Supplementary Comparison EURAMET.EM-S35
Comparison of High-Current Ratio Standard

TECHNICAL PROTOCOL

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1. Introduction

The scope of the comparison is the validation of NMI CMCs for quantities related to dc high currents (CMC classification 8.7.1, 8.7.2 and 8.7.3), for current values in the range 100 A – 600 A. Previous CCEM and EUROMET comparisons on dc current do not cover the current range exploited in the present comparison.

The procedures outlined in this document should allow for a clear and unequivocal comparison of the measurement results. The protocol was prepared following the CCEM guidelines for key, supplementary and pilot comparisons [1].

2. Travelling standard

2.1 Description of the standard

Standard details	- Type	:	LEM IT-600 S
	- Serial number	:	8100088322
	- Nominal primary current	:	0 - 600 A
	- Nominal primary to secondary current ratio	:	1/1500
	- Power supply	:	0 V, and ±15 V

The travelling standard, characterized at METAS, is a zero flux current transformer with embedded electronics. Mechanical and connection details are shown in fig.1.

2.2 Quantities to be measured

- Current ratio	:	1:1500	nominal value	
- Primary current	:	90 A 300 A 600 A	(mandatory) (optional) (optional)	nominal values.
- Secondary current	:	60 mA 200 mA 400 mA	(mandatory) (optional) (optional)	nominal values.
- Supplied voltage	:	0 V ±15 V	nominal values.	
- Environmental condition	:	temperature	it should be measured on the primary current bus bar, as close as possible to the measuring head;	
		humidity pressure	no characterization will be done for both quantities, because no significant influence is expected.	
- Measurement condition	:	transformer	no primary conductor or bus-bar is supplied;	
		load resistance R_m (ref. fig.1)	the recommended value is 1 Ω, however it must not exceed 2.5 Ω;	
		initial warm up	the travelling standard should be powered during at least 24 hours in laboratory conditions before starting measurements.	

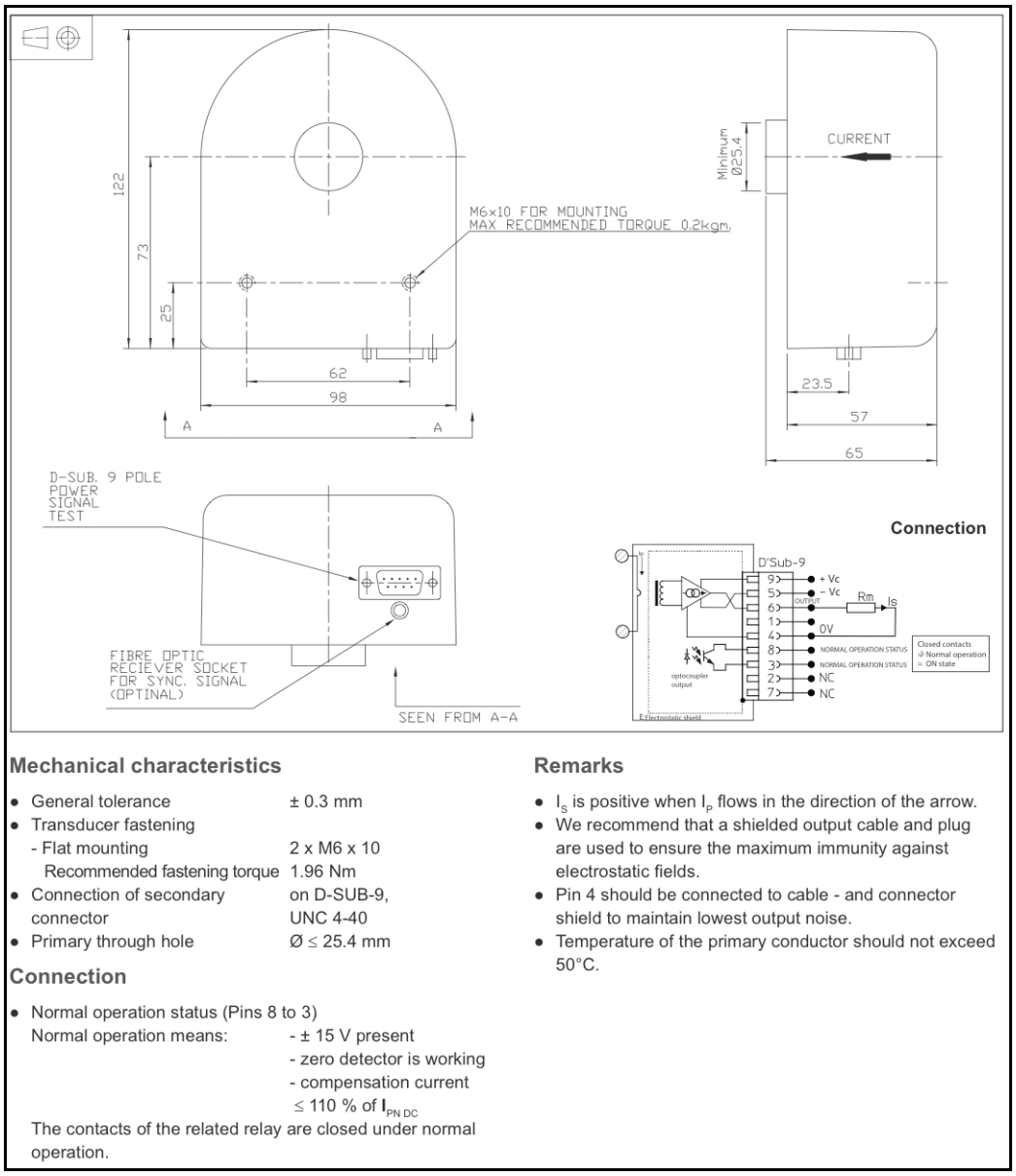

Fig. 1 – LEM IT-600 S current comparator datasheet

2.3 Method of computation of the Reference value

The comparison reference value (CRV) will be evaluated following the following principles:

- the results obtained by the pilot laboratory will be used to determine the drift behaviour of the travelling standards;
- the results provided by the participants will be corrected to the nominal temperature (23 °C) using the sensitivity coefficients determined by the pilot laboratory;
- for the calculation of the CRV and the degrees of equivalence, the procedures described in the guideline [2] will be used;
- if for a result, the uncertainty contribution due to the traceability to another NMI amounts to a substantial part of the overall uncertainty value, the result is not taken into account in the calculation of the CRV.

3. Organisation

3.1 Co-ordinator and members of the support group

The pilot laboratories for the comparison are the Federal Office of Metrology (METAS) and the Istituto Nazionale di Ricerca Metrologica (INRIM).

Co-ordinator:

Cristina Cassiago (INRIM)
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Support group:

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Bernd Schumacher (PTB)
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JT Janssen (NPL)
e-mail: jt.janssen@npl.co.uk

3.2 Participants

The following institutes announced the interest to participate in the comparison.

No	Acronym	Institute	Country
1	CMI	Czech Metrology Institute	Czech Republic
2	INRIM	Istituto Nazionale di Ricerca Metrologica	Italy
3	LNE	Laboratoire national de métrologie et d'essais	France
4	METAS	Federal Office of Metrology METAS	Switzerland
5	MIKES	Centre for Metrology and Accreditation	Finland
6	NPL	National Physical Laboratory	United Kingdom
7	PTB	Physikalisch-Technische Bundesanstalt	Germany
8	SIQ	Slovenian Institute of Quality and Metrology	Slovenia
9	SMD	SPF Economie, PME, Classes Moyennes et Énergie - Qualité et Sécurité- Service Etalons	Belgium
10	SP	SP Technical Research Institute of Sweden	Sweden
11	VSL	VSL Dutch Metrology Institute	Netherlands

Table 1: Participants

3.3 Time schedule

The comparison is carried out in 2 loops. The circulation of the standard starts in November 2012 and is planned to end in November 2013. The detailed time schedule for the comparison is given in Appendix A2.

A period of 4 weeks is allowed for the measurements in each laboratory, including the time necessary for transportation. It is intended to re-measure the standards at certain intervals in the pilot laboratory to establish a drift rate for the standard and to detect transport problems.

In agreeing with the proposed circulation time schedule, each participating laboratory confirms that it is capable to perform the measurements in the limited time period allocated in the time schedule. If, for some reasons, the measurement facility is not ready or custom clearance should take too much time, the laboratory is requested to contact immediately the co-ordinator. According to the arrangement made in this special case eventually the travelling standard must be sent directly to the next participant before the measurement has been finished or even without performing any measurements. In such a case, there is a possibility to carry out the measurements at the end of the comparison.
If delay occurs, the pilot laboratory shall inform the participants and revise, if necessary, the time schedule, or skip one country and put it at the end of the circulation.

3.4 Transportation

Transportation is at each laboratory's own responsibility and cost. Due to the time constraints, a recognised courier service (e.g. UPS, DHL...) guaranteeing an adequate delivery time, including the time for customs procedure, should be used. Where appropriate, customs procedures have to be examined in advance of the transport. The courier service has to be informed that the transport case should not be exposed to extreme temperatures or mechanical shocks.
In some countries, the case will be transported with an ATA carnet for customs clearance. Upon each movement of the package, the person organising the transit must ensure that the carnet is presented to customs on leaving the country, and upon its arrival in the country of destination. When the package is sent unaccompanied, the carnet must be included with the other forwarding documents so that the handling agent can obtain customs clearance. IN NO CASE SHOULD THE CARNET BE PACKED INSIDE THE CASE. In some cases it is possible to attach the carnet to the case. The carnet must be stored in the laboratory very carefully because a loss of the carnet may cause a serious delay in the comparison schedule.
On receipt of the case, the participant shall inform the pilot laboratory by sending the receipt form given in Appendix A5 by fax or e-mail.
Immediately after the completion of the measurements, the case is to be transported to the next participant. It is advisable to organise this transport beforehand. The pilot laboratory has to be informed through the form given in Appendix A6 about the dispatch of the case. The next participant should be informed as well.

3.5 Unpacking, handling, packing

The transport case contains the following items:

Packing list
- DC Current Comparator LEM IT-600 S
- Connection cable for power supply and current output, with unequivocally labelled connectors
- Ambient conditions recorder. This recorder is used to monitor the temperature of the standards during transport.
- Instruction sheet.

On receipt of the case, unpack the standards carefully and check for any damage and the completeness of the audit pack according to the packing list. The ambient conditions recorder should not be removed from the transport case. If possible, the transport case should be stored in the laboratory. Any damage of the standard or missing item shall be reported on the receipt form to be sent to the co-ordinator.

Before sending the case out, check the packing list and ensure everything is enclosed. The standard should be packed in the original transport case as illustrated in the instruction manual. *Ensure that the ATA carnet (where applicable) is packed outside the case for easy access by customs*.

3.6 Failure of the travelling standard

If the standard should be damaged during the comparison, the comparison co-ordinator has to be informed immediately.

3.7 Financial aspects, insurance

Each participating laboratory covers the costs of the measurements, transportation and eventual customs formalities as well as for any damage that may occur within its country. The overall costs for the organisation of the comparison are covered by the organising pilot laboratory. The pilot laboratory is responsible for insurance and for any loss or damage of the standard during transportation.

4. Measurement instructions

4.1 Measurement performance

- Pre-conditioning : the standard should be installed in laboratory at the working temperature, at least 24 h before starting the measurements.
- Temperature : (23 ± 1) °C; the temperature should not exceed the given limits.
- Humidity : (50 ± 10) %;
- Power supply : the travelling standard must be supplied with 0 V, and ±15 V. A power supply is not part of the travelling material. The supplied values should not lay more than 5% away from the nominal value. The measured power supply values must be provided together with the measurement results;
- Measurand : secondary to primary current ratio R defined as follows:

$$R = \frac{I_S - I_{off}}{I_P} \tag{1}$$

where I_P is the input current (primary current) flowing in the travelling standard and I_S the output current (secondary current) of the travelling standard. I_{off} is the output current of the travelling standard when the input current is zero. The value of R shall be measured for both polarities at a given current value.

- Results : The measurement results of R shall be given as:
  $R+$ = measurement performed with positive current[(1)],
  $R-$ = measurement performed with negative current,
  R_M = result obtained by averaging $R+$ and $R-$ measurements or measured in other way (for instance with a direct measurement). In this last case, if $R+$ and $R-$ can not be evaluate independently it must be declared.

[(1)] I_S is positive when I_P flows in the direction of the arrow on top of the travelling standard (see fig.1).

4.2 Method of measurement

The measurement method is not specified. It is assumed that every participant uses its normal measurement method. The method and the traceability scheme have to be described in the measurement report (see below).

5. Uncertainty of measurement

5.1 Main uncertainty components

A detailed uncertainty budget in accordance with the Guide to the Expression of Uncertainty in Measurement [3] shall be reported for primary current of each nominal value.
To have a comparable uncertainty evaluation, a list of principal uncertainty contributions is given. Depending on the measuring methods, this list may vary and can include:

- reference standard (drift, temperature and current dependence, etc.)
- measuring set-up (stability, gain and offset-effects, electrical configuration, primary current tolerance, etc.)
- measuring method
- tolerances (of primary current, etc…)
- leakage effects
- temperature
- humidity
- reproducibility (centring error, etc…)

In the uncertainty budget for each uncertainty contribute it must be indicated

- probability distribution
- degrees of freedom

If the traceability of the reference standard depends on another NMI, it should be indicated.

5.2 Scheme to report the uncertainty budget

A proposed scheme for the uncertainty budget is given in Annex A3.

6. Measurement report

Each participant is asked to submit a printed and signed report by mail within ***6 weeks after completing*** the measurements. A copy of the report together with an Excel worksheet containing the detailed measurement(see Appendix 4), and their Adobe Acrobat copies (printed as PDF/A), are also to be sent by e-mail. In the case of differences between electronic and paper versions of the report, the signed paper form is considered to be the valid version. If the deadline for sending the results is not kept, the concerned laboratory may be excluded from the comparison.
The report should contain at least the following (see also Appendix A4):

- description of the measuring set-up including the electrical circuit configuration;
- traceability scheme; if the traceability to the SI is provided by another NMI, the name of the NMI has to be stated (needed to identify possible sources of correlation);
- description of the measurement procedure;
- the measurement results: mean current value and the corresponding mean date of measurement; individual results in the form described in Appendix A4;
- the ambient conditions of the measurement: the temperature and humidity with limits of variation;
- a complete uncertainty budget in accordance with the principles of the Guide to the Expression of Uncertainty in Measurement [3], 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 comparison reference value; it is also an essential part of the final report which will appear in the BIPM Key Comparison Database.

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

7. Report of the comparison

The pilot laboratory will prepare the draft A report within three months after completion of the circulation. This report will be prepared with the aid of the support group and will be sent to all participants for comments.

References

[1] "CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons", March 2007, http://www.bipm.org/en/committees/cc/ccem/guidelines.html.

[2] M. G. Cox, "The evaluation of key comparison data*", metrologia* 39, pp. 589-595, 2002.

[3] BIPM Guide JCGM 100:2008

Annexes

A1 Detailed list of participants

No	Acronym	Institute	Name	e-Mail	Address	Country	Telephone	Telefax
1	CMI	Czech Metrology Institute	Renata Styblíková	rstyblikova@cmi.cz	V Botanice 4 150 72 Prague 5	Czech Republic	+420 257 288 335 +420 602 196 072 (mob)	+420 257 328 0777
2	INRIM	Istituto Nazionale di Ricerca Metrologica	Enrico Gasparotto	e.gasparotto@inrim.it	Strada delle Cacce 91 10135 Turin	Italy	+39 011 3919 438	+39 011 346384
3	LNE	Laboratoire national de métrologie et d'essais	Daniela Istrate	daniela.istrate@lne.fr	Av. Roger Hennequin 78197 Trappes Cedex	France	+33 01 30 69 32 05	+33 01 30 16 24 52
4	METAS	Federal Office of Metrology METAS	Alessandro Mortara	alessandro.mortara@metas.ch	Lindenweg 50 3003 Bern-Waben	Switzerland	+41 31 323 33 28	+41 31 323 32 10
5	MIKES	Centre for Metrology and Accreditation	Jari Hällström	jari.hallstrom@mikes.fi	Tekniikantie 1 02151 Espoo	Finland	+358 10 6054 441	+358 10 6054 498
6	NPL	National Physical Laboratory	Colin Porter	colin.porter@npl.co.uk	NPL Module 2 Hampton Road Teddington Middlesex TW11 0LW	United Kingdom	+44 (0)20 8943 6195	+44 (0)20 8943 7176 +44 (0)20 8614 0499
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8	SIQ	Slovenian Institute of Quality and Metrology	Matjaz Lindic	matjaz.lindic@siq.si	Trzaska cesta 2 1000 Ljubljana	Slovenia	+386 1 4778 310	+386 1 4778 303
9	SMD	SPF Economie, PME, Classes Moyennes et Énergie - Qualité et Sécurité- Service Etalons	Dana Vlad	dana.vlad@economie.fgov.be	Bd Albert II, 16 B1000, Bruxelles	Belgium	+32(0)22 77 89 18	+32(0) 22 77 54 08
10	SP	SP Technical Research Institute of Sweden	Anders Bergman	anders.bergman@sp.se	Box 857 SE-501 15 BORAAS	Sweden	+46 10 5165678	+46 33 125038
11	VSL	VSL Dutch Metrology Institute	Gert Rietveld	grietveld@vsl.nl	Thijssweg 11 2629 JA Delft	The Netherlands	+31 (15) 2691500	+31 (15) 2612971

A2 Schedule of the measurements

Period	Start date	End date	Laboratory	
	2012/10/29	2012/12/02	Pilot laboratory	
1	2012/12/03	2012/12/30	VSL	Loop 1
2	2013/01/07	2013/02/03	SP	
3	2013/02/04	2013/03/03	MIKES	
4	2013/03/04	2013/03/31	PTB	
5	2013/04/01	2013/04/28	LNE	
	2013/04/29	2013/06/02	Pilot laboratory	
6	2013/06/03	2013/06/30	INRIM	Loop 2
7	2013/07/01	2013/07/28	NPL	
8	2013/09/02	2013/09/29	CMI	
9	2013/09/30	2013/10/27	SIQ	
10	2013/10/28	2013/11/24	SMD	
	2013/11/25	2013/12/22	Pilot laboratory	

A3 Typical scheme for an uncertainty budget

Quantity X_i	Estimate x_i	Standard uncertainty $u(x_i)$	Probability distribution / method of evaluation (A, B)	Sensitivity coefficient c_i	Uncertainty contribution $u(R_i)$	Degree of freedom ν_i
R						
			Combined standard uncertainty:			
			Effective degrees of freedom:			
			Expanded uncertainty (95% coverage factor):			

The detailed uncertainty has to be provided in this form for $R+$, $R-$ and R_M for each nominal value.

A4 Layout of the measurement report

1. Measurand
2. Measurement set-up and traceability scheme
3. Measurement procedure
4. Results
   a. Ambient conditions
      Temperature: mean value, uncertainty and range of variation
      Humidity: mean value, uncertainty and range of variation
      Power supply level: mean value, uncertainty and range of variation
   b. Data of measurement
   c. Ratio value, combined standard uncertainty
5. Detailed uncertainty budget

Detailed results

These results have to be supplied using the xls mask supplied by the coordinator

Date	Primary current (A)	$u(I_P)$ (A)	Secondary current (A)	$u(I_S)$ (A)	Temperature (°C)	$u(T)^{(*)}$ (°C)	Humidity (%)	$u(H)^{(*)}$ (%)	Power supply (V)	$u(PS)^{(*)}$ (V)	Power supply variation (%)	Measurement result (Ratio value)	Combined standard uncertainty (Ratio uncertainty)

(*) Combined standard uncertainty (incl. type B components)

A5 Confirmation note of receipt

T e l e f a x T e l e f a x T e l e f a x

(Please pass on immediately!)

To: Istituto Nazionale di Ricerca Metrologica (I.N.RI.M.)
attn.: Dott.ssa Cristina Cassiago

Strada delle Cacce 91, 10135 Torino, Italy

fax: +39 011 346384
e-mail: c.cassiago

From: (participating laboratory):

Fax: *International* +

Pages (total): 1

In the case of faulty reproduction, please call:

Re: **Supplementary Comparison EURAMET.EM-S35**
Receipt of travelling standards

Date: ---

We confirm having received the travelling standards on: ---

After visual inspection:

☐ No damage of the suitcase and the travelling standards has been noticed

☐ the following damage(s) must be reported(if possible add a picture):

Date: --- Signature: ---

A6 Confirmation note of dispatch

T e l e f a x T e l e f a x T e l e f a x

(Please pass on immediately!)

To: Istituto Nazionale di Ricerca Metrologica (I.N.RI.M.)
attn.: Dott.ssa Cristina Cassiago

Strada delle Cacce 91, 10135 Torino, Italy

fax: +39 011 346384
e-mail: c.cassiago

From: (participating laboratory):

.....

.....

.....

Fax: *International* +

Pages (total): 1

In the case of faulty reproduction, please call:

.....

.....

Re: **Supplementary Comparison EURAMET.EM-S35**
Receipt of travelling standards

Date: .....

We have informed the next participant on ..... that we will send travelling standards to them.

We confirm having sent the travelling standad on ..... to the next participant.

Additional informations:

.....

.....

.....

.....

.....

.....

.....

.....

Date: ..... Signature: .....