APMP Key Comparison APMP.EM-K5.1
"Comparison of 50/60 Hz AC Power"
Technical Protocol

This technical protocol is based on the protocol of the corresponding EUROMET Key Comparison of AC Power at 50 Hz [1] written by Hüseyin Çaycı (UME, Turkey). This comparison has been completed.

1. Introduction

In 2006, an APMP Key Comparison of 50/60 Hz electric power was organised to link with the CCEM key comparison CCEM.EM-K5. The National Institute of Metrology (China) will be as the pilot laboratory, which is responsible for providing the traveling standard, coordinating the schedule, collecting and analyzing the comparison data, and preparing the draft report.

2. Traveling Standard

2.1. General requirements

The selected traveling standard is an EMH C1-2 power converter, based on a time-division-multiplication scheme. The instrument is configured as an ac power-to-dc voltage transducer, with a nominal full-scale dc output of 10 V.

2.2. Description of the standard

The traveling standard has separate (electrically isolated) voltage and current inputs on the front panel with the voltage range of 120 V and the current range of 5 A. The input frequency capability of the instrument is between 45 Hz to 65 Hz. The internal dc reference voltages (nominally +7.04... V and –7.04... V) can be monitored from the front panel. The nominal full-scale dc output of 10 V is also available at the front panel (Volt OUT).

Details of the Traveling Standard

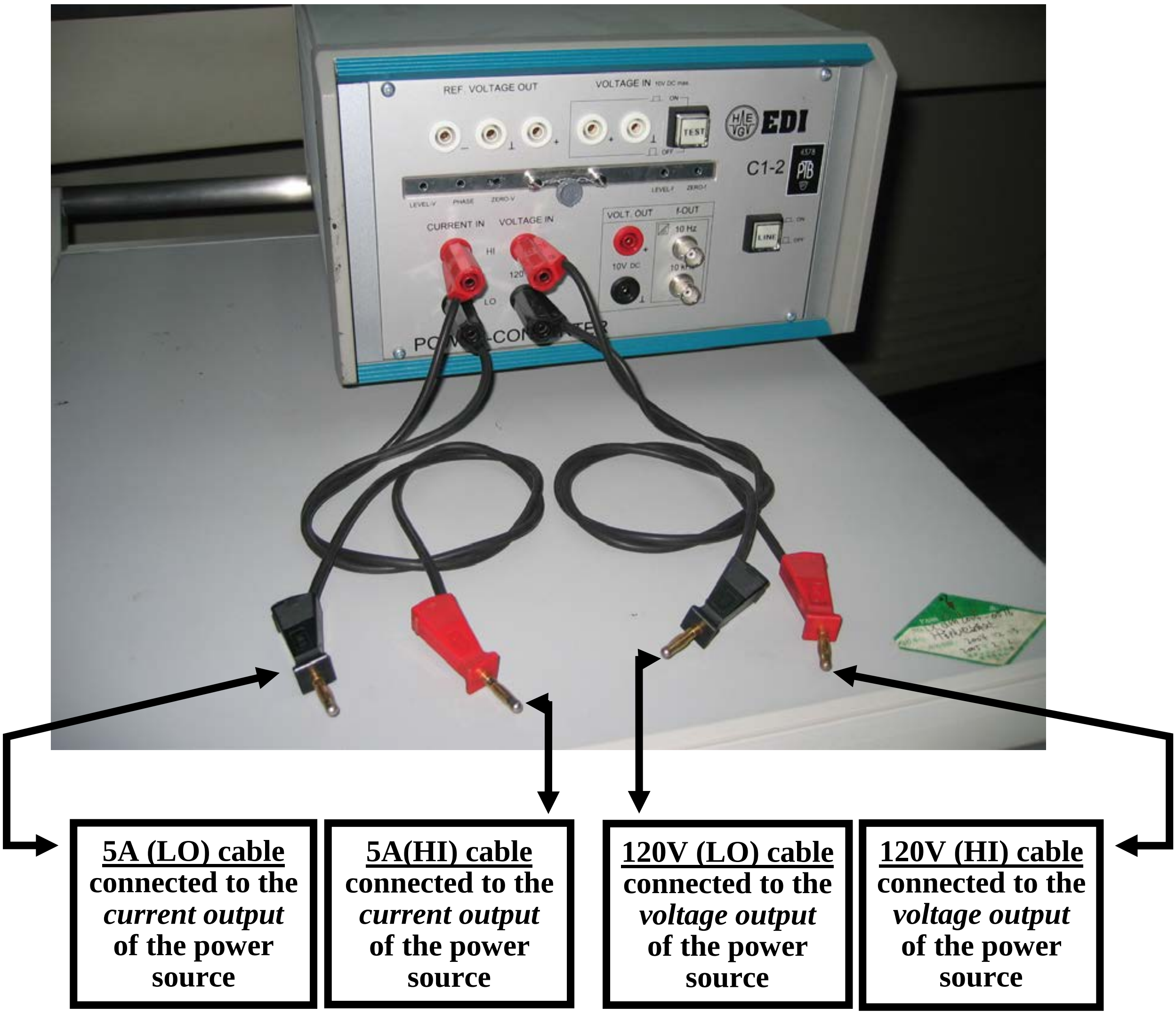
Manufacturer : EMH
Model : C1-2
Serial number : 24910

Power supply voltage : 220 - 240 V at 50 Hz.

Accuracy Class : 0.005% (10 VDC Output)

Figure 1. Front panel of the traveling standard C1-2.

Figure 2. Current and voltage input connections of the traveling standard.



Participants shall use twisted cables for both current and voltage input connections.

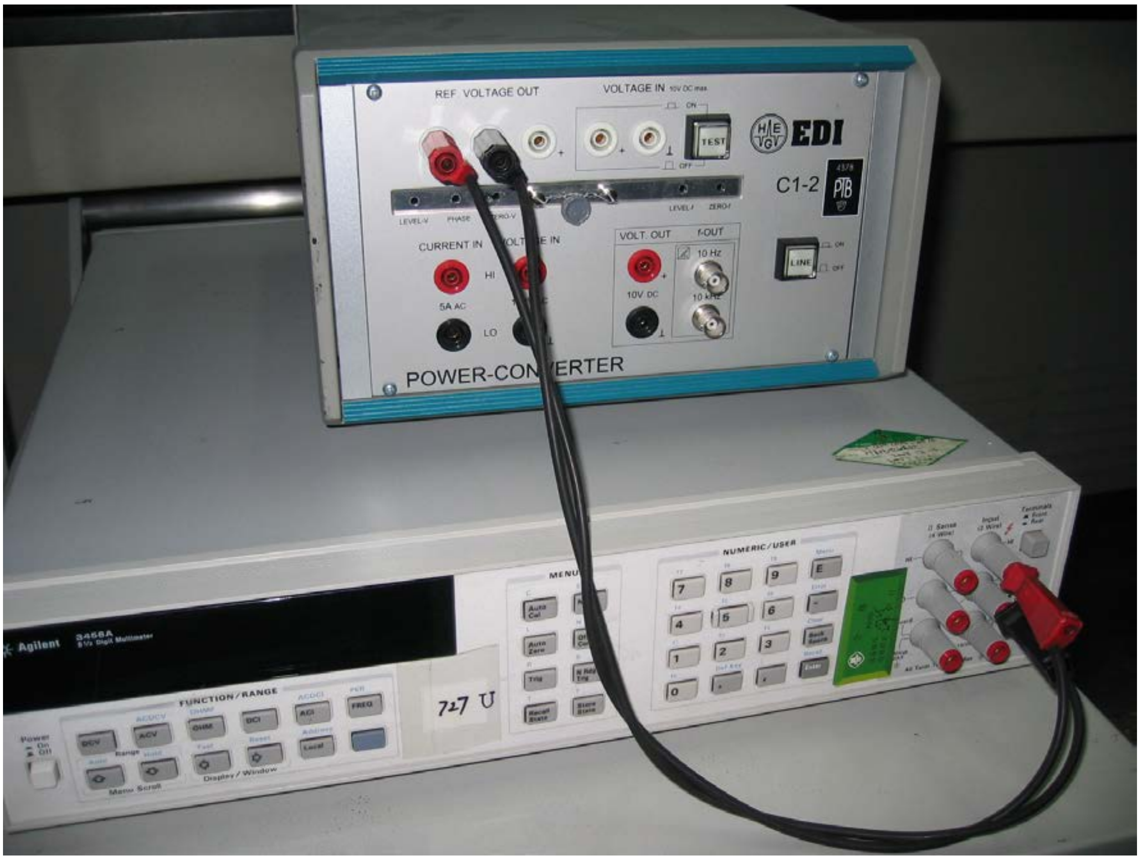
Figure 3. Measurement of the voltage output (VOLT. OUT) of the traveling standard.

A digital multimeter with a high input impedance shall be used to measure the DC voltage. An Agilent (HP) 3458A digital multimeter is shown in the Figure 3 as an example for the measurement of DC voltage values from the traveling standard. Voltage and current input connections are not shown in the figure.

Figure 4. Positive DC reference voltage (+) measurement at the reference voltage output (REF. VOLTAGE OUT) by means of a digital multimeter.

Positive output connection of the traveling standard is shown in the Figure 4.

Figure 5. Negative DC reference voltage (-) measurements at the reference voltage output (REF. VOLTAGE OUT) standard by means of a digital multimeter.



Negative output connection of the traveling standard is shown in the Figure 5.

The multimeter shall be programmed to measure the DC reference values with the best possible resolution and accuracy.

During the measurement of DC reference voltages, no AC signal shall be connected to the traveling standard.

2.3. Quantities to be measured

Main measurements (nominal test power) shall be performed at:

Voltage	: 120 V
Current	: 5 A
Power Factor	: 1, 0.5L, 0.5C, 0L, 0C (L: inductive load, C: capacitive load)
Frequency	: 53 Hz (slightly aside from 50 Hz)

DC output voltage of the traveling standard (10 V nominal at the rated input) shall be measured at the VOLT.OUT sockets (10 V DC). The DC output voltage is measured using a digital voltmeter of high resolution (e.g. Agilent-HP 3458A), which is calibrated against a dc voltage standard immediately before the test. The integration time of the multimeter shall be selected to be long enough to eliminate the traveling standard's input frequency dependence. **Example:** The integration time can be set to a multiple integer of the period of the fundamental wave of the mains. The integration time T_i is then set to 10.0 s (500 NPLC at 50 Hz).

Additional measurements (with no test power applied) shall be performed at the following three "no power" conditions:

Voltage: 120 V	Current: 0 A
Voltage: 0 V (input shorted)	Current: 5 A
Voltage: 0 V (input shorted)	Current: 0 A

With no voltage or current applied, there will be a small DC offset at the output. Participants shall record the mean output offset voltage and report, but will not correct for the offset.

DC reference voltage measurements (+7.04...V and -7.04...V) shall be performed at the REF.VOLTAGE OUT sockets. The mean DC ref voltages shall be recorded during the measurements.

Particular requirements for ambient conditions:

The power-converter shall not be exposed to draughts of cold or hot air (e.g. fan-output of neighboring power amplifier).

Measurements shall be made, preferably, at the temperature of 23°C for the aim to link to CCEM.EM-K5, however a temperature of 20°C is also allowed. The temperature condition shall be reported.

2.4. Method of computation of KCRV

KCRV will be computed similarly to CCEM.EM-K5 and EUROMET.EM-K5.

3. Organization

3.1. Contact person and Support Group

<u>Contact person</u>

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<u>Support Group</u>

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3.2. Participants

Table 1. List of participants, contact names, e-mails, phone and fax numbers.

Laboratory address	Contact name, e-mail, tel & fax number
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3.3. Time Schedule

One month has been allowed for each participant and includes transportation time to the next participant. The suggested term for the measurements is 2 weeks, so that the traveling standard could be sent to the next recipient within expected time.

If there will be an unexpected delay, then the contact person and the next recipient shall be informed by fax or e-mail.

Table 2. List of the participants and measurement dates

Laboratory	**Measurement Dates**
NIM, China	April of 2011
VNIIM, Russia	May of 2011
NIM, China	July. of 2011
KRISS, Korea	August of 2011
NMC, Singapore	Sept. of 2011
NIM, China	Oct. of 2011

NMI, Australia	Nov. of 2011
NIM, China	Jan. of 2012
JEMIC, Japan	Jan. of 2012
NML-SIRIM, Malaysia	Feb. of 2012
NIM, China	March of 2012
MSL, New Zealand	April of 2012
SCL, Hong Kong	May of 2012
NIM, China	June of 2012
MASM, Mongolia	July of 2012
NIMT, Thailand	Oct. of 2012
NIM, China	Nov. of 2012
CMS, Taiwan	Jan. of 2013
VMI ,Vietnam	March of 2013
NIM, China	April of 2013
KIM-LIPI, Indonesia	May of 2013
NIM, China	June of 2013

3.4. Transportation

Each participant will be responsible for both arranging and the cost of transport (including, where necessary, Customs clearance) and insurance of the devices from arrival in their laboratory until arrival in the subsequent laboratory. The value for insurance purposes should be the current replacement value. The current value (June 2007) is 14000 **Euro.**
An invoice (60% of the current value) is required for some of the participant countries so one will accompany the Traveling Standard. The invoice **must always** travel with the equipment, so please ensure that the correct paperwork accompanies the Traveling Standard. It will be down to the freight companies at each stage of the journey to ensure customs declaration at each relevant stage. Endorsements by customs will be required at entry to and departure from each country.

Participants shall inform the pilot laboratory by e-mail or fax when the Traveling Standard has arrived by filling the following form given in Figure 5.

Figure 5. Sample form for the information of arrival of the traveling standard.

Confirmation Note For Receipt		
Date of Arrival		
NMI		
Name of Responsible Person		
Traveling Standard	☐ Damaged	☐ Not Damaged
Voltage short connector	☐ Received	☐ Not Received
Invoice	☐ Received	☐ Not Received
Additional Notes:		

Participants shall also inform the next recipient and the pilot laboratory by e-mail or fax about the shipment of the Traveling Standard by filling the following form.

Figure 6. Sample form for the information of dispatch of the traveling standard.

Confirmation Note For Dispatch		
Date of Shipment		
NMI		
Name of Responsible Person		
Shipment Information (company name etc.)		
Traveling Standard	☐ Damaged	☐ Not Damaged
Voltage short connector	☐ Enclosed	☐ Not Enclosed
Invoice	☐ Enclosed	☐ Not Enclosed

Additional Notes:

3.5. Unpacking, Handling, Packing

The Traveling Standard will be circulated in a transportation case, which is well furnished for the safety of the traveling standard. Participants shall check the package, when they receive it, to verify that everything in the parts list is present. Any discrepancies should be reported to the pilot laboratory by e-mail or fax. Participants shall take care when packing the traveling standard to ensure that all parts are enclosed.

3.6. Failure of Traveling Standard

If any failure of the traveling standard is noted, then the pilot laboratory shall be informed immediately by e-mail or fax. If the traveling standard needs to be repaired, then the participant will send it to the pilot laboratory.

3.7. Financial Aspects, Insurance

Participants will be responsible for the costs of shipment to the next recipient (transportation and customs formalities).

4. Measurement Instructions

4.1. Tests before measurements

The voltmeter shall be calibrated with a DC voltage standard immediately before measurements.

4.2. Measurement performance

<u>Warm-up time of the traveling standard (C1-2 Power-Converter)</u>

The traveling standard shall be plugged to the mains supply for 24 hours and signal voltage and current shall be connected to the instrument for at least 2 hours before starting the measurements. After these procedures have been performed, one may find that the traveling standard will be extremely stable even if the voltage and current input signals are shut off momentarily. Particularly, if the power supply of the traveling standard will be shut off in any time, then the warm-up time procedure shall be performed once again. During the whole test in 2 weeks one should de-energize the traveling standard at least once (for > 2 hours).

Ranges of applied values

Participant shall use the nominal values during the measurements within the tolerances given below:

Voltage : ± 0.2% of 120V
Current : ± 0.2% of 5A
Power Factor : ± 0.2% of the nominal values

Participants shall inform the pilot laboratory if the tolerances are different from the values given above.

Short-term changes in temperature and humidity shall be within the tolerances given below:

Temperature : ± 1°C of 23°C (or 20°C)
Humidity : Between 30% and 60%

4.3. Method of measurement

Description of the measurement methods shall be given to the pilot laboratory within the measurement reports.

5. Uncertainty of measurement

The uncertainty must be calculated following the GUM [5], including standard uncertainties, degrees of freedom, correlations, scheme for the evaluation of uncertainty (Annex A1).

6. Measurement Report

Participants shall report the mean errors and uncertainties in terms of apparent power.

The report shall be sent to the pilot laboratory within 6 weeks after completing the measurements. In addition to the results, the report shall contain a brief description of the measurement technique, circuit diagram of the measurement setup and all relevant defining conditions such as temperature and date of measurement (Annex A2).

The report shall contain an uncertainty budget and statement. The uncertainty calculations shall comply with the requirements of the GUM. The report shall include the coverage factor and the complete uncertainty budget.

7. Report of the Comparison

Draft A Report will be prepared after the completion of the measurements and circulated to the participants. Following this, Report B will be prepared.

References

1. "Technical Protocol of EUROMET Key Comparison Supplementing CCEM-K5, Comparison of AC Power at 50 Hz", Hüseyin Çaycı , July 2004
2. "Key comparisons and mutual recognition arrangement," Bureau International des Poids et Mesures
   website: http://www.bipm.fr/enus/8_Key_Comparisons/key_comparisons.html
3. P. Miljanić et al., "The development of a high precision time-division power meter," in CPEM 84 Dig., Delft, the Netherlands, pp 67-68, 1984.
4. N. Oldham, Thomas Nelson, Nien Fan Zhang, and Hung-kung Liu, "Final Report of CCEM-K5 Comparison of 50/60 Hz Power," June 2002.
5. Guide to the Expression of Uncertainty in Measurement, 1999. International Organization of Standards, Geneva, Switzerland. ISO ENV 13005:1999.

A1. Typical scheme of an uncertainty budget

The uncertainty of measurement must be determined using the Guide for the Expression of Uncertainty in Measurement [5]. Detailed information on the uncertainty must be provided in this form.

Participant laboratories are requested to report the main uncertainty components of their measurement systems, identifying all the pertinent uncertainty sources and quantifying their contribution to the expanded uncertainty.

In order to have a comparable uncertainty evaluation, each laboratory is asked to report the following information in the form of an uncertainty budget:

i. The result of the type A method of uncertainty estimation which yields the standard deviation of the mean values of data sets recorded by the participant in order to calculate its final report value.
ii. The result of the type B method of uncertainty estimation.
iii. The expanded uncertainty estimated at a 95.45 % level of confidence.
iv. The degrees of freedom for the estimation of the expanded uncertainty at a 95.45 % level of confidence.

Main uncertainty components y_i	Standard uncertainty $u(y_i)$	Type method A or B of evaluation/probability distribution function	Sensitivity coefficient c_i	Uncertainty contribution $u(R_i)$	Degrees of freedom n_i
1) Standard deviation of the calibration error of the traveling standard		Type A pdf: Normal			
2) uncertainty components of the reference standard of the participant					
3) Ambient conditions					
3.1) temperature 3.2) humidity					
Root square sum of Type A standard uncertainties and effective degrees of freedom					
Root square sum of Type B standard uncertainties and effective degrees of freedom					
Combined standard uncertainty and effective degrees of freedom					
Expanded uncertainty (95.45 % coverage factor)					

A2. Layout of the measurement report

1. Identification of the traveling standard: C1-2.
2. Identification of the participant laboratory and its representative.
3. Results:
    a. Mean value of the calibration error of traveling standard at the active power values, expressed in ± µW/VA.
    b. Expanded uncertainty estimated at a 95.45 % confidence level and the degrees of freedom of the calibration error of the traveling standard at active power.
    c. Mean value of the relevant parameters measured by the traveling standard: DC reference voltage and additional measurements (Shown in 2.3).
    d. Mean date of measurement.
    e. Ambient conditions: mean value and spread of temperature and humidity measurements.
4. Detailed uncertainty budget as in *Annex A1*.
5. Report the date and time when the traveling standard is de-energized and energized.
6. Signature and title of the laboratory representative.