. Valdés
Australia	B. Inglis
Austria	R. Dittler
Brazil	J.A. Herz da Jornada
Bulgaria	A. Todorova
Canada	J. Lusztyk
Chile	R. Nuñez Brantes
China	WANG Qinping
Czech Republic	A. Šafařik-Pštrosz
Denmark	K. Carneiro
Egypt	S.Z. Zahwi
Finland	T. Hirvi
France	L. Érard
Germany	E.O. Göbel
Hungary	P. Pákay
India	V. Kumar

Ireland	J. Kane
Israel	G. Deitch
Italy	P. Vigo
Japan	A. Ono
Korea (Republic of)	LEE Sekyung
Malaysia	A.R.Z. Abidin
Mexico	H. Nava-Jaimes
Netherlands	E.W.B. de Leer
New Zealand	K. Jones
Norway	H. Kildal
Poland	B. Lisowska
Portugal	C. Nieto de Castro
Romania	F. Iacobescu
Russian Federation	L.K. Issaev
Serbia and Montenegro	D. Milošević
Singapore	V. Tan
Slovakia	D. Podhorský
South Africa	T. Demana
Spain	Á. García San Román
Sweden	H. Andersson
Switzerland	W. Schwitz
Thailand	P. Totarong
Turkey	A. Şahin
United Kingdom	D. Walker
United States	A. Bement

Of the fifty-one Member States of the Metre Convention, forty-one were represented. In addition, Dr Kaarls welcomed the representatives of eight Associates of the CGPM: Belarus, Chinese Taipei, Hong Kong (China), Kenya, Latvia, Lithuania, Slovenia, and the Ukraine.

8 Approval of the agenda

The agenda printed in the Convocation (see page 389) was approved, with a slight modification of the order: Item 15 on the "Programme of work of the BIPM" was moved forward in the programme, to be addressed during the afternoon session of the first day of the Conference.

The President then asked Prof. Kovalevsky to present his report.

9 Report of the President of the CIPM on the work accomplished since the 21st General Conference (October 1999 – September 2003)

Professor Kovalevsky, President of the CIPM, presented the following report:

"In conformity with Article 7 of the Rules annexed to the Metre Convention, it is my pleasure as President of the CIPM to report on the work accomplished since the 21st General Conference held in October 1999.

Let me first welcome Greece and Malaysia, which have joined the Metre Convention since the last CGPM as new Member States, as well as Serbia and Montenegro (the former Yugoslavia), which was reintegrated into the Convention. Let me also welcome the first fifteen countries and economies that have taken advantage of the new Associate status of the CGPM agreed by the 1999 CGPM. These are Belarus, Chinese Taipei, Cuba, Ecuador, Hong Kong (China), Jamaica, Kenya, Latvia, Lithuania, Malta, Panama, the Philippines, Slovenia, Ukraine and Viet Nam.

9.1 Introduction

The Metre Convention is among the oldest intergovernmental conventions, but its work continues to make a very substantial impact on many aspects of business, science, and economic and social life. No one questions the fundamental objectives of the Convention. Indeed, as shown later in my report, there is strong international encouragement to extend its activities and influence still further. This places great strains on the BIPM, the CIPM and its Consultative and Joint Committees and, again as pointed out later, these pressures have led the CIPM to make decisions on priorities that should be set for the future. This has not been a painless task. I am however convinced that, with the support of the General Conference, we will be able to agree on a clear direction for the next few years and that the future of the Convention is a sound and challenging one.

Before I move into the detail of my report of activities over the last four years, there is one notable event that took place in 2000 and which I believe we ought to comment on at the beginning of this Conference. This was the 125th anniversary of the signing of the Convention. To mark the occasion, a special conference was organized in cooperation with the French Academy of Sciences, and we were pleased to welcome the directors of many National Metrology Institutes, past colleagues who had played an important part in the development of the Convention, and many others with an interest in metrology. The conference included a number of technical presentations, among them five from Nobel prizewinners. It was a fascinating day and we reviewed the many contributions that the Convention and metrology have made to science, to commerce, and to society. It is impossible to comment on all the presentations but I thought that I might mention just one remark from Prof. Steve Chu. Metrology can sometimes be portrayed – unfairly, as we all know – as the pursuit of ever more accurate measurements. Sometimes this is needed for commercial reasons but, scientifically, metrology is always at the forefront of understanding. "In my experience," said Prof. Chu, "accurate measurement is at the heart of physics, and new physics starts at the next decimal place." A glance at the list of Nobel laureates over the last fifty years or more confirms this: metrology is often among the earliest applications of work that is eventually recognized through Nobel prizes. This is testimony to our scientific efforts in which we take pleasure and pride, but

we must never forget that metrology also serves society, industry, international trade and the international economy. Indeed, these are probably the main motivations today for membership of the Convention. This, you will find, is a reoccurring theme in my report to you.

I intend first to comment on the progress made on some of the key Resolutions that were passed at the last General Conference. I shall then report on the great success of the CIPM MRA that was signed at the time of the last Conference, and then draw your attention to some of the more significant achievements in the work of the CIPM, the Consultative Committees and the BIPM. In some areas, my report will be relatively brief as the topics are considered in greater depth within other agenda items.

9.2 Progress on Resolutions since the last General Conference

Let me begin with a general survey of progress on some of the key Resolutions from the last General Conference.

Resolution 1 of the 21st CGPM welcomed the CIPM report, written by Dr W.R. Blevin, then Secretary to the CIPM, and entitled *National and international needs relating to metrology: International collaborations and the role of the BIPM*. This seminal report set the scene, and the priorities, for the work of the CIPM and the BIPM over the past four years. In addition, it proved to be a valuable and farsighted review of the issues with which metrology needed to deal. It was widely used by NMIs and governments as a blueprint for the pattern of work of NMIs and national metrology programmes.

In particular, it highlighted the explosion – if I may use that word – of metrology in chemistry. At that time, the BIPM had hardly begun to develop its activities in chemistry although the Consultative Committee for Amount of Substance (CCQM), as it was then called, had been created in 1993 and had begun its work. Similarly, many NMIs had only just begun to develop chemical metrology as a major topic. Many of them started to create alliances with other suitable national laboratories in the field of chemistry in order to address the metrological issues outlined in the "Blevin's Report" and recommended by 1999 CGPM Resolution 10.

This report also drew attention to several other topics that are also now part and parcel of our day-to-day concerns as metrologists. Presciently, on the technical side, the report highlighted nanotechnology, the environment, software and acoustics. It also pointed to the need for the BIPM and the CIPM to develop international collaborations and partnership with organizations that are involved in precise measurements in order to achieve its objectives more effectively. Since then, Memoranda of Understanding (MoUs) have been drawn up with the International Laboratory Accreditation Cooperation (ILAC), the World Meteorological Organization (WMO) and the World Health Organization (WHO). The CIPM is looking forward to establishing similar arrangements with other international organizations. Draft Resolution A, presented for your consideration, deals with these initiatives.

However, in the last four years, the evolution and the extension of needs in metrology have increased even faster than predicted by the report. This is particularly true in the fields of application to social and economic needs in medicine, environment, safety and food. This led the CIPM to commission a similar report entitled *Evolving needs for metrology in trade, industry and society and the role of the BIPM* in the run-up to this General Conference. I have to resist the temptation to go into detail about the latest report, which was drafted for the CIPM by its Secretary, Dr Robert Kaarls, as it is a substantial agenda Item itself. I simply want to say that not only does it highlight new needs for metrology but it also identifies changes in the way that the

Metre Convention operates and in its relationships with other international and inter-governmental organizations. Furthermore it comments on the way in which the role of the BIPM is changing to meet the new challenge. You will have the opportunity to discuss this important piece of work later in the Conference.

However, it is clear that this report will not be the last. The next years will obviously bring new developments and unexpected events are sure to occur. For these reasons, drafting such documents must be a continuous task, as is the consequent need to update the activities of the BIPM. Draft Resolution E invites the CIPM to pursue its efforts in this direction.

The BIPM has also increased its close liaison with the NMIs, and meetings of NMI directors have been a regular and, we hear, a much-valued part of the international metrology scene. They bring together the actors of the Metre Convention and have themselves stimulated additional networks and collaborations among NMIs. Indeed, deeper regional collaborations and mutual dependencies as well as strategic development plans have featured strongly in the minds of NMI directors and the regional metrology organizations (RMOs) over the last few years. This clearly helps NMIs to work together in order to address new needs while still being able to meet their national responsibility for the provision of a national measurement system. Directors' Meetings have additionally proved to be an invaluable sounding board and discussion forum for the BIPM itself and we have received much good advice and many strategic steers from these meetings.

Resolution 3 of the 21st CGPM in 1999 on Associates of the General Conference of Weights and Measures also pointed to the need to extend the benefits of the CIPM MRA to more States and Economies. This is a topic of debate and a corresponding Resolution at this Conference. I am pleased to report that various initiatives to promote the value of membership of the Metre Convention and Associate status have resulted in an increase in membership. At the time of the last CGPM there were forty-eight Member States. There are now fifty-one Members and fifteen Associates, with several new applications for Associate status in the pipeline. In addition, there are also indications from groups of countries that they are interested in "group membership" under the Associate status. I draw your attention to the fact that this growth is at a time when proposals to governments about membership and financial contributions to international bodies are scrutinized very carefully indeed. Hard questions are asked about value for money and the necessity of such memberships. Our growth is, therefore, testimony to the way in which the Metre Convention still meets a real need in today's world.

I am also delighted to see that a similar growth in membership has taken place in the regional metrology organizations. This has been particularly evident in the Asia Pacific and African RMOs as well as in the Americas. But the RMO initiatives – and especially those that support and encourage smaller or newer metrologically active countries and economies – serve to unite and to share best metrological practice among members. This mutual support is invaluable and is often carried out with financial help from regional economic bodies as well as those NMIs that have development and international collaboration programmes. We have seen clear evidence that countries which, as recently as ten years ago, had little or no metrology are now playing a significant role regionally and, in many cases, internationally. Many are attending this Conference and we hope to see many more join the activities of the CGPM as well as the Convention as they grow in confidence, competence and metrological maturity. These developments also serve to show that metrology is not just for the top-level NMIs, and that the Convention has a role to play in supporting countries' needs whatever the level of measurement uncertainty that meets the needs of their economies and their societies. In this respect, the BIPM and several other international organizations are working together with a view to the formal creation of a "Joint Committee on Coordination of Assistance to Developing Countries in

Metrology, Accreditation and Standardization (JCDCMAS)". This Committee is still at the preliminary organizational stage. It will be discussed later, as it is the object of Draft Resolutions C and D.

The last General Conference passed a number of Resolutions relating to scientific and technical matters. These are all being pursued actively in NMIs and in the work of the Consultative Committees. For example, Resolution 4 addressed the need to place Earth resources, environmental and human well-being measurements on a sound, SI-traceable footing. While we have made significant progress on medical measurements we have had, somewhat disappointingly, less success with certain parts of the space and atmospheric studies communities. However, the recent initiatives between the BIPM and the WMO – while heavily resource-intensive from the BIPM side – are well placed to pursue this issue more vigorously and I hope that progress will indeed be made on this important issue.

9.3 The CIPM Mutual Recognition Arrangement

The implementation of the *Mutual Recognition Arrangement of national measurement standards and of calibration and measurement certificates issued by National Metrology Institutes* established by the CIPM (in short, the CIPM MRA) is expected by many to be the most far-reaching metrological development since the Metre Convention itself.

I believe that this is for three reasons. First, because it places metrology at the heart of fair trade and demonstrates its essential role in helping to provide objective evidence of compliance with international specification standards. Second, it has developed much greater levels of confidence in the world measurement system, especially through key comparisons. Finally, the economic and financial benefits are considerable. In order to provide some basis for this assertion, we asked independent analysts to assess the economic benefits of the MRA at an international level. The resulting report, *Potential Economic Impact of the CIPM Mutual Recognition Arrangement*, shows that, even taking the relatively limited impact on NMIs from the establishment of multilateral equivalence, the total annual saving to all NMIs is about 85 million euros.

We began the MRA initiative with the belief that it would be important and with the knowledge that all of us would be committing substantial resources to make it work effectively. The level of resource commitment may have been larger than we estimated but we did not underestimate the value and significance of the results. On the technical side, there are now more than 15 000 reviewed and reliable calibration and measurement capabilities (CMCs) on the BIPM key comparison database (KCDB). There have been over 300 CIPM and more than 120 RMO key comparisons, together with many more related regional comparisons. We have learned a great deal and many participants – large and experienced as well as small and new – have, for the first time perhaps, entered into key comparisons and found out that they sometimes had unsuspected errors in their realizations of the International System of Units, SI. Generally these differences were more of metrological interest than of significance in the marketplace, but this has not always been the case and it has been a valuable experience for all concerned. The transition period may be drawing to a close but it is clear that the processes that have been set up to launch the CIPM MRA will have to be maintained and continued. For example, NMIs will wish to see their KCDB entries revised as they improve their measurement capabilities. In addition, there will, of course, be the continuing need for key comparisons at some appropriate repetition interval to ensure the long-term credibility of the CIPM MRA.

One important issue that has emerged during the discussions on the CIPM MRA has been that of traceability and equivalence. In some cases there has been some confusion between the terms and a number of bodies have looked to us for clarification. Our position is that traceability is the familiar "unbroken chain of calibrations" to the units and quantities of the SI as realized at NMIs or similar organizations. The important point is that the concept of traceability to any named organization is metrologically meaningless. We know however that some bodies – usually NMIs – are mentioned in legislation or regulations and, of course, these bodies have a responsibility to realize and maintain the SI units and quantities in their particular country. I believe that our reformulation of the traceability concept is a helpful interpretation of the issue and that it should help to remove what some may regard as a technical barrier to trade. So, for the purpose of meeting existing legislative and regulatory requirements in cases where a calibration is requested by a company in another country, the company has to do two things. First, it has to demonstrate that any calibration is traceable to the SI as realized in the country where calibrations were made. Second, it then has to rely on the CIPM MRA for evidence of the equivalence that the SI realization in that country is equivalent to the SI realization in the country of that company. It is my understanding that the NMIs in question share a similar broad interpretation of the process and the Conference may wish to discuss this issue during the week.

We have created the framework for enhanced confidence in the world metrology system and the NMIs have now done the majority of the initial technical work. The next step is to work with the accreditors, the legislators and the regulators to encourage them to use the results. We have made a start and have seen some encouraging signs of progress – real indicators of success for the CIPM MRA. Let me give just four examples:

- First, we have signed a MoU with the ILAC and set up a joint working party to make recommendations on how we can work more closely together and strengthen the connections between our two MRAs. For the first time, we now have a way in which we can provide evidence of the equivalence of the national standards to which accredited laboratories trace their own measurements.
- Second, international trade negotiators see the MRA as crucial to the underpinning of trade between the United States and Europe. As a result, the EU/US trade agreement drawn up in 2000 – only a year after the signing of the MRA – cites the CIPM MRA as providing objective evidence of the equivalence of standards as well as recognition of the measurement capabilities of NMIs that are signatories to the MRA.
- Third, the European Union has launched a project – REGMET – which helps regulators to use the MRA as evidence of equivalent measurements. This is a huge step forward and I am pleased to see that colleagues in EUROMET have established collaborations with the APMP and the SIM in order to draw in the regulators from their regions. Regulator support is critical to the impact and success of the MRA, and I also welcome the hard work of colleagues from the National Institute of Standards and Technology (NIST, United States) to raise awareness of the MRA with US regulators. All this is a huge service to world trade and will reduce transaction costs and help to reduce the technical barriers to trade that are targeted by the World Trade Organization (WTO).
- Finally, we have signed an MoU with the World Health Organization (WHO) and can offer a sound, internationally robust and proven framework that the organization can use to help meet its own objectives for accurate and traceable measurement in medicine. The CIPM MRA allows the WHO to do this in a way that helps to ensure that measurements are accepted and are reproducible worldwide.

As one of the major aims of the MRA was to help to reduce technical barriers to trade, our consultants asked a number of questions about how metrology impacted on the costs of trade. Surprisingly, no robust estimates of this existed and we learned from the assessment that, even at a very conservative estimate, the MRA should have a direct impact on trade worth over 4 000 million euros. In addition, the MRA is a tool in reducing the technical barriers to trade by avoiding multiple, and not necessarily consistent, metrological controls of goods.

In view of this major involvement of the CIPM MRA in international trade, it appeared important that the Metre Convention should be accepted as an observer on the WTO Committee on Technical Barriers to Trade. Despite several applications, we have not yet succeeded. Draft Resolution B requests the help of Member States to obtain this status.

We are quite confident that the decision to proceed with the MRA was the correct one. As we are aware that NMIs are investing a great deal of time and resources in key comparisons, Quality Systems and the analysis of comparison results; we are working hard, in collaboration with the NMIs, to raise awareness of the MRA and of the benefits of participation. This is especially important in the world of regulation, legislation and accreditation and we hope to do more in years to come. Draft Resolution F calls for a general adoption of the CIPM MRA as a framework for international acceptance of calibration and measurement certificates. This is especially important in view of the extension of metrology into new fields. Draft Resolution G invites the inclusion of new designated laboratories in the MRA list to fill the domains not covered by the NMIs.

In the context of the MRA, I can also report that the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) has met regularly and has, I believe, become an extremely useful body. In early days it naturally enough focused on some of the problems that inevitably emerge when a complex arrangement like the MRA is implemented. These problems were steadily solved and the JCRB issued regular guidance notes and papers that amplified and explained the details of the MRA and how it was to be interpreted among signatories. One early success for the JCRB was the work it did on the minimum criteria that NMI Quality Systems would have to meet to fulfil the requirements of the MRA. This was a useful process and led to provisional agreement on best practice and the need for RMO chairpersons to report to the JCRB that individual NMIs and designated institutes had presented details of their system to RMO members and that the systems met the agreed criteria.

We are now approaching the end of the transition period and many of the early technical issues have been resolved. The JCRB is therefore turning its attention to a range of issues of general interest to RMOs and NMIs. Among these is the MoU that BIPM has established with the ILAC and the JCRB has set up a joint working party with ILAC to address common issues. The JCRB also discussed more strategic matters. Recent meetings have, for example, dealt with the Metre Convention's efforts to promote the benefits of membership to developing countries. It has also discussed the strategies adopted by NMIs within regions and which are leading to mutual dependence and the selective provision of calibration and other services. The JCRB currently meets twice a year – once at the BIPM and once within an RMO. We welcome this as it brings the BIPM into greater day-to-day contact with NMIs and allows us to learn in detail about the needs of members. In this connection, BIPM staff are regular attendees at RMO technical committee meetings. This gives us valuable knowledge about the implementation of the MRA and any problems that are encountered "on the ground". It also means that the BIPM is better informed about technical programmes in the RMOs and, therefore, how we can decide on research programmes and other technical activities at the BIPM that fill gaps in the field and meet the real needs of NMIs. I am pleased to report that the RMOs are growing in strength and

effectiveness – they have launched initiatives to increase their membership and they make a real impact on economic and technical infrastructures worldwide. It is now almost impossible to see how the Convention could meet and address its responsibilities without a strong RMO network.

9.4 The Consultative Committees

I now turn to the work of the Consultative Committees. In many ways these are the Metre Convention in action. All are lively and all develop a style and personality that best meet the requirements of their field. Demands and requests for membership and observer status are growing and the CIPM regularly reviews the membership as well as the criteria for membership. There have been twenty-seven full Consultative Committee meetings since January 1999, compared with nineteen in the previous four-year period. In addition, Committees are helped by specialized working groups, and in recent years new ones were created in technical areas such as viscosity, hardness and gravimetry, as well as several in various domains of chemistry, while other working groups deal with the analysis of key comparison results.

This is essential work but it is putting an increasing demand on BIPM resources. The problem is exacerbated because of the continued, but essential, expansion of the Metre Convention into new areas. In some cases, chairs or secretariats of Committees can be, and are being, shared with NMIs and we are already finding new ways of dealing with the problem. However, as will be seen later in the agenda when the Conference discusses the future work and programme of the BIPM, we cannot expect NMIs to come to our rescue on every occasion that a new activity is proposed. The issue of balance between the BIPM as a technical and as an administrative organization is also always uppermost in our minds and there is no doubt that we would be less effective if the BIPM were to become entirely an office-based body. Of course, the BIPM provides secretariat expertise to all the Consultative Committees but does not always maintain a laboratory-based activity at Sèvres. Acoustics, force and radiofrequency measurement provide just three examples. However, the BIPM manages to sustain its high level of technical support because of the general metrology skills it maintains, as well as the considerable experience it has in the technical and other issues that arise in international metrology. We may return to this later in our discussions.

I would like to mention a few highlights of the Consultative Committee work. These will be brief as you have more extensive reports in the regular communications from the BIPM. You will also have an opportunity to hear the Presidents of Consultative Committees present reports on the results and the importance of their work later in the Conference.

The **Consultative Committee for Length (CCL)** met in 2001 and 2003. One of its main preoccupations is the practical realization of the definition of the metre and a new edition was published under the auspices of *Metrologia* and placed on the BIPM website earlier this year. This remains a useful document but we are conscious that there are new developments in optical frequency standards and that the user community is interested in the most up-to-date values for optical frequencies from trapped atoms and ions. This interest is stimulated by the development of femtosecond “comb” systems that now allow absolute frequency measurements, related to the microwave frequency standard, of optical sources. These developments demand a regular dialogue between the “length” and the “frequency” community. In fact a joint meeting of the CCL and the CCTF will have discussed such matters in September this year. The CCL also organized a highly successful workshop on the practical issues associated with new comb technology that was attended by over fifty people from twenty-five NMIs. The aim of the

workshop was to give an opportunity for NMIs that were considering entering this field to discuss practical issues with those that already have combs. The BIPM is well placed to organize such events and we are pleased to have feedback that indicates that they fill a valuable need among the NMI community. The CIPM, through Draft Resolution H, requests the CGPM to approve this policy.

The CCL's main dimensional measurement work is carried out in its Working Group on Dimensional Metrology. This group has been concerned with a number of key comparison results and with the issue of how best to link RMO and CIPM key comparisons. The group also has an active discussion group on nanotechnology that has been encouraged to look closely at whether there are any specific international needs that could require coordination or action by the CCL.

The **Consultative Committee for Mass and Related Quantities (CCM)** met in 2002. In addition to considering the results of key comparisons, the CCM has a lively and important set of permanent and *ad hoc* working groups. Those on hardness, flow, and viscosity deal with industrially important quantities and all are evaluating how best to deal with their areas of responsibility. The CCM Working Group on Density has published a very useful review of the density of water that resulted in a new density table published in *Metrologia* in 2001.

The CCM Working Group on Gravimetry was established under the auspices of the CCM in order to organize and discuss the periodic comparisons of relative and absolute gravimeters, the last of which was successfully completed in 2001.

The CCM Working Group on the Avogadro Constant continues to stimulate debate and collaboration between NMIs. The target is a relative standard uncertainty of N_A of 2 parts in 10^8 in six years. The project is a collaboration between several organizations, and when the CIPM discussed the report of the Avogadro working group last year it decided to accept the CCM offer to help to coordinate this effort.

This is in itself an interesting initiative and I expect to see other proposals for coordination of major projects that require several partners. It also stimulates a few additional remarks. This element of our work is mentioned in the Convention but has reduced to some extent in recent years. However, several Consultative Committees have shown signs of reviving such an approach. This is happening in "new" areas such as the measurements of the properties of pure materials in the CCQM, as well as in more traditional areas. I welcome it and expect it to be a growing trend as NMIs become more technically selective. There are two reasons for this selectivity: first, because budgetary limitations mean that no NMI today can do everything. Collaboration is then the only real option and the BIPM can help to facilitate this process. Second, as RMO policies concerned with mutual dependence begin to be implemented, NMIs that reduce their activity in certain areas will want to maintain their technical competence by relying on others. While these moves are inevitable in today's climate, and are probably to be welcomed, there are dangers. The General Conference, supported by the CIPM, must, I believe, keep an eye out for situations in which the totality of NMI activity becomes sub-critical in any one field, especially if this threatens the integrity of the world measurement system. We also need to ensure sufficient long-term research into new measurement techniques, especially if they are likely to result in new determinations or realizations of SI units and quantities. The BIPM can help to identify such long-term or worldwide trends as well as specific requirements for metrology in what are often referred to as "metrology roadmaps".

I return to the work of the Consultative Committees with a few remarks on the **Consultative Committee for Time and Frequency (CCTF)**. At the last General Conference I drew your attention to the CCTF's interest in new optical frequency standards, many of which challenge the performance of the best caesium atomic clock techniques that realize the SI second. One of the major problems reported to you in 1999 was that conventional time-transfer systems were showing limitations in their ability to compare caesium fountain clocks as well as optical trapped ion or atom sources. To some extent, femtosecond laser-based frequency combs may have come to our rescue at the high-accuracy, high-frequency end of the scale but the CCTF is still concerned to ensure that improvements are made in two-way, satellite-based, time and frequency transfer. Indeed a highly successful workshop was held on this topic in 2001 and a more recent meeting in May 2003 discussed the current situation. This is an important area of CCTF work and is an excellent example of the way in which the BIPM works to help improve the effectiveness of the work of individual NMIs.

A major improvement in the calculation of International Atomic Time (TAI) and Coordinated Universal Time (UTC) has also been made through the initiative of the CCTF and the BIPM Time section. Proposals for careful analysis of the weighting of individual clocks as well as attention to the algorithms used to calculate TAI were discussed at a workshop held in 2002. At this, the BIPM was able to report a number of improvements in the TAI service, the most notable being a faster turnaround in the production of *Circular T*. This is important, of course, for individual NMIs as it helps them steer their national time scales more effectively. However, it is also increasingly important to the international navigation community as was clear from collaborations we have had with the projected European high-accuracy Galileo system for global positioning. The Galileo consortium was asking for much earlier access than we had generally made available to any differences in its time scale and the world mean. We have now responded and can now provide them, and others, with this service. As part of this collaboration, we are also negotiating a contribution from the Galileo time scale to TAI. Other improvements in the accuracy of TAI will come from contributions from more caesium atomic fountain clocks, and we look forward to receiving time scale contributions from more NMIs in the next few years as the systems that they have under construction come on line with regular data.

I should also mention current thinking on the future redefinitions of UTC. In addition to the *status quo*, several possibilities exist for its replacement and the future of the current leap second system is under discussion. The leap second, while often of fascination to journalists and the media, is increasingly an expensive nuisance to global positioning systems as well as to other computer-based timing systems that have to update their scales if a leap second is inserted. One possibility is to let TAI and UTC diverge, and only to realign them when the difference becomes of practical significance to the ordinary person. This matter is, of course, not simply one for the CCTF, and we shall continue to work with the International Telecommunication Union and other interest groups on this issue.

The **Consultative Committee for Electricity and Magnetism (CCEM)** has seen no diminution in the importance and need for work on electrical quantities. CCEM delegates report that NMIs are continuing to expand the range and accuracy of electrical services required by their customers. This has meant that the CCEM continues to deal with a wide range of electrical issues as well as key comparisons under the CIPM and RMO management. Like the CCL, it has devised a satisfactory way of linking these comparisons when there is no common use of a reference standard. But it is also mindful of the load on NMIs in this active area of metrology and has thus sought to limit the number of key comparisons. It has also reorganized the work of its radiofrequency and low-frequency working groups.

The CCEM Working Group on Electrical Methods to Monitor the Stability of the Kilogram continues to review the progress of major projects on watt balances. However the group feels that some further progress is still needed before beginning to monitor the kilogram artefact at better than 1 part in 10^8.

The CCEM has also discussed the need for an improved calculable capacitor and a collaborative project between the BIPM and the NML CSIRO in Australia is currently at the planning stage. This will help to create a link between the electrical and mechanical units and improve confidence in the robustness of the SI.

As I am sure the President of CCEM will remind us later, the CCEM has set up a Working Group on ac Measurements of the Quantized Hall Resistance. This group has studied the frequency dependence effects in existing sample devices, identified a number of modifications to chip design, and set up a project to see if these results are reproducible in different NMIs. It is a good example of the worldwide collaboration that can be stimulated by the Consultative Committees.

The CCEM keeps an eye on developments in current measurements, especially single electron tunnelling. This work is making interesting progress but there is still some way to go, as well as a number of practical problems to be overcome, before the technique performs at levels of accuracy that are of interest. In passing, I should note that this area is again one that benefits from collaboration and the sharing of tasks at the international level.

Finally, the CCEM has revised the very popular and useful Guidelines to Reliable Measurements of the Quantized Hall Resistance.

After a four-year break, the **Consultative Committee for Thermometry (CCT)** met in 2000, 2001 and 2003. The Committee has agreed guidelines for key comparisons and is expanding its work in low-temperature scales, humidity and thermophysical properties. As far as key comparisons are concerned, the CCT has debated, and successfully resolved, significant differences in the results of several NMIs. In low-temperature measurement, the CIPM accepted a CCT recommendation on the use of a provisional scale below 0.65 K. The CCT is also looking hard at the current performance and limitations of the International Temperature Scale of 1990 (ITS-90) and the techniques such as gas thermometry used to make temperature-related measurements. One immediate outcome of this work will be in the uncertainty budgets used by NMIs in their key comparisons as well as in the reviews of CMCs at RMO level.

The **Consultative Committee for Photometry and Radiometry (CCPR)** met twice since the last General Conference, holding meetings in 2001 and 2003. Its Working Group on Key Comparisons pioneered the use of “cut-off values” for the analysis of early key comparison results – a concept that was taken up by several other key comparison groups. The UV Working Group has also done a great deal of good work in bringing together the efforts of several NMIs in the ultraviolet (UV) region. Part of its original remit – that of helping to understand and resolve some of the large differences in national scales – has been completed. But the CCPR felt that as the UV was an important area with medical as well as human well-being applications, the work of the group should continue and should be extended to shorter wavelengths. It has also recognized that there are an increasing number of users of synchrotron radiation in the UV.

In scientific metrology recent developments of cryogenic radiometers have made it possible to cover a far wider range than before and the CCPR continues to see a trend towards greater use of cryogenic radiometers in many NMIs. It has noted growing confidence in the potential of a detector-based scale for radiometric measurements.

The CCPR also began to take an interest in many of the new industrial requirements that were changing the pattern of work at some NMIs and so has developed what has come to be called "measurement of appearance". The Committee will continue to operate in this area as well as other "downstream" or market-related quantities and measurements of industrial and commercial interest.

The CCPR has also dealt with high-temperature eutectic techniques of relating temperature and radiometric measurements as some interesting developments are expected to take place in this field over the next few years.

The **Consultative Committee for Ionizing Radiation (CCRI)** manages a very large number of key comparisons. In many cases, the BIPM is also the pilot laboratory because of the unique nature of the facilities and reference standards maintained at Sèvres. It has established a number of additional collaborations with international bodies. Most of the work of the CCRI is through working groups – or Sections as they are traditionally called. Section II (Radionuclide measurements) has a particularly interesting project concerned with a review of high-efficiency detection systems. This should result in the development of a prototype ionization chamber to extend and reproduce aspects of the International Reference System (SIR) regionally and therefore help to extend the capability of smaller NMIs.

The CCRI is very concerned over restrictions on the international movement of radioactive material. In some cases, the Committee believes that these restrictions will have the, perhaps unintended, effect of hampering movement of the small calibration and verification samples that are actually needed to monitor radioactive materials worldwide. The CCQM and the CIPM support the CCRI's concerns and are proposing Draft Resolution I to the General Conference on this issue.

The newest of the CIPM Committees, the **Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV)** held its first meeting just before the last CGPM since when it has held three additional meetings in 2001 and 2002. I can report to the Conference that the Committee is working well and clearly fulfilling the need identified at, and reported to, the 1999 Conference. Perhaps understandably, the early work of the Committee centred on the identification of key comparisons and their analysis. Several have already been completed and a correspondingly large amount of activity has been established at RMO level. The CCAUV has most recently turned its attention to a review of emerging needs at NMIs. This review should help to shape the future pattern of work and priorities of the CCAUV as well as stimulate thinking about whether some of this activity should be carried out as research collaborations between the NMIs. Other Consultative Committees are also tackling similar reviews of long-term detailed scientific needs that should be of help to NMIs as they formulate their programmes. The relatively traditional areas of airborne acoustics and vibrations are well covered by CCAUV work, and this has increased confidence in the standards and in microphones used as transfer devices. The growing work in underwater and medical acoustics is proving to be a particularly interesting development, which is creating new collaborations and activities at NMIs.

It is now difficult to think of the work of the Metre Convention without chemistry, yet the **Consultative Committee for Amount of Substance: Metrology in Chemistry (CCQM)** has only been in existence for ten years. In that time its membership has grown and now it is the largest of all the Consultative Committees. A "CCQM event" now includes many working group and ancillary meetings as well as workshops and seminars. This way of working is an exciting one, and it is clear that inclusion of chemical metrology in the work of the Metre Convention was well justified. Although the CCQM may have started out as a relatively modest activity in

analytical chemistry, gas analysis and certified reference materials; the CCQM remit now covers inorganic chemistry, surface science, organic chemistry, laboratory medicine, and bioanalysis. The subject of food is already part of the work of the Committee and a meeting is to take place in November between the BIPM/CIPM and the Codex Alimentarius Commission of the United Nations Food and Agriculture Organization and the World Health Organization. This meeting may well be the beginning of a major new activity for the Metre Convention as it seeks to translate the concepts of traceability and uncertainty from physics and engineering into chemistry and into new areas of measurement.

Not only has the CCQM changed our way of working but it has brought new concepts with which to wrestle. We are closer than before to the market, we interact strongly with regulators and legislators, and we are asked to fill gaps in the provision of lists of validated material and processes for them. This means we have to think hard, and be open minded, about the use of terminology and methods of analysis that have their basis in the mature areas of physical measurements but which do not always carry over into chemical metrology. In meeting these challenges, the CCQM has to establish close collaborations with those that have specialist knowledge and competence in these new fields. So it is perhaps no surprise that two of the Memoranda of Understanding that have been signed by the BIPM/CIPM come from the chemistry area: MoUs and exchanges of letters of understanding with the WMO and the WHO.

Finally I turn to the **Consultative Committee for Units (CCU)**. This committee is small but essential as one of its responsibilities is the revision of the brochure that deals with SI units and quantities. Interestingly, analysis of the "hits" on the BIPM website shows that the most popular section is the one devoted to the SI Brochure!

The CCU has met twice since the last Conference and is now well on the way to a final draft of the eighth edition of the Brochure. It is a painstaking and thorough task that also leads the work of the Committee into the need to consider revisions or new names for certain units and quantities. The CCU believes that when considering the case for a new name or unit, it must be confident that its proposals are likely to be taken up in the relevant community and must fill a specific user need. It therefore needs to work with other international scientific unions and to take advice from the Committee on Data for Science and Technology (CODATA) and other revisions of the fundamental constants.

The CCU is increasingly asked to consider units and measurements of quantities that are not within the current system. This is particularly true in chemistry.

One particularly important role of the CCU is to act as an independent think-tank in relation to new definitions of the base units and it has developed our understanding and appreciation of the implications and meanings of current definitions of SI units. It has, therefore, specifically contributed to thinking on the kilogram. Informal discussions also take place on the possibility and implications of redefinitions of other units on a "quantum" basis.

A topic relating to the work of the CCU concerns the symbol for the decimal marker in the SI. The tradition in BIPM publications is to use the point on the line in English language texts and the comma in French language texts. However, some international standardizing bodies specify that the comma on the line should be used in all languages. In response to this, three Draft Resolutions (K, L and M) from Australia, the United Kingdom and the United States, propose that the BIPM's procedures be adopted as best practice worldwide. These Resolutions are very similar in their wording. It is expected that representatives of these countries will work together to harmonize their versions and present a single common Draft Resolution to the CGPM.

In completing my report and review of the work of the CIPM Consultative Committees I should draw the attention of the Conference to the changing nature of their work. To begin with there is, of course, the enormous work associated with the CIPM MRA. I have already mentioned some others:

- an increase in formal relations with international organizations;
- more attention to workshops and other knowledge or technology transfer events; and
- a move towards measurement issues that may – only a few years ago – have been thought to be too industrial an activity for NMIs and the Metre Convention.

In addition, the Consultative Committees have to take note of what is agreed on Quality Systems within the RMOs and they sometimes have to make tough, often technically challenging, decisions during the process of key comparison analysis. Much of this is new to the Committees but it has been carried out well, with an openness and spirit of collaboration that bodes well for the future work of the Convention.

The workload of the Committees has increased. We can help reduce some of the burden through electronic paper provision and more rapid reporting to NMIs of the outcomes of the Consultative Committee meetings and other relevant work through e-mail and by publication of working and other papers on the BIPM website. In many cases, meetings and reports are now "paperless". This is something that I believe will aid, and simplify, the speed of communication. I hope that the Conference will support this trend as an efficient, effective, appropriate and quick way of disseminating the work of the Convention and its activities.

Some of this increased workload is, of course, because we are a victim of our own success and the influence of the CIPM MRA is being widely appreciated and welcomed in new communities. This is to be welcomed and we simply have to find ways of meeting our objectives while remaining consistent with our remit under the Metre Convention.

9.5 The CIPM

Traditionally, I also report to you on changes within the CIPM. At the last CGPM, I commented on the principles that lie behind the election of members of the CIPM. I also commented on the relatively rapid changes that have taken place in membership, and the destabilizing effect or loss of "folk memory" that this can have. I repeat the same point this year. The CIPM is an important body in a number of respects and we therefore need to attract senior and well-connected individuals as members. For example, we obviously value its scientific and technical contributions and the time that its members give to it and to the Consultative Committees. We also value the advice and guidance that it can give to the BIPM on its role in a changing metrological world and in a world of changing management styles and priorities at the NMIs. I can reassure the CGPM that the CIPM is taking all these responsibilities seriously and is working effectively. I can also report that the geographical balance of the International Committee is about right but that in looking for new members; we shall need to consider carefully how we cover the new areas of work of the Metre Convention and the BIPM. In some cases, we have dealt with this in the past through the appointment of Consultative Committee Presidents from outside the main CIPM membership. This will continue to be an option although we also need to continue our close relations with senior NMI metrologists who are active in their own countries and regions. We must keep this under review and the next President of the CIPM will, I am sure, wish to update the next General Conference on our success in this respect.

I have several changes to report. You will recall that the last CGPM confirmed the eight provisional elections made by the CIPM under Article 14 (1875) of the rules annexed to the Metre Convention. Resignations received since the last Conference were from: Dr William Blevin; Dr Katharine Gebbie; the late Dr Olli Lounasmaa; Dr Kozo Iizuka; Dr Paul Pâquet; Dr Roy VanKoughnett; and Prof. Andrew Wallard. New provisional members are: Dr Karen Brown, Deputy Director of the National Institute of Standards and Technology (NIST, United States); Dr Seton Bennett, Deputy Director and Director of International Metrology of the National Physical Laboratory (NPL, UK); Dr Franz Hengstberger, Manager of Regional and International Metrology of the National Metrology Laboratory (CSIR-NML, South Africa); Dr Barry Inglis, Director of the National Measurement Laboratory (NML CSIRO, Australia); Dr Janusz Lusztyk, Director of the Institute for National Measurement Standards (NRC-INMS, Canada); Dr Mitsuru Tanaka of the National Metrology Institute of Japan (NMIJ/AIST); and Dr Wolfgang Schwitz of the Federal Office for Metrology and Accreditation (METAS, Switzerland). There are no outstanding vacancies on the CIPM.

As was announced at the last CGPM, Dr T.J. Quinn has reached retirement age and will leave his duties on 31 December 2003. The CIPM has reviewed the *curricula vitae* of seventeen applicants and interviewed several of them. Finally, the CIPM elected Prof. Andrew Wallard as his successor, with effect from 1 January 2004. In the meantime, Prof. Wallard has joined the BIPM as Director designate**.**

At present, the bureau of the CIPM consists, in addition to the President and the Director, of two Vice-Presidents (Prof. Giorgio Moscati and Dr Barry Inglis) and a Secretary (Dr Robert Kaarls). In addition, taking into account my wish to terminate my duties in the CIPM during 2004, Prof. Ernst Göbel has been nominated President-elect and participates in bureau meetings.

9.6 The BIPM

First of all, I wish to mention the conclusion of a twenty-year programme of construction on the Pavillon de Breteuil site. The last building, the Pavillon du Mail, was inaugurated in April 2001. The decision to construct it has proven be a far-sighted one. It provides excellent meeting and conference facilities without which we could not cope with the demands for the number, as well as the size, of Consultative Committee and Working Group meetings. It also houses the BIPM workshop that previously was in cramped and unsuitable conditions, offices and a low-vibration room for highly sensitive experiments. We are proud of this and I hope that many of you will come to see it on Wednesday, during this Conference.

At each General Conference, Member States are required to examine the work of the BIPM and its proposals for the work to be carried out in the next four years. The CGPM is then asked to vote an appropriate budget – the subject of Draft Resolution J.

The BIPM holds a special place in the work of the Metre Convention. There are two basic and interlinked tasks. The first is the essential administration of the Convention and the management of the CIPM Consultative Committees, Joint Committees, and liaison with international and intergovernmental bodies on behalf of Member States and NMIs. Secondly, there is the technical and scientific work that goes on at the BIPM which gives it credibility internationally and which allows staff to understand the issues involved in international metrology. The BIPM technical programme, which is carefully chosen to avoid duplication with NMI programmes and to maintain essential and unique facilities such as the mass artefact, the SIR comparison apparatus, the international time scale TAI, and many others. These are all good examples of the benefits to

NMIs from sharing the cost of unique facilities and capabilities. The consultants' report on the international impact of the CIPM MRA stressed the importance of the technical credibility that comes from a scientific programme at the BIPM and we have seen, from the 2002 questionnaire completed by NMI directors, that the scientific work of the BIPM is greatly valued. In order to ensure that the BIPM technical programme is up to date and that it meets the needs of Member States, however, it is important to maintain flexibility and to respond to changing priorities. This is the task of the CIPM, to which the BIPM Director and senior staff present their past achievements and future plans each year. Other inputs come, of course, from the regular contact that staff have with NMI colleagues through visits as well as through Consultative Committees, each of which has the BIPM work programme on its agenda. We welcome these inputs and while it is clearly not always possible to do everything that NMIs and Member States might want us to do, and it is not always sensible to make too rapid a change of direction, the essential priorities and orientations of the programmes are clear. As the tasks of the BIPM under the Convention have been the object of recent debate, I should like to draw your attention to the statement of the "role of the BIPM". This was discussed by NMI directors and by the CIPM and was quoted in the "Kaarls' Report". For ease of reference, I reproduce the statement in the following paragraphs:

The goal of the BIPM is worldwide uniformity of measurement.

The BIPM will achieve this goal by providing the necessary scientific and technical basis for such uniformity and by collaborating with other institutions and organizations that have related missions. Therefore, its principal tasks are:

The International System of Units (SI)

- to keep up to date and disseminate the text of the International System of Units known as the SI Brochure.

Basic scientific and technical tasks

- to conserve and disseminate the primary standard of mass, the International Prototype of the kilogram;
- to establish and disseminate International Atomic Time and, in collaboration with the International Earth Rotation Service, Coordinated Universal Time;
- to make its own realizations of other base and derived units of the SI and, if necessary, other units that are not yet possible to link to the SI;
- to participate in the development of primary methods of measurement and procedures in chemical analysis and bioanalysis and where necessary to maintain its own standards in these fields;
- to undertake research focused on the development of present and future measurement units and standards, including appropriate fundamental research, studies of the conceptual basis of primary standards and units and determination of physical constants, and to publish the results of this research.

Specific technical services delivered to NMIs

- to carry out certain international comparisons of practical realizations of certain base and derived units of the SI, as may be necessary to meet the needs of the ensemble of the NMIs;
- to provide a specialized calibration service for NMIs for selected national measurement standards whenever this is desirable and feasible;
- to provide opportunities for technology transfer during calibrations and comparisons organized by the BIPM;
- to provide facilities for the exchange of scientific staff between the BIPM and NMIs;
- to provide certain consultancy services to NMIs related to peer review of their activities.

Global coordination of metrology

- to provide support as necessary in the operation of the CIPM Mutual Recognition Arrangement for national measurement standards and for calibration certificates issued by NMIs through the operation of the BIPM key comparison database, the management of the JCRB and through participation in meetings of Consultative Committees and appropriate meetings of the RMOs and through the publication of the results of key and supplementary comparisons;
- to provide the scientific and administrative Secretariat for the General Conference on Weights and Measures, the CIPM and its Consultative Committees as well as the secretariat for meetings of directors of NMIs and the various Joint Committees and to publish reports of their deliberations.

Relations with other organizations

- to enter into agreements with intergovernmental and international organizations where such agreements would help in the coordination of the work of these organizations with that of the BIPM or the CIPM and where it may stimulate corresponding coordination at the national or regional level;
- to collaborate, and where appropriate enter into agreements to establish Joint Committees with intergovernmental and international bodies having related missions;
- to act on behalf of the NMIs of Member States of the Metre Convention in representing their common interest as the occasion arises.

Information and publicity

To promote as widely as possible using all appropriate methods, the activities carried out under the Metre Convention, in particular:

- to provide through the BIPM website, a centre for information on matters related to the Metre Convention, the CIPM, its Consultative Committees, Joint Committees, the CIPM MRA, including the BIPM key comparison database, and matters related to international metrology;
- to edit and arrange for the publication of *Metrologia*, the international scientific journal of metrology;
- to ensure, with other appropriate organizations, that basic documents needed for uniformity of measurements, such as those on vocabulary in metrology (VIM) and on the expression of uncertainty in measurement (GUM), are kept up to date and widely disseminated;

- to organize workshops and summer schools for the benefit of staff from the NMIs.

Cost-effectiveness and evolving role of the BIPM

The BIPM will carry out these tasks in the most cost-effective and efficient way possible designed to achieve its goal and will continue to be ready to adapt and change its tasks as the need arises and as decided by the CIPM acting under the authority of the Member States of the Metre Convention.

Work of the BIPM

In addition to the regular reports to the CIPM and to Consultative Committees, the work of the BIPM is reported regularly to governments and to meetings of NMI directors in a variety of ways. First there is the *Director's Report on the Activity and Management of the International Bureau of Weights and Measures (BIPM)*, prepared in July each year and widely distributed. Administrative and financial matters are reported to governments through the annual report to Member States, and the annual audited accounts are prepared for the CIPM. Delegates are therefore well aware of the detailed work that is carried out in support of the Convention, so all I need to do is draw your attention to a few general points. This may, however, be a little more detailed than usual because of the important decisions that the Conference needs to take on the BIPM dotation.

The BIPM has made several important changes, innovations and crucial changes of direction in the last four years. In the following, those that have an impact on the workload and cost of the organization are described.

I begin with the work needed to put the **BIPM key comparison database (KCBD)** in place. We operate the KCDB with only two staff and some help from the IT section. The KCDB site alone receives over 3000 "visits" per month – a figure that is growing rapidly. In addition to the KCDB, we are extending the services we provide through the website, which is now our principal means of communication and provision of information for Member States and NMIs. For example, the site offers metrology search engines, links to NMI websites and to relevant international organizations. In addition, all Committees now operate electronically and papers are made available through dedicated pages on the BIPM website. As a consequence, and as an example of the additional services to Committee members, the conference room in the Pavillon du Mail is equipped with state-of-the-art facilities. These allow members to access web-based papers through individual Internet connections and to connect to the projection facilities. From user surveys, we learn that these services are greatly appreciated and highly regarded.

Other BIPM **services to Member States** have also grown over the last four years. Let me give just three examples:

- The volume of BIPM publications and reports continues to grow and reflects the increased Consultative Committee and related activity. In the last year for which we have full records (2002), some 1550 pages of reports were produced: twice that for 1999, the year of the last CGPM, and 50 % more than in 2001.
- We now receive some 600 visitors a year, the majority for technical meetings. BIPM facilities are heavily used and 120 days of meetings were held in 2002, whereas there were only 90 in 2000.

- We organized, in July 2003, the BIPM metrology summer school for younger staff of NMIs that was attended by eighty students from twenty-five different countries.

In recent years many NMIs have adopted **Quality Systems**. In some cases this was to respond to the gently chiding remarks of some accreditors that NMIs should "prove they are as good as they say they are". In other cases, NMIs adopted Quality Systems as one of a number of new management methods.

The CIPM MRA of course requires a Quality System as one of the elements of compliance. The BIPM took the view that it should also introduce quality procedures and decided to begin with its measurement services. Progressively this will be extended to other aspects of work. The BIPM decided to adopt and self-declare that its system met the requirements of ISO/IEC 17025 but wished to validate this through peer review. This work is well advanced: some external visits from experts have already taken place and BIPM is on track to have its calibration services assessed by the end of 2003. A senior member of staff was transferred to take on the responsibilities of Quality Manager.

At present the BIPM has seventy permanent and short-term contract **staff.** This figure is likely to reduce over the next few years as staff retire and, because of budgetary constraints, are not replaced. We have, however, begun to resource the new activities in chemistry, and the Chemistry section now has four professional and technical staff in post. Three staff were new experienced recruits because it was clear that the BIPM did not have the chemical and related skills that it needed to carry out its technical work or to service the needs of the CCQM and the wider community. The fourth staff member was the result of an internal transfer. In order for the section to continue to meet the needs of Member States and for it to cooperate effectively with international and intergovernmental organizations, we should plan for an increase of two appropriately qualified and experienced professional staff. These will be new recruits. The work of this section is just as intellectually challenging and stimulating as metrology in existing fields. There are differences but I, for one, find it a fascinating and vital new activity that is a natural and essential extension of the current work and responsibilities of the Metre Convention.

Internal mobility is always a challenge in a small organization, but four people have changed jobs in the last three years and three more internal job moves are already planned.

In order to achieve its work goals, the BIPM has benefited from a number of **guest workers and secondees.** This has always happened to some extent but is clearly a way of working that is more in keeping with the changing and increasingly close nature of the relationships between the BIPM and NMIs. A particularly valuable secondment has been the Secretary to the JCRB – a task that required someone with a broad experience of RMO matters. Dr Angela Samuel's highly successful secondment from the NML CSIRO (Australia), to this post is shortly coming to an end and I am pleased to say that the CENAM (Mexico), has agreed to second Dr Ismael Castelazo to fill it. I should like to express my gratitude to both Member States for their support. In addition we have attracted six Research Fellows who came to work for periods of a year or more. Unfortunately we do not believe that budgetary resources will allow us to continue to pay for such secondments and, as you will see from the details provided to you, this valuable source of expertise is unlikely to be maintained in the future.

This flow of colleagues from NMIs to BIPM, and *vice versa*, is however important for the future of the BIPM, its relevance to NMI work, and its international networking. I remind the Conference that we have discussed this issue before and that the BIPM is ready to host more staff from NMIs if directors can release them and help pay towards their costs of secondment. It

is an excellent way for younger staff, in particular, to make valuable contacts as well as to develop a top-down view of the work of metrology at an international level.

During the last year we have worked hard at a formulating a **long-term strategy** for the development of the BIPM. This was set in the light of current and future changes in world metrology and in the pattern of current and future work. To help us, we have sought views from Member States and a number of NMI directors and we gratefully acknowledge their advice and commitment to this process.

From the outset it was crystal clear that we would have to make some hard decisions if we were to satisfy the obvious technical needs identified in the "Kaarls' Report". We also knew that these future needs could not be satisfied within current budgets and that we needed to set priorities. After establishing criteria against which we could compare our overall technical priorities, we decided on the minimum set of activities that we thought necessary to meet current and future needs. We believe that we can now meet future needs through some significant cuts in scientific work at the BIPM of lower priority than the remainder, together with a proposal for a modest budget increase. This would be the first time since 1964 that such a request has been made to the General Conference and is presented to you in Draft Resolution J. We have also reviewed BIPM administrative and accommodation costs to see if further economies could be made.

In coming to our **conclusions on the technical priorities** we were made particularly aware that a large number of Member States wished to see the majority of current services maintained. However, we realized that this would not be possible if we were to diversify, albeit highly selectively, into a number of new areas of work. Our final views on priorities were therefore based on a variety of inputs that included surveys and assessments of what NMIs valued, the views of directors in their annual meetings, together with discussions with a number of governments from a wide range of Member States. All this led to a number of conclusions on the current resource allocations at the BIPM. Despite their excellence and despite the value that we knew they brought to a number of Member States, we concluded that the Photometry and Radiometry section should be closed. Additionally, we proposed that the work on lasers should be restructured to concentrate on calibration and characterization of laser sources and comb comparison techniques. This meant that this section would reduce significantly in size over the next few years. We also decided that we should implement both of these conclusions as soon as possible, while continuing to discuss the case for a budget increase with those concerned. This is because the cost savings we implemented would not, of themselves, be sufficient to allow us to address the highest priority needs for the future, most especially those in chemistry and related fields.

In deciding to reduce staffing to fit into the financial planning assumptions in the "Programme of work and budget of the BIPM for the four years 2005 to 2008", we, of course, also took a hard look at whether we could achieve additional **administrative efficiencies and savings**. As part of this we benchmarked our administration costs against other NMIs where we could look at comparable data. We also compared the costs of providing support services through external contractors. In the latter case, it was always more expensive to use external services as multitasking among BIPM staff meant that any potential savings would not be as large as might be expected.

We examined the potential for savings in equipment and other general expenditure. As a result, the BIPM's **external purchases** are now managed by a full-time professional. He has already saved over 3 % of total laboratory and general expenditure.

We also looked at the arrangements that apply to ***Metrologia*** and concluded that we could reach an arrangement that helped to reduce administrative and production costs and that would allow the journal to be marketed more vigorously than in the past. This, we believe, will help *Metrologia* begin to build a presence in the new areas of activity of world metrology. As a result, we now have a contract with the United Kingdom's Institute of Physics under which they have taken on much of the routine work and where the BIPM still retains editorial control. This has been in operation for nearly a year and is proving to be very successful.

I can therefore report that the BIPM's administrative costs compare well with other organizations. The CIPM is satisfied that these and other efficiency and cost-saving measures introduced in recent years are keeping overheads as low as possible.

On **accommodation**, we welcome the successful completion of the Pavillon du Mail. However, we are also acutely aware that we work in a special environment and that we are custodians of historic and beautiful buildings. Their maintenance is not cheap but it is our responsibility to preserve their character as well as to provide a suitable environment for the technical activities of the BIPM. We have no plans for further building at the moment so our proposed work programme will have to be carried out within existing laboratories and offices. A number of laboratories have already been refurbished with the chemical metrology programme in mind and we shall continue to review the balance of accommodation between the existing sections. In common with all NMIs, a significant and unavoidable part of our running costs covers maintenance and investment in air-conditioning systems.

Many of the decisions and actions that I have reported are themselves the correct course for the BIPM to take as a well-managed organization that can live within its projected budgets. But, more than that, they have been taken so that we could come to this General Conference with a clear, and I hope convincing, picture of continued attention to costs in a time of technical expansion and managerial change. Without them we would not have been able to demonstrate to you that we have already taken our share of the pain and that, with your additional financial support, we have a sound strategy to deal with the changes that we expect for the BIPM in the years to come. Our strategy cannot, of course, be static. At a time of rapid change, long-term planning is difficult but we shall continue to monitor the environment in which we operate and, with advice from the CIPM, will react accordingly. I can reassure you that the CIPM and the BIPM management and staff are alert and open to the new ways of working that will be required to ensure a successful and lively organization that meets the needs of the Convention Members.

It is clear that all this will be a matter of debate in the Conference and in the Working Group on the Dotation. In the meantime, I commend to you the proposals in Draft Resolution J which have the full support of the International Committee.

My final remarks concern the technical work in the laboratories of the BIPM over the last four years. I do not intend to go into any great detail as this has already been reported comprehensively to you in the relevant annual reports made by the Director. I shall simply refer to a few highlights from each section.

Length

The work on 532 nm Nd:YAG-stabilized lasers has demonstrated that, as we expected, these lasers have a very high short-term stability and are useful as interferometric sources and as reference standards in optical comb systems. Several international comparisons have taken place and the dispersion of individual lasers is routinely in the 5 kHz range.

In collaboration with the Institute of Laser Physics (ILP, St Petersburg, Russian Federation), we have developed a compact solid state 532 nm laser that will be used, together with novel interferometric modelling software, in several other projects at the BIPM, notably the calculable capacitor and the watt balance.

Our work on methane-stabilized and rubidium-stabilized lasers is drawing to a close now that optical comb techniques have replaced the traditional chains in which the methane-stabilized laser played a key part.

The major development in the last few years has, of course, been in optical comb technology. This made it possible to conclude the long-standing comparison service on iodine-stabilized He-Ne lasers and to replace it with an absolute frequency calibration service based on combs established at the BIPM. We have now built two comb systems – one portable – and have demonstrated, for the first time and in collaboration with colleagues from the East China Normal University, that combs appear to perform well at the sub-hertz level for optical frequency measurements made on our stabilized laser references. These systems are now to be used in a further series of international comb comparisons to investigate possible systematic effects and to increase confidence in comb techniques worldwide.

Gravimetry continues to play an important part in our work, the highlight being the Sixth International Comparison of Absolute Gravimeters in 2001, in which several new analytical techniques were applied and, as a result, we improved on past performance.

Mass

The section continues to make regular recalibrations of prototype standards for NMIs and also to produce new kilogram standards.

There have been a number of improvements in BIPM balances. We have negotiated a licensing agreement for the flexure strip balance and have commissioned the new Metrotec 1 kg balance. This balance now has a reproducibility and repeatability of less than 1 μg. In order to achieve this we have improved the performance of the laboratory conditions and have automated various aspects of the measuring process. The balance is playing a key role in the calibration of the 100 g reference standards used by METAS in their watt balance experiments.

A substantial part of the work of the section is the developments of tools to analyse and improve weighing processes. In particular the use of ellipsometry is now well established as a way to study surface contamination from water vapour and carbon-based substances. The magnetic properties of standards are regularly measured by the new BIPM susceptometer that has been copied by several NMIs and we have commissioned the hydrostatic weighing apparatus used to make volume measurements of new mass standards. In addition, we have shown that improvements can be made to air density measurements so that the uncertainties based on the traditional CIPM formula can be reduced by a factor of five.

Finally, a small but important project has been the measurement and characterization of silicon artefacts used in the Avogadro constant project.

Time

The core work of the Time section continues to be the production of *Circular T*, which allows the BIPM to disseminate the reference time scales TAI and UTC based on data from NMIs and other time centres. The section has made a number of improvements in the past few years that have improved the performance of time scales and the computational speed of TAI and UTC. The most notable among these has been the development of improved algorithms and the revision of weights assigned to individual clocks. We now have increased confidence in the stability and accuracy of time scales at one part in 10^{15} level. The section has welcomed the regular contribution to TAI from a number of caesium-fountain clocks and is starting to analyse their uncertainty data.

This work has been helped by the commissioning of two hydrogen masers for time and frequency transfer applications as well as the provision of the BIPM internal time reference network.

Time and frequency comparison is a major practical as well as a research activity within the section. Particular attention has been paid to two-way time transfer links that have been part of the TAI calculation since 2000 and to other promising techniques, including dual-frequency carrier phase methods. These have been used to compare remotely separated hydrogen masers at the 10^{-15} level and continued improvement is expected.

Electricity

Over the last few years, significant progress has been made with programmable Josephson junction arrays and the Electricity section has compared a number of devices with the BIPM reference standards. The outcome is that we can find no measurable difference at the 0.1 nV to 10 V level and we feel confident in the performance of these arrays. The PTB (Germany) has kindly donated one such array to the BIPM.

AC quantum Hall effect devices are increasingly popular as reference standards and, in collaboration with NMIs in the CCEM Working Group on ac Measurements of the QHR, we have been steadily reducing the frequency dependence of devices through the insertion of gates on and around the circuitry. Current state of the art is at the 1 to 2 parts in 10^8 per kilohertz level.

The BIPM service for capacitor calibrations is very much in demand and has shown the value of earlier decisions to construct a high-accuracy measurement chain that can provide a service from 10 pF to 100 pF with uncertainties at the level of a few parts in 10^8. Improvements have been made in the bridges as well as in the understanding of some small systematic frequency dependencies of the high-precision resistors used in the measurement system.

A major achievement during the last four years came from studies concerned with the noise characteristics of voltage standards and diagnostic equipment. This work initially concentrated on the identification of pressure and, to some extent, temperature dependencies of the output of Zener diode reference devices, as well as a number of ground loop problems with some commercial devices. As a result of further related studies into noise performance using the Allan variance (or deviation) technique pioneered in the analysis of microwave and optical frequency standards, the section produced unique results for the performance of Zener sources and nanovoltmeters. Techniques were established to identify the point beyond which $1/f$ noise limitations made it unnecessary to average the results over longer periods. The merits of this technique were quickly picked up and a number of NMIs collaborated with the BIPM to transfer its knowledge and technology into their own systems. The Allan variance methodology is not

limited to applications in electricity and collaborations with the BIPM Chemistry section will seek to apply it to ozone reference photometer characterizations.

The Electricity section is also heavily involved in voltage and resistance comparisons, having made some improvements to its own equipment and introduced a further degree of automation. It is also much in demand as a pilot of key comparisons and as a participant in RMO comparisons especially when it can supply travelling standards or can make measurements on artefacts during a comparison.

Calibration services from the section continue to be those that are in highest demand from NMIs.

Radiometry, Photometry, Thermometry and Pressure

The small team in this section has been heavily involved in key comparisons, either as pilot or in the analysis of results.

Comparisons of detectors, both single element as well as trap detectors, combined with experience with the BIPM cryogenic radiometer system, have helped to increase worldwide confidence in the use of detector-based scales. For most practical purposes, the BIPM has routinely used detectors for absolute realizations of the candela and lumen as well as for the characterization of filter radiometers. Recent key comparison results also showed the need to adjust the BIPM maintained candela and lumen based on the reference value from the key comparison.

The BIPM's very modest resources in temperature measurement have played a crucial role as pilot in a key comparison of water triple-point cells. The equipment has been improved in order to reduce uncertainties and to add automation to the data processing. Early results from the key comparison show that the repeatability of the system has indeed improved.

A recent collaboration with the NMIJ/AIST (Japan) in the characterization and investigation of metal-carbon eutectic fixed points in the range 1100 °C to over 2500 ºC is in its early stages. It is, however, already showing interesting and promising results in terms of low uncertainties that may make it possible to measure lower temperatures with a similar reduction in uncertainty.

Ionizing Radiation

The work of the Ionizing Radiation section, as ever, is characterized by a huge demand for calibrations and measurements from NMIs. One recurring theme in the last four-year period has, therefore, been continued efforts to improve facilities, extend competencies and capabilities in order to respond more effectively to Member States and to new scientific requirements in all the section's areas of responsibility.

The most eye-catching improvements are in new high-stability x-ray high-tension generators, modifications to the current measuring systems for medium-energy x- and γ-dosimetry systems and, at long last, the installation of a ^{60}Co source. These capital equipment investments have generally replaced old or unreliable equipment and have done much to improve the efficiency with which the section can deliver its programme.

In x-ray standard work, new correction factors based on Monte Carlo calculations have been studied and introduced.

The SIR continues to be a workhorse of the section and is constantly in demand for new or improved measurements, having demonstrated its unique role in activity measurement. Extending the scope of measurement capabilities and modifications, through new detectors, better mathematical techniques applied to the SIR efficiency curve, together with new triple-to-double coincidence ratio counting, has allowed the BIPM to respond to the need for improved uncertainties and to measurements on new radionuclides.

Chemistry

BIPM technical work in chemistry is only a few years old but it has already achieved several notable successes. The initial work, in collaboration with the NIST, focused on gas standards and especially on the development and characterization of ozone photometers for ground-level ozone standards based on the NIST-designed standard reference photometer. The first comparisons have already been held with NMIs from EUROMET and have demonstrated agreement consistent with the evaluation of the uncertainty of the measurements. The BIPM will act as the pilot laboratory for CCQM-P28 (ozone ambient level), for which twenty institutes have registered their participation. The pilot study will underpin ozone-related air-quality measurements in regional, national and international networks.

The ozone programme is also supported through the establishment of a gas-phase titration facility. This will act as a second method for primary ozone concentration measurements underpinned by additional facilities for NO and NO_2 gas standards.

Summary

Standing back from these short reviews of key achievements and activities allows one to appreciate just how much has been achieved by a relatively small number of people. The BIPM staff must balance a wide range of requirements and, of course, the work of Consultative Committees, working groups and key comparison reports all have to take a high priority and must meet short deadlines and tight time scales, as must the comparison and calibration services to Member States. This makes it all the more remarkable that the BIPM continues to create new knowledge that is relevant to NMI programmes. It also means that the niches chosen for their work programmes must be carefully chosen in order to maximize the impact of small teams. I believe this to be the case. I note also that the publication record of BIPM staff is extremely high, comparing very favourably with the highest rates in NMIs.

Publications

Since October 1999 the following have been published:

21st General Conference on Weights and Measures (1999), *Proceedings*, 402 pp.

International Committee for Weights and Measures, *Report of the meetings,* **67** (88th meeting, 1999), 311 pp.; **68** (89th meeting, 2000), 134 pp.; **69** (90th meeting, 2001), 159 pp.; **70** (91st meeting, 2002), 213 pp.

Director's Report on the Activity and Management of the International Bureau of Weights and Measures, **1** (2000), 199 pp.; **2** (2001), 226 pp.; **3** (2002), 237 pp.

Annual Report of the BIPM Time Section, **12** (1999), 99 pp.; **13** (2000), 97 pp.; **14** (2001), 102 pp.; **15** (2002), 96 pp.

Consultative Committee for Acoustics, Ultrasound and Vibration, 1st meeting (1999), 77 pp.; 2nd meeting (2001), 94 pp.

Consultative Committee for Amount of Substance: Metrology in chemistry, 6th meeting (2000), 94 pp.; 7th meeting (2001), 106 pp.; 8th meeting (2002), 86 pp.

Consultative Committee for Electricity and Magnetism, 22nd meeting (2000), 130 pp.; 23rd meeting (2002), 146 pp.

Consultative Committee for Ionizing Radiation, 16th meeting (1999), 203 pp.; 17th meeting (2001), 238 pp.

Consultative Committee for Length, 10th meeting (2001), 208 pp.

Consultative Committee for Mass and Related Quantities, 7th meeting (1999), 74 pp.; 8th meeting (2002), 91 pp.

Consultative Committee for Photometry and Radiometry, 15th meeting (2000), 86 pp.; 16th meeting (2001), 107 pp.

Consultative Committee for Thermometry, 20th meeting (2000), 83 pp.; 21st meeting (2001), 83 pp.

Consultative Committee for Time and Frequency, 14th meeting (1999), 137 pp.; 15th meeting (2001), 142 pp.

Consultative Committee for Units, 14th meeting (2001), 74 pp.

Circular T (monthly), 6 pp.

To these publications must be added 40 BIPM Reports and about 170 articles in scientific journals or conference proceedings, and *Metrologia* volumes **37**, **38**, **39** and **40**.

The President of the Conference then invited questions and comments from delegates.

On behalf of the German delegation, Dr Röhling thanked Prof. Kovalevsky and the CIPM, Dr Quinn and the BIPM for the work achieved over the last few years. He remarked that Prof. Kovalevsky had demonstrated that the BIPM continues to fulfil its mission within the Metre Convention, and said that the German delegation fully shared the opinions presented in the President's report and supported the continuation of the work. As a representative of the German Ministry for Economy and Work, and as President of the PTB's Scientific Council, he said he fully appreciated the activities undertaken and the importance of the CIPM MRA, and foresaw that the contribution of the BIPM would become increasingly clear in the years to come.

He lent his voice to the appeal for observership status of the BIPM on the WTO's Technical Barriers to Trade Committee.

Pointing out that the domains covered by metrology were becoming ever broader and the technical level of the measurements involved continually increasing, while budgetary resources were being decreased, not only in Germany but in most European countries, he said he was nevertheless confident that the established structure would be able to deal with demands. He congratulated the CIPM and BIPM on the programme which was starting up in chemical

measurements, underlining the importance of maintaining a balance between new activities and the traditional fields of metrology.

He then commented on the thorough appraisal of the PTB undertaken in 2002, carried out by an international panel of experts including Drs Kaarls and Quinn. The PTB had been rated very highly in nearly all fields, but the review committee had made a number of recommendations concerning the budget, internal structure, and certain subjects for deeper study in the coming years: notably metrology in chemistry and information technology (IT).

Finally, he pointed out that budgetary concerns were ubiquitous, and that the German Government had decided that, in general, their contributions to international organizations should remain stable. He hoped that a compromise would be found during the Conference, bearing in mind both the requirements of the BIPM and the restrictions imposed by the national budgets.

Professor Kovalevsky thanked him for his appreciation of the work undertaken at the BIPM.

Dr Kumar (India) added his appreciation of the excellent work achieved by the BIPM and made a few comments on the benefits of links between the BIPM and developing countries such as India. He noted that metrology is a very specialized area of work, falling largely under the responsibility of the NMIs. National governments exert pressure on the NMIs, particularly with respect to eliminating technical barriers to trade, and India, like many other countries, is in the process of registering CMCs in the BIPM key comparison database. However, he warned, India is a poor country and any sharp increase in the dotation of the BIPM would have to be carefully negotiated. He volunteered to represent India on the working group on the dotation. Dr Kumar noted that several commercial companies, particularly IT and experimental research companies, had established facilities in India and asked if it might not be appropriate for the BIPM to also set up a remote centre. He also invited guest workers to come to the NPLI from the BIPM and other NMIs.

Professor Bordé then turned to the formation of the working group on the BIPM dotation, and invited Dr Kaarls to propose the list of members.

Dr Kaarls reminded delegates that the working group on the BIPM dotation would meet during the afternoon of Tuesday 14 October, and if necessary again during the afternoon of Thursday 16 October, to consider Draft Resolution J (page 413) and make a recommendation to the Conference. He proposed the following list of members for the working group on the dotation: Canada, China, France, Germany, Italy, Japan, the Republic of Korea, Mexico, Norway, the Russian Federation, Serbia and Montenegro, the United Kingdom, the United States, along with India.

The proposed list was accepted with the further addition of Australia and Egypt, whose delegations indicated that they would also like to participate. Professor Bordé noted that each participating delegation should nominate a maximum of two people for the working group. A report of the discussions of the working group is presented under Item 16 (page 361).

10 External relations

10.1 Organisation Internationale de Métrologie Légale

On behalf of the Organisation Internationale de Métrologie Légale (OIML), Dr Gerard Faber, President of the Comité International de Métrologie Légale (CIML), thanked Dr Terry Quinn for his leadership of the BIPM and his contribution to metrology in general, and welcomed Prof. Andrew Wallard as incoming Director of the BIPM. He congratulated the BIPM on the work achieved during the last four years and said that the OIML would continue to provide support when needed.

He commented that the BIPM and OIML are sister organizations and need to work together as many of their tasks and objectives are common to both.

He noted that the OIML also has a busy schedule of meetings, citing their forthcoming annual CIML meeting, to be held in November 2003 in Kyoto, Japan; the 12th International Legal Metrology Conference, to be held in Berlin in October 2004; and the CIML meeting in 2005 which will be held in France to celebrate the 50th anniversary of the founding of the OIML.

One of the core activities of the OIML is the setting of international recommendations in legal metrology and keeping them updated. An important current area of work is the development of mutual recognition systems, based on a mutual acceptance arrangement (MAA) for the recognition of type-approval test results. Subsequently the OIML wishes to see international acceptance not only of the results but of the associated certificates, and in a further step, international recognition of results of initial verification. The forthcoming meeting in Kyoto will vote on this MAA, and during its implementation the OIML will look carefully at the experience of the CIPM MRA, particularly with respect to how the regional organizations are used.

Mr Faber then turned to the cooperation between the CIPM, OIML and ILAC, in the form of annual meetings which have been held between the three organizations since 1997. He commented that these meetings had proved extremely useful, and had enabled the identification of several areas for common actions. He noted that the boundary lines between legal metrology and scientific metrology, or between legal metrology and accreditation issues, are sometimes vague. He gave as examples: the essential interaction between the CIPM and OIML in the development of the "Model law on metrology", which aims to give a legal basis to traceability; the work of the CIPM and OIML on the promotion of the SI; and the increasingly important role of accreditation in legislation, as an essential part of the metrology system.

He hoped that cooperation between the three organizations, and particularly between the CIPM and OIML, would continue to increase, citing several projects for further joint action: the exchange of information concerning developments in Member States; intensifying cooperation in programmes for developing countries; and – in particular – with respect to public relations. He believed it was essential to communicate the importance of metrology, as a key tool for economic and social development; metrology must be brought to the attention of ministers, decision makers, consumers, industry, universities and schools.

He concluded by announcing that New Zealand and Viet Nam have recently joined the OIML as full members, so the OIML now represents 109 countries in total (60 full members and 49 corresponding members). On behalf of all these countries he presented his best wishes for a successful Conference.

10.2 International Laboratory Accreditation Cooperation

On behalf of the International Laboratory Accreditation Cooperation (ILAC), Mike Peet, ILAC Chairman, then gave the following address:

"Mr President, Ladies and Gentlemen,

On behalf of our 78 members, representing 65 economies, I would like to acknowledge and thank you for the increasing and close cooperation between our two organizations, including a presentation by Prof. Wallard at our General Assembly in Bratislava three weeks ago.

The focus of ILAC activities, including our Arrangement signed in Washington 2000, is to ensure that the output of the 25 000 or so laboratories accredited by our member bodies worldwide is credible not only within their own economies but throughout the world. The link with and support of your own CIPM MRA activities to this process is essential.

Also in support of credible measurement from accredited laboratories, ILAC is actively involved in the CCQM, JCTLM and the JCRB, as well as a separate BIPM/ILAC working group.

We are all aware of increasing global emphasis on trade liberalization. ILAC acknowledges the need to holistically address the needs of developing countries in terms of the sophisticated infrastructures required to ensure that local conformity assessment is accepted by the rest of the world, and not to create another more sophisticated technical barrier to trade. We hereby thank both BIPM and OIML for their active role and support of current initial work in the JCDCMAS in appropriately addressing issues of mutual concern.

I would like to close by expressing our appreciation to Dr Quinn for the work and support of ILAC over many years and express our support to Prof. Wallard for the challenges that lie ahead."

10.3 World Meteorological Organization

On behalf of the World Meteorological Organization (WMO), Dr Miroslav Ondras, Senior Scientific Officer, gave the following address:

"Mr President, Distinguished Delegates, Ladies and Gentlemen,

Allow me, on behalf of the WMO and on my own, to begin by expressing my appreciation to the International Bureau of Weights and Measures for inviting WMO to the 22nd General Conference on Weights and Measures. I am pleased and honoured to have this opportunity to address this august assembly.

For the first time WMO participates in the General Conference on Weights and Measures based on the Working Arrangement between WMO and the International Committee for Weights and Measures, which was concluded earlier this year. Both organizations agreed to keep each other informed on current and planned activities in which there may be mutual interest. They also agreed to collaborate in the implementation of the programmes of mutual interest. Therefore, allow me to briefly introduce WMO and some of its many activities that may be of particular interest to your organization.

The World Meteorological Convention, by which the World Meteorological Organization was created, came into force in 1950. One year later, WMO was established as a specialized agency of the United Nations by agreement between the UN and WMO. As of today, it has 185 Member Countries and Territories.

The purposes of WMO are to facilitate international cooperation in the establishment of networks of stations for making meteorological, hydrological and other observations; and to promote the rapid exchange of meteorological information, the standardization of meteorological observations and the uniform publication of observations and statistics. It also furthers the application of meteorology to aviation, shipping, water problems, agriculture and other human activities, promotes operational hydrology and encourages research and training in meteorology.

There are number of areas that are of common interest to both our organizations. WMO, through its Member countries, seeks to ensure homogeneous and accurate meteorological, hydrological and environmental measurements. In this regard, I should like to draw your attention specifically to:

- the WMO World Radiation Centre, Davos, Switzerland, which maintains the World Standard Reference for solar radiation;
- ten WMO World Calibration Centres for such parameters as carbon dioxide, carbon monoxide, methane, ozone, and others;
- four Quality Assurance Science Activity Centres for a worldwide Quality Asssurance programme in atmospheric chemistry measurements; and
- the WMO World Infrared Radiometer Calibration Centre, Davos, Switzerland, which would be operational as from 2004.

In addition to this, WMO regularly organizes comparisons of standards to maintain their reliability and to transfer these standards to the Member Countries for the use in regional and national programmes.

Mr President,

WMO's Instruments and Methods of Observation Programme coordinates, standardizes and advances technological systems and methods for meteorological observations and measurements. The programme publishes technical reports and guidance material on performance characteristics of instruments and on observing practices. It coordinates calibrations and intercomparisons of instruments and develops quality-control standards and procedures. It also develops guidelines and proposals for capacity building and arranges and supports training programmes for instrument experts and technicians. The programme is carried out under the technical responsibility of the WMO Technical Commission for Instrument and Methods of Observation (CIMO).

In 2002, a representative of the BIPM attended for the first time a session of the CIMO Commission, and the collaboration between our organizations is now being continued at the level of expert teams that address meteorological radiation and atmospheric composition measurements and Quality Management Systems and Commercial Instruments Initiatives.

It may be of interest to you that WMO has established thirteen Regional Instrument Centres around the world. These centres keep meteorological standard instruments linked with recognized international standards and assist WMO Members in calibrating their national standard meteorological instruments.

World, Regional, and National Radiation Centres were also established for maintaining the World Standard Reference for Solar Radiation Measurements. The World Radiation Centre in Davos, Switzerland and the World Radiation Data Centre in St Petersburg, Russian Federation, serve as centres for international calibration of meteorological radiation standards.

WMO recognized that international comparisons of instruments and observing systems, together with agreed quality control procedures, are essential for the establishment of accurate and stable datasets. WMO plans in the next 4-5 years to co-organize international comparisons of precipitation measurements, thermometer screen/shielding, hygrometer measurements, and radioprobes.

Mr President,

WMO's Atmospheric Research and Environment Programme coordinates and fosters research on the structure and composition of the atmosphere, on changes in the physics and chemistry of clouds and weather, on tropical meteorology, and on weather forecasting.

This Programme aims to help WMO Members to implement research projects and to disseminate relevant scientific information, to draw the attention of Members to outstanding research problems of major importance such as atmospheric composition and climate change, and to encourage and assist Members in incorporating the results of research into forecasting or other techniques appropriate to operational activities, particularly when they involve changes of procedures which require international cooperation and agreement. The Programme comprises the Global Atmosphere Watch (GAW), the Weather Prediction Research Programmes, the Tropical Meteorology Research Programme and the Physics and Chemistry of Clouds and Weather Modification Research Programme.

The WMO's GAW integrates its own and other monitoring networks with international research activities involving the measurement of the chemical and physical properties of the atmosphere. GAW serves as an early warning system to detect further changes in atmospheric concentrations of trace gases, UV radiation, acidity and toxicity of deposition, as well as the atmospheric burden of aerosols. This system provides framework design, standards, inter-calibrations, and data collection systems for global monitoring and data evaluation. The major goal "To evaluate the influence of atmospheric chemistry on the environment including transboundary and urban pollution (air quality, acid deposition, stratospheric ozone depletion and increasing UV radiation)" is achieved through various supporting structure tools, such as Quality Assurance Science Activity Centres, GAW World Calibration Centres and WMO GAW Ozone Mapping Centre.

Mr President,

I have mentioned only some of the activities carried out under the eight major WMO programmes, where BIPM and WMO have already started some activities. WMO recognizes the important mission of the BIPM, appreciates the efforts of BIPM to involve international and intergovernmental organizations so as to promote homogenous measurements worldwide, and looks forward to a fruitful collaboration between both organizations.

I wish to thank you again for inviting WMO to the 22nd General Conference on Weights and Measures.

Thank you for your attention."

Dr Quinn expressed his appreciation to the WMO for the welcome they had extended to him and Dr Wielgosz during a visit two years previously when they suggested a more formal link between the two organizations. This link has successfully been established with the CIPM and BIPM, and hence to the national metrology organizations, and is of importance for many areas

of work, including measurement of solar radiation. He hoped that an increasing number of links will be made at the national level with the data centres of the WMO.

10.4 World Health Organization

Dr Quinn then spoke on behalf of the World Health Organization (WHO), saying that Dr Anarfi Asamoa-Baah, Executive Director of the WHO, had expressed his regrets at being unable to be present at the Conference, due to the recent change of Director General.

Dr Quinn took the opportunity to explain some of the interactions that the BIPM has had with the WHO, and on a broader scale to introduce an important subject already mentioned by the President of the Academy of Sciences: measurements and activities related to clinical chemistry. This broadening of the activities of metrology towards chemistry, clinical chemistry and medicine, will be one of the themes of the present Conference.

He started by introducing a new activity undertaken within the BIPM, in response to a call for help from the world's diagnostics industry, pointing out that the global market for *in vitro* diagnostic devices is about 20 billion euros.

An EC Directive on *In Vitro* Diagnostic Medical Devices, the "IVD Directive", which will come into force on 1 January 2004, requires that "the traceability of values assigned to calibrators and/or control materials must be assured though available reference measurement procedures and/or available reference materials of higher order". When this Directive was first published (in 1998), no such reference procedures or reference materials having any international recognition existed.

The US medical diagnostic industry, which supplies 60 % of the EU market, called upon the NIST for help. At a preliminary meeting held at the NIST in 2000, it became clear that it was a worldwide problem, not purely an American one; and the BIPM was therefore approached by the IFCC, IRMM and NIST and asked to help. Two further meetings took place in 2001, with the result that a Workshop on Traceability in Laboratory Medicine took place at the BIPM in 2002, sponsored by the BIPM, the IFCC, the NIST, and the IRMM. This was a unique meeting between communities who had not previously been brought together, including almost all of the interested parties in diagnostic measurements. In addition to the sponsors, it was attended by representatives of ILAC, the IVD industry, regulators, professional organizations, NMIs, and reference materials producers. The list of attendees included: representatives of the European Commission, the American Food and Drug Administration, the Japanese Healthcare Technology Foundation, Quality Assurance organizations: the European Quality Assurance Ltd, the College of American Pathologists, the European Committee for External Quality Assurance Programmes in Laboratory Medicine, representatives of the diagnostics industry: the European Diagnostic Manufacturers Association, and the corresponding American and Japanese organizations (AdvaMed and JACR), a number of NMIs, the National Institute for Biological Standards and Control, ISO/IEC, and the American Centers for Disease Control.

At this meeting, it was decided that a Joint Committee for Traceability in Laboratory Medicine (JCTLM) should be set up, supported by the BIPM, the IFCC, ILAC and the WHO, and including participants drawn largely from the interested parties present at the meeting. In practice it was not easy to establish how such a heterogeneous group of different organizations might work together. Agreement on the formalities of setting up the Joint Committee was only reached in September 2003. The principal sponsors and executives are the BIPM, IFCC and

ILAC; for the moment, the WHO is participating at the technical level only due to legal and other problems.

In parallel with the discussions relating to setting up the Joint Committee, two working groups, established at the Workshop in 2002, have been drawing up lists of reference materials and reference methods that can be used to meet the requirements of the IVD Directive. These lists will be published on the BIPM website early in 2004.

The JCTLM is an important initiative that may well have far-reaching consequences. Internationally recognized and accepted equivalence of measurements in laboratory medicine and traceability to appropriate measurement standards could lead to: improved quality of healthcare for the patient; reduction of costs for governments and healthcare insurers, due to the reduction in number of repeat measurements; and reduction of costs for the IVD industry.

In parallel with this development, the BIPM has developed a working arrangement with the WHO, and a Memorandum of Understanding (MoU) between the CIPM and WHO was signed in October 2002. Dr Quinn read out the text of Article I of this MoU, which is available on the BIPM website.

In addition to the discussions relating to the creation and operation of the JCTLM, Dr Quinn alluded to a proposal for a worldwide consultation of national bodies in the healthcare field, to be run jointly by the WHO and the BIPM.

Dr Quinn concluded by pointing out that activities between international organizations in the health field are increasing enormously and have immense importance. It is vital that the BIPM and the metrology community respond to this urgent need.

Professor Kovalevsky then read the texts of Draft Resolutions A, B and C, related to coordination activities and work with external bodies.

Professor Bordé invited discussion of these three Draft Resolutions.

For Draft Resolution A, Dr de Leer (The Netherlands) suggested replacing the English phrase “concept of traceable measurements” in the first bullet point with “traceable measurement results”, or “traceable calibration and measurement results”, saying that traceability is a property of the result of a measurement (or the value of a standard). Dr Semerjian (United States) suggested an alternative, more concise, wording: “concept of traceability”. Dr Carneiro (Denmark) added that to avoid confusion in other fields of work, it should perhaps be specified that the Resolution concerns measurement traceability, not just traceability, and recommended that the *International Vocabulary of Basic and General Terms in Metrology* (VIM) should be followed. Dr de Leer and Dr Valdés (Argentina) agreed that it is was important to distinguish between product traceability and measurement traceability, pointing out that in the field of food safety, for example, traceability is interpreted differently. Dr Quinn confirmed that the proposed revised wording conformed with the definition of traceability being discussed by the Working Group for the Revision of the VIM, in the Joint Committee for Guides in Metrology (JCGM). Professor Kovalevsky said that a revised version containing the wording “concept of traceability of measurement results” would be presented for voting on Friday 17 October. It was noted that the same change would be required in the final bullet point.

When the revised text of Draft Resolution A2 was presented on Thursday 16 October, Dr Lusztyk suggested a further minor rewording of the third bullet point. Draft Resolution A3 was finally adopted unanimously as Resolution 1 (see page 374).

Dr de Leer commented that the same type of remark applied to Draft Resolution B: here, "comparable measurements" should be written "comparable measurement results". Attention was also drawn to the difference in wording between the English and French texts: "comparability" versus "équivalence". Dr Semerjian suggested changing the order of the words to "the increasing role of measurement reliability and comparability in world trade" and Professor Wallard suggested also changing "role" to "need". Dr de Leer repeated that it is was important to insert the word "results", and it was decided that a small group (Dr Semerjian, Dr de Leer, Prof. Kovalevsky and Dr Quinn) would meet to discuss the suggested changes to Draft Resolution B and present a modified version to the Conference. Dr Röhling (Germany) renewed his call for delegates at the CGPM to contact their foreign commerce delegates at the WTO, to press for the CIPM's application for observership of the WTO TBT Committee to be considered as soon as possible; this application is currently blocked pending the resolution of unrelated issues.

This revised version B2 was presented on Thursday 16 October and was duly adopted unanimously as Resolution 2 (see page 374).

There were no comments on Draft Resolution C and the text was adopted unanimously during the voting on 17 October as Resolution 3 (see page 375).

11 Report of the CIPM on evolving needs for metrology in trade, industry and society and the role of the BIPM

Dr Kaarls gave a brief *résumé* of the CIPM report entitled *Evolving Needs for Metrology in Trade, Industry and Society, and the Role of the BIPM*, distributed to Member Governments and NMI directors in April 2003. This report is a follow-up to the CIPM report entitled *National and International Needs Relating to Metrology*, distributed in 1998 and discussed during the 21st CGPM in 1999.

He reminded delegates that the 21st CGPM had made several important decisions. It had endorsed the expansion of the Metre Convention to cover an ever increasing number of areas of science. It also accepted that Member States have the responsibility of providing, through the Metre Convention, the necessary infrastructure to support reliable measurements everywhere. As a consequence, the General Conference had approved a reformulation of the role of the BIPM. It also witnessed the signing of the CIPM MRA and agreed to the creation of the category of Associates to the CGPM. Dr Kaarls pointed out that it was tacitly understood, and had been noted, that the budget approved for the period 2001-2004 would not be sufficient to continue the adopted programme of work after 2004.

As a result of the financial conditions imposed by the 21st CGPM, the consequences of the introduction of the CIPM MRA, the growing needs for metrology in chemistry and the biological sciences, the implication of the EU IVD Directive mentioned by Dr Quinn (see Item 10.4), and further questions on traceability and measurement uncertainty in new areas such as food analysis, the CIPM felt it was important to reconsider the budgetary situation. Dr Kaarls noted that requirements and developments also continue to evolve in the classical areas of metrology (physics and engineering); and advances in information technology are opening up new methods of working.

The International Committee considered many issues in compiling the new report, including: the programme of work adopted by the 21st CGPM; the work stemming from the CIPM MRA, such as the BIPM key comparison database and the JCRB; the new relations established with other international organizations; the increasingly important role of the regional metrology organizations; the services provided by the BIPM based on its scientific expertise; and the extension of its metrological activities into new fields, in particular into chemistry. In all areas, the needs of developing countries have to be carefully considered. The CIPM has taken into account the responses of the directors of NMIs to two questionnaires distributed last year, and their opinions expressed at the Directors' Meeting in April 2002. It has also carefully considered the results of a study by KPMG on the economic impact of the CIPM MRA, and the results of other independent national studies of the economic impact of metrology.

The report finds that the NMIs deliver considerable benefits in international competitiveness and commercial innovation processes, and generate significant indirect benefits; for example, in terms of health, the environment and food safety. There is therefore a clear economic rationale for the public funding of metrology, in general, and for its extension to emerging technologies such as nanotechnology, chemistry, and biotechnology.

Moving on to the conclusions of the report and the recommendations of the CIPM, Dr Kaarls pointed out that international and global coordination under the Metre Convention is indispensable for achieving an efficient and effective long-term stable global measurement system, capable of addressing the needs of trade, industry and society with respect to traceable and comparable measurements and test results. The removal of non-tariff barriers to trade requires internationally recognized comparability and traceability, and the CIPM MRA is a key element in fulfilling this. Further, the CIPM MRA confers significant benefits to signatory nations and operates in a very cost-efficient and effective way.

Based on the results of questionnaires distributed as part of the KPMG study, the CIPM recognizes that the BIPM has an increasingly important role in representing and promoting world metrology. It must have the status and the means to act as the world's focus for scientific and industrial metrology, with a credible, neutral, and international voice. It should continue to be responsible for the International System of Units, the International Prototype of the Kilogram, International Atomic Time and Coordinated Universal Time, and unique facilities such as the International Reference System in ionizing radiation, and it should have a small activity in chemical purity analysis. It should maintain laboratory activity in carefully selected areas, organize comparisons, and deliver appropriate technical services to NMIs. It should, of course, re-evaluate the existing programme, taking into account the financial situation and the need to deliver it as efficiently as possible. In addition, it should continue its role in global coordination, including relations with other organizations, information and publicity.

Finally, the report contains two recommendations from the CIPM: first, that the governments of Member States give and maintain sufficient financial support to their own NMIs, including the important area of metrology in chemistry, and also make available the necessary financial resources to the BIPM as requested in Draft Resolution J; secondly, that the governments approve the recommended programme of work and corresponding budget for the BIPM.

Professor Bordé invited questions from the delegates.

Professor Göbel remarked that the report made clear the important role of the BIPM, and pointed out that this role is made possible by the presence of leading experts in metrology who are active at the BIPM. He recommended that its scientific role be preserved and strengthened.

Dr Kaarls then read Draft Resolution E. There were no comments and the text was adopted unanimously during the voting on 17 October as Resolution 5 (see page 376).

12 Programme of future work at the BIPM

Dr Quinn opened this item by giving a brief presentation of the role of the BIPM, and presenting a set of histograms showing how the budget is distributed between the different scientific sections, between research and coordination activities, and for upkeep of the site.

The future work of the BIPM is described in the proposed "Programme of work and budget" reproduced in Appendix B, which includes a section on the role of the BIPM.

Dr Quinn highlighted the importance of the SI Brochure, a new edition of which is currently being prepared by the CCU. This brochure is widely distributed and the current edition is also available on the BIPM website; indeed the section on the SI is one of the most frequently consulted parts of the website.

He also pointed out that time and frequency measurement is one of most rapidly advancing areas of metrological science. Currently, the uncertainty of realizing the time scale is similar to the uncertainty of comparison of clocks and the uncertainty of the primary standards. The uncertainty of the best frequency standards is improving rapidly, however, and is expected to fall below 1 part in 10^{17} within a few years. High-level research must therefore be continued at the BIPM to improve the means both of comparing clocks and establishing the timescale, to fully take account of this progress in meeting world needs for improved time keeping; we cannot have the clocks better than the timescale.

He also highlighted the new BIPM activities in chemical analysis. Chemical analysis and bioanalysis are new fields, and Dr Quinn pointed out that unless the BIPM has some laboratory activity in these areas it would not be able to attract top-class staff; and without the top-class staff, it would not be in a position to fulfil its role in international collaboration.

He pointed out that research forms a small but essential part of the BIPM's activity as a scientific institution. In general, between twenty and thirty articles are published in the refereed scientific literature each year, by a scientific staff of about thirty.

On technical services, he remarked that the BIPM pilots a large number of international comparisons. Piloting comparisons is a time-consuming and expensive business, but when it is undertaken by the BIPM, it saves the NMIs money because the BIPM acts on behalf of everyone and costs are therefore shared. He also noted that the consultancy services related to peer review activities are increasingly in demand, but due to the small number of scientific staff it is difficult for the BIPM to release staff to many NMIs for reviews which often last about a week.

In its role as a focus for coordination in metrology, Dr Quinn remarked that the number of meetings held at the BIPM has increased rapidly.

On information and publicity, he pointed out that a new version of the BIPM's website was launched just prior to the 92nd CIPM meeting. The website is widely consulted throughout the world, and a great deal of work was involved in building the new site. The new arrangement for the publication of the scientific journal *Metrologia* with Institute of Physics Publishing (IOPP, UK) is working well and proving cost-effective; all issues published in 2003 have all appeared on time. Previously, the resources for producing *Metrologia* at the BIPM were over-stretched.

The first BIPM Summer School, which was held in July 2003, has already been mentioned by Prof. Bordé. This was a very successful event, attended by more than eighty young metrologists from 22 different countries. The present state of metrology was presented by world-leaders in the field, and Dr Quinn foresees that the links established between the students would be wholly to the future benefit of the metrology community.

Dr Quinn then turned to the relative elements of the BIPM budget, comparing, with the aide of histograms, the situation at the last CGPM in 1999 with the current situation expected at the end of 2008. He demonstrated that the fraction of the budget spent on salaries will decrease from about 57 % in 1999 to about 49 % in 2008; that spent on pensions will increase from about 12 % in 1999 to about 16 % in 2008; laboratory costs will remain constant at about 17 %; building maintenance will increase from about 3 % in 1999 to 6 % in 2008; travel costs will increase slightly, from about 2 % in 1999 to 3 % in 2008. Other categories of expenditure are very small: energy, publications, meetings, insurance, bureau of the CIPM, and miscellaneous Items.

He then showed the relative staff costs per section as a percentage of total staff costs, which illustrated the changes resulting from the CIPM's decisions in 2002. For the Length section, staff costs would decrease from 14 % of the total in 1999 down to about 3.5 % in 2008; for the Mass section, the costs will increase slightly; the Time and Electricity sections remain roughly constant; the Radiometry section disappears completely; the Ionizing Radiation section increases slightly; Publications stay about the same; expenditure on Information Technology and Quality System is significantly more; and the Chemistry section, the KCDB and JCRB are completely new since 1999.

Dr Quinn then showed relative laboratory expenditure as a percentage of total laboratory expenditure, again demonstrating a significant change. In 1999, almost 25 % of the laboratory expenditure was devoted to the Length section, simply because lasers and the associated equipment were very expensive; this will be reduced to a small amount in 2008; the fraction spent on the Mass section will go down a little; the Time and Ionizing Radiation sections will stay roughly the same; the fraction spent on the electricity laboratories will increase slightly; the Chemistry section will represent about 20 % of laboratory expenditure; the KCDB and Publications will stay roughly the same, but the Publications section would shift its areas of activity towards external communication and web-based work; IT and Quality are increasingly expensive, the website is expensive, and IT security is expensive. Finally, a fraction of the capital will be set aside as "start-up expenses", so that by 2008 the Director will have at his discretion a sum representing 12 % to 13 % of the normal capital budget to be used depending on requirements at that time.

Dr Quinn then presented an analysis of the distribution of time given to the various activities of the scientific staff at the BIPM, comparing all scientific staff with the heads of sections. On average, the scientific staff spend about 40 % of their time on maintenance and development of standards, whereas the heads of sections spend less than 25 %. The heads of section, however, spend a high proportion of their time – nearly 25 % – on matters related to the Consultative Committees and coordination. He compared these figures to the results of a recent comparative

study carried out at the BNM, NIST, NMIJ, NPL and the PTB, on how their budgets are spent. Almost without exception the scientific staff in these institutions spend more than 40 % of their time on research. He pointed out that the BIPM is already working at the lowest level of viability for its scientific work programme and its increasing role of coordination. As it is a small institution, almost everyone is multitasking.

He then showed the number of meetings held at the BIPM each year from 1977 to 2003, and the total number of days involved. These meetings were classified as: Consultative Committee (CC) meetings; the annual CIPM meetings; the four-yearly CGPMs; additional working groups that take place outside the time of the CCs; and the recent Summer School. It is clear that there has been a very substantial increase in this area of the BIPM's activity. Up to 1994, the average number of CC meetings held per year was 2.5, whereas since 1995 it has been about 5.6. This is because the BIPM is responding to the requirements of the NMIs and the regions for more meetings. The work of coordination is increasing almost exponentially with the number of meetings that take place.

He then showed the distribution of staff costs, and pointed out that the main area of expenditure relates to laboratory costs (including the work of the CCs and publications). Of the laboratory costs, 40 % are related to development and maintenance of standards. The various other Items – the BIPM workshop (6 % to 7 %), publications, administration and the secretariat – are relatively low.

Finally, Dr Quinn turned to the fraction of the BIPM budget spent on building maintenance. He showed a graph demonstrating the spending on maintenance from 1912 to 1990. There are occasional peaks in the curve, due to major works on the Pavillon de Breteuil or laboratories, or the construction of new buildings (the laser building and the Nouveau Pavillon); however, on average over this period the fraction spent on basic maintenance lies somewhere around 8 % of the total budget, which represents the cost of maintaining historic buildings. From 1989 into the 1990s, this fraction dropped to a very low level to save for the construction of the Pavillon du Mail, which contains a meeting room for 120 people, and without which we would not be able to cope with the meetings of the Consultative Committees or Directors' Meetings. Over the next four years, although we are nearly doubling the level of maintenance work, from 4 % to 7 %, all we are doing is bringing it back up to the level where it has been for the last 100 years.

There were no questions.

Professor Wallard, incoming Director of the BIPM, commented that Dr Quinn's was a hard act to follow, thanking Dr Quinn for his stewardship of the BIPM and saying that the success of the CIPM MRA was a fitting tribute.

He then presented the scientific and organizational programme of work proposed for the period 2005 to 2008, discussing first the mission of the BIPM and how its priorities are judged, then the mechanisms used to deliver the programme. He concluded with a few remarks on how changes are handled.

Professor Wallard reminded delegates that the BIPM's mission, as presented in Appendix B (see pages 416-418), has already been discussed on a number of occasions, including at the 21st CGPM and at several meetings of NMI directors. The broad goal is worldwide uniformity of measurement. The BIPM provides the scientific and technical basis for this uniformity, and collaborates intensively with other organizations with common interests.

The Consultative Committees advise on the priorities for the work programme of the BIPM, and during their meetings allocate various tasks to the BIPM. The number of such meetings is increasing, and the number of tasks they allocate to the BIPM is also increasing. The Member States are asked for their views on priorities and we adapt our work accordingly. The results of the questionnaire distributed in 2002 gave us a very good idea about what matters to Member States, and in which direction we need to move the BIPM over the next few years. We also undertake external surveys on the effectiveness of our work, and we report regularly, to the CCs, to the CIPM, and to this Conference, as well as on a day-to-day basis through the interactions between BIPM staff and the staff from other laboratories.

The main areas of the proposed future programme build on the BIPM's achievements of the past. The main function is the maintenance and improvement of the standards we are obliged to maintain: we must maintain the kilogram and the timescale, and under the Metre Convention rules we must provide various comparison and calibration services, with fixed and travelling standards. However, we only do this when it is more cost effective for the BIPM to do it rather than the individual NMIs. Professor Wallard cited various examples of travelling standards – such as femtosecond combs, the Josephson and quantum Hall systems, and the ozone spectrophotometers – which can be moved and used to validate the realizations of the units and quantities of the SI in the NMIs.

For an organization like the BIPM, it is vital and cost effective to maintain an ability, through unique facilities, to pilot comparisons and to review, by virtue of its technical competence, key comparisons; to act as a project coordinator; and to act as a network pilot. The BIPM fulfils this in a multitude of ways: for example, it already pilots key comparisons in lasers, capacitance, ionizing radiation, and gravimetry; it coordinates the calculable capacitor project; and it is a pilot in the purity analysis networks for organic chemistry and for laboratory medicine.

The CCs are, of course, also project coordinators. There has been a huge increase in the technology and information transfer out of the BIPM to the NMIs, and between the NMIs. This is achieved through workshops, through *Metrologia* (for which the routine functions have been contracted out, leaving the high-level editorial control at the BIPM). The BIPM also produces authoritative publications, often in conjunction with other organizations, including the "Kaarls' Report" – *Evolving Needs for Metrology in Trade, Industry and Society, and the Role of the BIPM* (an authoritative statement from the world's metrological community), the SI brochure, and the VIM and GUM guides.

Illustrating the BIPM's role in knowledge transfer, Prof. Wallard listed that during the last four-year period, there have been over 300 visitors to the scientific sections, the scientific staff have published over 230 papers and reports, over 170 conference lectures have been given, and there have been over 100 guest workers. He referred to the BIPM's website, which is a unique resource, presenting not only the activities of the BIPM, but the work of the Metre Convention as a whole. Recently a great of effort has been put in to developing a new version of the website, and he emphasized the importance of IT in facilitating the organization of meetings, the distribution of the working documents, and the publication of the results of these meetings as rapidly as possible.

The KCDB is the outward product of the CIPM MRA, representing the huge intellectual effort made by the BIPM, NMIs and RMOs in analysing key comparisons, producing comparison reports, and validating CMCs. It is important to find ways of increasing the use of the KCDB to fulfil our objectives. We plan, for example, to extend the CIPM MRA to meet the needs of trade, and of regulators, accreditators and other users of the MRA.

Professor Wallard predicted that there will be an increasing number of international collaborations during the period of the work programme. As we saw earlier (Item 10 of the Agenda), MoUs already exist with a number of organizations. These MoUs are important, and of course lead to new work, as joint projects are identified and undertaken with the external organizations. We have also established a number of Joint Committees, which all extend the influence and impact of the Metre Convention throughout the world, and bring together the efforts and resources of international and intergovernmental bodies in a unique way. Much of the importance of establishing these links at the international and intergovernmental levels, as the BIPM is in a position to do through the Metre Convention, is that many of them can in turn be taken up at the national level; this is of great benefit to national laboratories particularly when setting up interactions in new areas.

Professor Wallard then turned to the principles used for establishing the BIPM's technical programme, pointing out that the technical work of the BIPM is not an end in itself but provides the intellectual basis which is used to support all the other tasks that are undertaken. These tasks include the huge and growing work of the CCs, the management, the analysis and the piloting of the comparison programmes, and of the other collaborative projects in which the BIPM takes part. Our technical base gives us the credibility and the independence to establish liaisons and MoUs with other international and governmental bodies. However, the BIPM is a small institute and consequently must be selective. It is important to find the niche in world metrology where it can be most effective, and not duplicate work that can be done more appropriately in other laboratories. The BIPM carries out all its work in the most efficient and cost-effective way possible, and he hoped the Member States recognized this as good value for money.

He then turned to the individual programmes, highlighting a number of issues.

He informed the Conference that the BIPM had stopped a lot of work in its Length section, concentrating on the calibration and comparison services used with fixed and portable femtosecond combs. The BIPM is currently the only metrology institute with a portable comb, which has already demonstrated its value in a number of comparisons that have been carried out both at the BIPM and at the NIST, Boulder. The BIPM has piloted key comparisons and monitored the iodine-stabilized reference laser that, for 20 years or so, has been the world reference in this area. The CCL, at its last meeting, asked the BIPM to develop a best-practice guide for femtosecond comb measurement, perhaps building on the very successful comb workshop held at the BIPM in 2003. In addition, the BIPM operates a very small commercial business, selling iodine cells to NMIs at cost and at a small commercial profit to other organizations. All this work has been endorsed and requested by the CCL at its last meeting. This was in conflict with last year's meeting of the CIPM, which recommended closure of this section in 2006. The broad area of interferometry is maintained as a core competence, widely applied in existing and new projects. The BIPM plans to host the next international comparison of gravimeters at the BIPM in 2005.

In the mass programme, we continue to supply and manufacture mass standards. Work is still needed to better understand the performance and limitations of the surface stability of platinum-iridium. There is an international programme in this area, jointly with a number of NMIs. In terms of networks and collaborative projects, the international Avogadro project is an area in which the BIPM can contribute unique expertise. Also, in light of the possible redefinition of the kilogram, the BIPM has a responsibility to monitor the International Prototype through a watt balance. There are also plans to license some BIPM developments in balance technology.

The time programme focuses on ways to increase the accuracy of TAI, speed up the service delivered, and improve the way in which it is disseminated. We intend to complete a calibration programme of GPS receivers for time transfers, and we urgently have to develop new methods of time transfer in the light of the new optical frequency standards now being developed; it is vital that we all work together on this project. It is an exciting time in length and optical frequency: the optical frequency standards are challenging the best that can currently be done with caesium beam standards. A joint working group has been set up between the Consultative Committees for Length (CCL) and for Time and Frequency (CCTF), to examine if, and when, any optical frequency standards can be used as secondary representations of the second.

In electricity, the programme of comparisons and validations of national standards will be continued, generally using portable standards. These portable standards are reliable, provide the necessary stability, and have been developed at the BIPM, which is the only organization to maintain high-level standards that can be moved around the world. The existing calibration service for standard cells will be closed. Travelling and fixed standards will be maintained in resistance. Finally, at the request of the Consultative Committee for Electricity and Magnetism (CCEM) the BIPM will continue to pilot the key comparison on capacitance.

Photometry and radiometry have had a fine and proud history at the BIPM, but Prof. Wallard confirmed that this section will close at the end of 2003. The standards and equipment will be archived or disposed of, as appropriate, and the three scientific staff of the section will be transferred to other areas of work within the BIPM. The two related Consultative Committees – for Radiometry and Photometry (the CCPR) and for Thermometry (the CCT) – will of course still have to be serviced from within our other activities at the BIPM.

The BIPM will continue to improve its reference standards in ionizing radiation, supporting and underpinning human health, well-being and society. These standards are used in comparisons, and in calibrations of the standards of national laboratories, particularly for the increasing number of national laboratories that do not have their own primary standards. The value of our collaborations with the International Atomic Energy Agency (IAEA) cannot be overestimated: the BIPM calibrates the IAEA's reference standards, and this has obvious implications for the global control of radioactive materials. The Consultative Committee for Ionizing Radiation (CCRI) have requested a new comparison of mammography energy levels and a new reference system for this area of work. This is obviously an extremely important service, also being developed by an number of NMIs. The BIPM will also continue to expand the International Reference System for radionuclides.

The new Chemistry section is planned to consume a growing proportion of the BIPM's scientific activities. A target has been set of providing 10 to 15 comparisons of ozone spectrophotometers each year, using the reference facility we have established jointly with the NIST. A key comparison of reactive gases will be undertaken, underpinning air-quality regulations. We plan to launch and to manage an international network in organic pure materials, and for this we require at least two new professional staff, qualified and experienced, either as our own staff or "on loan" for a period from other laboratories. As discussed by the CCQM and with the NMIs, there is a need for a reference facility for pure materials, and the BIPM can fill this gap. Finally, as mentioned earlier, we need to manage the international framework for measurements in laboratory medicine, for drugs, and perhaps also for food – through liaisons with industry, the NMIs, regulators and with legislators.

We shall have to adapt the KCDB, the external face of the CIPM MRA, as we deal with new areas of metrology. Many people share our confidence in it and are keen to share the results with

regulators and others. It is important that this leads to reciprocal open access to markets; the KCDB is a neutral product, which can be used by regulators and legislators in different countries.

Turning to related support services, Prof. Wallard commented that the BIPM's Quality System, which complies with ISO/IEC 17025 for measurement services, will be expanded to other activities such as TAI, the KCDB, and various administrative services. He remarked that the BIPM IT section is highly regarded, and is always praised in the responses to questionnaires distributed to delegates at meetings. This service will continue to be developed. He said that it was important for the BIPM to continue to increase its emphasis on external communications, and confirmed that the BIPM planned to return to a programme of planned building maintenance at the level of between 5 % and 7 % of the budget.

Professor Wallard then highlighted the importance of staff training programmes, including technical training, managerial training, and language skills. Referring to Draft Resolution J, he said he hoped that both BIPM staff and NMI staff would benefit, through attachment opportunities for guest workers, and that the meeting of directors would agree specific areas in which staff exchanges could be arranged.

Over the next few years, the BIPM will increasingly be looking for opportunities to work closely with the NMIs in the growing work of servicing the Consultative Committees and associated working groups. The BIPM has to manage the planned reduction in number of staff, while balancing the needs for technical activity and for international coordination and liaison. The next four-year programme is all about change and value for money.

Professor Wallard pointed out that a key comparison typically takes about 1.5 man years to pilot from start to finish, and costs roughly 150 000 €; if the BIPM pilots it, this cost is shared. He reminded delegates of the KPMG report, already mentioned by Dr Kaarls, saying that the economic impact of the CIPM MRA is clear. Although the BIPM cannot undertake all the key comparisons in the world, the Consultative Committees still encourage it to take on more!

Finally, he mentioned new activities such as the JCTLM, where the input of the BIPM on behalf of the Metre Convention is vital in terms of efficiency and impact.

As incoming Director, he remarked that he had first worked at the BIPM in the 1970s with Mr Chartier, and needed no convincing of the value of the organization. The BIPM has changed enormously and is changing faster and faster, taking on a whole variety of new projects within reducing resources. In recent years, the BIPM has reduced its laboratory work by 10 % in order to increase its coordination work. He estimated that this has double or trebled over the last years and now takes about 40 % of the time of senior staff. The BIPM has also introduced measures to save money, and has delivered the programme the CGPM charged it with, without any additional budget. He was convinced that there is very little scope for new cost-cutting of any significance. To deliver the proposed 2005-2008 work programme it will need more money.

He emphasized that the CIPM had already taken tough decisions to live within its means and that it would not ask for more money unless it had to. In relation to the planned cuts and closures he said that he had received protests from the CCL, who made a very strong recommendation to the CIPM to maintain the work in comb technology and international comparisons.

In concluding, he commented that he had worked in an NMI and in government. He was keenly aware that a successful change or restructuring programme comes at a price, and stressed that if the international community wants a successful BIPM then it must share the investment. His

intention was to take the best of the past and merge it with the challenges of the future, and he commended the proposed programme of work and Draft Resolution J to the CGPM.

Professor Bordé thanked Prof. Wallard and invited questions from the floor.

Dr Ono (Japan) expressed his appreciation of the achievements of the BIPM and those of Dr Quinn, noting that since its creation the BIPM has contributed much to metrological science. However, he said that the role of the BIPM was now changing and he was concerned about the proposed programme of work. He suggested that the chemistry programme may be too expensive, too heavy for the BIPM to undertake, and may also be too late. He warned that the BIPM should choose its priorities carefully in this area, and asked the BIPM to take on more coordination work in this area.

Dr Quinn thanked him for his kind words about the past activities of the BIPM, and commented that to understand the present it is important to look at the past. The success of the BIPM in all areas, including its increasing role in coordination, is founded upon its technical expertise. Obviously the BIPM cannot grow in all areas, but it needs to maintain a small nucleus of people on which it can build links with visitors. It would not be possible to attract good people to work at the BIPM in the absence of laboratory activities.

Professor Wallard said that he took Dr Ono's advice seriously but reminded the Conference that the proposed programme of work in chemistry was largely based on the advice of the CCQM, who considered that, with the proposed level of investment, the BIPM would be able to make a significant contribution to the field. He pointed out that the level of investment was modest in absolute terms, and that the BIPM would be part of a network, coordinating with ten to fifteen other laboratories. He promised to continue to take advice in this area, especially from the CCQM.

Dr McGuiness (United Kingdom) endorsed Dr Ono's comments on the achievements of the BIPM and the work of Dr Quinn and went on to consider the future role of the BIPM. He postulated that most people would agree that neither of the extremes – purely technical or purely coordination work – were realistic. He heartily supported the continuation of technical work at some level, saying that it was important to be able to attract the best people to work at the BIPM. He gave his support to the proposed programme, which he considered to be a reasonable compromise between technical and coordination activities, but he suggested that a principle of prioritization should be introduced and said he would welcome a debate on the criteria on which a future work programme should be based.

Dr Shehata (Egypt) said that the BIPM played a valuable role in helping developing countries establish metrology infrastructures. Although Egypt was not yet in a position to benefit fully from the BIPM's proposed programme in chemistry, because their infrastructure was not yet developed, they welcomed the move towards chemistry and were willing to support it financially. However, he regretted the closure of the BIPM's Radiometry and Photometry section, saying that this placed an additional financial burden on NMIs such as the National Institute for Standards (NIS), which would now have to pay to establish traceability through other NMIs. He called for the CGPM to provide an alternative.

Dr Lusztyk (Canada) lent his strong support to the concept of compiling criteria and asked the CGPM, in the light of the number of NMIs now developing chemical programmes, who should coordinate and set up international collaboration in these areas? If it is not the BIPM, then some other organization(s) will have to fill the vacancy. But Dr Lusztyk pointed out that the BIPM has

already earned enormous trust and said he had faith that the bureau could lead international collaboration in this area. If the CGPM is of the same opinion, then the BIPM's chemistry programme must be balanced to make it reasonable in terms of cost and coordination.

Dr Vaucher (Switzerland) argued in favour of maintaining the BIPM Length section, saying that currently only a very small number of NMIs have frequency comb systems. Although he did not question the need for the BIPM to be active in new fields, he considered it premature to close the BIPM Length section when a possible new secondary representation of the second is being considered. Prof. Bordé added his support for the BIPM's work on stabilized lasers.

Dr Quinn said he agreed completely with the suggestion to develop criteria, but hard decisions had had to be taken by the CIPM in October 2002 when it had become clear that with the budget increase likely to be voted by this General Conference would not be sufficient to sustain all of the then proposed programme to 2008. The CIPM's decisions were based on the possibility of offering a unique service, and the laser programme has changed since the development of frequency combs. In the longer term, an appropriate role for the BIPM might have been to carry out comparisons between its own optical clocks, and remote optical clocks, using fixed and travelling comb standards. However, this project is impossible in the light of the budgetary restrictions and, realistically, the work should now be restricted to comb comparisons and calibrations of lasers using this technique. The CIPM had to choose, and the broad choice was made in favour of the chemistry programme. Dr Quinn said he understood completely the disappointment of the length community, but affirmed that the CIPM's choice had been taken based on objective criteria.

Dr Semerjian (United States) commented that not everyone was yet convinced that the BIPM had found an appropriate niche in chemical metrology. He called for further debate on the selected area of activity before discussing more investment.

Dr Kaarls responded as President of the CCQM, noting that he would be reporting more fully later on the activities of the Consultative Committee, but affirming that both the CCQM and its Working Group on Organic Analysis (OAWG) had discussed at length, and on many occasions, the type of work that should be undertaken at the BIPM. The proposed programme of work in chemistry is the result of these discussions and has the unanimous support of the laboratories working in similar fields. He promised that the programme would be closely tuned by the CCQM.

Dr Carneiro expressed his concern about the number of key comparisons required by the Consultative Committees, saying that he would like to see an analysis of the number of key comparisons required and the frequency with which they should be conducted, based on the results obtained thus far. Such an analysis should allow them to be run more efficiently, with a concomitant saving. Statistics from EUROMET indicate that the number of key comparisons is levelling off and he said he hoped this would be mirrored at the global level.

Dr Quinn agreed that initially a very large number of key comparisons had been started, but commented that the situation was evolving; the Consultative Committees now usually wait to finish existing comparisons before starting new ones. In general, the activity is levelling off, as the community realizes that it is not necessary to hold a key comparison in every area. The periodicity is also being extended.

Professor Wallard added that the subject had been discussed at the last meeting of the CCL and its Working Group on Dimensional Metrology. At its 11th meeting (September 2003) the CCL decided to changed the way it runs key comparisons, particularly those comparisons involving

gauge blocks. He agreed that key comparisons should be chosen carefully, not just undertaken for the sake of carrying out a comparison, but selected as a means of validating the CMCs of laboratories. He noted that certain key comparisons had already proved extremely efficient as a means of identifying and diagnosing previously undiscovered problems at certain laboratories, and commented that the level of equivalence was often not as high as initially thought.

Professor Kovalevsky then returned to the comments of Dr McGuiness, saying that in 2002 the CIPM had had to make their decision fairly rapidly because it was essential to reduce the expenditure of the BIPM in 2003. They had sought and taken on board the opinions of as many people as possible, but he supported Dr McGuiness' suggestion that a set of criteria be established and noted that this should be done during the coming year. He added that the criteria might have to be modified with time, so that they continued to give maximum benefit for the Member States of the Metre Convention, and said that the CIPM would discuss the matter at its meeting on Friday 17 October, at the close of the Conference. He suggested that a group should be formed, comprising CIPM members and perhaps also CGPM delegates, to define the criteria.

Dr Érard also wholeheartedly welcomed Dr McGuiness' suggestion, proposing that the list of criteria should be considered at the next meeting of directors. He said it was essential that the BIPM did not reproduce work done at the NMIs, and questioned the necessity of the BIPM constructing a calculable capacitor.

Dr Kumar (India) said that, as Director of the NPLI, he appreciated how hard it is to close an activity and congratulated Dr Quinn and Prof. Wallard on the proposed work programme. He agreed that the BIPM needed to maintain its technical activity in order for its voice to be heard, but pointed out that its coordination activities currently represent about 30 % of the budget and they are likely to increase, so it was important to discuss how to control this increase, and perhaps outsource some of the coordination work.

Dr Bement (United States) said he did not question the scientific expertise of the BIPM related to its research work, which was needed for it to deliver many of its technical functions, but pointed out that much of the coordination work; for example, the attendance of its staff at meetings of other international organizations, and general publicity related to metrology, could also be carried out by NMIs. He recommended that the intellectual resources be considered carefully with a view to maximizing leverage in the coordination activities.

Dr Quinn agreed, adding that secondments could be of great help over a broad range of activities.

Dr Lusztyk noted that the Consultative Committees of the CIPM are very important advisory groups in terms of Member States and NMIs, and called for the NMIs to take responsibility for the advice given by their representatives at the CCs. He recommended that management systems in NMIs ensure that their representatives on these Committees are fully briefed, and urged the delegates to make sure that they present the opinion of their institutes.

Professor Bordé summarized the discussion, saying that for the BIPM to survive and function, even in a coordinatory role, it must have scientific credibility in the fields of physics and chemistry, where it must maintain activity in some aspects at the highest level.

There was no further discussion, and Dr Quinn then read Draft Resolution J.

13 Report on the implementationof the CIPM Mutual Recognition Arrangement

Dr Quinn reported that there were now about almost 500 key comparisons registered in the KCDB. This represents an enormous amount of work, but it seems to be the only way to demonstrate quantitative agreement between all national standards. Indeed, the results thus far have generally demonstrated very good agreement between the measurement standards of the major industrialized states. The comparisons have been carried out in a clear and transparent manner, and the results are being submitted at the rate of three to four sets per week.

A large amount of work has also been devoted to the development of Appendix C, which currently contains over 15 000 CMCs. Dr Quinn paid tribute to all the staff in the NMIs who have contributed to the key comparisons, and thanked in particular the people who have been involved in regional reviews.

Two of the problems that have arisen are: (i) a too detailed statistical analysis has sometimes led to unjustified delays; and (ii) sometimes a lack of communication between the regions which has led to delays in the treatment of CMCs. He drew attention to the recent decision of the CIPM to create working groups to discuss CMCs, but commented that overall the system is working well.

Looking forward, he said that the key comparisons would have to be renewed, and called for continual vigilance so that the CMCs in Appendix C remain up to date and supported by key comparisons.

The next challenge was to publicize the MRA and the KCDB to regulators, accreditators and industries. He called for NMI directors to sell the product as a remarkable tool to the people who need to use it, and mentioned briefly a suggestion of Dr Schwitz on recommending it to governments, which would be presented as a proposed modification of Draft Resolution F.

There were no questions from the floor, and Dr Quinn then read out the text of Draft Resolution F.

Dr Ono suggested inserting an additional sentence under “noting” to emphasize the credibility of the MRA as endorsed by international comparisons and peer reviewing between NMIs in a transparent manner. Dr Valdés called for attention to the wording, with respect to peer reviewing, drawing attention to section 7.3 of the Arrangement. Professor Kovalevsky suggested that some general wording relating to Quality Systems could be used instead.

Dr Bement remarked that it was particularly important to promote the CIPM MRA to national regulatory, accreditation, and standardization bodies. He suggested that another sentence should be added under “invites” to call for a concerted effort to make the MRA as inclusive as possible. Dr Šafarik suggested deleting the words “legislative bodies”, pointing out that they are already covered by the description “regulatory bodies”.

Dr Hengstberger called for the notion of reciprocity to be highlighted, suggesting that the word “mutual” should be inserted before “acceptance” in the text.

Dr Sacconi wondered whether the term “nominated institutes” could be used instead of “designated” institutes. Dr Quinn said he understood the problem, but pointed out that the term “designated institutes” is defined in the text of the MRA; he hesitated about using different language. Dr Sacconi noted that the term “nominated institutes” also appears in the MRA,

relating to participation in key comparisons, and encouraged the strengthening of this interpretation.

Professor Issaev suggested that the Resolution should mention the importance of the CIPM MRA to trade, and in particular to the WTO.

Dr de Leer noted that a draft law on construction is being introduced in the Netherlands, with explicit mention of the CIPM MRA. However, as the Arrangement is signed by directors of NMIs it may not be sufficient for national legal purposes. He suggested another addition along the lines of "noting that the MRA has the full support of all our governments". Dr Quinn replied that in some respects this was similar to the proposal that would be made by Dr Schwitz, but pointed out that in the "Essential Points" and in the "Preamble" to the CIPM MRA it is stated that the Director signs with the approval of the (governmental and other official) authorities in their own country.

Dr Schwitz was then invited to present his proposal, mentioned earlier by Dr Quinn. He applauded the CIPM MRA, calling it the most important landmark in international metrology since the signing of the Metre Convention in 1875. He pointed out that it provides the step from recognition of a system to recognition of standards and capabilities. It is a huge, worldwide, ongoing project, which requires significant input in terms of effort and funding, and involvement at all levels. The CIPM MRA has already had significant impact within the metrological community, allowing verification of laboratory's capabilities, with immediate benefit for our measurement systems. However, he pointed out that, as yet, it has only had modest recognition at the political and regulatory levels and we are now at a stage where it is important to correct this.

Dr Schwitz suggested that it would be useful to amend Draft Resolution F with a call for the CIPM to prepare a formal declaration of acceptance of the MRA and the global framework for mutual recognition of CMCs, which should be sent, on behalf of the CGPM, for signature by Member Governments. It should encourage them to use and refer to the CIPM MRA in appropriate national legislation and in bi- or multilateral trade agreements.

Dr Quinn reminded the conference that the name of the MRA had previously been changed from Agreement to Arrangement, because the CIPM had been advised that it would be difficult to get an "Agreement" signed. While he was fully in favour of recommending the CIPM MRA to all governments, he was less sure that they should be asked to sign something. He called on delegates at the CGPM and directors of NMIs to reflect on how best to promote the MRA to users.

Dr Bennett agreed with Dr Schwitz that a logical step would be for the CGPM to ask the CIPM to discuss the question and report back on how to encourage governments to use the CIPM MRA, saying that it was important to maintain the momentum of the Arrangement.

Dr Bement raised a general question about what is meant by the word "key". He reminded delegates that the initial intent of the Arrangement was to demonstrate traceability to the SI. One might question whether we have now gone well beyond that, to a system of greater inclusion. The system has perhaps blossomed into something much more than was originally intended.

Professor Göbel remarked that although Dr Quinn had requested NMI directors to promote the CIPM MRA, the General Conference provides an appropriate arena to prepare the political floor for this.

Dr Carneiro called for NMI directors to coordinate their efforts to promote the MRA, suggesting that this should be done perhaps with the support of the CIPM. He pointed out that it is

important to make the advantages of the MRA clear to the outside world, and suggested that the CIPM should produce promotional material for distribution in each country.

Dr Lusztyk considered that a CGPM Resolution would have more political weight than a Recommendation or other document produced by the CIPM, and Dr Schwitz agreed but said that another four years would be too long to wait.

Finally it was agreed that a small group, comprising the delegations of the Czech Republic, Japan, The Netherlands and Switzerland, would revise the draft text and present a new version of Draft Resolution F on the morning of Thursday 16 October.

Dr Schwitz thanked the CGPM for the improvements that had been made in this revised version, particularly Draft Resolution F2. Dr Érard drew attention to a problem with the translation in the fifth bullet point under "noting". Dr Quinn agreed that this should be looked at again, and requested that the MRA should always be referred to as the CIPM MRA, to distinguish it from other MRAs in existence.

During the voting on 17 October, revised Draft Resolution F2 was adopted unanimously as Resolution 6 (see page 377).

Dr Quinn then read the text of Draft Resolution G. After a brief discussion, it was agreed that the word "Governments" in the first bullet point under "recommends" should be changed to "appropriate authorities".

When Draft Resolution G2 was presented on Thursday 16 October, it was noted that the French equivalent of "facilities" should be "moyens" rather than "équipements", and that in the English text the words "calibration results" should replace "calibrations" in the final bullet point. The revised text G3 was duly adopted unanimously on Friday 17 October as Resolution 7 (see page 378).

Dr Quinn then read the text of Draft Resolution N.

▮ Relationship between National Metrology Institutes and National Accreditation Bodies

Draft Resolution N

The 22nd General Conference,

considering

- the key role played by National Metrology Institutes (NMIs) at the origin of accreditation of calibration and, in some countries, also of testing laboratories to meet the increasing demand for the calibration of measuring standards and instruments traceable to the SI that could no longer be met directly by the NMIs themselves,
- the essential character of a close technical cooperation between the staff of NMIs and National Accreditation Bodies (NABs),
- the overriding importance to the paying customer of technical competence in the accreditation process of calibration and testing laboratories,
- recent tendencies towards a complete separation between NMI and NAB activities in the name of impartiality, independence and integrity of the latter,

- the evident danger that such a complete separation may have for the technical competence of NABs and, in consequence, for accredited calibration and testing laboratories,
- that the specification and implementation of national policies related to the national measurement and the national accreditation systems are ultimately the responsibility of national Governments,
- that in some countries the NMI is responsible for operating the NAB and in others the NMI and NAB are combined in a single institution,

emphasizing the importance of equitable and uniform policies in respect of both large and small metrology and accreditation systems in all regions of the world,

recognizing the importance of world-wide harmonization of such policies,

welcomes the recent CIPM-ILAC Memorandum of Understanding between the International Committee for Weights and Measures and the International Laboratory Accreditation Cooperation (ILAC),

calls upon all organizations in the area of accreditation to recognize that NMIs and accredited calibration laboratories together provide the essential route to traceability to the SI and hence to reliability in measurements for the whole economy and society and that they should work closely together,

recommends that

- Member Governments of the Metre Convention ensure that an appropriate relationship exists between NMIs and NABs,
- this relationship fosters collaboration on matters concerning traceability of measurement and ensures effective and complementary actions under the CIPM MRA and the ILAC MRA.

Mr Squirrell (ILAC) said he very much supported a Resolution along these lines as a means of guaranteeing technical competence. He is aware that some NMIs are concerned about restructuring in light of the stricter ISO/IEC Standard 17001 (on impartiality). He reminded delegates that this Standard was still in draft form, with no consensus as yet. The final draft would be circulated after the next meeting of ISO CASCO, at the end of October 2004, and he therefore urged all members to comment on this important document. He reassured delegates that ILAC would not implement the new Standard until January 2006, and said there would be a period of implementation. The key point is that there should be impartiality in the decision-making process. Returning to Draft Resolution N, he noted that some countries have multiple accreditation bodies, and warned that any NMI entirely responsable for a NAB was unlikely to meet the new requirements. He reiterated that ILAC was not pushing for more separation between the NMIs and NABs, and indeed recognized the importance of strengthening links with NMIs, but it has to comply with ISO Standards.

There was general agreement that the metrological community should clarify that calibration is not considered a part of conformity assessment.

Professor Göbel voiced his strong support of Draft Resolution N, and pointed out that the Draft ISO/IEC Standard 17001 forbids contact between NMIs and NABs. This, he said, was going too far!

Dr Schwitz suggested that the Resolution indicates how to interpret the ISO/IEC proposals. He pointed out that the NMIs have responsibility for their national measurement systems, which

also include the work of the accreditation bodies. It is obviously important for metrologists and accreditors to work closely together.

Professor Issaev (Russian Federation) reminded the Conference that ISO documents were not mandatory. In Russia, there is strong resistance to the notion that calibration is part of conformity assessment. He argued that the CIPM MRA is a stronger document, prescribing that calibration certificates must be recognized.

Dr de Leer was concerned that the discussion had been led by the accreditation bodies, and pointed out that the text did not cover the situation in the Netherlands and many other countries, where the NMI and NAB are fully separated. He also recommended that the phrase "competent calibration laboratories" be used under "calls upon", in accordance with ISO/IEC 17025. In reply to his first point, Prof. Göbel noted that in other countries, such as Germany, there was no separation at all, but that appropriate steps had been taken to avoid internal conflicts of interest.

Dr Inglis (Australia) warned that the issue had the potential to do serious damage to metrological infrastructures. He presumed the BIPM had had an input to the ISO/IEC Standard and urged the CIPM to intervene on behalf of Member States before the ISO CASCO meeting at the end of the month. Dr Quinn replied that, in fact, the BIPM has not been kept fully informed. Although the BIPM has Liaison A status in ISO CASCO and receives all the ISO CASCO documents, there had been no formal contact with the working groups. In this case, it was the NMIs who alerted the BIPM to the problem and Dr Quinn had written to the ISO General Secretary to clarify the position. In response, the BIPM has been invited to attend the ISO CASCO meeting at the end of October and Dr Kaarls will represent the BIPM at that event. Dr Quinn concluded that it was not possible for the BIPM to monitor all of ISO's activities, and it was agreed that NMIs should keep close contact with their ISO CASCO representative.

When the revised Draft Resolution N2 was presented, it stimulated considerable further discussion. Dr Bement expressed the support of the Government of the United States for the Resolution, but submitted a list of five requests for changes. With regard to the first bullet point under "considering", he suggested that the phrase "could no longer be met directly by the NMIs themselves" should be omitted, because it assumes a commonality in decision making which has not been established; it is not true for all NMIs. Where the text refers to national accreditation bodies he suggested that they should be called "nationally recognized accreditation bodies". In the fourth bullet point, he suggested a change from "recent tendencies towards a complete separation" to "recent tendencies towards requiring a complete separation", saying that this was a matter of policy rather than a natural tendency. In the sixth bullet point, he pointed out that once it is stated that these systems are ultimately the responsibility of national governments, the phrases under "emphasizing" and "recognizes" were *non sequitur*. He suggested either eliminating these two phrases, or changing the word "policies" to "practices"; this latter would also make it consistent with ILAC documentation. Finally, in the seventh bullet point, he recommended changing the wording to " the relationship between the NMI and the NAB varies from country to country; the NAB may be part of the NMI, it may be operated by the NMI, or it may be completely separate".

Dr Jacobescu (Romania) supported Dr Bement's suggestions, and requested that another comment be inserted stating that the CGPM does not consider calibration to be a conformity assessment activity.

Dr Schwitz and Dr de Leer also expressed their support for Dr Bement's suggestions. Dr de Leer then turned discussion to the sentence "called upon", pointing out that here it states that NMIs and accredited calibration laboratories "together provide the essential route for traceability to the

SI", whereas in fact ISO/IEC 17025 does not require that calibration laboratories be accredited; it is sufficient that the calibration laboratory be competent. He therefore proposed changing the description from "accredited" to "competent".

Dr Kaarls and Dr Schwitz felt that the Resolution should keep the description "accredited" while not excluding other laboratories. Professor Göbel pointed out that use of the words "accredited and competent" would be consistent with ISO/IEC 17025. Dr Inglis raised the question "What is meant by 'competent' "?.

Dr Bennett then made three comments. Concerning the previous discussion, he suggested a simple rewording to read "... together provide **an** essential route", to retain the reference to accreditation laboratories while recognizing that there may be other routes. He added his voice to the support expressed for Dr Bement's proposed changes. Finally, under "emphasizing" he suggested that "harmonized" should be used instead of "uniform".

It was agreed that the draft text would be revised in the light of these discussions, and the revised Draft Resolution N3 was duly adopted unanimously as Resolution 11 (see page 382).

14 Report on the admission of Associates of the General Conference

Dr Quinn read Draft Resolution D.

He commented that this Resolution reflects a number of the comments that have already been made during the Conference. One of the initiatives that has already been taken is to address a letter to fifty-one States that are not yet Members or Associates. This letter was sent earlier in 2003, and is also posted on the BIPM website. It includes a useful compilation of the advantages of membership of the Metre Convention and associateship of the CGPM.

Dr Quinn informed the Conference that he had been approached by a representative of CARIMET concerning the possibility of CARICOM becoming an Associate Entity of the CGPM. The 92nd meeting of the CIPM (October 2003) had discussed the application and the Committee were willing to interpret the word "Economy" as a formal regional economic cooperation. Dr Quinn proposed that a combined weighting should be used for CARICOM, and this would allow fifteen or so small States to participate, when they would not have been able to do so individually. He asked the CGPM to endorse this procedure.

Dr Bement expressed his full support, welcoming the spirit of inclusivity.

Dr Tse noted that, in 2000, Hong Kong (China) had become the first Associate of the CGPM. However, the significant increase in their subscription in 2002 represented a large burden and he felt that the minimum level was still too high. Dr Quinn explained the way in which the subscriptions are calculated. The CGPM votes the overall dotation for the BIPM for the next four-year period. This sum is distributed over all the Member States, weighted by their coefficients of contribution to the United Nations. The minimum contribution for a Member State is about 0.5 % of the dotation. For Associates of the CGPM, the calculation is again based on their coefficients of contribution to the United Nations but the minimum subscription is 0.05 % of the dotation. As Hong Kong (China) does not have a coefficient of contribution to the United Nations, China's coefficient was used as the reference and the subscription for Hong Kong (China) assessed in proportion to the relative GDPs of China and Hong Kong (China).

Changes in the UN coefficient for China or changes in the relative GDPs of China and Hong Kong (China) will lead to changes in the subscription to the BIPM from Hong Kong (China) over which the BIPM has no control.

Dr Zahwi (Egypt) called for the BIPM to maintain its traditional activities such as photometry and radiometry, and length, or to subsidize the replacement services if the BIPM calibration services were cut. Otherwise, he warned, developing countries would not benefit from Member or Associate status.

Dr Quinn assured Dr Zahwi that the CIPM were well aware that these activities benefit smaller and developing States, but repeated that there had been no alternative to cutting the services in order to balance the BIPM's budget. He added that he had tried to negotiate special rates with NMIs but had been unsuccessful. He reminded delegates that the BIPM would soon be providing new calibration services in the field of chemistry and that the feedback so far was that developing, as well as developed, countries would benefit substantially from this work.

There were no further questions.

15 Reports of Presidents of Consultative Committees

15.1 Consultative Committee for Length

Dr Myung Sai Chung, President of the Consultative Committee for Length (CCL), presented the following report.

"It is my pleasure to present the report of the CCL.

The 10th meeting of the CCL was held at the BIPM on 19 and 20 September 2001. Recent progress in the implementation of the CIPM Mutual Recognition Arrangement and the activities of the two CCL working groups, on dimensional metrology and on the *mise en pratique*, were reported.

The Working Group on Dimensional Metrology (WGDM) has met each year since 1996.

WGDM meeting	Date	Location	List of documents	Agenda	Attendees	Chair-person's report	Minutes
1st	21-10-1996	TUD (Denmark)	[/96-22b]	[/96-10a]	[/96-10b]	[/96-10e]	[/96-22b]
2nd	15-09-1997	BIPM (Sèvres)	[/97-18a]	[/97-18]	[/97-19]	[/97-20]	[/97-30]
3rd	19-07-1998	SPIE (San Diego)	[/98-10]	[/98-11]	[/98-12]	[/98-13]	[/98-43]
4th	21/22-09-1999	BIPM (Sèvres)	[/99-20]	[/99-21]	[/99-22]	[/99-23]	[/99-60]
5th	19/20-09-2000	BIPM (Sèvres)	[/00-20]	[/00-21]	[/00-22]	[/00-23]	[/00-54]
6th	17/18-09-2001	BIPM (Sèvres)	[/01-20]	[/01-21]	[/01-22]	[/01-23]	[/01-50]
7th	17/18-09-2002	BIPM (Sèvres)	[/02-]	[/02-21]	[/02-]	[/02-23]	[/01-55]

The codes in this table refer to WGDM documents; in this case, to the list of documents submitted to a meeting, the Chairperson's report to the meeting, and the minutes issued after the meeting. Meetings are characterized by activity reports given by working group representatives for each metrology region, and also reports from each of the discussion group moderators and pilots of current CCL key comparisons. All these reports are catalogued in the cited list of documents for each meeting, and those available in electronic format are archived on the BIPM website, linked to the WGDM document page.

In 1997, the CCL approved six key comparisons in dimensional metrology topics:

No.	Type	Pilot	Start	Duration/ years
CCL-K1	gauge blocks	METAS (Switzerland)	03-1998	1.5
CCL-K2	long gauge blocks	NPL (United Kingdom)	10-1999	1.5
CCL-K3	angle standards	CSIR (South Africa)	07-1998	1.5
CCL-K4	diameter standards	NIST (United States)	09-1998	2
CCL-K5	1-D CMM artefacts	PTB (Germany)	03-1998	2
CCL-K6	2-D CMM artefacts	CENAM (Mexico)	01-2000	2

Each pilot, in some cases teamed with one or two experts from other NMIs, produced a technical protocol that has been approved by the participants and the WGDM, and these are available on the BIPM website. Except for CCL-K1, the start and/or duration of the comparisons have been delayed or extended. Generally, it has been very difficult to keep to the schedule, as some participants suffer equipment problems during their turn, or there are extraordinary delays with transport, notably with customs processing. This is the current status:

	CCL-K1	CCL-K2	CCL-K3	CCL-K4	CCL-K5	CCL-K6
Planning start	09-1997	10-1997	01-1999	01-1999	01-1998	04-2000
Circulation start	03-1998	09-1999	07-2002	11-2000	04-1999	12-2002
Circulation end	09-1999	08-2001	-2003	12-2002	11-2001	12-2002
Draft A report	09-1999	09-2001	-2003	-2003	04-2003	09-2003
Draft B report	01-2001	02-2003	-2003	-2003	06-2003	-2003
App. B listed	08-2001	09-2003	-2004	-2004	11-2003	-2004

Dates highlighted grey are estimates. It can be seen that the first cycle is nearly complete. CCL-K1 and -K2 have finished. Appendix B provides more detailed information on each comparison and lists the participants.

Several comparisons have experienced difficulties with artefact shipments entering/leaving the Russian Federation, where the customs requirements are not clear. At the 6th WGDM meeting, the D.I. Mendeleyev Institute for Metrology (VNIIM, Russian Federation) delegates proposed that the Cooperation in Metrology among the Central European Countries (COOMET) circulation should take place at the end of the schedule for each remaining current key comparison, preceded by a pilot measurement, just in case the artefacts are delayed indefinitely or damaged. Furthermore, the VNIIM and the Russian Research Institute for Metrological Service (VNIIMS, Russian Federation) will work closely with each pilot to ensure that customs documents are correctly completed on entry and exit from the country. The VNIIM and the

VNIIMS plan to advise the customs authorities so that this situation should improve over time, and special precautions should not be necessary in future comparisons.

Several decisions were made at the last CCL meeting concerning the ongoing key comparison BIPM.L-K10 on 633 nm iodine-stabilized He-Ne lasers:

- The CCL approves the results of BIPM.L-K10.
- The key comparison reference value (KCRV) is the value of the BIPM4 laser.
- The degree of equivalence of each laboratory with respect to the reference value has been decided, but not the equivalence between two laboratories.

At present, no additional key comparison topics have been recommended for approval by the CCL.

The CCL, at its 10th meeting, adopted the following recommendations by the WGDM:

1) Customs formalities for CCL key comparison artefacts: The CCL adopts the recommendation that each CCL member, when replying to an invitation to participate in a key comparison, shall provide all the information about the formalities necessary for customs clearance to the WGDM chairperson and to the pilot laboratories, together with details about the contact person at each NMI for customs questions.

2) NANO4 (grating pitch) study to provisional Appendix B: Given that the WGDM has reviewed and approved the preliminary results of the NANO4 study on grating pitch, CCL adopts the recommendation that, when the final report is ready, the results of NANO4 be considered as officially approved and submitted to the provisional BIPM key comparison database (Appendix B), provided that the participants all agree to such publication.

Linking CIPM and regional comparisons numerically requires the WGDM to determine some kind of offset for the linking laboratories. The problem is that we have no confidence that such an offset has any scientific meaning. It is agreed that recent results show that some laboratories have performed in a similar way, measuring consistently longer or shorter in both comparisons. This can be taken into account by the expert committee when reviewing both comparisons. Sometimes it is possible to identify causes for these biases. For example, a length-dependent bias often indicates an error in temperature measurement. It would be normal practice to rectify this immediately. To build it into future comparisons as a deviation from a reference value would add an unnecessary uncertainty (see Appendix C, Calibration and Measurement Capabilities of National Metrology Institutes, of the BIPM key comparison database for further discussion on this point).

The MRA Technical Supplement really deals with testing principal techniques and methods for realizing the SI unit of length, such as the various iodine-stabilized lasers, where offsets may be due to the laser cavity design or the specific method employed. In this case, there will be deviations from a KCRV, which will be persistent and can be measured and accounted for. The WGDM has identified key techniques which are too far removed from the realization of the SI to be significantly influenced by its realization. Perhaps these would be better described as supplementary comparisons, which of course do not require a KCRV. This issue was discussed at the WGDM meeting and at the 11th CCL meeting.

Although the MRA Appendix C listing of services is not the direct business of the CCL, the fact remains that WGDM members are all members of their respective regional Length committees, and WGDM meetings are a convenient opportunity to discuss these issues. Thus the meetings in the last three years have been two-day meetings, with the first day concentrating on Appendix C

issues. One of the great difficulties addressed in the early stages was the need to express each country's calibration and measurement services using a common terminology, so that similar services could be readily compared between countries. A harmonizing document, such as the VIM, is needed to catalogue the types of dimensional measurements that are offered as services – a sort of dimensional VIM, or DimVIM as it became known. The DimVIM organizes dimensional services by major classes (such as end standards, line standards, angle standards), and subclasses and then specific types of instruments or gauges, and names the measurands that might be reported for each. The list was discussed and refined by the WGDM to create a consensus vocabulary of accepted English-language terms to describe each service offered by a country. Another challenge was to harmonize the entries of each service into the standard Excel sheet template, for listing in Appendix C. The WGDM created a detailed instruction guide, to be used by each country in creating their listings of CMCs. A brief instruction and a worked example completed the DimVIM suite of documents. Our colleague from the Centro Español de Metrología (CEM, Spain) undertook to translate the DimVIM suite into Spanish, mainly to help those countries in the SIM to work with the English documents, as all submissions have to be made in English only. The result of this effort was that the Length CMCs from all countries in all regions were submitted with a high degree of harmonization, greatly speeding up the process of regional and interregional review.

The DimVIM, which is posted on the BIPM website, is still evolving and has proved a useful basis for organizations outside the WGDM who wish to have a service list. Other Consultative Committee working groups have followed our lead and developed their own procedures, finding this approach effective for reviewing CMCs.

The WGDM maintains an interest in nanotechnology and the NMI programmes that have recently been launched in this field. One of the future issues for the working group and for the CCL is to consider the need for international activities in nanotechnology.

Since the 1997 CCL meeting there have been three meetings of the *Mise en Pratique* Working Group (MePWG), at the CPEM 98 in Washington (United States), at the BIPM in December 2000 and on 18 September 2001, immediately prior to the CCL meeting. The December 2000 meeting was particularly significant in that its major thrust was to begin a review process for the implications of the newly emerging comb technology that is having such a major impact on absolute frequency measurement of optical frequency standards. This technology now looks capable of bridging the microwave to optical gap with high accuracy, in an effective and efficient manner, in contrast to the frequency chains of recent years. It has major implications in three areas:

1) The ease of measurement of any optical/near-infrared frequency or wavelength standard.

2) The serious possibility that high-performance optical frequency standards may form the reference for a microwave frequency signal by providing a link to an optical standard using widespan comb technology. The follow-on implication of this provision is the potential use of optical standards as secondary representations of the SI second.

3) The methodology for future laser and optical frequency standard international comparisons. Here, the development of small breadboard femtocomb systems for measuring stabilized laser and cold atom and ion optical frequency references lead to the view that the BIPM should adapt their comb system to be a travelling measurement capability. Such a system could be used to measure optical references in various metrology institutes, and/or compare directly with the institute's own femtocomb system. This approach has the capability to

improve upon stabilized laser comparisons carried out under the laser key comparison, but does not rule out such comparisons taking place in the traditional heterodyne way.

Following this 2000 MePWG meeting, the Working Group met just prior to the 10th meeting of the CCL in 2001, in order to draft proposals to the CCL which would take account of new measurements with the comb technology on existing and potentially new recommended radiations. As a result of this meeting, six initial proposals were made to the CCL which may be summarized as follows:

- A change of name for the *mise en pratique* was suggested, in order to take account of applications in spectroscopy, telecommunications and time, in addition to dimensional metrology.
- Research and investigation into femtocomb technology should be encouraged in order to properly understand and extend the technique to highest accuracy and simple application.
- The addition to the recommended radiations list of new radiations in cold atoms and ions with frequency values measured to high accuracy, updated values of existing radiations of cold atom, ion and gas cell types, and new gas cell radiations for the optical telecommunication region.
- The transfer of some iodine-stabilized radiations to the secondary list, where the likelihood of future improvements in measured values was small.

The CCL adopted the proposals. In addition, the question was considered of a future joint working group between the CCL and the Consultative Committee for Time and Frequency (CCTF) to consider the relationship between some of the *mise en pratique* recommended radiations and their suitability as future secondary representations of the second. Dr Quinn undertook to raise this issue with the appropriate delegates to the CCTF and CCL, in order to form a view before the CIPM meeting. This group met just before the 11th meeting of the CCL.

Concerning the future activities of the BIPM, the CCL supports work on the new femtosecond comb technology in order to use these new frequency standards for international comparisons. The organization of such future comparisons has to be established in order to succeed the traditional He-Ne laser comparison at 633 nm. The organization of a comparison of Nd:YAG lasers at 532 nm also has to be investigated by the BIPM.

There will be new members of the two CCL working groups. The National Metrology Institute (UME, Turkey) will participate in the WGDM; and the Czech Metrological Institute (CMI, Czech Rep.), the Istituto di Metrologia G. Colonnetti (IMGC, Italy), the Centre for Metrology and Accreditation (MIKES, Finland), the NMi (The Netherlands) and the UME will participate in the MePWG.

The 11th meeting of the CCL was held in September 2003 at the BIPM."

He then read the text of Draft Resolution H.

Professor Bordé thanked Dr Chung and invited comments from the floor.

In reply to a question from Dr Lusztyk, Dr Chung confirmed that a seven-yearly cycle had been proposed for the CCL key comparisons.

Dr Sacconi (Italy) expressed his regret at the planned closure of the BIPM Length section, citing their timely work on femtosecond frequency combs and drawing attention to the fact that only about ten laboratories will be able to offer comb services. He called for activity to be maintained in selected areas, citing Recommendation 1 of the 11th meeting of the CCL (2003) asking the

CIPM to reconsider the proposed closure, and advising that the views of the CCL, as world experts in the field, be taken seriously.

Dr Bement expressed the United States' support for Draft Resolution H and the work of the CCL. He proposed the addition of the words "and microwave" in the part "recommends".

Professor Bordé commented that the various optical and microwave frequencies do not give rise to the same level of accuracy in the realization of the metre, and expressed reservations about putting them on the same footing. Dr Quinn did not share this anxiety, noting that the second is defined through the caesium atom, whereas the frequency chosen for a particular realization of the metre depends on the application. The *mise en pratique* deliberately includes a range of different methods to suit different domains.

Professor Bordé accepted this, but argued that to keep ahead in the time domain, work was needed particularly on the most accurate frequencies, where the realizations are ultimately the best clocks. He drew attention to a calcium standard developed at the NIST, which is exploited both as a clock and to give a practical realization of the metre. He agreed with Dr Quinn that the recently created joint working group CCL-CCTF has a lot of work to do!

Professor Göbel commented that he preferred the term "optical frequency standard" to "clock". There were no further comments on the text of the Resolution.

A minor change was made to the French wording of the first bullet point when a revised version Draft Resolution H2 was presented on Thursday 16 October. The revised text was duly adopted on Friday 17 October as Resolution 8 (see page 379).

15.2 Consultative Committee for Mass and Related Quantities

Dr Tanaka, President of the Consultative Committee for Mass and Related Quantities (CCM), presented the following report.

"I am pleased to present the report of the CCM.

The CCM held its 8th meeting in May 2002. Its main concerns were the facilitation of technical cooperation among member NMIs for the improvement of global measurement standards, and the implementation of key comparisons for the MRA in the fields of mass and related quantities. Currently, ten working groups are engaged in these activities according to their technical expertise. For example, by organizing timely meetings or inviting specialists to become members or observers. These are the working groups for mass standards, density, force, high pressure, medium pressure, low pressure, the Avogadro constant, hardness, fluid flow, and gravimetry. The CCM has organized two meetings of working group chairpersons, in October 2000 and June 2003, to foster close links among the activities of the working groups, particularly with respect to key comparisons. Invited delegates from major RMOs helped the CCM to respond to technical problems common to different regions. The secretariat, the President and the Executive Secretary of the CCM coordinate these functions on behalf of the members of the CCM, helping the chairpersons from an administrative viewpoint and liaising with the BIPM and the CIPM.

Organizational improvements within the CCM since the last CGPM include:

- establishment of a Working Group on Hardness (2000, CIPM, upgraded from the *ad hoc* Working Group on Hardness) and a Working Group on Gravimetry (2002, CIPM);

- chairpersons' first meeting (October 2000, NPL, United Kingdom); second meeting (June 2003, Cavtat, Croatia);
- establishment of a Coordinating Committee for the Working Group on the Avogadro Constant (2002, CIPM); and
- changes in personnel: President of CCM, chairpersons of working groups for mass, density, high pressure, medium pressure, low pressure.

Mass standards

The Working Group on Mass Standards met in 2001 in Istanbul, and in 2002 at the BIPM.

One of the scientific issues relating to the performance of kilogram prototypes is to determine whether the change in mass is predictable in an environment that includes a cleaning process. The calibration at the BIPM of platinum iridium prototypes of NMIs after their third periodic verification made possible a systematic study of the change in mass. The study of fourteen prototypes at different periods after the third verification concluded that changes of mass following cleaning are not identical for each standard and that rates of short-term and long-term mass increase following the cleaning are not universal. It seems evident that the BIPM must maintain a sufficient number of Pt-Ir standards in order to maintain the stability of the unit of mass between periodic verifications (or until such time as a satisfactory alternative to the present definition of the kilogram becomes available).

The following activities were carried out by NMIs, by the BIPM or in cooperation between different organizations:

- surface contamination and stability of mass standard artefacts; by monitoring molecular changes on the surface and mass by adopting such molecular sensing technologies as ellipsometry, thermodesorption mass spectrometry, x-ray photoelectron spectroscopy and time-of-flight secondary ion mass spectroscopy, with controlled surface manipulation by means of various cleaning processes;
- surface roughness evaluation technology on the mass standard artefact; using light scattering and a mechanical profilometer;
- magnetic properties of mass standard artefacts and their interactions with balances; with a special comparison for magnetic property evaluation technology;
- temperature and convection effects in the mass calibration environment; with initial temperature distribution and density difference of artefacts;
- volume determination of mass standard artefacts for buoyancy correction.

The working group has undertaken five CIPM key comparisons, the status of which is as follows:

- CCM.M-K1 (1 kg), CCM.M-K2 (multiples and submultiples) and CCM.M-K3 (50 kg) are completed, draft B reports have been accepted and final reports are to be approved.
- Preparatory work for CCM.M-K4 (1 kg) is under way. Stability checks on the travelling standards were completed in 2002. Circulation of the travelling standards is envisaged for 2003.
- Measurements for CCM.M-K5 (multiples and submultiples) have been completed.

The working group confirmed future plans for CIPM key comparisons and their periodicity, and the status of RMO key comparisons was reported by RMO delegates and discussed by the group.

Density

The Working Group on Density met in 2002 at the BIPM, reporting on the following research carried out by NMIs.

The recommended density table for Standard Mean Ocean Water (SMOW) was derived from four experimental results by NMIs reported in the last decade. Data analysis on the results was carried out by the Water Density Task Group, approved by the working group and endorsed by the CIPM, and published in *Metrologia* [2001, **38**(4), 301-309]. The table gives the corrections for air pressure, isotopic abundance and air dissociation with an uncertainty over the temperature range of approximately 0.8×10^{-6}. It is expected to be widely used in volumetry, materials science and precision metrology, such as in volumetry for mass standard artefacts and ionization radiation metrology.

Research work by the BIPM and the PTB (Germany) on the precise density of air revealed a smaller relative uncertainty, 7×10^{-6}, by the artefact method than by the environmental correction method using the CIPM-recommended formula, with a difference of the order of 10^{-4}. This could be partially attributed to the discrepancy between the two reported values of the concentration of argon in air, 9.17×10^{-4} and 9.34×10^{-4}.

Considerable progress in the absolute and relative density measurements of mercury at 20 °C was reported by the PTB, with a current uncertainty of 3×10^{-6} in the absolute value, which promises many applications in precision manometry and the determination of fundamental constants. For density measurement, the technology involved adopts tantalum for sinkers in hydrostatic weighing in mercury. The PTB announced a possible service plan for other NMIs.

Other activities reported by NMIs concerned: sensing technology for density of air and the measurement of density of moist air, and research on the refractive index of air.

The working group has also undertaken a CIPM key comparison on the density of silicon, CCM-D.K1, in which all calibration is complete and the draft A report will soon be available. It is well understood that the silicon crystal artefact offers the best features in terms of the primary standard of density. As at present, nine NMIs have a silicon sphere national density standard but only four of them are capable of absolute measurement, it was decided that the comparison should use a perfect crystal silicon sphere with a mass close to 1 kg for the transfer standard, but that the participants' hydrostatic weighing calibration technologies should be compared.

The working group prepared future plans for CIPM key comparisons, on liquid density (CCM.D-K2), the mass standard artefact (CCM.D-K3) and hydrometry (CCM.D-K4).

RMO key comparisons were reported and discussed with respect to their linkage to CIPM key comparisons, and were approved for provisional equivalence.

Force

The Working Group on Force met in 2001 at the NIST (United States). The current topics of research for the group include: improvement in the stability of force transducers, torque measurement standards, dynamic force metrology and many other topics, conducted by individual NMIs as well as cooperatively.

The status of CIPM key comparisons undertaken by the working group is given below. Each key comparison consists of calibration on a set of force transducers circulated together with electrical reading devices and humidity and temperature monitoring devices.

The instability of the transfer standard requires a star circulation programme, in which calibration by the pilot laboratory follows calibration by each participant.

- The calibration phases of low force measurements CCM.F-K1.a (5 kN and 10 kN) and CCM.F-K1.b (5 kN) have been completed by the participants and draft A reports circulated. The discussion at the meeting revealed that one of the main problems associated with the comparisons is the stability of the force transfer standards and the evaluation of results for the calculation of the key comparison reference values. The draft B report will be circulated by October 2003. Characteristics of the transducer such as temperature dependence, uncertainties and short-term transducer drift must be supplied to the participants for their analysis, along with the uncertainty component list.
- CCM.F-K2.a (50 kN and 100 kN) and CCM.F-K2.b (50 kN), now in the planning phase, will start in 2004.
- CCM.F-K3.a (0.5 MN and 1 MN) and CCM.F-K3.b (0.5 MN) will start in 2004. The transfer standards have been selected and stability is now being investigated by the pilot laboratory.
- CCM.F-K4.a (2 MN and 4 MN) and CCM.F-K4.b (2 MN) have started. The loading and unloading procedure is very critical and must be agreed by discussion.
- CCM.F-K5 to -K22, which have all been completed, were approved for provisional equivalence.

High pressure

Since the Working Group on High Pressure met in May 2002 at the BIPM, the NMIs have continued their research activities with the following aims:

- improvement of national pressure scales;
- study and realization of new pressure transducers to be used as transfer standards for comparisons or for specific industrial applications;
- acquisition of more automatic measuring systems with dedicated sensors for data acquisition and software treatment in real time;
- theoretical calculations using more advanced mathematical methods (finite-element method, numerical and statistical methods); for example, for simulation processes or for important areas such as the elastic distortions in pressure balances that are currently being researched with important and interesting results (as well as throwing light on new problems previously insufficiently researched, such as the determination of the elastic constants of materials used for each piece in the piston-cylinder assembly).

The working group agreed on a policy for choosing a CIPM key comparison according to the pressure media and the range of pressure.

The calibration of gas media, gauge mode, up to 7 Mpa, covered by comparisons CCM.P-K1.a (50 kPa to 1 MPa), CCM.P-K1.b (50 kPa to 1 MPa) and CCM.P-K1.c (80 kPa to 7 MPa), has been successfully completed and approved for equivalence, results being published in the BIPM key comparison database. The transfer standard of the piston cylinder is calibrated by the participants in terms of the area of the piston; i.e., the ratio of mass times gravity to pressure.

The calibration of liquid media, gauge mode, up to 100 MPa, will be covered by CCM.P-K7 in the calibration phase from 2003 to 2005. This particular comparison is intended to respond to the need for linkages among the RMO key comparisons and bilateral key comparisons currently under way.

Another liquid media comparison, CCM.P-K8 (gauge mode, 100 MPa to 500 MPa), for which the measurements have been completed, was selected for use in merging the comparison results at the EUROMET level already available in 1999.

RMO key comparisons were reported, linkages discussed by the working group, and approved.

Medium pressure

The Working Group on Medium Pressure met in May 2002 at the BIPM.

The research carried out by NMIs include such subjects as developing a new manometer and a special pressure balance for low pressure operation.

Key comparisons CCM.P-K2 and CCM.P-K6 (10 kPa to 120 kPa in absolute and gauge modes) used a piston-cylinder assembly from the BIPM. The calibration phase has finished and the evaluated results have been prepared as draft A reports. The comparisons suffered from various problems, particularly relating to the repeatability of the transfer standard and gauge- and absolute-mode differences in this lower pressure range. The performance of the piston-cylinder was checked prior to and during circulation, and showed anomalous instability which in practice was acceptable for the continuation of the key comparison. A delay in circulation was caused by the loss of a carnet; however, the draft A report was discussed by the participants.

Key comparison CCM.P-K10 (10 kPa to 140 kPa, gauge mode), completed in 1995, was approved for provisional equivalence. RMO key comparisons were reported and evaluated.

Low pressure

The Working Group on Low Pressure met in May 2002 at the BIPM, and discussed cooperative research activities such as the improvement in stability of low pressure transfer standards through the use of resonant silicon gauges, and the development of ultra-high vacuum spinning rotor gauges.

The working group has undertaken the following CIPM key comparisons using low pressure and vacuum gauges as transfer standards:

- CCM.P-K4 (1 Pa to 1000 Pa, absolute mode), and CCM.P-K5 (1 Pa to 1000 Pa, gauge mode), were successfully completed and the results are available in the KCDB.
- CCM.P-K3 (3 μPa to 9 mPa) finished its calibration phase and analysis of the results is under way. During the circulation of three ionization gauge transfer standards, two of them were damaged but the surviving standard and two spinning rotor gauges were used to complete the comparison.
- CCM.P-K9 (0.1 mPa to 1000 mPa) was approved for provisional equivalence and the status of RMO key comparisons was reported and discussed.

The choice of future CIPM key comparisons for comprehensive coverage over the entire pressure range was discussed and the conclusion was reached that it should be shared with other pressure working groups. Finally, the decision was made to repeat CCM.P-K9 as the next comparison and to set a periodicity of ten years for each key comparison.

Joint meeting for pressure working groups

This meeting, which took place in May 2002 at the BIPM, discussed coordination of the timetable of key comparisons and concluded that one CIPM key comparison on pressure every three years would be sufficient to ensure equivalence among CMCs once the function of Quality Systems for similar calibration technologies is established in each participating NMI. Priority for the next three years was given to the high pressure comparison CCM.P-K7.

Future plans for key comparisons include CCM.P-K9, CCM.P-K10 or -K2 and -K6, and CCM.P-K11 or -K7 or -K8, organized by the working groups on low, medium and high pressure, respectively*.

The working groups for pressure periodically organize CCM Pressure Metrology Conferences, the third of which took place in 1999 at the IMGC (Italy), to facilitate collaboration among NMIs in research and technical activities. The fourth conference is scheduled for 2005 and is being organized by the NPL (United Kingdom).

The Avogadro constant and the future redefinition of the kilogram

The Working Group on the Avogadro Constant met in 2000 in Sydney (Australia), in 2001 at the NMIJ (Japan), in 2002 in Ottawa (Canada), and in 2003 at the BIPM. The determination of the Avogadro constant is one of the promising routes for redefining the mass standard, under the assumption that the mass of a 1 kg silicon crystal sphere can provide the mass of a silicon atom if the number of atoms in the sphere is counted by measuring the unit cell volume and the volume of the sphere using a coherent length standard. In fact, the ratio of the molar mass of silicon to the mass of the silicon atom, thus measured, defines the Avogadro constant, which in practice involves precision measurements of the macroscopic density of a silicon sphere, the lattice spacing of the crystal, and the molar mass averaged over the sphere.

Above all, the measurement uncertainty of the molar mass in determinations of the Avogadro constant using natural silicon has reached a technical limit, making the largest contribution to the uncertainty. New results for N_A obtained through the cooperation of members give a measurement uncertainty between 2×10^{-7} and 3×10^{-7}. The data show differences up to $\pm 5 \times 10^{-7}$ with respect to an average value, but all data are 1×10^{-6} lower than the CODATA 1998 recommended value derived by adjustment of the fundamental constants.

Details of technologies for measurement of the density and lattice spacing of silicon, quantitative evaluation of the chemical composition and imperfection of the crystal and surface of the sphere were discussed with the results of comparisons in order to identify the practical limits of each technology.

Apart from natural silicon, enriched ^{28}Si of purity 99.99 % indicates a potential breakthrough of the major limit confronting molar mass measurement, promising a relative standard uncertainty of less than 5×10^{-8}. This concept would involve an NMI capable of enriching a practical amount of silicon, and current investigation shows that a small 99.93 %-enriched ^{28}Si crystal has already been grown and characterized.

The discussions at the last CCM meeting and the CIPM meeting in 2001 pointed out, after a measure of support for the idea, that the resource problems faced by every member of the

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* Since this meeting took place, CCM.P-K10 has been completed and measurements finished for CCM.P-K8; CCM.P-K2 and -K6 are under way.

working group must be taken into account in planning the project, and that transparency of implementation will always be important for directors of NMIs. On the basis of these considerations, the CIPM decided to set up a coordinating committee for the Avogadro constant project consisting of the delegates from NMIs with a special interest in the coordination of this research. The first meeting of the committee was held after the working group meeting.

International Avogadro coordination

At the first meeting, a work plan and management structure including the pilot functions of the participating laboratories were drawn up. A basic assumption in this cooperation is the availability of the enriched material (min. 99.985 % ^{28}Si). Some Russian institutes are reported to have the technology to enrich ^{28}Si to 99.99 %, but chemical and isotopic measurements on samples produced so far have not been traced back to standards. Isotopic contamination from ^{nat}Si is a serious concern at all stages, particularly when the contamination is not uniform. The financial problems associated with producing the material were discussed.

Another process for determining the Avogadro constant is under way at the PTB.

The "ion accumulation" experiment measured the mass of a gold atom in terms of the kilogram for the first time. The relative uncertainty was 1.5 % and the deviation from the value reported in the literature was 0.6 %. With the small ion current of, approximately, 10 μA available at the time of the measurements, and with an oscillating quartz crystal used as a balance, this result was the best that could be expected. With a new ion source operating with bismuth (purchased in 2002), an ion current of 10 mA or more and a considerable improvement in the uncertainty is expected.

Hardness

The Working Group on Hardness met in September 2001 at the IMGC and in May 2002 in Rio de Janeiro (Brazil).

Technical work in which the working group participated included a pilot study on Rockwell diamond indenters, studies on the possibility of a common definition of the Rockwell hardness scales for NMIs, and studies on uncertainty determination in hardness measurements.

With the present level of knowledge, it does not seem possible to predict the performance of a diamond indenter using only direct measurement of the geometry. The above-mentioned study is intended to solve the problem.

The present definition of Rockwell hardness as given by the ISO limits the improvement of calibration uncertainty in NMIs. For example, the influence parameters of the hardness test are not well identified and a number of them do not have any metrological basis. A new document, *Guidelines on the estimation of uncertainty in hardness measurements*, was published by the European co-operation for Accreditation (EA 10/16) in October 2001.

The following CIPM key and related comparisons have been undertaken by the working group:

- CCM.H-S1.a (Rockwell C), -S1.b (Rockwell A), -S1.c (Rockwell D), -S1.d (Rockwell 15N), -S1.e (Rockwell 30N), -S1.f (Rockwell 45N) are all at draft B report stage and are aimed at unification of the Rockwell hardness scales. For the comparisons, seventy-four specially developed hardness test blocks were circulated and calibrated by participants. The cone diamond indenters used to make hardness measurements have a significant effect on measurement results.

Unification requires laboratories to have good repeatability as expressed by the standard deviations of the measurements. For the most important Rockwell hardness scale, HRC, six laboratories achieved adequate repeatability. For this scale, the measurements from seven laboratories agreed within ± 0.3 HRC when using a common indenter, but only four laboratories agreed when using their own indenters.

- CCM.H-K1.a (0.2 HV), -K1.b (1 HV) and -K1.c (30 HV) for the Vickers hardness scale use three sets of hardness reference blocks for the three hardness scales, with hardness levels of 240 HV, 540 HV and 840 HV. Preparation of draft B reports is now under way.
- CCM.H-K2 for the Brinell hardness scale is in progress.
- A pilot study for the Martens hardness scale is planned.

Fluid flow

The Working Group on Fluid Flow met in June 2000 in Salvador (Brazil), April 2001 in Istanbul (Turkey), April 2002 in Arlington (United States) and May 2003 in Groningen (The Netherlands).

Despite their short experience in CIPM activities, the long history and expertise of member NMIs, supported by their communications through academic and industrial flow measurement societies and very intensive discussions at the recent meetings, lead them to the consensus required to undertake key comparisons within the framework of the CIPM MRA.

The CIPM key comparisons were chosen to cover six different fields in fluid flow metrology: water flow, hydrocarbon liquid flow, air speed, liquid volume, high pressure gas and low pressure gas flow. CCM.FF-K1, -K2, -K3, -K4, -K5.a, -K5.b and -K6 are all in the planning phase, but for some of them the protocols will soon be complete.

As all NMIs interested in a national calibration service recognized as being based on the MRA are invited to be members, the working group could discuss issues and problems from both global and regional viewpoints, which automatically elaborated the concept of a combined key comparison. The key comparison is recognized as being advantageous in linking the regional product to the global one and also in sharing very expensive transfer standards.

However, it was later agreed that the ideal linking scheme would be based on an agreement between the Working Group on Fluid Flow and the CCM Technical Committee on Fluid Flow in each field, at their convenience, particularly in relation to their time schedules.

Calibrations in the fluid flow field involve time-consuming operations requiring large numbers of personnel and extensive facilities, and great care must be taken in transporting the huge and expensive transfer standard. The global distribution of such infrastructure, together with the industrial requirements, makes it difficult to design a CIPM key comparison in the usual manner.

Discussion at the meetings covered the statistical evaluation of the KCRV and its uncertainty, calculation of equivalences, listing of Items in the uncertainty budget, choice of range of flow rate, and evaluation of the stability of the transfer standard.

Gravimetry

Gravimetry plays a very important role in the CCM field, as seen in the derivation of force and pressure standards, and the mutual recognition of national gravity standards is accepted in both industrial and regulatory measurement fields. The Working Group on Gravimetry was formed on

the basis of a decision by the CIPM in 2002, initially with fifteen members specializing in gravimetry. The working group first met at the European Center for Geodynamics and Seismology (Luxembourg), in 2002, and discussed the results of the last International Comparison of Absolute Gravimeters (ICAG-2001) conducted at the gravity sites of the BIPM.

This comparison, using seventeen relative and seventeen absolute gravimeters, measured links between five sites of the BIPM gravity network as well as investigating various methods of data processing, including a combined adjustment of the relative and absolute data. The final results, reported in *Metrologia* [2002, **39**(5)], revealed that some further comparisons will be necessary in order to give a definite reference value, as in other key comparisons. The acceleration at a BIPM site was determined with an uncertainty of 5.5 μGal.

The working group also discussed the data-processing method for future comparisons, the development of technical protocols, the organization of regional comparisons, and a plan for carrying out continuous gravity observation at the BIPM using a superconducting gravimeter.

Chairpersons' meetings

Guidelines for CIPM Key Comparisons describes the role of the technical working groups in the CCM as that of a key comparison working group in other Consultative Committees. The first meeting in October 2000 was intended to coordinate the activities of the different groups and discussed the following: suggested format for reporting results of KCDB Appendix B (key and supplementary comparisons); current status of CCM key comparisons and pilot studies; specific problems in producing draft B reports; calculation of key comparison reference values, approval of key comparisons for Appendix B; administrative procedures for future key comparisons; CCM approval of new key comparisons; CCM approval of results for Appendix B; procedures for bilateral key comparisons; consideration of RMO key comparisons; and the status of CMCs (KCDB Appendix C). At the second meeting in June 2003, in addition to these topics, the relationship of CIPM key comparisons to RMO key comparisons and to the supporting evidence for CMCs was discussed and the new role of the CCM in cooperative facilitation of these linkages was formulated."

Professor Mills asked what uncertainty Dr Tanaka anticipated could be achieved in the Avogadro determination of the kilogram. Dr Tanaka estimated a relative uncertainty of the order of 10^{-8}.

Professor Bordé asked how the silicon crystals would be obtained. Dr Tanaka said that a number of institutes, not just NMIs, were collaborating to produce samples. This is an area of high technology, and many different techniques are used to detect imperfections. The Russians are producing a ^{28}Si sphere of 99.99 % purity which will be ready in the next few years. Professor Göbel added that samples have already been grown with purity 99.985 %. Single crystals at this level have been available for some time, but the next question is whether the same technique can be scaled up to produce a crystal of 5 kg.

Professor Bordé asked what strategy was used to measure the atomic mass of ^{28}Si, which is of interest in determinations of the Planck constant *h*. Professor Göbel replied that only the macroscopic mass was needed in the Avogadro experiment. Dr Tanaka added that current data for the atomic mass were reliable to 10^{-8}, and Prof. Mills noted that the relative atomic mass was known to 10^{-9}.

Professor Göbel then asked whether the key comparisons in the domain of force (CCM.F-K1 to CCM.F-K4) are all necessary. Dr Tanaka explained that these four comparisons had been scheduled to cover a wide range of forces, measured using different devices. He reassured Professor Göbel that efforts were being made to reduce the number of key comparisons being undertaken.

In reply to a question from Dr Šafarik, Dr Tanaka said that five key comparisons (CCM.FF-K1 to CCM.FF-K5) are planned in the field of fluid flow. None of these has been started as yet.

15.3 Consultative Committee for Time and Frequency

Professor Leschiutta, President of the Consultative Committee for Time and Frequency (CCTF), presented the following report.

"I am pleased to present this report giving an overview of current CCTF time and frequency activities, and the progress made since the last General Conference in 1999.

The CGPM mission being a global one, I will mention major events with a direct or indirect impact on BIPM activities, as well as those directly organized by the BIPM.

The report covers the following topics: CCTF activities and external events sponsored by the CCTF; progress in the definition of the second; research on TAI formation; possible modifications to UTC; comparisons between remote and near clocks; and applications.

CCTF activities and external CCTF-sponsored events

In the period 1999-2003, the CCTF, with the help of the BIPM Time section, organized two meetings in 1999 and 2001, both held at the BIPM. The proceedings have now been published. The CCTF held its 15th meeting in June 2001. At the previous meeting in April 1999, twenty-seven NMIs were represented as well as some international organizations, while at the 15th meeting the attendance rose to thirty laboratories [CCTF members, three laboratories as observers and four international organizations − the International Astronomical Union (IAU), International Telecommunication Union (ITU), International Union of Geodesy and Geophysics (IUGG) and the International Union of Radio Science (URSI)].

In June 2001, Dr Patrizia Tavella (Istituto Elettrotecnico Nazionale Galileo Ferraris, IEN, Italy) replaced Prof. Paul Pâquet (Observatoire Royal de Belgique, ORB, Belgium) as chairperson of the CCTF Working Group on TAI. The working group organized a meeting of laboratories participating in TAI in June 2001. A CCTF Working Group on TAI Sub-Group on Algorithms was set up, chaired by Dr Tavella.

The 15th meeting of the CCTF also set up a Joint Working Group CCL/CCTF on Secondary Representations of the Second, with the participation of laboratories active in the development of frequency standards.

The increasing attendance at these meetings bears out the relevance of the time and frequency activities and initiatives arising from the BIPM and ultimately from the CGPM.

Progress in the definition of the second

The present definition of the second, adopted by the CGPM in the 1960s, is again proving its validity and vitality; that in less than half a century has allowed progress in reducing uncertainty from 10^{-9} to 10^{-15}.

The most recent development is the caesium fountain. Research in this field is very active at the moment, as documented in the table, which lists the fountains now operating and reporting data to the BIPM, together with those in an advanced stage of development or currently under development.

Atomic fountains worldwide

Operational

1. SYRTE FO1 (France) $u_B = 1.0 \times 10^{-15}$
2. SYRTE FO2 (France) $u_B = 0.8 \times 10^{-15}$
3. SYRTE FM (France) $u_B = 0.8 \times 10^{-15}$
4. NIST F1 (United States) $u_B = 0.7 \times 10^{-15}$
5. PTB CSF1 (Germany) $u_B = 0.9 \times 10^{-15}$
6. IEN CSF1 (Italy) $u_B = 1.8 \times 10^{-15}$
7. USNO (United States): used only as highly stable reference

Advanced development

8. METAS (Switzerland), continuous fountain
9. NPL (United Kingdom)
10. NMIJ/AIST (Japan)

Under development

11. Italy (Turin Polytechnic)
12. Russian Federation
13. Brazil
14. China
15. Republic of Korea
16. Canada

Research on TAI formation

Research on improvements to the current algorithm for the calculation of time scales is under way at the BIPM and in some laboratories, mainly in order to increase the stability of TAI. In this connection, a new way of assigning an upper limit to relative weights of clocks has been implemented at the BIPM Time section in the algorithm for TAI.

Fruitful discussions took place at the International Time-Scale Algorithms Symposium, the fourth of a series, held at the BIPM in March 2002, and organized by the BIPM, IEN and the U.S. Naval Observatory (USNO, United States). A special issue of *Metrologia* [2003, **40**(3)] is dedicated to this meeting.

Linked with TAI is the construction of Reference Systems, an activity of the CCTF in cooperation with the International Earth Rotation Service (IERS) of the IAU. The effects of relativistic corrections are also under consideration.

Possible modifications to UTC

During the 2001 CCTF meeting, the problem of maintaining the current UTC time scale was raised.

UTC was formed between 1960 and 1970 by the ITU after an exhaustive consultation of many international organizations and was based on a real problem: how to conciliate the stable definition of the atomic second with the observed slowing of the period of rotation of the Earth? The situation has now completely changed and the question arises about the permanence of a time scale, no longer necessary but rooted in our culture.

The ITU has set up a Special Rapporteur Group on UTC, in which the BIPM participates. This group organized an international colloquium at the IEN in May 2003. No final decision was taken but a proposal to be submitted to the ITU was elaborated.

The IAU has also formed a Working Group on UTC with the participation of the BIPM. Members attended the UTC colloquium at the IEN and backed the proposal to be submitted to the ITU.

Comparisons between remote and near clocks

Research on the accuracy and stability of caesium fountains as frequency sources, and of their manifestations, the time scales, is not possible without reliable and accurate comparisons between remote laboratories and within laboratories.

Important activities in this field have been carried out at the BIPM Time section, whether directly or through the organization of a series of measurements, on at least four topics:

- calibrations of GPS receivers, organized by the BIPM Time section, with about 50 % of the GPS receivers in TAI calibrated at present;
- use of “geodetic” receivers for time comparison in TAI: a campaign has been successfully run since April 2002 to test the inclusion of dual-frequency GPS observations in TAI;
- routine use of the “two-way satellite time- and frequency-transfer technique” (TWSTFT) via geostationary satellites for TAI formation;
- use of the “precise” GLONASS code for time transfer.

An agreement between the BIPM and the International GPS Service (IGS), which started as a joint Pilot Project for Time and Frequency Comparisons using GPS and is now under the responsibility of a working group of the IGS, is also of relevance to this work.

Applications

A number of technological applications, such as satellite navigation or digital communications, are currently using time and frequency technologies with accuracy requirements approaching the maximum capabilities of NMIs.

It is therefore the CCTF's duty to remain abreast of those developments requiring accurate frequency standards or time scales, to be aware of changing requirements and to elaborate guidelines for future activities. To mention just a few of these: new clocks in space, time scales and synchronization in space, the Galileo project, and two programmes with atomic clocks in space under way in Europe and the United States.

As an example, the European Space Agency has formed a working group to study all aspects of time under the Galileo project, with the participation of the BIPM and European NMIs.

Related activities

Since January 2001, the BIPM has shared with the USNO the IERS Conventions Product Centre, the responsibility of establishing standards and conventions for astrometry and geodesy.

Time and frequency metrology plays an important role in the development of both science and technology, as borne out by the activities in most of the NMIs linked to the BIPM and by the increasing attendance at CCTF meetings.

This branch of metrology, and consequently the BIPM, must remain receptive and closely connected to progress in fundamental science and in the most advanced applications. To illustrate this continuing effort, in September 2003 a joint meeting with representatives of the CCL and the CCTF will be held at the BIPM to explore possible secondary representations of the second."

Professor Leschiutta finished by recalling Prof. Bordé's opening remarks, and speculating that one day the complete system of units could be based on the second and a few fundamental constants!

Professor Bordé then invited questions from delegates.

Dr Bement asked if the CCTF had considered what the limiting accuracy will be in the ability to transfer time, due to atmospheric dispersions and other effects. Professor Leschiutta replied that the accuracy and stability of the best new clocks is already better than the precision of current methods of time transfer. One of the major activities of the BIPM and other time laboratories is thus in improving methods of time transfer and time comparison. A very important domain of work is the development of portable optical clocks. Another is the placing of newer clocks on satellites.

Professor Bordé noted that there are really two ways of improving clock comparisons. He drew attention to the presence of cold atomic clocks on the international space station, where one of the goals was to compare clocks on Earth, presently using microwave radiation. He highlighted,

in particular, the ACES and PARKS projects. The other technique is to carry around a portable comb-generator associated with a good clock. He cited, in particular, the PHARAO clock, which has already been used to compare the caesium and hydrogen clocks in Munich to an optical transition.

He then turned attention to the importance of such work to studies of the fundamental constants, noting that comparing different clocks (for example, Cs and Rb or Cs and H) at different times allows a limit to be placed on the temporal variation of the fine structure constant α.

Dr Schwitz asked how many caesium fountains were participating in the construction of TAI. Professor Leschiutta replied that as of September 2003 there are four fountain clocks that contribute on a regular basis; details are available in the *Circular T* distributed by the BIPM Time section. He said he was very interested to see the new approach being developed and tested at METAS with two continuous fountains. Dr Schwitz confirmed that the METAS fountains were already working and were currently being characterized.

Finally, Prof. Leschiutta returned to the final accuracy of the fountain approach, and ventured his personal opinion, that they would reach a few parts in 10^{16} when problems such as the black body effect have been resolved.

15.4 Consultative Committee for Electricity and Magnetism

Professor Göbel, President of the Consultative Committee for Electricity and Magnetism (CCEM), presented the following report.

"It is my pleasure to present the report of the CCEM.

The CCEM has met twice since the 21st CGPM in 1999. It discussed matters relating to fundamental constants and the SI, including the work on electrical methods to monitor the stability of the kilogram and the status of the least-squares adjustment of the fundamental constants with, of course, special emphasis on work involving improvements in the knowledge of K_J and R_K, the Josephson and von Klitzing constants. The metrological use of single-electron tunnelling (SET) devices was another topic of discussion. Methods for carrying out accurate measurements of the quantized Hall resistance at frequencies in the kilohertz range is of great current interest and developments are being encouraged and closely followed by the CCEM Working Group on ac Measurements of the Quantum Hall Resistance (ACQHR). The CCEM is also keenly interested in the development and use of programmable (current-biased) arrays of Josephson junctions having constant voltage steps of much greater amplitude, and hence much better stability, than the older arrays of unbiased junctions. The CCEM reviewed the availability of both types of array as well as that of quantum Hall devices. Key comparisons in electricity and magnetism were a major issue for the CCEM and in this area, detailed work is being carried out, in their respective domains, by the Working Groups on Low Frequency Quantities (WGLF) and Radiofrequency Quantities (GT-RF). These groups are making a conscious effort to lighten the workload that key comparisons place on NMIs by speeding up key comparison processes, on the one hand, and maintaining the number of key comparisons to a manageable level, on the other. Finally, the CCEM regularly reviews the activities of the Electricity section of the BIPM.

CCEM work on scientific metrology

The CCEM Working Group on Electrical Methods to Monitor the Stability of the Kilogram now meets on a yearly basis. Although, as its name suggests, it is primarily interested in electrical methods to achieve its goal; it continues to maintain close links with research using alternative methods having the same aim. It is useful to recall that to monitor the stability of the kilogram, the relative uncertainty in the independent determination of its mass should be about 1 part in 10^8 or less.

The relative uncertainty of the mass levitation experiment is now about 1 part in 10^6 and it is hoped that future improvements can reduce this. Work to measure the Avogadro constant using a silicon artefact has driven the relative uncertainty down from 4 parts in 10^7 to less than half that. Although one of twenty-three silicon crystals showed a discrepancy of 3 parts in 10^6, the CCM Working Group on the Avogadro Constant noted that the results on the remaining crystals were self-consistent and decided to exclude the single outlier. The physical reason for the anomaly is still unclear.

By using isotopically enriched silicon, experts hope to achieve a relative uncertainty of 5 parts in 10^8 in the measurement of the molar mass by 2005. In an experiment at the PTB (Germany), a mass spectrometer is used to accumulate an accurately measurable mass of singly ionized gold by measuring a current level of 0.1 mA. Present efforts are concentrating on increasing current levels up to 30 mA and, using bismuth atoms, a mass of 30 g could be accumulated in six days. This would lower uncertainties to below 1 part in 10^6. Watt balance experiments are currently being carried out at the NPL (United Kingdom), the NIST (United States) and the METAS (Switzerland). A shift in NPL results of 3 parts in 10^7 occurred in April 2000 and is now thought to be due to a tilt in the balance support. The balance is being realigned and new measurements are in progress with a hope of achieving a relative uncertainty of 5 parts in 10^8 some time in 2003. Modifications are being made to improve the NIST moving-coil watt experiment and then to try to repeat the results reported in 1998, which achieved a relative uncertainty of 9×10^{-8}. The METAS watt balance, which uses a 100 g mass and a compact experimental apparatus, has now achieved a repeatability of 6 parts in 10^7. Present efforts concentrate on reducing hysteresis in the magnet-coil assembly. A new watt experiment is in the late design stages at the BNM-LNE/LAMA (France). Finally, the BIPM is studying various schemes for constructing a watt balance, including one using a permanent magnet at cryogenic temperatures.

The CCEM regularly monitors the progress in SI determinations of the Josephson and von Klitzing constants and the coherence of the conventional values of these fundamental constants, designated $K_{J\text{-}90}$ and $R_{K\text{-}90}$, used to assure stable, highly reproducible reference standards of voltage and resistance. At its 22nd meeting in September 2000, the CCEM noted that the latest CODATA least-squares adjustment of the values of the fundamental constants indicated that the values of $K_{J\text{-}90}$ and $R_{K\text{-}90}$ remain comfortably coherent with the SI values and declared that the relative one standard deviation uncertainty assigned to R_K in 1988 could now be reduced by a factor of two to 1×10^{-7}. At its 89th meeting in October 2000, the CIPM agreed with the CCEM declaration. At its 23rd meeting in September 2002, the CCEM again examined the values and uncertainties assigned to $K_{J\text{-}90}$ and $R_{K\text{-}90}$ and saw no reason to recommend any further changes. In a related issue, the CCEM regularly examines the need to revise its *Technical Guidelines for Reliable Measurements of the Quantized Hall Resistance*, established in 1988. After considering more recent published results on issues such as imperfect quantization and non-ideal contacts to the device, wide discussions with experts both inside and outside the metrology community were pursued. All this work resulted in some revisions to the Guidelines. These were agreed and the revised version was published in *Metrologia*.

The CCEM follows the regular progress in the metrological use of SET devices. In the European Union's COUNT project, an electron pump produced currents of 3.2 pA that were measured with a Type A uncertainty of 4 parts in 10^6. The PTB has reported achieving a relative uncertainty of 1 part in 10^4 in the definition of the current plateau of a surface acoustic wave device. The NIST is making steady progress in the development of seven-junction Cooper-pair pumps, and the development of capacitance standards whose charges are known by counting electrons.

The activities of the ACQHR group reflect the great interest for electrical metrology in measuring the QHR directly at a frequency in the kilohertz range. In 2000, experts from the BIPM and the NPL reported relative uncertainties below 1 part in 10^7 in the definition and measurement of the Hall resistance at kilohertz frequencies using gate electrodes, and now several laboratories have attained this level of uncertainty. One of the ACQHR's ongoing projects is to offer possibilities for experts from the participating laboratories, the METAS, the NRC and the PTB, to work together for several weeks in one of the laboratories with the goal of perfecting measurement techniques and improving experimental devices. The difficulty in achieving uncertainties approaching those claimed for QHR measurements at dc is reflected by the opinion of the ACQHR that it is still premature to propose guidelines for reliable ac measurements of the QHR.

At present, the best primary reference standards of voltage are realized using series arrays of tens of thousands of nearly identical Josephson junctions. The usual technology uses junctions consisting of a thin insulating layer separating two superconducting electrodes. Under irradiation at millimetre-wave frequencies, each junction can develop across it a quantized dc voltage whose value depends on the frequency of irradiation and a quantum number representing the total number of constant voltage steps. The current-voltage characteristic of such a junction shows that for a small range of currents, of the order of $\pm$ 20 μA, applied through the junction, the output voltage remains constant; and if the current is increased above this value the output voltage changes by one or more quantized steps. Although this feature is very useful, because it eliminates the need to bias junctions individually, it makes the output voltage of the array unstable in the presence of small perturbations. An alternative technology has been developed at the NIST and the PTB to produce arrays of junctions that are able to maintain a constant voltage over current ranges of the order of several milliamperes. Using these junctions in a voltage standard requires applying a bias current but the resulting output voltage is very stable against small perturbations. By arranging arrays of such junctions into cells containing numbers of junctions that increase in, for example, a binary sequence, it is possible to synthesize a wide range of voltages, hence the name "programmable array". This technology is already being applied using programmable arrays as potentiometers to measure, for example, resistance ratios. Developments in this rapidly evolving field are being followed by the CCEM.

The CCEM makes a special effort to survey the availability of metrological-quality QHR samples and arrays of Josephson junctions. Several NMIs are successfully making small quantities of QHR devices. Some of the devices produced in 1990 by a French industrial firm are still available from the BIPM. The NRC has announced that it is seeking partners to participate financially in a project to fabricate QHR devices for metrological purposes.

Several NMIs are also producing arrays of Josephson junctions in small quantities. The NIST and the PTB have successfully transferred the technology of fabrication of unbiased arrays producing outputs of up to 10 V and 1 V, respectively, to commercial firms. At present, only a very limited number of programmable arrays are being produced by the NIST, the PTB and the

VTT (Finland); the last two institutes can make a very small number available for research purposes in the framework of collaborative projects.

CCEM work on key comparisons

The CIPM MRA assigns a major role to the Consultative Committees and the CCEM has made a considerable effort to carry out this task. The preparation of lists of CMCs of NMIs is well advanced in the area of electricity and magnetism. An important part of this work was the preparation and acceptance of the CCEM classification scheme for CMCs in electricity and magnetism. The CCEM helps to coordinate the work of RMOs by inviting RMO technical chairpersons in electricity and magnetism to attend CCEM meetings concerned with the MRA. An annual meeting of RMO technical chairpersons in electricity and magnetism precedes these CCEM meetings.

The CCEM has always expressed a great interest in international comparisons and it carries on a vigorous programme of key comparisons. It has now approved for provisional equivalence a total of eight CCEM and RMO key comparisons of dc and low frequency quantities and seventeen comparisons of high frequency quantities. It has approved for full equivalence, which includes giving the numerical results in the BIPM key comparison database, six CCEM and two RMO comparisons of dc and low frequency quantities. It also approves on a regular basis results from the nine BIPM ongoing key comparisons. It is worth mentioning that on two occasions the CCEM approved the linking of large-scale CCEM and RMO key comparisons, one of 10 pF capacitance and one of 10 V dc standards. This demonstrates the feasibility of the critical linking process foreseen in the CIPM MRA. All this progress is the result of considerable effort. The pilot laboratories responsible for preparing, carrying out, reporting and seeing through the approval of a CCEM comparison must devote considerable time to the enterprise. This has led to expressions of concern by some NMIs about the quantity of work dedicated to key comparisons. The CCEM Working Group on Key Comparisons (WGKC) examined this issue carefully and noted that: (1) in some cases key comparisons of similar quantities were running in parallel; (2) comparisons begun before the preparation of the *Guidelines for CIPM Key Comparisons* had inadequate protocols and analysis methods; and (3) the review process for key comparison reports was too complicated. The CCEM accepted the following proposals to increase the efficiency and decrease the workload of key comparisons: (1) insist on a well-prepared protocol that clearly defines the goals and expectations of each comparison; (2) reduce the number of participants; (3) provide guidance to report authors; (4) simplify the review process; (5) revise the key comparison scheme to include only eight key comparison areas in dc and low frequency and seven in the radiofrequency area and (6) allow only one key comparison at a time in each of the defined areas. Progress has already been made to implement these improvements.

At the beginning of a comparison a small committee is formed to provide support to the person in the pilot laboratory who is responsible for the comparison. The first task of each committee is to approve the comparison protocol. The number of NMIs requesting participation in CCEM comparisons should decrease now that the successful linking of two pairs of large-scale CCEM and RMO key comparisons has demonstrated that it is not necessary to participate in a CCEM key comparison to see an NMI's equivalence tabulated in the KCDB. The CCEM is now preparing guidance documents on creating, carrying out, reporting and agreeing key comparisons. The acceptance process has been accelerated by the creation of a restricted BIPM website for posting comparison reports so that they can be discussed via the Internet and approved at any time, not only at the annual meetings of the working groups responsible.

Finally, the WGKC disbanded and the CCEM set up the WGLF, making it and the GT-RF directly responsible to the CCEM, removing one step in the process of securing CCEM approval of a key comparison. These measures received the enthusiastic support of all the CCEM delegates. The Director of the BIPM expressed the view that the treatment of key comparison reports is often too rigorous and that considerable time could be saved by simplifying the analysis of the results. This view is shared by a number of CCEM delegates."

As President Elect of the CIPM, he took the opportunity of his last appearance as President of the CCEM to thank Dr Tom Witt (BIPM) for his important contributions both within the BIPM and as Executive Secretary of the Committee. Finally, he drew attention to the revised *Technical Guidelines for Reliable dc Measurements of the Quantized Hall Resistance*, published by Delahaye and Jeckelmann (*Metrologia*, 2003, **40**(5), 217-223).

Professor Bordé asked what steps were necessary to be fully confident in the relations expressing K_J and R_K in terms of e and h. Professor Göbel replied that for the Josephson constant the BCS theory and the Josephson device prove the relation $K_J = h/2e$. For the quantum Hall effect the situation is different; there is not a conclusive theory proving the relation $R_K = h/e^2$, and it remains necessary to improve the SI realization of the ohm. The SI realization of the ohm is achieved through the calculable capacitor, hence the importance of reducing its uncertainty so as to improve the absolute representation of the SI ohm. Thirdly, of course, the quantum metrological triangle could be closed to 1 part in 10^8.

Professor Bordé remarked that he considers the fine-structure constant α to be the key to relating the electric and magnetic quantities and encouraged the pursuit of studies on this constant and the calculable capacitor. Professor Göbel agreed, adding that the PTB was also actively studying this constant and its stability.

15.5 Consultative Committee for Thermometry

Dr Quinn expressed the regrets of Prof. Ugur, President of the Consultative Committee for Thermometry (CCT), who for reasons beyond his control was unable to attend and present his report.

On behalf of Prof. Ugur, Dr Quinn drew attention to the printed version of the report of the CCT and presented a historical overview of the Committee. He started by pointing out that thermometry was one of the very early tasks at the BIPM under the Metre Convention, because the length of the metre bar varied with temperature. He also noted that the very first international temperature scale, the Normal Hydrogen Scale, was developed at the BIPM.

In the first decade of the 20th century, the so-called "*grands laboratoires*" (Physikalisch-Technische Reichsanstalt, PTR, the National Physical Laboratory, NPL, and the National Bureau of Standards, NBS) discussed how thermometry could be put on a sound physical and international basis. By the time the 5th CGPM met in 1913, there were already plans to establish an international temperature scale.

The problem in thermometry is that the quantity we need to measure, thermodynamic temperature, requires a long, complicated and tedious measurement process – and even today it is not possible to measure thermodynamic temperature directly with the precision that is required in many parts of industry. Therefore some practical means of giving an indication of temperature is required. This can be illustrated most simply by saying that thermodynamic temperatures can

be obtained with a gas thermometer, while practical temperatures are obtained using a resistance thermometer.

The first World War intervened, and no further progress was made until 1927, when the 7th General Conference adopted the International Temperature Scale of 1927 on a provisional basis. It was planned that an International Conference on Thermometry should be organized within a very short time. However, no such Conference took place; instead, the International Committee created a Consultative Committee for Thermometry and Calorimetry, which first met in 1933, with the task to develop and improve the International Temperature Scale.

The Scale was revised in 1948 (IPTS-48), and again in 1968 (ITS-68), each time becoming more complicated, though not necessarily closer to thermodynamic temperature. Between 1948 and 1968, an enormous amount of work was undertaken in the NMIs on measuring thermodynamic temperatures, and developing the procedures and algorithms for a practical temperature scale, and the 1968 temperature scale differed significantly from that of 1948. We now know that many of these changes, in fact, took the scale further away from thermodynamic temperature.

Within a year or two of the promulgation of ITPS-68, the CCT was busy with its revisions. It was finally in 1990 that the next revision took place: the ITS-90, in which Dr Quinn and others in the room were closely involved. This scale was even more complicated, but the CCT believed it to be much closer to thermodynamic temperature than was IPTS-68.

During all this time, many international comparisons were carried out of measurements of the fixed points on which the scale is based. In the 1980s and 1990s, it was thought that the subject was quite well understood. However, when the CCT started to set up key comparisons, as part of the CIPM MRA, other detailed points began to emerge.

The CCT found itself unable to agree on many aspects related to these comparisons. There were deep divisions within the Committee, particularly with regard to how to evaluate the uncertainties of the measurements on the fixed points but also on the interpretation of the key comparison reference value. These problems had taken many years to resolve, and had made it very difficult to proceed to a conclusion in many key comparisons in thermometry. There are still no CMCs in thermometry published in the KCDB.

Part of the problem was, he thought, that many of the people involved, particularly in thermometry, have become obsessed with the fine detail of the statistical analyses of the results of the key comparisons. Dr Quinn commented that this may be a fine academic study, but he urged the directors of the NMIs to look closely at what is going on in their thermometry sections, to make sure that the delegates they send to the Consultative Committees have a reasonable idea of the objective of the task, and to introduce a sense of reality into the field of thermometry.

Having said all this, he noted that there were now signs that things were coming together, and expressed hope that CMCs in thermometry would be published in the KCDB within the coming year. Dr Quinn called urgently for this, pointing out that thermometry is a major area of physical science and engineering, and temperature measurement an important part of industrial activity, so it is essential that the subject be properly represented on the KCDB.

Finally, he drew attention to a new working group of the CCT, the ninth, which has been created to study the requirements of thermophysical measurements. He welcomed this development, in an area of great importance to many users.

Dr Quinn presented the report of the CCT.

"It is a pleasure to present the report of the CCT, which has met three times since the last General Conference.

The 20th meeting of the CCT, convened for 12-14 April 2000, came to an abrupt halt when Dr John Nicholas had a heart attack. His subsequent death was a shock to all present. The meeting reconvened to commemorate this dear friend and colleague and thereafter discussed only the issues that needed immediate attention. The 21st meeting of the CCT was held from 12 to 14 September 2001 and the 22nd meeting from 14 to 16 May 2003.

Working Group 1: defining fixed points and interpolating instruments

Efforts in this field have been focused on techniques for realizing the fixed points of the ITS-90 and on interpolating instruments. At the 20th meeting it was decided to widen the scope of the work to include the issue of impurities in fixed points. The main aim is to revise *Supplementary Information for the International Temperature Scale of 1990*.

The CCT considered it valuable to revive the BIPM web bibliography of publications relevant to thermometry. The BIPM could then link to NMI bibliography web pages and allow access through its search engine. Laboratories were requested to send the appropriate URLs to the Executive Secretary.

The 2003 meeting further discussed *Supplementary Information* and agreed the following:

- It should specify that the reference temperatures are for chemically pure substances.
- The isotopic concentrations corresponding to the assigned temperature should in general be specified.

In the absence of other information, the isotopic concentration would be the naturally occurring composition. When sufficient knowledge of isotopic effects is available, procedures for correction to an isotopic composition specified in *Supplementary Information* would be made. A procedure to incorporate such a correction for the triple points of water and for equilibrium hydrogen is under development.

The following draft recommendations are in progress:

- Revision of the relevant document on the estimation of fixed-point cell uncertainty arising from impurities. Methods based on chemical assays are primarily recommended, supplemented by thermal analysis (such as the slope of a melting curve) and comparisons between cells. Estimates of uncertainties based on representative comparisons are mainly useful as a validation tool to check for contamination during preparation. Reliance on thermal analysis alone should be avoided as a means of determining cell uncertainty.
- Proposed methods for correction of the experimentally determined *liquidus* point for impurity concentrations. Working Group 1 agrees that such a correction is in principle desirable, but only if the uncertainty of the chemical analysis is at a level of 100 % ($k = 2$) or better. Present evidence is that chemical assay results have variable utility, with uncertainties in the range 20 % to 300 %. The working group requests information on other chemical analysis techniques available or in use by NMIs, and may seek the advice of the Consultative Committee for Amount of Substance, which has recently discussed the analysis of trace impurities and concluded that reliance on a single method is generally insufficient.
- Proposed methods of experimentally determining the *liquidus* point.

Working Group 2: secondary fixed points and techniques of approximation to the ITS-90

The main scope of this work is the revision of the monograph *Techniques for Approximating the International Temperature Scale of 1990*, including the uncertainties that can be obtained with the approximating techniques.

It was decided that revisions to the document should extend well beyond a simple updating of the references.

An electronic version (in PDF format) of the existing *Techniques* document has been prepared. This document and the most recent list of secondary reference points (*Metrologia*, 1996, **33**, 133-154) will be hosted on the BIPM website. It is envisioned that *addenda* produced by the CCT working groups will be published electronically as they become available, and that the final text of the new documents will be made available on the BIPM website, thus allowing rapid updates and easy access.

The CCT has also examined the reference functions for Au/Pt (NIST) and Pt/Pd (NIST/IMGC) thermocouples, and endorsed the NIST Au/Pt and NIST/IMGC reference functions for general use as an aid to the International Electrotechnical Commission's process of defining international standards for these important thermocouple types.

Working Group 3: uncertainties

The CCT has decided to prepare a proposed guideline for the uncertainty analysis of standard platinum resistance thermometers (SPRTs) calibrated at the defining fixed points of the ITS-90. It was agreed that the guideline should be called *CCT Guidance Document on Uncertainties of SPRT Calibrations.*

It was also decided that this work and that on defining fixed points and interpolating instruments are strongly correlated, and the documents prepared by these two studies should be cross-referenced.

The CCT has organized various workshops on the issue of uncertainty in temperature measurements, either as independent events or in association with workshops relating to temperature measurement.

Another workshop will be held at TempMeko 2004 on uncertainties in temperature measurements, especially on fixed points.

Working Group 4: thermodynamic temperature determination and extension of the ITS-90 to lower temperatures

At the 1999 General Conference, the CGPM invited the CIPM to prepare a ^{3}He melting pressure equation as a function of thermodynamic temperature to serve as the basis for an extension of the ITS-90 below its present lower limit of 0.65 K.

The extension of the ITS-90 to below 0.65 K, known as the Provisional Low Temperature Scale of 2000 (PLTS-2000), has been discussed by the CCT. The scale is labelled provisional because its uncertainty below 10 mK is larger than desirable. Also, not all the work supporting this scale has been published in refereed journals. The scale is a compromise between supporting scales rather than a consensus. However, the CCT proposed the adoption of the provisional version because of the lack of new measurements and the genuine need for the scale. The PLTS-2000

overlaps with the ITS-90 between 0.65 K and 1 K to correct for the deviations of the ITS-90 as shown by thermodynamic measurements. Such an overlap also existed between the IPTS-68 and the EPT-76 at the low end of the IPTS-68. In the overlapping range, the temperatures can be distinguished by the index; T_{2000} refers to the PLTS-2000, while T_{90} refers to the ITS-90. The CCT unanimously accepted the PLTS-2000 and the CIPM also adopted this scale in October 2000.

The CCT has been watching new developments in both thermodynamic and ultra-low temperature thermometry, and noted with interest the recent development of a tunnel-junction noise thermometer by Spietz *et al.* of Yale University that is potentially useful as a thermodynamic probe over a very wide range of temperatures. It may initially find application at very low temperatures where the relative uncertainty, currently 0.1 % of T, is of interest.

Working Group 5: radiation thermometry

The CCT had decided to dissolve the joint CCPR/CCT Working Group on Thermodynamic Temperature Determinations for High Temperature Black Bodies as there was no longer a need for it. The Consultative Committee for Photometry and Radiometry accepted the CCT's recommendation, provided that the CCT Working Group 5 continues to liaise with the CCPR.

A workshop on uncertainties in radiation thermometry, held in 2001, has produced a document giving conclusions and recommendations on the evaluation of uncertainty in radiation thermometry. Within the scope of this document, the analysis completed to date considers realizations above the silver point, and includes the following key features:

- sensitivity coefficients in an uncertainty model;
- "normal" and "best practice" uncertainty values characterized for three different realization schemes (two lamp-based, one thermometer-based);
- links to the requirements of Appendix C of the MRA, where services "normally offered" by NMIs are listed; and
- some technical limitations on implementation (such as determination of the wavelength, filter stability, and the non-linearity of the thermometer).

The current work plan includes the consideration of uncertainty budgets for radiation thermometry below the silver point, as well as the identification of initial values for metal-carbon eutectics for consideration as secondary reference points.

Studies concerning the ITS-90 and discussions on the ITS-20XX

In order to evaluate the future needs regarding the International Temperature Scale, a workshop entitled "Towards ITS-20XX" was held in conjunction with the 8th Temperature Symposium in Chicago, October 2002.

The CCT has decided to be active on this subject, and assess the situation and future needs through various activities, including workshops and surveys.

There is general agreement within the temperature community that the role of the CCT is to look ahead to identify and anticipate changes likely to be required, including the possibility of an officially promoted, useful approximation to the ITS-90 that would be helpful in terms of cost and application. Lower-temperature applications for radiation thermometry, and new thermo-

couple functions for use both above and below 0 ºC were cited as practical potential improvements.

Working Group 6: humidity measurements

Work in this area is focused mainly on the organization of a key comparison.

Studies on humidity measurements are increasing, as indicated by the successful workshop on humidity in 2002 in Chinese Taipei, and by TempMeko 2001. There were many CCT-related activities at these events, including the meetings of Working Group 6.

Working Group 7: key comparisons

CCT-K1: realizations of the ITS-90 from 0.65 K to 24.5561 K using rhodium-iron resistance thermometers. This key comparison has been ongoing since 1996 and the first measurements were made in 1998. All measurements are now complete and data reduction is in process. The intention is to compile a matrix of laboratory temperatures for all twelve thermometers at some fifty or sixty comparison temperatures, to look for discrepant values that may require discussion with the individual participants, and to circulate the draft A report in 2003. It is hoped that the process can be completed, and an agreed draft B report and the associated Appendix B entries obtained in the timeframe of TempMeko 2004.

CCT-K2: realizations of the ITS-90 from 13.8 K to 273.16 K using capsule-type standard platinum resistance thermometers (SPRTs). This key comparison is complete and the final report and relevant Appendix B entries are in the KCDB.

CCT-K3: realizations of the ITS-90 from 83.8 K to 933.5 K using long-stem SPRTs. This key comparison is complete and the final report and relevant Appendix B entries are in the KCDB.

CCT-K4: aluminium and silver fixed points. This key comparison is complete and the final report and relevant Appendix B entries are in the KCDB.

CCT-K5: realizations of the ITS-90 between the silver point and 1700 °C using vacuum strip lamps as transfer standards. Measurements are complete and the draft A report has been distributed to the participating laboratories for discussion.

CCT-K6: humidity standards. The protocol of the comparison has been prepared and measurements will start soon.

CCT-K7: water triple point cells. Measurements have started. The draft A report is anticipated early in 2004.

International equivalence of temperature measurements and corresponding international comparisons

A major component of this work is to discuss the progress of key comparisons. Various meetings have been held since January 2000 between key comparison coordinators and the relevant working group, which is called upon to identify where no consensus in uncertainties exists. Protocols are to be required for all key comparisons, including those that are ongoing, so that key comparisons carried out by RMOs can be linked to CCT key comparisons. The protocols must guarantee that the results of an RMO key comparison are compatible with and can be compared with those of a CCT key comparison.

There has been some discussion on the interpretation of the phrases “significant unresolved deviations”, which appears in the MRA Appendix B and Appendix C in the context of the compatibility of entries, and “significant deviations”, which may be identified by the pilot during the key comparison. This issue has not been resolved completely.

Discussion of the status and results of RMO comparisons

No regional or bilateral comparisons are known to be planned or in progress related to CCT-K1. CMCs in this temperature region have been submitted for inclusion in Appendix C by COOMET, and it is anticipated that further submissions will be forthcoming from other RMOs.

A report on the bilateral key comparison equivalent to CCT-K2 between the All-Russian Research Institute for Physical, Technical and Radiophysical Measurements, Gosstandart of Russia, Moscow (VNIIFTRI), and the NRC (Canada) has been submitted to the CCT. A speedy resolution is anticipated, and the corresponding Appendix B entries are expected to appear in the KCDB by the end of 2003. Regional key comparisons equivalent to CCT-K3 are under way at APMP and EUROMET. The SIM is undertaking some supplementary comparisons in this temperature region, and there have been some difficulties related to customs and transport of artefacts between countries. Also, a bilateral key comparison between the CENAM (Mexico) and the NIST (United States) is expected to start in 2003.

An APMP comparison equivalent to CCT-K4 is planned. The protocol has been under discussion among the participants.

Two regional key comparisons equivalent to CCT-K5 are being undertaken by APMP and EUROMET.

An RMO key comparison corresponding to CCT-K6 has been completed within APMP, and a similar exercise will begin within EUROMET in the coming year. A bilateral key comparison between the NIST and the Instituto Nacional de Metrologia, Normalizaçao e Qualidade Industrial (INMETRO, Brazil) will take place within the SIM.

There are no known regional or bilateral comparisons planned or in progress related to CCT-K7.

SADCMET intends to undertake a series of supplementary comparisons in a variety of temperature regions.

Working Group 8: calibration and measurement capabilities

The CCT has set up the working groups required to deal with CMC assessment and the relationship between CMC claims and key comparisons. These have handled the CMC claims and the majority of temperature CMC entries have been reviewed.

Working Group 9: thermophysical properties

The CCT, realizing the importance of thermophysical properties, has established a working group to study the requirements of thermophysical measurements. Most of the work in this area is focused on assessment of the field and identifying potential key comparisons. Service categories have been identified and integrated with the service categories of other temperature-related measurements.

Other issues

The CCT expressed its thanks to Mr M. Durieux, who has attended seventeen CCT meetings and acted as Rapporteur for fifteen of these (since 1971). The Committee acknowledged Mr Durieux's scientific contributions to metrology and to the IPTS-68 and the low-temperature scales in particular, as well as his exemplary efforts in recording the Minutes of all discussions."

Professor Bordé invited questions from delegates.

Dr de Castro (Portugal) reported that the work of CCT WG9 was progressing well under the chairmanship of Mr J. Redgrove, NPL. Key comparisons have been proposed in the areas of thermal conductivity and thermal diffusivity and, possibly in the future, in thermal capacitance.

Dr Schwitz returned discussion to the lack of progress in the field of thermometry in the CIPM MRA, and suggested that Dr Quinn should write to the directors of the NMIs and designated institutes, as well as the RMOs involved so as to encourage a more consensus-bound approach. Dr Quinn replied that he had certainly mentioned the matter during several meetings of the CCT, but said that he would be happy to write a letter as well.

Professor Göbel asked if there were any plans to revise the ITS-90. Dr Quinn said that discussions were on-going but this was not an urgent matter, because the ITS-90 works well.

Professor Kovalevsky asked if there were any thoughts about extending the scale down to microkelvin or nanokelvin? Dr Quinn explained that the ITS-90 currently goes down to 0.6 K, below which there is an extension going down to about 1 mK. At lower temperatures there is no need for an international practical temperature scale, because thermodynamic temperatures can be measured directly with the precision required. The same applies to very high temperatures.

15.6 Consultative Committee for Photometry and Radiometry

Dr Hengstberger, President of the Consultative Committee for Photometry and Radiometry (CCPR), presented the following report.

"It is my pleasure to present the report of the CCPR.

The CCPR currently meets at two-yearly intervals. Since the 21st General Conference the CCPR has held two meetings, both of them at the BIPM. The first, under the chairmanship of Professor A.J. Wallard, took place from 24-26 April 2001 and the second, under the chairmanship of Dr F. Hengstberger, from 17-19 June 2003. In the period immediately following the signing of the CIPM MRA between NMIs in 1999, the CCPR focused its work on the selection and initiation of the key comparisons required in the field. Since then the focus has shifted to the processing and evaluation of comparison data; the selection of methods for calculating key comparison reference values; and the compilation and implementation of detailed procedures for preparing drafts and final reports of comparisons. In order to streamline the interregional review process for CMCs submitted by NMIs for inclusion in Appendix C of the KCDB and to facilitate interregional agreement on CMC service categories, the CCPR followed a recommendation by the JCRB and formed a working group (WG-CMC) on this subject. At its 2003 meeting, the CCPR reaffirmed its 1977 decision in this respect (Recommandation 1) and agreed to make a recommendation to the CIPM to include an Appendix on the treatment of photobiological quantities in the new edition of the SI brochure. A task group under Mr J. Bastie (BNM, France) will draft the required text by the end of 2003.

International work in the field of photometry and radiometry will inevitably be significantly affected by the planned closure of the photometry and radiometry laboratories at the BIPM, particularly as the BIPM has been pilot laboratory for many of the key comparisons. The BIPM laboratory also maintained representations of the world mean candela and lumen in the form of groups of standard lamps, although other NMIs can maintain scales which can be compared on a regular basis and so maintain a world mean candela. The closure will also affect members of the Metre Convention, particularly the lesser-developed countries, in that they can no longer use that laboratory to obtain traceability from an independent source for their laboratory standards. The BIPM will in future still provide the secretariat for the CCPR, as it does for all other Consultative Committees.

Joint Working Group with the CCT (WG-CCT)

The terms of reference of the working group are:

- to develop and improve optical methods for temperature measurement in the framework of the International Temperature Scale;
- to maintain good links with the radiometry community; and
- to maintain liaison between the CCT and the CCPR.

The work of the group is currently focused on:

- examining the base-line parameters underlying the radiation thermometry scale realization; and
- monitoring the progress and function of eutectic mixtures of metals and carbon used for a new generation of high-temperature black-body radiators.

This work has now been incorporated into CCT Working Group 5: radiation thermometry, where Dr N.P. Fox (NPL, United Kingdom) represents the CCPR as an observer. Although the activities of the group are largely carried out by e-mail correspondence; it has met, since its establishment in 2000, in Berlin (2001), Chicago (2002) and Paris (2003). The CCPR observer reports back to the CCPR on these activities at each CCPR meeting.

CCT Working Group 5 has already completed a document entitled *Uncertainty Budgets for Realization of Scales by Radiation Thermometry* and is coordinating activities at various NMIs on metal-carbon eutectics. Black-body radiators using metal-carbon eutectics are also important new standards for realizing spectral radiance and spectral irradiance scales in radiometry.

As this is no longer a separate CCPR working group, this work will be reported in future reports to the CGPM under the heading “Liaison with CCT on work in radiation thermometry”.

Working Group on Calibration and Measurement Capabilities (WG-CMC)

Although the CCPR has long maintained an informal working group to deal with CMC analysis, this has, as recommended by the JCRB, been formalized and will have the following terms of reference:

- to establish and maintain lists of CMC service categories, and where necessary draw up rules for the preparation of CMC entries;
- to agree on detailed technical review criteria for CMCs;
- to coordinate and, where possible, conduct interregional reviews of CMCs submitted by regional metrology organizations for posting in Appendix C of the KCDB; and

- to coordinate the review of existing CMCs in the context of new results of key and supplementary comparisons.

In line with the JCRB recommendation, the WG-CMC members are representatives of the Technical Committees of the RMOs in the field of photometry and radiometry. The President of the CCPR is currently contacting the proposed members of the new working group to resume the urgent work on CMC service categories and to review pending interregional CMC submissions. He intends to hold a meeting of the working group in 2004 under his own chairmanship and to propose rotating the chairmanship alphabetically among RMOs at subsequent meetings. Important work on CMC service categories and the interregional reviews will continue in the meantime via e-mail.

Working Group on Key Comparisons (WG-KC)

At the request of the members, the President of the CCPR chairs the WG-KC, the current areas of which are:

- to establish and maintain a list of key and other comparisons in the field of photometry and radiometry, which will adequately support CMC claims by NMIs in this field of measurement in the spirit of the CIPM MRA between NMIs;
- to coordinate and schedule key comparisons, to review progress in comparisons and to recommend the inclusion of the results of key comparisons in Appendix B of the KCDB;
- to provide supplementary guidelines and/or interpretations of the guidelines on conducting key comparisons included in the MRA, specifically for the field of photometry and radiometry;
- to recommend general principles for the calculation of key comparison reference values in photometry and radiometry;
- to provide guidance on the range of CMCs supported by particular key comparisons;
- to identify areas where additional key comparisons are needed; and
- to monitor RMO key comparison activity.

At this stage, the working group has defined six key comparisons in photometry and radiometry and the first round of all of these comparisons has either been completed or is in progress. The WG-KC has one or more task groups for each ongoing key comparison, depending on whether the comparison is carried out as a single exercise or as a number of separate sub-comparisons. In the case of key comparisons of the same parameter carried out in different wavelength regions, different WG-KC task groups and pilot laboratories manage the individual sub-comparisons. A letter after the key comparison number identifies the sub-comparison and task group. The task group members are representatives of the pilot laboratory and of selected participating laboratories, and each task group reports progress and problems at WG-KC meetings. WG-KC task groups are disbanded after the production of the final comparison report.

The WG-KC agreed on some general recommendations to task groups regarding the calculation of key comparison reference values, and an additional task group on drawing up CCPR guidelines for comparison report preparation under Dr Y. Ohno (NIST, United States) was approved at the 2003 meeting.

CCPR key comparison of spectral irradiance (CCPR-K1)

This comparison is carried out separately over two overlapping wavelength regions. The first (CCPR-K1.a) covers the region from 250 nm to 2500 nm and is piloted by the NPL (United Kingdom). It has twelve participants and is being carried out in three phases with four laboratories per phase. Completion of all the measurements by the participating laboratories is expected in 2003. Data analysis and compilation of draft A of the comparison report is projected for December 2003 and the final draft B for May 2004. Altogether, the duration of the comparison will be about three to four years. In an informative analysis of its costs incurred as a pilot laboratory, the NPL estimates an expenditure of 300 person days for measurements and equipment maintenance, in addition to investments in equipment, automation and facility upgrades.

The second sub-comparison (CCPR-K1.b) takes place in the ultraviolet region (200 nm to 400 nm). So far, the pilot laboratory (PTB, Germany) has carried out the selection, ageing and testing of the deuterium lamps used as transfer. The first participants will receive their lamps during fall 2003 to start their measurements.

CCPR key comparison of spectral responsivity (CCPR-K2)

For this comparison, the wavelength range covered is divided into the three overlapping regions 900 nm to 1600 nm (CCPR-K2.a), 300 nm to 1000 nm (CCPR-K2.b), and 200 nm to 400 nm (CCPR-K2.c); the three sub-comparisons are piloted by the NIST, BIPM and PTB, respectively.

Comparison CCPR-K2.a is currently at draft A stage and draft B should become available soon.

Comparison CCPR-K2.b is at draft B stage and agreement has been reached among the participants at a task group meeting in 2003 on all outstanding issues concerning the final report.

The special transfer standards to be used in comparison CCPR-K2.c have all been received and tested by the pilot laboratory (PTB). They should be circulated to the first group of participants in September 2003 to start their measurements.

CCPR key comparison of luminous intensity/luminous responsivity (CCPR-K3)

The two sub-comparisons, CCPR-K3.a using luminous intensity standard lamps, and CCPR-K3.b, using photometric detectors have been finalized. CCPR-K3.a, piloted by the PTB, was already completed in 1999 and the results are included in Appendix B of the KCDB. CCPR-K3.b, piloted by the BIPM, has also been completed and will publish its final report shortly.

CCPR key comparison of luminous flux (CCPR-K4)

This key comparison was completed in 1999 with the PTB as pilot laboratory and the results have been accepted in Appendix B of the KCDB.

CCPR key comparison of spectral diffuse reflectance (CCPR-K5)

One of the three rounds of this comparison has been completed so far, and the second round is now in progress with the NIST as pilot laboratory.

CCPR key comparison of spectral regular transmittance (CCPR-K6)

The pilot laboratory (BNM) has received all the results from participants and is currently analysing the data and compiling draft A of the comparison report.

Apart from coordinating the key comparisons, the WG-KC also monitors progress with three supplementary comparisons. The first (CCPR-S1) deals with spectral radiance measurements and is piloted by the Institute for Optophysical Measurements of the Gosstandart of Russia (VNIIOFI). The measurements are almost complete and the pilot laboratory is about to start data analysis and prepare the draft A report. Supplementary comparison CCPR-S2 deals with measurements of the aperture areas of absolute radiometers and is piloted by the NIST. Most measurements by participants are completed and the pilot laboratory will soon start on the analysis of the data and the preparation of the report. Comparison CCPR-S3 for cryogenic radiometers has been completed and the final report has been approved and published.

Working Group on UV Radiometry (WG-UV)

The chairmanship of the WG-UV has changed from Dr B. Wende (PTB) to Dr E. Ikonen (Helsinki University of Technology, HUT, Finland). The terms of reference of the WG-UV are:

- to study measurement problems in the UV range and encourage coordination of the work of NMIs in that field; and
- to take initiatives aimed at improving worldwide equivalence in the field of UV radiometry, taking into account not only traditional techniques but also techniques such as synchrotron radiation, cryogenic radiometry and novel techniques for improving the stability of transfer standards.

Agreed priority actions include:

- coordinated research on UV and VUV transfer standard detectors;
- comparison of spectral responsivity in the VUV range from 10 nm to 250 nm; and
- coordinated research into suitable diffuse reflectance transfer standards for the UV range.

It was decided at the CCPR meeting in 2003 that the comparison of spectral responsivity in the VUV range (the second item above) will be dealt with as one of the sub-comparisons of key comparison CCPR-K2 and that the sub-comparison will be piloted by the PTB.

Working group meetings have been held during the reporting period in Madrid (October 1999), Paris (April 2001), Washington (May 2002) and Paris (June 2003).

Concluding remarks

With the first round of CCPR key comparisons either completed or well advanced, several complex problems concerning the acceptance of results and the calculation of key comparison reference values resolved, and the first two rounds of interregional review of CMC submissions completed, the focus of CCPR work will shift somewhat to maintenance issues and also back to the scientific aspects of the field. Maintenance issues include: the completion of all first-round key comparisons, further completion of the list of service categories, initiation of further rounds of interregional CMC reviews, advice on the range of parameters supported by specific key comparisons, and decisions on the repetition intervals between the various key comparisons. On

the scientific side, issues of optical power and energy measurements as well as metrology issues for fibre-optic communications have not been tackled for a number of years due to the priorities imposed by the implementation of the MRA. These will need urgent attention in the future. Another area of future attention will be cooperation with other international organizations active in photometry and radiometry, for example the International Commission on Illumination (CIE), the World Meteorological Organization (WMO) and others. The recent signing of a Memorandum of Understanding between the CIPM and the WMO is already facilitating CCPR cooperation with the relevant WMO committees.

I would finally also like to pay tribute to the dedicated staff in the BIPM Photometry and Radiometry section, led by Dr Michael Stock since Dr Rainer Köhler moved to other duties at the BIPM. Dr Stock, and before him Dr Köhler, and their team have enjoyed the respect of their colleagues at NMIs around the world through their scientific excellence. Although they will be redeployed in other suitable positions at the BIPM after the proposed closure of the laboratory, the international metrology community in this field will sorely miss their scientific and technical contributions."

Professor Bordé thanked Dr Hengstberger for his presentation and invited comments.

Dr de Leer commented that the challenge was to increase cooperation between metrologists working in the fields of photometry and radiometry, and chemistry.

Dr Lusztyk echoed the importance of metrology in the biosciences mentioning, in particular, techniques such as spectroscopy, spectrophotometry and colorimetry. He pointed out that quantitative measurements made with DNA chips are almost entirely based on colorimetry, and the quality of these measurements depends to a great extent on metrologists providing appropriate quantitative support.

Dr Hengstberger confirmed that the CCPR understood the shift of focus towards chemistry and accepted the BIPM policy in this area. He expressed his confidence that the challenges in the field of photometry and metrology would be met by the capable network of NMIs.

Professor Kovalevsky suggested that the CCPR could perhaps collaborate on some common problems with the IAU. One of the major tools of astronomers is photometry and spectrophotometry. For very good reasons, astronomers use their own system of units; although the unit W/s is appropriate for the Sun for example, other units are generally used for the stars. He wondered if it might be appropriate to contact the president of the photometry commission to see if some common problems could be considered.

Dr Hengstberger noted that the CIE has very close links with the IAU, particularly in regard to reducing light pollution.

Professor Bordé then asked about a subject already raised at the previous CGPM: How does the CCPR quantize the coherence of sources?

Dr Hengstberger replied that some of the corrections applied, for example, for diffraction at apertures, are influenced by the theory of coherence, which is still developing. We are nearing the point where we can use the theoretical results for numerical corrections in radiometry. Characterization of the coherence of sources is an area of study, but coherence is not measured in the key comparisons.

Professor Göbel asked if it was necessary to cover the entire range of wavelengths in key comparisons of some quantities?

Dr Hengstberger explained that the field comprises about fifty different quantities, of which the CCPR has selected a handful for checking by key comparisons. However, each of the selected quantities, such as spectral irradiance or spectral responsivity, is "key" over the whole wavelength range covered by radiometry. So although the CCPR does not check all the fifty quantities, each of the selected quantities is checked over the whole wavelength range.

Professor Bordé thanked Dr Hengstberger again.

15.7 Consultative Committee for Ionizing Radiation

Professor Moscati, President of the Consultative Committee for Ionizing Radiation (CCRI), presented the following report.

"I am pleased to present the report of the CCRI.

The wide variety of applications of ionizing radiation in medicine, science and technology calls for measurements covering a wide range of radiation types, energies and doses. At one end of the scale, measurements in the medical and industrial fields usually involve high levels of activity (from TBq to PBq), together with high dose levels (from Gy to MGy). At the other end, measurements to support health legislation and activity in the environment need to cover low doses (μGy to mGy) and low levels of activity (from Bq to kBq). Many requirements in the medical area lie between these extremes. At all levels, there is increasing government interest in ionizing radiation measurements and the need internationally for all radiation measurements to be fully linked to the SI. The pressure to reduce uncertainties in measurement arising from regulators and users provides a strong incentive for NMIs to keep ahead of requirements in the field.

The CCRI fulfils a key role in bringing together representatives of the world's ionizing radiation metrology institutes, national and international, and providing a forum in which they can reach consensus on measurement issues. The work initiated by the CCRI, both at the BIPM and at the NMIs, provides a secure and permanent link between ionizing radiation measurements and the SI.

Since the 21st General Conference in 1999, the CCRI and each of its three Sections, Section I (X- and γ-rays, electrons), Section II (Radionuclide measurements) and Section III (Neutron measurements) have met twice, from 21 to 29 May 2001 and 22 to 30 May 2003. The meetings took place in the new Pavillon du Mail at the BIPM where the facilities added to the efficiency and effectiveness of discussions and were much appreciated. As an innovation for the CCRI, during its 17th meeting in 2001, Section II held a seminar on liquid scintillation counting; and following this, at the CCRI 18th meeting in 2003, Section I held a seminar on radiometry and dosimetry using synchrotron radiation. Each of these state-of-the-art seminars was well received and seminars may well become regular agenda items. Running the three Section meetings contiguously seems to work well although it is quite a heavy workload for the BIPM.

In the following report the highlights of the work of the CCRI, which are closely linked to the corresponding activity of the BIPM, are described in Section order. Further details may be found in CCRI publications.

X- and *γ*-rays, electrons

In dosimetry, the discussions in CCRI(I) have focused on the analysis of the results of the various key comparisons to be published in the KCDB. Correction factors relating to free-air standards and cavity ionization chambers used in key comparisons have been hotly debated for a number of years and several decisions and a Recommendation were made at the 2003 meeting to resolve these outstanding issues. The Key Comparison Working Group recommended the procedures to follow in order to ensure that the results of as many NMIs as possible are included in the KCDB by the end of 2003.

The CIPM international key comparisons in dosimetry are of two types, the BIPM ongoing comparisons and the CCRI(I) comparisons. Since 1999, over thirty comparisons of primary standards involving sixteen countries have been carried out, allowing NMIs to meet the recommendation that they should compare their standards, at least, every ten years to comply with the CIPM MRA. These results are grouped into seven key comparisons in the KCDB and cover twenty-one primary standards laboratories. For national laboratories in twenty-one Member States that maintain secondary standards, periodic calibration at the BIPM allows them to take part with confidence in RMO key comparisons. For countries outside the Metre Convention that use ionizing radiation, particularly in the medical radiotherapy area, the IAEA, in cooperation with the WHO, coordinates a network of secondary standards dosimetry laboratories. The IAEA dosimetry references are traceable to BIPM standards with periodic calibrations of its reference instruments being carried out in the BIPM radiation beams. The IAEA is an Observer on the CCRI(I) and presents a report at each meeting of its dosimetry work. Reports from the other international observers resulted in a discussion on a report committee being set up by the International Commission on Radiation Units and Measurements to resolve the issues of values and uncertainties for the physical constants used in the dosimetry measurement equations.

Radionuclide measurements

The CIPM comparisons of activity measurements include both CCRI(II) absolute measurements and BIPM ongoing relative measurements. In CCRI(II) comparisons, aliquots of the same radioactive solution are distributed at a given date among the participants. BIPM relative measurements use the SIR to which samples of any suitable *γ*-emitting radionuclide are submitted at any time by NMIs for comparison against the SIR reference sources.

The discussions during the two CCRI(II) meetings centred on two main areas: the establishment of key comparison reference values, and the extension of the SIR for the comparison of pure-beta emitters. A Key Comparison Working Group was formed to re-examine the SIR comparison results and, in particular, to produce a mechanism for identifying and dealing with outliers. This procedure was agreed in summer 2002 and production of the final reports for publication in the KCDB began that autumn. Over half of the fifty-nine ongoing key comparisons for activity have now been published. The SIR continues to serve as a verification system for laboratories that use secondary or derived methods for radionuclide standardization. Following trials at the BIPM, an operational system for the extension of the SIR, using both the CIEMAT-NIST and triple-to-double coincidence ratio methods, will facilitate the future ongoing comparison of beta emitters.

During the last four years, the CCRI(II) undertook an unprecedented number of comparisons, organized by the BIPM. These included activity measurements of ^{241}Am, ^{152}Eu, ^{192}Ir, ^{32}P, ^{238}Pu,

^{89}Sr, ^{204}Tl and ^{65}Zn, with an average of twenty participants for each comparison. Working groups ensured that the standardization methods and the chemical content of the solutions had been properly addressed, particularly prior to the ^{192}Ir and ^{204}Tl comparisons. The results of all completed comparisons look satisfactory although a further comparison of ^{32}P is planned to resolve some differences. There are now twenty-two CCRI(II) comparisons in the KCDB with degrees of equivalence already published for more than five of these. However, the transportation of these small quantities of radioactive material is not a trivial problem, especially for ^{238}Pu and ^{241}Am. Consequently, a recommendation was made by the CCRI to the CIPM and this, at least in part, has resulted in Draft Resolution I for this CGPM.

A stable and reproducible standard ionization chamber, realizable by any NMI, is under joint development at the NPL (United Kingdom) and the IRMM as a project of Section II. The incorporation of such a chamber into the SIR would initially provide a back-up instrument and, once proved, could eventually replace the SIR ionization chambers. Having identical chambers at each NMI should ultimately facilitate comparisons of gamma emitters, particularly of short-lived radionuclides, and make it possible to conduct many more comparisons.

Neutron measurements

The main activities of Section III have been the organization and analysis of key comparisons and the exchange of information on research and development at NMIs. A more rapid pace of key comparisons in support of the CIPM MRA began in 1999 and has continued ever since.

The publication of the completed comparison of 24.5 keV neutron fluence measurements was discussed in detail along with the entry of these results, the reference value, and equivalence statements into Appendix B of the KCDB. The issues surrounding the uncertainties in this comparison were finally resolved at the 2003 meeting, so the publication can proceed. Three comparisons in progress were discussed. The final draft report on the fast neutron fluence-rate comparison for four mono-energetic neutron sources in the keV and MeV energy ranges CCRI(III)-K10, piloted by the PTB (Germany), is expected within the next few months. All measurements for the neutron source emission-rate comparison CCRI(III)-K9.AmBe, piloted by the NPL (United Kingdom), are scheduled for completion by the end of 2003. Agreement was reached for the thermal neutron fluence-rate comparison CCRI(III)-K8, piloted by the NIST (United States), to proceed under a revised protocol. This was following the successful example of the CCRI(III)-K10 comparison at a single laboratory, rather than by the slower procedure involving the circulation of a transfer instrument to many laboratories around the world.

Section III received a report on the status of the RMO comparison of neutron survey meter calibrations (EUROMET Project No. 608), piloted by the Institut de Radioprotection et de Sûreté Nucléaire of the BNM (France), and this is now designated EUROMET.RI(III)-S1. Plans were made for two participants to conduct a bilateral comparison of neutron fluence-rate measurements at 19 MeV as a EUROMET supplementary comparison.

An important part of the work of Section III is the exchange of information on the status of neutron metrology at the participants' laboratories, outlining resources, facilities, instruments, current applications and future needs. To facilitate this exchange, it was agreed that the slides of presentations made at the last meeting would be made available on the CCRI(III) website."

Dr Shehata (Egypt) asked Prof. Moscati to comment on the nature of the agreement reached in the levels of uncertainties in the CCRI key comparisons. Professor Moscati explained that the

laboratories participating in a CCRI key comparison submit their results together with an estimated uncertainty budget. In cases where some of these uncertainties appear to be unrealistically low, the CCRI Working Group on Key Comparisons has decided to fix a minimum uncertainty for each comparison, reflecting the lowest uncertainties achievable with state-of-the-art techniques in the best laboratories. Unless lower uncertainty claims are backed up by appropriate scientific evidence, the CCRI Working Group on Key Comparisons automatically increases lower claims to this minimum value.

Dr Vaucher (Switzerland) returned to Prof. Moscati's comments about future challenges and asked what the CCRI's view was on proton dosimetry. Professor Moscati replied that the Consultative Committees tried to remain aware of current trends and needs of the NMIs and users, and the CCRI would of course deal with proton dosimetry if there was a demand for it. He added that some high-energy physics laboratories are proposing trials with hadrons, which deliver a high dose locally.

Professor Bordé then invited Prof. Moscati to read Draft Resolution I and invited questions.

Dr Kaarls added that this Draft Resolution was also presented on behalf of the Consultative Committee for Amount of Substance (CCQM). He noted that the CCQM had encountered significant problems with transporting samples for international comparisons; gas cylinders were sometimes delivered empty after having had their contents examined by customs officials!

Dr Šafarik (Czech Republic) noted that many bodies deal with customs and transport procedures, which are harmonized to some extent on the regional and international levels; he mentioned: the UN Economic Commission for Europe dealing with the facilitation and harmonization of trade procedures in general; the World Customs Organization, dealing with harmonization of customs procedures; and other specialized international organizations such as the International Air Transport Association, dealing with transport procedures. He commented that it was difficult for national bodies to interact with these bodies, so proposed the addition of a phrase inviting the BIPM to deal with these international organizations.

Dr Inglis pointed out that the word "unimpaired" should be replaced by "unimpeded".

There were no further questions.

There revised version Draft Resolution I2 was subsequently voted unanimously as Resolution 9 (see page 380).

15.8 Consultative Committee for Amount of Substance

Dr Kaarls, President of the Consultative Committee for Amount of Substance: Metrology in Chemistry (CCQM), presented the following report.

"I am pleased to present the report of the CCQM.

Ten years have passed since the establishment of the CCQM by the CIPM in 1993, based on the hypothesis that the traceability of measurement results in chemistry was feasible, despite the fact that only in a very limited number of cases had this been demonstrated. Many chemists at that time were, to say the least, rather sceptical about the possibility of improving the existing situation, although it became increasingly clear that in support of trade, industry and society the need existed for comparable measurements traceable to common long-term stable references. In fact almost all chemists claimed implicitly that their measurement results were traceable to the

SI as they expressed their results in SI units. However, these results were often presented without an uncertainty statement, so that the rigour of the measurements could not be assessed.

Now, after ten years of the CCQM, we can state that global comparability and traceability of measurements in chemistry can be realized with uncertainties that, in general, are sufficient for their intended purpose. Although an enormous amount of work still has to be done, we now see that in almost all fields of chemical analysis the issues of traceability and measurement uncertainty are being addressed.

As the amount of work is very substantial and resources are limited we, the NMIs, have to set priorities, dictated by the needs of trade, industry and society, and have to cooperate with other suitable and competent institutes. Therefore, the CCQM is liaising with many other organizations, a number of which are now members or observers of the CCQM.

Since the 21st General Conference, the CCQM has met every year (6-7 April 2000, 4-6 April 2001, 18-19 April 2002 and 10-11 April 2003). The number of members and observers has increased over the last four years, demonstrating the still growing interest of the (designated) NMIs and other intergovernmental and international organizations. This of course reflects the rapidly expanding needs of trade, industry and society for reliable, comparable and traceable measurements in all fields of chemistry.

Despite the importance and number of measurements in chemistry, including the huge demand for clinical measurements carried out every day in the health sector, metrology in chemistry has still not developed at the same pace as "classical" physical metrology at most of the NMIs (with the exception of some ten NMIs). Efforts to improve metrology in chemistry are nevertheless increasing. This process has been aided by the nomination of key institutes within a country, such as the national health institute or environmental or food testing institute, to the status of designated NMI for certain quantities and ranges.

The wide interest in metrology in chemistry is clearly demonstrated by the full participation of many NMIs and other designated institutes in the activities of the seven CCQM working groups, each of them already being comparable in size to other Consultative Committees. The broad scope of CCQM activities is also demonstrated by its membership which includes several other intergovernmental and international organizations, such as the World Meteorological Organization, World Health Organization, International Atomic Energy Agency, International Federation of Clinical Chemistry and Laboratory Medicine, International Union of Pure and Applied Chemistry, ISO Committee on Reference Materials (ISO REMCO), International Laboratory Accreditation Conference, and Cooperation on International Traceability in Analytical Chemistry (CITAC). The Institute for Reference Materials and Measurements of the European Commission is also an active member. Overall, the CCQM meetings are attended by some sixty representatives from about twenty-five different countries, while some 120 experts participate in the meetings of the CCQM working groups, which are held prior to the plenary CCQM meeting.

CCQM working groups

The major activity of the CCQM has been the organization of studies and key comparisons, undertaken by the seven CCQM working groups:

- Working Group on Organic Analysis, chaired by the NIST (United States);

- Working Group on Inorganic Analysis, chaired by the Laboratory of the Government Chemist (LGC, United Kingdom);
- Working Group on Gas Analysis, chaired by the NMi VSL (The Netherlands);
- Working Group on Electrochemical Analysis, chaired by the Slovak Institute of Metrology (SMU, Slovakia);
- Working Group on Bioanalysis, chaired by the LGC/vice-chair the NIST;
- Working Group on Surface Analysis, chaired by the NPL (United Kingdom);
- Working Group on Key Comparisons and CMC Quality, chaired by the NRC (Canada).

The areas covered by the CCQM include health, food, environment, advanced materials, commodities, forensics, pharmaceuticals, biotechnology, surface analysis and general analytical applications. The lists of studies, key comparisons and results are published on the BIPM website: http://www.bipm.org/en/committees/cc/ccqm/.

Since the beginning of these activities, some eighty studies and key comparisons have been carried out or are under way. The results of these comparisons underpin the claimed CMCs of the (designated) NMIs. Nevertheless there are still several groups of CMCs where direct evidence of their reliability based on the results of a study or a key comparison is not yet available. The Working Group on Key Comparisons and CMC Quality is investigating which areas should be considered in more detail by the initiation of a study or key comparison.

Almost all CCQM working groups meet twice a year, once at the BIPM prior to the plenary CCQM meeting in April and again during the second half of the year. In general, the second meeting is held at the premises of one of the member institutes of the working group. These meetings at the NMIs are often combined with a peer review visit of the chemical division of the institute and greatly contribute to the further improvement of the capabilities and competences of NMIs, as well as to the establishment of mutual confidence in measurement capabilities between NMIs.

As many NMIs in the field of metrology in chemistry are still in the development phase, the CCQM has a policy of assisting these NMIs by admitting them as observers to the working groups and allowing them to participate in studies. Note that the situation is different to most other fields of metrology, because the number of participants in studies and key comparisons is not limited by the number of samples available.

Working Group on Organic Analysis

The studies and key comparisons carried out by the CCQM Working Group on Organic Analysis include:

- cholesterol, glucose and creatinine in serum;
- organic contaminants in tissue;
- pp'-DDE in corn oil and fish oil;
- pp'-DDT in fish oil;
- gamma-HCH in fish oil;
- PCBs in sediment;
- ethanol in aqueous matrix;
- LSD in urine;
- drugs of abuse in urine;

- purity of compounds (glucose, DDE, xylene, TBT); and
- NMR studies.

Almost all the results after a first study are very satisfactory with measurement uncertainties generally of the order of 1 % to 3 %, or better.

During its last meeting, the CCQM approved the initiation of the following studies and key comparisons:

- ethanol in aqueous matrix on forensic levels;
- volatile organic compounds in organic solvents;
- purity of atrazine and chlorpyrifos compounds; and
- organic solutions of PAHs, PCBs and pesticides.

It is expected that this working group will continue comparisons that fulfil the needs of clinical chemistry, while more work is to be expected on purity analysis.

Working Group on Inorganic Analysis

The studies and key comparisons carried out by the CCQM Working Group on Inorganic Analysis include:

- calcium in serum;
- arsenic in shellfish;
- lead in wine;
- copper, cadmium, zinc, etc. in wine;
- cadmium and zinc in rice;
- metals in synthetic food digest;
- cadmium and lead in natural water;
- lead and cadmium in sediments;
- minor elements in steel;
- constituents in aluminium alloy;
- di- and tributyltin in sediment;
- sulphur in fuels;
- elemental solutions (Al, Cu, Fe, Mg); and
- anions in calibration solutions.

Almost all the results after a first study are very satisfactory with an uncertainty of the order of 1 %.

During the last meeting of the CCQM further work was agreed as follows:

- minor elements in steel;
- potassium hydrogen phthalate assay; and
- sulphur in fuels.

Working Group on Gas Analysis

The studies and key comparisons carried out by the CCQM Working Group on Gas Analysis, or those that are currently under way, include:

- CO, CO_2, NO and SO_2 in nitrogen;
- natural gas;
- propane in nitrogen;
- benzene, toluene, xylene (BTX) in nitrogen and air;
- VOCs in air;
- dynamic mixing methods;
- reactive gases at ambient levels;
- greenhouse gases at ambient levels;
- ozone at ambient levels;
- ethanol in air; and
- purity analysis of gases, including H_2O.

Most of the results are very accurate, achieving uncertainties much better than 1 % and in several cases approaching 0.01 %.

During the last meeting of the CCQM further work was agreed as follows:

- different types of natural gases;
- reactive gases at ambient levels (NO in nitrogen and SO_2 in air); and
- SF_6 and CFCs in nitrogen.

Working Group on Electrochemical Analysis

The studies and key comparisons carried out by the CCQM Working Group on Electrochemical Analysis include:

- pH (phosphate and phthalate buffers);
- fundamental studies on pH standards;
- electrolytic conductivity;
- coulometry;
- HCl assay; and
- KHP assay.

The results have been quite good and have contributed to a better comparability in pH and conductivity measurements.

During the last meeting of the CCQM further work was agreed as follows:

- pH measurement of carbonate buffer solutions;
- KHP assay; and
- electrolytic conductivity.

Working Group on Bioanalysis

The CCQM Working Group on Bioanalysis was established at the 6th meeting of the CCQM in April 2000. The aim of this working group is to address metrological issues in biotechnology and molecular biology. The work can be distinguished between nucleic acid/gene, protein and cell measurements. Quantitative DNA and RNA analyses are becoming increasingly important in different fields of measurements, such as food testing (GMOs), clinical and therapeutic measurements, and forensics (DNA fingerprinting). Instrument manufacturers and users require traceability and calibration. In the meantime, the need for internationally comparable and traceable measurements in the field of clinical chemistry and laboratory medicine has become an urgent issue as the European Commission has issued a Directive demanding traceability of *in vitro* diagnostic measurements to standards of "higher order", to come into force on 1 January 2004.

The interest in the work of this CCQM working group is high and many (designated) NMIs are already members or observers. The working group is still in the phase of establishment and developing its final programme. To date, it has agreed on the following studies:

- DNA profiling;
- DNA primary quantification; and
- peptide/protein quantification in proteomics.

Several other proposed studies are in a phase of further preparatory investigation and discussion, including:

- PCR quantitation study;
- fluorescent dyes spectral correction studies;
- comparability study of the results obtained by DNA profiling techniques;
- circular dichroism study of protein solutions; and
- biomolecular (gene/protein/cell) measurements.

Working Group on Surface Analysis

The CCQM Working Group on Surface Analysis was also established during the 6th meeting of the CCQM in April 2000. A growing number of NMIs have been asked by industry to address metrological problems in surface analysis. In particular the developments in nanotechnology, the semiconductor industry and industries producing and working with thin-layer technologies are highly dependent on proper surface measurements. These industries also include, for example, polymers, coatings and paint, and measurements dealing with corrosion for aerospace, protein adhesion and toxicity for body implants.

A first study carried out by the working group, of SiO_2 on Si wafers, has been very successful in comparing and characterizing a large number of techniques and demonstrating that the level of comparability of measurements could be improved, with uncertainties reduced to below 1 nm. Work proposed for the near future includes:

- dopant distribution in Si;
- Fe-Ni and Co-Pt alloy thin-film composition;
- coatings;
- surface layers, contaminants;

- polymer surfaces; and
- thin-film multilayer systems.

The methods and technologies are of great interest to industry, and the continuation of this work within the CCQM is highly desirable.

Working Group on Key Comparisons and CMC Quality

So far, as I reported during the meeting of the 21st CGPM in October 1999, the CCQM Working Group on Key Comparisons has coordinated the proposals for studies and key comparisons by the other working groups, seeking a balanced approach, promoting the right priorities and trying to prevent overloading the NMIs with comparisons.

The CIPM MRA is still being implemented in the field of metrology in chemistry. As this field of activity is relatively new for many NMIs, it has become clear that the regional and interregional review of claimed Calibration and Measurement Capabilities required further discussions than in general were needed in the more "classical" field of metrology in physics. These discussions require input from experts of the CCQM, to review CMCs for which there are underpinning comparison results, as well as the more difficult cases where there are currently no international comparison results to underpin the claim. Therefore the CCQM decided at its April 2003 meeting to widen the scope of the working group into a CCQM Working Group on Key Comparisons and CMC Quality. It is composed of representatives/experts of the RMOs and of experts from all the CCQM working groups.

As the NMIs not only deliver services to their customers by offering calibration and measuring capabilities, but in many cases also produce and distribute Certified Reference Materials (CRMs), this working group will also look into the criteria to be fulfilled for accepting CRMs in Appendix C of the KCDB.

General issues

The CCQM has continued its discussions on issues of common and general importance.

Joint CCQM working group meetings

Joint meetings of the CCQM working groups are organized on occasions when their work programmes overlap. These have included joint meetings of the Working Group on Inorganic Analysis with the Working Group on Electrochemical Analysis; of the Working Group on Organic Analysis with the Working Group on Bioanalysis; and of the Working Group on Organic Analysis with the Working Group on Gas Analysis. They have proved very useful and will be continued in the future.

CCQM workshops

The work of the CCQM has greatly benefited from a number of workshops it has organized:

- In December 1999, a workshop was held on defining uncertainty budgets and the calculation of measurement uncertainty.

- In April 2002, a very successful workshop on traceability in chemical measurements was held, where the need for traceability by the different user communities was discussed and the mechanisms being used or planned by NMIs to achieve traceability were described.
- In November 2003, a workshop will be held to address the needs of regulators, accreditation bodies, industry and other sector-specific organizations for traceability in food analysis.

The very successful workshop on traceability in laboratory medicine, held in June 2002, organized by the BIPM, the IFCC, and the CCQM should also be mentioned.

Certified Reference Materials

CRMs are widely used for calibration and method validation. Most NMIs deliver different CRMs to their customers as a means of disseminating traceability.

Appendix C of the KCDB lists the CRMs delivered by the NMIs. These CRMs are only those indicative of the quantities/measurands and measurement ranges delivered by an NMI to its customers. The intention is not that the CIPM MRA should cover the whole catalogue of CRMs delivered by NMIs.

However, those CRMs mentioned should be based on the laboratory's own measurement capabilities and the competence of the NMI to characterize (with respect to stability, homogeneity, etc.) and assign a value to the CRM.

Competence in the value assignment of the CRMs can be demonstrated by compliance with appropriate ISO guides and standards, such as ISO *Guide 34* relating to the general requirements for the competence of reference material producers.

The CCQM Working Group on Key Comparisons and CMC Quality is studying a further refinement of the criteria to be fulfilled for CRMs to be mentioned in Appendix C.

Cooperation with the ISO REMCO has been established in order to address common issues.

The need for special CRMs, in particular, matrix materials, is almost infinite. It is clearly an impossible task for NMIs to produce and deliver all the CRMs needed. A further task for NMIs is to certify and deliver very pure materials, based on the application of direct assays or indirect (impurity) measurements. Such materials are the basis of calibration solutions, and as such at the top of the traceability chain. This is a considerable challenge.

CRMs delivered by the NMIs under the CIPM MRA are accompanied by a certificate with an uncertainty statement for a traceable measurement result for its value assignment. This is not always true of commercially produced CRMs. The lack of demonstrated traceability is a great difficulty for the chemical laboratory community when seeking accreditation according to International Standard ISO 17025, or ISO 15189 in the field of clinical laboratories.

Cooperation with other intergovernmental and international organizations

Accurate measurements traceable to the SI, being long-term, stable, fixed anchor points, are essential for several programmes in the environmental area. Likewise, the measurement programme of the WMO requires accuracies at the highest achievable levels. Therefore, with this in mind, the CIPM has signed a MoU with the WMO assuring close cooperation with the BIPM, CCPR and CCQM.

Measurements in clinical chemistry and laboratory medicine form a huge daily activity all around the world. Comparability and traceability are now high on the agenda of the clinical and *in vitro* diagnostics community. Conformance with regulations (e.g. the EC IVD Directive), accreditation requirements, better treatment of patients and cost savings require more accurate and precise measurements. Therefore the CIPM has also signed a MoU with the World Health Organization, while the long-standing cooperation with the IFCC has been intensified. As many of the measurements are chemical analyses, close cooperation has now been established with the CCQM and, in particular, with the CCQM Working Groups on Organic Analysis and on Bioanalysis, while some work also has to be done by the CCQM Working Group on Inorganic Analysis.

Cooperation with the IAEA and the IRMM is realized by the participation of these institutes in the different CCQM working groups.

With respect to standardization and guidance documentation, cooperation has now been established with CITAC, ISO REMCO, and IUPAC.

Joint Committee on Traceability in Laboratory Medicine

After a few preparatory meetings and driven by the introduction of the EC Directive on *in vitro* diagnostic measurements, requiring traceability to standards of higher order, the BIPM, IFCC and ILAC, supported by representatives of regulators, industry associations, quality assurance and proficiency testing providers and documentary standards organizations, decided in June 2002 to establish a Joint Committee on Traceability in Laboratory Medicine (JCTLM). The aim of the JCTLM was to support the worldwide comparability, reliability and equivalence of measurement results in laboratory medicine. Lists of validated higher-order reference materials and reference measurement procedures will also be published, and a list of reference measurement laboratories will be drawn up.

The WHO and laboratories that are custodians of WHO International Standards have been active in the meetings of the JCTLM and are cooperating in its activities.

The JCTLM, which is currently chaired by the IFCC with the secretariat provided by the BIPM, has two working groups:

- Working Group 1 on Reference Materials and Reference Procedures, co-chaired by the NIST and the IRMM, is currently reviewing reference materials and reference methods which have been nominated as being of higher order.
- Working Group 2 on Reference Measurement Laboratories, co-chaired by the German Association of Clinical Chemists, the University of Bonn (Germany) and the University of Ghent (Belgium), has developed criteria which laboratories must fulfil to demonstrate their competence as reference measurement laboratories.

Working Group 1 has eight sub-groups on:

- electrolytes (calcium, chloride, potassium, etc.);
- enzymes (AST, amylase, CK, GGT, etc.);
- metabolites and substrates (cholesterol, urea, etc.);
- proteins (albumin, troponin-1, PSA);
- nucleic acids (DNA, RNA);
- drugs (digoxin, lithium, etc.);

- hormones (cortisol, estriol, testosterone, etc.); and
- coagulation factors.

New sub-groups will be established to review the following groups of reference materials and methods:

- blood grouping and typing;
- blood gases;
- infectious diseases;
- non-electrolyte metals; and
- vitamins.

It has been proposed that a series of measurements will need to be undertaken to ensure the comparability of the reference materials that have been reviewed as of a "higher order". These comparisons will be carried out by laboratories that have demonstrated their competence in the field, such as NMIs that have successfully participated in key comparisons and have measurement capabilities that have been accepted under the CIPM MRA and published in Appendix C.

An International Recognition Arrangement is in preparation, under which the framework established by the JCTLM for the recognition of higher-order reference materials and measurement procedures could be used.

Codex Alimentarius Commission of the WHO and the FAO, World Anti-Doping Agency (WADA) and the pharmaceutical sector

In many other areas of chemical analysis a move towards accreditation is taking place, together with the need to demonstrate the traceability of measurement results. It is expected that cooperation with these organizations and sectors will be established in the near future, making use of the activities already existing under the CCQM and the JCTLM.

The CCQM workshop on traceability in food analysis, already mentioned, will be held in November 2003 at the BIPM.

Material properties

Good knowledge of material properties is indispensable in today's industry and society.

The CCQM has tabled the first proposals to investigate needs and to study the existing situation and start cooperative action in the area of materials. The proposals include the production, characterization and value assignment of CRMs, including chemical CRMs, optical filters, heat transfer coefficients, etc.

This discussion has been taken up by the CIPM as these material properties involve the expertise of several other Consultative Committees.

Viscosimetry

In September 1999, a first meeting was organized at the BIPM to investigate the problems, needs and possibilities for further activities in viscosity measurements. As it was not immediately clear

to which Consultative Committee this activity should be reported, the CIPM decided to create an *Ad Hoc* Working Group on Viscosity (AHWGV), chaired by the President of the CCQM.

At the second meeting in October 2001, it was decided to organize a comparison on kinematic viscosity up to 40 000 mm^2/s and at temperatures up to 100 ºC organized by the PTB (Germany) in close cooperation with Cannon Instrument Company in the United States.

Eleven NMIs with an independent scale of viscosity participated in this comparison, while seven other NMIs not having an independent scale also participated. The results of the comparison were presented at the 3rd meeting of the AHWGV in November 2002. In general, the comparison has been successful, with results within 0.1 % to 1 % uncertainty, depending on viscosity and temperature. The final report was published in 2003.

The comparison demonstrated good agreement with the results of the Cannon Instrument Company, which has organized the ASTM viscosity scale over a long period of time.

Taking into account the type of work involved and the organizational aspects, in that the majority of NMIs have activities in the field of viscosity, the CIPM is expected to decide at its 2003 meeting that in future the Working Group on Viscosity will report to the Consultative Committee for Mass and Related Quantities.

Designated institutes

In many countries, the NMIs do not currently have broad expertise with respect to metrology in chemistry. In order to serve trade, industry and society at short notice in an efficient and effective way, a number of them are making use of existing capabilities and expertise in metrology in chemistry available in several national institutes and universities by designating these institutes to act as an NMI for certain quantities and measurement ranges in chemistry, so that they can participate in the CIPM MRA.

In some countries, the metrological laboratory of a private, commercial company has been designated for certain quantities and measurement ranges. In such cases, the facilities should be accessible to every potential customer on an equal footing and a level economic playing field should be guaranteed.

For certain types of measurement in chemistry, the use of expensive facilities such as a reactor for instrumental neutron activation analysis is required. As most NMIs do not have such facilities in-house, it is strongly recommended that they make use of available reactors in their country.

BIPM programme of metrology in chemistry

At the 21st meeting of the CGPM in 1999, the CCQM was of the opinion that it would be essential for the BIPM to build up its own fundamental knowledge in the field of metrology in chemistry in order for it to become a competent partner in the international community of chemists and to assist clearly in the establishment of a worldwide system of traceability and comparability in the field of measurements in chemistry. Therefore the CCQM advised the CIPM to establish a chemical metrology activity at the BIPM. The CCQM notes that in the period since the 21st CGPM such a chemical activity has started. A work programme on ozone reference standards has been developed and the first series of international comparisons has been successful. The comparison programme is now being extended as a CCQM study with the BIPM

as the pilot laboratory, with twenty laboratories registered as participants. In 2003, after discussions during 2002 with the working groups concerned, the CCQM unanimously advised that the Chemistry section of the BIPM should add a small activity on purity analysis in the field of organic and clinical chemistry, as part of the global cooperation of NMIs.

The various activities in the BIPM programme of work give it the required status to speak for the international metrological community, bringing together the different intergovernmental and international organizations with interests in metrology, serving the wider community in establishing globally recognized comparability through traceability to the SI, or if not (yet) possible to other internationally agreed references. The extension of the programme to some activities in the organic/clinical field is seen as essential to consolidate the position of the BIPM in the field of metrology in chemistry.

Conclusions

Very good progress has been made over the ten years of the CCQM's existence, demonstrating that accurate metrology in chemistry is possible. Several issues still need to be addressed:

- education on metrology in chemistry, including the understanding of traceability and measurement uncertainty;
- understanding and research with respect to the definition of the measurand (discrepancies between results arise due to imprecise definition of the measurand);
- method-dependent measurements;
- matrix problems;
- commutability in clinical and therapeutic measurements; and
- the use of non-SI units in those cases where traceability to the SI is not (yet) achievable, for example units related to biological activity.

Professor Bordé thanked Dr Kaarls and invited questions.

In response to a question from Prof. Mills, Dr Kaarls cited biological activity as an example of a quantity with a bio-unit not traceable to the SI. To quantify biological activity the laboratories of the WHO produce CRMs with activity expressed in "WHO units". The CRM they produce has a WHO unit of 1. This holds for the batch, but when another batch is made it may have a different activity but again this is defined as having an activity of 1 WHO unit. In fact, ideally it should be possible to express such activity in mol mol^{-1} s^{-1} or similar, but Dr Quinn pointed out that the biological activity of these molecules cannot generally be specified in terms of the physical chemical measurements we can make, because we do not understand sufficiently well the interaction between these complex molecules and the human body. Until one can make a physical chemical measurement that has a 1:1 correspondence with its biological activity, arbitrary units are necessary. He cited the example of insulin.

In answer to a question from Prof. Göbel, Dr Kaarls confirmed that the JCTLM database of higher order reference materials is distinct from Appendix C of the KCDB.

Dr Shehata (Egypt) asked Dr Kaarls to explain the principle of traceability achieved through CRMs to the definition of the mole. Dr Kaarls explained that CRMs are samples whose properties and composition are very well known from calibrations made using primary methods used to calibrate instruments. Dr Quinn added that this question was one of the first addressed by

the CCQM after its creation, and the reason why the CCQM spent a considerable amount of time talking about primary methods in chemical analysis. A primary method is a method that allows the results of an analysis to be obtained directly in moles on the basis of measurements made using other base units of the SI. The primary method is the way you get from the definition of the mole to the amount of substance in a particular sample without any prior knowledge of its chemical content in moles. Almost all base units of the SI are realized through primary methods – they are used in time, temperature, length, electric current, luminous intensity, as well as amount of substance. The only unit that is not realized in this way is the kilogram because the realization of the unit exists already in the form of the International Prototype of the kilogram.

Professor Bordé asked if laser spectroscopy was used to measure the quantity of foreign gases in air, such as ozone and SF_6. Dr Kaarls replied that laser spectroscopy is indeed one of the many technologies used to make such measurements. Professor Bordé suggested that it might be appropriate to develop such laser systems at the BIPM in the future. He thanked Dr Kaarls and invited Dr Valdés to present the work of the CCAUV.

15.9 Consultative Committee for Acoustics, Ultrasound and Vibration

Dr Valdés, President of the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV), presented the following report.

"It is my pleasure to deliver the report of the CCAUV.

The CCAUV was established in 1998 at the 87th meeting of the CIPM, as the result of recommendations from a working group chaired by Prof. A.J. Wallard, who presided over the activities of the new Consultative Committee during the first two years. At its 89th meeting, the CIPM agreed to designate Dr J. Valdés, member of the CIPM, as President of the CCAUV. The first meeting of the CCAUV took place at the BIPM in July 1999, followed by second and third meetings in October 2001 and October 2002, respectively, with Dr P.J. Allisy-Roberts (BIPM) as Executive Secretary. Twenty-eight delegates, five observers and one guest were present at the last meeting, besides the BIPM members and the President. After that meeting, Dr Giuseppe Basile retired with effect from April 2003 as the representative of the IMGC (Italy) on the CCAUV.

During the 21st CGPM (October 1999) it was reported that a special issue of *Metrologia* devoted to acoustics, ultrasound and vibration would be welcomed. Such a publication appeared in December 1999 [Vol. **36**(4)], containing a series of interesting articles in the areas of airborne as well as underwater acoustics. This special issue of *Metrologia*, together with the extensive list of publications now included in the CCAUV section of the BIPM website, is a valuable reference source for researchers in this field of metrology.

Since its creation, the CCAUV has initiated an active programme of key comparisons. Of the CIPM key comparisons, two have already been completed and published, another should be published in the near future, one draft A report is under consideration, two more are in progress, and two further comparisons are planned to start in 2003-2004. There are also several RMO key comparisons: six in acoustics (one approved, two reports in progress, one with measurements in progress and two planned); two in ultrasound (both planned); and four in vibration (two approved, one of which should have linked results published soon, one for which the report is in progress and another which is just starting). A supplementary comparison of the SIM circulating two pistonphones is also complete.

The detailed status of the CIPM key comparisons, available in the KCDB, may be summarized as follows:

- CCAUV.A-K1: Comparison of sound pressure in air from 63 Hz to 8 kHz.
  The comparison report is nearing completion and should be published before the end of 2003 with results for twelve participants.
- CCAUV.A-K2: Comparison of sound pressure in air at low frequencies from 2 Hz to 125 Hz.
  This comparison is planned for after 2004 with at least eight participants.
- CCAUV.A-K3: Comparison of sound pressure in air from 31.5 Hz to 31.5 kHz.
  Measurements started in January 2003 with twelve participants.
- CCAUV.A-K4: Comparison of free-field sound pressure in air from 2 kHz to 40 kHz.
  This comparison has been postponed until 2004.
- CCAUV.U-K1: Comparison of ultrasonic power at three frequencies and five power levels.
  This comparison ran from 1999 to 2002 and was published in November 2002 with the results available in the KCDB for nine participants.
- CCAUV.U-K2: Comparison of ultrasonic pressure at 1 MHz to 15 MHz.
  This comparison is in progress with five participants and the measurements should be complete by July 2003. The report may be ready before the end of 2003.
- CCAUV.V-K1: Comparison of charge sensitivity from 40 Hz to 5 kHz.
  This comparison ran from 2000 to 2001 and was published in December 2002. The results are available in the KCDB for twelve participants.
- CCAUV.W-K1: Comparison of sound pressure in water from 1 kHz to 500 kHz.
  This comparison ran from 2000 to 2002 and the draft A report is currently being considered by the seven participants.

Interesting discussions took place during the CCAUV meetings concerning the determination of KCRVs, estimation of uncertainties, stability of the objects being circulated, and reference standards involved such as standard microphones. In some cases, as for example when processing the CCAUV.V-K1 data, the pilot laboratory performed an extensive investigation into the determination of the KCRV, including five methods in total: fit, mean, median, likelihood and weighted mean. The decision was taken to use the weighted mean.

Other matters concerning the scope of the CCAUV also arose during discussions around key comparisons, as for example the need for even lower frequency acoustical measurements, for applications beyond human hearing such as acoustical microscopy.

It is desirable to ensure the maximum possible participation of NMIs in key comparisons and in the work of the CCAUV. In situations where NMIs do not have specific expertise, but this is available in a national centre of expertise, Member States could associate such national centres with the NMIs, and designate them under the Mutual Recognition Arrangement. This would allow them to participate in meetings and in the technical work of the CCAUV. In turn, the activities and facilities of these centres could be used to provide services for industrial, scientific, medical and other organizations that require or would benefit from calibrations that are traceable to the SI.

The classification of services in the field of Acoustics, Ultrasound and Vibration (AUV) metrology was also discussed in connection with the CMC submissions of NMIs for the JCRB.

During the second meeting of the CCAUV, new challenges for AUV metrology were presented, including quite new ideas and developments in the domain of nanotechnology. An *ad hoc* working group created for that purpose produced a document, which was considered during the

3rd meeting of the Committee. This contributed to the report that the CIPM was preparing for the 22nd CGPM, addressing more technical considerations than those in *National and International Needs Relating to Metrology*, prepared by the CIPM for the 21st CGPM.

All the CCAUV meetings included reports from regional representatives presenting an overview of the regional activities, reports from NMIs on their new facilities, programmes and research areas, and reports from international observers on the IEC and ISO Technical Committees related to AUV. The current information related to these topics is included in the thirty-nine working documents presented during the last CCAUV meeting.

Several international scientific meetings encompass the activities of the CCAUV. A Sound and Vibration Workshop was announced to coincide with the IEC/TC29 meeting scheduled to take place in Copenhagen in September 2003.

Last but not least, the CCAUV entered into a long-standing discussion concerning dimensionless units which have application in AUV metrology. The CCU had raised the question as to whether the neper, the bel or both would be adopted as SI units. During the last CCAUV meeting, the Director of the BIPM provided an overview of the history and current status of the topic, after which the proposal was addressed by the delegates. Both personal and institutional opinions were put forward from some NMIs, there were contributions from international observers, and the latest papers on the subject submitted to *Metrologia* by the President of the CCU *et al.* and the President of the CCAUV were discussed. The CCAUV was in agreement that the *status quo* should be maintained, keeping both the neper and the bel outside the SI. Certainly, the best reason for not changing would be to avoid the confusion that would be created by any change, with influences not only in the metrology community, but in all facets of commerce and industry. The CCAUV proposal to maintain the current status was also supported by the IEC, and finally by the CIPM at its meeting in October 2002.

In the CCAUV section of the BIPM website, a number of documents have been made available, including an extensive list of bibliographies submitted by the member NMIs. He encouraged members to continue to submit these, to develop this valuable resource.

He then turned to the discussions of the CCAUV, CCU and CIPM concerning the neper and bel, and briefly presented his only views on the subject. In what he called Logic A, which is currently applied, the ratio of two quantities of the same kind is considered a new quantity. Within this system, it is necessary to name the new quantity; for example, mass fraction. In this case we have kg kg^{-1}, which might be called the unit “one”, or “uno”. He posed the question, however: how would this new unit be realized? He suggested that in this case, the uno could be realized by comparing two kilogram standards on a balance, although his own preference would simply be to use the SI base unit, the kilogram.

He then presented Logic B, in which division of one quantity by another of the same kind expresses the number of times one quantity fits into the other. This is a number, not a new quantity, and might be called a coefficient, a factor, or a ratio; no SI unit would be assigned to it.

A choice should be made between Logic A or Logic B. In the field of acoustics, confusion arises as a result of use of the decibel with different power and field quantities, without specifying to what the decibel is referred. He suggested that use of the underlying accepted SI units was preferable, and drew attention to a paper on this subject he had published in *Metrologia*, 2002, **39**(6), 543-549.”

Professor Bordé thanked Dr Valdés for his presentation, and invited questions.

Dr de Leer took up the discussion on the use of ratios as units, citing the example of mol mol^{-1} in chemistry. Here it is not possible to divide one mole of a specified compound by a mole of another specified compound, so it is not possible to give special names. Dr Valdés agreed that one might talk about 10^{-6} mol mol^{-1}, if one chose not to use ppm, but there was no need to introduce a new unit microunomol!

Professor Mills pointed out that chemists use mole fraction very widely and find it useful. He said that he agreed with much of what Dr Valdés had said, but pointed out that people are not going to stop using the decibel and the CCU would like to lead them into a more logical way of using it and defining it.

Dr Inglis said he was interested in the work Dr Valdés had presented on nanoscale microphones. He asked whether there was a need for new standards in this area, and perhaps even future key comparisons? Dr Valdés estimated the timescale would be between five and ten years from now.

In answer to a comment from Prof. Bordé, Dr Valdés explained that the nanoscale microphones were being developed by a team trying to reach the quantum limit in their search for gravitational waves.

15.10 Consultative Committee for Units

Professor Mills, President of the Consultative Committee for Units (CCU), presented the following report.

"It is my pleasure to deliver the report of the CCU. The CCU has held two meetings since the last CGPM in 1999. The 14th meeting was held in April 2001 and the 15th in April 2003.

14th meeting of the CCU, April 2001

1. We reviewed the responsibilities of the CCU. We see our main responsibilities as the consideration of possible changes to the International System of Units (SI); the preparation of successive editions of the SI Brochure, which is the official definition of the SI; and the promulgation of the SI through all science, technology and engineering.

2. We considered possible changes to the definitions of the base units in the coming years.

   (i) A small change that we plan to make in the next edition of the Brochure is to add to each of the definitions of the base units a statement of the quantity that is fixed by the current definition. Thus the present definition of the metre fixes the speed of light; the definition of the kilogram fixes the mass of the prototype; the definition of the second fixes the frequency of the hyperfine transition in the caesium atom; the definition of the ampere fixes μ_0, the permeability of free space; the definition of the kelvin fixes the temperature of the triple point of water; the definition of the mole fixes the molar mass of the carbon atom; and the definition of the candela fixes the luminous intensity of the specified source.

   (ii) Major changes can be foreseen to the definition of the kilogram, the second, and possibly the kelvin at some stage in the next ten years or so.

   The kilogram is in need of a new definition because the mass of the prototype is known to vary by several parts in 10^8 over periods of time of the order of a month, due to changing surface chemistry effects. One possible new definition would be in terms of the mass of a carbon atom, and would fix the Avogadro constant; and an alternative in terms of the

equivalent mass of a photon through the Einstein and Bohr relations, $E = mc^2 = hv$, would be realized using a watt balance, and would fix the Planck constant. These alternatives have different advantages, and neither can at present be realized with quite the desired accuracy. It is not yet possible to choose between them.

The change to be expected in the definition of the second is a change from the microwave frequency of the caesium atom used in the present definition to an optical frequency that would be more than 100 times higher. This would give significantly higher precision in realizing the definition. A number of alternative atomic spectral transitions are being considered in various research laboratories around the world. To realize such a definition requires a highly stable flywheel oscillator that can be locked to the optical transition, and can be compared with the microwave transition of the caesium atom with the necessary precision.

The anticipated change in the definition of the kelvin is one that would fix the value of the Boltzmann constant, and would be realized by an experiment that would relate temperature to energy. At present such experiments are a long way from the necessary precision, but developments are to be expected in this field.

The CCU is following these developments, and will take advice from the many metrologists working in these fields and from the other appropriate Consultative Committees before any change is made.

3. The CCU reconsidered the proposal that the neper, symbol Np, should be adopted as an SI unit alongside the radian, which we presented to the last CGPM in 1999. Delegates who were present at that meeting will remember that it was received with many doubts, as a result of which the proposal was withdrawn for further consideration. The CCU still considers that the neper should be regarded as an SI unit closely related to the radian, and three members of the CCU published a paper in *Metrologia* explaining the arguments for this action (I.M. Mills, B.N. Taylor and A.J. Thor, Definitions of the units radian, neper, bel and decibel, *Metrologia*, 2001, **38**, 353-361). However, after putting various modified proposals to the CIPM, none of which gained approval, we have decided to leave this proposal for the present.

4. The CCU considered the problems created by the different meanings attached to the names “SI units” and “units of the SI”. According to all recent editions of the SI Brochure, including the current 7th edition published in 1998, the name “SI units” should be taken to span only the coherent units, not including any multiple or submultiple prefixes; but the name “units of the SI” should be taken to span all units including those involving prefixes. According to this rule the centimetre and the millimetre, for example, are not SI units, but they are units of the SI. It appears to be contrary to the rules of English grammar to read different meanings into the names “SI units” and “units of the SI”.

   The CCU has decided to resolve this situation by stating that both “SI units” and “units of the SI” shall be taken to have the same meaning, which should include both the coherent units and all units obtained by adding multiple or submultiple prefixes. When it is desired to refer to only the SI units without prefixes, the name “the coherent SI units” should be used. The next edition of the Brochure will be written in this way.

5. The question of extending the SI prefixes beyond their present range from 10^{+24} to 10^{-24} was discussed, but it was decided to make no change. The possibility of changing the recommended prefix symbols for deca, hecto and kilo, from da, h and k to the capital letters

D, H and K was also discussed, but a decision was again made to make no change. The CCU believes that even small changes to the rules of the SI should only be made when the case is very strong, because any changes may cause confusion, and have consequences in the changes that have to be made in many other documents around the world based on the SI.

6. The CCU discussed the possibility of adopting a name and symbol for the number one, to be used for dimensionless quantities. The possibility of the name uno, symbol U, was considered. The advantage of such a unit is that it would be possible to use it with prefixes, to express the values of dimensionless quantities equal to very large or very small numbers, thus avoiding the use of ambiguous and language-dependent symbols such as ppm, ppb and ppt. The disadvantage is that the uno would be a dimensionless unit equal to one that might be used to express the value of a wide variety of different quantities, which may itself cause confusion. See the report below of the 15th meeting of the CCU in 2003.

15th meeting of the CCU, April 2003

At this meeting, our most recent, we began seriously to discuss and work on preparing the manuscript for the next edition of the SI Brochure. There will be a number of changes from the previous edition, outlined below. We hope to have a fairly complete manuscript by spring 2004, and to achieve publication early in 2005.

1. We plan that the next edition shall be entirely available on the Internet, through the BIPM website, with the advantage of the search facilities that this will make possible.

2. We plan to extend Chapter 1 in a tutorial style, to introduce the basic idea of an international system of units, the SI, based on an international system of quantities, the ISQ. We shall also explain the significance of coherent quantities, and of dimensions, more fully than at present. We shall introduce the problems of some of the newer quantities involved in biological research.

3. We plan to make only small changes to Chapter 2 on the definitions of the base units of the SI, and to make no changes at all to the wording of the actual definitions. We shall emphasize the difference between defining a unit and realizing the definition. A number of small changes will also be made to the section on derived units, including a revised description of the problems of dimensionless units. Chapter 4, which is concerned with non-SI units, is provided mainly for information and assistance for the reader. We shall emphasize the advantages of using SI units, while discouraging but not condemning those who, for various reasons, may wish to continue to use non-SI units. We shall simplify the subdivision of non-SI units in Tables 6 to 10. We plan to extend Chapter 5, which is concerned with practical advice on how to use and write text and equations involving SI units. A number of changes will also be made to the appendices.

4. The CCU also discussed, once again, the possibility of introducing the uno, symbol U, to represent the number one used as a unit for dimensionless quantities. Although we do not plan to take any action on this at the present time, it was decided that we should prepare a paper that could be widely circulated to the scientific unions and National Metrology Institutes to canvass opinion on this proposal. There seems little doubt that the CCU will discuss this again in future meetings.

Summary and conclusion

I should like to emphasize the importance of the role that the CCU plays as guardian of the SI, and in providing guidance in its use. Most users of the SI have specialized expertise in particular areas of science, and this applies to metrologists as much as to others. However, the CCU has to take a broad view of its responsibilities, and in this respect it is somewhat different from the other Consultative Committees. It is important that we should be thinking about new developments in all fields where quantitative measurements are involved, and their implications for the way in which units are defined, the definitions are realized, and the results are presented. Science is forever changing, and we have to respond to these changes if we are to maintain the value of the SI. The Brochure plays an important role in disseminating information on the SI to professional metrologists, members of the many international committees on standardization, as well as to all practising scientists and technologists around the world.

I should like to express my thanks and appreciation to the current members of the CCU, many of whom travel long distances to take part in our discussions. I find these discussions always stimulating and valuable. I would also like to encourage directors of NMIs around the world to bring to the attention of bright young metrologists the possibility that they might play a part in the work of the CCU. We would welcome new young members, who may thus become part of a new generation contributing to this work."

He drew attention to the presence of the SI brochure on the web and concluded by thanking Prof. Peter Martin for his role as Executive Secretary of the CCU since 1998.

Professor Leschiutta commented that the SI brochure is very widely distributed, and recommended that the BIPM should continue to produce a printed version. Dr Quinn confirmed that this had always been the intention.

Professor Bordé then invited Prof. Mills to present Draft Resolution L2.

Professor Mills explained that the governments of Australia, the United Kingdom, and the United States had submitted Draft Resolutions on the symbol for the decimal marker in the International System of Units. At its 92nd meeting (October 2003) the CIPM had discussed these texts and the text presented by the CIPM, Draft Resolution L2, is an amalgamated version.

He gave a brief background to the subject, saying that it was not a technical matter, but concerned wide use in the community of the decimal marker. Of the current Member States of the Metre Convention, the populations of those countries where it is customary to use a decimal point add up to 3.6 billion (3.6×10^9), and the populations of those countries where it is customary to use a decimal comma add up to 1.0 billion (1.0×10^9). There are currently 30 Member States using a decimal point, and 34 Member States using a decimal comma. Some Member States use both. Despite this, the ISO recommends that the decimal marker shall be a comma. The existing recommendation is therefore at conflict with customary practice in the world, particularly in the English-speaking world, where documents written in the English language universally use the decimal point.

Professor Mills then read the text of Draft Resolution L2, which proposes that the decimal marker shall be either the point on the line or the comma on the line, and Prof. Bordé invited discussion.

▮ Symbol for the decimal marker in the International System of Units (SI)

Draft Resolution L2

The 22nd General Conference,

considering that

- a principal purpose of the International System of Units (SI) is to enable values of quantities to be expressed in a manner that can be readily understood throughout the world,
- values of quantities are normally expressed as a number times a unit,
- often the number in the expression of the value of a quantity contains multiple digits with an integral part and a decimal part,
- in Resolution 7 of the 9th General Conference, 1948, it is stated that "In numbers, the comma (French practice) or the dot (British practice) is used only to separate the integral part of numbers from the decimal part",
- following a decision of the International Committee made at its 86th meeting (1997), the International Bureau of Weights and Measures now uses the dot (point on the line) as the decimal marker in all English language versions, including the English text of the SI Brochure (the definitive international reference on the SI), with the comma (on the line) remaining the decimal marker in all of its French language publications,
- nevertheless, some international bodies use the comma on the line as the decimal marker in their English language documents,
- furthermore, some international bodies, including some international standards organizations, specify the decimal marker to be the comma on the line in all languages,
- the prescription of the comma on the line as the decimal marker in many languages is in conflict with the customary usage of the point on the line as the decimal marker in those languages,
- in some languages that are native to more than one country, either the point on the line or the comma on the line is used as the decimal marker depending on the country, while in some countries with more than one native language, either the point on the line or comma on the line is used depending on the language,

declares that the SI symbol for the decimal marker shall be either the point on the line or the comma on the line,

reaffirms that "Numbers may be divided in groups of three in order to facilitate reading; neither dots nor commas are ever inserted in the spaces between groups", as stated in Resolution 7 of the 9th CGPM, 1948.

On behalf of Prof. Thor (Secretary of ISO TC 12), Dr Andersson (Sweden) suggested that the adjective "SI" should be deleted from the point "declares", because the decimal marker is not limited to that system. Professor Mills said that personally he did not object to this, but explained that the feeling of the CIPM had been that the authority of the CGPM concerned the SI, even though the decimal marker is of course a broader issue. Professor Göbel suggested that "SI" could be deleted and another clause added: "in particular this should be the case for the SI".

This received wide support, and the three delegations from the three originator States expressed their approval. Dr Kaarls agreed that a revised version would be presented for voting.

When the amended draft was subsequently presented to the Conference, it was without the inclusion of this additional sentence; Drs Kaarls and Quinn explained that efforts had been made to include the comment, but whatever phraseology was used the comment had appeared to be limiting, and so had finally been abandoned. Dr Kaarls reminded delegates that of course Resolution 7 of the 9th CGPM (1948) did not mention the SI either.

The revised text, Draft Resolution L3, was duly adopted unanimously, without further discussion, as Resolution 10 (see page 381).

16 Annual dotation of the BIPM: Report of the working group on the dotation

The working group of the 22nd CGPM on the BIPM dotation (hereafter called the Budget Committee) met on Tuesday afternoon 14 October 2003 and on Thursday afternoon 16 October 2003. The Committee was chaired by the Secretary of the Conference, Dr Robert Kaarls, and was made up of the following Member States: Australia, Canada, China, Egypt, France, Germany, India, Italy, Japan, Republic of Korea, Mexico, Norway, Russian Federation, Serbia and Montenegro, United Kingdom, United States of America.

16.1 Meeting of Tuesday 14 October

The meeting on Tuesday 14 October opened with the Chairman explaining the task of the Budget Committee. He then read out the text of Draft Resolution J and gave a brief summary of the extensive discussions and consultations that had led up to the adoption of the Draft by the CIPM in October 2002. An account of these is given in the Convocation to the 22nd CGPM sent to Member Governments in December 2002 and, more extensively, in the Appendix to the document "Programme of Work and Budget of the BIPM for the years 2005 to 2008" sent to Member Governments in April 2003.

The points he highlighted were:

- the rapid evolution in needs for national and international activities in metrology not only in the classical areas of metrology but areas such as chemistry, biotechnology and laboratory medicine, where traditionally metrology had not been considered of high priority; these are described in the report of the CIPM to the CGPM on *Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM*;
- the results of the two questionnaires sent in 2002 to the directors of the NMIs;
- the results of consultations with the directors of the NMIs during the Directors' Meeting in April 2002;
- the successful development of the CIPM MRA; and
- the report by KPMG on the economic impact of the CIPM Mutual Recognition Arrangement and the BIPM.

The Chairman also reminded the Budget Committee of the fact that the 21st CGPM in 1999 adopted the programme of work at that time proposed by the CIPM for the BIPM, which included new activities in chemistry as well as the work which was foreseen would arise from the CIPM MRA (notably the KCDB). He drew attention to the fact that it was recognized and noted by the 21st CGPM that the budget agreed in 1999 would not be sufficient to continue all these activities after 2004, unless a substantial increase in dotation could be accepted by the 22nd Conference in 2003.

In fact, the work load of the BIPM had increased even more than had been foreseen in 1999. In 2002, it became clear that the increase in dotation that would be required to be voted by the 22nd CGPM in 2003 in order to maintain all of work then being done would be larger than consultations with directors of NMIs had shown Member States would be likely to approve. At its meeting in October 2002, the CIPM therefore decided to make significant cuts in programme that would allow a much smaller increase in budget to be asked of Member States. These cuts, some of which were to take place immediately, were designed to allow a balanced budget in 2008 while maintaining the core programme of the BIPM, and allowing the extensions into chemistry that were seen to be essential. Included in these cuts were the immediate closure of the Photometry and Radiometry section of the BIPM and a reduction of the activities of the Length section, which together with the other measures will lead to an overall reduction in numbers of permanent staff at the BIPM and a reduction in reserves to about 39 % of annual budget and a balanced budget by the year 2008. The financial previsions underlying this forecast were based on an assumed increase of dotation of 6.7 % in 2005 plus annual increases for inflation of 1.8 % (as proposed in Draft Resolution J).

The Chairman of the Budget Committee then asked for the preliminary opinion of the Member States represented in the Committee on Draft Resolution J. Nine of the sixteen States present indicated that they would be ready to vote for the Draft either as it stands (Australia, Canada, China, Italy, Norway, Serbia and Montenegro and the United Kingdom) or with modifications to provide the same total amount but with the increase spread over four years (France and Russia). The position of Egypt was that no increase above price inflation in France could be accepted; for Germany the increase in the first year should not exceed 5 %; for India no increase above inflation; Japan did not agree with the proposal because it was not nominally zero growth but wished to look more closely at some details; the Republic of Korea did not wish to express an opinion at this stage; for Mexico no increase above inflation; and for the United States no increase at all but would be willing to consider the inclusion of inflation not exceeding 1.8 % *per annum*.

There followed a discussion concerning the programme of work at the BIPM. All expressed support, but Egypt and Mexico wished to draw attention to the reduction in services to smaller States that has resulted from the cuts in programme decided by the CIPM in 2002. This was noted by others but counterbalanced by the greatly increased role of coordination now undertaken by the BIPM. After further discussion, the Committee unanimously supported the programme of work proposed for the BIPM, particularly the necessity of maintaining its core programme of scientific work. This programme should be aimed at maintaining the broad technical competence that was needed to carry out technical work that was of value to Member States and also to pursue BIPM's wider coordination and international liaison mission. This increased role of coordination was unanimously supported by the Committee. The Committee took a positive view of the increase of activities in the field of chemistry, including, in particular, work on ozone standards and on purity measurements in the field of organic and biological

analysis in support of clinical chemistry and laboratory medicine triggered by the *In Vitro* Diagnostics Directive of the European Union.

The Budget Committee then discussed how the divergent views expressed by Member States concerning the dotation could be brought together. The German delegation suggested that BIPM reserves could be used to support the proposed programme and that subsequent inflation increases could be paid from the dotation. In response, the Director of the BIPM pointed out that the reserves had already been reduced to some 45 % of annual operating funds and that it is already envisaged that further reduction to some 39 % is planned to be reached in 2008. He said that reserves at or around that level were necessary because: (a) fluctuations in income from year to year have been more than 20 %, and income from Member States comes at all times of the year and reserves are needed to support cash flow; (b) there is a lack of payments in those cases where Member States were in default for up to three years until the redistribution rules are applied. The Committee accepted that for these reasons a level of reserves of about 40 % is prudent.

Further discussions indicated that while most of those States that had originally said that they could not accept any increase above inflation were prepared to be flexible and not block the wishes of the majority, the United States maintained its original position. It was concluded, therefore, that no agreement could be reached and that the Chairman should report back to the Conference on Thursday morning and that a second session of the Budget Committee should take place on Thursday afternoon.

The conclusions to be reported by the Chairman of the Budget Committee to the Conference were as follows:

- Member States of the Budget Committee agreed unanimously on the work programme of the BIPM;
- several Member States wished their view to be noted that the BIPM should maintain calibration facilities that served the NMIs of the Member States;
- no agreement could be reached on the budgetary consequences of the proposed programme; a large majority of the members of the Budget Committee acknowledged that they obtained a good return on investment from their contributions to the BIPM;
- despite the fact that delegations expressed serious concerns about the financial situation in their own country there was general support for some real increase in dotation in order to make it possible for the BIPM to carry out the proposed programme of work;
- proposals were made to spread the proposed increase over the whole period of 4 years in the period 2005 to 2008 instead of a single large increase in the first year;
- the United States would vote for a proposal for no increase, would abstain on a proposal for an increase to allow for annual inflation of 1.8 % but would veto any proposal for a real increase; this was a position not taken by any other delegation;
- unless some flexibility could be found in the position of the United States, there seemed no possibility for reaching a solution acceptable to all Member States; and
- it was suggested that a possible way forward was to split the proposed budget into two parts, one being an obligatory part with increases corresponding to inflation only, and a second part being a discretionary part to provide for the real increase wished for by the majority of Member States; the Budget Committee decided to consider this suggestion and re-convene on Thursday afternoon.

Finally, the Chairman in a closing statement said that an increase only at the level of 1.8 % to account for inflation, would result in a further reduction in the number of comparisons and calibrations carried out for NMIs. The Committee had considered this generally to be undesirable as it would, among other things, make membership of the Metre Convention less attractive to smaller and developing countries – something that contradicted the overall wishes of the General Conference. Many points had been made by various delegations as to the desirability of maintaining the BIPM in a position to meet demands placed upon it. Not only is the BIPM a highly efficient organization but also money spent at the BIPM on work for Member States is highly cost effective and saves Member States money that they would otherwise have to spend themselves. He cited the importance of the new activities in laboratory medicine as an example of the important new work that the BIPM was embarking on for Member States.

16.2 Meeting of Thursday 16 October

The Budget Committee continued its meeting on Thursday afternoon.

This second meeting began with a discussion on the proposal that had been made on the Tuesday for the dotation to be split into two parts. There was wide agreement that such a solution in which the major part of the increase was considered to be discretionary would not be a viable solution for the BIPM. It would result in the income of the BIPM being uncertain to such an extent that no proper programme planning would be possible. Another solution must be found.

The German delegation then announced that the maximum increase in the first year (2005) that it could accept would be 5 %, including inflation.

The Japanese delegation then presented the results of its detailed study of the proposed budget increases. It declared first of all that it would accept the proposed costs for BIPM staff salaries and for the pension fund as presented in the “Programme and Budget” document but it considered that significant cuts could be made in the provisions for investments in laboratory equipment and the maintenance of the BIPM buildings. That the proposed salary and pension costs should be maintained in any budget settlement was then agreed by the Committee.

In reply to the Japanese suggestion that the levels of spending on building maintenance were too high, it was pointed out that the amounts foreseen for the period 2005 to 2008 were at about the average level that has been spent for the past one hundred years and reflect the costs of maintaining historic buildings and providing up-to-date laboratory accommodation. The Committee supported the need for an adequate provision for the buildings at the BIPM.

Japan then proposed an increase of 3.6 % in 2005, including a provision of 1.8 % for inflation, to be followed by further annual increases of 1.8 % in 2006, 2007 and 2008.

The discussions in the Budget Committee then made clear that this proposal would not provide a realistic way forward for the BIPM and that it could only lead to considerable further immediate reduction in staffing levels, and to further closures of laboratory work. It was also pointed out that the Metre Convention operating procedures made no financial provisions for redundancies and as the BIPM reserves were not designed to provide for staff redundancies, any costs associated with consequent reductions in staff would have to be borne directly by Member States.

There then followed a discussion on the figure to be taken for inflation. It emerged that an estimate of 1.8 % for inflation was considered by most delegations to be an underestimate, and

the Committee took advantage of this to review the level. Agreement was reached among all delegations that an annual increase of 2 % for inflation would be acceptable.

As a result of further discussions, the German and Japanese delegations then agreed on a compromise proposal: the dotation for 2005 should include a step increase of 3 % plus an increase of 2 % for inflation leading to a total increase of 5 % with further increases for inflation of 2 % in 2006, 2007 and 2008.

The Chairman then asked each delegation to express its opinion on this proposal. Delegates from fifteen Member States accepted the compromise proposal and indicated that they would recommend it to the Conference and be ready to vote for such a proposal if it were put to the Conference. The sixteenth, the United States, maintained its position that it would veto any proposal for a real increase.

There followed further discussion after which the United States made a counter proposal that while accepting the inflation increases of 2 % *per annum*, the increase agreed by the German and Japanese delegations be reduced from 3 % to 1.6 %. The United States would abstain on such a proposal and would not use its veto.

This counter proposal was not accepted by any of the other delegations. The resulting deadlock led to a return to the suggestion that the dotation could be in two parts: one part fixed and the other part "discretionary". In this case, the discretionary part would be the difference between the 3 % initial increase accepted by all except the United States and the 1.6 % proposed by the United States. In this way, the increase in 2005 would come to a total of 5 % if all the discretionary parts were paid.

Most members of the Committee, whilst reluctantly accepting that this proposal could provide the necessary compromise, felt that the division was in a sense arbitrary and was basically unsatisfactory. They also wished to give the BIPM as secure a financial allocation as possible, as uncertainty in the budget could lead to difficulties for its management. There was general consensus that the "discretionary" part should be made as firm as possible and that Member States should be invited to declare their intention to pay it.

The final proposal to be put to the Conference and agreed by all Member States of the Budget Committee, included a discretionary part of the budget designed to make up the difference between an increase of 3.6 % and the proposed 5 % for the year 2005.

16.3 Report to the Conference

The results of the discussions in the Budget Committee were reported to the CGPM on Friday morning by the Chairman of the Budget Committee as follows:

- the Budget Committee had two difficult meetings, and discussed the proposed budget in a considerable degree of detail;
- as the United States originally declared that its general policy for international organizations was not to accept any increase and that it would veto an increase of more than 1.8 % as a yearly correction for inflation, no initial agreement could be reached;
- a constructive proposal had been made by Germany and Japan and based on an increase of 5 % in 2005, including an inflation correction of 2 %, together with a further increase for inflation of 2 % per year over the period 2006-2008, was finally agreed by all but one of the members of the Budget Committee;

- the delegation of the United States subsequently declared that it would not veto, but would abstain, on a proposal based on an increase of 3.6 % in the year 2005, made up of a single real increase of 1.6 % plus an inflation correction of 2 % for 2005, and a subsequent yearly provision for inflation only of 2 % over the period 2006-2008; and
- finally, agreement was reached on a discretionary step of about 134 000 euros per year on average over the period 2005-2008 thereby making up for the difference between the 3.6 % proposal that was acceptable to the United States, and the 5 % proposal acceptable to the other members of the Budget Committee.

The chairman of the Budget Committee was therefore able to present a modified Resolution to the CGPM based on the above compromise. However, he remarked that this compromise is less than the budget proposed by the CIPM and thus requires the CIPM and the Director of the BIPM to reconsider the programme of work of the BIPM.

The CIPM and BIPM would try to avoid any further reduction in the calibration services delivered to the NMIs.

As suggested by several delegates, the CIPM and BIPM will consider whether any other sources of financial support may be obtained from other organizations.

The CGPM also expressed strong support for sponsored secondments and fellowships at the BIPM. These would enable Members States to provide suitably qualified people who would take part in the BIPM core programmes as well as in additional projects that met commonly agreed interests of the Member State and the BIPM.

16.4 Discussion

When the modified Resolution J2 was presented on the morning of Friday 17 October, several further comments were made.

Dr Bement reminded delegates that his initial instruction from the American Government had been to veto any increase in the dotation. He had indicated the conditions under which he would be able to withhold this veto, and he remarked that good progress had been achieved. However, further changes were still required. Firstly, a rewording under “further decides” to “further decides to support the increasing workload of the BIPM by an additional discretionary contribution”, so that the “at risk” part of the budget is not specifically tied to the coordination activities but to the workload in general. Secondly, under “requests”, to “requests Member States to declare to the BIPM at the latest by 1 April 2004 their intent to pay a share of this discretionary contribution”. Otherwise, by a play of words, the discretionary contribution has been changed to a non-discretionary contribution, which would require the American delegation to veto the Resolution.

Dr Kaarls assured him that the intention had not been to make the discretionary contribution obligatory, but rather to establish on how much support the BIPM can count in order to carry out its work programme. The changes proposed by the American delegation were agreed, with a minor rewording to indicate the span of the discretionary part over all four years, and to facilitate the wording of the French version.

Dr Pákay, Hungary, said that although he intended to vote in favour of the Resolution, current economic problems in Hungary were forcing staff cuts at the OMH, and the closure of the OMH section on microwave measurements. He called on the decision-makers at the BIPM to bear in

mind such problems. Dr Quinn said that the BIPM of course remained sensitive to the budgetary problems of Member States.

Dr Šafarik (Czech Republic) noted that it was important to consider what would happen after 2008. Member States should be aware that in 2008 the budget required will be based on the sum of the two parts: "fixed" and "discretionary". Professor Kovalevsky pointed out that the 22nd CGPM could not take a decision concerning the 23rd CGPM, but agreed that the comment was important and should be noted in the Proceedings.

Dr Jones (New Zealand) expressed concern about having a discretionary component of the budget, calling for clear guidance on how to explain to governments why there is a discretionary component and what that discretionary component gives. What is really a small amount of money could be put at risk by the difficult task of explaining the split. Professor Kovalevsky replied that a formal request for the discretionary component would of course be addressed to all Member Governments, stating their proportion of it (the same as for the fixed part) and explaining the idea of the discretionary component. The bureau of the CIPM would reflect on the best way of explaining the new Resolution.

Dr Carneiro (Denmark) turned discussion to the three bullet points concerning staff secondments and sponsorship of fellowships at the BIPM, suggesting that this part on scientific collaborations might be more appropriate elsewhere, rather than in the text of the Resolution on the dotation. Dr Quinn explained that the Committee had included the points here because, due to budget restrictions, the BIPM has already had to stop financing research fellowships itself. The Resolution is formally asking NMIs to help carry out the extra workload by providing secondments, so these bullet points are indeed intimately linked with the financial part.

Dr Blevin (Australia) lent his support to the suggestion from the United States' delegation that the wording in the bullet point "further decides..." should be changed from "increasing coordination role" to "increasing workload", reminding delegates that the Metre Convention states that the BIPM is managed by the CIPM, not by the General Conference. If the CGPM starts specifying particular uses for parts of the budget, it is going against this delegation to the CIPM in the Convention. The panel agreed that this modification had been made.

Dr Quinn checked that the modified wording of the final line "requests" was acceptable to everyone.

16.5 Voting on Draft Resolution J3

During a preliminary vote then an official vote, modified Draft Resolution J3 was passed as Resolution 12 with no votes against and one abstention (United States) (see page 383).

In the name of the CIPM, Prof. Kovalevsky thanked delegates for this vote, which he said gave full confidence for the coming four years.

17 Proposals by delegates

Professor Bordé reminded participants that the Convocation requested that Member States inform the CIPM at least six months before the General Conference of their wishes or any proposals that they would like to submit for consideration. This is in order that the CIPM can abide by the decision of the 9th General Conference (Resolution 10, 1948), that "(1) the wishes or proposals thus deposited will be distributed by the bureau of the CIPM to all Member States of the Convention at least four months before the opening of the Conference, so that delegates may receive the necessary instruction and authority; (2) all other wishes and proposals will be presented to the Conference only if the CIPM has had time to study them and has approved them".

Professor Bordé reported that no formal proposals had been received from Member States, and no other issues were raised by delegates.

18 Renewal of half of the International Committee

In conformity with Articles 7 (1875) and 8 (1921) of the Rules annexed to the Metre Convention, half of the membership of the International Committee must be proposed for renewal by secret ballot at the General Conference. Incoming provisional members (those who have been provisionally elected since the last Conference to fill vacancies) are first, the remainder being selected by lot from among the remaining members of the International Committee.

The following members (the six new members since the 21st General Conference, plus the name of Dr Semerjian in place of Dr Brown, plus two other names drawn by lot during the 92nd meeting of the CIPM, October 2003; see the report of that meeting) were proposed for election or re-election by the 22nd General Conference: Dr Bennett, Dr Chung, Dr Hengstberger, Dr Inglis, Dr Kaarls, Dr Lusztyk, Dr Schwitz, Dr Semerjian, Dr Tanaka.

Mr Érard (France) and Dr Jones (New Zealand) acted as scrutineers of the ballot. All nine proposed members were elected with a large majority. A total of four votes were cast for three other candidates, all of whom, however, were already members of the CIPM.

19 Votes on all Resolutions

Revised Draft Resolution A was adopted unanimously as Resolution 1.

Revised Draft Resolution B was adopted unanimously as Resolution 2.

Draft Resolution C was adopted unanimously as Resolution 3.

Draft Resolution D was adopted unanimously as Resolution 4.

Draft Resolution E was adopted unanimously as Resolution 5.

Revised Draft Resolution F was adopted unanimously as Resolution 6.

Revised Draft Resolution G was adopted unanimously as Resolution 7.

Revised Draft Resolution H was adopted unanimously as Resolution 8.

Revised Draft Resolution I was adopted unanimously as Resolution 9.

Revised Draft Resolution L2 was adopted unanimously as Resolution 10.

Revised Draft Resolution N was adopted unanimously as Resolution 11.

As reported in section 16.5, revised Draft Resolution J was adopted as Resolution 12 with no votes against and one abstention (United States).

The final texts of the Resolutions are presented on pages 373-384.

20 Other business

Delegates were reminded that the meeting of directors, held on the morning of Wednesday 15 October, concerned only NMI directors from Member States, not Associates.

The Chairman thanked the French Ministry of Foreign Affairs for hosting a reception for delegates at the Centre de Conférences Internationales on the evening of Monday 13 October. He also thanked the British Ambassador, Sir John Holmes, for hosting a reception at the British Embassy on the evening of Thursday 16 October, to say farewell to Dr Quinn and to welcome Prof. Wallard as Director of the BIPM.

20.1 Visit to the BIPM

Delegates to the General Conference were invited to visit the BIPM on Wednesday 15 October 2003. They had the opportunity to visit the laboratories, examine the projects and facilities, and talk to the staff.

20.2 Visit to the depository of the metric prototypes

The visit to the depository of the metric prototypes at the Pavillon de Breteuil took place at 16 h 00 on 15 October 2003, in the presence of the President of the CIPM, the Director of the BIPM, and the representatives of the Curator of the Archives de France.

The three keys necessary to open the depository were assembled: the key entrusted to the care of the Director of the BIPM, the one deposited at the Archives Nationales in Paris, brought by Mrs C. Béchu and Mr E. Rousseau, and finally the one kept by the President of the CIPM.

The doors of the vault and the safe having been opened, the presence in the safe of the International Prototype of the kilogram and its official copies was observed.

The following indications were noted on the measuring instruments placed in the safe:

temperature:	22 °C
maximum temperature:	24 °C
minimum temperature:	21 °C
relative humidity:	61 %

The safe and the doors of the vault were then locked.

The Director of the BIPM,	*For the Curator of the Archives Nationales,*	*The President of the CIPM,*
T.J. Quinn	C. Béchu	J. Kovalevsky

20.3 The CIPM Mutual Recognition Arrangement

During the Conference, Dr Z. Nikolai, Dr G. Sydorenko and Dr G. Deitch signed the MRA on behalf of the NMIs of Belarus, the Ukraine, and Israel, respectively.

21 Closure of the Conference

The President of the Conference thanked all present, particularly Dr Kaarls, Secretary of the Conference, Prof. Kovalevsky, President of the CIPM, and Dr Quinn, Director of the BIPM. He then expressed his thanks, along with his best wishes, to Professor Wallard, incoming Director of the BIPM, and his appreciation to all the personnel of the BIPM, in particular Mrs F. Joly and the Secretariat, and Mrs B. Perent, Administrator of the BIPM. Finally he thanked the French Ministry of Foreign Affairs for having hosted the Conference at the Centre de Conférences Internationales, all the contributors, particularly the Presidents of the Consultative Committees, and the translators.

Professor Kovalevsky also expressed his thanks to the delegates for their presence and active participation, and on behalf of the CIPM thanked them for their confidence in the BIPM. He said that the programme of work of the BIPM would have to be adjusted in the light of the adopted Resolution 12, but promised that Prof. Wallard would do the maximum to ensure that the scientific work of the BIPM and the calibration services offered to Member States would be

maintained, within the framework established by the CIPM in 2002. Finally, he thanked the Conference President, Prof. Bordé, for having chaired the meeting in such an excellent manner.

Professor Bordé reminded delegates that the next General Conference would take place in four years' time, in October 2007, and closed the Conference at 15 h 15.

Resolutions adopted by the 22nd General Conference on Weights and Measures (2003)

Links with other organizations

Resolution 1

The 22nd General Conference,

considering

- the work of the Metre Convention in extending traceability of calibration and measurement results into new application areas,
- the evident value of collaboration and Joint Committees already established by the International Bureau of Weights and Measures (BIPM) with other international organizations,
- the need to seek efficiency through collaboration and partnerships with other international organizations, where these serve the common aims and objectives,
- the long-standing relations with the Organisation Internationale de Métrologie Légale (OIML),

noting and welcoming the formal arrangements recently created by the BIPM with the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the World Meteorological Organization (WMO), and the efforts of the BIPM to draw up similar arrangements with other bodies,

invites

- international and intergovernmental organizations for which metrology impinges on their activities to cooperate with BIPM, to develop similar formal relationships and, if necessary, participate in Joint Committees,
- all Member States to help implement the results of these collaborations and the joint efforts so as to extend the influence and impact of the Metre Convention and of traceability of calibration and measurement results into user domains where these form part of national rather than international responsibilities.

Metrology and trade

Resolution 2

The 22nd General Conference,

considering

- the increasing importance for world trade of reliability in measurement and comparability of measurement results,
- the commitment of the World Trade Organization (WTO) to the reduction in non-tariff barriers to trade,
- the recent report commissioned by the International Bureau of Weights and Measures (BIPM) from a commercial consulting company on the economic impact of the CIPM Mutual Recognition Arrangement on world trade,

notes the long-standing application made by the BIPM for observer status on the WTO Committee on Technical Barriers to Trade, and

requests Member States of the Metre Convention to press for a positive acceptance of this application as soon as possible.

On the coordination of the initiatives to support the implementation of metrology, accreditation, and standardization in developing countries and economies

Resolution 3

The 22nd General Conference,

considering

- the desirability of extending relationships between the Metre Convention and the bodies working on aspects of metrology, accreditation and standardization infrastructures in developing countries and economies,
- the value of creating a coherent, coordinated approach to metrology, accreditation and standardization,
- the creation of a Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization (JCDCMAS), involving representatives of the International Bureau of Weights and Measures (BIPM), the International Accreditation Forum (IAF), the International Electrotechnical Commission (IEC), the International Laboratory Accreditation Cooperation (ILAC), the International Organization for Standardization (ISO), the International Telecommunication Union (ITU), the Organisation Internationale de Métrologie Légale (OIML), and the United Nations Industrial Development Organization (UNIDO),
- the initiatives of several Member States of the Metre Convention in support of metrology in developing countries,

noting the independent policy relationships between Member States of the Metre Convention and a number of the partner bodies in the JCDCMAS,

welcomes and supports the participation of the Metre Convention in the work of the JCDCMAS with the specific remit to assist in a coherent technical implementation of metrology, accreditation and standardization in developing countries and economies in such a way as to avoid any conflict with the independent policies and activities of the National Metrology Institutes of Member States of the Metre Convention.

Value and benefits of the Metre Convention for Member States and for Associates of the General Conference

Resolution 4

The 22nd General Conference,

considering

- the clear technical and economic benefits to countries and economies of being Member States of the Metre Convention or Associates of the General Conference,
- the desirability of extending the number of Member States or Associates so as to widen the impact and the benefit of participation in the CIPM Mutual Recognition Arrangement (MRA),
- the need to ensure that the CIPM MRA is not seen as a technical barrier to trade but, on the contrary, is seen as an Arrangement that gives equal opportunities to all,

welcomes

- the initiatives already taken by the International Bureau of Weights and Measures to promote membership of the Metre Convention and increase the number of Members and Associates of the General Conference,
- the potential of the Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization (JCDCMAS) for alerting non-members to the merits of membership, and

invites Member States to promote wider membership through their initiatives, such as aid programmes in developing countries, and through their discussions in appropriate international fora.

Report on evolving needs for metrology in trade, industry and society, and the role of the International Bureau of Weights and Measures

Resolution 5

The 22nd General Conference,

considering

- Resolution 11 of the 20th General Conference, which recommended to the International Committee that it study the long-term needs relating to metrology,
- Resolution 1 of the 21st General Conference, which noted the Report to the General Conference on long-term needs relating to metrology,
- the new Report adopted by the International Committee in October 2002,

notes

- the content of the new Report,
- its contribution to the identification of priorities within current activities and to the setting of new priorities,

- its contribution to the decisions of the International Committee on the programme of future work at the International Bureau of Weights and Measures (BIPM),

thanks the many organizations and individuals who contributed to the work of the International Committee, and

invites the International Committee

- to continue to keep a careful watch on the increasing demands placed on the National Metrology Institutes and the BIPM as far as their current work in metrology is concerned and the additional activities generated by new needs in such areas as chemistry, biotechnology, medicine, the environment and food,
- to report to the next General Conference on the adequacy of the response of the BIPM to meet these needs together with any financial and programme implications there may be in relation to the meeting of such international needs through the activities of the BIPM, and
- if necessary, to update their 2002 Report.

On the importance of the CIPM Mutual Recognition Arrangement

Resolution 6

The 22nd General Conference,

noting

- the positive social and economic impact, including the lowering of costs in non-tariff barriers to trade that are expected to follow from adoption by regulators and legislators of the CIPM Mutual Recognition Arrangement (MRA),
- the effect of the CIPM MRA in building mutual confidence between trading partners,
- the interest already created with certain regulatory authorities, trade organizations and national authorities,
- the use of the CIPM MRA, for example, in facilitating the European Union/United States trade agreement,
- that the credibility of the CIPM MRA is based upon a secure technical foundation, namely, the key comparisons, Quality Systems and other measures to ensure quality,
- that the CIPM MRA has been signed with the approval of the appropriate official authorities in each country,

welcomes the interest shown by these bodies, and

invites

- all Member States to promote the CIPM MRA among their national regulatory, accreditation and standardization bodies as a framework for acceptance of calibration and measurement certificates from National Metrology Institutes (NMIs) and designated institutes as well as from accredited laboratories that can demonstrate traceability to the International System of Units through standards realized by the signatory NMIs and designated institutes,

- the International Committee to prepare a declaration on the importance and application of the CIPM MRA in trade, commerce and regulatory affairs, and to bring it to the attention of the Governments of the Metre Convention with the recommendation that the principles of the CIPM MRA be included in intergovernmental agreements as appropriate,

encourages the International Committee to take all possible steps to increase the number of signatories of the CIPM MRA representing NMIs and other designated institutes that form part of the metrological infrastructure of the Members States of the Metre Convention and the Associates of the General Conference.

Involvement of National Metrology Institutes in the complete range of work of the Metre Convention

Resolution 7

The 22nd General Conference,

considering

- the importance of the subject matter covered by the terms of reference of the Consultative Committees,
- the location of many national centres of expertise in the relevant disciplines in specialized institutes outside the National Metrology Institutes,
- the desirability of ensuring the maximum possible participation of National Metrology Institutes and other designated institutes in key comparisons in these areas,

noting that the official notification of changes to the list of designated institutes in Appendix A of the CIPM Mutual Recognition Arrangement (MRA) is transmitted to the International Bureau of Weights and Measures through the signatory National Metrology Institute,

recommends

- that Governments or appropriate official authorities of the Member States of the Metre Convention make appropriate arrangements to associate (or link) the activities and facilities of these other national centres of expertise to the National Metrology Institute by designating them under the CIPM MRA so that they can participate in the activities defined by the MRA, and
- that these facilities be used to provide services for industrial, scientific, medical and other organizations that require or would benefit from calibration results that are traceable to the International System of Units.

Revision of the *mise en pratique* of the definition of the metre

Resolution 8

The 22nd General Conference,

recalling that

- the 21st General Conference in 1999 welcomed the adoption in 1997 by the International Committee of a revised *mise en pratique* of the definition of the metre, and
- the Conference also recommended that national laboratories pursue experimental and theoretical research on optical wavelength and frequency standards, including the development of new techniques for the comparison of different standards over a wide range of wavelength and frequency to improve yet further the experimental basis of the International System of Units (SI),

considering that

- new techniques based on trapped ions and atoms have opened up the possibility of highly accurate and stable optical clocks and frequency standards,
- these systems appear to have the potential for providing the basis for a future, improved, definition of the second,
- the introduction of femtosecond comb technology has considerably facilitated the absolute frequency measurement of optical radiation sources, including those sources used to realize the metre,
- the International Committee in 2002 updated the recommended values of a number of radiations published in the 1997 *mise en pratique* and added values for several new radiations,

welcomes

- the adoption of these new values and their subsequent publication in *Metrologia* in 2003, and
- the close collaboration and discussions between the length and time and frequency communities aimed at the eventual linking of optical and microwave frequency standards,

recommends that national laboratories continue to develop reliable and proven techniques for the generation and comparison of optical and microwave frequency standards, and

invites the International Committee to keep this important subject under regular review, especially in relation to a possible redefinition of the second.

Requirements for cross-border transport of measurement standards, metrological equipment and reference materials

Resolution 9

The 22nd General Conference,

considering

- recent events that are understandably requiring stricter control of container, luggage and carry-on belongings of national and international travellers, as well as unaccompanied packages,
- that these controls are making it more and more difficult, and sometimes impossible, to transport equipment, standards, and reference materials that are needed for comparisons of national measurement standards,
- that these comparisons rely intrinsically on frequent and unimpeded transportation of standards, many of which have limited stability and so require rapid movement,
- that certain samples or equipment are fragile and can become contaminated or damaged beyond the point of use if not handled carefully by personnel in airports, freight handling agencies or customs officials,
- that the inherent dangers in transport of certain samples in the nuclear, chemical and pharmaceutical field for metrology are far less than those envisaged from the point of view of those that seek to prohibit or restrict wholesale movement of such goods,
- the importance of implementing new procedures that can facilitate the unimpeded transport of such materials,
- that this facilitation could be accomplished by modifications, guidance notes or other addenda to existing regulations that inform officials as to the course of action to be undertaken in the case of metrological samples and equipment,

recommends that National Metrology Institutes, government bodies and international organizations responsible for the control and regulation of the movement of goods and substances, all work with relevant bodies to investigate, propose and implement special procedures that relate to the free and unimpeded movement of metrological materials and equipment among National Metrology Institutes, designated institutes and the International Bureau of Weights and Measures,

and further **recommends** the International Committee to draw the attention of other international organizations having responsibilities in this area to this Resolution.

Symbol for the decimal marker

Resolution 10

The 22nd General Conference,

considering that

- a principal purpose of the International System of Units (SI) is to enable values of quantities to be expressed in a manner that can be readily understood throughout the world,
- the value of a quantity is normally expressed as a number times a unit,
- often the number in the expression of the value of a quantity contains multiple digits with an integral part and a decimal part,
- in Resolution 7 of the 9th General Conference, 1948, it is stated that "In numbers, the comma (French practice) or the dot (British practice) is used only to separate the integral part of numbers from the decimal part",
- following a decision of the International Committee made at its 86th meeting (1997), the International Bureau of Weights and Measures now uses the dot (point on the line) as the decimal marker in all the English language versions of its publications, including the English text of the SI Brochure (the definitive international reference on the SI), with the comma (on the line) remaining the decimal marker in all of its French language publications,
- however, some international bodies use the comma on the line as the decimal marker in their English language documents,
- furthermore, some international bodies, including some international standards organizations, specify the decimal marker to be the comma on the line in all languages,
- the prescription of the comma on the line as the decimal marker is in many languages in conflict with the customary usage of the point on the line as the decimal marker in those languages,
- in some languages that are native to more than one country, either the point on the line or the comma on the line is used as the decimal marker depending on the country, while in some countries with more than one native language, either the point on the line or comma on the line is used depending on the language,

declares that the symbol for the decimal marker shall be either the point on the line or the comma on the line,

reaffirms that "Numbers may be divided in groups of three in order to facilitate reading; neither dots nor commas are ever inserted in the spaces between groups", as stated in Resolution 7 of the 9th CGPM, 1948.

Relationship between National Metrology Institutes and Nationally recognized Accreditation Bodies

Resolution 11

The 22nd General Conference,

considering

- the key role played by National Metrology Institutes (NMIs) at the origin of accreditation of calibration and, in some countries, also of testing laboratories to meet the increasing demand for the calibration of measuring standards and instruments traceable to the International System of Units (SI),
- the essential character of a close technical cooperation between the staff of NMIs and Nationally recognized Accreditation Bodies (NABs),
- the overriding importance to the paying customer of technical competence in the accreditation process of calibration and testing laboratories,
- recent tendencies towards the requirement for complete separation between NMI and NAB activities in the name of impartiality, independence and integrity of the latter,
- the evident danger that such a complete separation may have for the technical competence of NABs and, in consequence, for accredited calibration and testing laboratories,
- that the specification and implementation of national practices related to the national measurement and the national accreditation systems are ultimately the responsibility of national Governments,
- that the relationship between the NMI and Nationally recognized Accreditation Body or Bodies varies from country to country; the body or bodies may be part of the NMI, be operated by the NMI or may be completely separated from it,

emphasizing the importance of equitable and harmonized practices in respect of both large and small metrology and accreditation systems in all regions of the world,

recognizing the importance of worldwide harmonization of such practices,

welcomes the recent CIPM-ILAC Memorandum of Understanding between the International Committee for Weights and Measures and the International Laboratory Accreditation Cooperation (ILAC),

calls upon all accreditation organizations to recognize that NMIs and accredited calibration laboratories together provide an indispensable route to traceability to the SI and hence to reliability in measurements and worldwide comparability of measurement results for the whole economy and society and that they should work closely together,

recommends that

- Member Governments of the Metre Convention ensure that an appropriate relationship exists between NMIs and NABs,
- this relationship fosters collaboration on matters concerning traceability of measurement results and ensures effective and complementary actions under the CIPM MRA and the ILAC arrangement,

and notes that calibration is not a conformity assessment activity.

Dotation of the BIPM for the years 2005 to 2008

Resolution 12

The 22nd General Conference,

considering

- the increasing importance of metrology for trade, industry, the environment and human health and safety in all Member States of the Metre Convention,
- the corresponding need for an efficient, highly expert, international coordination of metrological activities,
- the central role played by the International Bureau of Weights and Measures (BIPM) in such coordination and the services it renders to Member States of the Metre Convention,
- the broadened responsibilities given to the BIPM at the 21st General Conference in 1999 but without any corresponding increase in dotation,
- the additional increase in workload, unforeseen at the time of the 21st General Conference, that has also been absorbed by the BIPM since the last General Conference,
- the extension of the range of work under the Metre Convention now carried out in Member States, notably in areas of chemistry, biotechnology and medicine,
- the need to extend the range of expertise among the scientific staff of the BIPM to meet demands in these new areas,
- the considerable efforts that continue to be made by the BIPM to enhance the efficiency of its operation, and its commitment to continue these efforts,

recognizing

- the difficult economic situation now existing in some Member States and the consequent strict limits on direct contributions to intergovernmental organizations,
- the high importance of the work of the BIPM for all Member States,
- the need to provide the financial and other means to enable the BIPM to meet the increasing demand placed upon it,

invites National Metrology Institutes (NMIs)

- to arrange, at their expense, a continuing series of short-term placements or secondments of their staff to the BIPM to work on projects of mutual interest integrated into the BIPM programme,
- to accept staff of the BIPM to work in their institutes on programmes of mutual interest,
- to sponsor a permanent programme of Fellowships at the BIPM for suitable staff with a view to establishing four such Fellowships at the BIPM by the end of 2004 on projects of mutual interest to the sponsoring NMI and the BIPM,

further invites individual governments, National Metrology Institutes and international organizations as well as private organizations and foundations to make additional financial contributions or contributions in kind to the BIPM,

decides that the fixed part of the annual dotation of the BIPM will be increased in such a way that the fixed part and the complementary part (defined by Article 6, 1921) of the Rules annexed to the Metre Convention (1875) shall, for those States that are members of the Metre Convention at the time of the 22nd General Conference, be

9 587 000 euros in 2005
9 779 000 euros in 2006
9 974 000 euros in 2007
10 174 000 euros in 2008,

further decides to support the increasing workload of the BIPM by an additional discretionary contribution of

130 000 euros in 2005
132 000 euros in 2006
136 000 euros in 2007
138 000 euros in 2008,

requests Member States to declare to the BIPM, at the latest by 1 April 2004, their intention to pay for the full four years their share of this discretionary contribution.

Appendix A

Convocation of the 22nd General Conference on Weights and Measures

Note: The text of the present Convocation was sent to the Governments of the Member States of the Metre Convention and Associates of the General Conference in December 2002. Three Draft Resolutions on the symbol for the decimal marker in the International System of Units (SI) were added in April 2003. A number of Draft Resolutions were modified during the General Conference; the final adopted Resolutions are given on pages 373-384.

Convocation of the 22nd General Conference on Weights and Measures

The 22nd General Conference is hereby convoked for

Monday the 13th of October 2003 at 10:00

at the Centre de Conférences Internationales, 19 Avenue Kléber, Paris 16e.

Constitution of the 22nd General Conference

Convention du Mètre (1875): Article 3*

> "The operation of the International Bureau of Weights and Measures shall be under the exclusive direction and supervision of an International Committee** which latter shall be under the control of a General Conference*** to be composed of the delegates of all the contracting Governments."

Rules annexed to the Metre Convention (1875): Article 7

> "The General Conference, mentioned in Article 3 of the Convention, will meet in Paris on the convocation of the International Committee at least once every six years.
>
> Its task is to discuss and to initiate measures necessary for the propagation and improvement of the metric system, and to sanction new fundamental metrological measurements and initiatives which may have been made between its meetings. It will receive a report from the International Committee on the work accomplished and will proceed, by secret ballot, to the renewal of half of the International Committee.
>
> Votes at the General Conference take place by States: each State has the right to one vote.
>
> The members of the International Committee have the right to take part in the meetings of the Conference. They may at the same time be delegates of their Governments."

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* BIPM translation.

** Often referred to in this document as CIPM or International Committee.

*** Often referred to in this document at CGPM or General Conference

Place and dates of sessions of the 22nd General Conference

All the sessions will take place at the

Centre de Conférences Internationales
19, avenue Kléber, Paris 16e

in a room offered by the Ministère des Affaires Étrangères de France with simultaneous translation in French and English.

First session,	Monday	13 October 2003	at 10:00
Second session,	Monday	13 October 2003	at 15:00
Third session,	Tuesday	14 October 2003	at 09:30
Fourth session,	Thursday	16 October 2003	at 09:30
Fifth session,	Friday	17 October 2003	at 09:30
Sixth session,	Friday	17 October 2003	at 15:00

A meeting of directors of National Metrology Institutes of the Member States will take place on Wednesday 15 October starting at 09:30 at the BIPM to be followed by visits to the laboratories and a reception in the grounds of the Pavillon de Breteuil. The Directors' Meeting of is not, formally, a part of the General Conference and will be chaired by the President of the International Committee.

The General Conference Working Group on the Dotation of the BIPM will meet at 15:00 on Tuesday 14 October and, if required, on Thursday 16 October at 15:00. The meetings of the working group will take place at the Centre de Conférences Internationales.

It is expected that most of the main points of the agenda up to and including Item 10 will be dealt with in session one, and that session two will concentrate on Items 11 and 15. Session 3 will consider Items 12 and 13 and will conclude with a number of reports from Consultative Committees (Item 14). Item 14 will be concluded in session four which will also contain a preliminary report of the Working Group on the Dotation so that the Group can complete its work and report to session five. This session and session 6 will be concerned with voting on all the Resolutions and the remaining agenda items.

Provisional agenda of the 22nd General Conference

1 Opening of the Conference.

2 Address by His Excellency the Ministre des Affaires Étrangères de la République Française.

3 Reply by the President of the International Committee.

4 Address by the President of the Académie des Sciences de Paris, President of the Conference.

5 Presentation of credentials by delegates.

6 Nomination of Secretary of the Conference.

7 Establishment of the list of delegates entitled to vote.

8 Approval of the agenda.

9 Report of the President of the International Committee on work accomplished since the 21st General Conference.

10 External relations, including those with the Organisation Internationale de Métrologie Légale (OIML), the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the World Meteorological Organization (WMO).

11 Report of the CIPM on evolving needs for metrology in trade, industry and society and the role of the BIPM.

12 Report on the implementation of the CIPM Mutual Recognition Arrangement.

13 Report on the admission of Associates of the General Conference.

14 Reports of Presidents of Consultative Committees:

- 14.1 The Consultative Committee for Length;
- 14.2 The Consultative Committee for Mass and Related Quantities;
- 14.3 The Consultative Committee for Time and Frequency;
- 14.4 The Consultative Committee for Electricity and Magnetism;
- 14.5 The Consultative Committee for Thermometry;
- 14.6 The Consultative Committee for Photometry and Radiometry;
- 14.7 The Consultative Committee for Ionizing Radiation;
- 14.8 The Consultative Committee for Amount of Substance;
- 14.9 The Consultative Committee for Acoustics, Ultrasound and Vibration;
- 14.10 The Consultative Committee for Units.

15 Programme of future work at the BIPM.

16 Annual dotation of the BIPM.

17 Proposals by delegates.

18 Renewal of half of the International Committee.

19 Votes on all Resolutions.

20 Other business.

21 Closure of the Conference.

Notes on the principal points of the agenda

Note on Draft Resolutions: the place in the Convocation at which the Draft Resolutions are presented does not necessarily reflect the position in the agenda at which they will be discussed or voted upon. In all cases, votes on the Resolutions are taken on the last day of the Conference after all discussion has been completed.

1 Opening of the Conference

The 22nd General Conference is taking place four years after the preceding Conference. The practice of having quadrennial General Conferences is now well established, since such a periodicity provides sufficient opportunity for Member States to review the important activities carried out under the Convention while not being so frequent that the administrative and other costs of running a General Conference are prohibitive.

5 Presentation of credentials by delegates

To help in the efficient organization of the Conference, it is desirable that the BIPM be informed of the composition of each delegation at least two weeks before the opening of the Conference.

Delegates entitled to vote at the Conference are required, on arrival, to present credentials from an appropriate authority of their Government.

9 Report of the President of the International Committee

Article 19 of the Rules annexed to the Metre Convention stipulates that "The President of the International Committee will give the General Conference an account of the work carried out since the time of the last meeting".

In his report to the 22nd General Conference, the President will review the important developments that have taken place in the affairs of the Metre Convention since the 21st General Conference.

The first task is to welcome Greece and Malaysia as new Member States of the Metre Convention and the re-integration of Yugoslavia into the Convention, and Chinese Taipei, Cuba, Ecuador, Hong Kong (China), Kenya, Latvia, Lithuania, Malta, Philippines, and Ukraine as Associates of the CGPM.

A major change during the period since the last General Conference, and one that has major implications for the work of the Metre Convention, as well as for several other intergovernmental and international organizations, is that National Metrology Institutes (NMIs) have identified many new requirements for traceable measurements. These now form entirely new areas of activity under the Metre Convention. We have noted the continued demand for higher accuracy in traditional areas of activity. We have also noted challenging applications in all of the key technologies such as nanotechnology, information technology and communications, space, biotechnology, medicine and pharmaceuticals that have been identified by Member States as important for their long-term economic development. There are issues that

the CIPM and the CGPM need to consider if traceable measurement is to be introduced into these areas. An important outcome of this burgeoning demand for measurement has been the recognition by even the largest NMIs that they cannot address all of these new demands individually and that cooperation is becoming essential. This raises the importance of the co-ordination and knowledge/technology transfer role of the BIPM through the CIPM Consultative Committees. The possibility of an increased role for the BIPM in this area was also identified in Resolution 1 of the 21st CGPM and future programmes of work will reflect this.

Over the past few years, many NMIs have been examining the economic importance of all areas of their work, have prioritized their work and are reflecting these priorities in the choice of projects and programmes. This process of priority setting has been facilitated by the local strategies of mutual dependence developed by some of the regional metrology organizations (RMOs). This greater degree of mutual dependence makes sense from the point of view of an individual NMI. But it will be important to ensure that, as a result of the choices made by NMIs there is still an adequate range and diversity of approaches to the improvement of the definitions and to the independent realizations of the International System of Units (SI). The Consultative Committees of the CIPM are uniquely positioned to maintain an oversight of this trend and to alert NMIs if there are gaps.

The CIPM has considered carefully how it should react to the trends and has discussed with and taken advice from NMI directors as to how best to extend the SI into the new areas. The CIPM has also looked particularly carefully at the BIPM's role in facilitating coordination of work at NMIs, as a facilitator of high-level contacts and connections at the intergovernmental level and as a unique focus for knowledge of international metrology and technology transfer between all NMIs. It has also looked hard at the balance of technical and administrative support that the BIPM has traditionally given to all members of the Metre Convention and at how it should plan to serve the needs of world metrology for the next decade. Much of this thinking was already implicit in the discussions at the 21st General Conference and in the report on *National and International Needs relating to Metrology* (the "Blevin" Report). But even that report and the debate at the 21st General Conference underestimated the speed and the extent of the expansion of metrology into new areas. Nor was it appreciated how far-reaching would become the importance now attached by Governments and international organizations to the relationship between metrology, trade, human health and safety. The impact and benefits already emerging from the CIPM Mutual Recognition Arrangement (MRA) as well as the work required to implement it in NMIs and at the BIPM were also underestimated. The CIPM therefore requested an update of the "Blevin" report presented to the 21st General Conference together with a new assessment of the implications of recent developments. In preparing this report, the CIPM consulted NMIs so as to solicit their views on the effectiveness and utility of the BIPM's activities. This will be reported separately together with important implications for the future. It will be a key issue for the Conference. In addition, and because of the unique role that it plays internationally, the BIPM also commissioned a report on the economic benefits that it brings to members of the Metre Convention through such activity. These reports result in major financial implications for the BIPM and for its activities. In this respect, the CIPM at its meeting in 2002, made a number of decisions regarding the future programme of work at the BIPM to enable it to meet changing demands for work while at the same time respecting the likely financial constraints for the period 2005 to 2008. These issues will be discussed further under agenda Items 15 and 16.

Resolution 1 of the 21st General Conference also encouraged the BIPM to develop its responsibilities beyond the traditional coverage of metrology and to address emerging global

need in, for example, chemistry and biotechnology. This has proved to be extremely far-sighted and the CIPM took the view that in order to promote and extend the concept of the SI and traceable measurement into these areas it was vital to develop partnerships with key bodies in the field. One particularly important way of doing this is to follow the support given at the last CGPM for an increase in the BIPM's interactions with other international and inter-governmental organizations. Since then several Memoranda of Understanding (MoUs) and agreements have been signed with key organizations and plans of action have been developed so as to tackle real issues of importance to both parties. The President will highlight the present state of activity in this field. He will discuss the growing importance of scientific as well as policy links with international organizations and the benefits that these bring to the implementation of initiatives to develop confidence in the accuracy and acceptability of measurements worldwide. The BIPM is uniquely positioned to open up such opportunities on behalf of the NMIs of Member States – a task that is more generally acceptable to the partner bodies than if it had come from a single NMI. In several cases, Joint Committees have also been created. These are now highly credible and increasingly influential bodies through which to work and their multipartite nature ensures that the results of their work are implemented in the new communities. The way in which the BIPM ensures that it has technical credibility when dealing with such bodies is a key issue for decisions in the CIPM and at this Conference. It is, however, broadly accepted that the BIPM's success is strongly related to its scientific and technical credibility and that this credibility is a direct result of its scientific programme.

Resolution 1 of the 21st General Conference welcomed the collaboration between the BIPM and the RMOs. It also welcomed the meetings between the CIPM and the NMI directors as well as collaborations with relevant international organizations. These interactions have increased substantially and such "Directors' Meetings" now form a regular, and highly regarded, part of life for NMIs and for the BIPM. Valuable two-way information flows have been established and the meetings have served as a unique, high-quality, sounding board and discussion forum for matters of mutual interest. There have also been many new links created at the working, technical level and BIPM staff are regularly invited to attend a range of meetings of the RMOs, especially when issues relating to the CIPM MRA are discussed. In response, the BIPM now makes sure that the positions of all RMOs can be represented at meetings of the CIPM Consultative Committees. This helps ensure, for example, that all RMO views can efficiently be taken into account in a single meeting and that the outcomes can be swiftly and effectively communicated back to the RMOs. At a different level, the Joint Committee of the Regional Metrology Organizations and the BIPM (the JCRB) now meets twice a year and is becoming the forum in which issues relating to the implementation of the MRA are being aired and operating decisions taken.

It is, however, the work of the CIPM MRA that has undoubtedly had the widest and most profound effect on the work of the BIPM. In fact, the effort needed to deal with all the consequent activities was far more than was thought to be the case at the last CGPM. It has also, of course, had a huge impact on the activities of the NMIs and the RMOs and is, as we hoped, already creating considerable interest among regulators, accreditors and other intergovernmental bodies. It has been an important influence on the reduction of non-tariff barriers to trade and is placed to have an impact on sanitary and phyto-sanitary issues. The details of this activity will be reported separately to the Conference but amongst the more significant results are:

- a full commitment to the work of the MRA by all NMIs and the national bodies on whose behalf they signed the MRA; the biggest impact here has been an increased level of participation in comparisons despite the significant resource implications;

- a more formal framework within which comparisons have been carried out with a consequential higher level of collaboration and interaction between NMI scientists;
- a thorough review of Calibration and Measurement Capability (CMC) claims within as well as between RMOs; many CMCs were challenged which resulted, in the majority of cases, in more realistic uncertainty budgets;
- the identification of significant and unsuspected errors in the realization of certain units and quantities at several NMIs that could otherwise have gone unnoticed for many years;
- a recognition by several countries as to the benefits of becoming an Associate of the CGPM particularly because of the advantages of recognition of their measurement capabilities that are conferred through participation in the MRA and the value that this brings to trade and international recognition;
- a closer relationship between BIPM and accreditors, particularly through an important MoU with ILAC, and intense intergovernmental activity as well as a great deal of work by the NMIs and regional economic groupings so as to take account of the MRA in regulation, legislation, and international trade agreements; and
- a perceived significant value to intergovernmental and international bodies in accessing and using those processes, established and accepted within the MRA, as a means of extending the Metre Convention framework into new areas of activity that identify a requirement for traceable measurement.

The period since the last Conference has seen the conclusion of a long-term plan for the provision of new buildings at the BIPM, financed by savings from current income without any additional dotation. A laboratory building for the laser work was completed in 1984, the construction of a building for a library and offices was finished in 1988 and, finally, a building for the mechanical workshop, offices and meeting facilities was completed in 2001. The BIPM is now well placed to meet immediate and foreseen demands.

In the period since the last Conference, the BIPM has used the most modern information technology to support its meetings and to enhance its communications and interfaces with the external world. The website, still in the process of evolution and development, is used by Consultative and Joint Committees to host all documents for meetings as well as information that is useful to the communities in between meetings. All Consultative Committees and Joint Committee meetings are now “paperless” and enhanced networking and information technology in the main conference room enables delegates to use individual PCs as well as to have real-time Internet access.

One especially significant event was the 125th anniversary of the signing of the Metre Convention itself. To celebrate the anniversary, a special conference, organized in collaboration with the French Academy of Sciences, was held in October 2000 at the time of a Directors’ Meeting and of the annual meeting of the CIPM. The conference attracted a large attendance and included eight technical presentations, five of which were delivered by Nobel Prize winners.

On personnel issues, there have been several changes to the membership of the CIPM itself, including a change of Secretary from Dr W.R. Blevin to Dr R. Kaarls as well as the election of two new Vice Presidents, Prof. G. Moscati and Dr B. Inglis. With several recent elections to the Committee we hope that we can look forward to a more stable membership over the next few, crucial, years for the BIPM. During the period since the last Conference, the CIPM has also appointed Andrew Wallard to succeed Terry Quinn as Director on 1 January 2004.

Finally, the President will report on the technical work of the BIPM since the 21st General Conference.

10 External relations

10.1 In the period since the last General Conference, there have been several meetings of the joint OIML/BIPM/ILAC working group. These have covered a range of topics but specific issues that have been discussed include:

- the relationship between the CIPM MRA and those either developed or being developed by the International Laboratory Accreditation Cooperation (ILAC) and the Organisation Internationale de Métrologie Légale (OIML);
- regular reviews of progress on joint activities including the Joint Committee for Guides in Metrology (JCGM), in particular, a definition of the term "traceability" that could be used by all three organizations; the JCGM operates through two working groups: Working Group 1, on the *Guide to the Expression of Uncertainty in Measurement* (the GUM) and Working Group 2, on the *International Vocabulary of Basic and General Terms in Metrology* (the VIM);
- discussions on the OIML draft law on metrology where BIPM has been asked for comments;
- action by the CIPM and others in relationship to the draft text of ISO 17011 regarding the position of NMIs that also operate accreditation services; this developed consensus on the steps that such NMIs had taken to avoid conflicts of interest and led to a redrafting of the relevant paragraphs; and
- a common position on the need to improve the coordination of the activities related to metrology in developing countries of the three organizations as well as those of the International Accreditation Forum (IAF), the International Electrotechnical Commission (IEC), the International Organization for Standardization (ISO), and the United Nations Educational, Scientific and Cultural Organization (UNESCO). As a result, these organizations have formed a Joint Committee, the Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization (JCDCMAS). The additional aim of the Committee is to promote metrology, accreditation and standardization and provide a technical and advisory resource for funding agencies so as to improve the effectiveness of their funding of metrology infrastructures in developing countries.

10.2 On 3 November 2001, the ILAC and the BIPM signed a Memorandum of Understanding, the text of which can be found on the BIPM website. It commits both organizations to strengthen cooperation and to refer, wherever possible, to the MRAs drawn up by the two organizations. In addition, there are separate formal arrangements between the BIPM, the World Health Organization (WHO) and the World Meteorological Organization (WMO). The WHO and WMO are invited to attend the CGPM as observers, and to appropriate meetings of Consultative Committees and Joint Committees. The letters of agreement between the BIPM and the organizations also recognize each other's responsibility and remit in the respective areas of common interest and the value of working together. The BIPM is invited to appropriate meetings of the organizations. These working agreements are of key importance in promoting metrology in areas where up to now it has not had a high profile.

10.3 The BIPM has also developed similar informal close working relations with a number of international and intergovernmental organizations so as to seek cooperation and define joint activities of mutual benefit. The CIPM believes that this should continue, noting in particular that as the Metre Convention extends its influence technically as well as into new domains of application, there are enormous advantages to working in collaboration with other organizations. There are three specific advantages. First, it clearly helps to unify and coordinate the work of the BIPM with organizations like the ILAC and the OIML that are also concerned with traceability and worldwide confidence in measurement in a general sense. Second, it enables the BIPM to work with user-based bodies that have knowledge, expertise and credibility in new communities such as health and food. Links and partnerships with these bodies are vital so as to ensure widespread, effective and efficient adoption of measurement-related practices. Third, and especially in the field of regulation trade and legislation, collaboration will help raise the profile of metrology and especially the relevance, uptake, and use of the CIPM MRA as a framework to be employed in support of their initiatives to reduce technical barriers to trade.

The CIPM therefore wishes to propose three Draft Resolutions to the General Conference. The first is aimed at general collaboration. The second draft is aimed specifically at the relevance of the MRA to trade. In this connection, the BIPM has been seeking "observer status" representation on the World Trade Organization (WTO) Committee on Technical Barriers to Trade. So far there has been no progress in securing such representation despite increasingly good cooperation at the working level. This remains a matter of considerable concern to the CIPM. Finally, the third Draft Resolution refers to the coordination of the initiatives to support metrology, accreditation and standardization in developing countries and economies.

▮ Links with other organizations

Draft Resolution A

The 22nd General Conference,

considering

- the work of the Metre Convention in extending the concept of traceable measurement into new application areas,
- the evident value of collaboration and Joint Committees already established by the International Bureau of Weights and Measures (BIPM) with other international organizations,
- the need to seek efficiency through collaboration and partnerships where these serve the common aims and objectives of other international organizations,
- the long-standing relations with the Organisation Internationale de Métrologie Légale (OIML),

noting and welcoming the formal arrangements recently created by the BIPM with the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the World Meteorological Organization (WMO), and the efforts of the BIPM to draw up similar arrangements with other bodies,

invites

- international and intergovernmental organizations for which metrology impinges on their activities to cooperate with BIPM, to develop similar formal relationships and, if necessary, participate in Joint Committees,
- all Member States to help implement the results of these collaborations and the joint efforts so as to extend the influence and impact of the Metre Convention and of traceable measurements into user domains where these form part of national rather than international responsibilities.

▮ Metrology and trade

Draft Resolution B

The 22nd General Conference,

considering

- the increasing role of reliable and comparable measurements in world trade,
- the commitment of the World Trade Organization (WTO) to the reduction in non-tariff barriers to trade,
- the recent report commissioned by the International Bureau of Weights and Measures from a commercial consulting company on the economic impact of the CIPM Mutual Recognition Arrangement on world trade,

notes the long-standing application made by the BIPM for observer status on the WTO Committee on Technical Barriers to Trade, and

requests Member States of the Metre Convention to press for a positive acceptance of this application as soon as possible.

▮ On the coordination of the initiatives to support the implementation of metrology, accreditation, and standardization in developing countries and economies

Draft Resolution C

The 22nd General Conference,

considering

- the desirability of extending relationships between the Metre Convention and the bodies working on aspects of metrology, accreditation and standardization infrastructures in developing countries and economies,
- the value of creating a coherent, coordinated approach to metrology, accreditation and standardization,
- the creation of a Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization (JCDCMAS), involving representatives of the International Bureau of Weights and Measures (BIPM), the International Accreditation Forum (IAF), the International Electrotechnical Commission (IEC), the International Laboratory

Accreditation Cooperation (ILAC), the International Organization for Standardization (ISO), the International Telecommunication Union (ITU), the Organisation Internationale de Métrologie Légale (OIML), and the United Nations Industrial Development Organization (UNIDO),

- the initiatives of several Member States of the Metre Convention in support of metrology in developing countries,

noting the independent policy relationships between Member States of the Metre Convention and a number of the partner bodies in the JCDCMAS,

welcomes and supports the participation of the Metre Convention in the work of the JCDCMAS with the specific remit to assist in a coherent technical implementation of metrology, accreditation and standardization in developing countries and economies in such a way as to avoid any conflict with the independent policies and activities of the national metrology institutes of Member States of the Metre Convention.

10.4 The CIPM also notes the desirability of an increase in the membership of the Metre Convention and of steps to promote the benefits of membership as well as of Associate membership of the General Conference. There are many countries and economies which are, for example, either a member of the WTO or of the OIML but which are not members of the Metre Convention. The CIPM believes that the JCDCMAS will inevitably draw the attention of developing countries and other non-members of the Metre Convention that are members of the partner bodies, to the work of the Convention. These are opportunities to be grasped. The CIPM is also aware that as there is evident willingness of international bodies such at the European Commission to refer to the CIPM MRA in its trade agreements with the United States as well as in other major trade agreements. This is on the one hand desirable and a mark of the perceived value of the MRA but its very success may actually create the possibility that such requirements for participation in the CIPM MRA may itself appear to be a technical barrier to trade. It therefore seems clear that renewed efforts should be made to extend the membership of the Metre Convention.

The CIPM welcomes the initiatives already taken by the BIPM to promote membership of the Convention and to attract new members. It therefore proposes the following Draft Resolution to the General Conference.

▮ Value and benefits of the Metre Convention for Member States and for Associates of the General Conference

Draft Resolution D

The 22nd General Conference,

considering

- the clear technical and economic benefits to countries and economies of being Member States of the Metre Convention or Associates of the General Conference,
- the desirability of extending the number of Member States or Associates so as to widen the impact and the benefit of participation in the CIPM Mutual Recognition Arrangement (MRA),

- the need to ensure that the CIPM MRA is not seen as a technical barrier to trade but, on the contrary, is seen as an Arrangement that gives equal opportunities to all,

welcomes

- the initiatives already taken by the International Bureau of Weights and Measures to promote membership of the Metre Convention and increase the number of members and Associates of the General Conference,
- the potential of the Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization (JCDCMAS) for alerting non-members to the merits of membership, and

invites Member States to promote wider membership through their initiatives, such as aid programmes, in developing countries, and through their discussions in appropriate international fora.

11 Report of the CIPM on evolving needs for metrology in trade, industry and society and the role of the BIPM

The last CGPM received and discussed a report *National and International Needs relating to Metrology* prepared by the then Secretary of the CIPM, Dr W.R. Blevin. This proved to be a widely-referenced and widely-used document, and the CIPM considered it important to update and review it so as to inform its own work as well as the decisions to be taken by the 22nd CGPM. This update, prepared by Dr R. Kaarls, is available on the BIPM website (www.bipm.org) and will be introduced by Dr Kaarls to the Conference.

This report emphasizes particularly the developments in new areas and their relevance to the needs of society. It highlights the growing role of the BIPM in the communities concerned. In respect of the new Report, the CIPM proposes the following Draft Resolution.

▮ Report on evolving needs for metrology in trade, industry and society, and the role of the International Bureau of Weights and Measures

Draft Resolution E

The 22nd General Conference,

considering

- Resolution 11 of the 20th General Conference, which recommended to the International Committee that it study the long-term needs relating to metrology,
- Resolution 1 of the 21st General Conference, which noted the Report to the General Conference on long-term needs relating to metrology,
- the new Report adopted by the International Committee in October 2002,

notes

- the content of the new Report,
- its contribution to the identification of priorities within current activities and to the setting of new priorities,
- its contribution to the decisions of the International Committee on the programme of future work at the International Bureau of Weights and Measures (BIPM),

thanks the many organizations and individuals who contributed to the work of the International Committee, and

invites the International Committee

- to continue to keep a careful watch on the increasing demands placed on the national metrology institutes and the BIPM as far as their current work in metrology is concerned and the additional activities generated by new needs in new areas such as chemistry, biotechnology, medicine, the environment and food,
- to report to the next General Conference on the adequacy of the response of the BIPM to meet these needs together with any financial and programme implications there may be in relation to the meeting of such international needs through the activities of the BIPM, and
- if necessary, to update their 2002 Report.

12 Report on the implementation of the CIPM Mutual Recognition Arrangement

The Director of the BIPM will report to the General Conference on the current state of the CIPM Mutual Recognition Arrangement (the MRA). Specifically he will comment on any changes or additions which may be necessary to the MRA as a result of representations from signatories. It also proposes that the formal end of the transition period for the MRA be 31 December 2003, by which time the majority of CMCs from signatories and designated laboratories will have been reviewed and entered into the BIPM key comparison database. In addition, the majority of NMIs and designated laboratories will have complied with or have firm plans to comply with the requirements for Quality Systems.

The considerable interest that the MRA has created among accreditors, regulators, intergovernmental bodies and users of NMI services will be presented to the General Conference. The CIPM notes that the report by private consultants on the international activities of the BIPM referred to the importance of promoting the importance, potential impact and overall benefit to be gained from widespread uptake of the MRA. The CIPM therefore proposes the following Draft Resolution to the General Conference.

▮ On the importance of the CIPM Mutual Recognition Arrangement

Draft Resolution F

The 22nd General Conference,

noting

- the positive social and economic impact, including lowering the costs of non-tariff barriers to trade, that are expected from adoption, by regulators and legislators of the CIPM Mutual Recognition Arrangement (MRA),
- the effect of the CIPM MRA in building mutual confidence between trading partners,
- the interest already created with certain regulatory authorities, trade organizations and national authorities,
- the use of the CIPM MRA, for example, in facilitating the European Union/United States trade agreement,

welcomes the interest shown by these bodies, and

invites all Member States to press their national regulatory, accreditation, standardization and legislative bodies to adopt the CIPM MRA as a framework for acceptance of calibration and measurement certificates from national metrology institutes (NMIs) and designated institutes as well as from accredited laboratories that can demonstrate traceability to the International System of Units through standards realized by the signatory NMIs and designated institutes.

13 Report on the admission of Associates of the General Conference

The President will inform the General Conference on the current situation.

14 Reports of Presidents of Consultative Committees

The Presidents of the ten Consultative Committees of the CIPM will make short presentations on the work accomplished since the 21st General Conference. The published reports of the meetings of the Consultative Committees cited by the Presidents in their reports are available on the BIPM home page on the World Wide Web (www.bipm.org).

In the interest of the widest possible involvement in the work of its Consultative Committees, and because some Member States do not always allocate responsibility for certain standards in National Metrology Institutes or designated institutes named in the CIPM MRA, the CIPM made the following draft proposal to the General Conference:

▮ Involvement of National Metrology Institutes in the complete range of work of the Metre Convention

Draft Resolution G

The 22nd General Conference,

considering

- the importance of the subject matter covered by the terms of reference of the Consultative Committees,
- the location of many national centres of expertise in the relevant disciplines in specialized institutes outside the National Metrology Institutes,
- the desirability of ensuring the maximum possible participation of National Metrology Institutes and other designated institutes in key comparisons in these areas,

noting that the official notification of changes to the list of designated institutes in Appendix A of the CIPM Mutual Recognition Arrangement (MRA) is transmitted to the International Bureau of Weights and Measures through the signatory National Metrology Institute,

recommends

- that Governments of the Member States of the Metre Convention make appropriate arrangements to associate (or link) the activities and facilities of these other national centres of expertise to the National Metrology Institute by designating them under the CIPM MRA so that they can participate in the activities defined by the MRA, and
- that these facilities be used to provide services for industrial, scientific, medical and other organizations that require or would benefit from calibrations that are traceable to the International System of Units.

14.1 The Consultative Committee for Length

The Consultative Committee for Length (CCL) met in September 2001 and concentrated on the reports of its two working groups: the Working Group on Dimensional Metrology (WGDM) and the Working Group on the *Mise en Pratique* of the Definition of the Metre. The WGDM deal mostly with the reports and conclusions of the key comparisons and the entry of appropriate data into Appendix C of the MRA. The Working Group on the *Mise en Pratique* reported on moves to deal with the advent of new comb-based frequency measurement technology especially its potential for linking optical and microwave frequency measurements. The Group prepared a set of recommended values for the frequencies of the light sources used in spectroscopy as well as in dimensional measurement. These will form the basis of a revised "*mise en pratique*" which is in course of finalization and publication.

▮ Revision of the *mise en pratique* of the definition of the metre

Draft Resolution H

The 22nd General Conference,

recalling that

- the 21st General Conference in 1999 welcomed the adoption in 1997 by the International Committee of a revised *mise en pratique* of the definition of the metre, and
- the Conference also recommended that national laboratories pursue experimental and theoretical research on optical wavelength and frequency standards, including the development of new techniques for the comparison of different standards over a wide range of wavelength and frequency to improve yet further the experimental basis of the International System of Units (SI),

considering that

- new techniques based on trapped ions and atoms have opened up the possibility of highly accurate and stable optical frequency standards and references,
- these systems appear to have the potential for providing the basis for a future, improved, definition of the second,
- the introduction of femtosecond comb technology has made it possible to make absolute frequency measurements on optical radiation sources, including those sources used to realize the metre,
- the International Committee in 2002 updated the recommended values of a number of radiations published in the 1997 *mise en pratique* and added values for several new radiations,

welcomes

- the adoption of these new values and their subsequent publication in *Metrologia* in 2003, and
- the close collaboration and discussions between the length and time and frequency communities aimed at the eventual linking of optical and microwave frequency standards,

recommends that national laboratories continue to develop reliable and proven techniques for the generation and comparison of optical frequency standards, and

invites the International Committee to keep this important subject under regular review, especially in relation to a possible redefinition of the second.

14.2 The Consultative Committee for Mass and Related Quantities

The Consultative Committee for Mass and Related Quantities (CCM) met in May 1999 (7th meeting) and in May 2002 (8th meeting). The earlier meeting concentrated on reports of CIPM key comparisons and reviewed projects at several NMIs on the precision weighing process, the cleaning and manufacturing processes for Pt-Ir prototypes and for stainless steel standards. Most of these activities were closely correlated with the activities of the Mass section

of the BIPM. The Committee also considered reports from its working groups on force, low, medium and high pressures, the Avogadro constant and hardness. The CIPM approved the results of the Working Group on Density which led to the publication of a new density table of water.

In 2000, common problems related to key comparisons were discussed at the chairpersons' meeting at the National Physical Laboratory (United Kingdom) which adopted CCM guidelines based closely on those issued by the BIPM for the implementation of key comparisons.

At its 8th meeting, the CCM took the first report from its Working Group on Fluid Flow established in 1999 and reviewed its work, as well as that of other working groups, on key comparisons. The linkages with RMO Technical Committees were discussed intensively by the RMO representatives and the current status, results and plans of many RMO key comparisons were approved. Details of the practical matters associated with key comparisons, such as transportation, stability, uncertainty of artefacts, and the period between key comparisons, were discussed within the working groups in the CCM in order to maintain best metrological practice.

The new Working Group on Gravimetry, created in 2001 by the CIPM, met and the results of its most recent comparison at the BIPM in 2001 were discussed.

The Working Group on the Avogadro Constant, at its annual meeting, revised its plans for a programme designed to achieve its target of an uncertainty level at the level of a part in 10^8.

A special publication of *Metrologia* featured the latest research achievements in pressure standards and a further edition is planned for the mass and density areas.

14.3 The Consultative Committee for Time and Frequency

The Consultative Committee for Time and Frequency (CCTF) met for its 14th meeting in April 1999 and for its 15th meeting in June 2001. The Committee noted and welcomed the progressive introduction of caesium fountains and the beginnings of their contribution to International Atomic Time (TAI). They also noted with interest the development of absolute frequency measurements of visible radiations made possible through advances in femtosecond comb technology and encouraged closer liaison between the CCTF and the CCL. The CCTF has also endorsed the work of the BIPM Time section in developing new algorithms for calculations of Coordinated Universal Time (UTC) and has considered the implications of a possible redefinition of UTC that may mean the abandonment of leap seconds. The CCTF is working with the International Telecommunications Union, which is responsible for these matters. The Committee is also monitoring the increasing use of atomic clocks in space and the emergence of a new European time system (Galileo).

14.4 The Consultative Committee for Electricity and Magnetism

The Consultative Committee for Electricity and Magnetism (CCEM) met for its 22nd meeting in September 2000 and for its 23rd meeting in September 2002. The 22nd meeting took particular note of the work towards redefining the kilogram based on "watt balances" and the relevance of the regular adjustments of the fundamental constants to electrical measurements. The work of the Committee and its working groups had been heavily influenced by the large number of key comparisons in the area as well as by the number of CMCs that are processed for inclusion in the BIPM key comparison database (KCDB). The CCEM Working Group on Key Comparisons had

taken a particular interest in the methods used to link CIPM and RMO comparisons in the same area.

Meetings of the Working Group for ac Measurements of the Quantized Hall Resistance, the Working Group on Radiofrequency Quantities and the Working Group on Key Comparisons immediately preceded the 23rd meeting of the CCEM in September 2002. The CCEM Working Group on Electrical Methods to Monitor the Stability of the Kilogram met in Ottawa in June 2002 after the CPEM 2002. All of these meetings reflect the high level of interest among the NMIs in the area of electricity and magnetism. In the domain of activities related to the MRA, the CCEM and its working groups put particular efforts into establishing procedures for carrying out RMO and CCEM key comparisons, approving the results and making them available through the KCDB. In doing this, special attention is being given to speeding up the key comparison process and maintaining the number of key comparisons at levels that will not become burdensome to NMIs. As for the scientific metrology side of the work of the CCEM, the Committee noted that the CIPM agreed with its declaration to reduce the relative standard uncertainty assigned to the conventional value of the von Klitzing constant to one part in 10^7. In this meeting the CCEM reaffirmed the importance given by electrical metrologists to maintaining the direct link of the electrical units to the SI rather than establishing the link indirectly through fundamental constants and theoretical calculations. It also took note of the continued interest in the calculable capacitor and the increased interest in using electrical measurements to link the kilogram to the watt. Finally the BIPM presented a proposal for a novel cryogenic experiment aimed at this goal.

14.5 The Consultative Committee for Thermometry

The Consultative Committee for Thermometry (CCT) has met twice since the last CGPM: for its 20th meeting in April 2000 and its 21st meeting in September 2001. Much of its work has been devoted to the processing and analysis of key comparisons and to the work, in several NMIs, on the extension of the International Temperature Scale of 1990 (ITS-90) to the measurement of temperatures below 0.65 K. Two new key comparisons of water triple-point cells and of humidity standards were initiated. The CCT also established a working group to organize key comparisons in the field of thermophysical properties. The Committee has reviewed and revised the terms of reference of its working groups and set new targets for their work. Most of the working groups met during the Temperature Symposium in Chicago in October 2002. On this occasion, a CCT workshop about the weaknesses of the ITS-90 was held.

14.6 The Consultative Committee for Photometry and Radiometry

The Consultative Committee for Photometry and Radiometry (CCPR) met for its 15th meeting in March 1999 and for its 16th meeting in April 2001. As with most other Committees, the topic of key comparisons has dominated the work of the CCPR with considerable debate on the analysis of key comparison results. It has also had to consider carefully how far its work should extend into the more applied areas of photometry and radiometry such as fibre optics and measurement of appearance. These are areas where commercial considerations play a great part in the work programmes of the NMIs as well as that of other organizations, and the Committee has to balance this need against its current interests in “core” techniques. As a consequence of the results of a key comparison in luminous intensity and luminous flux, the CIPM agreed in 2001 with a CCPR recommendation to adjust the values of the candela and lumen as maintained

by the BIPM. The CCPR Working Group on Air-UV Radiometry has monitored the important developments in black-body and synchrotron radiation technology and their relevance to the work on the Committee. The CCPR has also noted the continued increased use of cryogenic radiometers in NMIs and the rise in confidence in detector-based scales. In its reports, it pointed to the increasing relevance of absolute radiometry to the ITS-90 and hence to the need for close liaison with the CCT.

14.7 The Consultative Committee for Ionizing Radiation

The Consultative Committee for Ionizing Radiation (CCRI) met in June 1999 (16th meeting) and in May 2001 (17th meeting). On both occasions the results and the processing of key comparison data occupied the attention of the Committee with particular emphasis being given to the linking of CIPM and RMO comparisons. The analysis and workload on the BIPM staff has been particularly heavy as the BIPM has many ongoing comparisons and has been pilot laboratory for many of the CCRI comparisons.

The CCRI was particularly concerned about the impact of customs procedures on the smooth passage of radioactive samples between laboratories and the increasingly tight restrictions on the movement of even small samples given worldwide concerns about terrorism. The CCQM had expressed similar concerns – especially as it moved into new areas such as food and pharmaceuticals. Other Consultative Committees had noted the increasing difficulty in transporting transfer standards during CIPM key comparisons and RMO key comparisons. In some cases travelling standards had been damaged or otherwise interfered with in such a way as to negate the results of work carried out up to that point in the comparison. The CCRI therefore took the lead in formulating the following Draft Resolution:

▮ Requirements for cross border transport of measurement standards, metrological equipment and reference materials

Draft Resolution I

The 22nd General Conference,

considering

- recent events that are understandably requiring stricter control of container, luggage and carry-on belongings of national and international travellers, as well as unaccompanied packages,
- that these controls are making it more and more difficult, and sometimes impossible, to transport equipment, standards, and reference materials that are needed for comparisons of national measurement standards,
- that these comparisons rely intrinsically on frequent and unimpeded transportation of standards, many of which have limited stability and so require rapid movement,
- that certain samples or equipment are fragile and can become contaminated or damaged beyond the point of use if not handled carefully by personnel in airports, freight handling agencies or customs officials,

- that the inherent dangers in transport of certain samples in the nuclear, chemical and pharmaceutical field for metrology are far less than those envisaged from the point of view of those that seek to prohibit or restrict wholesale movement of such goods,
- the importance of implementing new procedures that can facilitate the unimpeded transport of such materials,
- that this facilitation could be accomplished by modifications, guidance notes or other addenda to existing regulations that inform officials as to the course of action to be undertaken in the case of metrological samples and equipment,

recommends that national metrology institutes, government bodies and international organizations responsible for the control and regulation of the movement of goods and substances, all work with relevant bodies to investigate, propose and implement special procedures that relate to the free and unimpaired movement of metrological materials and equipment among national metrology institutes, designated institutes and the International Bureau of Weights and Measures.

14.8 The Consultative Committee for Amount of Substance

The Consultative Committee for Amount of Substance (CCQM) has continued to make an impact in chemical measurement. It has taken the initiative to broaden its liaisons with international organizations in other areas. In particular, the CCQM has been instrumental in opening up discussions with the laboratory medicine community as a result of which the JCTLM has been formed. In addition, the CCQM is leading the thinking about coordinated work in biotechnology and pharmaceuticals. In order to begin work in these areas the CCQM has organized several crucial international symposia and workshops to bring interested parties together – often for the first time.

The CCQM has held four meetings since the Convocation of the last General Conference: the 5th meeting in February 1999, the 6th meeting in April 2000, the 7th meeting in April 2001 and the 8th meeting in April 2002. The 9th meeting of the CCQM is scheduled for April 2003.

Early successes included the establishment of a worldwide traceability framework for gas analysis and development of the concept of traceability and uncertainty as these concepts apply to chemical measurements. The CCQM's choice of the analytes and certified reference materials for key comparisons has been made with careful reference to their impact and utility in the fields of food, commodities, health, biotechnology, the environment, forensic science, advanced materials and general analytical chemistry. In this way, the Committee is seen to be reacting to the high-priority needs of user communities. The CIPM strongly supports the view that the Metre Convention should be seen to be responding positively and quickly to the needs of these communities as they impact strongly on consumers and the quality of life. They also impact on the regulators that are implementing new regulations; e.g. the regulation with respect to *In Vitro* Diagnostic measuring devices (EU IVD Directive).

The CCQM has tackled new challenges that are largely specific to the fields of chemistry and chemical analysis. In particular, the classification of certified reference materials and the format of CMC claims are different from those in the physical and engineering fields and have required extensive consultation with practitioners in order to make entries into the KCDB in a “user-friendly” and relevant form. The CCQM also recognized that in order to make progress in new areas, there was a need to launch several specific working groups in areas such as gas analysis, organic and inorganic analysis, electro-chemical analysis, surface analysis, and bio-analysis

(including proteomics and genomics). Many NMIs are not active in fields that are covered by the CCQM and it has therefore been necessary to involve a large number of other designated specialist institutions from Member States. This has been successfully achieved, although the numbers of attendees at CCQM meetings makes it the largest Consultative Committee as a result of which the CCQM makes full use of all of the BIPM's current resources.

The CCQM has intensified its cooperation with the ISO, in particular with respect to the traceability and measurement uncertainty of certified reference materials (ISO REMCO) and several other international organizations, like the American Organization of Analytical Chemists (AOAC), Eurachem/CITAC (the Co-operation on International Traceability in Analytical Chemistry), and the National Conference of Standards Laboratories (NCSL). Strong links with the regional metrology organizations are also fostered in support of the development of metrology in chemistry in these areas.

The CCQM has forged important links with a number of international organizations, including: the WMO, and especially its Global Atmospheric Watch programme (GAW); the WHO; and the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC). The last two organizations have been particularly supportive and constructive in the establishment of the Joint Committee for Traceability in Laboratory Medicine (JCTLM). The membership of this Committee also includes: representatives from the ILAC; quality assessment organizations; regulators from the European Union, Japan and the United States; reference materials producers; and the IVD industry associations from the European Union, Japan and the United States.

Further cooperation is expected to take place with the international organizations in the fields of: food testing (Codex Alimentarius of the WHO and the Food and Agriculture Organization of the United Nations, FAO), abusive drugs, and forensic analysis.

At this very moment, some forty key comparisons and about sixty studies have been carried out or are in progress, covering an increasing number of fields of chemistry. This will give a firm basis for comparability and underpinning of the measurement and calibration capabilities of the participating NMIs, as well as the recognition of measurement and calibration certificates issued by the participating NMIs.

14.9 The Consultative Committee for Acoustics, Ultrasound and Vibration

The Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV) is the newest Consultative Committee and held its first meeting in the July before the last CGPM, its second in October 2001 and its third in October 2002. The Committee has been active in unifying and coordinating the efforts of those with technical responsibilities and interests in the fields within the CCAUV's terms of reference. Its work has been hampered to some extent because many Member States do not always allocate responsibility for certain standards, such as those relating to underwater acoustics or to medical measurements, to organizations that are either open or that are linked to the national metrology system.

The initial meetings of the CCAUV have been important stimuli which have helped focus the attention of NMIs on the work of the Committee, broaden its membership, and provide opportunities to share technical knowledge so as to increase the capabilities and competence of new entrants into the field. At its first meeting, the CCAUV launched a number of key comparisons and was pleased at its second meeting to note that some had already been completed and that the process of linking them with RMO comparisons was well in hand. At its

second meeting, the CCAUV launched a consultation exercise to identify the priorities that will set its future workplan and a draft report was presented to its third meeting.

14.10 The Consultative Committee for Units

The Consultative Committee for Units (CCU) has held one meeting in April 2001, its 14th, since the last General Conference, concentrating on revisions to the SI Brochure with the publication of the 8th edition. It has also begun to consider the implications of any changes to the definition and realization of the unit of mass in parallel with the experimental progress made worldwide and the regular reports to the CCEM and the CCM.

The CCU has continued to debate issues relating to the neper, the bel and the decibel, following the withdrawal of Draft Resolution L at the 21st General Conference. Since then, several members of the CCU have published a discussion paper in *Metrologia* and have pursued the debate. The CIPM does not wish to make further proposals until consensus is reached.

In April 2003, the governments of Australia, the United Kingdom, and the United States had submitted three Draft Resolutions on the symbol for the decimal marker in the International System of Units (SI).

In the English language, the symbol used to separate the integral part of a number from the decimal part – called the decimal marker – is broadly understood to be the point on the line. This symbol is also used as the decimal marker in many other languages, including those spoken by the most populous nations on Earth. However, despite these well known facts, some international bodies employ the comma on the line as the decimal marker in their English language publications; and, moreover, two of the world's most influential international standardizing bodies specify in their international standards that the comma on the line shall be the symbol for the decimal marker in all languages. Since the standards coming from these bodies are widely misinterpreted as defining the modern metric system, that is, the SI, there is a great deal of confusion worldwide concerning the correct symbol for the decimal marker in the SI. Indeed, this issue was brought to the attention of the 21st CGPM in 1999 by Dr Castelazo (Mexico), as is duly recorded in the proceedings of that CGPM (page 319).

The adoption of a Resolution will bring an end to this unwelcome confusion, because it states clearly and unequivocally that both the point on the line and the comma on the line are SI symbols for the decimal marker, that the symbol to be used in a given language is that in common use in that language, and that, in particular, in the English language the SI symbol for the decimal marker is and shall continue to be the point on the line. This is consistent with the decision taken by the CIPM at its 86th meeting in 1997, namely, to allow the BIPM to employ the point on the line as the decimal marker in all of its English language publications and to continue to employ the comma on the line as the decimal marker in all of its French language publications.

We conclude by noting that the usage of the dot (point on the line) as the decimal marker is so ingrained in the English language that it is impossible to conceive of it ever changing.

Draft Resolution K on the symbol for the decimal marker in the SI was presented to the 22nd CGPM by the Government of Australia.

Symbol for the decimal marker in the International System of Units (SI)

Draft Resolution K

The 22nd General Conference,

considering that

- a principal purpose of the Système International d'Unités (SI) is to enable values of quantities to be expressed in a manner that can be readily understood throughout the world,
- values of quantities are normally expressed as a number times a unit,
- often the number in the expression of the value of a quantity contains many digits with an integral part and a decimal part,
- the second paragraph of Resolution 7 of the 9th General Conference on Weights and Measures (CGPM), 1948, states "In numbers, the comma (French practice) or the dot (British practice) is used only to separate the integral part of numbers from the decimal part. Numbers may be divided in groups of three in order to facilitate reading; neither dots nor commas are ever inserted in the spaces",
- the dot (point on the line) remains, and is sure to remain, the decimal marker in the English language, which is by far the dominant language in science and technology today, in addition to being the preferred decimal marker in many other languages,
- notwithstanding this fact, some international bodies use the comma (on the line) as the decimal marker in their English language documents,
- furthermore, some international bodies, including some international standards organizations, specify the decimal marker to be the comma on the line in the English language as well as in all other languages,
- the World Trade Organization has ruled that international standards should be used wherever possible,
- the resulting dual use of both the point on the line and the comma on the line as a decimal marker in the same language, in particular the English language, causes confusion and has a potential negative impact on international trade, especially in the labelling of packages,

declares that

- the SI symbol for the decimal marker shall be either the point on the line or the comma on the line depending upon the custom of the language in use,
- in particular, the SI symbol for the decimal marker in the English language is and shall continue to be the point on the line.

Draft Resolution L on the symbol for the decimal marker in the SI was presented to the 22nd CGPM by the Government of the United States.

▮ Symbol for the decimal marker in the International System of Units (SI)

Draft Resolution L

The 22nd General Conference,

considering that

- a principal purpose of the International System of Units (SI) is to enable values of quantities to be expressed in a manner that can be readily understood throughout the world,
- values of quantities are normally expressed as a number times a unit,
- often the number in the expression of the value of a quantity contains multiple digits with an integral part and a decimal part,
- in Resolution 7 of the 9th General Conference on Weights and Measures (CGPM), 1948, it is stated that "In numbers, the comma (French practice) or the dot (British practice) is used only to separate the integral part of numbers from the decimal part,"
- following a decision of the CIPM made at its 86th meeting (1997), the BIPM now uses the dot (point on the line) as the decimal marker in all of its English language publications, including the English text of the SI Brochure (the definitive international reference on the SI), with the comma (on the line) remaining the decimal marker in all of its French language publications,
- the point on the line remains, and is sure to remain, the decimal marker in the English language, which is by far the dominant language in science and technology today, in addition to being the preferred decimal marker in many other languages,
- notwithstanding these facts, some international bodies use the comma on the line as the decimal marker in their English language documents,
- furthermore, some international bodies, including some international standards organizations, specify the decimal marker to be the comma on the line in all languages, including English,
- the prescription of the comma on the line as the decimal marker in English and many other languages is in conflict with the customary usage of the point on the line as the decimal marker in those languages, and the use of both in the same language causes unwelcome confusion,

declares that

- the SI symbol for the decimal marker shall be either the point on the line or the comma on the line depending upon the custom of the language in use,
- in particular, the SI symbol for the decimal marker in the English language is and shall continue to be the point on the line.

Draft Resolution M on the symbol for the decimal marker in the SI was presented to the 22nd CGPM by the Government of the United Kingdom.

Symbol for the decimal marker in the International System of Units (SI)

Draft Resolution M

The 22nd General Conference,

considering that

- a principal purpose of the International System of Units (SI) is to enable values of quantities to be expressed in a manner that can be readily understood throughout the world,
- values of quantities are normally expressed as a number times a unit,
- often the number in the expression of the value of a quantity contains multiple digits with an integral part and a decimal part,
- in Resolution 7 of the 9th General Conference on Weights and Measures (CGPM), 1948, it is stated that "In numbers, the comma (French practice) or the dot (British practice) is used only to separate the integral part of numbers from the decimal part,"
- following a decision of the CIPM made at its 86th meeting (1997), the BIPM now uses the dot (point on the line) as the decimal marker in all of its English language publications, including the English text of the SI Brochure (the definitive international reference on the SI), with the comma (on the line) remaining the decimal marker in all of its French language publications,
- the point on the line remains, and is sure to remain, the decimal marker in the English language, which is by far the dominant language in science and technology today, in addition to being the preferred decimal marker in many other languages,
- notwithstanding these facts, some international bodies use the comma on the line as the decimal marker in their English language documents,
- furthermore, some international bodies, including some international standards organizations, specify the decimal marker to be the comma on the line in all languages, including English,
- the prescription of the comma on the line as the decimal marker in English and many other languages is in conflict with the customary usage of the point on the line as the decimal marker in those languages, and the use of both in the same language causes unwelcome confusion,

declares that

- the SI symbol for the decimal marker shall be either the point on the line or the comma on the line depending upon the custom of the language in use,
- in particular, the SI symbol for the decimal marker in the English language is and shall continue to be the point on the line.

15 Programme of future work at the BIPM

A detailed programme of the work to be carried out at the BIPM during the years 2005 to 2008 corresponding to the dotation requested below in draft Resolution J will be proposed by the International Committee in a document entitled "Programme of work and budget of the International Bureau of Weights and Measures for the years 2005 to 2008". Following past

practice, this document will be sent to Member States not less than six months before the Conference, thus not later than April 2003.

16 Annual dotation of the BIPM

The 21st CGPM in 1999 decided to increase the annual dotation of the BIPM by 1.5 % *per annum* from 2001 to 2004, an amount set to cover only foreseen price increases in France during this period. However, it was known at the time that the programme of work adopted by the Conference would lead to a significant real increase in costs, but a real increase in dotation was not voted by the CGPM. Instead, the BIPM was asked to absorb most of the increase in cost by improvements in efficiency and, if necessary, by small cuts in programmes. The CIPM, in its 1998 report to Member States on *National and International Needs relating to Metrology,* drew attention to the fact that, in the absence of a real increase in dotation voted by the 21st CGPM, by the time of the 22nd CGPM in 2003 it would be necessary for the Conference to vote a significant increase in dotation or accept that there would be significant reductions in programme at the BIPM.

Since the 21st CGPM in 1999, the workload of the BIPM has increased even more than was foreseen at the time. This has been due largely to the additional work related to the implementation of the CIPM MRA.

In considering the future programme of work, the Committee has also taken into account the rapid extension of needs for international activity in metrology into the fields of chemistry, bioanalysis, medicine, food and other similar areas. Requirements for international activity in the traditional fields have by no means shown any signs of diminishing (see the report of the CIPM to the Member States, *Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM*, mentioned under Item 11 of the draft agenda). The additional dotation required for the maintenance of the full programme currently being carried out by the BIPM is now estimated to be about 1.1 million euros on 1 January 2005 plus increases to cover price increases in France at the beginning of the three subsequent years of the *quadrennium*. In order to enter further into the field of chemistry towards bioanalysis and medicine, it was estimated that the dotation should increase by an additional 0.8 million euros on 1 January 2005, making a total of 1.9 million euros.

A careful study was made by the Committee of current and future needs for work at the BIPM. This included questionnaires to directors of the NMIs of Member States in respect of the current services and activities of the BIPM as well as new ones in the field of chemistry. Discussion of various options for the future programme and their corresponding costs were discussed by the directors at a meeting held at the BIPM in April 2002. Further proposals were subsequently sent to directors in July 2002 and comments were invited in time for the meeting of the CIPM that took place in October 2002.

During the period July to October 2002 it became clear that an increase in dotation of 1.9 million euros was not likely to be acceptable and that the CIPM would have to consider the priorities of work at the BIPM, and make a request that was significantly smaller than this. The CIPM at its meeting in October 2002 took careful note of the results of all these consultations. It examined carefully the priorities among the current programmes at the BIPM and considered how best to reduce some of the current activities while at the same time maintaining the science base of the BIPM and preparing a future programme that will meet the foreseeable needs of NMIs in the years to come. The outcome was the following CIPM proposal for an increase in dotation.

The starting point for the dotation for the new *quadrennium* is the dotation voted by the previous General Conference for the last year of the current *quadrennium*. In the present case this is the dotation for 2004 voted by the 21st CGPM, namely, 9 094 000 euros. To this should be added the contributions from the three States, Greece, Malaysia and Yugoslavia, that have joined or re-integrated the Metre Convention since the 21st CGPM. Their contributions together amount to 1.76 % of the total. Thus, the new starting point for the calculation of the 2005 dotation is 9 254 000 euros. The CIPM proposes that this be increased by 8.5 % (which includes a real increase of 6.7 % plus 1.8 % to cover price increases in France) on 1 January 2005 to 10 041 000 euros and that on 1 January of each of the three succeeding years of the *quadrennium* it be increased by a further 1.8 % to cover price increases in France.

The dotations thus requested for each of the years 2005 to 2008, given below in Draft Resolution J, will allow the programme of work to be carried out that will meet the minimum requirements of Member States while allowing a balanced budget to be maintained for the years 2005 to 2008. The programme will, however, be a smaller programme than that foreseen at the time of the 21st CGPM. Full details of the programme for the years 2005 to 2008 will be found in the document referred to above under Item 15 of the draft agenda.

▮ Dotation of the BIPM for the years 2005 to 2008

Draft Resolution J

The 22nd General Conference,

considering

- the increasing importance of metrology for trade, industry, the environment and human health and safety in all Member States of the Metre Convention,
- the corresponding need for an efficient, highly expert, international coordination of metrological activities,
- the central role played by the International Bureau of Weights and Measures (BIPM) in such coordination and the services it renders to Member States of the Metre Convention,
- the broadened responsibilities given to the BIPM at the 21st General Conference in 1999 but without any corresponding increase in dotation,
- the additional increase in workload, unforeseen at the time of the 21st General Conference, that has also been absorbed by the BIPM since the last General Conference,
- the extension of the range of work under the Metre Convention now carried out in Member States, notably in areas of chemistry, biotechnology and medicine,
- the need to extend the range of expertise among the scientific staff of the BIPM to meet demands for work in these new areas,
- the considerable efforts that continue to be made by the BIPM to enhance the efficiency of its operation, and its commitment to continue these efforts,

invites National Metrology Institutes

- to arrange, at their expense, a continuing series of short-term placements or secondments of their staff to the BIPM to work on projects of mutual interest integrated into the BIPM programme,
- to accept staff of the BIPM to work in their institutes on programmes of mutual interest,

- to sponsor a permanent programme of Fellowships at the BIPM for suitable staff with a view to establishing four such Fellowships at the BIPM by the end of 2004, and

decides that the fixed part of the annual dotation of the BIPM will be increased in such a way that the fixed part and the complementary part (defined by Article 6, 1921) of the Rules annexed to the Metre Convention (1875) shall, for those States that are members of the Metre Convention at the time of 22nd General Conference, be

10 041 000 euros in 2005
10 222 000 euros in 2006
10 406 000 euros in 2007
10 593 000 euros in 2008.

17 Proposals by delegates

Delegates from Member States are requested to let the International Committee know of their wishes or any proposals they would like to submit to the General Conference as soon as possible, but in any case at least six months before the General Conference, so that, in accordance with the decision of the 9th General Conference (1948) "the wishes or proposals thus deposited will be distributed by the bureau of the Comité to all Member States of the Convention at least four months before the opening of the Conference so that Delegates may receive the necessary instructions and authority; all other wishes and proposals being presented to the Conference only if the International Committee has time to study them and has approved them".

18 Renewal of half of the International Committee

In conformity with Articles 7 (1875) and 8 (1921) of the Rules annexed to the Metre Convention, the Conference will proceed by secret ballot to the renewal of half of the membership of the International Committee. Outgoing members are first, those who in the case of vacancies have been provisionally elected since the last Conference, and second, those selected by ballot from among the remaining members of the International Committee. Outgoing members are eligible for re-election.

December 2002

For the International Committee for Weights and Measures
Pavillon de Breteuil, F-92312 Sèvres Cedex

The Secretary,
R. Kaarls

The President,
J. Kovalevsky

Appendix B

Programme of work and budget of the International Bureau of Weights and Measures for the four years 2005-2008

Introduction

This document provides information on Items 15 and 16 of the provisional agenda of the 22nd General Conference. Agenda Item 15 discusses the programme of future work at the BIPM while agenda Item 16 concerns the annual dotation, total income and budgeted expenditure, for each of the four years 2005 to 2008.

In its report, entitled *Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM*, being sent to Governments of Member States, the CIPM laid out the role of the BIPM in the early decades of the 21st century.

At its 91st meeting, in October 2002, the Committee also made certain decisions concerning the priorities of the individual programmes carried out at the BIPM. These are reported here in the Appendix to this document, which is an extract from the Report of the 91st meeting of the CIPM. The programme of work that is presented in outline here should be viewed in the context of these decisions and the role of the BIPM.

In each of the scientific areas, as well as in the various support services, the work is designed to fulfil the broad requirements as set out by the CIPM in 2002 in the following text:

The role of the BIPM

The goal of the BIPM is worldwide uniformity of measurement.

The BIPM will achieve this goal by providing the necessary scientific and technical basis for such uniformity and by collaborating with other institutions and organizations that have related missions. Therefore, its principal tasks are:

The International System of Units (SI)

- to keep up-to-date and disseminate the text of the International System of Units known as the SI Brochure.

Basic scientific and technical tasks

- to conserve and disseminate the primary standard of mass, the International Prototype of the kilogram;
- to establish and disseminate International Atomic Time (TAI) and, in collaboration with the International Earth Rotation Service, Coordinated Universal Time (UTC);
- to make its own realizations of other base and derived units of the SI and, if necessary, other units that are not yet possible to link to the SI;
- to participate in the development of primary methods of measurement and procedures in chemical analysis and bioanalysis and where necessary to maintain its own standards in these fields;
- to undertake research focused on the development of present and future measurement units and standards, including appropriate fundamental research, studies of the conceptual basis of primary

standards and units and determination of physical constants, and to publish the results of this research.

Specific technical services delivered to NMIs

- to carry out certain international comparisons of practical realizations of certain base and derived units of the SI, as may be necessary to meet the needs of the ensemble of the National Metrology Institutes (NMIs);
- to provide a specialized calibration service for NMIs for selected national measurement standards whenever this is desirable and feasible;
- to provide opportunities for technology transfer during calibrations and comparisons organized by the BIPM;
- to provide facilities for the exchange of scientific staff between the BIPM and NMIs;
- to provide certain consultancy services to NMIs related to peer review of their activities.

Global coordination of metrology

- to provide support as necessary in the operation of the CIPM *Mutual Recognition Arrangement (MRA) of national measurement standards and of calibration certificates issued by NMIs* through the operation of the BIPM key comparison database, the management of the Joint Committee of the Regional Metrology Organizations and the BIPM (the JCRB) and through participation in meetings of Consultative Committees and appropriate meetings of the Regional Metrology Organizations and through the publication of the results of key and supplementary comparisons;
- to provide the scientific and administrative Secretariat for the General Conference on Weights and Measures, the CIPM and its Consultative Committees as well as the secretariat for meetings of directors of NMIs and the various Joint Committees and to publish reports of their deliberations.

Relations with other organizations

- to enter into agreements with intergovernmental and international organizations where such agreements would help in the coordination of the work of these organizations with that of the BIPM or the CIPM and where it may stimulate corresponding coordination at the national or regional level;
- to collaborate, and where appropriate enter into agreements to establish Joint Committees with intergovernmental and international bodies having related missions;
- to act on behalf of the NMIs of Member States of the Metre Convention in representing their common interest as the occasion arises.

Information and publicity

To promote as widely as possible using all appropriate methods, the activities carried out under the Metre Convention, in particular:

- to provide through the BIPM website, a centre for information on matters related to the Metre Convention, the CIPM, its Consultative Committees, Joint Committees, the CIPM MRA, including the BIPM key comparison database, and matters related to international metrology;

- to edit and arrange for the publication of *Metrologia*, the international scientific journal of metrology;
- to ensure, with other appropriate organizations, that basic documents needed for uniformity of measurements, such as those on vocabulary in metrology (VIM) and on the expression of uncertainty in measurement (GUM), are kept up-to-date and widely disseminated;
- to organize workshops and summer schools for the benefit of staff from the NMIs.

Cost effectiveness and evolving role of the BIPM

The BIPM will carry out these tasks in the most cost-effective and efficient way possible designed to achieve its goal, and will continue to be ready to adapt and change its tasks as the need arises and as decided by the CIPM acting under the authority of the Member States of the Metre Convention.

15 Programme of work at the BIPM

The programme of work at the BIPM, Item 15 of the draft agenda of the 22nd General Conference, is treated here under the following headings:

15.1 Length

15.2 Mass

15.3 Time

15.4 Electricity

15.5 Ionizing radiation

15.6 Metrology in chemistry

15.7 General laboratory and scientific services

15.8 General administrative services

15.9 Buildings and grounds

15.10 Staff

15.11 Contribution to the pension fund

15.1 Length

International comparisons

A substantial part of the planned programme for the Length section concerns two basic comparison and measurement services: first, absolute frequency measurements of stablilized laser systems laser using the BIPM femtosecond comb system and secondly, gravimeter comparisons. In addition, we will continue to offer calibrations of 1D gratings and 2D grids as part of our current nanotechnology project related to displacement interferometers in the micrometre ranges.

The substitution of absolute frequency comb-based measurements for the long-standing heterodyne (beat frequency) techniques offers the possibility of relatively simple direct frequency measurements of a wide range of laser sources in the visible and near infrared regions. In order to improve the efficiency of the visible laser comparisons, we shall replace the current "on demand" service with two comparison periods during each year. NMI needs for these measurements will be kept under review so as to determine the future pattern of demand for the service. Over the first part of the workplan period, we shall investigate the performance and limitations of comb techniques and assess their characteristics through systematic studies of the two BIPM systems as well as through international comparisons using the BIPM portable device due to be completed in 2003. The longer-term need for this unique role for the BIPM facility will depend on whether comb systems perform satisfactorily and as expected.

Current plans in the infrared are to complete a direct frequency measurement of the 3.39 μm methane-stabilized system in 2003 and then to maintain, but not develop, this system during the proposed programme of work so as to be in a position to make comparisons if required.

Gravimetry

The next major comparison in the field of gravimetry is the ICAG-2005 series of measurements. In preparation for this, we shall continue to improve our data recording and processing capabilities. We shall also modify the BIPM absolute gravimeter and, as a result, be in a better position to improve the comparison technique for gravimeters and to investigate discrepancies reported during the ICAG-2001 measurements. In the workplan, the local BIPM network will be monitored regularly using the improved absolute gravimeter so as to ensure that changes between ICAG-2001 and ICAG-2005 do not result from local variations.

Nanotechnology

Nanotechnology is still emerging as a major metrological subject and a future role for BIPM during the workplan period will be considered at meetings of the CCL's Working Group on Dimensional Metrology and the nanotechnology discussion group. Should there be an emerging need for reference facilities or comparison projects then BIPM's current relatively modest level of activity will be reviewed.

Stabilized lasers at the BIPM

In the next few years, as frequency comb technology matures, the BIPM will continue to maintain reference laser systems at 633 nm and 532 nm, the latter being especially useful for improvement of the short-term stability of frequency combs. The methane-stabilized 3.39 μm system will be maintained as a reference system for NMIs that operate frequency chains and require comparisons.

The BIPM's current service for iodine cell gas filling and performance assessment will be maintained for as long as there is a requirement from NMIs. No further development is planned apart from automation of some of the more time-consuming aspects of the filling process.

Interferometry

Precise distance measurement is a core competence of the BIPM. We shall develop compact, high-performance light sources and interferometric systems that meet the common needs of the BIPM projects on the watt balance, calculable capacitor and absolute gravimeter.

15.2 Mass

Manufacture and calibration of mass standards

The BIPM will continue to supply NMIs of Member States of the Metre Convention with 1 kg platinum-iridium standards made to match the mass of the International Prototype within 1 mg. These new prototypes are currently calibrated with an uncertainty of 5 μg and subsequently take part in the periodic calibrations organized by the BIPM.

Although the principal task of the BIPM with respect to calibrations of mass standards concerns 1 kg Pt-Ir prototypes, calibrations are also made of 1 kg stainless steel standards. These are carried out both for NMIs whose national standards are of stainless steel and for institutes that rely on stainless steel artefacts as secondary standards. The balances and other equipment necessary not only to provide these calibrations but also to provide the calibrations and density measurements of Pt-Ir prototypes must always be maintained at the highest level with the ability to introduce the latest technology as soon as it is available. Some of these developments we make ourselves but others are brought in from outside sources. Linked to the calibration service is the need to monitor the density of air.

In addition to essential equipment, mass metrology also requires laboratories to maintain a clean environment as well as stable underpinning of balance supports. Our laboratories have not been refurbished for many years and, of even more concern, the supporting soil has become unstable, producing a problem that has become chronic and, while high-quality results can still be obtained, we nevertheless foresee the need to renovate our balance laboratories within the next five years.

We anticipate increased demands for the calibration of mass standards from 1 kg to 100 g, used by certain NMIs in watt balances (see below). An important part of the calibration, which in this context approaches applied research, will involve characterization of mass changes between normal atmosphere and vacuum. Improved capabilities for effecting air-buoyancy corrections will be required as well as more advanced techniques for comparing mass standards under vacuum with those maintained in air. We are already making progress in this endeavour but we foresee continuing our efforts at least through 2008. Mass standards destined for use with watt balances must meet stringent requirements for magnetic susceptibility and intrinsic magnetization. We will maintain our new expertise in the characterization of these properties and improve on it if necessary.

Balance development

The FB-2 balance is operational in both air and vacuum. It has a type A standard uncertainty in the comparison of two 1 kg masses of less than 0.1 μg. A major balance manufacturer has been licensed to use essential features of the FB-2 balance technology. As part of the licensing agreement, we will acquire an early production model of the commercially-produced balance and this will add to our ability to carry out mass comparisons in vacuum.

A new balance, made by Metrotec to our specifications, complements the Mettler-Toledo HK 1000 MC acquired some years ago and which is no longer in production. We use the HK 1000 MC for our normal calibration service but will gradually rely more heavily on the newer technology.

Stability of Pt-Ir and other mass standards

An alloy of 90 % platinum and 10 % iridium was chosen in the 19th century for manufacture of the International Prototype of the kilogram. The same alloy is still used by the BIPM to manufacture national prototypes for NMIs.

Metallurgical technology and machining techniques have improved over the years as have various methods of surface analysis. In conjunction with the NMIJ/AIST (Japan), we plan to study Pt-Ir alloy as presently produced and machined with a view toward a better characterization of its physical properties and to introducing techniques that lead to improved mass stability. A complementary programme, focusing on novel cleaning methods, will be carried out in collaboration with the NPL (UK).

Avogadro project

Measurement of the Avogadro constant by exploiting the properties of single-crystal silicon offers the possibility (along with the watt balance) of monitoring the stability of the present kilogram standard. A working group of the CCM was established to coordinate international efforts in this area following which a more formal arrangement among interested parties has emerged. A long-term strategy has been mapped out and a time sequence of specific goals has been established. The Mass section will take a lead role in coordinating efforts to determine the accurate mass of 1 kg silicon spheres. We will also provide technical support for maintaining a database accessible to all participants, an element which is considered essential given the complexity and international character of the Avogadro project.

Watt balance project

Among the decisions taken by the CIPM in 2002 was that work should begin at the BIPM on a watt balance project. This is a long-term project and it has as its aim the development of a watt balance capable of monitoring the mass of the International Prototype of the kilogram with an uncertainty of about 1 part in 10^8. This project brings together BIPM staff from the Mass, Electricity and Length sections. In addition, we hope that when it is fully under way, there will be occasional visiting staff from NMIs who will participate. Plans for the design of the BIPM watt balance are expected to be finalized during 2004 following an extensive preliminary study in 2003. The major part of the construction and development will thus take place during the *quadrennium* 2005 to 2008 after which we hope that it will be operational.

15.3 Time

Computation and diffusion of TAI and UTC

The algorithm used for the calculation of TAI must be updated as necessary in order to keep up with the improvement in quality of the timing data and with the progress in the techniques of

clock comparison. At present, about 83 % of the clocks are either commercial caesium clocks of the new type or active, auto-tuned hydrogen masers, and these contribute 89 % to the total weight of TAI. The algorithm for calculation of TAI assigns weights to clocks to avoid the loss of stability that would otherwise arise when the number of participating clocks changes. An upper limit to weights stops the best clocks increasing their weights without limit. On 1 January 2001, we started the process of changing the weighting method by adopting, for each month of calculation, an upper limit to clock weights that depends on the number of participating clocks. In this way, TAI becomes increasingly dependent on the more stable clocks. This should render TAI more stable. When a sufficiently long series of data becomes available, we plan to study the evolution of the stability of TAI that will result from the implementation of the new weighting procedure.

The time laboratories have often indicated their desire to have TAI published with a shorter delay. To meet this demand, and to make the process more reliable, we have embarked on the automation of the calculation of TAI. A first step, based on the old programmes has been accomplished. We shall achieve full automation after the programs have been rewritten in a more flexible language better adapted to our needs of calculation and data treatment.

As it is now possible to obtain clock comparison data from distant clocks in near real time, the question of the production and diffusion of time scales available in real time that predict UTC as precisely as possible will become very important. We are considering these new applications whilst maintaining the current status of the reference time scales TAI and UTC.

The introduction of new, more accurate, primary frequency standards has also improved the accuracy of TAI. These are “classical” caesium beam standards, some of which use optical techniques for the excitation and detection of the atoms. Frequency measurements of two caesium fountains are periodically reported and used to evaluate the fractional deviation of the scale interval of TAI from the SI second. Since April 2000, the reports of results of primary frequency standards have followed the CCTF directives concerning the characterization of their uncertainties. As these standards operate only intermittently and over limited periods of time, specialized frequency comparison techniques are needed to compare them with each other and to allow their accuracy to be reflected in that of TAI. Together with the laboratories operating primary frequency standards, the Time section is involved in the comparisons that will be made over the next few years. The reduced uncertainties of such standards will require a more detailed understanding of their operation in order to optimize their use in TAI. The drift that has been observed recently between caesium fountains and the classical caesium beam clocks will be studied and the possible reasons for this drift investigated in future collaborations with the time laboratories.

Clock comparisons

Clock comparisons in TAI are carried out employing two techniques: GPS C/A-code single and multi-channel common views and two-way time and frequency transfer (TWSTFT). The increasing number of GPS multi-channel receivers installed in the time laboratories and the introduction of TWSTFT allow the comparison of distant clocks with an uncertainty approaching a nanosecond. Furthermore, the reliability of clock comparison has increased with the introduction of TWSTFT as an alternative technique to the GPS common-view. Precise ephemerides of GPS satellites and ionospheric maps, both provided by the International GPS Service (IGS), are used for the calculation of common views. The BIPM organizes calibration campaigns of GPS receivers in time laboratories. About 30 % of the receivers have been calibrated at present; we plan to conclude with the calibration of all receivers providing clock

comparison data in the next two to three years. In future, it will be necessary to consider techniques that use the carrier phase or the precise code (P code); with this aim, studies are under way. The improved accuracy and stability of new clocks and primary standards (e.g. fountain clocks) lead to new demands for accuracy in time transfer. In consequence, improved clock comparison techniques must be developed to ensure that their progress matches that of the clocks. A pilot study to use GPS P3 code measurements obtained with calibrated geodetic-type receivers to compute time links has been successfully carried out in 2002 with the participation of about ten laboratories. We shall study the feasibility of introducing these measurements officially into TAI, but some questions still remain concerning the data acquisition, and format needs to be clarified.

At the request of the CCTF, we shall publish uncertainties for time links in TAI. After the calibration of receivers and time links we shall be able to assign realistic values to the uncertainties of these links.

We are planning to publish the values of $[UTC - UTC(k)]$ with a resolution of 0.1 ns (instead of 1 ns) for those laboratories equipped with two-way stations. To achieve this, we shall modify some formats of data submission and amend the input/output and transfer files used in the calculation of TAI.

Space-time reference systems

The International Astronomical Union (IAU) adopted in 2000 the Resolutions proposed by the BIPM/IAU Joint Committee on General Relativity for Space-time Reference Systems and Metrology. This joint committee was disbanded in January 2001; the work is being continued by the IAU Working Group on Relativity for Celestial Mechanics, Astrometry and Metrology (RCMAM). We are on the point of applying the IAU 2000 Resolutions.

The improvement of the clocks and the prospect of their operation in space, as well as the refinement in clock comparisons and the link between these techniques and those of space geodesy, open new fields of study calling for collaboration in the areas of fundamental physics and reference systems.

In a joint effort with the USNO, the BIPM Time section has the responsibility for providing the conventions for astronomy and geodesy in the framework of the International Earth Rotation Service (IERS). The update of the volume containing the conventions is at the stage of a final revision. Before the end of 2003 we shall start studies on the consistency of the procedures used by the IERS analysis centres with the adopted conventions with a view to determining the impact of possible inconsistencies on the IERS products.

Dynamical time scales

Timing of millisecond pulsars is one of the experiments that requires reference time scales of utmost long-term stability. On the other hand, it is possible that the stability of pulsar rotation periods will provide information on the very long-term stability of atomic time scales. We shall maintain an interest in this and any other technique that can give rise to dynamical time scales (binary pulsars, solar system ephemerides, etc.)

Time laboratory

The time laboratory has considerably increased its number and range of both GPS and GLONASS receivers to meet the increasing importance of receiver calibrations for TAI. Besides the HP 5071A high-performance atomic clock, two active hydrogen masers were installed in December 2001. These new frequency standards are used for testing new techniques of clock comparison, and they provide a frequency reference to the Length section. Maintenance of the equipment at a high level of quality and reliability is necessary in order to meet the increase in calibration requirements. At the same time, it is imperative that we gain competence in any new clock comparison technique accessible to the resources of the BIPM. This is a continuing programme.

15.4 Electricity

Maintenance of a representation of the volt, international comparisons and calibrations

The basic reference standards of the BIPM for international comparisons and calibration of voltage standards are 1 V and 10 V Josephson array standards. The ongoing programme of comparisons of national representations of the volt made by transporting BIPM Josephson systems will continue. To date, some twenty such comparisons have been made and these are designated as one of the key comparisons by the Consultative Committee for Electricity and Magnetism (CCEM). One of the most promising recent developments in voltage metrology is the successful fabrication of programmable arrays of Josephson junctions with remarkably stable output voltages. The BIPM will incorporate such arrays in a new, more compact portable instrument for use in the key comparisons of Josephson voltage standards. For all NMIs, including those that do not yet have Josephson arrays as their reference standards, the series of bilateral comparisons using BIPM Zener standards will continue. A small group of BIPM Zener standards is at the disposal of NMIs wishing to participate in bilateral comparisons. Much of the work of the BIPM in this field is aimed at improving the stability, reliability and ease of use of its Josephson standards and understanding more completely the behaviour of its Zener travelling standards. This will continue as will the calibration service for Zener standards sent to the BIPM by NMIs. In the past several years the BIPM has received very few requests for calibrations of Weston cells; this calibration activity has ceased.

Maintenance of a representation of the ohm, international comparisons and calibrations

The basic reference standards of the BIPM for international comparisons and calibration of resistance standards are its quantum-Hall resistance standards. The programme of on-site comparisons of quantum-Hall standards will continue but is likely to be less extensive than that for the Josephson standards since travelling wire-wound resistors are relatively much more stable than the comparable voltage standards. The programme of bilateral comparisons of resistance standards using the BIPM travelling standards allows the comparison of laboratories' standards with an uncertainty of about 5 parts in 10^8. The calibration of resistance standards for NMIs is an important part of our activity and will continue. During the period 2005 to 2008 improvements will be made to the quantum-Hall systems as understanding of the physics of these devices progresses.

Capacitance standards derived from the quantized-Hall resistance

Since 1998, the BIPM has maintained capacitance standards derived from the quantized-Hall resistance through a chain of impedance bridges. After the BIPM had demonstrated, in international comparisons, the accuracy of its link from the quantized Hall resistance to capacitance at 10 pF and 100 pF, the CCEM entrusted new ongoing key comparisons of these quantities to the BIPM. The number of capacitance calibrations at the BIPM reflects how important it is for NMIs to have permanent access to a stable capacitance standard. This work requires the measurement of the quantized-Hall resistance at a frequency of 1.6 kHz as a consequence of which we will participate in the study of the behaviour of quantum-Hall devices at these frequencies.

Calculable capacitor

At the suggestion of the NML CSIRO, the BIPM is collaborating in the construction of a new calculable capacitor to an NML design. It is planned to make two of these devices, one for the BIPM and one for the NML. The design is based on the existing NML capacitor but will incorporate a certain number of improvements designed to reduce the overall uncertainty to about 1 part in 10^8. The BIPM will contribute to the design of a new optical interferometer that will also be used both in the calculable capacitor and, in a modified form, in its watt balance project. The design is expected to be finalized during 2004 with construction to take place during the quadrennium 2005 to 2008.

Studies of the stability of electrical standards and detectors

We are continuing our use of low-frequency (below 10 Hz) spectral analysis techniques to examine the stability and noise characteristics of nanovoltmeters, detectors, standard cells and Zener-diode standards. The results of a preliminary study carried out in 1998, indicate that these and other methods of time series analysis are powerful tools for analysing many types of measurement data that up to now have not been examined in this way. This work will continue.

15.5 Ionizing Radiation

Dosimetry

Dosimetry comparisons will continue to have an important role for the NMIs to maintain their degrees of equivalence in the BIPM key comparison database. The updating of the BIPM x- and gamma-ray facilities should be completed in this four-year period without interrupting the comparison programme. Calibrations will continue of transfer instruments used as secondary standards by NMIs that have no primary standards. This ensures their traceability to the SI and supports their CMCs in the MRA Appendix C. The BIPM also participates in comparisons using passive dosimeters, particularly for the Secondary Standards Dosimetry Laboratories of the IAEA and the WHO. The IAEA standard is traceable to the BIPM.

The ionometric standard of absorbed dose to water for ^{60}Co developed at the BIPM and its comparison with the standards of a number of national laboratories based on other methods will be supplemented by the development of a graphite calorimetric standard during the next four years. This will enhance the robustness of the key comparison results for absorbed dose to water. The demand from the NMIs to use the transfer system for the comparison of high-energy

x-ray beams based on ionometric measurements is increasing. However, a portable calorimetric primary standard for high energies will be developed and this will ultimately replace the transfer system at these energies. Investigations will be undertaken to consider the implications for the BIPM of extending its comparisons to high-energy electron beams and the dosimetry of brachytherapy sources.

In x-ray dosimetry, the CCRI has asked the BIPM to develop a system for comparisons at mammography energies and work has already started on this project. Such comparisons should start within the current period.

Monte Carlo calculations using various radiation transport codes have led to improvements in the existing air kerma standards, and these techniques will be extended to the absorbed dose standards.

Radionuclides

The International Reference System (SIR) continues to expand its database and provide the key comparison reference values for gamma-emitting radionuclides including short-lived radionuclides principally used for cancer diagnosis. Pure beta emitters are being sent to the BIPM for analysis and reference values will be available for these in the future. The extension of the SIR to include pure alpha emitters, low-energy gamma emitters and radionuclides that decay by electron capture is progressing. Radionuclides with more complex disintegration schemes require further work before they too can be included. The work on the SIR will continue.

The periodic organization and analysis of comparisons with a specific radionuclide continue to be major tasks for the BIPM. These comparisons are selected by Section II of the CCRI and will become more frequent to satisfy the requirements of the NMIs. It will become increasingly possible to link these comparisons to the SIR so that the NMI comparison values can be added to the SIR database and the KCDB. Research will continue on developing new methods of activity determination such as the triple-to-double coincidence ratio method and on the identification of, and correction for, impurities in radionuclide solutions using hyperpure germanium spectroscopy.

15.6 Metrology in chemistry

Gas metrology

The programme of work embarked upon in 2001 aimed to establish the BIPM as the pilot laboratory and international centre for comparisons of national ozone reference standards, in collaboration with the NIST. This initial objective is already nearly met and needs only the completion of the current CCQM pilot study. During the period 2005 to 2008, we expect some ten to fifteen comparisons each year with the BIPM reference standards of instruments drawn from the thirty or so national institutes maintaining such standards. Studies will be made to characterize and eliminate causes of systematic error within the ozone standard reference photometers. The programme will thus underpin measurements of ground-level ozone monitoring networks, at the national, regional and international level.

The automation of the gas phase titration system, as a potentially primary method for the measurement of ozone concentrations will be completed. Successful completion of the project will allow an evaluation of the accuracy of the value of the absorption cross section of ozone at

253.7 nm. The use of the facility as a system to deliver calibration mixtures with well-defined mole fractions of nitrogen monoxide and nitrogen dioxide, where that total amount fraction of these gases is less that 1 μmol/mol, will be investigated.

The stability of gravimetrically prepared nitrogen monoxide gas standards will be evaluated.

The range of operation of the primary facility for the dynamic preparation of nitrogen dioxide gas standards will be extended to mole fractions less than 1 μmol/mol. The range of operation of the FTIR facility will be extended to mole fractions of less than 1 μmol/mol for reactive gases, with the incorporation of a gas cell with pathlength of 40 m. This part of the work programme will allow the BIPM to participate in and co-pilot an international comparison for reactive gases, relevant to air quality regulations.

Organic analysis

The programme of metrology in chemistry will be extended to the field of organic analysis with the recruitment of two staff members. Following consultation with experts from the CCQM, a programme of work in the field of organic pure substance reference materials will be undertaken. The programme is in response to the requirement to demonstrate the traceability of measurement results as formulated in international standards such as ISO/IEC 17025 and ISO 15915. The laboratory programme at the BIPM will concentrate on validated methodologies for determination of purity, including an initial study on direct assay methodologies such as NMR and differential scanning calorimetry. The programme will be linked to activities of NMIs with the formation of network activities in fields of interest. A consultation process with the institutes has identified the following areas where a network activity would be of benefit to the NMIs: pharmaceuticals; antibiotics; hormones; mycotoxins; pesticides, herbicides and dioxins; volatile organic hydrocarbons; organometallic species; and clinically relevant analytes as a component of a reference measurement system for laboratory medicine. Liaison with the international standardization bodies will be established to disseminate information on these activities, which will allow the international requirements for traceable measurement results to be met in these fields of application.

15.7 General laboratory and scientific services

Mechanical workshop

The workshop moved into its new premises in the Pavillon de Mail in 2001. These at last provide facilities for the workshop that meet modern standards of safety and efficiency, and have considerably enhanced the productivity of the service. The use of computer-aided design and numerically controlled machines continues to be central to the operation of the mechanical workshop. In the new building, provision is made for temperature-controlled space for metrology and houses the form and dimension measuring machines as well as a scanning electron microscope. Insofar as it is possible within the budgetary constraints, the mechanical workshop will continue to be equipped with the most up-to-date and efficient machine tools and measuring instruments that allow the demanding requirements of a metrology laboratory to be met.

Temperature and pressure measurements

The capabilities for routine, but highly accurate, calibrations of platinum resistance thermometers for the room-temperature region and in pressure for the atmospheric pressure range will be maintained for the internal use of other sections at the BIPM. These two capabilities are among those considered to be part of the essential infrastucture of a metrology institute.

Information technology

Within the BIPM it is essential to maintain an efficient and up-to-date information technology infrastructure. This is required not only for the scientific work but also for internal secretarial and editing functions, for external communication, and for the BIPM key comparison database (see below). An important part of the work in the Time section relies on data sent to the BIPM on a regular basis by some sixty laboratories and observatories around the world. It is essential that these data be received in a reliable and efficient way.

We shall continue to provide an up-to-date BIPM web page containing useful information about the BIPM, the Metre Convention, the various Committees of the CIPM and their publications. Useful links to the web pages of NMIs are included and we shall maintain the powerful search engine for metrology.

Most meetings at the BIPM are now "paperless" in which all documents and working papers are received and distributed electronically. During meetings, provision is made at the meeting table for access to the internet as well as for projection of Power Point presentations.

Security of electronic communications and of the internal electronic infrastructure is of high priority; a high but reasonable level of protection is maintained.

The BIPM key comparison database

The Mutual Recognition Arrangement of national measurement standards and of calibration and measurement certificates issued by National Metrology Institutes called for the creation of a single worldwide database at the BIPM. This is the BIPM key comparison database (KCDB, at http://www.bipm.org/kcdb). It contains the results of key comparisons which provide the technical basis of the Arrangement, as well as the lists of CMCs of NMIs. During the initial four-year period of implementation of the MRA (December 1999 – December 2003), the whole system, including the underlying databases and web structure, was developed and first data were published. These include results of about 60 CIPM key comparisons and 13 000 CMCs covering a number of fields of metrology. For the coming four-year period, we foresee that a large amount of data will have to be treated for publication via the KCDB. These include the results of about 300 CIPM and RMO key comparisons that are still in progress and many CMCs, especially in the fields of chemistry, ionizing radiation, thermometry and time and frequency, that are still in the early stages of intra-regional review. In addition, the BIPM will continue to be very attentive to the requests of KCDB users in order to keep the system useful and up-to-date.

Quality System

The BIPM is putting in place a Quality System covering its calibration and measurement services that will meet the requirements of ISO 17025 with external peer review.

The Joint Committee of the Regional Metrology Organizations and the BIPM

The BIPM provides the chairmanship and secretariat of the Joint Committee of the Regional Metrology Organizations and the BIPM, the JCRB. This is a new task that followed upon the implementation of the CIPM MRA. The JCRB meets twice per year and is charged with overseeing the operation of a large part of the MRA, notably that concerned with the data entry to Appendix C, the calibration and measurement capabilities of the NMIs. The proper running of the JCRB is a key element in the successful operation of the MRA and is an increasingly heavy task that is shared with the RMOs and the NMIs.

15.8 General administrative services

Finance, personnel and general administration

Finance, personnel and general administration and purchasing are under the responsibility of one professional helped by an additional professional and one full time and two part-time assistants. This is a very small staff to run these services.

Secretariat

The Secretariat of the BIPM consists of two professionals, one full-time and one part-time, and two secretaries, the former comprising the secretary-cum-personal assistant to the Director and a librarian who also assists in BIPM publications and translations. The work load on the Secretariat, and also the administrative services, continues to increase with the rise in the number of meetings of Consultative Committees and Working Groups and the number of participants attending these meetings. Much of this is due to the implementation of the MRA but it is also a consequence of the increased number of meetings related to the BIPM's increasing links with other international organizations. Every effort is made to improve efficiency by making best use of information technology.

Publications

The publications of the BIPM are an essential part of its activities and all modern means of communication are actively employed. The reports of the meetings of the General Conference, of the CIPM and of the Consultative Committees, and the successive editions of the SI brochure are the main formal publications of the BIPM. Produced in French and English, these are distributed to all Member States and Associates of the CGPM, to NMIs and also widely among the metrology community. These documents are now available free of charge from the BIPM website. The other main publication of the BIPM is the journal *Metrologia*, now in its fortieth year of publication. Starting with Volume 40, 2003, *Metrologia* is now published under license on behalf of the BIPM by Institute of Physics Publishing (UK). Full editorial control remains with the BIPM and the Editor continues to be a member of the staff of the BIPM. This change was made to improve the efficiency of the production, distribution and marketing as well as to reduce the workload on the BIPM. In 2004 it is planned to increase the annual number of issues from six to ten including the publication of one or two special issues or conference proceedings. There exists, in addition, a web-only *Technical Supplement* to *Metrologia* for the publication of the final reports of key and supplementary comparisons. The staff responsible for publications is

headed by the Editor of *Metrologia* and includes the assistant editor, part of the time of the librarian and one part-time secretary.

In addition to contributing to BIPM publications, the scientific staff publish the results of their work in refereed journals, including but not exclusively *Metrologia*, and present the results of their work at scientific conferences. During the ten-year period 1993 to 2002, the annual average output published by BIPM staff comprised some twenty publications in refereed journals, a dozen or so publications in conference proceedings and about ten BIPM reports.

Library

The library of the BIPM continues to be a part of the institute essential for the efficient pursuit of the scientific work. The number of journal subscriptions remains essentially constant, but as interest and work evolve the individual journals taken are subject to change. The creation of the section for metrology in chemistry after the 21st CGPM required an expansion of the library into this new area. In order to keep the costs under control it was necessary to cease taking some of the less commonly used journals in the traditional areas of work at the BIPM. Unfortunately, experience has shown that the cost of subscriptions to scientific journals increases at a rate above that of inflation. As a result, the more expensive journals, unless they are considered part of the BIPM core collection, are abandoned. Subscription to Contents journals is an efficient and cost-effective way of keeping abreast of publications not held in the library.

Travel and transport of equipment

As a general principle, travel by the scientific staff and the Director to national laboratories, conferences and meetings related to metrology is an essential part of the activities of the BIPM and will continue.

The cost of travel and transport of equipment has increased by some 60 % during the period 1999 to 2002 and now accounts for nearly 4 % of the annual budget. This reflects the increasing number of meetings that BIPM staff now attend related to the operation of the MRA. Every effort is made to meet the requests for BIPM participation in expert meetings around the world organized by RMOs. The main cost of such travel, however, is not the direct financial one but the time taken. The number of invitations to take part in meetings and conferences as well to visit national laboratories is such that many of these have regretfully to be declined simply for lack of time.

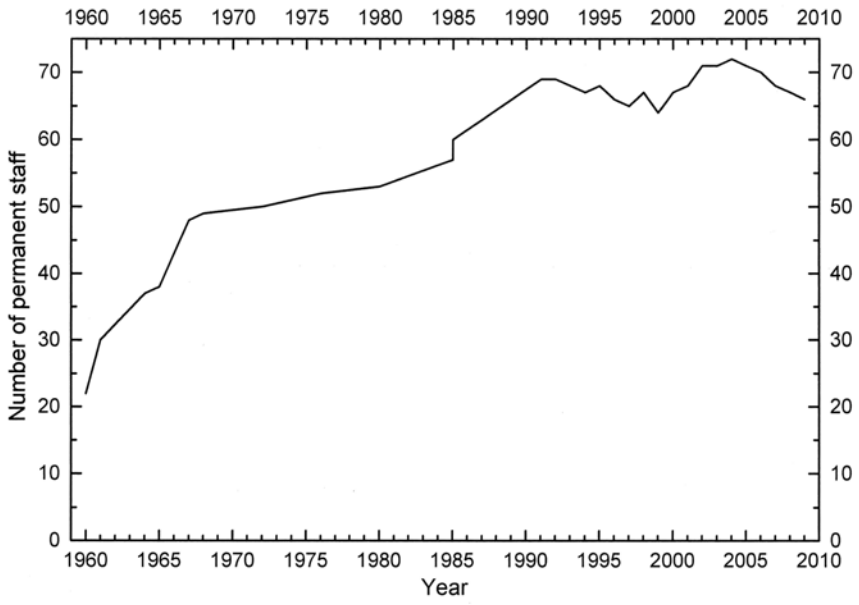
15.9 Buildings and grounds

The Pavillon de Breteuil is a historic site and both the Pavillon itself and the grounds must be maintained to a high standard. The maintenance of buildings ranging in date from the time of Louis XIV (the Pavillon de Breteuil) to the present day is not only expensive but requires a wide range of skills and techniques. Foreseen in the coming *quadrennium* are major works in the roofs of the two seventeenth century buildings, the Pavillon de Breteuil and the Petit Pavillon. The opening in 2001 of the Pavillon du Mail for the workshop, offices and additional meeting rooms, completed the long-term plan for building presented to the 17th General Conference in 1983 and mentioned at every succeeding Conference. Since its opening, the much improved facilities for meetings of up to one hundred people have been used extensively.

There are no future plans for extensions to or construction of buildings at the BIPM. Maintenance and renovations of the buildings will, however, continue to be required. These will include the maintenance of the fabric of the Pavillon de Breteuil. These will be needed either to take account of new requirements resulting from changes in programme, such as the extension into organic chemistry and the installation of a watt balance project or simply the updating of old installations. The maintenance of adequate air conditioning in the laboratories is a major task that needs continual surveillance and updating of equipment but it is one of the essential requirements for today's metrology.

15.10 Staff

The total number of full time equivalent permanent staff employed at the BIPM on 1 March 2003 was 71 plus 5 Research Fellows These staff are distributed among the various sections as shown in the organizational chart on the following page. The evolution in the number of permanent staff since 1960 and its predicted numbers up to the year 2008 are shown below in the Figure. The average age of all staff on 1 March 2003 was 48 years and that of the scientific staff 46 years.



ORGANIZATIONAL CHART OF THE INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES ON 1 MARCH 2003

DIRECTOR
Dr T. J. Quinn

Deputy Director
Director designate
Prof. A. J. Wallard [9]

JCRB
Dr A. E. Samuel [8]

KCDB
Dr C. Thomas [6]
Dr S. Maniguet [2]

LENGTH	MASS and RELATED QUANTITIES	TIME	ELECTRICITY	RADIOMETRY and PHOTOMETRY	IONIZING RADIATION	CHEMISTRY
(Prof. A. J. Wallard)	**Dr R. S. Davis**	**Dr E. F. Arias**	**Dr T. J. Witt**	**Dr M. Stock**	**Dr P. Allisy-Roberts**	**Dr R. Wielgosz**
Mr R. Felder	Dr H. Fang	Mr J. Azoubib	Mr F. Delahaye	Mr R. Goebel	Dr D. T. Burns	Dr M. Esler
Dr S. Picard	Ms C. Goyon	Dr Z. Jiang	Dr D. Reymann	Mr S. Solve	Dr C. Michotte	Dr J. Viallon
Dr L. Robertsson	Mr A. Picard	Dr W. Lewandowski			Dr G. Ratel	
Dr L. Vitushkin	Dr H. Parks [2]	Dr G. Petit			Ms C. Kessler [2]	
Prof. L. Ma [1]		Dr P. Wolf [10/3]				
Dr M. Zucco [2]						
Mr J. Labot	Ms J. Coarasa	Ms H. Konate	Mr D. Avrons		Mr C. Colas	Mr P. Moussay
	Mr J. Hostache	Ms M. Thomas	Mr R. Chayramy		Mr M. Nonis	
			Mr A. Jaouen		Mr P. Roger	
					Mr C. Veyradier [6]	

FINANCE and GENERAL ADMINISTRATION	SECRETARIAT	PUBLICATIONS	IT and QUALITY SYSTEMS	WORKSHOP and SITE MAINTENANCE
Ms B. Perent	**Ms F. Joly**	**Prof. P. W. Martin**	**Dr R. Köhler**	**Mr J. Sanjaime**
Mr F. Ausset	Ms D. Le Coz [3/6]	Dr J. R. Miles	Mr L. Le Mée	Mr F. Boyer
Ms D. Etter	Ms G. Négadi		Mr G. Petitgand	Mr M. De Carvalho
Ms M.-J. Martin [3]	Ms J. Varenne			Mr J.-B. Caucheteux
Ms D. Saillard [6]				Mr D. Rotrou
Mr C. Dias Nunes [7]				Mr P. Benoit
Ms A. Dominguez [3/7]				Mr E. Dominguez [5]
Ms I. Neves [3/7]				Mr P. Lemartrier
Ms R. Prieto [7]				Mr C. Neves [5]
Ms R. Vara [7]				
Mr A. Zongo [4/7]				

1 - Senior Research Fellow
2 - Research Fellow
3 - Not full time
4 - Also Workshop
5 - Also Caretakers
6 - Also Publications
7 - Caretakers, Cleaners, Gardeners
8 - On secondment from NML CSIRO
9 - Also Head of Length section
10 - On secondment at SYRTE Observatoire de Paris since 1 September 2002

15.11 Contribution to the pension fund

Following an actuarial study in 1994, the CIPM continues to follow the plan it decided at that time to increase the annual allocation to the pension fund each year from 1996 to 2008 by an amount equivalent to 2 % of the salaries. A follow-up study in 2001 confirmed the tendencies indicated in 1994 but showed that the number of BIPM pensioners had increased at a higher rate than foreseen due mainly to early retirements. In 1994, it was predicted that the number of pensioners would double by 2010, increasing from 24 to 48. In fact, in 2003 there are already 42 pensioners and this number is now expected to reach 58 by 2010 and 66 by 2018, at which point there will be one pensioner for every active member of the staff. The most recent actuarial study indicated, nevertheless, that the provisions now being made for the pension fund will allow all calls upon it to be met for the foreseeable future.

16 Annual dotation of the BIPM

The CIPM, in the Convocation to the 22nd General Conference, asked the Conference to adopt the following dotations for the years 2005 to 2008:

10 041 000 euros in 2005
10 222 000 euros in 2006
10 406 000 euros in 2007
10 593 000 euros in 2008.

The justification for these figures is given in detail in the Convocation to the 22nd General Conference and need not be repeated here, but see also the Appendix to this present document.

In what follows, the projected overall costs are given for the programme of work described above in Section 15 of the present document. The cost headings (operating expenses, laboratories' expenditure, staff expenses, etc.) are those used in the financial part of the document entitled *Rapport annuel aux Gouvernements des Hautes Parties contractantes sur la situation administrative et financière du Bureau International des Poids et Mesures* distributed each year to Member Governments of the Metre Convention. All figures are given in thousands of euros.

Annual budgets for the years 2005 to 2008 are presented in Section 16.1. The corresponding breakdown of costs by category is shown graphically in Tables 16.1.2 to 16.1.5. In establishing the budget proposals for each year, additional sums of about 5 % of the total have been included over and above the dotation. These additional sums represent subscriptions from Associates of the General Conference, projected income from interest on capital and other minor revenues from services, sale of Pt-Ir prototypes, and royalties including *Metrologia,* etc. (see the *Rapport annuel aux Gouvernements des Hautes Parties contractantes sur la situation administrative et financière du Bureau International des Poids et Mesures* for recent years).

16.1 Budgets for each of the years 2005-2008

16.1.1 Recapitulation of income (in thousands of euros)

	2005	2006	2007	2008	4 years
A. Dotation	10 041	10 222	10 406	10 593	41 262
B. Subscriptions*	155	157	160	163	635
C. Other income	414	409	425	419	1 667
Total	10 610	10 788	10 991	11 175	43 564

* Only the present ten Associates of the CGPM are included (March 2003)

16.1.2 Recapitulation of expenditure (in thousands of euros)

	2005	2006	2007	2008	4 years
A. Staff expenditure (15.10)	5 497	5 476	5 427	5 517	21 917
B. Contribution to the pension fund (15.11)	1 591	1 667	1 738	1 857	6 853
C. General services (15.8)	1 123	1 093	1 154	1 115	4 485
D. Laboratory expenditure (15.1 to 15.7)	1 930	1 860	1 840	1 870	7 500
E. Buildings (15.9)	407	629	767	750	2 553
F. Miscellaneous and contingent	62	63	65	66	256
Total	10 610	10 788	10 991	11 175	43 564

16.1.3 Staff

	2005	2006	2007	2008
Permanent staff	71	69	68	67
Research Fellows	1	0	0	0
Total	72	69	68	67

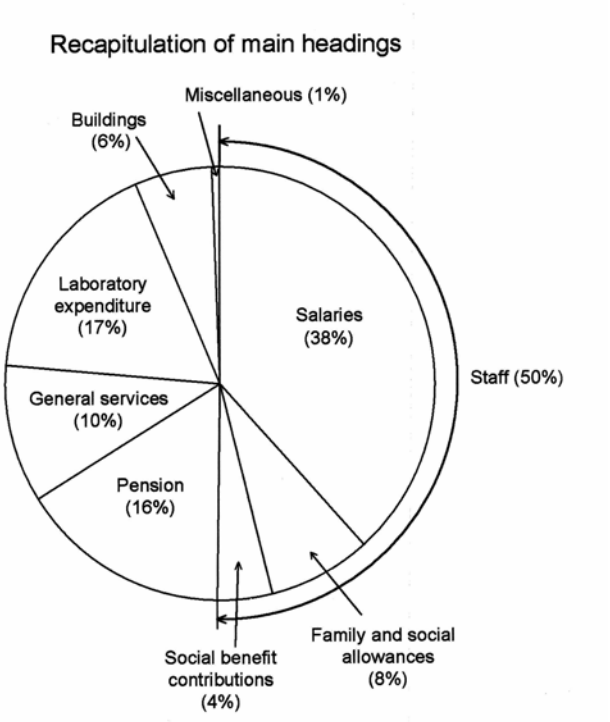
16.1.4 General services (in thousands of euros)

	2005	2006	2007	2008	4 years
Heating, water, electricity	165	168	171	174	678
Insurance	34	36	38	40	148
Publications	97	58	59	60	274
Office expenses	156	158	161	163	638
Travel, transport of equipment	362	358	345	351	1 416
Meetings	68	70	130	72	340
Library	202	205	209	213	829
Bureau of the Comité	39	40	41	42	162
Total	1 123	1 093	1 154	1 115	4 485

16.1.5 Laboratory expenditure (in thousands of euros)

	2005	2006	2007	2008	4 years
Length	156	120	60	61	397
Mass	180	183	187	190	740
Time	83	84	90	92	349
Electricity	260	265	270	274	1 069
Ionizing radiation	206	210	214	217	847
Metrology in chemistry	360	366	374	380	1 480
Workshop	104	105	107	109	425
General laboratory and scientific services, IT, KCDB	291	296	302	307	1 196
Start-up costs for new projects including organic chemistry	290	231	236	240	997
Total	1 930	1 860	1 840	1 870	7 500

16.2 Graphical representations of projected expenditure for the years 2005-2008



Recapitulation of main headings, including breakdown of staff costs 16.1

Appendix

The following is an extract from the Report of the 91st meeting of the CIPM held in October 2002. It gives an account of the decisions made concerning the future programme of work; decisions that are reflected in the programme described in this document now presented to Member States.

BIPM programme and budget for the years 2005 to 2008

An extensive discussion took place on the programme and budget of the BIPM for the years 2005 to 2008. The CIPM considered the results of the consultations with directors of NMIs (the questionnaires, the meeting in April 2002 and the responses to a document sent to directors in July 2002) on the future programme and budget of the BIPM. The outcome was that the CIPM decided to make some changes to the programme of the work of the BIPM, so as to face up to an expected shortfall of income and at the same time to respond to changing needs in metrology. The following is a summary of the discussion and the conclusions.

According to the rules of the CGPM, the official Convocation containing the elements of the agenda, including particularly the CIPM proposals for the dotation for the next four-year period, must be sent to Member Governments at least nine months before the opening of the Conference. For the 22nd CGPM that opens on 13 October 2003, the deadline for receipt of this document is thus early in January 2003. In fact, the Convocation is always sent out by the end of December.

Introduction

Members of the CIPM and directors of NMIs had been informed that an increase in 2005 of 1.1 million euros (some 12 % of the 2004 dotation) would be needed to maintain all of the BIPM current activities and that an increase of 1.9 million euros (some 20 % of the dotation) would be needed to maintain the current programme and embark upon extensions into organic chemistry, bioanalysis and medicine.

The first reactions from some Member States to these proposals indicated it was extremely unlikely that the 22nd CGPM would agree to vote a step increase in budget for the year 2005 of more than about half of even the 1.1 million euros needed to maintain the current activities, plus a small amount for inflation for that and the succeeding years. We were informed that if, at the time of the Conference, a proposal were made for an increase much greater than this, it would be likely to be vetoed.*

The difference between these indications and what was requested was sufficiently large that the bureau recommended to the CIPM that it take strategic decisions at its meeting in October 2002 on how to deal with this and that these not be left until after the CGPM in 2003.

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* The formal procedure for adopting the dotation at a General Conference requires it to be adopted with no votes against. Abstentions are allowed but if there is a single vote against, it fails. The consequence of a failed dotation Resolution is that the dotation voted by the preceding General Conference remains unchanged. This is because the successive Resolutions on the dotation simply modify the previous one. Thus, if the proposed modification fails the dotation for the last year of the previous *quadrennium* continues until such time as agreement to change it is reached.

For the purposes of making concrete proposals for the programme of work and budget, the following starting hypothesis was taken: that there will be a 5 % (0.45 million euros) step increase in dotation on 1 January 2005 plus an increase for inflation of 1.5 % in this and the subsequent three years of the *quadrennium* 2005 to 2008.

Broad strategic options

Since the 21st CGPM in 1999, the BIPM has been pressed to undertake, and has undertaken, considerably more activities than were envisaged at the time. The role of the BIPM in coordinating international activities in metrology, relations with other organizations as well as the work stemming from the implementation of the MRA have all been much greater than foreseen. The response of the BIPM has been widely welcomed by NMIs and it is clear that all of this must continue.

On the basis of the hypothesis stated above, significant reductions in the current BIPM programme will, however, have to be made.

In deciding how to proceed, the CIPM took a number of considerations into account:

1. The needs of NMIs in respect of the services supplied by the BIPM as set out in the responses to the second questionnaire to directors; these include all the coordination and international relations activities as well as the KCDB, JCRB and the scientific and technical work in the laboratories that provide calibration and other services to NMIs and the scientific base of the BIPM.
2. There are no across-the-board economies that would have a significant effect.
3. The magnitude of the savings that need to be made is such that one of the large scientific sections will have to be closed.
4. In deciding which of the large sections must be closed, there are strategic decisions that must be taken regarding what should remain as the base for the future core programme of work.
5. The consequences of the changes with respect to the staff of the BIPM.

Much of the thrust of the Report on *Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM,* adopted by the CIPM in 2002 and shortly to be published, relates to the emerging needs for international metrological activity in chemistry, biotechnology and medicine. Contacts we have had with NMIs all over the world confirm this view. It was the opinion of the Committee that while it is clear that a large activity at the BIPM in these fields is for the present not possible, it is essential to have a minimum of two high-level specialists in these fields. If we do not do this, we shall not be present in any of the international forums and we shall not even know how to respond to requests for information to meet the most urgent needs. Even if, as has been suggested by some directors, BIPM activities in these areas can be mainly supported by staff seconded from some NMIs, it will still be necessary to have a minimum of in-house expertise to provide continuity, without which such a programme could not work.

While it is not yet clear how the BIPM will in due course become involved, at the first meeting of a working group of the new Joint Committee for Traceability in Laboratory Medicine (JCTLM) there was already a call to set up an infrastructure to supply reliable data for an eventual database to hold lists of reference materials and reference methods that will be drawn up by the JCTLM. The BIPM provides the secretariat for this new Joint Committee.

It is widely recognized that the success the BIPM as an intergovernmental organization has had up to now in its international work of coordination rests on its scientific credentials. This was also a clear outcome of the outside consultations made by KPMG. Without a scientific base, it would not be possible to attract high-level specialists, in any field, to come to the BIPM. If it were simply an office it is unlikely that any of the present senior scientific staff would be here. The short experience we have in chemistry indicates that having a specialist on the staff has been an essential support to our coordination work.

Therefore, if the BIPM does not enter in some way into the fields of organic chemistry, bioanalysis and medicine, it is difficult to see how it can play the pivotal role in these new fields of metrology that the recent KPMG study indicated it has in physical metrology. This role is highly valued not only by directors of NMIs but by an increasing number of organizations outside the direct field of metrology but having interests closely related to metrology.

The first important decision made by the CIPM was that it is essential to embark on a minimum laboratory programme in the new areas in order to secure the future of the BIPM and to meet the clearly stated requirements of NMIs.

In order to take the decisions necessary to re-orientate the BIPM so that it enters, at least, to a minimum extent into these new fields, it was necessary to have a clear view of the short- and medium-term priorities in respect of each of the current programmes of the BIPM. This was because the new work must be at the expense of some of the existing programme. A high priority in making these decisions was also the importance of making the best use of the highly qualified and motivated staff of the BIPM.

Priorities in the present programme

It is clear that the BIPM is an essential component of the international metrological infrastructure. Its presence in international activities representing the interests of NMIs, its role in coordinating international metrology, its contacts with other international organizations directly and through Joint Committees, its support to Consultative Committees and RMOs as well as its key role in the implementation of the CIPM MRA through the KCDB and the JCRB, are all activities having the highest priority. That these activities be maintained and developed is in no way contentious and to do this there must be a sound scientific base.

Within the scientific and technical programme there are, however, various levels of priority. These are:

Top priority: The mass and time-scale programmes

These are the central core of the BIPM scientific activities: for the mass work we have a specific mandate in the Metre Convention and for time scales we have a specific mandate through successive CGPM Resolutions. The content of the mass and time programmes are continually under review, but while small economies can be foreseen in the time work resulting from increasing use of automation, it is the view of the CIPM that the mass programme should expand to include a watt balance project. This is because a requirement for any future definition of the unit of mass based on atomic or fundamental constants is a long-term commitment to monitoring the mass of present artefact, the International Prototype. The BIPM is uniquely positioned and capable of making such a commitment.

Second priority: Ionizing radiation and chemistry

The ionizing radiation programme at the BIPM provides the principal reference for most national dosimetry and radioactivity comparisons and provides the link to the SI for the extensive network of Secondary Standards Dosimetry Laboratories run by the IAEA. No economies can be foreseen as the present activities are at the lower limit of viability. The present small chemistry programme is the first step into the new fields discussed above and must have a high priority.

Third priority: The electricity, the laser and gravimetry programmes

The electricity and laser programmes each have particular significance.

The electricity programme would be an essential contributor to any watt balance project at the BIPM. It also holds the only high-accuracy travelling standards of the Josephson volt and the quantum-Hall resistance. Both of these are unique and currently provide the only means to check the consistency of NMI standards at the highest level of accuracy. Such a capability is essential (either at the BIPM or elsewhere) for the foreseeable future. There are also proposals, in collaboration with the NML CSIRO (Australia), to build a new calculable capacitor to be installed at the BIPM to provide one of the few long-term world references in this field. Several NMIs have expressed interest in participating in this project. Note also that half of all the calibration certificates issued by the BIPM are for electrical standards serving nearly half of all the Member States of the Metre Convention. Some capability in electrical measurements is part of the essential core competence of the BIPM.

In the case of the laser programme, the new programme is centred on femtosecond comb technology. With the development of this new technology, the thirty-year programme of laser comparisons of 633 nm He-Ne lasers using the BIPM lasers as reference has come to an end. This also provides a natural break point for other visible and infrared laser comparisons. The femtosecond comb work is at the frontiers of science and is in preparation for a possible future BIPM role in comparing optical frequency standards at a level of accuracy beyond that feasible by satellite techniques. The short and medium-term aim of the new BIPM programme in this field is thus to prepare for optical frequency comparisons, to validate the performance of frequency combs and meanwhile to provide a service of frequency measurement for the 633 nm standards of the smaller NMIs.

The gravimetry programme is very small but is highly valued and increasingly seen as essential by the geophysics community at whose request we recently established a formal working group. A new request has arrived asking for further support from the metrology community to help improve links between all aspects of geophysics and the SI. The long-standing series of comparisons of absolute gravimeters at the BIPM is strongly supported by the International Union of Geophysics and Geodesy. The gravimetry work at the BIPM will contribute to a watt balance project.

Fourth priority

In the fourth priority we place the photometry and radiometry programme and the small activity in nanometrology. In the case of the photometry and radiometry programme the arguments for work at the BIPM are less compelling than for the other programmes mentioned above. This is because with the almost universal adoption by NMIs of the cryogenic radiometer as the reference for radiometric and photometric standards, the former role of the BIPM in maintaining

the mean world lumen and candela on a set of incandescent lamps has disappeared. Furthermore, there are no BIPM travelling standards that are essential to compare cryogenic radiometers. It is clear, however, that maintenance of the lumen and the candela at the BIPM enable the BIPM to continue its long-standing calibration service that is highly appreciated by many smaller NMIs. However, it should be noted that the present complement of three professionals but no technical staff is not sufficient for the current programme.

The nanometrology programme provides a small but useful support to the work in this field of the CCL but cannot be considered to have high priority at the BIPM as CCL work in this area is still relatively limited.

Core competences

Underpinning all of the above, there are a certain number of core competences that should be preserved at the BIPM. These include a basic knowledge of electrical measurements, optics and interferometry, pressure and temperature measurements as well as electronics, mechanical design and a mechanical workshop to build experimental apparatus.

Programme decisions

The CIPM considered these priorities and made the following decisions:

1. A maximum of two new staff will be recruited for organic chemistry and a small laboratory programme started during the period 2004 to 2006.
2. A watt balance project will be started and a calculable capacitor project will be pursued in collaboration with the NML CSIRO.
3. The staff of the KCDB will be re-enforced and provision made for a permanent secretariat for the JCRB.
4. The photometry and radiometry programme will be terminated in 2004. The three professional staff will be transferred to the Electricity section and when the present three professional staff of the Electricity section retire within the next few years, will become the core of the Electricity section. The calibration service of incandescent lamps will, therefore, cease but attempts will be made to arrange calibrations for the BIPM's former clients with some NMIs in their local RMOs. (Note: On average a total of about twenty-five lamps are calibrated each year.)
5. The work in the Length section will be focused solely on the femtosecond laser project and it will continue only until 2006 when it will be closed. Longer-term continuation of the present programme would continue to require heavy investment in both equipment and high-level scientific staff and under the present circumstances this is beyond our resources. The existing four permanent staff of the section will progressively be re-deployed to other areas of work at the BIPM.

Staff

The Committee expects the changes outlined above to be achieved without any forced staff redundancies by taking advantage of retirements, internal transfers from areas being reduced or closed and the completion of all the short-term Research Fellow appointments.

The present staff (October 2002) comprises 71 permanent employees plus six Research Fellows. It is planned to reduce this by 2008 to 67 permanent staff and no Research Fellows. Note that

staff numbers fluctuate year on year as a result of retirements and overlapping recruitments, and in 2003 there will be up to 75 permanent staff but only five Research Fellows.

However, visiting scientists are essential for the scientific programme of the BIPM. They also are needed to provide additional scientific support so that heads of sections can be more visible in RMO technical meetings; an activity we recognize to be of high priority and one that should be increased. The CIPM asks the NMIs to be ready to send suitable people on secondment, at their expense, to the BIPM for periods of one or two years so as to maintain a constant presence of four or five Research Fellows. This is specifically mentioned in the Draft Resolution on the dotation.

Additional funding

The absence of any additional capital funding for new or updating major equipment or basic infrastructure, over and above the annual dotation voted at successive CGPMs, distinguishes the BIPM from many NMIs. In the current period of low price inflation, there is no longer the possibility of making savings from the annual budget for these purposes. Such savings of a few percent of the dotation per year had been possible during the 1970 and 1980s when the increases voted by successive general Conferences turned out to be a little larger than price increases in France that actually occurred. In view of the impossibility of making significant savings from annual budget, the CIPM considered asking Member States at the 22nd CGPM to make a single lump-sum contribution for restructuring during the next four-year period. The sum envisaged would have been about 1 million euros, sufficient to cover updating laboratory air conditioning, refurbishment of laboratories, and major renovation of the roofs of the two seventeenth century buildings of the site, the Pavillon de Breteuil and Petit Pavillon. In the end, however, no such request for a single lump sum is being made because it was thought that the chances of success were too remote. These additional costs are, therefore, absorbed into the CIPM's proposed increase in the dotation. The possibility of an additional contribution to the BIPM pension fund was also discussed but not proceeded with.

While considering the consequences of a future shortfall in income from existing Member States and Associates, we must not forget the possibility of a small increase in income from increased membership of the Metre Convention or from other sources and this must be explored.

Liste des sigles utilisés dans le présent volume
List of acronyms used in the present volume

1 Sigles des laboratoires, commissions et conférences*
Acronyms for laboratories, committees and conferences

ACQHR	CCEM Working Group on ac Measurements of the Quantum Hall Resistance
AHWGV	*Ad Hoc* Working Group on Viscosity
AIEA/IAEA	Agence internationale de l'énergie atomique/International Atomic Energy Agency
AIST	Agency of Industrial Science and Technology, Tokyo et Tsukuba (Japon)
AMA/WADA	Agence mondiale antidopage/World Anti-Doping Agency
AOAC	Association of Official Analytical Chemists
APMP	Asia/Pacific Metrology Programme
AQSIQ	Bureau d'État de la supervision de la qualité, de l'inspection et de la quarantaine, Beijing (Chine)
ASTM	American Society for Testing and Materials, West Conshohocken, PA (États-Unis)
BelGIM	Institut national de métrologie bélarussien, Minsk (Bélarus)
BEV	Bundesamt für Eich- und Vermessungswesen, Vienne (Autriche)
BIML	Bureau international de métrologie légale
BIPM	Bureau international des poids et mesures/International Bureau of Weights and Measures
BmwA	Bundesministerium für wirtschaftliche Angelegenheiten, Vienne (Autriche)
BNM	Bureau national de métrologie, Paris (France)
BNM-SYRTE	Bureau national de métrologie, Systèmes de Référence Temps Espace, Observatoire de Paris (France)
BRML	Bureau roumain de la métrologie légale, Bucarest (Roumanie)
CARICOM	Carribean Community
CARIMET	Coopération métrologique des Caraïbes/Caribbean Institute of Metrology
CC	Comité consultatif du CIPM/Consultative Committee of the CIPM
CCAUV	Comité consultatif de l'acoustique, des ultrasons et des vibrations/Consultative Committee for Acoustics, Ultrasound and Vibration
CCEM	Comité consultatif d'électricité et magnétisme/ Consultative Committee for Electricity and Magnetism
CCL	Comité consultatif des longueurs/Consultative Committee for Length
CCM	Comité consultatif pour la masse et les grandeurs apparentées/Consultative Committee for Mass and Related Quantities
CCPR	Comité consultatif de photométrie et radiométrie/ Consultative Committee for Photometry and Radiometry
CCQM	Comité consultatif pour la quantité de matière : Métrologie en chimie/ Consultative Committee for Amount of Substance : Metrology in chemistry

* Les laboratoires ou organisations marqués d'un astérisque soit n'existent plus soit figurent sous un autre sigle./Organizations marked with an asterisk either no longer exist or operate under a different acronym.

CCRI	Comité consultatif des rayonnements ionisants/Consultative Committee for Ionizing Radiation
CCT	Comité consultatif de thermométrie/Consultative Committee for Thermometry
CCTF	Comité consultatif du temps et des fréquences/Consultative Committee for Time and Frequency
CCU	Comité consultatif des unités/Consultative Committee for Units
CEI/IEC	Commission électrotechnique internationale/International Electrotechnical Commission
CEM	Centro Español de Metrología, Madrid (Espagne)
CENAM	Centro Nacional de Metrología, Mexico (Mexique)
CGPM	Conférence générale des poids et mesures/General Conference on Weights and Measures
CIE	Commission internationale de l'éclairage/International Commission on Illumination
CIEMAT	Centro de Investigaciones Energéticas, Medio-ambientales y Tecnológicas, Madrid (Espagne)
CIML	Comité international de métrologie légale
CIPM	Comité international des poids et mesures/International Committee for Weights and Measures
CITAC	Cooperation on International Traceability in Analytical Chemistry
CMI	Český Metrologický Institut/Czech Metrological Institute, Prague et Brno (Rép. tchèque)
CMS/ITRI	Centre for Measurement Standards of the Industrial Technology Research Institute, Hsinchu (Taiwan)
CNR	Consiglio Nazionale delle Ricerche, Turin (Italie)
CODATA	Committee on Data for Science and Technology
Codex Alimentarius Commission : Commission créée par la FAO et l'OMS	
COOMET	Coopération métrologique entre les États d'Europe centrale/ Cooperation in Metrology among the Central European Countries
CPEM	Conference on Precision Electromagnetic Measurements
CSIR-NML	Council for Scientific and Industrial Research, National Metrology Laboratory, Pretoria (Afrique du Sud)
DCSMS	State Enterprise "Transcarpathian Regional Standardization, Metrology and Certification Center", Uzhgorod (Ukraine)
DFM	Danish Institute of Fundamental Metrology, Lyngby (Danemark)
ENEA	Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, Rome (Italie)
ENEA-INMRI	Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti, Rome (Italie)
EUROMET	European Collaboration in Measurement Standards
FAO	Organisation des Nations unies pour l'alimentation et l'agriculture/Food and Agricultural Organization of the United Nations
GAW	*voir* OMM-WMO/GAW
GT-RF	Groupe de travail pour les grandeurs aux radiofréquences du CCEM/ CCEM Working Group on Radiofrequency Quantities
GUM	Glówny Urzad Miar/Central Office of Measures, Varsovie (Pologne)
HUT	Helsinki University of Technology, Helsinki (Finlande)
IAEA*	*voir* AIEA
IAF	International Accreditation Forum

IATA	International Air Transport Association
IAU*	*voir* UAI
ICAG	International Comparison of Absolute Gravimeters
IEC*	*voir* CEI
IEN	Istituto Elettrotecnico Nazionale Galileo Ferraris, Turin (Italie)
IERS	Service international de la rotation terrestre/International Earth Rotation Service
IFCC	Fédération internationale de chimie clinique et médecine de laboratoire/ International Federation of Clinical Chemistry and Laboratory Medicine
IGS	International GPS Service for Geodynamics
ILAC	International Laboratory Accreditation Cooperation
ILP	Institute of Laser Physics, Académie des sciences de Russie, Novosibirsk et Saint-Pétersbourg (Féd. de Russie)
IMGC	Istituto di Metrologia G. Colonnetti, Turin (Italie)
IMGC-CNR	Istituto di Metrologia G. Colonnetti, Consiglio Nazionale delle Ricerche, Turin (Italie)
INMETRO	Instituto Nacional de Metrologia, Normalizaçao e Qualidade Industrial, Rio de Janeiro (Brésil)
INPL	National Physical Laboratory of Israel, Jérusalem (Israël)
INTI	Instituto Nacional de Tecnología Industrial, Buenos Aires (Argentine)
IOPP	Institute of Physics Publishing, Londres (Royaume-Uni)
IPQ	Instituto Português da Qualidade, Lisbonne (Portugal)
IRMM	Institut des matériaux et mesures de référence, Commission européenne/Institute for Reference Materials and Measurements, European Commission
ISO	Organisation internationale de normalisation/International Organization for Standardization
ISO CASCO	Organisation internationale de normalisation, Comité pour l'évaluation de la conformité/International Organization for Standardization, Committee on Conformity Assessment
ISO REMCO	Organisation internationale de normalisation, Comité pour les matériaux de référence/International Organization for Standardization, Committee on Reference Materials
ITU*	*voir* UIT
IUGG*	*voir* UGGI
IUPAC*	*voir* UICPA
IUPAP*	*voir* UIPPA
JACR	Japanese Association of Cardiac Rehabilitation, Tokyo (Japon)
JCDCMAS	Comité commun pour la coordination de l'assistance aux pays en voie de développement dans les domaines de la métrologie, de l'accréditation et de la normalisation/Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization
JCGM	Comité commun pour les guides en métrologie/Joint Committee for Guides in Metrology
JCRB	Comité mixte des organisations régionales de métrologie et du BIPM/ Joint Committee of the Regional Metrology Organizations and the BIPM
JCTLM	Comité commun pour la traçabilité en médecine de laboratoire/Joint Committee on Traceability in Laboratory Medicine
JV	Justervesenet, Oslo (Norvège)

KRISS	Korea Research Institute of Standards and Science, Daejeon (Rép. de Corée)
LAMA	Laboratoire de Mathématiques du CNRS, Le Bourget (France)
LGC	Laboratory of the Government Chemist, Teddington (Royaume-Uni)
LNE	Bureau national de métrologie et d'essais, Paris (France)
LNMC	Latvijas Nacionâlais Metroloìijas Centrs, Riga (Lettonie)
MAA	Arrangement mutuel d'acceptation de l'OIML des résultats d'essais d'approbation type/OIML Mutual Acceptance Arrangement for the recognition of type-approval test results
MePWG	Groupe de travail du CCL sur la mise en pratique/CCL Working Group on the *Mise en Pratique*
METAS	Office fédéral de métrologie et d'accréditation, Wabern (Suisse)
METI	Ministère de l'Économie, du Commerce et de l'Industrie, Tokyo (Japon)
MIKES	Mittatekniikan Keskus/Centre for Metrology and Accreditation, Helsinki (Finlande)
MIRS	Institut de métrologie de la République de Slovénie, Ljubljana (Slovénie)
MIT	Massachusetts Institute of Technology, Cambridge MA (États-Unis)
MoU	Protocole d'accord/Memorandum of Understanding
MRA	Arrangement de reconnaissance mutuelle du CIPM/CIPM Mutual Recognition Arrangement
MSL	Measurement Standards Laboratory of New Zealand, Lower Hutt (Nouvelle-Zélande)
NAB	National Accreditation Body
NAFTA	North American Free Trade Agreement
NCM	National Centre of Metrology, Sofia (Bulgarie)
NCSL	International Conference of Standards Laboratories
NIM	National Institute of Metrology, Beijing (Chine)
NIMT	National Institute of Metrology of Thailand, Bangkok (Thaïlande)
NIS	National Institute for Standards, Le Caire (Égypte)
NIST	National Institute of Standards and Technology, Gaithersburg MD (États-Unis)
NMi VSL	Nederlands Meetinstituut, Van Swinden Laboratorium, Delft (Pays-Bas)
NMI	National Metrology Institute
NMIJ/AIST	National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba (Japon)
NML CSIRO	Commonwealth Scientific and Industrial Research Organization, National Measurement Laboratory, Lindfield (Australie)
NML	*voir* CSIR
NPL	National Physical Laboratory, Teddington (Royaume-Uni)
NPLI	National Physical Laboratory of India, New Delhi (Inde)
NRC	Conseil national de recherches du Canada, Ottawa (Canada)
NRC-IENM/ -INMS	Conseil national de recherches du Canada, Institut des étalons nationaux de mesure/National Research Council of Canada, Institute for National Measurement Standards, Ottawa (Canada)
OIML	Organisation internationale de métrologie légale
OMC/WTO	Organisation mondiale du Commerce/World Trade Organization
OMH	Országos Mérésügyi Hivatal, Budapest (Hongrie)
OMM/GAW	Organisation météorologique mondiale, Programme de la veille de l'atmosphère globale/World Meteorological Organization, Global Atmosphere Watch programme
OMM/WMO	Organisation météorologique mondiale/World Meteorological Organization

OMS/WHO	Organisation mondiale de la santé/World Health Organization
ORB	Observatoire Royal de Belgique, Bruxelles (Belgique)
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig et Berlin (Allemagne)
RCMAM	Groupe de travail de l'UAI sur la relativité en mécanique céleste, en astrométrie et dans le domaine de la métrologie/ IAU Working Group on Relativity for Celestial Mechanics, Astrometry and for Metrology
REGMET	Project for Improving Dialogue between EU Regulatory Bodies and National Measurement Institutes
RMO	Regional Metrology Organization
SADCMET	Southern African Development Community Cooperation in Measurement Traceability
SAMTS	State Agency for Metrology and Technical Surveillance, Sofia (Bulgarie)
SCL	Standards and Calibration Laboratory (Hong Kong)
SIM	Système interaméricain de métrologie/Sistema Interamericano de Metrología
SIRIM	Standards and Industrial Research Institute, Shah Alam (Malaisie)
SIS	Swedish Standards Institute, Stockholm (Suède)
SLM	Slovak Legal Metrology, Banská Bystrica (Slovaquie)
SMU	Slovenský Metrologický Ústav/Slovak Institute of Metrology, Bratislava (Slovaquie)
SP	SP Sveriges Provnings- och Forskningsinstitut/Swedish National Testing and Research Institute, Borås (Suède)
SPIE	International Society for Optical Engineering
SPRING	Standards, Productivity and Innovation Board, Singapour (Singapour)
SSDL	Laboratoires secondaires de dosimétrie de l'AIEA/Secondary Standards Dosimetry Laboratories of the IAEA, *voir* AIEA
SYRTE*	Systèmes de Référence Temps Espace, *voir* BNM
TUD	Technical University of Denmark, Lyngby (Danemark)
UAI/IAU	Union astronomique internationale/International Astronomical Union
UGGI/IUGG	Union géodésique et géophysique internationale/International Union of Geodesy and Geophysics
UICPA/IUPAC	Union internationale de chimie pure et appliquée/International Union of Pure and Applied Chemistry
UIT/ITU	Union internationale des radiocommunications/International Telecommunication Union
UME	Ulusal Metroloji Enstitüsü/National Metrology Institute, Marmara Research Centre, Gebze-Kocaeli (Turquie)
UN	Nations unies/United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
UNMS SR	Úrad pre normalizáciu, metrológiu a skúšobníctvo Slovenskej republiky/Slovak Office of Standards, Metrology and Testing, Bratislava (Slovaquie)
URSI	Union radioscientifique internationale/International Union of Radio Science
USNO	U.S. Naval Observatory, Washington DC (États-Unis)
VNIIFTRI	All-Russian Research Institute for Physical, Technical and Radiophysical Measurements, Gosstandart of Russia, Moscou (Féd. de Russie)
VNIIM	Institut de métrologie D.I. Mendéléev/D.I. Mendeleev Institute for Metrology, Saint-Pétersbourg (Féd. de Russie)

VNIIMS	Russian Research Institute for Metrological Service of Gosstandart of Russia, Moscou (Féd. de Russie)
VNIIOFI	Institut des mesures en optique physique, Gosstandart de Russie, Moscou (Féd. de Russie)
VSL*	Van Swinden Laboratorium, Delft (Pays-Bas), *voir* NMi
VTT	Centre for Metrology and Accreditation, Technical Research Centre of Finland, Espoo (Finlande)
WADA	*voir* AMA
WGDM	Groupe de travail du CCL sur la métrologie dimensionnelle/CCL Working Group on Dimensional Metrology
WGKC	Working Group on Key Comparisons
WGLF	CCEM Working Group on Low-Frequency Quantities
WHO*	*voir* OMS
WMO*	*voir* OMM
WTO*	*voir* OMC
WTO/TBT	Organisation mondiale du commerce, Comité sur les obstacles techniques au commerce/World Trade Organization, Technical Barriers to Trade Committee
ZMDM	Bureau des mesures et métaux précieux/Bureau of Measures and Precious Metals, Belgrade (Serbie-et-Monténégro)

2 Sigles des termes scientifiques
Acronyms for scientific terms

ACES	Atomic Clock Ensemble in Space
ADN/DNA	Acide désoxyribonucléique/Deoxyribonucleic acid
ARN/RNA	Acide ribonucléique/Ribonucleic acid
AUV	Acoustics, Ultrasound and Vibration
CMC	Possibilités en matière de mesures et d'étalonnages/Calibration and Measurement Capabilities
CMM	Machine à mesurer les coordonnées/Coordinate Measuring Machine
COUNT	Projet de recherche de l'Union Européenne en électricité/Research project supported by the European Commission "Counting Electrons One by One: Measurement of Very Small Electrical Currents"
CRM	Certified Reference Material
DNA	*voir* ADN
EIPT-48/ IPTS-48	Échelle internationale pratique de température de 1948/International Practical Temperature Scale of 1948
EIT-68/ITS-68	Échelle internationale de température de 1968/International Temperature Scale of 1968
EIT-90/ITS-90	Échelle internationale de température de 1990/International Temperature Scale of 1990
EPBT-2000/ PLTS-2000	Échelle pratique de température de 1990/International Temperature Scale of 2000
EPT-76	Échelle pratique de température de 1976/Practical Temperature Scale of 1976
FTIR	Fourier Transform Infrared Technique
GDP	Gross Domestic Product
GLONASS	Global Navigation Satellite System
GMO	*voir* OGM
GPS	Global Positioning System

GUM	Guide pour l'expression de l'incertitude de mesure/Guide to the Expression of Uncertainty in Measurement
IPTS-48	*voir* EIPT-48
ISQ	Système international de grandeurs/International System of Quantities
ITS-68	*voir* EIT-68
ITS-90	*voir* EIT-90
IVD	Diagnostic *in vitro*/*In Vitro* Diagnostic
KCDB	Base de données du BIPM sur les comparaisons clés/ BIPM Key Comparison Database
KCRV	Valeur de référence de la comparaison clé/Key Comparison Reference Value
NMR	Résonance magnétique nucléaire/Nuclear Magnetic Resonance
OGM/GMO	Organisme génétiquement modifié/Genetically Modified Organism
PHARAO	Projet d'horloge atomique à refroissement d'atomes en orbite
PLTS-2000	*voir* EPTB 2000
QHR	Résistance de Hall quantifiée/Quantum Hall Resistance
RNA	*voir* ARN
SET	Effet tunnel monoélectronique/Single Electron Tunnelling
SI	Système international d'unités/International System of Units
SIR	Système international de référence/International Reference System
SMOW	Standard Mean Ocean Water
SPRT	Thermomètre à résistance de platine étalon/Standard Platinum Resistance Thermometer
TAI	Temps atomique international/International Atomic Time
TWSTFT	Comparaison de temps et de fréquence par aller et retour sur satellite/Two-way Satellite Time and Frequency Transfer
UTC	Temps universel coordonné/Coordinated Universal Time
UV	Ultraviolet
VIM	Vocabulaire international des termes fondamentaux et généraux de métrologie/International Vocabulary of Basic and General Terms in Metrology
VUV	Ultraviolet dans le vide/Vacuum Ultraviolet

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