

INTER-LABORATORY COMPARISONS FOR EMERGING NATIONAL METROLOGY INSTITUTES

A. Praba Drijarkara, Clemens Sanetra

Imprint

Published by: Physikalisch-Technische Bundesanstalt
Bundesallee 100
38116 Braunschweig, Germany

Responsible: Dr. Marion Stoldt
Phone: +49 531 592-82 00
Fax: +49 531 592-82 25
E-Mail: marion.stoldt@ptb.de
www.ptb.de/q5

Text: A. Praba Drijarkara, Clemens Sanetra

Layout: Jenko Sternberg Design GmbH
(www.jenko-sternberg.de),
Physikalisch-Technische Bundesanstalt

Photos: Physikalisch-Technische Bundesanstalt

As of: October 2012

Acknowledgement

The idea to write this guide was initiated by the APMP Developing Economies Committee and PTB's Technical Cooperation Department as organizers of many intercomparison exercises for developing NMIs in the Asia-Pacific region.

In the preparation of this guide, various inputs have been taken into account, especially those gained by interviews with coordinators and coaches from both developing and developed NMIs having participated in the APMP-DEC-PTB intercomparison program. We would like to thank the TC Chairs for their valuable advice and contributions, in particular the Lead TC Chair Dr. Ilya Budovsky who gathered the relevant information.

Dr. Robert Kaarls, Secretary of the CIPM and President of the CCQM revised the final draft and gave valuable inputs. Dr. Anna Cypionka, PTB project coordinator, accompanied the process and took care of the final revision.

Content

Content	4
Foreword	5
Introduction	6
Outline	8
1 Initiating a Comparison	9
1.1 Analysis of Emerging NMIs' Needs	9
1.2 Decision to Carry out a Comparison	9
1.3 Financial issues	10
2 Organization of a Comparison	11
2.1 Selection of Coordinating Institute and Coaching Institute	11
2.2 Designation of the Coordinating Institute	12
2.3 Designation of the Coaching Institute	12
2.4 Call for Participants	13
2.4.1 Availability of Necessary Resources for Conducting the Measurement	13
2.4.2 Traceability to SI Units	13
2.4.3 Commitment from Management	14
2.4.4 Established Measurement Procedures	14
2.5 Differentiating the Levels of Participation	14
3 Preparation of Technical Protocol	16
3.1 Tentative Schedule	16
3.2 Registration of Comparison	16
4 Preparatory Workshop	17
4.1 Objectives	17
4.2 Invitation to Participants	17
4.3 Logistics, Venue and Accommodation	18
4.4 Timetable and Program	18
4.4.1 Laboratory Reports Presentation	20
4.4.2 Review of Calibration Methods	20
5 Circulation of Travelling Standards	21
5.1 Trouble-Shooting	21
5.2 Organization of Loops	23
6 Reporting the Result to the Coordinating Institute	24
7 Draft A Report	25
7.1 General Remarks	25
7.2 Separate Reports for Non-Official Loop and Non-CIPM-MRA NMIs	25
8 Concluding Workshop	26
9 Preparation of Draft B Report, Approval and Publication	28
10 Feedback to and Follow-up by RMO and Concerned Committees	29
11 Glossary	31
12 References	34

Foreword

Membership in the Meter Convention is increasing yearly with the aim of integrating all countries worldwide in the International System of Units (SI). The member economies are represented by their national metrology institutes (NMIs). Benefit arises once the NMI joins the mutual recognition arrangement of the International Committee on Weights and Measures (CIPM-MRA) and is able to demonstrate technical competence through so-called Calibration and Measurement Capabilities (CMCs).

As a result, less experienced NMIs become more active in the regional metrology organizations (RMOs) and more new NMIs are joining. Their experiences differ vastly from those of well-established NMIs, many of which have been active members of the Metre Convention and RMOs since decades.

The reasons why an economy at first did not have (or might still not have) an NMI acting at the regional or international level are manifold. In the Asia-Pacific region, where this guide was developed, more NMIs from developing or even least-developed economies sign the CIPM-MRA and have become more active in APMP (Asia-Pacific Metrology Programme). In these economies financial resources are scarce and a lack of understanding the importance of metrology for economic development has inhibited the establishment of the NMIs on an international level. In many of the economies, metrology is still no priority and the laboratories suffer from constraints in budget, personnel and equipment.

Other NMIs in the process of entering or re-entering the international stage come from countries undergoing political changes, as for example the states of the former Soviet Union and new candidates for the European Union. In these countries the NMIs might be well established, but struggling to comply with the modern requirements the international system. Some small but well developed economies which never saw the necessity to have their own NMI do not lack resources but are just beginners in metrology. Throughout this document, the term “emerging” refers to NMIs that are still undergoing major developments.

Having described the situation of the emerging NMIs it is clear that they need special support for their international integration. Signing up as an Associate of the General Conference of Weights and Measures (CGPM) or as a Member State of the Metre Convention and signing up to the CIPM-MRA is only a first and comparably easy step. The ultimate goal is the international recognition of the technical competence through CMCs making the successful participation in international inter-laboratory comparisons indispensable.

Within APMP a concept has been developed to facilitate the access of emerging NMIs to inter-laboratory comparisons, as a participant, but also to gain experience in organizing comparisons: Comparisons on an intermediate technical level or in a measurement field of special relevance to the emerging NMIs are conducted. Some comparisons are strictly non-official and for exercise purpose only, others combine official and exercise purposes depending on the needs of the participating NMIs. Before and after the comparison participants are trained in workshops. The comparisons are organized by a team consisting of a coordinator from an emerging NMI and an assigned coach/expert from an advanced NMI.

So far, APMP and PTB have organized 7 of these comparisons providing valuable learning experiences for the participating NMIs. With this guide we wish to share the concept with future organizers and participants of exercise comparisons in APMP and other RMOs. By explaining the concept step-by-step and highlighting the recurring challenges we hope to make it easier to organize many more comparisons for emerging NMIs.

Introduction

Inter-laboratory comparisons (or simply comparisons) constitute the technical basis of the CIPM Mutual Recognition Arrangement (MRA). The main comparisons, called the key comparisons, are carried out either by CIPM Consultative Committees (CCs), BIPM, or regional metrology organizations (RMOs). There are also supplementary comparisons which may be carried out “to meet specific needs not covered by key comparisons” [1]. These comparisons have stringent rules and guidelines that must be followed by the participants. Successful participation of a national metrology institute (NMI) in a comparison will lead to confidence in calibration and measurement certificates issued by that NMI.

There is a third category of comparison, an exercise called pilot study, which is intended to gain experience in new parameters, new methods and new fields. In some cases NMIs take part in pilot studies because they are not yet ready to participate in a key or supplementary comparison. However, emerging NMIs are not the specific target group for pilot studies.

In the metrological hierarchy the starting points are CC key comparisons mostly on the level of primary standards or higher order methods, which then are repeated in the regions as RMO key comparisons. All other comparisons, e.g. on lower levels, performed with other methods than in key comparisons, etc. are considered supplementary comparisons. For emerging NMIs not yet in the technical condition to participate in key comparisons, these supplementary comparisons on the lower levels are of special importance. On the other hand, developed NMIs are concentrating more on key comparisons. Low-level supplementary comparisons are not of priority to them, especially once they have covered their CMC claims with key comparisons. Occasionally developed NMIs may be willing to organize a bilateral comparison with an emerging NMI.

The situation described in the above paragraph applies for a number of APMP members from developing economies. They missed out on the opportunity to participate in comparisons and needed comparisons that were designed for their needs and suitable for their technical level enabling them not only to participate successfully, but also eventually to coordinate comparisons.

Since 2003, the APMP Developing Economies’ Committee (DEC) carried out a number of comparisons organized and participated by emerging NMIs, guided by the more experienced NMIs. Until now, a number of such comparisons (listed in table A) have been conducted successfully. Some of these comparisons were formally planned and recognized as either key or supplementary APMP comparisons, although this is just a by-product of the initiative. (To retrospectively declare a comparison to be official, when the result of a comparison was unexpectedly favourable, is not allowed!)

Area	Scope	Organizer	Coach	Registration
Mass	Weights, class E2, 100 mg, 2 g, 20 g, 500 g and 1 kg, class E2	VMI, Vietnam	NMIA, Australia	APMP.M.M-K6, incl. exercise for non-CIPM-MRA members
Temperature	LIGT and IPRT -40 °C to 250 °C	NIMT, Thailand	NMIA, Australia	APMP.T-S3, incl. exercise for non-CIPM-MRA members
Length	Gauge Blocks, Steel: 1 mm, 5 mm, 10 mm, 50 mm and 100 mm Tungsten carbide: 1 mm, 5 mm, 10 mm, 50 mm and 100 mm	KIM-LIPI, Indonesia	KRISS, Korea	APMP.L-S3, incl. exercise for non-CIPM-MRA members
Pressure	Pressure Gauge, 10 – 100 MPa	SIRIM, Malaysia	PTB, Germany	Exercise
Electrical Measurands	Digital Multimeter	NPLI, India	NMIA, Australia	APMP.EM-S8
Temperature	Liquid in Glass Thermometers, -40 °C to 250 °C	ITDI, Philippines	NIMT, Thailand	APMP.T-S8 and exercise loop

The concept has been established as an important tool for the development of emerging NMIs. By providing lessons learned and by giving a detailed description of the important steps, we hope to offer support for future coordinators and participants and thus prepare them for the recurring challenges of the comparisons. The guide is intended to complement, not to replace, a number of valuable documents already published by the CIPM concerning comparisons. Specifically, it addresses a number of issues that are particular to comparisons for emerging NMIs, such as preparatory and concluding workshops, and problems typically encountered in developing economies.

A number of guides and other documents about comparisons are available on the BIPM website: (<http://www.bipm.org/en/cipm-mra/documents/#comparisons>). Readers are advised to first familiarize themselves with this document available there.

Outline

The BIPM website mentioned above provides a number of reference documents describing the process of comparison, from initiation to reporting. The principal document to be used as reference here is the CIPM-MRA-D-05 (at the time of writing this guide, version 1 of the CIPM-MRA-D-05 was used). The main steps of the process are illustrated in the following chart. The dark blue boxes indicate the steps mentioned in the CIPM Guide (they apply to all comparisons in general), whereas the light blue boxes show additional steps that are relevant for an exercise-type comparison, or elaboration of the main steps which require special attention by emerging NMIs. All of these steps are described in the relevant sections of this Guide.



1 Initiating a Comparison

1.1 Analysis of Emerging NMIs' Needs

The term “emerging NMI” can mean either an NMI belonging to a developing economy, or an NMI having a relatively young age. As such, emerging NMIs have different capabilities, experiences, resources, and needs, compared to the leading NMIs with decades of history. The primary difference lies in the fact that developed NMIs usually are capable of realizing most of the primary standards of measurement (with higher precision), whereas for the emerging NMIs, many of their highest standards are secondary standards or lower (with lower precision). The fact that emerging NMIs do not possess or operate state-of-the-art measurement standards may be simply due to the fact that they do not yet have the capability or resources to operate the highest precision standards, but also due to a lack of demand for the highest precision measurement from their economy or industries.

Keeping in mind the above, it is necessary for emerging NMIs to carefully determine what capabilities they must develop. They should be relevant to the needs of their own economies, but not necessarily the same as those of their neighboring countries.

Lead Questions for a Demand Survey, examples:

- Which industries, value chains, and testing capabilities exist?
- Which measuring instruments are mainly in use in the industrial processes?
- Which scopes are accredited and need traceability?
- In which fields the regulatory bodies need traceability; which instruments are in use?

1.2 Decision to Carry out a Comparison

A RMO should consider offering a comparison with a special focus on emerging NMIs in a certain field of measurement or for a certain type of calibration/measurement service (henceforth called “service”) if one or more of the following conditions hold true:

- A key comparison for the service has been conducted at CC or RMO level, but the emerging NMIs were not able to participate, mainly because they did not have or did not need the highest level of measurement precision.
- No supplementary comparison has been conducted for the type of service that is more relevant for the emerging NMIs.
- One or more NMIs are still in the preparation stage to offer the service and would like to compare their performance, but are not yet ready for an official comparison.
- One or more NMIs have the competence to carry out the service, but are not yet an Associate of the CGPM or a Member State of the Metre Convention and a CIPM signatory, or have only an observer status in a RMO.

In the case that the RMO has set up a committee to deal with the specific needs of emerging NMIs (like the DEC in APMP), this committee could be the leading committee to identify the general needs as emerging NMIs do not normally have staff participating in all TCs. So the DEC or similar committee identifies through its members the general needs in metrological parameters, range, method, and uncertainty and coordinates with the respective TC. Such a committee is a better advocate than individual NMIs and can accompany and monitor the whole process, follow-up, formulate and publish the lessons learnt and coordinate with the Technical Committees.

The process of identifying these needs could also be initiated and coordinated by the respective Technical Committee Chair. Alternatively, an emerging NMI that feels the need for such comparison can volunteer to take the initiative.

When a need for comparison has been identified, the proposed comparison should be specified in terms of:

- calibration and measurement capability (e.g. measurand or type of instruments which can be calibrated) to be compared by making use of travelling standards (also called transfer standards) or other artifacts, like (C)RMs,
- instruments to be calibrated (the travelling standards; also called transfer standards or artifacts)
- measurement range and expected measurement uncertainty value
- method of measurement, comparison or calibration.

1.3 Financial Issues

The RMO and the participants should be aware of the costs involved in a comparison. The following list names the most important expenses incurred in a comparison:

Expenses of a Comparison:

- 1 Procurement of travelling standards**
(including costs for repair or replacement in case of damage)
- 2 Shipping cost**
(limited to shipment to the next participant's port of entry, excluding customs clearance; hand-carriage might be necessary in exceptional cases)
- 3. Customs clearance**
(paid by or organized by recipient)
- 4. Preparatory and concluding workshops**
(cost for venue, accommodation, travel)
- 5. Consumables to carry out measurement**

All of these costs must be communicated clearly to the participants, especially those who are participating for the first time.

2 Organization of a Comparison

2.1 Selection of Coordinating Institute and Coaching Institute

The principal player in a metrological comparison is the “pilot institute”, which is an NMI tasked with coordinating the comparison, analysing the results and preparing the reports. In the comparisons participated mainly by emerging NMIs, the trend has been to appoint a “coordinating institute”, guided by a “coaching institute”. The coordinating institute is usually an emerging NMI, while the coaching institute is a developed NMI with the relevant experience. In effect, the coordinating institute and the coaching institute share the tasks normally performed by a pilot institute. The appointment of coordinating institute and coaching institute can be determined by consensus among the members of a technical committee, subject to approval by the TC Chair and considering the issues described in the following subsections. Table 2 summarizes the tasks of the coordinating institute and the coaching institute.

In practice, both the coordinating institute and the coaching institute shall appoint persons in charge in their respective institutes to carry out the tasks according to their roles. Informally, these persons might be known as the “coach” and the “coordinator”. However, to avoid confusion, the terms “coach” and “coordinator” shall only be used to refer to the institutes, not the persons.

	“Pilot Institute”	
	Coordinating Institute	Coaching Institute
Expertise	Experienced in performing the measurements, good communication and coordinating skills	Has participated in relevant key comparisons, so that it is able to provide a reference value for the proposed comparison
Tasks:		
Communication	Communicate with participants (invitation for workshops, follow-up on status of comparison, collect measurement results)	Keep regular contact to coordinating institute, assist in all steps of the comparison, resolve difficult technical problems, revise the measurement results.
Protocol	Prepare protocol with help of coaching institute and input from participants	Give technical advice for preparing the protocol according to international rules, revise and approve final version of protocol
Artifacts (travelling standards or CRM)	Together, the coaching institute and the coordinating institute share and coordinate the task of preparing the artifacts and delivering them to the participants.	
Workshops	Organize and moderate workshops, prepare its own lab for practical exercise, provide technical guidance on measurements to other participants	Back-up the coordinating institute, provide technical guidance on performing inter-laboratory comparison, act as lecturer, adviser and trainer in the workshops, revise calibration procedures and measurement uncertainty calculations
Reference value	Assure stability of the artifact through regular measurements before and during comparison (between loops).	Provide reference value, link the comparison to a key comparison and if possible to a Key Comparison Reference Value (KCRV)
Draft A and B report	Collect data from participants, prepare and circulate Draft A report, present Draft A report at concluding workshop and prepare Draft B report	Supervise preparation of draft A and B report, approve final versions

2.2 Designation of the Coordinating Institute

The coordinating institute is responsible for organizing the comparison from start to finish. The term “coordinating institute” here is used in lieu of the term “pilot institute” used in official comparisons, implying that the coordinating institute does not exactly fulfill the same role as the pilot institute. The reason is that the coordinating institute is an emerging NMI that is considered to have not yet the experience to be a pilot institute. (In some cases it is not even yet a signatory to the CIPM-MRA.) Only in collaboration with the experienced coaching institute the role of a “pilot institute” can be fulfilled.

The coordinating institute should be reliable and have proven expertise regarding the specific measurements to be performed in the comparison. The key person of the coordinating institute should also be someone who is good at communicating with the other participants.

Coordinating a comparison imposes additional burden on the coordinating institute, both in terms of man-hour and finance. Since the travelling standards will travel to and from the coordinating institute more than once (sometimes up to 4 times or more, depending on the number of participants and the arrangement of the loops), the coordinating institute must be aware of the costs and time involved. If the coordinating institute cannot bear the cost alone, it should discuss this issue with the other participants to work out a favourable solution for sharing the costs.

2.3 Designation of the Coaching Institute

The coaching institute is an NMI whose role it is to guide the coordinating institute in preparing and executing the comparison. Therefore the coaching institute is expected to have sufficient experience in participating and piloting key comparisons, preferably comparisons at CC level.

The role of the coaching institute is to advise the coordinating institute on the procedures of the comparison, as well as to impart technical knowledge and skills to the participants with regards to the measurement. The coaching institute will also act as a link to the relevant key comparisons. Therefore, the requirements for a coaching institute are:

- having participated successfully in a relevant key comparison, either at CC or RMO levels;
- having coordinated another comparison;
- having a staff member who can oversee the comparison from beginning until the end.

The coaching institute must be available for participation in the workshops, and if necessary, for a pre-visit to the coordinating institute for consultations, training, audit, etc., and for analysing data and preparing reports. Before deciding on the designation of the coordinating institute, it might be worth arranging a visit by the coaching institute to the possible coordinating institute, to evaluate whether it has the adequate resources to conduct the measurement and organize the comparison.

2.4 Call for Participants

After the proposed comparison has been specified, an invitation to participate shall be sent out to all members of the RMO. Although the emerging NMIs form the main target group of this type of comparison, some of the more advanced NMIs might also be interested for various reasons. Therefore the invitation should be sent out by the respective TC Chair, even when the text is prepared by the designated coordinating institute and/or coaching institute.

In the previous step (i.e. the process of determining the comparison), prospective NMIs may have already stated their intention to participate in the comparison; however, once the comparison is defined, it is necessary for these NMIs (and perhaps other NMIs not involved in the initial process) to confirm their participation. The criteria for participation must be clearly defined at this stage. Specifically, the criteria which are outlined below.

2.4.1 Availability of Necessary Resources for Conducting the Measurement

Since the main purpose of comparisons is to test the capability and competence, the participating NMIs must fulfil certain predefined conditions and have the necessary resources in order to perform the measurement. These include:

- traceable measurement standards and supporting equipment
- staff members who have the knowledge, skill and experience to carry out the measurement
- consumables
- room conditioning system to achieve the required ambience conditions.

2.4.2 Traceability to SI Units

Participating NMIs must ensure that their measurement standards are traceable to a recognized primary standard as a realization of SI units either by their own laboratory or through an NMI listed with the respective CMCs in the BIPM Key Comparison Database (KCDB).

In most cases, emerging NMIs do not have primary standards or primary measurement capabilities; in such cases, the standards and measurements must be traceable to another NMI or DI that has published the relevant CMC in the KCDB for the specific parameter, range and uncertainty (CIPM-MRA-D-04, Section 8) [3]. This applies also for emerging NMIs that already have higher or primary standards but no recognition (CMCs) on that level. If an NMI traces back to these standards it does not have “recognized” traceability and has to get it from another NMI with CMCs in this field although it results in additional costs.

For example, in the comparison of liquid-in-glass thermometers (LIGTs), one NMI has its own fixed points which are primary standards for temperature, the values of which are disseminated through standard platinum resistance thermometers (SPRTs) to the LIGTs. However, if the NMI has not participated in a comparison for SPRTs, it cannot be traceable to its own fixed points; it should get traceability for its SPRTs from another NMI who has demonstrated calibration and measurement capabilities in SPRTs.

2.4.3 Commitment from Management

The top management of the NMIs must express commitment to support the laboratories' participation in the comparison.

The management must ensure that the person in charge of the measurement will be available throughout the comparison schedule. There have been a number of cases where the persons in charge were reassigned to other positions or duties in the middle of the comparison loop, which hindered their effective involvement in the comparison. If there is any change of personnel, care must be taken to ensure that the new personnel receive all the necessary information about the comparison. This applies for the participants, and especially for the coordinating institute, because a change of personnel at the coordinating institute could jeopardize the successful completion of the reports.

The management must be aware of the resources required and mentioned above and assure that these requirements are met.

2.4.4 Established Measurement Procedures

The main idea behind comparisons is to demonstrate competence in performing a regular measurement service. Normally, an NMI intending to participate in a comparison should already offer the measurement as a regular service. However, given the conditions of emerging NMIs as the target group of the comparison participants are probably still in the process of establishing the service. In this case, it is necessary to at least ensure that they already have documented procedures for measurement and uncertainty evaluation.

2.5 Differentiating the Levels of Participation

In some cases, emerging NMIs may still be at the stage of developing or perfecting their capability in a particular area of measurement or calibration. They may be interested in joining a comparison in that area of measurement; however, their intention may not be to get an immediate proof of competence to support their CMCs. They might want to participate to develop their capabilities and get feedback about their performance. Under these circumstances, having an unsatisfactory result in an official comparison would be against their interest because the result will be permanently recorded. Therefore, it helps to differentiate between the "experienced" participants and the "novice" participants.

Another situation where a participant could be treated differently is when the country or economy of that participant is not yet a member of the Metre Convention, or is not yet a signatory of the CIPM-MRA. Current CIPM regulations do not allow for the inclusion of comparison results from non-signatories of the CIPM-MRA. Formally, the comparison can be split into "official" and "non-official" loops. The official loop is for the participants who are already confident with their measurement capability, whereas the non-official loop is for those who need an exercise.

The protocols (or the principal part of the protocols) of both loops can be the same; the difference lies in the reporting. The formal report of the comparison (which eventually will be published at the KCDB) will contain only the results from the participants of the official loop.

A separate report to the RMO can be prepared, containing results from the non-official participants only, or from all participants. This report can be circulated internally and confidentially among the participants, or (as agreed by all participants) published as a technical report in a publication.

One of the possible options for parallel official and non-official loops is the use and circulation of different travelling standards. This applies in case that the exercise group e. g. cannot cover the planned measurement range or does not reach the same measurement uncertainties as the official group. (see Section 5.2).



3 Preparation of Technical Protocol

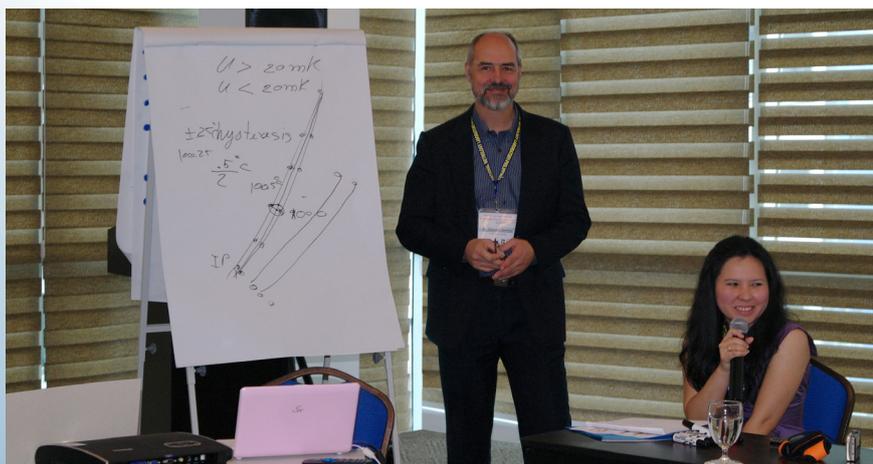
The technical protocol is an essential part of the comparison. Perhaps the most practical way to prepare a protocol is by modifying one from a previous comparison for a similar type of measurement. The coordinating institute should first prepare a draft protocol (either modifying one from a previous comparison, or making a new one) and consult with the coach to revise the draft until a version adhering to the international best practice is available. Details of the technical protocol are already covered in depth in the CIPM MRA-D-05. When a draft protocol is ready, it can be circulated to the participants to seek comments and suggestions. This process can be continued until, and preferably finalized during the preparatory workshop (see next section).

3.1 Tentative Schedule

At this stage, it is also necessary to draw up the tentative schedule, taking into account any time restrictions or conflicts of schedules reported by the participants.

The main consideration for drawing up the schedule is the choice between official and non-official loops as described in the previous section. The coordinating institute must be placed at the beginning and the end of each loop. The coaching laboratory should be placed immediately before or after the coordinator, to ensure better control of the stability of the standards and link the results to higher-level comparison or KCRV.

Existing regulations regarding customs clearance in the different countries should be taken into account. Participants can be divided into two groups – those whose countries are members of the ATA system and those whose countries are not. Stricter transportation rules by airlines have considerably delayed recent comparisons. Especially equipment with hazardous substances such as liquid-in-glass thermometers or battery powered equipments can be rejected and require early clarification with the transporting company.



3.2 Registration of Comparison

When it has been decided whether a part or the whole comparison will be an official comparison (see 2.3), an application can be made for the registration of the comparison at the KCDB. Such an application has to be made through the respective Technical Committee (TC) Chair before the start of the circulation of standards, after the protocol has been fixed.

4 Preparatory Workshop

4.1 Objectives

As the comparisons for emerging NMIs focus on the learning and training aspects, workshops should be organized to better prepare the participants for the comparison and help analyzing the results. The first is a preparatory workshop conducted before the circulation of travelling standards. The purpose of the preparatory workshop is not only to familiarize participants with the protocol and to share technical knowledge about the measurement of the travelling standards, but also to provide theoretical and practical training, as well as an individual analysis of the situation of each participating laboratory's capabilities. This workshop can also be used to finalize the protocol and the schedule.

Although it is not formally required to have face-to-face meetings before commencing a normal comparison, in this context it is beneficial to have such meeting. In a normal comparison, it might be assumed that the participants are well aware of the rules of the technical protocol in particular, and of the measurement techniques involved in general. However, among many emerging NMIs, such knowledge might not be uniformly distributed and some of them might not yet have participated in international activities. It is especially valuable for them to compare their own situation with colleagues at a similar level or learn from the expert coach or from more advanced colleagues. Both aspects play an important role for emerging NMIs. Active participation in face-to-face meetings is very crucial and contributes also very much to make acquaintance with the outside world and helps very much to build up the necessary mutual confidence. Experience shows that NMIs that do not very regularly actively participate in meetings do not develop.

4.2 Invitation to Participants

The coordinating institute normally hosts the preparatory workshop. As host, the coordinating institute is responsible for inviting the participants and making arrangement for accommodation and the necessary travel documents such as visa recommendation letters.

The invitation should be issued at the earliest point in time. On several occasions in the past, participants were not able to take part in workshops due to late notice of the workshop dates. Their participation was prevented by delayed visa application or lacking budget approval and/or travel authorization by their institutions. It is important for participating institutes to choose their delegates carefully. The delegates should be directly involved in the day-to-day activities of the laboratory and will conduct the measurements of the comparison. They should have sufficient experience in the area of measurement involved, and also possess sufficient communication skills in the language used for the workshops and reporting. It can also be helpful to send two persons, so the second person can learn to improve his/her competence and broaden his/her horizon. Ideally, both the preparatory and concluding workshops should be attended by the same persons.

In a number of past occasions, the person in charge of comparison at some laboratories was reassigned to other positions or duties during the comparison cycle, so that other personnel had to take over. While such changes might be inevitable, laboratory management should take this issue into consideration and ensure that the persons in charge of a comparison can maintain their active involvement at least until the comparison is finished, and preferably can stay for a much longer period in the same job in order for the institute not to lose the obtained knowledge and experience and to ensure a long-term sustainable development. This is another reason for having always a back-up person involved and also two participants in the workshops.

4.3 Logistics, Venue and Accommodation

The host is expected to arrange the logistics and accommodation for the participants. Transportation from airport to hotel, and between the hotel and the workshop venue (ideally in the NMI), should be arranged by the host, especially where public transportation is not available or convenient for the participants. Hotel or lodging should be chosen so as to make it convenient to travel to and from the workshop venue.

Costs of logistics and accommodation must be discussed and agreed among the host, coach, sponsors (if any) and the other participants before invitations are sent. See Section 4.1 concerning the distribution of expenses. It is recommended to hold the workshop at the coordinating institute's own campus or building, rather than having it at a public convention hall. There are some advantages of conducting the workshop in the host's own facilities: it makes it easy to access the laboratories or other supporting facilities, as well as saving costs.

4.4 Timetable and Program

The workshop may last up to three days. The first day can be used for laboratory presentations and discussion. On the second day, technical lectures and practical exercises are conducted. The third day can be used to discuss the protocol, logistics and any technical issues related to the comparison, see Table 3.

Time	Session	Presenter
Day 1		
9.00	Information on the workshop schedule	Host (= Coordinator)
9.15	Welcome address by Host	Host (= Coordinator)
9.35	Opening address by Coach	Coach
9.55	Icebreaking	
10.35	Coffee Break	
10.50	Laboratory Reports	Participants
12.10	Lunch	
13.10	Laboratory Reports	Participants
14.30	Coffee Break	
14.45	Laboratory Reports	Participants
16.45	Closure	Host (= Coordinator)
Day 2		
9.00	Information on the Workshop Schedule	Host (= Coordinator)
9.30	Lecture on Calibration Technique	Coach
10.30	Coffee Break	
10.45	Lecture on Calibration Technique	Coach
11.45	Lunch	
13.10	Practical Exposure to Calibration Practice	Host (= Coordinator)

Time	Session	Presenter
14.30	Coffee Break	
14.45	Practical Exposure to Calibration Practice	Host (= Coordinator)
16.45	Closure	
Day 3		
9.00	Introduction to ISO 17025	Host (= Coordinator)
10.00	Coffee Break	
10.45	Introduction to Measurement Uncertainty	Coach
12.00	Lunch	
13.00	Introduction to Measurement Uncertainty	Coach
14.00	Coffee Break	
14.15	Presentation of the Technical Protocol	Host (= Coordinator)
15.00	Discussion on the Technical Protocol	Coordinator, Participants, Coach
8.30	CIPM MRA, Inter-laboratory Comparisons and KCDB	Coach
9.30	Open Discussion	Coordinator, Participants, Coach
10.30	Coffee Break	
11.00	Lab Tour	
12.00	Evaluation and Closure of Workshop	Coordinator, Participants, Coach

The following topics should be covered during the preparatory workshop:

Presentation of individual situation and competence of participating laboratories:

reviewed by the coach and commented by the peers (Note: In the past, this has led to changes in the considered travelling standards during the workshop as too many laboratories had overestimated their capabilities!)

Sharing of the technical knowledge with peers and learning from the coach:

including theoretical background of the measurement, evaluation of measurement uncertainty, and hands-on practice in the laboratory of the host NMI.

Receiving feedback and specific recommendations for improvements:

including the implementation in the laboratory back home.

Discussion of technical protocol

Clarification of the participating status:

official comparison, official comparison with non-official loop, exercise comparison, CIPM signatory status, etc. This is important for the organization and sequence of the measurements, the reporting and publications.

4.4.1 Laboratory Reports Presentation

Participants in the workshop are expected to present reports about their laboratories, particularly the equipment, measurement methods and general conditions relevant to the type of measurement being compared. Although some background information about the countries or the institutes might be interesting in the presentation, those parts should not take too much time of the presentation. The focus of the report shall be strictly limited to the issues relevant to the type of measurement being compared. To make sure that this rule is adhered to, the coordinating institute or the coach should prepare a presentation template.

Structure of Laboratory Report for Workshops

Brief introduction of organization

- Short history
- Organizational structure
- Area of research/services

Overview of laboratory

- Scope of services
- Main instruments/standards
- Traceability sources and chains to CMCs
- Human resources
- Quality system status (accredited or not?)
- CIPM MRA status

Calibration/measurement practices (for the measurement being compared)

- Measurement method (summary of work instructions)
- Instruments used
- Evaluation of measurement uncertainty: description of uncertainty components and uncertainty budget
- Problems/shortcomings

[For concluding workshop] Experiences during comparison measurement

- Problems and solutions

4.4.2 Review of Calibration Methods

It is a good idea for the participants to bring the calibration methods or work instructions and discuss them with the coach to get some feedback for improvement. Some laboratories might hold the opinion that their quality documents should not be exposed to external parties (apart for accreditation or peer review process), so this part is strictly voluntary and confidential. However, the potential benefit of sharing the documents in this closed forum far outweighs any negative impact that might occur.

5 Circulation of Travelling Standards

The instructions and information regarding circulation and handling of travelling standards must be clearly described in the technical protocol. The organizer must ensure that all participants have read and understood these instructions, before sending the standards.

There are two aspects to the circulation of travelling standards: the technical aspect and the administrative aspect. The first relates to the instructions on how the standards should be handled, packed and transported. The latter relates to the monitoring and documentation, including customs procedures of imports and exports.

5.1 Trouble-Shooting

The most common problems related to circulation of travelling standards and the solutions are tabulated below.

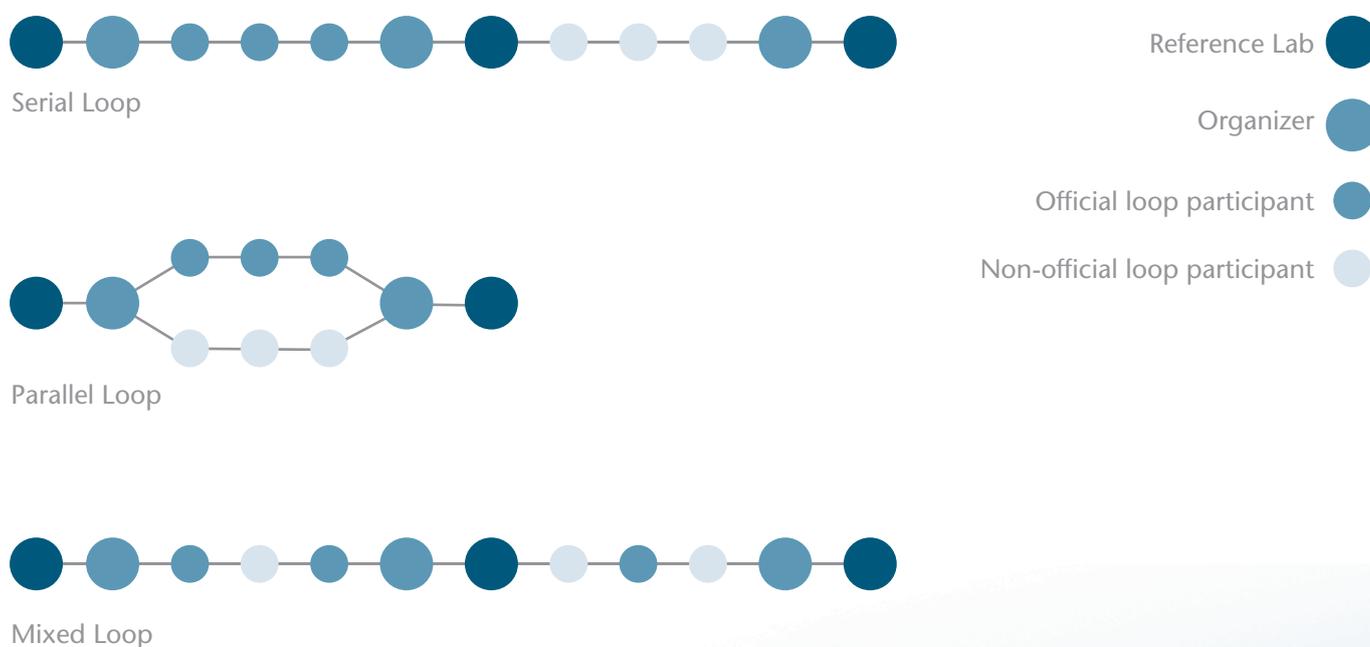
Problems	Solutions
Standards getting damaged due to improper handling or inadequate packaging	<ol style="list-style-type: none"> 1. Protocol should clearly define the steps for packaging the standards. It is very helpful to include photographs of the packaging and its contents, as well as step-by-step pictures of the packing/unpacking process. 2. Packaging material and construction should be chosen so as to provide adequate protection to standards, but easy to open and reuse to ensure that participants use the same manner of packaging. 3. Attach warning signs to the packaging to prevent customs officers or forwarding agents from handling the standards incorrectly (for example, touching the standards with bare hands). The warning should be written in the languages of both the senders and the recipients, as well as English. 4. When the standard is particularly delicate or fragile, the protocol should require the standard to be carried as hand luggage. 5. It should be clearly indicated what is "up" and "down".
Parts of instruments or documents missing from packaging	<ol style="list-style-type: none"> 1. Protocol should include the packing list (checklist), including all parts and documents. 2. Packing list should also be attached or included in the packaging and checklist be filled out by sender and confirmed by recipient.
Lengthy process of customs clearance, especially in economies not member of the ATA system	<ol style="list-style-type: none"> 1. Separating the loops for economies with and without ATA Carnet. Since economies with ATA Carnet in general have faster custom clearance process, these economies can be put on the first loops, while economies without ATA Carnet can be in the latter loops. 2. In some cases, the loop for the economies without ATA Carnet use a star arrangement: the standards are shipped from the coordinating institute to the participant, then back to the coordinating institute, before going to the next participant, and so on. However, this system puts more financial burden on the coordinating institute, as well as lengthening the whole loop. 3. It might be worth hand-carrying the travelling standards (if they are small enough, regardless of the fragility of the standards) to the non-ATA Carnet economies, because in many cases this method is easier and certainly faster than going through normal customs process if using cargo.

Problems	Solutions
Loss of ATA carnet	<p>In some cases the ATA carnet got lost when economies with and without ATA agreement participated in the same loop. Non-ATA economies customs did not know what the document was for and just kept it and did not forward it to the next participant.</p> <p>Therefore, it is recommended to send the ATA carnet separately or pack it inside the box before sending the travelling standard to a non-ATA economy. At least it should not be sent together with the shipping documents to a non ATA member economy.</p>
Sender, recipient or coordinating institute losing track of shipment	<ol style="list-style-type: none"> 1. Three-way communication among sender, recipient and coordinating institute must be maintained prior to dispatch, during shipment and after receipt. Sender should inform the recipient and not start the dispatch before getting an "okay" from the recipient. 2. All contact information, including name of person in charge of each laboratories, shipping addresses (for cargo, not for letter), email addresses, direct telephone and facsimile numbers must be recorded in the protocol. All changes must be immediately reported to the coordinating institute and the protocol must be updated accordingly. 3. Even though currently email is the most convenient and fastest way of communication, in some cases the parties may need to rely on other forms of communication such as telephone and facsimiles. Alternative email addresses, other than those provided by the institutions, may be needed.
Excessively long overall circulation time	<ol style="list-style-type: none"> 4. All participants shall agree in advance on a strict time schedule for transportation and carrying out the measurements. If a participant is not (yet) ready at the planned time to carry out the measurements, then this participant should be removed from the agreed schedule, and – if still possible – should join later on by the end of the planned schedule. One should avoid that comparisons take years, because then none of the results are of any importance to the participants anymore.

5.2 Organization of Loops

As described in 2.3 it might be necessary to split the group of participants into an official and a non-official loop. In practice, the separation can be achieved in a number of ways:

Separate loops, one running after the other (usually the official loop first);
 separate loops, both running in parallel;
 mixed loops.



Separation of loops can reduce the risks of shipment delays and damages to travelling standards assuming that the more experienced NMIs have sufficient experience and resources to ensure smooth transport and avoid damages to the standards.

In terms of the time required to conduct the comparison, parallel loops are preferable over a serial or mixed loop. Another advantage of parallel loops is that different travelling standards with different ranges and precisions can be used for the official and the non-official comparison, in case the participants in the exercise loop cannot cover the whole range of the official loop. However, it requires the availability of more than one travelling standard, preferably of identical or similar specifications. It also requires the coordinating institute and the coaching institute to perform more repeat measurements and send the reference measurements more often. When such redundancy cannot be afforded, separate and serial loops are the next best choice.

In any case, each loop must include the coordinating institute and the coaching institute, so that all participants can be linked to the link value of a key comparison or a KCRV.

6 Reporting the Result to the Coordinating Institute

It is important for participants to send the measurement report as soon as possible, within the time limit specified in the protocol. This is necessary in order for the coordinating institute to compile and analyse the data and send feedback whenever finding suspicious data.

Participants are reminded again that participation in inter-laboratory comparisons reflects their routine calibration services; therefore all the necessary resources to carry out the analysis and prepare the report in timely manner should already be available.

Participants must report the result using the format specified in the protocol. Care must be taken to ensure that the measurement values are consistent with the units of measurement specified in the report form. Example: a laboratory usually reports the deviation of gauge block in units of μm , but the report form requires the participants to report the values in nm. If the laboratory fills in the values in μm (e.g. "0,02" instead of "20"), a confusion might arise and the laboratory might be wrongly classified as an outlier.

Another common error is inverting the sign of the measurement values. Some laboratories may be accustomed to reporting the "error of indication", whereas the protocol may specify "correction" as the measurand which would have the opposite signs.

Participants have to send the report in the format specified in the technical protocol. Nevertheless, it is of benefit to issue also a regular calibration certificate to be brought to the concluding workshop. In this case the coach can revise it and can give valuable recommendations for improvements.

Although participants may send the report by email for faster delivery and convenient compilation by the coordinating institute, a hard copy report should still be sent as a formal report. In the case of dispute involving discrepancy of data at a later date, the hard copy report shall serve as proof of authenticity.

The organizer should send a confirmation to the participants who have sent their results. The organizer should make a general check of the data to identify possible outliers or abnormal results. When such abnormalities are found, the organizer should notify the respective participant and suggest them to recheck the data and the calculation, in case there is a calculation error. The notification should be worded in such a way that the participant cannot deduce which data is wrong or the magnitude of the discrepancy. Participants are generally allowed to revise their report before Draft A report is finalized.

Reports from participating laboratories are strictly confidential. Only the organizer and the coach shall have access to the reports, until the final report is published. The integrity of the reports must be maintained and a procedure needs to be established so that no parties are able to change the data to match the reference value. This can be done in either of the following ways:

- the coach (as the reference laboratory) keeps its data until all participants send their reports, after which it can reveal the reference value to the organizer; or
- a neutral bystander is appointed to get the records of all data (including those from the participants, the organizer and the coach) before handing the package over to the coordinating institute and coach for evaluation.

7 Draft A Report

7.1 General Remarks

After all participants (including the coaching institute) have completed their measurements and submitted their reports, and after the coordinating institute has performed a general check on the data and notified any suspicion, the coordinating institute can start the preparation of the report. The sequence of report preparation follows the protocol for key comparisons (Section 4.7 of CIPM-MRA-D-05), with the exception of the part about the determination of reference values, which is determined by the coaching institute. The key points of the reporting sequence are as follows:

- Report goes through the stages of Draft A, Draft B and Final Report. This should also be applied for exercise comparisons as a learning process for organizer and participants.
- Draft A is confidential; it is accessible to participants only. It may not be transmitted to any party outside of the participants, nor may it be shown in conferences involving non-participants.
- Draft A report is circulated to the participants for feedback and correction of blunders, like typing errors. In general, no corrections of original measurement data are allowed. The very limited exception is when a discrepancy not attributable to the performance of the laboratory occurs (for example, if an excessive drift or a malfunction is detected in the travelling standard).



7.2 Separate Reports for Non-Official Loop and Non-CIPM-MRA NMIs

If the comparison includes non-official loops, results from these loops cannot be included in the report of the official loops. Therefore a separate report to the RMO must be prepared for the non-official loops. Also, in the strictest interpretation of the CIPM-MRA protocol, reports from non-signatory participants (even if they participate in the official loop) are not supposed to be included in the formal reports, if the comparison is registered as a key or supplementary comparison. In this case, the organizer should prepare a separate report for the non-official participants, which will not be sent for publication in the KCDB. This report may be published by the RMO. This condition must be communicated to non-signatory participants prior to the comparison, and specified in the protocol and the preparatory workshop.

8 Concluding Workshop

The concluding workshop, held after all measurements have been completed and the Draft A report has been circulated, aims at sharing experiences and lessons learned during the circulation of the travelling standards as well as developing recommendations and corrective actions for the participants and orientation for further improvements. This workshop can also be used to evaluate the results, discuss the Draft A report, and share experiences encountered during the comparison. As in the preparatory workshop, participants are required to present their laboratory report, focused on the measurement process and related activities.

One important benefit of a closing workshop is the opportunity for participants to identify possible causes of their unsatisfactory or outlying results through discussion with the experts or repetition of the measurement in the host's laboratory. If the reference standards are easy enough to carry (as in the case of the comparison for calibration of gauge blocks by mechanical comparison), the participants can bring their own reference standards and repeat the measurement on the same travelling standards used in the comparison.



An example for a schedule for a concluding workshop can be found below. Note, that each comparison is unique. The template shall be adjusted according to the needs and characteristics of the comparison.

As mentioned in the previous section, participating laboratories should issue a calibration certificate for their measurement results, using their standard formats for routine calibration services. This certificate can be presented during the laboratory report, and the coach can give feedback and recommendation to improve the certificate. Schedule of a past concluding workshop:

Time	Session	Presenter
Day 1		
9.00	Information on the Workshop Schedule	Host (= Coordinator)
9.10	Welcome Address by Host	Host (= Coordinator)
9.20	Opening Address by Coach	Coach
9.40	Icebreaking	
10.10	Coffee Break	
10.25	Laboratory Reports	Participants
11.55	Lunch	
12.55	Laboratory Reports	Participants
14.55	Coffee Break	
15.10	Laboratory Reports	Participants
16.40	Clarification of Draft A report	Host (= Coordinator)
17.00	Closure	Host (= Coordinator)
Day 2		
9.00	Information on Uncertainty Budgets	Host (= Coordinator)
10.00	Discussion on Technical Issues	Coach
10.30	Coffee Break	
10.45	Discussion on Technical Issues	Coach
12.00	Lunch	
13.00	Replication of Measurement	Host (= Coordinator)
15.00	Coffee Break	
15.15	Replication of Measurement	Host (= Coordinator)
17.00	Closure	
Day 3		
9.00	Current State of CIPM MRA and KC	Coach
10.00	Coffee Break	
10.15	Follow-up Plan	Coordinator, Participants, Coach
12.00	Lunch	
13.00	Evaluation of Workshop and Comparison	Coordinator, Participants, Coach
14.00	Coffee Break	
14.15	Closing Ceremony	Host (= Coordinator)

9 Preparation of Draft B Report, Approval and Publication

Continuing the sequence of reporting, after Draft A is accepted during or before the concluding workshop, the coordinating institute should prepare the Draft B report. When Draft A is approved by all participants, it becomes Draft B and can be submitted to the technical committee for approval. It is no longer confidential. In case of non-official loops or exercises a Draft B report serves only for training purposes.

For official comparisons, the Draft B report must be submitted for inter-RMO review and final approval to the relevant Consultative Committee as well. This is not necessary for exercise-type comparisons.

When Draft B is finally approved in the inter-RMO review, it becomes the Final Report. The Final Report for an official comparison will automatically be published in the KCDB.



10 Feedback to and Follow-up by RMO and Concerned Committees

The objectives of an exercise comparison for emerging NMIs is much broader than for any other comparison. It should facilitate the integration of the emerging NMIs in the technical work of the RMO. The coordinating institute and coach should carefully collect the feedback from the participants and provide it to the respective committees within the RMO. These are the technical committee and any committee dealing with the issues of the emerging NMIs and/ or training programs.

Examples for issues raised by participants in the past are:

- Problems with recognized traceability
- Problems with traceability covering the entire measurement range
- Problems with environmental condition in the laboratory or required stability
- Insufficient characterization of involved equipment (e. g. baths, furnaces, etc.)
- Different considerations in the estimation of the measurement uncertainty
- Procedures not validated or not harmonized
- Problems in the processing of the data.
- Communication problems between staff that lead to reporting of wrong data

Responsibility to use the training as an important ping stone for the development of the laboratory lies with the participants as well:

- Make the training sustainable by sharing knowledge with colleagues
- Use the network of fellow participants for support
- Share experiences and issues in the technical committee

A valuable result of many coached comparisons is the ongoing networking of the participants as they have shared their experiences in the workshops and learned from each other, which is a perfect basis for keeping contact and always knowing whom to ask in case of questions and doubts.

By publishing this guide, we hope that many more emerging NMIs can take advantage of participating in exercise comparisons.



11 Glossary

Associate member

State or economy that is not a full member of the Metre Convention but is able to participate in the CIPM MRA

CC

Consultative Committee of the CIPM

CMC

Calibration and measurement capability; capability to perform a calibration and measurement service specified for a particular value or range of values and particular measurement conditions, with an assigned uncertainty value

CRM

Certified Reference Material

DEC

Developing Economies' Committee of the APMP

Draft A report

A report prepared as soon as all the results of a comparison have been received from all participants; includes the results transmitted by the participants, identified by name, and a first calculation of the key comparison reference value

Draft B report

A draft A report that has been approved by all participants, ready to be submitted for approval by the corresponding Consultative Committee

Emerging NMIs

NMIs that are in the stage of developing their capabilities. Some of these belong to developing economies/countries. Some others belong to developed countries that have only recently started developing their metrological capabilities

Key comparison

A key comparison is one of the set of comparisons selected by a Consultative Committee to test the principal techniques and methods in the field [1]

Measurement competence

The ability of a laboratory to carry out a measurement or calibration service according to the accepted best practice. For a metrology laboratory, it is commonly evaluated against the ISO/IEC 17025

Member State

Full member of the Metre Convention (sometimes called member of the BIPM)

MRA (CIPM MRA)

Mutual Recognition Arrangement of the CIPM

NMI

National Metrology Institute

Official comparison

In the context of this guide, an official comparison is either a key comparison or supplementary comparison which are registered in the Appendix B of the CIPM MRA

Pilot study comparison

Pilot studies are a category of comparison normally undertaken to establish measurement parameters for a “new” field or instrument, or as a training exercise. The results of pilot studies are not considered sufficient support for claims of calibration and measurement capability (CMC) [1]

Primary standard

Measurement standard established using a primary reference measurement procedure, or created as an artifact, chosen by convention [4]

(Measurement) Protocol

A technical document specifying what must be measured and how the artifact should be handled

RMO

Regional Metrology Organization, such as APMP in Asia-Pacific, Euramet in Europe, SIM in the Americas, etc.

Secondary standard

Measurement standard established through calibration with respect to a primary measurement standard for the same quantity [4]

Service

In the context of drawing up the CMC table; a “service” is a particular type of measurement or calibration that a laboratory can perform, specified by the type of device being measured or calibrated (and sometimes the specific measurand of that device), and the method of measurement/calibration. A service is then something that can be compared among NMIs

Supplementary comparison

A supplementary comparison is a comparison, usually carried out by an RMO to meet specific needs not covered by key comparisons (e.g. regional needs), for instance measurements of specific artefacts, or measurements of parameters not within the “normal” scope of the Consultative Committees [1]

TC

Technical Committee of the RMO, which can be counterpart to the relevant CC in the CIPM

(Metrological) Traceability

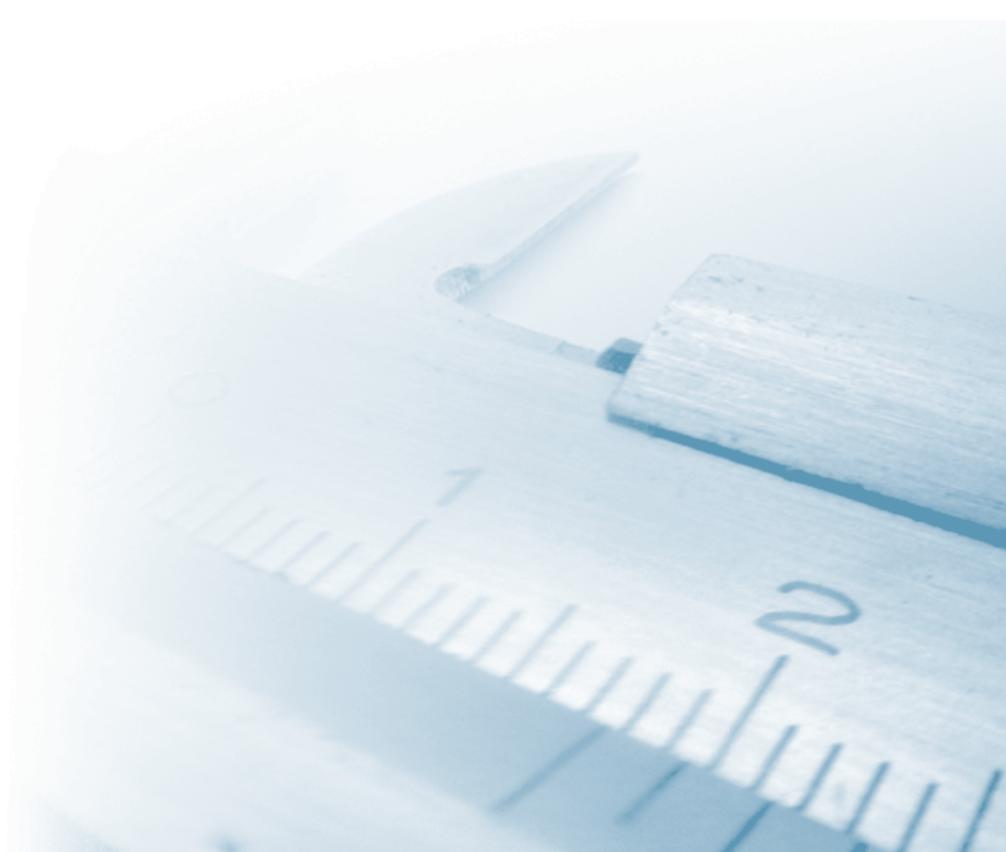
Property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty [4]

Travelling standard

Measurement standard, sometimes of special construction, intended for transport between different locations [4]. In the specific sense, this term is applied for the device being circulated to be measured/calibrated by the participants of a comparison. It is sometimes called "comparison artefact"

Value chain

Series of production steps for a product. At each step value is added to the product



12 References

- [1] Measurement comparisons in the CIPM MRA (CIPM MRA-D-05) Version 1.1,
http://www.bipm.org/utils/common/CIPM_MRA/CIPM_MRA-D-05.pdf
- [2] Mutual recognition of national measurement standards,
http://www.bipm.org/en/cipm-mra/mra_main_text.html (accessed 18 January 2011)
- [3] Calibration and Measurement Capabilities in the context of the CIPM MRA (CIPM MRA-D-04), Version 2,
http://www.bipm.org/utils/common/CIPM_MRA/CIPM_MRA-D-04.pdf
- [4] International vocabulary of metrology — Basic and general concepts and associated terms (VIM)/JCGM 200:2008

