


Technical protocol for BIPM.EM-K13a&b comparisons			 Quality Management System
Author: R. Goebel	Date: 2015/01/12 Version: 1.1	Authorized: Michael Stock	

Protocol for BIPM Key Comparisons of Electrical Resistance Standards using 1 Ω and 10 k Ω Resistors as Travelling Standards (BIPM.EM-K13.a and b)

1. Introduction

This protocol applies to comparisons BIPM.EM-K13.a (1 Ω resistance standards) and BIPM.EM-K13.b (10 000 Ω resistance standards) which constitute the BIPM programme of on-going bilateral comparisons of resistance standards. Both resistance values (1 Ω and 10 000 Ω) are to be measured at DC. In order to have a common reference value for all bilateral comparisons in this programme, the BIPM value is always taken as the comparison reference value.

The programme is open to NMIs and designated institutes of Member States of the BIPM, according to BIPM/DIR-P-01, which maintain a representation of the ohm. The representation can be based on the Quantized Hall Resistance (QHR), on a calculable capacitor through a quadrature bridge, or on the maintenance by the participating laboratory of reference resistance standards with values deduced from previous calibrations by the BIPM or by national metrology institutes. In the last case, the participating laboratory must be able to extrapolate the results of previous calibrations (or previous bilateral comparisons used as calibrations) in order to predict the value of its reference standards at the date of the comparison.


The BIPM is the pilot laboratory for all bilateral comparisons in this programme. These are key comparisons and at the beginning of the comparison the BIPM will file a declaration form with the chairperson of the CCEM working group on low-frequency quantities. The results and reports of completed comparisons will be published in the BIPM key comparison data base.

Technical changes to this protocol need to be approved by the CCEM WGLF (low frequency working group).

2. Principle of the comparison

The travelling standards used should allow resistance transfer at the 1 Ω and 10 000 Ω level with a standard transfer uncertainty not higher than a few parts in 10^8 . The BIPM proposes a set of conventional wirewound resistance standards. Alternatively or in addition, any suitable set of standards belonging to the participating laboratory can also be used.

The comparison is carried out following an initial/return measurement pattern: the BIPM travelling standards are first calibrated at the BIPM over a period of about four

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weeks. They are then sent to the participating NMI where they are calibrated over a similar period of time, and finally re-calibrated after their return at the BIPM.

If the travelling standards are provided by the NMI, an alternative circulation pattern can be: NMI – BIPM – NMI.

All measurement results are corrected to the reference temperature (23.000 °C) and the reference pressure (1013.25 hPa). The result of the comparison is expressed as the difference between the calibrations from the two laboratories, together with its associated uncertainty.

In both cases the pilot laboratory is the BIPM.

3. Customs and dispatching, charging policy

It is preferable, whenever possible, to hand-carry resistors to and from the BIPM in order to minimize possible changes in resistance. However, reasonably good results have been obtained for resistors shipped via express courier services.


For transport of the BIPM travelling standards to countries outside the European Union (EU), the BIPM will establish a license for temporary exportation. When sending the standards to the BIPM, laboratories of countries outside the EU are requested to mark the package: “BIPM, réglementation spéciale, ne pas dédouaner d’office, ” and to ask their carrier to contact the BIPM, according to the instructions given in Annex 1 ADM-DOU-T-02: “Instructions for metrology institutes shipping equipment to the BIPM for comparisons”, which will be provided by the BIPM. In all cases the laboratory shall notify the BIPM before sending back the standards. This shall be made by returning to the BIPM the form BIPM/ADM-DOU-F-12 (Annex 2) after having completed the relevant sections.

No insurance is required for the transportation of the BIPM standards. The charging policy for BIPM measurement services is described in BIPM/DIR-P-01. The BIPM will pay for the transportation of the standards to the participating laboratory, and the participating laboratory will pay for the transportation back to the BIPM.

If travelling standards belonging to the participating laboratory are used, the necessary custom arrangements should be discussed in advance with the BIPM.

4. Measurements

From our experience, it may require up to two weeks of time for travelling resistance standards to recover a regular temporal behaviour following transportation. Results of measurements made during the period of recovery of the travelling standards may have to be deleted from consideration in the calculation of the final results of the

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comparison. Following the recovery period, we recommend measuring the resistors about three times per week for four to six weeks.

The NMI should carry out the resistance measurements using its usual techniques.

The reference temperature for BIPM resistance measurements is 23 °C and the resistors are kept at this nominal temperature during the whole period of measurements. If possible, the participating laboratory should use the same nominal temperature.

The BIPM measurements are carried out with a 50 mA DC current for 1 Ω resistors and 100 μA for 10 kΩ resistors. If possible, the participating laboratory should use the same nominal currents. In order to limit power effects, nominal currents larger than 100 mA in 1 Ω and 200 μA in 10 kΩ should be avoided. Further details on the BIPM techniques may be found in [1] and [2].

If travelling standards belonging to the NMI are used, their temperature coefficients and pressure coefficients must be provided by the owner-laboratory: these coefficients will not be determined by the BIPM.

The BIPM applies a correction for the variation of the resistance as a function of pressure; the participating laboratory should therefore measure the local pressure with an uncertainty of a few hPa. The average atmospheric pressure at the BIPM is close to the standard atmospheric pressure (1013.2 hPa). The variation of pressure with altitude is of the order of -0.13 hPa/m, so that pressure effects can become significant for laboratories located at high elevations. When using resistors in an oil bath, the pressure of the head of oil above the resistor should be included, using the top of the insulating plate containing the potential and current terminals as the reference plane.

5. Reporting results

The participating laboratory is requested to send its measurement report to the BIPM not later than 6 weeks after the end of its measurements.


The results shall be reported in a table containing the following quantities, recorded for each measurement day:

- Reference of the travelling standard
- Date, nominal current, pressure, temperature of the travelling standard, measured resistance (not corrected for pressure or temperature).

The uncertainty on the pressure and temperature measurements shall be stated.

A detailed uncertainty budget must be provided in the measurement report, including:

- The uncertainties (A and B type) associated with the value of the NMI's reference standard (traceability to the NMI's primary reference or to another laboratory, stability, etc.).
- The uncertainties (A and B type) associated with the transfer from the NMI's reference standard to the travelling standard.

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6. Comparison report

The BIPM is responsible for the preparation of the comparison report (draft A and draft B), following the procedure given in the document CIPM-MRA-D-05, “Measurement comparisons in the CIPM-MRA”

7. References

- [1] T. J. Witt, F. Delahaye and D. Bournaud, “The 1987 international comparison of 1- Ω resistance standards at the BIPM and the resulting agreement among determinations of R_H ”, *IEEE Trans. Instrum. Meas.*, **38**, 279-283, 1989.
- [2] F. Delahaye, D. Bournaud and T. J. Witt, “Report on the 1990 international comparison of 1 Ω and 10 k Ω resistance standards at the BIPM”, *Metrologia*, **29**, 273-283, 1992.
- [3] [CIPM-MRA-D-05](http://www.bipm.org/utils/common/CIPM_MRA/CIPM_MRA-D-05.pdf), Measurement comparisons in the CIPM-MRA
http://www.bipm.org/utils/common/CIPM_MRA/CIPM_MRA-D-05.pdf
- [4] BIPM/ADM-DOU-T-02, Instructions for metrology institutes shipping equipment to the BIPM for comparisons
- [5] BIPM/ADM-DOU-F-12, Shipping instructions for comparisons


8. Bibliography

F. Delahaye, “DC and AC techniques for resistance and impedance measurements”, *Metrologia*, **29**, 81-93, 1992.


T.J. Witt, “Electrical resistance standards and the quantum Hall effect”, *Rev. Sci Instrum.*, **69**, 2823-2843, 1998.

10. Revision History

Version number	Date of Issue/Review	Summary of change
1.0	2012/11/09	First inclusion into QMS Update of references to other procedures and forms
1.1	2015/01/12	Update admin procedure version in annex

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Annex 1

Procédures Administration / Instructions for metrology institutes shipping equipment to the BIPM for comparisons				
Author : Isabelle Andernack Laïla Dell'Oro	Date : 2013/12/10 Version : 2.1	Authorized : Sigrid Arlen	BIPM/ADM- DOU-T-02	

INSTRUCTIONS for METROLOGY INSTITUTES **shipping equipment to the BIPM for** **COMPARISONS**

General Information

- Equipment shipped to the BIPM for comparisons is subject to Customs' formalities, which vary according to the country of origin.
- Before shipping any material to the BIPM, the metrology institute shall complete the relevant parts of the form **BIPM/ADM-DOU/F-12**, and return it duly signed to the BIPM (fax: **+33 1 45 07 70 99** or e-mail at **ldelloro@bipm.org**. The form should be received by the BIPM at least 2 weeks before shipment is planned.
- Parcels from countries other than the E.U. must be labelled as follows:


BIPM - REGLEMENTATION SPECIALE - NE PAS DEDOUANER D'OFFICE

and the metrology institute from which the equipment originates should give specific instructions to their carrier to contact the BIPM

[Contact: Administration, tel.: +33 1 45 07 70 29 fax: +33 1 45 07 70 99]

prior to clearing the instrument through Customs. The BIPM will then take the appropriate action to clear the equipment through French Customs.

- No Customs' operations are carried out on Saturdays or Sundays. The metrology institute should ensure that if their equipment is subject to Customs' formalities, it should arrive in France on a working day of the week preceding that planned for the comparison.
- Customs' operations for hand carried equipment may require processing by the BIPM. In this case, relevant costs will be charged to the metrology institute.

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Customs' formalities

Equipment arriving from a country within the E.U.:

- There are no Customs' formalities. The metrology institute does not need to take further action.

Equipment arriving from a country outside the E.U.:

- There are Customs' formalities. In order for the equipment to pass through Customs, the metrology institute is required to undertake one of the following procedures:
 - i. ship the equipment with an ATA carnet. This carnet is available through the Chamber of Commerce and Industry (or equivalent within your country, provided your country recognises this system) and is issued with one year validity. It simplifies the Customs' operations and avoids duties and taxes;
 - ii. ship the equipment by diplomatic bag to the relevant Embassy in Paris (although this has the advantage of by-passing all Customs' formalities, it is unlikely that this process is available to all metrology institutes);
 - iii. if neither of these procedures can be adopted, a temporary importation will be arranged by the forwarding agent of the BIPM (all sections of the form **BIPM/ADM-DOU/F-12** must then be completed) and the relevant costs will be charged to the metrology institute. For hand carried equipment this will include an appointment on arrival at the airport with the forwarding agent of the BIPM, on a working day..


Transport of equipment between Paris Airports and the BIPM

Equipment arriving from a country within the E.U.:

- For equipment originating from a metrology institute within the E.U., it is expected that the metrology institute will arrange a door-to-door delivery.
- In the case of air transport, it is expected that the metrology institute will arrange for their carrier to transport the equipment to and from Paris airports and the BIPM.

Equipment arriving from a country outside the E.U.:

- For those countries employing the ATA carnet system, it is expected that the metrology institute will arrange a door-to-door delivery. In the case of air transport, it is expected that the metrology institute will arrange for their carrier to transport the equipment to and from Paris airports and the BIPM. The relevant costs will be charged to the metrology institute.

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- For hand carried equipment, the metrology institute will arrange its transport between Paris airports and the BIPM.
- Where a temporary importation has to be arranged, the BIPM via its forwarding agent will arrange and meet the transport of the equipment to and from Paris airports and the BIPM.


Insurance of equipment

- In all cases, organisation and payment of insurance for a visiting metrology institute's instrument remain the responsibility of the visiting metrology institute.


Return of equipment

- It is the responsibility of the metrology institute to make prior arrangements for the return of their equipment after the comparison. The BIPM should be informed of these arrangements using form **BIPM/ADM-DOU/F-12**.
- No shipment back to the metrology institute will be arranged by the BIPM in the absence of this form duly completed and signed.
- Part "4. Instructions for return" of the form BIPM/ADM-DOU/F-12 is not applicable for BIPM equipment.

Version number	Date of Issue/Review	Author	Modifications / comments
2.1	10-12-2013	LD	Updated contact names

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Annex 2

Procédures Administration / Shipping instructions for comparisons				
Authors : Isabelle Andernack Brigitte Perent	Date : 2012/09/12 Version : 1.1	Authorized : Brigitte PERENT	BIPM/ADM-DOU-F-12	

1. SHIPPING INSTRUCTIONS FOR COMPARISONS

• Name of the metrology institute:		
• Person to be contacted:		
• Address:		
• Tel.:	• Fax:	• e-mail:

2. ATA carnet: <input type="checkbox"/>	Diplomatic bag: <input type="checkbox"/>	Other case: <input type="checkbox"/>
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3. SHIPPING INFORMATION

• Description of the equipment (copy of proforma invoice required):	
• Value of the equipment:	• Number of packages:
• Gross weight:	• Net weight:
• N° AWB (when available):	• Date AWB:
• Name of the carrier:	
• Hand carried by air (if necessary):	• flight number*:
	• Date:
<small>* A copy of the flight ticket and passport is required for travellers coming from non European countries</small>	
• Hand carried by other means of transportation (to specify):	• Date:

4. INSTRUCTIONS FOR RETURN

• Insurance: <input type="checkbox"/> Yes <input type="checkbox"/> No		
• Name of the carrier:		
• Tel.:	• Fax:	• e-mail:
• Your client number with the carrier:		

5. I agree to pay for all the costs related to Customs' formalities and transport of equipment.

Date	Name and title	Signature