

EURAMET Key Comparison of AC-DC High Voltage Transfer Standard EURAMET.EM-K9

Technical protocol

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1. Scope

The CIPM Consultative Committee for Electricity and Magnetism (CCEM) has decided to repeat the key comparisons CCEM-K6a and CCEM-K9 of AC-DC voltage transfer difference that were performed in the 1990th and beginning of 2000th, respectively. The CCEM-K6a covered AC-DC voltage transfer standards at the lowest attainable level of uncertainty and CCEM-K9 covered AC-DC high voltage transfer standards. The new CCEM comparison combined the two key comparisons into one key comparison of AC-DC voltage transfer standards CCEM-K6a/K9. The comparison has been organized by a support group of the National Metrology Institutes RISE, INTI, PTB, NMIA and NIST and the circulation of the travelling standards has been finalized.

In order to link the National Metrology Institutes organized in EURAMET to the key comparison CCEM-K6a/K9, the EURAMET Technical Committee for Electricity and Magnetism decided to organize the corresponding RMO key comparison EURAMET.EM-K9 of AC-DC High Voltage Transfer Standard with support group of the National Metrology Institutes PTB, LNE and CMI. Moreover, PTB kindly provided the travelling standard.

The protocol was prepared following the CCEM and EURAMET guidelines for planning, organizing, conducting and reporting key, supplementary and pilot comparisons.

2. Definition of the measurand

The AC-DC voltage transfer difference δ of a transfer standard is defined as:

$$\delta = (V_{ac} - V_{dc}) / V_{dc} ,$$

where

V_{ac} is the rms value of an AC input voltage,

V_{dc} is a DC input voltage which, even if reversed, produces the same mean output response of the transfer standard as V_{ac} .

Differences are expressed in microvolts per volt ($\mu\text{V}/\text{V}$) and a positive sign signifies that more AC than DC voltage was required for the same output response.
The reference plane of the AC-DC voltage difference is at the centre of a T-connector.

3. The travelling standard

The 500 V and 1000 V travelling standard provided by PTB consists of a PTB series resistor with the type designation “110k Ω III Planar B” and a 1 V PMJTC (silicon) with the serial number 323-3-29. The PMJTC was manufactured by IPHT in cooperation with PTB. The nominal parameters are listed below:

Voltage range:	250 V to 1000 V
Output emf:	4.88 mV (250 V), 19.47 mV (500 V), 77.32 mV (1000 V)
Heater resistance:	92.6 Ω
Nominal current:	9 mA
Thermocouple resistance:	9.38 k Ω
Range resistor:	110.2 k Ω

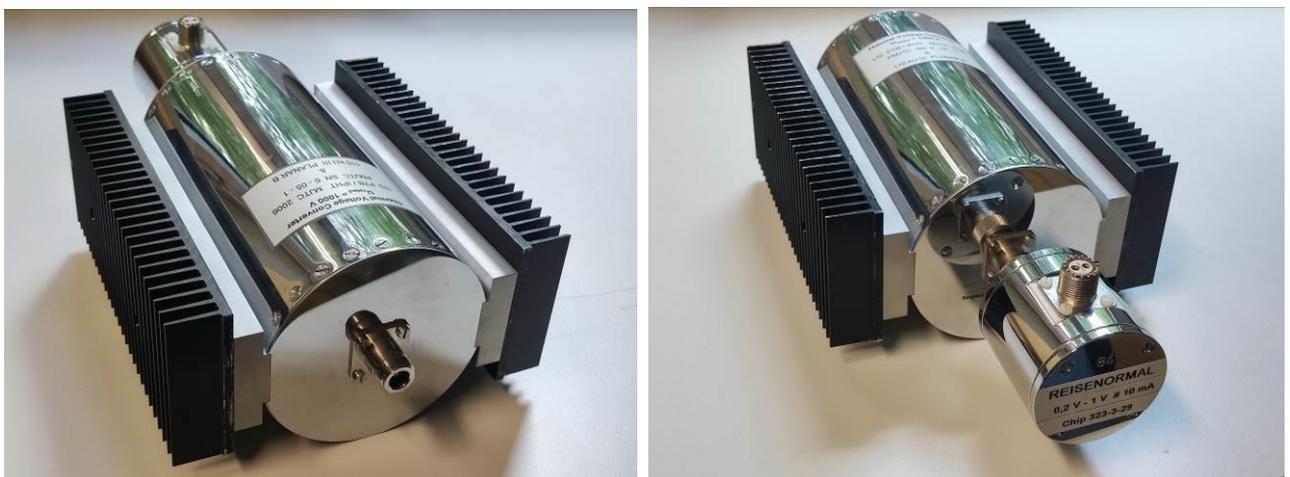


Fig. 1: 500 V and 1000 V travelling standard (from left to right: input and output side)

The traveling standard has a N-female connector at the input and a twin connector at the output. For safety reasons input low and output low are connected to the case while the pins of the output are shunted with a capacitor of 2.2 μF .

Included is an adapter for twin to banana connector, which can (optionally) be used at the output of the thermal converter.

4. Measurement conditions

The participating laboratories are asked to follow their usual measurement procedure to their best measurement capabilities in respect to the time frame of the comparison.

- The traveling standard should acclimate for at least 24 h before a measurement can start.
- After acclimation, check input and output resistances of the travelling standard by following the instructions given in Appendix 1.
- During the comparison measurement:
 - The reference plane of the measured AC-DC voltage transfer difference should be at the centre of a type N-Tee connector with type N male output connector for the connection of the travelling standard. The type of Tee connector used and the reference plane of the measured AC-DC voltage transfer difference have to be reported.
 - Input low and output low of the travelling standard must always be connected to ground during measurement. As described in section 3, input low and output low are internally connected to the standard case. Therefore, the case needs a defined potential and has to be connected to measurement ground using a single wire.

- The recommended ambient conditions are temperature (23 ± 1) °C and relative humidity (45 ± 10) %.
- A minimum of 30 min should be allowed for stabilisation after voltage is applied.
- The measuring frequency should be within 1 % of the nominal frequency. The frequency and its uncertainty should be reported.
- A minimum delay time of 60 s between switching the input voltage and reading the output voltages should be used.

5. Measuring scheme

The AC-DC voltage difference of the travelling standard shall be measured at the following voltages and frequencies:

Mandatory

Voltage: 500 V.

Frequencies: 1 kHz, 10 kHz, 20 kHz, 50 kHz and 100 kHz.

Optional

Voltage: 500 V.

Frequency: 10 Hz

Voltage: 1000 V.

Frequencies 10 Hz, 1 kHz, 10 kHz, 20 kHz, 50 kHz and 100 kHz.

6. Measurement uncertainty

A detailed uncertainty analysis and an uncertainty budget in accordance with the ISO Guide to the Expression of Uncertainty in Measurement should be reported.

To have a more comparable uncertainty evaluation a list of principal uncertainty contributions is given, but the uncertainty contributions will depend on the measuring methods used.

- reference standard(s),
- step-up procedure,
- measuring set-up,
- level dependence, e.g. due to dc-effects,
- connectors,
- temperature,
- measuring frequency,
- reproducibility.

7. Report

Each participant is asked to submit a report within one month after completing the measurements. The report should contain at least:

- a detailed description of the measurement set-up and the reference standard,
- definition of the measurand,
- detailed description of the measurement procedure,
- a statement of traceability, if the national standard is not considered to be a primary standard,
- the ambient conditions of the measurement: the temperature and the humidity with limits of variation,
- the values of other influence parameters: the frequency of the measuring signal and its uncertainty,
- the results of the measurements,
- a complete uncertainty budget in accordance with the principles of the ISO Guide to the Expression of Uncertainty in Measurement.

The participants are also asked to report a summary of the measuring results (Appendix 2) and uncertainty budgets (Appendix 3). Please send the report and the summary by e-mail to the pilot laboratory (only to andre.mueller@ptb.de).

The pilot laboratory will inform a participating laboratory if there is a large deviation between the results of the laboratory and the preliminary reference values. No other information on the results will be communicated before the completion of the circulation.

8. Transportation and customs

- Transportation is at each laboratory's own responsibility and cost. Due to the time constraints please use a recognised courier service e.g. UPS or DHL for the transport of the travelling standard. Do not use a forwarding agent that does not guarantee an adequate delivery time, including the time for customs procedure.
- The case will be transported with an ATA Carnet only if needed for customs clearance. Please take special care to ensure that the carnet always stays with the package.
- On receipt of the case, unpack the devices carefully and check for any damage. The list of contents of the packing case should also be checked (see Appendix 4). If something is missing, please contact the pilot laboratory by sending an e-mail to andre.mueller@ptb.de. If ATA carnet provided also check carefully that the carnet has been stamped on entry into your country.
- Before sending the case out, check the packing list and ensure everything is enclosed. If ATA carnet provided ensure that the carnet is packed outside the case for easy access by Customs and ensure that the carnet is stamped by Customs on exit from your country.

In countries where ATA-carnet is not recognized standard customs procedures will be used. For customs purposes and/or transport insurance the value of the travelling standard is 10.000 EUR.

The travelling standard and accessories are packed in a transport case of size 65 cm · 50 cm · 30 cm and a total weight of 10 kg. The transport case can easily be opened for customs inspection.

9. Circulation scheme

Participants in the comparison are BEV, BIM, CEM, CMI, FTMC, GUM, IMBIH, INRIM, IPQ, JV, LNE, Metroser, PTB, RISE, SIQ, SUT, Trescal, UME, UMTS and VSL.

The circulation scheme is arranged after consulting the participating laboratories and is summarized in separate Excel file.

As the comparison must be finished within a reasonable period of time, only two weeks are allowed for each participant to measure the travelling standard. The time of transportation to the next participant is one week between participants without ATA carnet and two weeks between participants with ATA carnet.

Please inform the pilot laboratories (by sending an e-mail to andre.mueller@ptb.de and pierre-jean.janin@lne.fr) if unforeseen circumstances prevent a laboratory from carrying out its measurements within the agreed time period. Usually, the travelling standard should then be sent without delay to the laboratory next in line. If time permits, the laboratory will be able to carry out measurements later.

10. Organisation

The comparison will be organized by a support group of the National Metrology Institutes CMI, LNE and PTB.

The general organisation of the comparison is made by Věra Nováková Zachovalová, CMI, Czech Republic. The technical protocol was jointly prepared by the support group. André Mueller, PTB, Germany, is responsible for monitoring stability of travelling standard and collation of reports from participants. Pierre-Jean Janin, LNE, France, is responsible for schedule. Věra Nováková Zachovalová, CMI, Czech Republic, and Pierre-Jean Janin, LNE, France, are jointly responsible for evaluation of

comparison results. Věra Nováková Zachovalová, CMI, Czech Republic is responsible for preparing of the report of the comparison.

The travelling standard will be dispatched from PTB in April 2025 and will return after the completion of each round.

Please inform the pilot laboratories (by sending an e-mail to andre.mueller@ptb.de and pierre-jean.janin@lne.fr) and the sending participant of the arrival of the package by e-mail. Please also inform the pilot laboratories and the next participant of the details when sending the package. Prepare the transport to the next participant so the travelling standard can be sent immediately after the measurements are completed.

Each participating laboratory covers the costs of the measurement, transportation and customs clearance as well as for any damage that may occur within its country. The support group covers their own costs for the organisation of the comparison. The pilot laboratory has no insurance for any loss or damage of the travelling standard.

11. Report of the comparison

Within four months after the completion of the circulation CMI, the NMI responsible for reporting, will prepare a first draft report in co-operation with PTB and LNE and send it to the participants for comments. The reporting of the comparison will follow the BIPM Guidelines. It is proposed that the reference values for each one of the measuring points will be calculated following the approach used in previous CCEM and EURAMET key comparisons related to AC-DC transfer standards measurement.

12. Contact persons

For general questions concerning the organization of the comparison, please contact:

Věra Nováková Zachovalová, CMI, Czech Republic
Telephone: 00420 454 555 305
E-Mail: ynovakovazachovalova@cmi.gov.cz

For questions concerning the circulation, please contact:

Pierre-Jean Janin, LNE, France
Telephone: +33 (0)1 30 69 11 26
E-Mail: pierre-jean.janin@lne.fr

For questions concerning the travelling standard, please contact:

André Müller, PTB, Germany
Telephone: +49 531 592-2130
E-Mail: andre.mueller@ptb.de

Appendix 1. Instructions for resistance check

General Precautions:

- **DO NOT SEPARATE** the thermal converter from its series resistance!
- **DO NOT EXCEED** the nominal current of 9 mA for input resistance!
- **DO NOT EXCEED** the nominal current of 100 μ A for the output resistance!
- **DO NOT EXCEED** the measuring voltage of 100 V between the heater and the thermocouple!
- **DO NOT measure directly with your test tips inside the contact sockets!**

Resistance Check Procedure:

1. Preparation

Be sure that the travelling standard is fully acclimated and its input and output is not connected. Select a suitable type of multimeter with resistance measurement function using a known constant current value.

2. Set Multimeter to Resistance Mode

Set your multimeter to its resistance measurement function. Use the 4-wire (Kelvin) measurement mode if available for higher accuracy. Make sure that the current is **limited** at relevant resistance range to 9 mA if you want to measure aprox. resistance value of 90 Ω at the input connector and to 100 μ A if you want to measure aprox. resistance value of 9 k Ω at the output connector.

3. Start at Highest Range

Set the multimeter to its highest range to prevent overloading or damaging the meter.

4. Measure Resistance

Connect the multimeter to the socket to be tested; the use of an appropriate adapter is required. Do not measure directly with your test tips inside the contact sockets! If the display of the multimeter indicates an overload adjust to a lower resistance range. Gradually lower the resistance range until a stable reading is obtained. Record the value and disconnect the travelling standard.

In case of any failure, stop the measurements and contact the pilot laboratory (by sending an e-mail to andre.mueller@ptb.de) immediately.

Appendix 2. Summary of results

EURAMET Key Comparison of AC-DC High Voltage Transfer Standard EURAMET.EM-K9

Please send this information by e-mail to Andre.mueller@ptb.de.

Institute:

Date of measurements:

Remarks:

Measurement results:

Voltage	Measured AC-DC voltage difference in $\mu\text{V}/\text{V}$ at frequency					
	10 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
500 V						
1000 V						

Expanded uncertainty:

Voltage	Expanded uncertainty in $\mu\text{V}/\text{V}$ at frequency					
	10 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
500 V						
1000 V						

Measurement frequency:

For all voltages	Frequency deviation in % at frequency					
	10 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Freq dev						
Exp unc						

Environmental parameters:

	Min	Max	Remarks*
Ambient temperature in $^{\circ}\text{C}$			
Relative humidity in %			

* e.g. nominal value and limits like $23\pm 1^{\circ}\text{C}$

Appendix 3. Summary of uncertainty budget

EURAMET Key Comparison of AC-DC High Voltage Transfer Standard EURAMET.EM-K9

Please send this information by e-mail to Andre.mueller@ptb.de.

Institute:

Date:

Remarks:

Measurement voltage: 500 V

Contribution of:	Standard uncertainty in $\mu\text{V}/\text{V}$ at frequency						Type A or B	Distri- bution
	10 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz		

Standard unc.								
Expanded unc.								

Measurement voltage: 1000 V

Contribution of:	Standard uncertainty in $\mu\text{V}/\text{V}$ at frequency						Type A or B	Distri- bution
	10 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz		

Standard unc.								
Expanded unc.								

Appendix 4. Packing list

EURAMET Key Comparison of AC-DC High Voltage Transfer Standard EURAMET.EM-K9

- 1 pc. PTB 1000 V series resistor, designation “110k Ω III Planar B”.
- 1 pc. IPHT/PTB Planar Multijunction Thermal Converter, 9 mA, S/N 323-3-29.
- 1 pc. Adapter for twin to banana connector.
- 1 pc. Technical protocol for the key comparison EURAMET.EM-K9.