SIM.EM-K12 COMPARISON PROTOCOL

AC-DC CURRENT TRANSFER DIFFERENCE
May 2010 – March 2011

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1. Scope

In order to strengthen the Interamerican Metrology System (SIM), interaction among its National Metrology Institutes (NMIs) must be promoted. At the same time according with the CIPM Mutual Recognition Agreement (MRA) objectives, NMIs must establish the degree of equivalence between their national measurement standards by performing regional comparisons, among other activities.

The objective of this comparison, registered as SIM.EM-K12, is to compare the measurement capabilities of NMIs in SIM in the field of ac-dc current transfer measurement. This action is aimed at determining the degree of equivalence of measuring capabilities in ac-dc current transfer difference. The proposed test points are selected to evaluate the measuring capabilities of the participants, both their measurement standards and their measuring procedures.

2. Definition of the Measurand

The quantity to be measured is defined as follows:
Ac-dc current transfer difference is defined as

$$\delta = \frac{I_{\mathrm{ac}} - I_{\mathrm{dc}}}{I_{\mathrm{dc}}} \qquad (1)$$

where
- *I*ac is an 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) and a positive sign means that more ac than dc current was required for the same output response.

3. Travelling standards description

- **10 mA**

The travelling standard for current of 10 mA is a Planar Multijunction Thermal Converter, identified as "PMJTC-90-2", manufactured by INTI (Fig. 2). It has the following nominal parameters:

Rated Input Current:	10 mA
Heater Resistance:	111 Ω
Thermocouple Resistance:	12 kΩ
Output Voltage at Rated Current:	100 mV

The Thermal Converter has an N-Female-type input connector and a type 10SL-4S output connector.

- **5 A**

The travelling standard for current of 5 A comprises a 0.2 Ω coaxial shunt, identified as "SHUNT 5 A**"** (Fig. 1) and a 1 V Planar Multijunction Thermal Converter, identified as "PMJTC-90-2" (Fig. 2). Both have been manufactured at INTI. Their main parameters are as follows:

Current Shunt, 5 A

Nominal Resistance	0.2 Ω
Input Connector	UHF
Output Connector	N-female

Thermal Converter, PMJTC-90-2

Rated Input Voltage:	1 V
Input Resistance:	111 Ω
Thermocouple Resistance:	12 kΩ
Output Voltage at Rated Voltage:	100 mV

Figure 1 Physical layout of the 5 A shunt.

Figure 2 Physical layout of the thermal converter PMJTC-90-2.

4. List of participants

NIST	National Institute of Standard and Technology, USA Contact. Thomas E. Lipe (thomas.lipe@nist.gov)
CENAM	Centro Nacional de Metrología (CENAM) Contact: Sara Campos (scampos@cenam.mx)
SIC	Superintendencia de Industria y Comercio, Colombia Contact: Alexander Martínez López (amartinez@correo.sic.gov.co)
UTE	Administración Nacional de Usinas e Transmisiones Eléctricas, Uruguay Contact: Spaggiari, Alfredo (ASpaggiari@ute.com.uy)
NRC	National Research Council, Canada Contact. Peter Filipsky (Piotr.Filipski@nrc-cnrc.gc.ca)
INMETRO	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial, Brasil Contact: Regis P. Landim (rplandim@inmetro.gov.br)
INTI	Instituto Nacional de Tecnología Industrial, Argentina Contact: Lucas Di Lillo (ldili@inti.gov.ar)
NIS	National Institute for Standards of Egypt Contact: Mamdouh Halawa (mamdouh_halawa@yahoo.com)

5. Timetable

As the comparison has to be finished within a reasonable period of time, **seven weeks** will be allowed for each participant. This time includes clearing customs, receiving, unpacking, preparation, making measurements, initial analysis of data, repeat if necessary, and shipping to the next laboratory.
The travel standard maximum time of measurement in each laboratory is 4 weeks. After this period of time, the standard should be send to the next participant.

The pilot laboratory is the Instituto Nacional de Tecnología Industrial (INTI). The travelling standard will be dispatched from INTI on May 23rd, 2010 and it should return to INTI in March 11th, 2011.
Table I shows the schedule for the SIM.EM-K12 Comparison. This can be adjusted due to dispatch time delay.

Table I: **Schedule for the SIM.EM-K12 Comparison of Ac-dc Current Transfer** (4 weeks for measurements and 3 weeks to dispatch forecast)

Laboratory	Reception of travelling standard	Dispatch of travelling standard
INTI		
UTE	23 May 2010	9 July 2010
CENAM	9 July 2010	27 August 2010
NIST	27 August 2010	15 October 2010
NRC	15 October 2010	3 December 2010
SIC	3 December 2010	21 January 2011
INMETRO	21 January 2011	18 March 2011
INTI	18 March 2011	April 14th 2012
NIS	April 14th 2012	March 16th 2012

6. Procedure in case of unexpected delay

If unexpected circumstances avoid a laboratory to carry out its measurements within the established schedule, it should send the travelling standard without delay to the next laboratory, according to the timetable. In case any participating laboratory needs to keep the travelling standard for a few days more than those established in the schedule, it must contact the pilot laboratory at least two weeks before the end of its term in order to determinate if the travelling standard can stay longer or not, depending on the required days the participating laboratory applies for.

7. 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, inclusive of the time for customs procedure
- 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. 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.
- A letter issued by INTI describing the travelling standard and the purpose of its travel will be attached with the instrument and should be used during its pass by customs in order that each participant can ask for temporal importation authorization. Please do not forget to include this document before passing the travelling standard to the next laboratory. At each transport the letter must be presented at customs on leaving the country and upon the arrival in the country of destination. (The letter is attached to this document, see Appendix I).

8. Handling the travelling standard

The travelling standard must be handled with care. Please, the receiving laboratory must inform the pilot laboratory upon the arrival of the travelling standard, by e-mail or by fax. Make sure that all the accompanying devices are complete upon reception (See Appendix V). Inform again the pilot laboratory and the next participant the details when sending the travelling standard.

Please at the arrival of the travelling standard to your laboratory test some points with the transfer standard, to verify if there is any damage caused during transportation, especially if you notice particular scratches on its container. In case of damage or evident malfunctioning of the travelling standard the pilot laboratory shall be informed immediately, see Appendix V.

Prepare the transport to the next participant so that the travelling standard can be sent immediately after the measurements are completed.

9. Measurements points

The measurements points are indicated in Table II.

Table II. Measurement points in ac-dc current transfer difference

Test #.	Test Current	Test frequency
1	10 mA	10 Hz
2	10 mA	55 Hz
3	10 mA	1 kHz
4	10 mA	10 kHz
5	10 mA	20 kHz

6	10 mA	50 kHz
7	10 mA	100 kHz
8	5 A	10 Hz
9	5 A	55 Hz
10	5 A	1 kHz
11	5 A	10 kHz
12	5 A	20 kHz
13	5 A	50 kHz
14	5 A	100 kHz

10. Measurement conditions

- Upon receiving the package, check input and output resistances of the two thermal converters. Check also that there is a high resistance (>100 MΩ) between the input and the output. In making these preliminary measurements, make sure **not to exceed** the nominal current of the thermal converters. In case of any failure, inform the pilot laboratory immediately.
- The connection of the output of the thermocouples to earth must remain at all times to protect the thermocouple.
- Care should be taken not to apply current above nominal, which may destroy the travelling standards.
- Recommended ambient conditions are temperature (23±1) °C and relative humidity (50±5) %.
- At least 30 minutes should be allowed for stabilisation after the first application of current.
- The measurement frequency should be within 1 % of its nominal value. The frequency and its uncertainty must be reported.
- Sufficient delay time should be used between successive applications of alternating and direct current.
- A datalogger will travel together with the travelling standard. It will be continuously monitoring temperature, relative humidity and atmospheric pressure. The datalogger should be left in the transportation case and it should be kept in the measurement area.

11. Reporting results

In order to have a uniform format with the same information from all the participants, the participants should send their reports following the format described in Appendix II and Appendix III. Each participating laboratory should send its results to the pilot laboratory, within six weeks after the measurements are completed.

12. Determination of the reference value

The reference values for each one of the measuring points will be calculated as the weighted mean of the reported values from laboratories in SIM who have taken part in the CCEM-K12 key comparison and whose reported values had been taken in consideration to calculate the reference values in such comparison. (i.e. NRC, NIST, INTI)

12.1 Reference value

The reference value is determined as:

$$\delta_{\text{reference value SIM.EMK12}} = \frac{\sum_{i=1}^{3} \delta_i / U_{\delta_i}^2}{\sum_{i=1}^{3} 1 / U_{\delta_i}^2} \tag{2}$$

where $U_{\delta i}$ is the expanded uncertainty associated with δ_i values, used to calculate the reference value, reported with a confidence level of 95 %.

Then the expanded uncertainty of the reference value will be,

$$U_{\text{reference value SIM.EMK12}} = \frac{1}{\sqrt{\sum_{i=1}^{3} 1 / U_{\delta i}^{\,2}}} \tag{3}$$

12.2 Degree of equivalence

The degree of equivalence (D_i) between the i-th participating laboratory with respect to the reference value, will be evaluated as the difference between the reported value from the i-th participating laboratory (δ_i) and the reference value,

$$D_i = \delta_i - \delta_{\text{reference value SIM.EMK12}} \tag{4}$$

For the participating laboratories that do not contribute to the reference value, the expanded uncertainty of the degree of equivalence will be evaluated as,

$$U_{D_i} = \sqrt{U_{\delta_i}^2 + U^2_{\delta\text{reference value}}} \tag{5}$$

For the laboratories whose values contribute to the reference value, the expanded uncertainty of the degree of equivalence will be evaluated as,

$$U_{D_i} = \sqrt{U_{\delta_i}^2 - U^2_{\text{reference value SIM.EMK12}}} \qquad (6)$$

12.3 Degree of equivalence between pairs

The degree of equivalence between the values of any pair of laboratories (D_{ij}), will be evaluated as the difference between their reported values,

$$D_{ij} = \delta_i - \delta_j \qquad (7)$$

The expanded uncertainty of the degree of equivalence between pairs will be evaluated as,

$$U_{D_{ij}} = \sqrt{U_{\delta_i}^2 + U_{\delta_j}^2 - 2 * r(\delta_i, \delta_j) * U_{\delta_i} * U_{\delta_j}} \qquad (8)$$

Correlation is expected when δ_i and δ_j have common traceability to a third national laboratory. Participating laboratories are required to ask the laboratory that performed the calibration of their standards to provide its uncertainty budget in order to be able to evaluate the correlation.

13. <u>Measurement Uncertainty</u>

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 setup;
- level dependence, e.g. due to dc-effects;
- connectors;
- temperature;
- measurement frequency;
- reproducibility;

14. Comparison report

Each participant is asked to submit a report within one month after completing the 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. 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.

The participants are also asked to report a summary of the measurement results, see Appendix I. Please also send the report and the summary 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.

15. Organisation

The pilot laboratory for the comparison is the Instituto Nacional de Tecnología Industrial (INTI), Argentina.
Please inform the pilot laboratory of the arrival of the package by e-mail or fax. Please inform the pilot laboratory again of the details when sending the package to the next participant, and also inform the next participant by e-mail or fax. A relevant fax form is enclosed in Appendix IV. Prepare the transport to the next participant so that 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 pilot laboratory covers the overall costs for the organisation of the comparison.

16. Comparison coordinator and members of the support group

Any questions related to the comparison should be directed the comparison coordinator:

Lic. Lucas Di Lillo
Instituto Nacional de Tecnología Industrial – INTI
Av. Gral. Paz 5445,
B1650WAB
San Martín, Buenos Aires
Argentina

phone: (+5411) 4724-6200 Ext. 6673
fax: (+5411) 4713-4140
email: ldili@inti.gob.ar

Members of the support group:

Name	Organization	Address	email
Sara Campos	Centro Nacional de Metrología (CENAM)	km 4.5 Carretera a los Cués. El Marqués. Querétaro C.P. 76246. MEXICO	scampos@cenam.mx
Gregory Kyriazis	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (Inmetro)	Av. Nossa Senhora das Graças, 50 25250-020 Duque de Caxias – RJ - Brasil	gakyriazis@inmetro.gov.br

Appendix I

LETTER TO THE CUSTOMS

Buenos Aires, Argentina, XXXX

To whom it may concern,

These devices are intended for comparison of the National Measurement Standards of Argentina, México, United States of America, Uruguay, Colombia, Brazil and Canada. The devices are to be returned to Argentina on November 2010 at the completion of this program.

National Agencies Involved:

▪ MEXICO Centro Nacional de Metrología (CENAM) km 4,5 Carretera a los Cués. El Marqués Querétaro C.P. 76241. México Tel: +52 442 211-05-00 ext. 3424 Fax: +52 442 211-05-48 Contact: Sara Campos e-mail: scampos@cenam.mx	▪ ARGENTINA Instituto Nacional de Tecnología Industrial (INTI) Parque Tecnológico Miguelete, Av. Gral. Paz e/Albarellos y Av. De los Constituyentes CC 157(1650) San Martín, Buenos Aires, Argentina Tel.: +5411 4754-4141 Fax: +5411 4713-4140 Contact: Lucas Di Lillo e-mail: ldili@inti.gob.ar
▪ URUGUAY Administración Nacional de Usinas y Transmisiones Eléctricas (UTE) Paraguay 2385 CP 11800 Montevideo, Uruguay Tel. +598 2 924 2042 Fax. +598 2 924 2004 Contact: Daniel Slomovitz e-mail: Labute@ute.com.uy d.slomovitz@ieee.org	▪ COLOMBIA Laboratorio de Corriente Continua y Alterna División de Metrología, Superintendencia de Industria y Comercio AK 50 # 26-55, Interior 2, CAN. Bogotá,D.C., Colombia tel: (57 1) 5 880 222 (57 1) 5 737 070 ext 1 442 Alexander Martínez López e-mail: amartinez@correo.sic.gov.co
▪ USA National Institute of Standard and Technology 100 Bureau Drive, M/S 8171, Gaithersburg, MD 20899-8171, USA Phone: 301 975 4251 Fax: 301 926 3972 Contact. Thomas Lipe e-mail: thomas.lipe@nist.gov	▪ CANADA National Research Council Canada | M-36, 1200 Montreal Road, Ottawa, Ontario K1A 0R6 Government of Canada | Gouvernement du Canada Phone: 613-993-2313 Fax 613-952-1394 Contact: Dr. Peter Filipski e-mail:Peter.Filipski@nrc-cnrc.gc.ca

▪ Brazil Instituto Nacional de Metrologia, Normalização e Qualidade Industrial Av. Nossa Senhora das Graças, 50 Duque de Caxias – RJ 25250-020, Brazil Phone: xx55(21)26791627 Fax: xx(21)26791627 Contact. Regis P. Landim e-mail: rplandim@inmetro.gov.br ▪	▪ Egypt National Institute for Standards Tersa Street, Haram PO Box 136 Giza, Code 1221, Egypt Phone: +202-333889783 Contact: Mamdouh Halawa (mamdouh_halawa@yahoo.com

The interlaboratory comparison package contains the following items packed in a case with dimensions 50 cm x 25 cm x 35 cm. The weight of the package is approximately around 2 kg.

Qty	Description	Value (USD)
1	AC-DC transfer standards Planar multijunction Thermal Converter, identified as "PMJTC-90-2", manufactured by INTI	1000.00
1	Temperature, Humidity and Pressure Datalogger	700.00
1	5 ampere travelling standard comprises a 0.2 Ω coaxial shunt, identified "SHUNT 5 A"	1000.00
(Value only for customs effects) Total		2700.00

Lic. Lucas Di Lillo
Instituto Nacional de Tecnología Industrial
Colectora de Avenida General Paz 5445 entre Albarellos y Avenida de los Constituyentes
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República Argentina
Email: ldili@inti.gob.ar

Appendix II

SUMMARY OF RESULTS

Appendix II. Summary of Results

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

Please also send this information by e-mail.

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							
5 A							

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							
5 A							

Measurement Frequency:

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 III

SUMMARY OF UNCERTAINTY BUDGET

Appendix III. Summary of Uncertainty Budget

SIM Key International Comparison of AC-DC Current Transfer Standards SIM.EM-K12
Please also send this information by e-mail.

Institute:
Date:
Remarks:
Measurement Current : 10 mA

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

Combined uncertainty (k=1)							
Expanded uncertainty:							

Measurement Current : 5 A

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

Combined uncertainty (k=1)							
Expanded uncertainty:							

Appendix IV. Packing List

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

Item	Approx. Value (U$S)	Dimensions (mm)	Weight (kg)
Planar Multijunction Thermal Converter, INTI, PMJTC-90-2	1000	50 cm x 25 cm x 30 cm	2
Current Shunt, INTI, SHUNT 5 A	1000		
Datalogger	700		
This Protocol			
Total Value	2700		

All items have been manufactured by INTI. They are to be transported in the custom carry case supplied. The maximum dimensions of the carry case are 50 cm x 25 cm x 35 cm. The weight of the package is approximately around 2 kg.

Appendix V

Forms for Notifying Receipt and Shipment of Artefact

Appendix V Forms for Notifying Receipt and Shipment of Artefact

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

ARTEFACTS RECEIVED

To:…*(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: *(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)