Protocol for BIPM on-going key comparisons of 10 pF and 100 pF capacitance standards (BIPM.EM-K14.a and BIPM.EM-K14.b)

1. Introduction

This protocol applies to comparisons BIPM.EM-K14.a (10 pF capacitance standards) and BIPM.EM-K14.b (100 pF capacitance standards) which constitute the BIPM programme of on-going bilateral comparisons of capacitance standards. Both capacitance values (10 pF and 100 pF) are to be measured at 1592 Hz and/or at 1000 Hz. 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 farad. The representation can be based on a calculable capacitance standard, on the link between capacitance standards and the quantized Hall resistance through a quadrature bridge, or on the maintenance by the participating laboratory of reference capacitance standards with values deduced from previous calibrations by the BIPM or by other national laboratories. 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 appear 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. Travelling standards

2.1. General requirements

The travelling standards used should allow capacitance transfer at the 10 pF and 100 pF level with a standard transfer uncertainty not higher than a few parts in 10^8. The BIPM proposes a set of two 10 pF and two 100 pF travelling standards. Alternatively or in addition, any suitable set of standards belonging to the participating laboratory can also be used.

2.2. Description of the BIPM travelling standards

The BIPM travelling standards are two 10 pF AH 11A standards (S/N 01309 and 01310) and two 100 pF AH 11A standards (SN 01312 and 01313) enclosed in a AH 1100 frame (S/N 00105).

The temperature coefficients of the BIPM standards in the AH frame, with respect to change in the ambient temperature, are less than 3 parts in 10^9 per kelvin. The voltage coefficients are less than 2 parts in 10^{10} per volt for the 10 pF standards and less than 1 part in 10^9 per volt for the 100 pF standards.

3. Transport of capacitors

3.1. Customs arrangements, transportation costs

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 back 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, BIPM/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 by fax (+33 1 45 07 70 99) 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 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.

3.2 Receipt of travelling standards

1. Check the transport case and the AH frame for any sign of physical damage. Notify the BIPM of the receipt and report any possible damage.

2. A copy of the AH 1100/11A Operation and Maintenance Manual is included in the shipment. Before applying power to the unit, **check that the correct line voltage is selected and that the appropriate fuse is fitted**, referring to pages 1-5 and 1-6 of the Manual.

3. Apply power to the frame and wait until the oven temperature is stable. If the frame does not appear to operate properly, notify the BIPM immediately. For the most precise measurements, it is recommended that the standards are left to stabilize for two or three days.

4. Quantitites to be measured

4.1. Measurement voltage

For these measurements the preferred rms voltage is 100 V for the 10 pF standards. In any case the rms voltage applied to the 10 pF standards should not exceed 100 V.

For these measurements the preferred rms voltage is 10 V for the 100 pF standards. In any case the rms voltage applied to the 100 pF standards should not exceed 20 V.

4.2. Measurement frequency

The preferred measurement frequency is 1592 Hz, but measurements may be made at a frequency of 1000 Hz. When measurements are carried out at both of these frequencies, it is requested to report the capacitances measured at 1592 Hz as well as a single estimate of the relative capacitance change from 1000 Hz to 1592 Hz, $(C_{1592} - C_{1000})/C_{1000}$, with the corresponding uncertainty.

4.3. The measured capacitance

The capacitance to be measured is the coaxial two terminal-pair capacitance **at the terminals on the AH1100 frame**. The capacitance "high" and "low" terminals must be connected to the "high" and "low" sides of the measuring bridge, respectively. Participants will determine any corrections for leads connecting the capacitance to the measuring bridge.
The recommended value of the von Klitzing constant, $R_{K\text{-}90} = 25\,812.807\ \Omega$, will be used for expressing measurement results based on a link to the quantized Hall resistance.

4.4. Recorded quantities

For each measurement, the following quantities should be recorded and given in the report:

1. the measurement date
2. the applied voltage
3. the measurement frequency
4. the measurement result for the capacitance as defined in 4.3
5. the air temperature in the vicinity of the AH1100 frame. The preferred nominal ambient laboratory temperature is 23 °C. No corrections should be made by the participating laboratory for ambient laboratory temperature.
6. the chassis temperature and the drift reading

4.5.Measurement period

Each capacitance should be measured several times (at least four times) over a time period of about 5 weeks.

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. In addition to the quantities mentioned in 4.4, the report must indicate how traceability to the SI is obtained and include a short description of the measurement method and of the measurement bridge. The report must also include a complete budget of uncertainty estimates listing the sources and the type (A or B). The main uncertainty components are expected to be:

- Experimental standard uncertainty of a single capacitance measurement (Type A)
- Uncertainty in the primary standard or working standard against which the travelling standards are measured (Type B)
- Uncertainty due to leads correction (Type B)
- If a coaxial measuring bridge is used, include the following: (Type B)
- -uncertainty due to imperfect current equalizers
  -uncertainty due to the injection network
  -uncertainty in the calibration of the main inductive-divider ratio used in the bridge
- Uncertainty associated with $(C_{1592} - C_{1000})/C_{1000}$, the estimate of the relative capacitance change from 1000 Hz to 1592 Hz.

Participants may need to include additional sources of uncertainty appropriate to their measurement system (calculable capacitor, quadrature bridge,…..)

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. Reference

CIPM-MRA-D-05, Measurement comparisons in the CIPM-MRA_
http://www.bipm.org/utils/common/CIPM_MRA/CIPM_MRA-D-05.pdf

BIPM/DIR-P-01, Measurement services of electrical standards: comparisons and calibrations

8. Revision History

Version number	Date of Issue/Review	Summary of change
1.0	2012/11/15	First inclusion into QMS Update of references to other procedures and forms
1.1	2015/01/12	Insertion of the last version of document BIPM/ADM-DOU-T-02 in annex 1; numbering of annex pages; correction of minor typing errors
1.2	2015/09/29	New BIPM logo

ANNEX 1

INSTRUCTIONS FOR METROLOGY INSTITUTES SHIPPING EQUIPMENT TO THE BIPM FOR COMPARISONS

1 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.

2 Customs' formalities

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

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

2.2 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..

3 Transport of equipment between Paris Airports and the BIPM

3.1 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.

3.2 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.
- 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.

4 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.

5 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

ANNEX 2

Procédures Administration / Shipping instructions for comparisons				QUALITY MANAGEMENT SYSTEM
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: ☐ Diplomatic bag: ☐ Other case: ☐

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:
  * A copy of the flight ticket and passport is required for travellers coming from non European countries
- Hand carried by other means of transportation (to specify): • Date:

4. INSTRUCTIONS FOR RETURN

- Insurance: ☐ Yes ☐ 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**