APMP.EM-K12
Key Comparison of AC-DC Current Transfer Standards

Technical Protocol

Pilot Laboratory: National Metrology Centre, A*STAR, Singapore

1 Introduction and Scope

The CCEM-K12 comparison of ac-dc current transfer standards was conducted during 2005 to 2007 with three APMP participants, NMIA (AU, pilot), VNIIM (RU) and NMC (SG). APMP TCEM decided to conduct a follow-up APMP comparison to link more APMP members to the CCEM key comparison, and agreed that NMC would be the pilot laboratory of this comparison. A support group was formed consisting of members from NMIA (AU), SML (NZ) and NMIJ (JP).

The comparison scope will be the same as CCEM-K12:

Current:	10 mA and 5 A
Frequency:	10 Hz, 55 Hz, 1 kHz and 10 kHz
	(Optional: 20 kHz, 50 kHz and 100 kHz)

2 Definition of the Measurand

Ac-dc current transfer difference is defined as

$$\delta = \frac{I_{ac} - I_{dc}}{I_{dc}}$$

where I_{ac} is a rms ac current, and I_{dc} is a dc current which, when reversed, produces the same mean output response as the rms ac current.

Differences are expressed in microamperes per ampere (μA/A). A positive sign signifies that more ac than dc current is required for the same output response.

3 The Travelling Standards

- **10 mA**

The travelling standard for the current of 10 mA is a Planar MultiJunction Thermal Converter (PMJTC), Serial number 32/2009, manufactured by IPHT, Germany. It has the following nominal parameters:

Rated Input Current:	10 mA
Heater Resistance:	90 Ω
Thermocouple Resistance:	6.64 kΩ
Output Voltage at Rated Current:	90 mV

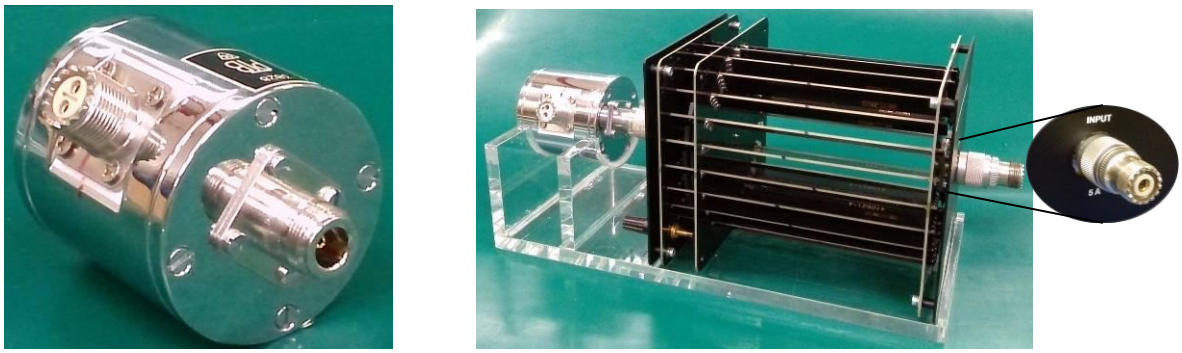
The thermal converter has a type-N female input connector and a UHF Twin female output connector, see Figure 1 a).

- **5 A**

The travelling standard for the current of 5 A comprises a Fluke A40B-5A precision current shunt, Serial number 163962344, and the above PMJTC for 10 mA. The current shunt has the following nominal parameters:

Nominal Resistance:	0.16 Ω
Nominal output voltage at 5A:	0.8 V
Power coefficient of resistance:	< 0.5 μΩ/Ω/W

It has type-N female connectors at both its input and output. For the current comparison, a type-N male-to-male adaptor is attached to the shunt's output for connecting with the PMJTC, and a UHF female-to-type-N male connector is attached to its input. A Perspex fixture is provided for easily assembling of the 5 A travelling standard. When assembled correctly the travelling standard can be positioned firmly on a flat surface, see Figure 1 b).



a) b)

Figure 1 Travelling standards: a) PMJTC for 10 mA (Type-N female for input and UHF twin female for output); b) Assembly of a current shunt and the PMJTC for 5 A (UHF female for input and UHF twin female for output).

4 Participating Laboratories and Organization

The following 11 laboratories will be participating the comparison.

NIMT National Institute of Metrology, Thailand
Contact: Mr Chalit Kumtawee, chalit@nimt.or.th
NIM National Institute of Metrology
Contact: Mr Zhang Jiangtao, Zhangjt@nim.ac.cn
NMIJ National Metrology Institute, Japan
Contact: Dr Hiroyuki Fujiki, h-fujiki@aist.go.jp
KRISS Korea Research Inst of Standards and Science, Rep of Korea

Contact: Hyung-Kew Lee, hyungkew.lee@kriss.re.kr

SCL Standards and Calibration Laboratory, Hong Kong, China
Contact: Dr Steven Yang, steven.yang@itc.gov.hk

NMIA National Measurement Institute, Australia
Contact: Thomas Hagen, thomas.hagen@measurement.gov.au

MSL Measurement Standards Laboratory, New Zealand
Contact: Mr Murray Early, murray.early@callaghaninnovation.govt.nz

NMISA National Metrology institute of South Africa, South Africa
Contact: Dr Eugene Golovins , egolovins@nmisa.org

NML-SIRIM National Metrology Laboratory, Malaysia
Contact: Dr. Mohd Nasir Zainal Abidin, drnasir@sirim.my

VMI VietNam Metrology Institute, Viet Nam
Contact: Mr. Nguyen Anh Son, sonna@vmi.gov.vn

NMC National Metrology Centre, A*STAR Singapore
Contact: Dr Jing Tao, jing_tao@nmc.a-star.edu.sg

The pilot laboratory is the NMC.

The support group consists of

- Dr Ilya Budovsky, NMIA
- Mr Murray Early, MSL, and
- Dr Hiroyuki Fujiki, NMIJ.

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 pilot laboratory covers the overall costs for the organisation of the comparison. The pilot laboratory has no insurance for any loss or damage of the travelling standard.

5 Time Schedule

As the comparison has to be finished within a reasonable period of time and the participant group is relatively big, six weeks will be allowed for each laboratory. This includes the time of customs clearance, transportation, unpacking, preparation and carrying out measurements, packing and shipping to the next laboratory.

The travelling standards will be dispatched from NMC on 20 January 2014, and will return after the completion of each of the two loops for evaluations. The schedule for this comparison is shown in Table 1. It may be adjusted prior and during the implementation due to unforeseen circumstances.

The longest measurement time in a laboratory is limited as four weeks. If a laboratory could not carry out its measurement within the agreed time period, it should contact the pilot laboratory and ship the travelling standards without delay to the next participant.

Table 1 Schedule for the APMP.EM-k12 Comparison of AC-DC current transfer standards

Date	*Laboratory*
20 Feb 2014	**NMC**
20 Feb 2014 – 3 Apr 2014	NMIA
3 Apr 2014 – 15 May 2014	SCL
15 May 2014 – 26 Jun 2014	NMIJ
26 Jun 2014 – 7 Aug 2014	KRISS
7 Aug 2014 – 18 Sep 2014	NIM
18 Sep 2014 – 30 Oct 2014	**NMC**
30 Oct 2014 – 11 Dec 2014	MSL
11 Dec 2014 – 22 Jan 2015	NMISA
22 Jan 2015 – 5 Mar 2015	NIMT
5 Mar 2015 – 16 Apr 2015	NML-SIRIM
16 Apr 2015 – 28 May 2015	VMI
28 May 2015	**NMC**

6 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 standards. Do not use a forwarding agent that does not guarantee an adequate delivery time, inclusive of the time for customs procedure.
- The case of the transfer standards will be transported with an ATA Carnet and a accompanying letter, as shown in Appendix 1, 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 (Appendix 2) should also be checked. 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. 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. Prepare the transport to the next participant beforehand so that the travelling standard can be sent immediately after the measurements in your laboratory are completed.
- Please inform the pilot laboratory and the sender of the arrival of the package by e-mail or fax. Please inform the pilot laboratory and the next participant of the details when sending the package to the next participant by e-mail or fax. A relevant fax form is enclosed in Appendix 3.

7 Measurement Conditions

a). The PMJTC is with delicate circuits and care needs to be taken to avoid any mechanical shocks.

b). Upon receiving the package, check if there is any damage during transportation. Check input and output resistances of the PMJTC. Check that there is high resistance (>100 MΩ) between the input and output. Make sure **not to exceed** the nominal currents of the PMJTC (10mA, for both input and output). In case of any failure, inform the pilot laboratory immediately.

c). The ac-dc transfer differences of the travelling standards are to be measured at the "Lo" position, i.e. with both its input and output earthed. The connection to earth must remain at all times to avoid excessive voltage between its heater and thermocouples which easily damages the insulation.

d). Test the travelling standard at a few points to verify if there is any failure. In case of any damage or failure, inform the pilot laboratory immediately.

e). Connect the PMJTC (see Figure 1 a)) to carry out 10 mA measurements. According to Figure 1 b) to assemble it with the shunt for 5 A measurements.

f). Care should be taken not to apply current above nominal values, which may destroy the travelling standards.

g). Recommended ambient conditions are 23±1°C in temperature and 50±5% in relative humidity.

h). At least 30 minutes should be allowed for stabilisation after the first application of current.

i). The measurement frequency should be within 1 % of its nominal value. The frequency and its uncertainty must be reported.

j). Sufficient delay time should be used between successive applications of alternating and direct currents.

8 Measuring Scheme

The ac-dc difference at 10 mA (PMJTC) and 5 A (Shunt + PMJTC) should be measured at the following frequencies:

- Mandatory: 10 Hz, 55 Hz, 1 kHz, and 10 kHz
- Optional: 20 kHz, 50 kHz, and 100 kHz.

9 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,
- measurement frequency, and
- reproducibility.

10 Report of the Comparison

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

- Detailed description of the measurement setup 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 measurement results,
- The ambient conditions of the measurement: the temperature and the humidity with limits of variation,
- A complete uncertainty budget in accordance with the principles of the ISO "Guide to the Expression of Uncertainty in Measurement", including degrees of freedom for every component and calculation of the coverage factor[1].

The participants are also asked to report separately a summary of the measurement results, see Appendix 4 and Appendix 5. Both the report and the summary are to be sent by e-mail.

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.

11 Comparison Coordinator

Any questions related to the comparison should be directed the Comparison Coordinator:

Dr T Jing
National Metrology Centre, 1 Science Park Drive, Singapore 118221
Phone: (+65) 6279 1911, Fax: (+65) 6279 1995
Email: jing_tao@nmc.a-star.edu.sg

[1] Such an analysis is a prerequisite to be considered in the calculation of the key comparison reference value. It is also an essential part of the final report which will appear in the BIPM Key Comparison Database.

Appendix 1 Letter with ATA Carnet

To whom it may concern

These devices are intended for an international comparison of the national measurement standards of Singapore, Thailand, China, Japan, Rep of Korea, Hong Kong (China), Australia, New Zealand, South Africa, Malaysia and Viet Nam.

These devices are the properties of the NMC, Singapore, and are to be returned to NMC after the completion of this program.

The national agencies involved are:

Singapore National Metrology Centre (NMC), 1 Science Park Drive, Singapore 118221 Contact: Dr Jing Tao Tel +65.62791911, Fax: +65.62791995, E-mail: jing_tao@nmc.a-star.edu.sg
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Viet Nam Vietnam Metrology Institute, No. 8 Hoang Quoc Viet Road, Cau Giay Dist., Ha Noi Contact: Mr. Nguyen Anh Son Tel: +84(4) 38361134, Fax: +84(4) 37564260, E-mail: sonna@vmi.gov.vn

Appendix 2 Packing List

APMP.EM-K12 Comparison of AC-DC Current Transfer Standards

Item		*Value (US$)*	*Dimensions (mm)*
1.	IPHT-PTB Planar Multi-Junction Thermal Converter (PMJTC), S/N 32/2009	1,171.00	ϕ 60 × 60
2.	Fluke A40B-5A precision current shunt, S/N 163962344	4,450.00	L170 × W130 × H130
3.	Support for 5A assembly	119.00	L280 × W130 × H70
4.	N-type male to UHF female adopter (Attached to shunt “in”)	51.00	
5.	N-type mal e to N-type male adopter (attached to shunt “out”)	25.00	
6.	Technical Protocol		
	Total Value	**5,816.00**	

All items are to be transported in the custom carry case supplied.
The dimensions of the carry case are 530mm× 440mm× 220mm. The total weight of the package is around 8 kg.

Appendix 3 Forms for Notifying Receipt and Shipment of Artefact

APMP.EM-K12 Comparison of AC-DC Current Transfer Standards

ARTEFACTS RECEIVED

To: (both sender and coordinator)

The package was received at ……..*(name of laboratory)*…. on …*(date)*..

The condition when it was received was *in good physical and working order

*damaged – *(explain)*

_____

(name of participant)

ARTEFACTS SHIPPED

To: (both recipient and coordinator)

The package was shipped through ….*(shipper)*….. on …*(date)*.. The shippers agent in the recipient country is ……..…*(agent name and contact details)*……..

Shipping Details:

Expected date of arrival at destination country:……..

Shipped: door-to-door / port –to – port

Air Way Bill No. (house): …….

If available: Master Air Way Bill No:
Flight details:

_____
(Name of Participant)

Appendix 4 Summary of Results

APMP.EM-K12 Comparison of AC-DC Current Transfer Standards

(Please send this information by e-mail to the pilot laboratory)

Institute:

Date of measurements:

Remarks:

Measurement Results:

Current	Measured ac-dc current difference (μA/A) at frequency						
	10 Hz	55 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
10 mA							
5A							

Expanded Uncertainty:

Current	Expanded Uncertainty (μA/A) at frequency						
	10 Hz	55 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
10 mA							
5A							

Frequency Measurement:

Current	Nominal Frequency						
	10 Hz	55 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Meas. Frequency							
Expanded Uncertainty							

Environmental parameters:

	Min	Max	Remarks
Ambient temperature (ºC)			
Relative humidity (%)			

Appendix 5 Summary of Uncertainty Budget

APMP.EM-K12 Comparison of AC-DC Current Transfer Standards

(Please send this information by e-mail to the pilot laboratory)

Institute:

Date:

Remarks:

Measurement Current : 10 mA

Contribution of:	Standard Uncertainty (μA/A) at frequency							Type A or B	Distribution
	10 Hz	55 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz		

Combined uncertainty							
Expanded uncrtaitny							

Measurement Current : 5 A

Contribution of:	Standard Uncertainty (μA/A) at frequency							Type A or B	Distribution
	10 Hz	55 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz		

Combined uncertaitny							
Expanded uncertaitny							