EUROMET 557 COMPARISON
OF AC-DC HIGH VOLTAGE STANDARDS

Key comparison Final Report

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Report on the EUROMET comparison of AC-DC high voltage transfer standards.

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Abstract : The international EUROMET 557 key comparison of AC-DC high voltage transfer standards started in February 2000 and was completed in March 2003. AC-DC transfer standards were compared at 200 V, 500 V and 1000 V. At 1 kHz, the agreement between the results given by the participants and the key comparison reference value is in the order of 5 µV/V at all test voltages. At the frequency of 100 kHz, the agreement at 500 V and 1000 V is in the order of 15 µV/V. In this comparison, the same travelling standards and then the same reference value as in the CCEM-K9 key comparison were used.

1) Introduction :

AC-DC thermal transfer techniques provide at present time the most accurate link between AC RMS voltages and DC voltages. These techniques imply thermal converters usually operating in the 1 V to 3 V ranges, which are associated with series range resistors for measurements at higher voltages. In order to reach a low level of uncertainty, their AC-DC transfer difference has to be determined by a step-up procedure.

At voltage levels of a few volts, most of National Metrology Institutes (NMIs) use multijunction thermal converters (MJTC) as primary standards in the low frequency domain. The frequency response of such converters is very flat and close to their DC response from 10 Hz to 100 kHz, and can be accurately calculated in this frequency range [1]. A recent international comparison (CCEM-K6.a) [2] at voltages of 1.5 V and 3 V, using PTB MJTCs as travelling standards, showed an agreement between the participating NMIs better than 0.6 µV/V at 1 kHz and 1.4 µV/V at 100 kHz.

At higher voltages, the frequency response of AC-DC transfer standards is derived from the primary standards by a step-up procedure which consists in calibrating, one after the other, each unknown standard against the neighbouring already calibrated standard. The assumption is made that the AC-DC transfer difference of each standard remains constant between the reduced voltage at which it is calibrated and the full rated voltage at which it is then used, as the reference converter, in the next step of the step-up procedure. This assumption is generally valid for voltages up to 100 V or 200 V, but at higher voltages, a voltage level dependence of the AC-DC transfer difference is observed. Dielectric losses [3] and variations of the resistance of the range resistor with temperature changes [3] seem to be mainly responsible for this dependence. Specific difficulties occur then in the determination of the AC-DC differences of the AC-DC standards at these voltages and particularly at frequencies above 20 kHz.

A previous comparison of such devices (CCE 92-4) showed large discrepancies between the results reported by the participants and no meaningful reference values for the travelling standards at these frequencies (> 20 kHz) could be computed from the reported results. In May 1999, at the meeting of AC-DC transfer experts in Silkeborg, Denmark, it was decided to cancel this comparison. A new comparison, conforming to the BIPM guildlines for key comparison and designated CCEM-K9, with new travelling standards, piloted by BNM-LNE[*], was restarted in February 2000. The support group was composed of METAS, SP and NRC. A regional key comparison, with the same travelling standards, designated EUROMET 557, was started in parallel. In this way, both comparison were directly connected ideally and no extra reference value had to be calculated. Let's notice that works performed in number of NMIs during this last decade greatly improved performances of high voltage AC-DC transfer measurements [4-8].

2) Scope of the comparison

The purpose of the present comparison was to check the agreement between the NMIs in the field of AC-DC transfer measurements at 200 V, 500 V and 1000 V. The test frequencies were 1 kHz, 10 kHz, 20 kHz, 50 kHz and 100 kHz.

The quantity to be measured was the AC-DC transfer difference δ of the travelling high voltage thermal converters, defined as

$$\delta = \frac{V_{AC} - V_{DC}}{V_{DC}}$$

where:

- V_{AC} is the RMS value of the AC voltage applied at the input of the converter;
- V_{DC}, the direct voltage, which when reversed, produces the same mean output voltage of the converter as V_{AC}.

[*] Since January 2005, when the activities of BNM were transfered to LNE, the french national metrology institute has been named LNE (Laboratoire National de Métrologie et d'Essais).

3) Organisation of the comparison and description of the travelling standards

This comparison was organised in two parallel loops. The CCEM and EUROMET loops were not separated.

In the first loop, the circulating standard (NIST-PTB/1000V) consisted of PTB-IPHT 400 Ω planar multijunction thermal converter, provided by PTB, associated with a 1000 V range resistor (s/n 030) for FLUKE 792 A transfer standard provided by NIST. This standard had to be measured at all the requested voltages and frequencies.

In the second loop, two standards were circulating. One of them (METAS/1000V) was a 1000 V standard (ref. RS1000/E + US6) developed and provided by METAS, consisting of a 1000 V range resistor associated with a single junction thermal converter to be measured at 500 V and 1000 V. The second standard (NIST-PTB/500V) was a PTB-IPHT 400 Ω planar multijunction thermal converter, provided by PTB, associated with a 500 V range resistor (s/n 034) for FLUKE 792 A transfer standard, provided by NIST, to be measured at 200 V and 500 V (optional).

The link between the different standards was established by BNM-LNE, PTB and METAS, who participated in both loops. These laboratories also monitored the long term stability of the standards by repeated calibrations during the comparison.

During the comparison, the NIST-PTB/1000V standard was destroyed twice. Each time, the 400 Ω planar MJTC was replaced by PTB. Therefore, 5 standards were finally used in this comparison.

For one group of participants they were :

- NIST-PTB/1000V[1] from February 2000 to December 2000, and called S1 later in the report ;
- NIST-PTB/1000V[2] from January 2001 to October 2001, also called S2 ;
- NIST-PTB/1000V[3] from December 2001 to June 2002, also called S3.

For the other group they were :

- METAS/1000V, which was measured at 1000 V and 500 V, and called S4 later in the report ;
- NIST-PTB/500V, measured at 500 V and 200 V, also called S5.

4) Participating NMI's

The NMI's are listed in the chronological order in which they participated for each travelling standard.

	LABORATORY	COUNTRY	Responsible person	Calibration date	Comparison
Travelling standard : NIST-PTB/1000V[1] (S1)					
1	BNM-LNE	France	Andre POLETAEFF	February 2000	CCEM-K9 EUR-557
2	BEV	Austria	Martin GARCOCZ	April 2000	EUR-557
3	MIKES	Finland	Tapio MANSTEN	May 2000	EUR-557
4	INETI	Portugal	Rui de MELLO FREITAS	June 2000	EUR-557
5	DANIAmet-AREPA	Denmark	Torsten LIPPERT	July 2000	CCEM-K9 EUR-557
6	NPL	United Kingdom	Gareth JONES	August 2000	CCEM-K9 EUR-557
7	SP	Sweden	Karl Erik RYDLER	September 2000	CCEM-K9 EUR-557
8	IEN	Italy	Umberto POGLIANO	October 2000	CCEM-K9 EUR-557
9	CEM	Spain	Miguel NEIRA	November 2000	CCEM-K9 EUR-557
Travelling standard : NIST-PTB/1000V[2] (S2)					
10	PTB	Germany	Manfred KLONZ	January 2001	CCEM-K9 EUR-557
11	VSL	The Netherlands	Cees Van MULLEM	May 2001	CCEM-K9 EUR-557
12	OMH	Hungary	Attila BARANYAI	October 2001	EUR-557
Travelling standard : NIST-PTB/1000V[3] (S3)					
13	JV	Norway	Harald SLINDE	March 2002	EUR-557
14	UME	Turkey	M. ARIFOVIC	April 2002	EUR-557
Travelling standards : METAS/1000V (S4) and NIST-PTB/500V (S5)					
15	METAS	Switzerland	Marc FLUELI	August 2001	CCEM-K9 EUR-557
16	CMI	Czech Republic	Jana HORSKA	December 2002	EUR-557

Table 1 : List of participating NMI's. Laboratories which performed complementary, stability monitoring measurements, are noted in blue.

The full names of the participating organisations are :

BNM-LNE : Bureau National de Métrologie – Laboratoire National d'Essais
BEV : Bundesamt für Eich- und Vermessungswesen
MIKES : Mittatekniikan keskus Mätteknikcentralen
INETI : Instituto Nacional de Engenharia, Tecnologia e Inovaçao
DANIAmet-AREPA :
NPL : National Physical Laboratory
SP : Sveriges Provningsanstalt
IEN : Instituto Elettrotecnico Nazionale
CEM : Centro Espanol de Metrologia
PTB : Physikalisch-Technische Bundesanstalt
NMi-VSL : Nederlands Meetinstituut – Van Swiden Laborarorium
OMH : Orszagos Mérésügyi Hivatal
JV : Justervesenet
UME : Ulusal Metroloji Enstitüsü
METAS : Métrologie et Accréditation Suisse
CMI : Cesky Metrologicky Institut

5) Laboratory procedures and standards

The measuring procedures and standards used in the different NMI's have been described in more or less detail in their reports. Some of them have been published elsewhere.

Almost all participants use an automatic or semi-automatic system to compare the travelling standards against their reference standards. In general the AC-DC measurement consists of an input sequence DC+, AC, DC-, AC, etc… Each time, either the output voltages of both thermal converters are directly measured (dual-channel method), or one of them only and the difference between them ("differential" method).

The number of measurements differs from one institute to another.

6) Uncertainty statements

The participants were asked to provide detailed uncertainty budgets in accordance with the Guide to the expression of uncertainty in measurements, first edition published in 1993 by BIPM/IEC/IFCC/ISO/IUPAP/OIML, based on the recommendation INC-1 (1980). In this report, all the uncertainties are presented with a probability of 95%.

Uncertainty budgets provided by the participants are given in appendix 2.

7) Determination of the reference value

As the same travelling standards have been used during the same period in the CCEM and the EUROMET comparisons, both comparisons are directly connected ideally. Then the reference value determined for the CCEM project has been also used in the EUROMET comparison. Nevertheless, the method used for this determination is described in both reports.

Although several travelling standards have been used, only one value should be given as the reference value for the comparison. For this reason, the AC-DC transfer difference of the travelling standard S2 (see the list of the travelling standards in paragraph 3) has been arbitrary chosen as the reference value. Values reported by each participant in the comparison were then adjusted by subtracting the deviation from S2 of the standard he measured. In this way, results of all participants were referred to standard S2.

Calculation of the deviations of the different standards from S2

The value $d_{rep}(S_i,L_j)_k$ of the AC-DC transfer difference of the travelling standard "S_i" reported by laboratory "L_j" (BNM-LNE, PTB or METAS), *k* being the number of the actual measurement can be written :

$$d_{rep}(S_i,L_j)_k = d(S_i) + d(L_j) + \varepsilon_k \quad \text{where :}$$

- $d(S_i)$ is the AC-DC difference of the travelling standard "S_i" ;
- $\delta(L_j)$ is the systematic error of laboratory "L_j" assumed to be the same for all the measurements performed by this laboratory at given test point ;
- ε_k is the random measurement error on $d_{rep}(S_i,L_j)_k$.

Each reported value leads then to an equation. In order to get only one solution for this system, the supplementary condition $\sum_j \delta(Lj) = K$ has been added. Values computed for the $d(S_i)$'s are depending on the value given to *K*, but not differences between them. The value of *K* has then been fixed to zero for the calculation of preliminary values of the AC-DC differences of the travelling standards.

This set of equations has been written in the matrix form :

$$[MeasRESULTS] = [X].[Y] + [\varepsilon]$$

with the solution :

$$[estY] = ({}^T[X].[X])^{-1}.{}^T[X].[MeasRESULTS]$$

where [*estY*] is an estimate of [*Y*].

Deviations d(S1) – d(S2), d(S3) – d(S2), d(S4) – d(S2) and d(S5) – d(S2) have been deduced from preliminary values computed for d(S1), d(S2), d(S3), d(S4) and d(S5).

Calculation of the uncertainty on the deviations of the different standards from standard S2.

The variance $Var[estY]$ of $[estY]$ is determined by :

$$Var[estY] = s^2.({}^T[X].[X])^{-1}$$

From reported values (matrix $[MeasRESULTS]$) and computed preliminary values (matrix $[Y]$), a one column error matrix $[\varepsilon]$ has been deduced :

$$[\varepsilon] = [MeasRESULTS] - [X].[estY]$$

If its elements are noted ε_l, s is given by :

$$s = \frac{\sum_l \varepsilon_l^2}{n-p}$$

where :

- n is the number of equations ;
- p, the number of parameters to determine.

The standard uncertainties of the determined parameters (matrix $[estY]$) are given in the main diagonal of matrix $Var[estY]$. If $u_{pr}(S_i)$ represents the standard uncertainty on the preliminary computed value of $d(S_i)$, the standard uncertainties u_{dev} of the deviations of the different travelling standards from S2 are given by :

- $u_{dev}(S1) = \sqrt{u_{pr}^2(S1) + u_{pr}^2(S2)}$ for S1 ;
- $u_{dev}(S3) = \sqrt{u_{pr}^2(S3) + u_{pr}^2(S2)}$ for S3
- $u_{dev}(S4) = \sqrt{u_{pr}^2(S4) + u_{pr}^2(S2)}$ for S4
- $u_{dev}(S5) = \sqrt{u_{pr}^2(S5) + u_{pr}^2(S2)}$ for S5

Calculation of the reference value

The reference value d_{ref} and the associated uncertainty u_{ref} were calculated from the set of adjusted values of participants in the CCEM project using :

$$d_{ref} = \frac{\sum_i d_{adj,i} / u_{adj,i}^2}{\sum_i 1/u_{adj,i}^2} \quad \text{and} \quad u_{ref} = \sqrt{\frac{1}{\sum_i 1/u_{adj,i}^2}} \quad \text{where :}$$

- $d_{adj,i}$ is the adjusted value for laboratory "L_i" ;
- $u_{adj,i}$ is the standard uncertainty of the adjusted value for laboratory "L_i" and is given by $u_{adj,i} = \sqrt{u_{rep,i}^2 + u_{dev,i}^2}$, $u_{rep,i}$ being the standard uncertainty reported by laboratory "L_i", and $u_{dev,i}$ the standard uncertainty of the deviation of the standard measured by this laboratory from the standard S2.

Numerical values

Numerical values deduced from measurements made in the frame of the CCEM project are given in tables 2 (deviation from standard S2) and 3a to 3c (reference value).

	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
	dSi - dS2	*U*	**dSi - dS2**	*U*	**dSi - dS2**	*U*	**dSi - dS2**	*U*	**dSi - dS2**	*U*
Deviation at 1000 V										
S1	**-0.7**	*1.6*	**-0.9**	*1.6*	**-1.1**	*1.6*	**-1.9**	*1.6*	**-5.4**	*1.6*
S3	**0.1**	*1.8*	**4.8**	*1.8*	**18.6**	*1.6*	**109.5**	*1.8*	**401.4**	*1.8*
S4	**0.5**	*1.6*	**5.6**	*1.6*	**16.2**	*1.4*	**81.0**	*1.6*	**290.8**	*1.4*
Deviation at 500 V										
S1	**-1.6**	*2.2*	**-0.7**	*1.6*	**-0.8**	*1.8*	**-2.1**	*1.6*	**-6.1**	*2.2*
S3	**-1.3**	*2.4*	**4.8**	*1.6*	**18.7**	*1.8*	**110.1**	*1.8*	**400.7**	*2.4*
S4	**-1.6**	*2.0*	**5.1**	*1.4*	**16.1**	*1.6*	**80.9**	*1.6*	**294.0**	*2.0*
S5	**-2.1**	*2.0*	**2.5**	*1.4*	**6.8**	*1.6*	**28.7**	*1.6*	**94.4**	*2.0*
Deviation at 200 V										
S1	**-1.5**	*2.2*	**-1.4**	*1.8*	**-1.4**	*1.2*	**-2.9**	*2.2*	**-5.8**	*2.4*
S3	**-0.3**	*2.2*	**5.2**	*1.8*	**19.1**	*1.4*	**110.3**	*2.2*	**405.8**	*2.4*
S5	**0.1**	*2.0*	**3.2**	*1.6*	**7.3**	*1.2*	**29.7**	*2.0*	**98.3**	*2.2*

Table 2 : Deviation of the different travelling standards from standard S2 and associated expanded uncertainties (µV/V)

1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
d	*U*	***d***	*U*	***d***	*U*	***d***	*U*	***d***	*U*
0.2	*3.1*	**-2.3**	*3.4*	**-5.2**	*3.7*	**-19.9**	*5*	**-53.1**	*10*

Table 3a : Reference value ("d") and associated expanded uncertainty ("*U*") at 1000 V (Values in µV/V)

1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
d	*U*	***d***	*U*	***d***	*U*	***d***	*U*	***d***	*U*
1.8	*2.8*	**-2.2**	*2.8*	**-5.8**	*3.2*	**-20.9**	*4.2*	**-59.9**	*7.6*

Table 3b : Reference value ("d") and associated expanded uncertainty ("*U*") at 500 V (Values in µV/V)

1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
d	*U*	***d***	*U*	***d***	*U*	***d***	*U*	***d***	*U*
1.4	*2.4*	**-2.5**	*2.5*	**-5.9**	*2.6*	**-21.9**	*3.5*	**-60.4**	*5.3*

Table 3c : Reference value ("d") and associated expanded uncertainty ("*U*") at 200 V (Values in µV/V)

8) Presentation of the results

In this report, the results are given in µV/V and the uncertainties presented with a probability of 95 %.

Reported values

Tables 4a to 4d show the reported values (column "d") and reported uncertainties (column "u") by all participants. Results of complementary participations of BNM-LNE, PTB and METAS to establish the link between the standards and check their long time stability are presented on dark background.

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			d	*u*	d	*u*	d	*u*	d	*u*	d	*u*
Travelling standard : NIST-PTB/1000V[1] (S1)												
	BNM-LNE	France	**5.3**	*16*	**-1.9**	*35*	**-9.1**	*35*	**-33.6**	*69*	**-79**	*69*
	PTB	Germany	**-0.4**	*8*	**-3.8**	*8*	**-7.4**	*8*	**-23.4**	*10*	**-62.1**	*30*
	BEV	Austria	**0**	*18*	**0**	*20*	**-1**	*24*				
	MIKES	Finland	**-0.6**	*10*	**-10**	*9.9*	**-17.9**	*10.8*	**-49.1**	*23.2*	**-98.8**	*82.1*
	INETI	Portugal	**13**	*32*	**22**	*40*	**28**	*52*	**32**	*68*	**31**	*102*
	DANIAmet-AREPA	Denmark	**4**	*21*	**1**	*21*	**-1**	*26*	**-20**	*41*	**-58**	*81*
	NPL	United Kingdom	**-1**	*13*	**-6**	*11*	**-12**	*23*	**-29**	*32*	**-69**	*62*
	SP	Sweden	**2**	*9*	**0**	*10*	**-4**	*11*	**-17**	*15*	**-48**	*23*
	IEN	Italy	**-1.4**	*14.8*	**-5.8**	*15.2*	**-12.9**	*25*	**-32.8**	*37.2*	**-71.9**	*79.4*
	CEM	Spain	**-7**	*36*	**-3**	*40*	**-8**	*44*	**-38**	*64*	**-68**	*98*
	PTB	Germany	**-0.4**	*8*	**-3.9**	*8*	**-7.6**	*8*	**-23.1**	*10*	**-61.3**	*30*
Travelling standard : NIST-PTB/1000V[2] (S2)												
	PTB	Germany	**-0.5**	*8*	**-3.8**	*8*	**-7.2**	*8*	**-21.9**	*10*	**-56.6**	*30*
	BNM-LNE	France	**7.4**	*16*	**0.4**	*35*	**-6.3**	*35*	**-30.4**	*69*	**-72.4**	*69*
	METAS	Switzerland	**-1.6**	*6*	**-4.1**	*6*	**-7.6**	*6*	**-21.7**	*10*	**-51**	*26*
	VSL	The Netherlands	**3**	*20*	**-3.1**	*20*	**-10.1**	*25*	**-25.2**	*35*	**-61.4**	*50*
	BNM-LNE	France	**7.4**	*16*	**-0.3**	*35*	**-7.4**	*35*	**-31**	*69*	**-72.8**	*69*
	OMH	Hungary	**-0.6**	*15.2*	**1**	*36*	**-20.6**	*140*	**-45.2**	*120*	**-80.2**	*200*
Travelling standard : NIST-PTB/1000V[3] (S3)												
	PTB	Germany	**0.3**	*8*	**1.5**	*8*	**12.2**	*8*	**87.5**	*10*	**329.5**	*30*
	JV	Norway	**-1**	*22*	**2**	*24*	**11**	*28*	**90**	*42*	**352**	*68*
	UME	Turkey	**1**	*30*	**6**	*30*	**18**	*40*	**96**	*44*	**355**	*66*
	METAS	Switzerland	**-1.3**	*5.6*	**1**	*5.8*	**11.4**	*5.8*	**88.7**	*9.4*	**351**	*28*
Travelling standard : METAS/1000V (S4)												
	BNM-LNE	France	**5.7**	*16*	**3.9**	*35*	**7.9**	*35*	**48.6**	*69*	**216.2**	*69*
	METAS	Switzerland	**-0.6**	*5.4*	**2**	*5.4*	**9.7**	*5.6*	**59.8**	*8.4*	**241**	*24*
	METAS	Switzerland	**-1**	*5.8*	**1.6**	*6*	**9.4**	*6*	**59.8**	*9*	**241**	*26*
	METAS	Switzerland	**-0.6**	*5.4*	**2**	*5.6*	**9.4**	*5.8*	**59.7**	*8.8*	**241**	*26*
	CMI	Czech Republic	**8**	*50*	**6**	*50*	**15**	*62*	**53**	*78*	**227**	*112*
	BNM-LNE	France	**8**	*16*	**6.2**	*35*	**8.4**	*36*	**51**	*69*	**217.4**	*69*

Table 4a : Reported values (“d”) and expanded uncertainties (“*U*”) at 1000 V (in µV/V)

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			d	*u*	d	*u*	d	*u*	d	*u*	d	*u*
Travelling standard : NIST-PTB/1000V[1] (S1)												
	BNM-LNE	France	**1.8**	*13*	**-3.2**	*21*	**-6.8**	*21*	**-25.7**	*36*	**-67.7**	*36*
	PTB	Germany	**-0.6**	*8*	**-3**	*8*	**-7.4**	*8*	**-24.6**	*10*	**-67.9**	*22*
	BEV	Austria	**0**	*13*	**-1**	*15*	**-3**	*19*	**-16**	*21*	**-47**	*31*
	MIKES	Finland	**-0.7**	*8*	**-9.4**	*7.3*	**-14.8**	*8*	**-45.1**	*13*	**-97.2**	*35.9*
	INETI	Portugal	**4**	*26*	**-12**	*30*	**-19**	*36*	**-40**	*46*	**-78**	*72*
	DANIAmet-AREPA	Denmark	**3**	*21*	**0**	*21*	**-4**	*21*	**-22**	*21*	**-60**	*41*
	NPL	United Kingdom	**-1**	*13*	**-8**	*10*	**-13**	*17*	**-31**	*24*	**-75**	*46*
	SP	Sweden	**2**	*8*	**0**	*9*	**-5**	*10*	**-18**	*14*	**-55**	*21*
	IEN	Italy	**-0.6**	*9.4*	**-5.7**	*9.4*	**-13.1**	*14*	**-35.2**	*20.2*	**-80.4**	*47.6*
	CEM	Spain	**-2**	*30*	**-4**	*30*	**-5**	*30*	**-29**	*38*	**-62**	*50*
	PTB	Germany	**-0.5**	*8*	**-3**	*8*	**-7.5**	*8*	**-24.8**	*10*	**-67.4**	*22*
Travelling standard : NIST-PTB/1000V[2] (S2)												
	PTB	Germany	**-0.5**	*8*	**-2.8**	*8*	**-7**	*8*	**-22.5**	*10*	**-60.5**	*22*
	BNM-LNE	France	**3.8**	*13*	**-1.3**	*21*	**-4.9**	*21*	**-22.8**	*36*	**-62.1**	*36*
	METAS	Switzerland	**2.2**	*6*	**-4.4**	*6*	**-7.9**	*6*	**-23.1**	*8*	**-58**	*24*
	VSL	The Netherlands	**2.6**	*15*	**-4.3**	*15*	**-9.2**	*20*	**-25.7**	*25*	**-63.8**	*40*
	BNM-LNE	France	**3.3**	*13*	**-1.6**	*21*	**-5.5**	*21*	**-23.6**	*36*	**-62.6**	*36*
	OMH	Hungary	**-0.4**	*22*	**-5.3**	*32*	**-7.1**	*30*	**-19**	*56*	**-61.1**	*94*
Travelling standard : NIST-PTB/1000V[3] (S3)												
	PTB	Germany	**0.1**	*8*	**2.4**	*8*	**12.4**	*8*	**88**	*10*	**332.1**	*22*
	JV	Norway	**0**	*20*	**3**	*22*	**13**	*24*	**91**	*34*	**351**	*48*
	UME	Turkey	**-1**	*22*	**5**	*22*	**15**	*26*	**92**	*36*	**348**	*56*
	METAS	Switzerland	**-1.3**	*5.4*	**0.9**	*5.6*	**11.2**	*5.6*	**87.6**	*8.8*	**343**	*26*
Travelling standard : METAS/1000V (S4)												
	BNM-LNE	France	**1.7**	*14*	**1.7**	*21*	**9.1**	*21*	**55.9**	*37*	**230.3**	*37*
	METAS	Switzerland	**-0.8**	*5*	**1.5**	*5.4*	**9.3**	*5.6*	**59.2**	*8*	**238**	*22*
	METAS	Switzerland	**-1.2**	*5.6*	**1.6**	*5.8*	**9.2**	*5.8*	**59.6**	*8.6*	**238**	*24*
	METAS	Switzerland	**-1.2**	*5.2*	**1.6**	*5.4*	**8.9**	*5.6*	**58.9**	*8.2*	**238**	*24*
	CMI	Czech Republic	**2**	*38*	**0**	*38*	**8**	*46*	**42**	*56*	**221**	*80*
	BNM-LNE	France	**3.4**	*14*	**3.5**	*21*	**10.6**	*21*	**56.8**	*37*	**229.7**	*37*

Table 4b : Reported values (“d”) and expanded uncertainties (“*U*”) at 500 V (in µV/V)

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			d	*U*	d	*U*	d	*U*	d	*U*	d	*U*
Travelling standard : NIST-PTB/500V (S5)												
	BNM-LNE	France	**0.6**	*13*	**-1.1**	*21*	**-0.8**	*21*	**3.8**	*36*	**31.9**	*36*
	METAS	Switzerland	**-1.7**	*5.4*	**-1.2**	*5.6*	**-0.3**	*5.6*	**6.8**	*8.6*	**38**	*24*
	METAS	Switzerland	**-1.3**	*5.6*	**-1.1**	*5.8*	**-0.3**	*5.8*	**6.9**	*8.6*	**38**	*24*
	METAS	Switzerland	**-1.7**	*5.2*	**-1.3**	*5.4*	**-0.4**	*5.4*	**6.3**	*8.2*	**36**	*24*
	CMI	Czech Republic	**2**	*38*	**-6**	*38*	**-3**	*46*	**2**	*56*	**30**	*80*
	BNM-LNE	France	**3.9**	*13*	**1.3**	*21*	**2.1**	*21*	**5.8**	*37*	**31.9**	*37*

Table 4c : Reported values (“d”) and expanded uncertainties (“*U*”) at 500 V (optional) (µV/V)

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			d	*U*	d	*U*	d	*U*	d	*U*	d	*U*
Travelling standard : NIST-PTB/1000V[1] (S1)												
	BNM-LNE	France	**-1.6**	*12*	**-7.2**	*13*	**-9.1**	*13*	**-31.1**	*16*	**-76.5**	*16*
	PTB	Germany	**-0.5**	*8*	**-2.7**	*8*	**-8.3**	*8*	**-24.5**	*10*	**-67.9**	*22*
	BEV	Austria	**0**	*10*	**-2**	*10*	**-5**	*12*	**-22**	*16*	**-58**	*21*
	MIKES	Finland	**-0.9**	*6.7*	**-3.2**	*5.3*	**-6.1**	*6.5*	**-23.1**	*6.8*	**-60.3**	*8.2*
	INETI	Portugal	**5**	*16*	**1**	*16*	**-3**	*18*	**-19**	*20*	**-55**	*30*
	DANIAmet-AREPA	Denmark	**2**	*11*	**-1**	*11*	**-6**	*11*	**-26**	*11*	**-72**	*26*
	NPL	United Kingdom	**5**	*8*	**-9**	*7*	**-11**	*10*	**-26**	*9*	**-67**	*13*
	SP	Sweden	**2**	*7*	**1**	*8*	**-3**	*9*	**-21**	*13*	**-55**	*19*
	IEN	Italy	**0.7**	*8.6*	**-5**	*8.8*	**-12.4**	*12.8*	**-34.7**	*18.2*	**-77.3**	*42.4*
	CEM	Spain	**2**	*22*	**2**	*22*	**-2**	*22*	**-22**	*24*	**-60**	*28*
	PTB	Germany	**0**	*8*	**-3.3**	*8*	**-7.5**	*8*	**-24.2**	*10*	**-66.9**	*22*
Travelling standard : NIST-PTB/1000V[2] (S2)												
	PTB	Germany	**-0.5**	*8*	**-3.3**	*8*	**-7.3**	*8*	**-22.7**	*10*	**-61.9**	*22*
	BNM-LNE	France	**2.9**	*12*	**-3.4**	*13*	**-6.3**	*13*	**-25.7**	*16*	**-70**	*16*
	METAS	Switzerland	**-2**	*4.6*	**-4.5**	*6*	**-8.2**	*6*	**-23.5**	*8*	**-61**	*24*
	VSL	The Netherlands										
	BNM-LNE	France	**0.8**	*12*	**-4.8**	*13*	**-8.7**	*13*	**-26.5**	*16*	**-71.6**	*16*
	OMH	Hungary										
Travelling standard : NIST-PTB/1000V[3] (S3)												
	PTB	Germany	**-0.1**	*8*	**2.6**	*8*	**12.5**	*8*	**87.3**	*10*	**333.6**	*22*
	JV	Norway	**0.3**	*18.4*	**3.7**	*18.4*	**14**	*20*	**91**	*26*	**352**	*36*
	UME	Turkey	**0**	*18*	**3**	*18*	**11**	*24*	**89**	*30*	**343**	*44*
	METAS	Switzerland	**-1.5**	*5*	**1.1**	*5.2*	**11.2**	*5.4*	**88.2**	*8.4*	**345**	*26*
Travelling standard : NIST-PTB/500V (S5)												
	BNM-LNE	France	**1.5**	*11*	**-1.2**	*12*	**0**	*12*	**3.8**	*16*	**29.6**	*16*
	METAS	Switzerland	**-1.2**	*5*	**-1.1**	*5.4*	**-0.3**	*5.4*	**6.9**	*8.2*	**38**	*24*
	METAS	Switzerland	**-1.4**	*5.4*	**-1.2**	*5.6*	**-0.2**	*5.8*	**6.9**	*8.2*	**38**	*22*
	METAS	Switzerland	**-1.6**	*5*	**-1.3**	*5.2*	**-0.5**	*5.4*	**6.6**	*7.8*	**37**	*22*
	CMI	Czech Republic	**-1**	*24*	**-7**	*24*	**-3**	*28*	**3**	*36*	**35**	*60*
	BNM-LNE	France	**1.4**	*11*	**-1.3**	*12*	**-0.4**	*12*	**2.1**	*16*	**25.8**	*16*

Tables 4d : Reported values (“d”) and expanded uncertainties (“*U*”) at 200 V (in µV/V)

Long term stability of the travelling standards

Discrepancies between PTB and METAS appear for standard S3 at 100 kHz for all voltage levels while for standard S2 values reported by these two laboratories are in good agreement. Drift of standard S3 is the most credible explanation for these discrepancies, as such a behaviour has already been noticed for some devices of the same type during the first months of their use.

In order to take it into account, values reported for standard S3 have been corrected, assuming a linear drift between December 2001 (date of calibration by PTB) and June 2002 (date of calibration by METAS). The total drift δ_{drift} during this period was estimated using :

$$\delta_{drift} = d(S3/METAS) + d(S2/PTB) - d(S2/METAS) - d(S3/PTB)$$

where :

- d(S3/METAS) is the value reported by METAS for S3 ;
- d(S2/PTB), the value reported by PTB for S2 ;

- d(S2/METAS), the value reported by METAS for S3 ;
- d(S3/PTB), the value reported by PTB for S3.

For all other standards, complementary measurements performed by BNM-LNE, PTB and METAS showed a good long term stability.

Adjusted values

Adjusted values have been obtained by subtracting from the reported values (Tables 4a to 4d), the deviation of the measured standard from standard S2 (Table 2). The standard uncertainty u_{adj} of the adjusted value has been computed using $u_{adj} = \sqrt{u_{rep}^2 + u_{dev}^2}$, u_{rep} being the reported standard uncertainty and u_{dev}, the standard uncertainty of the deviation of the measured standard. Tables 5a to 5d show the adjusted values (column "d") with the associated expanded uncertainty (column "*U*").

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			d	*U*	**d**	*U*	**d**	*U*	**d**	*U*	**d**	*U*
Travelling standard : NIST-PTB/1000V[1] (S1)												
1	BNM-LNE	France	**6.0**	*16.1*	**-1.0**	*35.0*	**-8.0**	*35.0*	**-31.7**	*69.0*	**-73.6**	*69.0*
2	BEV	Austria	**0.7**	*18.1*	**0.9**	*20.1*	**0.1**	*24.1*				
3	MIKES	Finland	**0.1**	*10.1*	**-9.1**	*10.0*	**-16.8**	*10.9*	**-47.2**	*23.3*	**-93.4**	*82.1*
4	INETI	Portugal	**13.7**	*32.0*	**22.9**	*40.0*	**29.1**	*52.0*	**33.9**	*68.0*	**36.4**	*102.0*
5	DANIAmet-AREPA	Denmark	**4.7**	*21.1*	**1.9**	*21.1*	**0.1**	*26.0*	**-18.1**	*41.0*	**-52.6**	*81.0*
6	NPL	United Kingdom	**-0.3**	*13.1*	**-5.1**	*13.1*	**-10.9**	*23.1*	**-27.1**	*32.0*	**-63.6**	*62.0*
7	SP	Sweden	**2.7**	*9.1*	**0.9**	*10.1*	**-2.9**	*11.1*	**-15.1**	*15.1*	**-42.6**	*23.1*
8	IEN	Italy	**-0.7**	*14.9*	**-4.9**	*15.3*	**-11.8**	*25.1*	**-30.9**	*37.2*	**-66.5**	*79.4*
9	CEM	Spain	**-6.3**	*36.0*	**-2.1**	*40.0*	**-6.9**	*44.0*	**-36.1**	*64.0*	**-62.6**	*98.0*
Travelling standard : NIST-PTB/1000V[2] (S2)												
10	PTB	Germany	**-0.5**	*8.0*	**-3.8**	*8.0*	**-7.2**	*8.0*	**-21.9**	*10.0*	**-56.6**	*30.0*
11	VSL	The Netherlands	**3.0**	*20.0*	**-3.1**	*20.0*	**-10.1**	*25.0*	**-25.2**	*35.0*	**-61.4**	*50.0*
12	OMH	Hungary	**-0.6**	*43.0*	**1.0**	*52.0*	**-20.6**	*80.0*	**-45.2**	*120.0*	**-80.2**	*200.0*
Travelling standard : NIST-PTB/1000V[3] (S3)												
13	JV	Norway	**-1.1**	*22.1*	**-2.8**	*24.1*	**-7.6**	*28.0*	**-19.5**	*42.0*	**-41.5**	*68.0*
14	UME	Turkey	**0.9**	*30.1*	**1.2**	*30.1*	**-0.6**	*40.0*	**-13.5**	*44.0*	**-41.1**	*66.0*
Travelling standard : METAS/1000V (S4)												
15	METAS	Switzerland	**-1.5**	*6.2*	**-4.0**	*7.2*	**-6.8**	*7.1*	**-21.2**	*10.1*	**-49.8**	*28.0*
16	CMI	Czech Republic	**7.5**	*50.0*	**0.4**	*50.0*	**-1.2**	*62.0*	**-28.0**	*78.0*	**-63.8**	*112.0*

Table 5a : Adjusted values ("d") and associated expanded uncertainties ("*U*") at 1000 V (in µV/V)

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			d	*U*	**d**	*U*	**d**	*U*	**d**	*U*	**d**	*U*
Travelling standard : NIST-PTB/1000V[1] (S1)												
1	BNM-LNE	France	**3.4**	*13.2*	**-2.5**	*21.1*	**-6.0**	*21.1*	**-23.6**	*36.0*	**-61.6**	*36.1*
2	BEV	Austria	**1.6**	*13.2*	**-0.3**	*15.1*	**-2.2**	*19.1*	**-13.9**	*21.1*	**-40.9**	*31.1*
3	MIKES	Finland	**0.9**	*8.3*	**-8.7**	*7.5*	**-14.0**	*8.2*	**-43.0**	*13.1*	**-91.1**	*36.0*
4	INETI	Portugal	**5.6**	*26.1*	**-11.3**	*30.0*	**-18.2**	*36.0*	**-37.9**	*46.0*	**-71.9**	*72.0*
5	DANIAmet-AREPA	Denmark	**4.6**	*21.1*	**0.7**	*21.1*	**-3.2**	*21.1*	**-19.9**	*21.1*	**-53.9**	*41.1*
6	NPL	United Kingdom	**0.6**	*13.2*	**-7.3**	*13.1*	**-12.2**	*17.1*	**-28.9**	*24.1*	**-68.9**	*46.1*
7	SP	Sweden	**3.6**	*8.3*	**0.7**	*9.1*	**-4.2**	*10.2*	**-15.9**	*14.1*	**-48.9**	*21.1*
8	IEN	Italy	**1.0**	*9.7*	**-5.0**	*9.5*	**-12.3**	*14.1*	**-33.1**	*20.3*	**-74.3**	*47.7*
9	CEM	Spain	**-0.4**	*30.1*	**-3.3**	*30.0*	**-4.2**	*30.1*	**-26.9**	*38.0*	**-55.9**	*50.0*
Travelling standard : NIST-PTB/1000V[2] (S2)												
10	PTB	Germany	**-0.5**	*8.0*	**-2.8**	*8.0*	**-7.0**	*8.0*	**-22.5**	*10.0*	**-60.5**	*22.0*
11	VSL	The Netherlands	**2.6**	*15.0*	**-4.3**	*15.0*	**-9.2**	*20.0*	**-25.7**	*25.0*	**-63.8**	*40.0*
12	OMH	Hungary	**-0.4**	*31.0*	**-5.3**	*36.0*	**-7.1**	*40.0*	**-19.0**	*63.0*	**-61.1**	*100.0*
Travelling standard : NIST-PTB/1000V[3] (S3)												
13	JV	Norway	**1.3**	*20.1*	**-1.8**	*22.1*	**-5.7**	*24.1*	**-19.1**	*34.0*	**-45.5**	*48.1*
14	UME	Turkey	**0.3**	*22.1*	**0.2**	*22.1*	**-3.7**	*26.1*	**-18.1**	*36.0*	**-49.9**	*56.1*
Travelling standard : METAS/1000V (S4)												
15	METAS	Switzerland	**0.4**	*6.3*	**-3.5**	*6.2*	**-6.9**	*6.2*	**-21.3**	*9.1*	**-56.0**	*26.1*
16	CMI	Czech Republic	**3.6**	*38.1*	**-5.1**	*38.0*	**-8.1**	*46.0*	**-38.9**	*56.0*	**-73.0**	*80.0*

Table 5b : Adjusted values ("d") and associated expanded uncertainties ("*U*") at 500 V (in µV/V)

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			d	*U*	**d**	*U*	**d**	*U*	**d**	*U*	**d**	*U*
Travelling standard : NIST-PTB/500V		**(S5)**										
15	METAS	Switzerland	**0.8**	*6.3*	**-3.6**	*6.2*	**-7.1**	*6.2*	**-21.8**	*9.1*	**-56.4**	*26.1*
16	CMI	Czech Republic	**4.1**	*38.1*	**-8.5**	*38.0*	**-9.8**	*46.0*	**-26.7**	*56.0*	**-64.4**	*80.0*

Table 5c : Adjusted values (“d”) and associated expanded uncertainties (“*U*”) at 500 V (optional) (in µV/V)

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			d	*U*	**d**	*U*	**d**	*U*	**d**	*U*	**d**	*U*
Travelling standard : NIST-PTB/1000V[1]		**(S1)**										
1	BNM-LNE	France	**-0.1**	*12.2*	**-5.8**	*13.1*	**-7.7**	*13.1*	**-28.2**	*16.2*	**-70.7**	*16.2*
2	BEV	Austria	**1.5**	*10.2*	**-0.6**	*10.2*	**-3.6**	*12.1*	**-19.1**	*16.2*	**-52.2**	*21.1*
3	MIKES	Finland	**0.6**	*7.1*	**-1.8**	*5.9*	**-4.7**	*6.6*	**-20.2**	*7.1*	**-54.5**	*8.5*
4	INETI	Portugal	**6.5**	*16.2*	**2.4**	*16.1*	**-1.6**	*18.0*	**-16.1**	*20.1*	**-49.2**	*30.1*
5	DANIAmet-AREPA	Denmark	**3.5**	*11.2*	**0.4**	*11.1*	**-4.6**	*11.1*	**-23.1**	*11.2*	**-66.2**	*26.1*
6	NPL	United Kingdom	**6.5**	*12.2*	**-7.6**	*12.1*	**-9.6**	*14.1*	**-23.1**	*16.2*	**-61.2**	*20.1*
7	SP	Sweden	**3.5**	*7.3*	**2.4**	*8.2*	**-1.6**	*9.1*	**-18.1**	*13.2*	**-49.2**	*19.2*
8	IEN	Italy	**2.2**	*8.9*	**-3.6**	*9.0*	**-11.0**	*12.9*	**-31.8**	*18.3*	**-71.5**	*42.5*
9	CEM	Spain	**3.5**	*22.1*	**3.4**	*22.1*	**-0.6**	*22.0*	**-19.1**	*24.1*	**-54.2**	*28.9*
Travelling standard : NIST-PTB/1000V[2]		**(S2)**										
10	PTB	Germany	**-0.5**	*8.0*	**-3.3**	*8.0*	**-7.3**	*8.0*	**-22.7**	*10.0*	**-61.9**	*22.0*
11	VSL	The Netherlands										
12	OMH	Hungary										
Travelling standard : NIST-PTB/1000V[3]		**(S3)**										
13	JV	Norway	**0.6**	*18.5*	**-1.5**	*18.5*	**-5.1**	*20.0*	**-19.3**	*26.1*	**-48.6**	*36.1*
14	UME	Turkey	**0.3**	*18.1*	**-2.2**	*18.1*	**-8.1**	*24.0*	**-21.3**	*30.1*	**-59.3**	*44.1*
Travelling standard : NIST-PTB/500V		**(S5)**										
15	METAS	Switzerland	**-1.5**	*6.3*	**-4.4**	*6.2*	**-7.5**	*6.1*	**-22.8**	*9.2*	**-60.3**	*24.1*
16	CMI	Czech Republic	**-1.1**	*24.1*	**-10.2**	*24.1*	**-10.3**	*28.0*	**-26.7**	*36.1*	**-63.3**	*60.0*

Table 5d : Adjusted values (“d”) and associated expanded uncertainties (“*U*”) at 200 V (in µV/V)

Final results

Final results (degree of equivalence between each laboratory and the reference value) are expressed as the deviation of the adjusted values (see tables 5a to 5d) from the reference value.

For laboratories contributing to the reference valence and for laboratories strongly correlated to one of them like AREPA (directly linked to PTB), the final uncertainty u_{fin} (uncertainty of the degree of equivalence with the reference value) was computed from $u_{fin} = \sqrt{u_{adj}^2 - u_{ref}^2}$, u_{adj} being the uncertainty of the adjusted value and u_{ref} the uncertainty of the reference value. This relation, has been established in appendix C of the guidelines for the evaluation of key comparison data (WGKC/2002-27 document published by he CCEM.

For the other laboratories (BEV, MIKES, INETI, OMH, JV, UME and CMI) the final uncertainty was computed from $u_{fin} = \sqrt{u_{adj}^2 + u_{ref}^2}$

Tables 6a to 6d present the final results (column “d”) with the associated expanded uncertainties (column “*U*”). Graphs 1 to 15 show the same results in a graphical form.

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			D	*U*	D	*U*	D	*U*	D	*U*	D	*U*
Travelling standard : NIST-PTB/1000V[1] (S1)												
1	BNM-LNE	France	**5.8**	*15.8*	**1.3**	*34.8*	**-2.8**	*34.8*	**-11.8**	*68.8*	**-20.5**	*68.3*
2	BEV	Austria	**0.5**	*18.4*	**3.2**	*20.4*	**5.3**	*24.4*				
3	MIKES	Finland	**-0.1**	*10.6*	**-6.8**	*10.6*	**-11.6**	*11.5*	**-27.3**	*23.8*	**-40.3**	*82.7*
4	INETI	Portugal	**13.5**	*32.1*	**25.2**	*40.1*	**34.3**	*52.1*	**53.8**	*68.2*	**89.5**	*102.5*
5	DANIAmet-AREPA	Denmark	**4.5**	*20.9*	**4.2**	*20.8*	**5.3**	*25.7*	**1.8**	*40.7*	**0.5**	*80.4*
6	NPL	United Kingdom	**-0.5**	*12.7*	**-2.8**	*12.7*	**-5.7**	*22.8*	**-7.2**	*31.6*	**-10.5**	*61.2*
7	SP	Sweden	**2.5**	*8.6*	**3.2**	*9.5*	**2.3**	*10.5*	**4.8**	*14.2*	**10.5**	*20.8*
8	IEN	Italy	**-0.9**	*14.6*	**-2.6**	*14.9*	**-6.6**	*24.8*	**-11.0**	*36.9*	**-13.4**	*78.8*
9	CEM	Spain	**-6.5**	*35.9*	**0.2**	*39.9*	**-1.7**	*43.8*	**-16.2**	*63.8*	**-9.5**	*97.5*
Travelling standard : NIST-PTB/1000V[2] (S2)												
10	PTB	Germany	**-0.7**	*7.4*	**-1.5**	*7.2*	**-2.0**	*7.1*	**-2.0**	*8.7*	**-3.5**	*28.3*
11	VSL	The Netherlands	**2.8**	*19.8*	**-0.8**	*19.7*	**-4.9**	*24.7*	**-5.3**	*34.6*	**-8.3**	*49.0*
12	OMH	Hungary	**-0.8**	*43.1*	**3.3**	*52.1*	**-15.4**	*80.1*	**-25.3**	*120.1*	**-27.1**	*200.2*
Travelling standard : NIST-PTB/1000V[3] (S3)												
13	JV	Norway	**-1.3**	*22.3*	**-0.5**	*24.3*	**-2.4**	*28.2*	**0.4**	*42.3*	**11.6**	*68.7*
14	UME	Turkey	**0.7**	*30.3*	**3.5**	*30.3*	**4.6**	*40.2*	**6.4**	*44.3*	**12.0**	*66.8*
Travelling standard : METAS/1000V (S4)												
15	METAS	Switzerland	**-1.7**	*5.4*	**-1.7**	*6.3*	**-1.6**	*6.1*	**-1.3**	*8.8*	**3.3**	*26.2*
16	CMI	Czech Republic	**7.3**	*50.1*	**2.7**	*50.1*	**4.0**	*62.1*	**-8.1**	*78.2*	**-10.7**	*112.4*

Table 6a : Degree of equivalence with KCRV ("D") and associated expanded uncertainties ("*U*") at 1000 V

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			D	*U*	D	*U*	D	*U*	D	*U*	D	*U*
Travelling standard : NIST-PTB/1000V[1] (S1)												
1	BNM-LNE	France	**1.6**	*12.9*	**-0.3**	*20.9*	**-0.2**	*20.9*	**-2.7**	*35.8*	**-1.7**	*35.3*
2	BEV	Austria	**-0.2**	*13.5*	**1.9**	*15.4*	**3.6**	*19.4*	**7.0**	*21.5*	**19.0**	*32.0*
3	MIKES	Finland	**-0.9**	*8.8*	**-6.5**	*8.0*	**-8.2**	*8.8*	**-22.1**	*13.8*	**-31.2**	*36.8*
4	INETI	Portugal	**3.8**	*26.2*	**-9.1**	*30.1*	**-12.4**	*36.1*	**-17.0**	*46.2*	**-12.0**	*72.4*
5	DANIAmet-AREPA	Denmark	**2.8**	*20.9*	**2.9**	*20.9*	**2.6**	*20.9*	**1.0**	*20.7*	**6.0**	*40.4*
6	NPL	United Kingdom	**-1.2**	*12.9*	**-5.1**	*12.8*	**-6.4**	*16.8*	**-8.0**	*23.7*	**-9.0**	*45.5*
7	SP	Sweden	**1.8**	*7.8*	**2.9**	*8.7*	**1.6**	*9.7*	**5.0**	*13.5*	**11.0**	*19.7*
8	IEN	Italy	**-0.8**	*9.3*	**-2.8**	*9.1*	**-6.5**	*13.7*	**-12.2**	*19.9*	**-14.4**	*47.1*
9	CEM	Spain	**-2.2**	*30.0*	**-1.1**	*29.9*	**1.6**	*29.9*	**-6.0**	*37.8*	**4.0**	*49.4*
Travelling standard : NIST-PTB/1000V[2] (S2)												
10	PTB	Germany	**-2.3**	*7.5*	**-0.6**	*7.5*	**-1.2**	*7.3*	**-1.6**	*9.1*	**-0.6**	*20.6*
11	VSL	The Netherlands	**0.8**	*14.7*	**-2.1**	*14.7*	**-3.4**	*19.7*	**-4.8**	*24.6*	**-3.9**	*39.3*
12	OMH	Hungary	**-2.2**	*31.1*	**-3.1**	*36.1*	**-1.3**	*40.1*	**1.9**	*63.1*	**-1.2**	*100.3*
Travelling standard : NIST-PTB/1000V[3] (S3)												
13	JV	Norway	**-0.5**	*20.3*	**0.4**	*22.3*	**0.1**	*24.3*	**1.8**	*34.3*	**14.4**	*48.7*
14	UME	Turkey	**-1.5**	*22.3*	**2.4**	*22.3*	**2.1**	*26.3*	**2.8**	*36.2*	**10.0**	*56.6*
Travelling standard : METAS/1000V (S4)												
15	METAS	Switzerland	**-1.4**	*5.6*	**-1.3**	*5.5*	**-1.1**	*5.3*	**-0.4**	*8.1*	**3.9**	*25.0*
16	CMI	Czech Republic	**1.8**	*38.2*	**-2.9**	*38.1*	**-2.3**	*46.1*	**-18.0**	*56.2*	**-13.1**	*80.4*

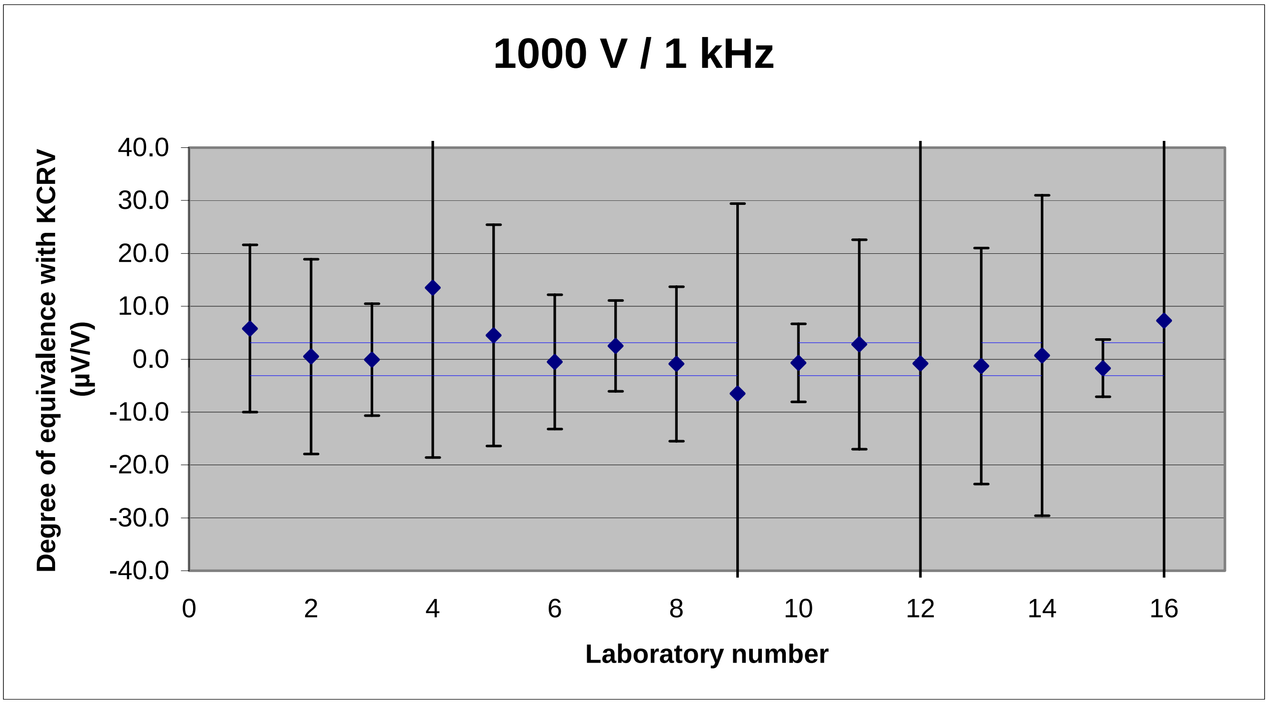
Table 6b : Degree of equivalence with KCRV ("D") and associated expanded uncertainties ("*U*") at 500 V (in µV/V)

	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			D	*U*	D	*U*	D	*U*	D	*U*	D	*U*
Travelling standard : NIST-PTB/500V (S5)												
15	METAS	Switzerland	**-1.0**	*5.6*	**-1.4**	*5.5*	**-1.3**	*5.3*	**-0.9**	*8.1*	**3.5**	*25.0*
16	CMI	Czech Republic	**2.3**	*38.2*	**-6.3**	*38.1*	**-4.0**	*46.1*	**-5.8**	*56.2*	**-4.5**	*80.4*

Table 6c : Degree of equivalence with KCRV ("D") and associated expanded uncertainties ("*U*") at 500 V (optional) (in µV/V)

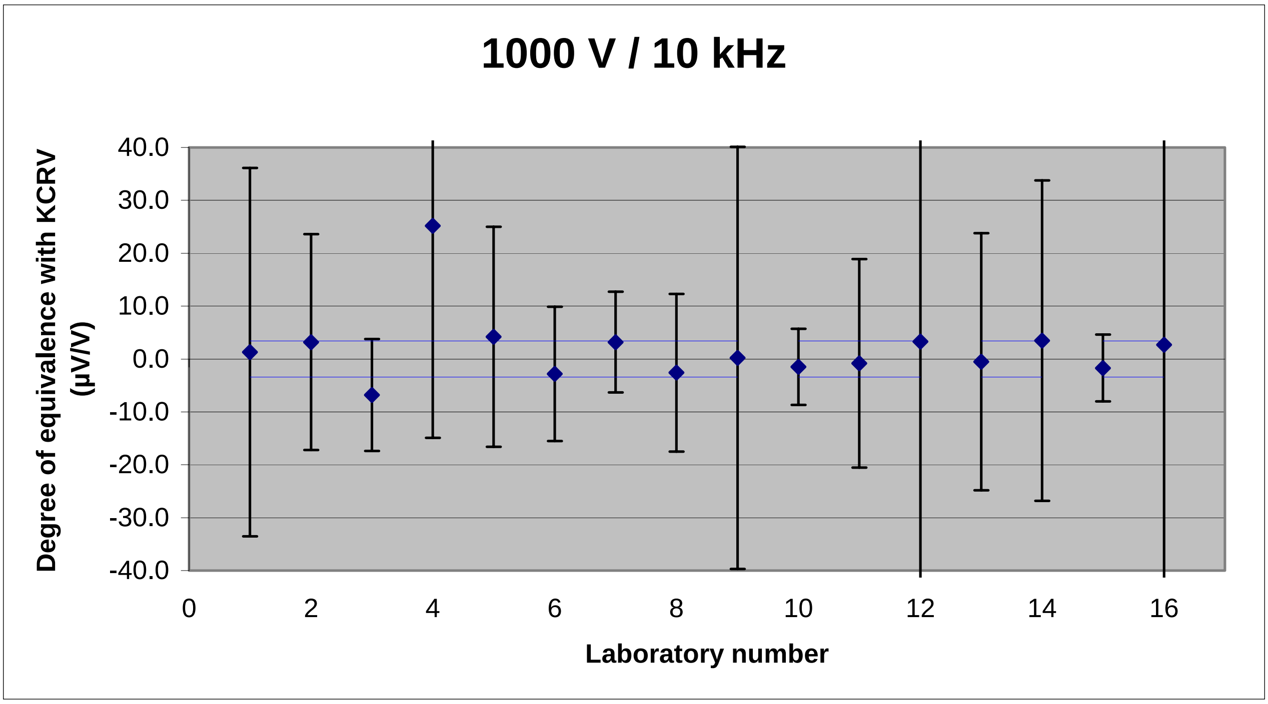
	LABORATORY	COUNTRY	1 kHz		10 kHz		20 kHz		50 kHz		100 kHz	
			D	*U*	D	*U*	D	*U*	D	*U*	D	*U*
Travelling standard : NIST-PTB/1000V[1] (S1)												
1	BNM-LNE	France	**-1.5**	*12.0*	**-3.3**	*12.9*	**-1.8**	*12.8*	**-6.3**	*15.8*	**-10.3**	*15.3*
2	BEV	Austria	**0.1**	*10.5*	**1.9**	*10.5*	**2.3**	*12.4*	**2.8**	*16.6*	**8.2**	*21.8*
3	MIKES	Finland	**-0.8**	*7.5*	**0.7**	*6.4*	**1.2**	*7.1*	**1.7**	*7.9*	**5.9**	*10.0*
4	INETI	Portugal	**5.1**	*16.4*	**4.9**	*16.3*	**4.3**	*18.2*	**5.8**	*20.4*	**11.2**	*30.6*
5	DANIAmet-AREPA	Denmark	**2.1**	*10.9*	**2.9**	*10.8*	**1.3**	*10.8*	**-1.2**	*10.6*	**-5.8**	*25.6*
6	NPL	United Kingdom	**5.1**	*12.0*	**-5.1**	*11.8*	**-3.7**	*13.9*	**-1.2**	*15.8*	**-0.8**	*19.4*
7	SP	Sweden	**2.1**	*6.9*	**4.9**	*7.8*	**4.3**	*8.7*	**3.8**	*12.7*	**11.2**	*18.5*
8	IEN	Italy	**0.8**	*8.6*	**-1.1**	*8.6*	**-5.1**	*12.6*	**-9.9**	*18.0*	**-11.1**	*42.2*
9	CEM	Spain	**2.1**	*22.0*	**5.9**	*22.0*	**5.3**	*21.8*	**2.8**	*23.8*	**6.2**	*28.4*
Travelling standard : NIST-PTB/1000V[2] (S2)												
10	PTB	Germany	**-1.9**	*7.6*	**-0.8**	*7.6*	**-1.4**	*7.6*	**-0.8**	*9.4*	**-1.5**	*21.4*
11	VSL	The Netherlands										
12	OMH	Hungary										
Travelling standard : NIST-PTB/1000V[3] (S3)												
13	JV	Norway	**-0.8**	*18.7*	**1.0**	*18.7*	**0.8**	*20.2*	**2.6**	*26.3*	**11.8**	*36.5*
14	UME	Turkey	**-1.1**	*18.3*	**0.3**	*18.3*	**-2.2**	*24.1*	**0.6**	*30.3*	**1.1**	*44.4*
Travelling standard : NIST-PTB/500V (S5)												
15	METAS	Switzerland	**-2.9**	*5.8*	**-1.9**	*5.7*	**-1.6**	*5.5*	**-0.9**	*8.5*	**0.1**	*23.5*
16	CMI	Czech Republic	**-2.5**	*24.2*	**-7.7**	*24.2*	**-4.4**	*28.1*	**-4.8**	*36.3*	**-2.9**	*60.2*

Table 6d : Degree of equivalence with KCRV (“D”) and associated expanded uncertainties (“*U*”) at 200 V (in µV/V)



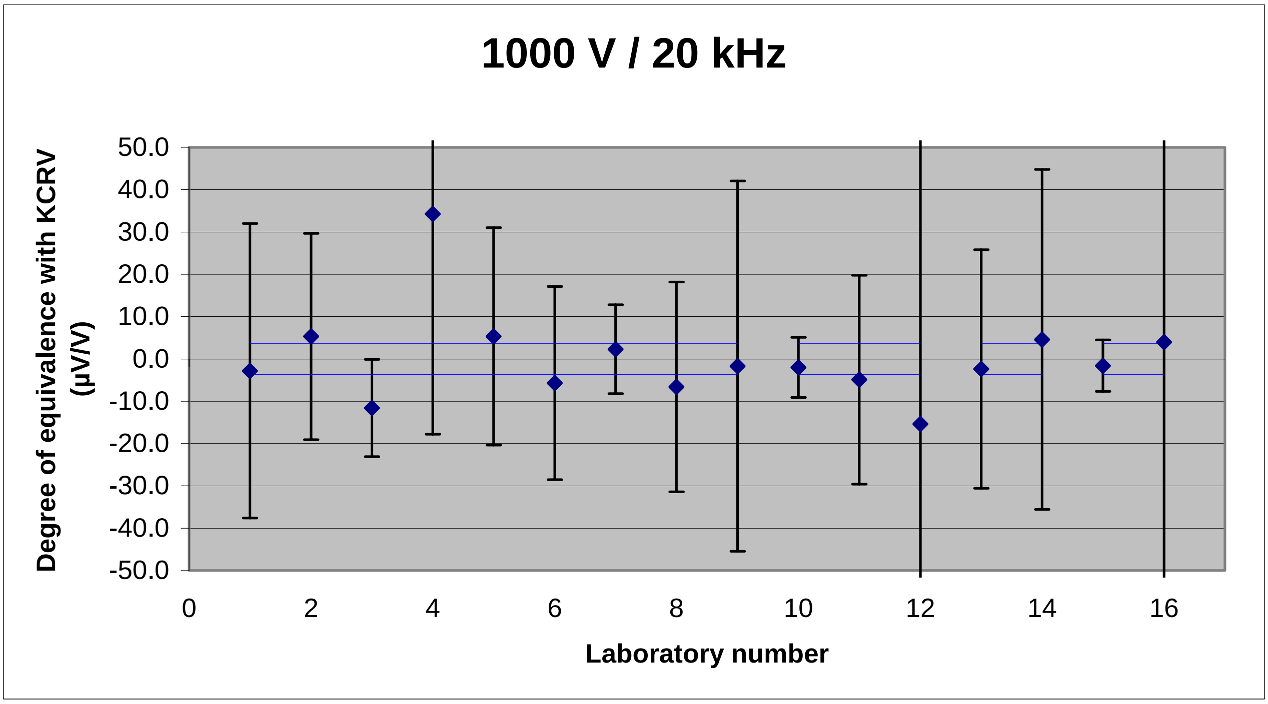
Graph 1 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 1000 V / 1 kHz

At 1000 V / 1 kHz, all given expanded uncertainties overlap the reference value. Results of 5 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 5 µV/V for most of the participants (12/16).



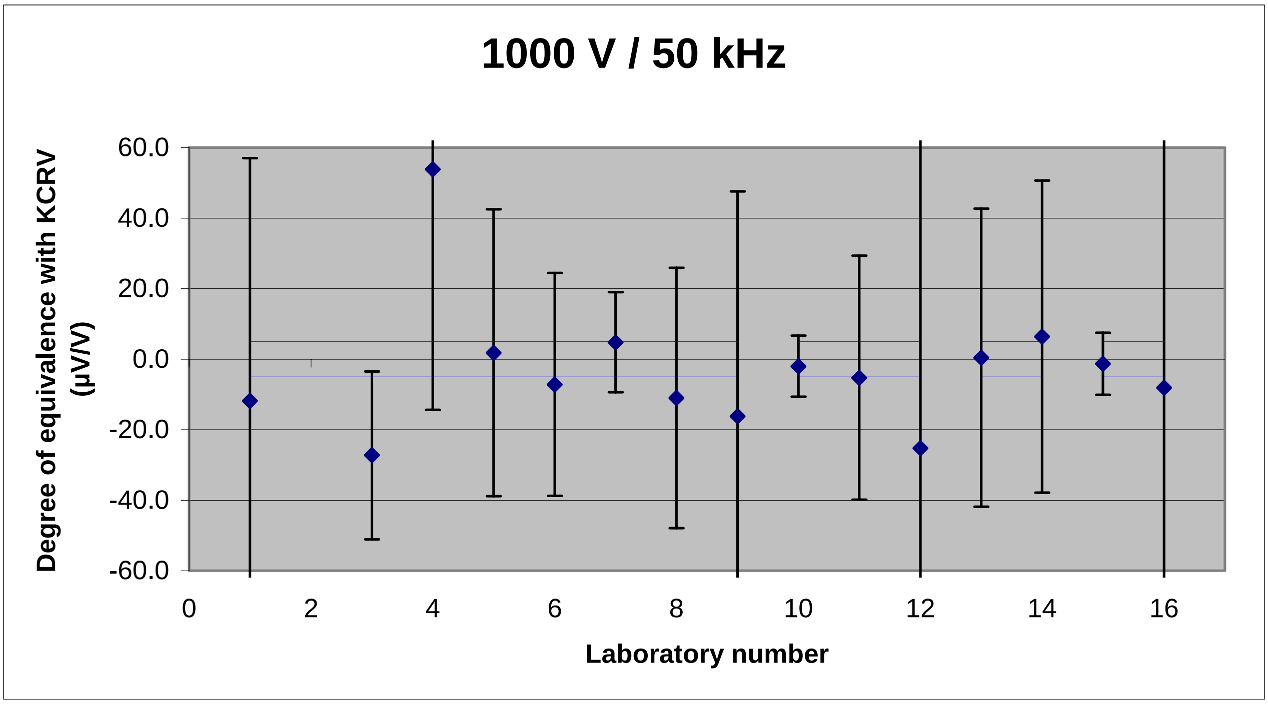
Graph 2 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 1000 V / 10 kHz

At 1000 V / 10 kHz, all given expanded uncertainties overlap the reference value. Results of 4 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 5 µV/V for most of the participants (14/16).



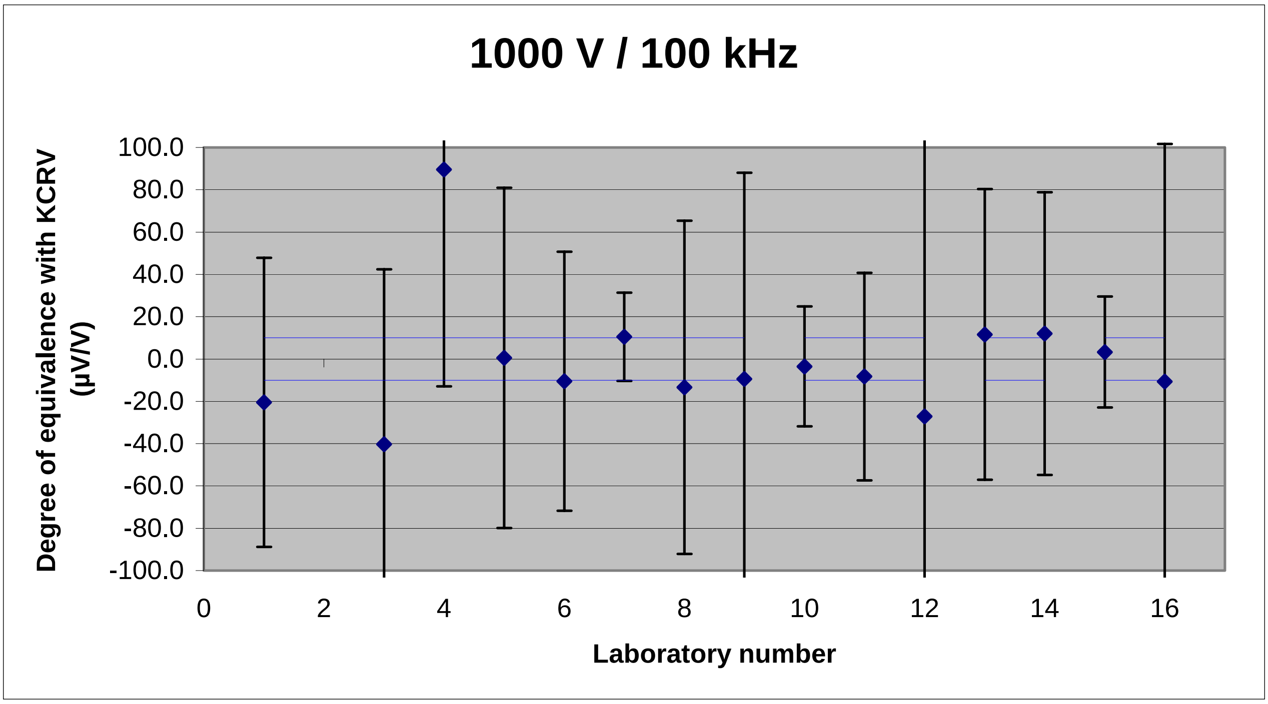
Graph 3 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 1000 V / 20 kHz

At 1000 V / 20 kHz, all given expanded uncertainties except one overlap the reference value. Results of 10 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 7 µV/V for most of the participants (13/16).



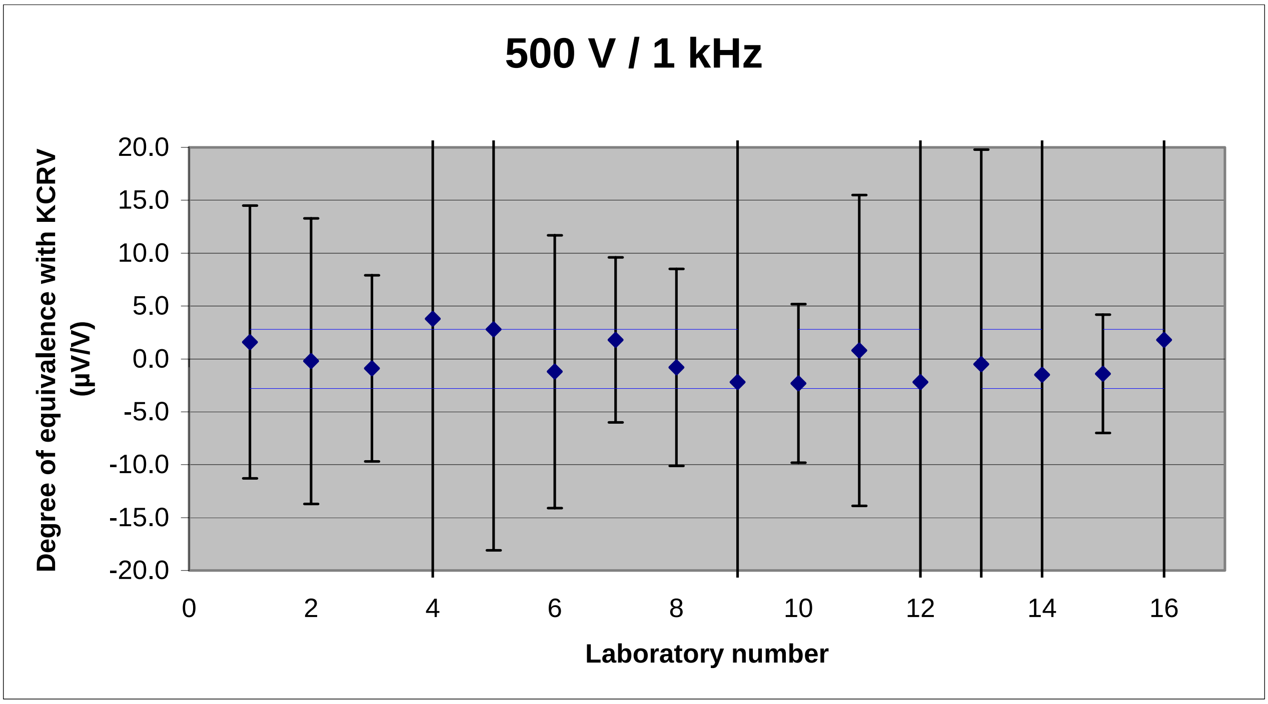
Graph 4 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 1000 V / 50 kHz

At 1000 V / 50 kHz, all given expanded uncertainties except one overlap the reference value. Results of 10 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 15 µV/V for most of the participants (11/15).



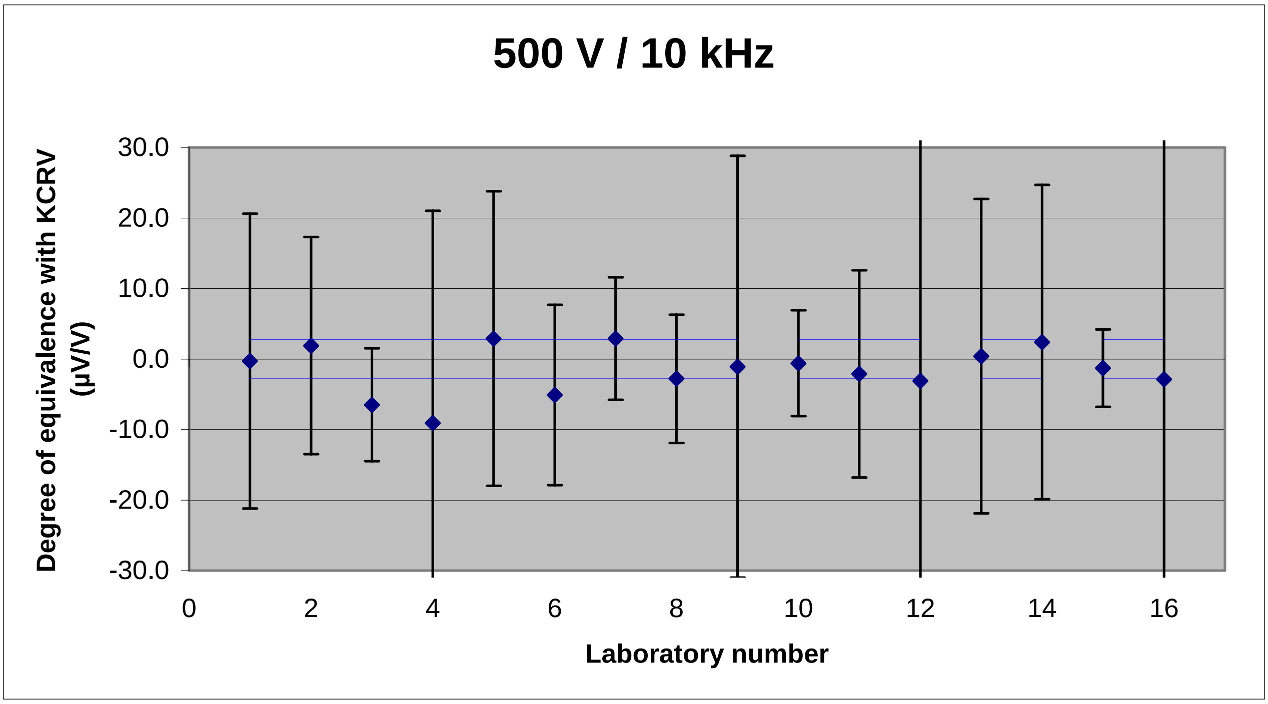
Graph 5 : Degree of equivalence with KCRV and corresponding associated expanded uncertainty at 1000 V / 100 kHz

At 1000 V / 100 kHz, all given expanded uncertainties overlap the reference value. Results of 10 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 15 µV/V for most of the participants (11/15).



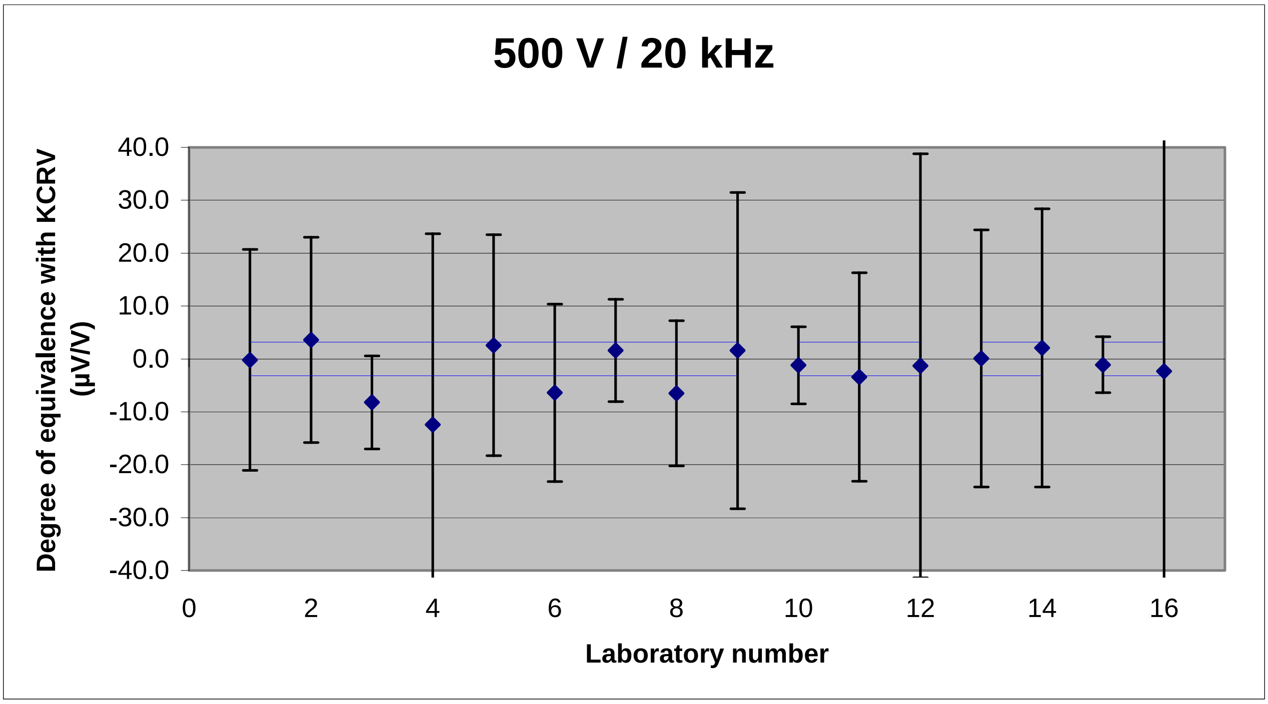
Graph 6 : Degree of equivalence with KCRV and corresponding associated expanded uncertainty at 500 V / 1 kHz

At 500 V / 1 kHz, all given expanded uncertainties overlap the reference value. Result of only 1 participant deviates from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 4 µV/V for all the participants.



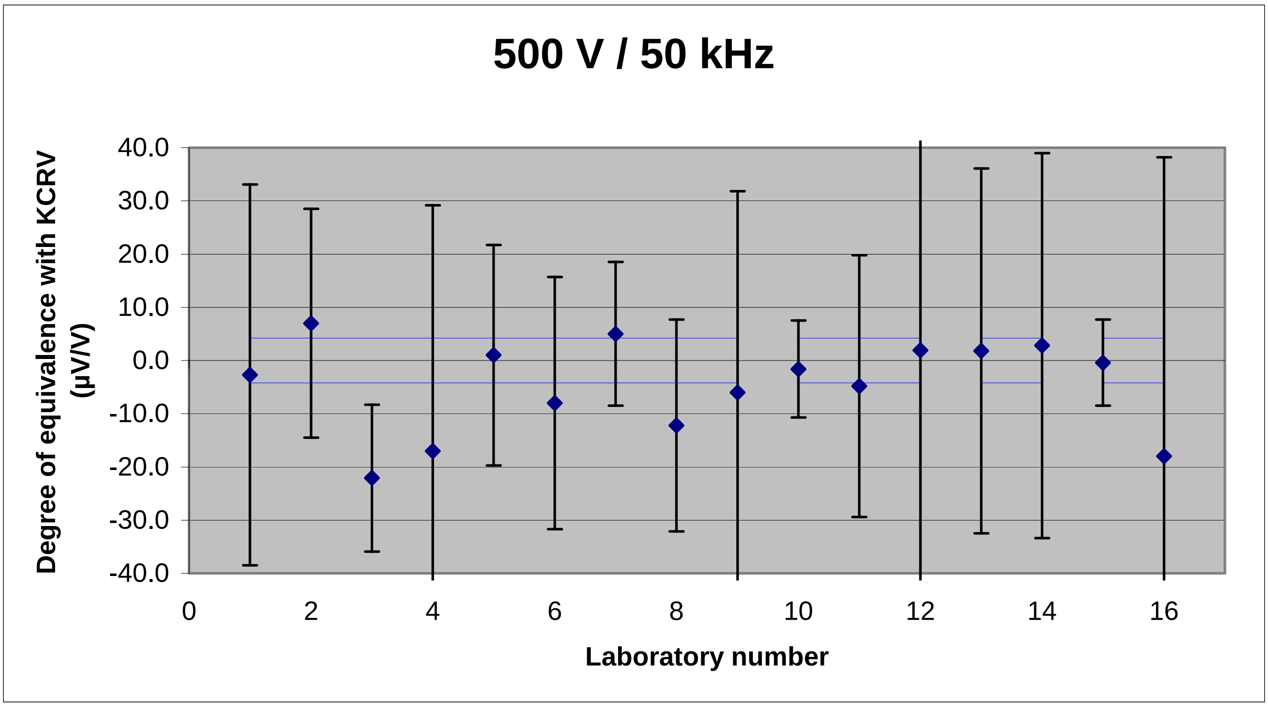
Graph 7 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 500 V / 10 kHz

At 500 V / 10 kHz, all given expanded uncertainties overlap the reference value. Results of 7 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 5 µV/V for most of the participants (13/16).



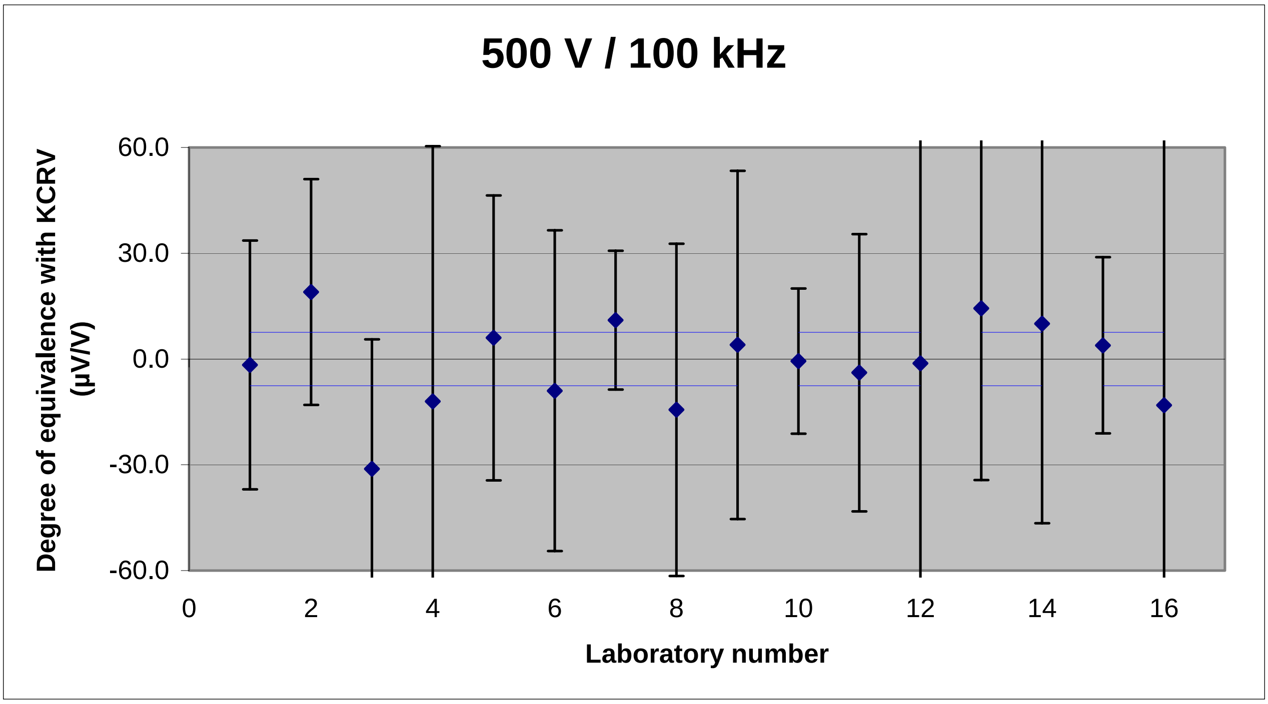
Graph 8 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 500 V / 20 kHz

At 500 V / 20 kHz, all given expanded uncertainties except one overlap the reference value. Results of 6 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 5 µV/V for most of the participants (12/16).



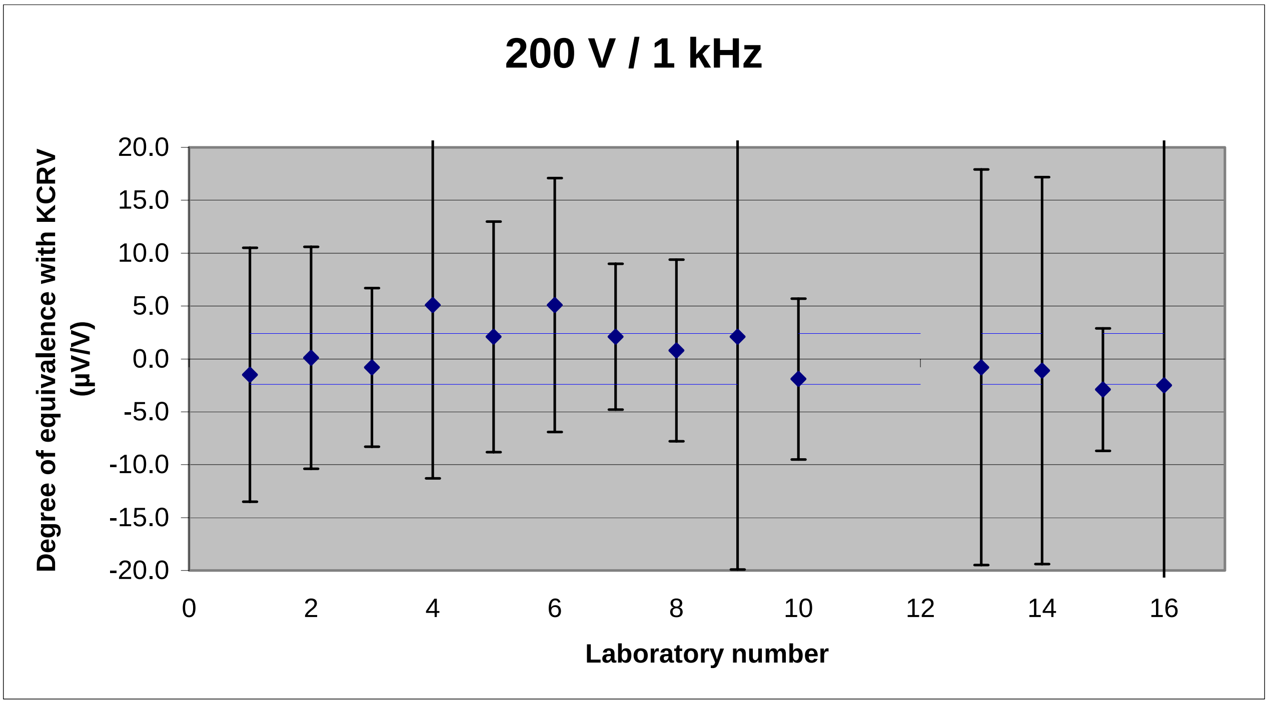
Graph 9 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 500 V / 50 kHz

At 500 V / 50 kHz, all given expanded uncertainties except one overlap the reference value. Results of 9 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 10 µV/V for most of the participants (12/16).



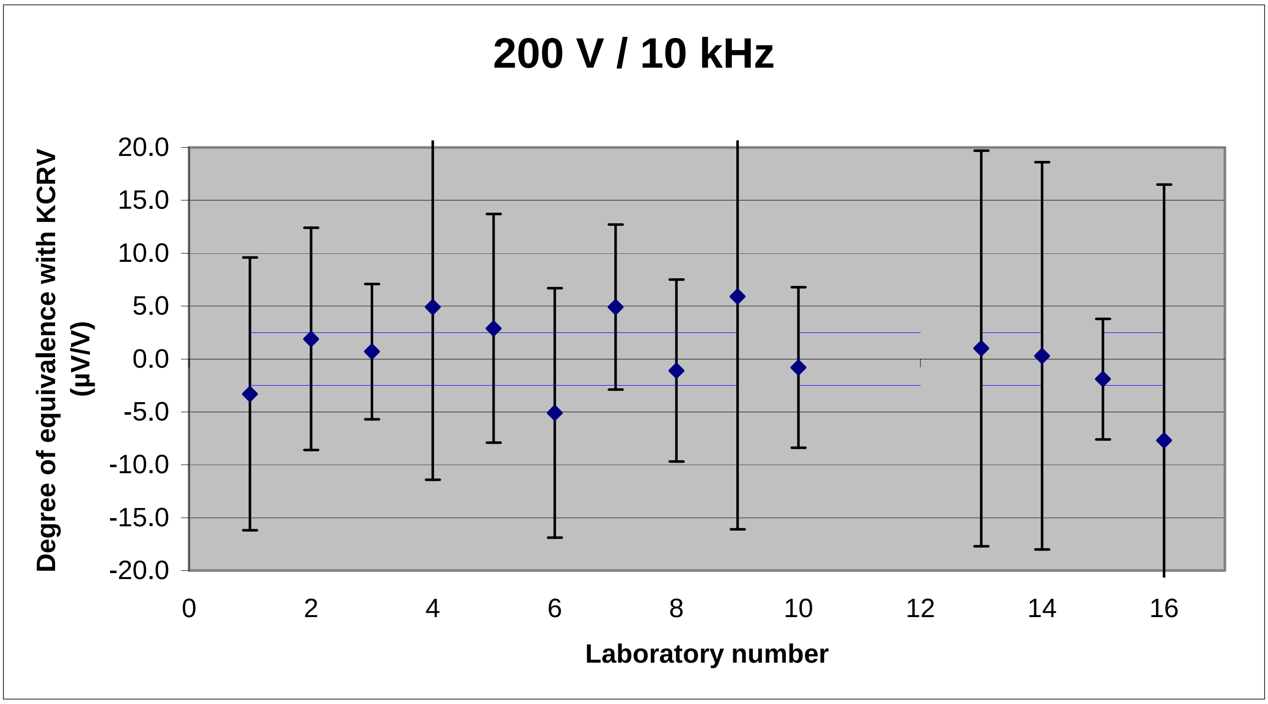
Graph 10 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 500 V / 100 kHz

At 500 V / 100 kHz, all given expanded uncertainties overlap the reference value. Results of 9 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 15 µV/V for most of the participants (14/16).



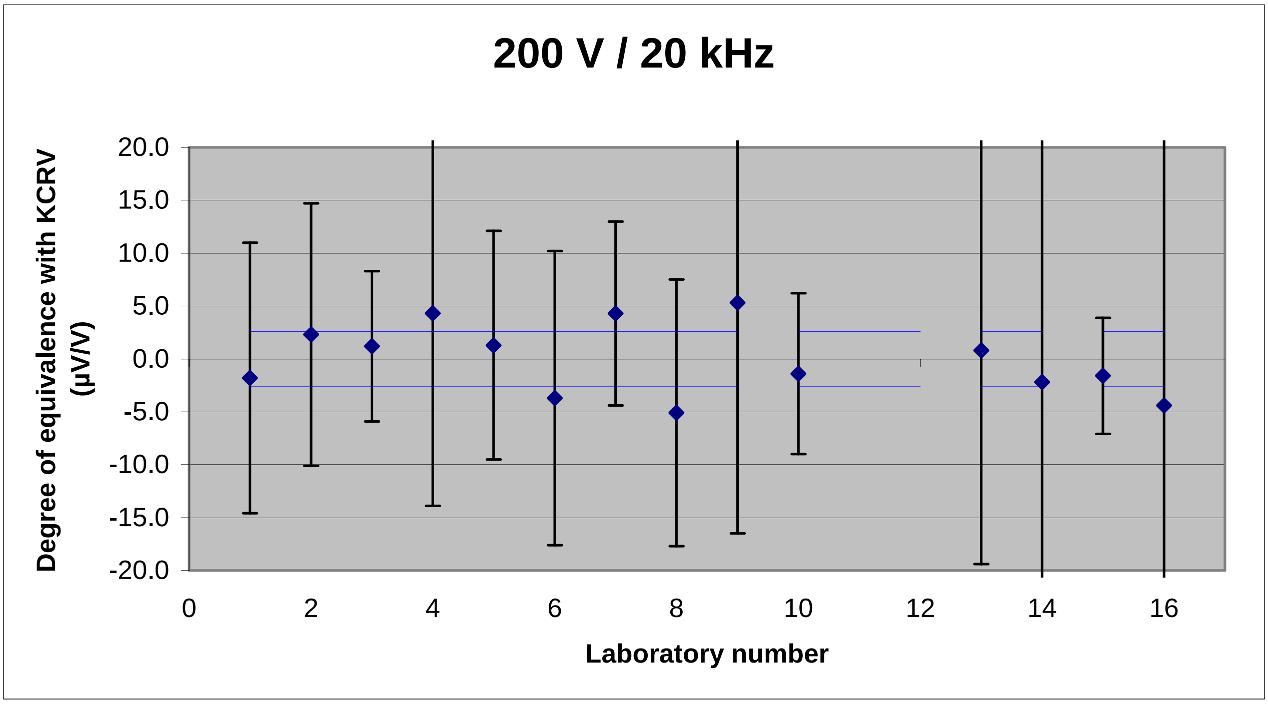
Graph 11 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 200 V / 1 kHz

At 200 V / 1 kHz, all given expanded uncertainties overlap the reference value. Results of 4 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 5 µV/V for most of the participants (12/14).



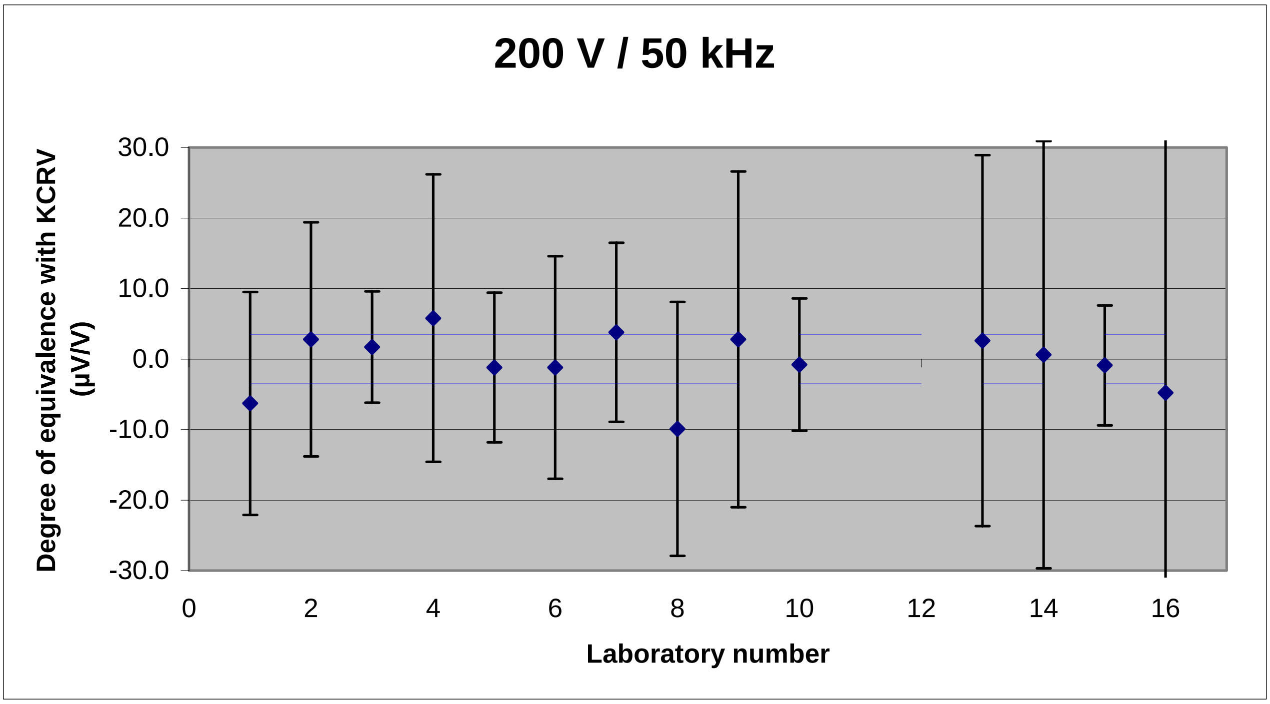
Graph 12 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 200 V / 10 kHz

At 200 V / 10 kHz, all given expanded uncertainties overlap the reference value. Results of 7 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 5 µV/V for most of the participants (11/14).



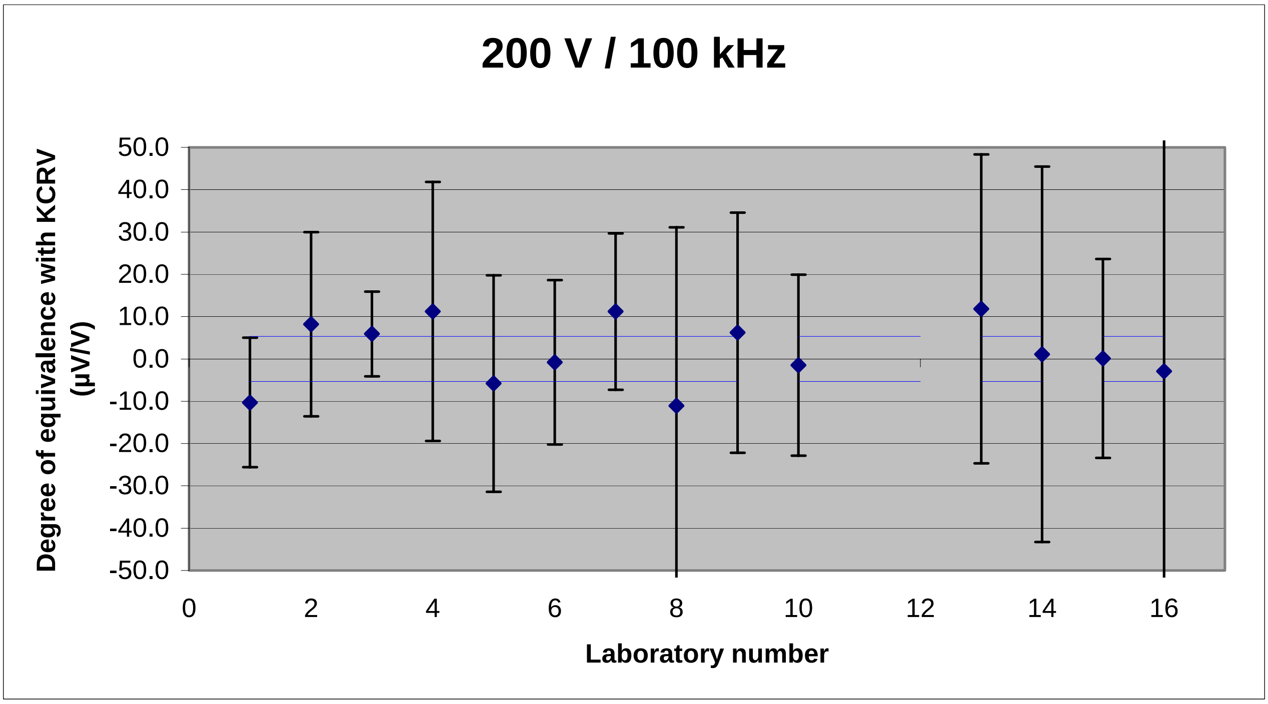
Graph 13 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 200 V / 20 kHz

At 200 V / 20 kHz, all given expanded uncertainties overlap the reference value. Results of 6 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 5 µV/V for most of the participants (12/14).



Graph 14 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 200 V / 50 kHz

At 200 V / 50 kHz, all given expanded uncertainties overlap the reference value. Results of 5 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 5 µV/V for most of the participants (11/14).



Graph 15 : Degree of equivalence with KCRV and corresponding expanded uncertainty at 200 V / 100 kHz

At 200 V / 100 kHz, all given expanded uncertainties overlap the reference value. Results of 9 participants deviate from the KCRV by more than the reference uncertainty. The agreement with the reference value is better than 10 µV/V for most of the participants (9/14).

9) Conclusion

In December 2002, key comparison EUROMET 557 of AC-DC voltage transfer standards at voltage levels of 200 V, 500 V and 1000 V was completed. Travelling standards were supplied by PTB, NIST and METAS. The NIST-PTB standards were based on PTB planar MJTCs associated with high voltage range resistors for FLUKE 792 A. One standard, based on a single junction thermal converter, was developed and supplied by METAS.

The results show agreement with the reference value of most of participating NMIs within their given expanded uncertainties. This agreement is in the order of 5 µV/V at 1 kHz for all voltages and in the order of 15 µV/V at 1000 V / 100 kHz. Works performed in recent years at a number of NMIs in the high voltage AC-DC transfer area certainly greatly contributed to these good results.

Tables of the degree of equivalence of all participants are given in appendix 1.

10) Acknowledgment

Colleagues participating in this comparison to show their best measurement capabilities and to adhere to the time schedule are gratefully acknowledged. NIST, PTB and METAS are also acknowledged for having supplied the travelling standards. Particular acknowledgment is addressed to Manfred KLONZ, Marc FLUELI, Karl Erik RYDLER and Peter FILIPSKI for the help they provided to the pilot laboratory in the organization of this comparison and the analysis of the results.

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APPENDIX 1

Degree of equivalence between pairs of laboratories

In the MRA, the estimation of the degree of equivalence will be used to express the relationship between each pair of participating laboratories.

The degree of equivalence between any pair of mutually independent laboratories *i* and *j* is given by:

$$D_{i,j} = d_i - d_j \quad \text{and} \quad U(D_{i,j}) = \sqrt{U^2(d_i) + U^2(d_j)}$$

where :

- d_i and d_j are the adjusted values for laboratories *i* and *j*;
- $U(d_i)$ and $U(d_j)$ the expanded uncertainties of these values.

In case of two mutually dependent laboratories (DANIAmet-AREPA and PTB) it is given by :

$$D_{i,j} = d_i - d_j \quad \text{and} \quad U(D_{i,j}) = \sqrt{\left|U^2(d_i) - U^2(d_j)\right|}$$

Tables 1a to 3t give the degrees of equivalence between all the pairs of participating laboratories.

Voltage : 1000 V Frequency : 1 kHz (1/4)			BNM-LNE		BEV		MIKES		INETI	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			6.0	*16.1*	0.7	*18.1*	0.1	*10.1*	13.7	*32.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	6.0	*16.1*			**5.3**	***24.3***	**5.9**	***19.1***	**-7.7**	***35.9***
BEV	0.7	*18.1*	**-5.3**	***24.3***			**0.6**	***20.8***	**-13.0**	***36.8***
MIKES	0.1	*10.1*	**-5.9**	***19.1***	**-0.6**	***20.8***			**-13.6**	***33.6***
INETI	13.7	*32.0*	**7.7**	***35.9***	**13.0**	***36.8***	**13.6**	***33.6***		
DANIAmet-AREPA	4.7	*21.1*	**-1.3**	***26.6***	**4.0**	***27.8***	**4.6**	***23.4***	**-9.0**	***38.4***
NPL	-0.3	*13.1*	**-6.3**	***20.8***	**-1.0**	***22.4***	**-0.4**	***16.6***	**-14.0**	***34.6***
SP	2.7	*9.1*	**-3.3**	***18.5***	**2.0**	***20.3***	**2.6**	***13.6***	**-11.0**	***33.3***
IEN	-0.7	*14.9*	**-6.7**	***22.0***	**-1.4**	***23.5***	**-0.8**	***18.1***	**-14.4**	***35.3***
CEM	-6.3	*36.0*	**-12.3**	***39.5***	**-7.0**	***40.3***	**-6.4**	***37.4***	**-20.0**	***48.2***
PTB	-0.5	*8.0*	**-6.5**	***18.0***	**-1.2**	***19.8***	**-0.6**	***12.9***	**-14.2**	***33.0***
VSL	3.0	*20.0*	**-3.0**	***25.7***	**2.3**	***27.0***	**2.9**	***22.5***	**-10.7**	***37.8***
OMH	-0.6	*43.0*	**-6.6**	***46.0***	**-1.3**	***46.7***	**-0.7**	***44.2***	**-14.3**	***53.7***
JV	-1.1	*22.1*	**-7.1**	***27.4***	**-1.8**	***28.6***	**-1.2**	***24.3***	**-14.8**	***38.9***
UME	0.9	*30.1*	**-5.1**	***34.2***	**0.2**	***35.2***	**0.8**	***31.8***	**-12.8**	***44.0***
METAS	-1.5	*6.2*	**-7.5**	***17.3***	**-2.2**	***19.2***	**-1.6**	***11.9***	**-15.2**	***32.6***
CMI	7.5	*50.0*	**1.5**	***52.6***	**6.8**	***53.2***	**7.4**	***51.1***	**-6.2**	***59.4***

Table 1a : Degree of equivalence at 1000 V / 1 kHz (1/4)

Voltage : 1000 V Frequency : 1 kHz (2/4)			DANIAmet-AREPA		NPL		SP		IEN	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			4.7	*21.1*	-0.3	*13.1*	2.7	*9.1*	-0.7	*14.9*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	6.0	*16.1*	**1.3**	***26.6***	**6.3**	***20.8***	**3.3**	***18.5***	**6.7**	***22.0***
BEV	0.7	*18.1*	**-4.0**	***27.8***	**1.0**	***22.4***	**-2.0**	***20.3***	**1.4**	***23.5***
MIKES	0.1	*10.1*	**-4.6**	***23.4***	**0.4**	***16.6***	**-2.6**	***13.6***	**0.8**	***18.1***
INETI	13.7	*32.0*	**9.0**	***38.4***	**14.0**	***34.6***	**11.0**	***33.3***	**14.4**	***35.3***
DANIAmet-AREPA	4.7	*21.1*			**5.0**	***24.9***	**2.0**	***23.0***	**5.4**	***25.9***
NPL	-0.3	*13.1*	**-5.0**	***24.9***			**-3.0**	***16.0***	**0.4**	***19.9***
SP	2.7	*9.1*	**-2.0**	***23.0***	**3.0**	***16.0***			**3.4**	***17.5***
IEN	-0.7	*14.9*	**-5.4**	***25.9***	**-0.4**	***19.9***	**-3.4**	***17.5***		
CEM	-6.3	*36.0*	**-11.0**	***41.8***	**-6.0**	***38.4***	**-9.0**	***37.2***	**-5.6**	***39.0***
PTB	-0.5	*8.0*	**-5.2**	***19.6***	**-0.2**	***15.4***	**-3.2**	***12.2***	**0.2**	***17.0***
VSL	3.0	*20.0*	**-1.7**	***29.1***	**3.3**	***24.0***	**0.3**	***22.0***	**3.7**	***25.0***
OMH	-0.6	*43.0*	**-5.3**	***47.9***	**-0.3**	***45.0***	**-3.3**	***44.0***	**0.1**	***45.6***
JV	-1.1	*22.1*	**-5.8**	***30.6***	**-0.8**	***25.7***	**-3.8**	***24.0***	**-0.4**	***26.7***
UME	0.9	*30.1*	**-3.8**	***36.8***	**1.2**	***32.9***	**-1.8**	***31.5***	**1.6**	***33.6***
METAS	-1.5	*6.2*	**-6.2**	***22.0***	**-1.2**	***14.5***	**-4.2**	***11.1***	**-0.8**	***16.2***
CMI	7.5	*50.0*	**2.8**	***54.3***	**7.8**	***51.7***	**4.8**	***50.9***	**8.2**	***52.2***

Table 1b : Degree of equivalence at 1000 V / 1 kHz (2/4)

Voltage : 1000 V Frequency : 1 kHz (3/4)			CEM		PTB		VSL		OMH	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-6.3	*36.0*	-0.5	*8.0*	3.0	*20.0*	-0.6	*43.0*
	$d_{adj\,i}$	$u(d_{adj\,i})$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
BNM-LNE	6.0	*16.1*	**12.3**	***39.5***	**6.5**	***18.0***	**3.0**	***25.7***	**6.6**	***46.0***
BEV	0.7	*18.1*	**7.0**	***40.3***	**1.2**	***19.8***	**-2.3**	***27.0***	**1.3**	***46.7***
MIKES	0.1	*10.1*	**6.4**	***37.4***	**0.6**	***12.9***	**-2.9**	***22.5***	**0.7**	***44.2***
INETI	13.7	*32.0*	**20.0**	***48.2***	**14.2**	***33.0***	**10.7**	***37.8***	**14.3**	***53.7***
DANIAmet-AREPA	4.7	*21.1*	**11.0**	***41.8***	**5.2**	***19.6***	**1.7**	***29.1***	**5.3**	***47.9***
NPL	-0.3	*13.1*	**6.0**	***38.4***	**0.2**	***15.4***	**-3.3**	***24.0***	**0.3**	***45.0***
SP	2.7	*9.1*	**9.0**	***37.2***	**3.2**	***12.2***	**-0.3**	***22.0***	**3.3**	***44.0***
IEN	-0.7	*14.9*	**5.6**	***39.0***	**-0.2**	***17.0***	**-3.7**	***25.0***	**-0.1**	***45.6***
CEM	-6.3	*36.0*			**-5.8**	***36.9***	**-9.3**	***41.2***	**-5.7**	***56.1***
PTB	-0.5	*8.0*	**5.8**	***36.9***			**-3.5**	***21.6***	**0.1**	***43.8***
VSL	3.0	*20.0*	**9.3**	***41.2***	**3.5**	***21.6***			**3.6**	***47.5***
OMH	-0.6	*43.0*	**5.7**	***56.1***	**-0.1**	***43.8***	**-3.6**	***47.5***		
JV	-1.1	*22.1*	**5.2**	***42.3***	**-0.6**	***23.6***	**-4.1**	***29.9***	**-0.5**	***48.4***
UME	0.9	*30.1*	**7.2**	***47.0***	**1.4**	***31.2***	**-2.1**	***36.2***	**1.5**	***52.5***
METAS	-1.5	*6.2*	**4.8**	***36.6***	**-1.0**	***10.2***	**-4.5**	***21.0***	**-0.9**	***43.5***
CMI	7.5	*50.0*	**13.8**	***61.7***	**8.0**	***50.7***	**4.5**	***53.9***	**8.1**	***66.0***

Table 1c : Degree of equivalence at 1000 V / 1 kHz (3/4)

Voltage : 1000 V Frequency : 1 kHz (4/4)			JV		UME		METAS		CMI	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-1.1	*22.1*	0.9	*30.1*	-1.5	*6.2*	7.5	*50.0*
	$d_{adj\,i}$	$u(d_{adj\,i})$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
BNM-LNE	6.0	*16.1*	**7.1**	***27.4***	**5.1**	***34.2***	**7.5**	***17.3***	**-1.5**	***52.6***
BEV	0.7	*18.1*	**1.8**	***28.6***	**-0.2**	***35.2***	**2.2**	***19.2***	**-6.8**	***53.2***
MIKES	0.1	*10.1*	**1.2**	***24.3***	**-0.8**	***31.8***	**1.6**	***11.9***	**-7.4**	***51.1***
INETI	13.7	*32.0*	**14.8**	***38.9***	**12.8**	***44.0***	**15.2**	***32.6***	**6.2**	***59.4***
DANIAmet-AREPA	4.7	*21.1*	**5.8**	***30.6***	**3.8**	***36.8***	**6.2**	***22.0***	**-2.8**	***54.3***
NPL	-0.3	*13.1*	**0.8**	***25.7***	**-1.2**	***32.9***	**1.2**	***14.5***	**-7.8**	***51.7***
SP	2.7	*9.1*	**3.8**	***24.0***	**1.8**	***31.5***	**4.2**	***11.1***	**-4.8**	***50.9***
IEN	-0.7	*14.9*	**0.4**	***26.7***	**-1.6**	***33.6***	**0.8**	***16.2***	**-8.2**	***52.2***
CEM	-6.3	*36.0*	**-5.2**	***42.3***	**-7.2**	***47.0***	**-4.8**	***36.6***	**-13.8**	***61.7***
PTB	-0.5	*8.0*	**0.6**	***23.6***	**-1.4**	***31.2***	**1.0**	***10.2***	**-8.0**	***50.7***
VSL	3.0	*20.0*	**4.1**	***29.9***	**2.1**	***36.2***	**4.5**	***21.0***	**-4.5**	***53.9***
OMH	-0.6	*43.0*	**0.5**	***48.4***	**-1.5**	***52.5***	**0.9**	***43.5***	**-8.1**	***66.0***
JV	-1.1	*22.1*			**-2.0**	***37.4***	**0.4**	***23.0***	**-8.6**	***54.7***
UME	0.9	*30.1*	**2.0**	***37.4***			**2.4**	***30.8***	**-6.6**	***58.4***
METAS	-1.5	*6.2*	**-0.4**	***23.0***	**-2.4**	***30.8***			**-9.0**	***50.4***
CMI	7.5	*50.0*	**8.6**	***54.7***	**6.6**	***58.4***	**9.0**	***50.4***		

Table 1d : Degree of equivalence at 1000 V / 1 kHz (4/4)

Voltage : 1000 V **Frequency : 10 kHz** (1/4)			**BNM-LNE**		**BEV**		**MIKES**		**INETI**	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-1.0	*35.0*	0.9	*20.1*	-9.1	*10.0*	22.9	*40.0*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-1.0	*35.0*			**-1.9**	***40.4***	**8.1**	***36.5***	**-23.9**	***53.2***
BEV	0.9	*20.1*	**1.9**	***40.4***			**10.0**	***22.5***	**-22.0**	***44.8***
MIKES	-9.1	*10.0*	**-8.1**	***36.5***	**-10.0**	***22.5***			**-32.0**	***41.3***
INETI	22.9	*40.0*	**23.9**	***53.2***	**22.0**	***44.8***	**32.0**	***41.3***		
DANIAmet-AREPA	1.9	*21.1*	**2.9**	***40.9***	**1.0**	***29.2***	**11.0**	***23.4***	**-21.0**	***45.3***
NPL	-5.1	*13.1*	**-4.1**	***37.4***	**-6.0**	***24.0***	**4.0**	***16.5***	**-28.0**	***42.1***
SP	0.9	*10.1*	**1.9**	***36.5***	**0.0**	***22.5***	**10.0**	***14.3***	**-22.0**	***41.3***
IEN	-4.9	*15.3*	**-3.9**	***38.2***	**-5.8**	***25.3***	**4.2**	***18.3***	**-27.8**	***42.9***
CEM	-2.1	*40.0*	**-1.1**	***53.2***	**-3.0**	***44.8***	**7.0**	***41.3***	**-25.0**	***56.6***
PTB	-3.8	*8.0*	**-2.8**	***36.0***	**-4.7**	***21.7***	**5.3**	***12.9***	**-26.7**	***40.8***
VSL	-3.1	*20.0*	**-2.1**	***40.4***	**-4.0**	***28.4***	**6.0**	***22.4***	**-26.0**	***44.8***
OMH	1.0	*52.0*	**2.0**	***62.7***	**0.1**	***55.8***	**10.1**	***53.0***	**-21.9**	***65.7***
JV	-2.8	*24.1*	**-1.8**	***42.5***	**-3.7**	***31.4***	**6.3**	***26.1***	**-25.7**	***46.7***
UME	1.2	*30.1*	**2.2**	***46.2***	**0.3**	***36.2***	**10.3**	***31.8***	**-21.7**	***50.1***
METAS	-4.0	*7.2*	**-3.0**	***35.8***	**-4.9**	***21.4***	**5.1**	***12.4***	**-26.9**	***40.7***
CMI	0.4	*50.0*	**1.4**	***61.1***	**-0.5**	***53.9***	**9.5**	***51.0***	**-22.5**	***64.1***

Table 1e : Degree of equivalence at 1000 V / 10 kHz (1/4)

Voltage : 1000 V **Frequency : 10 kHz** (2/4)			**DANIAmet-AREPA**		**NPL**		**SP**		**IEN**	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			1.9	*21.1*	-5.1	*13.1*	0.9	*10.1*	-4.9	*15.3*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-1.0	*35.0*	**-2.9**	***40.9***	**4.1**	***37.4***	**-1.9**	***36.5***	**3.9**	***38.2***
BEV	0.9	*20.1*	**-1.0**	***29.2***	**6.0**	***24.0***	**0.0**	***22.5***	**5.8**	***25.3***
MIKES	-9.1	*10.0*	**-11.0**	***23.4***	**-4.0**	***16.5***	**-10.0**	***14.3***	**-4.2**	***18.3***
INETI	22.9	*40.0*	**21.0**	***45.3***	**28.0**	***42.1***	**22.0**	***41.3***	**27.8**	***42.9***
DANIAmet-AREPA	1.9	*21.1*			**7.0**	***24.9***	**1.0**	***23.4***	**6.8**	***26.1***
NPL	-5.1	*13.1*	**-7.0**	***24.9***			**-6.0**	***16.6***	**-0.2**	***20.2***
SP	0.9	*10.1*	**-1.0**	***23.4***	**6.0**	***16.6***			**5.8**	***18.4***
IEN	-4.9	*15.3*	**-6.8**	***26.1***	**0.2**	***20.2***	**-5.8**	***18.4***		
CEM	-2.1	*40.0*	**-4.0**	***45.3***	**3.0**	***42.1***	**-3.0**	***41.3***	**2.8**	***42.9***
PTB	-3.8	*8.0*	**-5.7**	***19.6***	**1.3**	***15.4***	**-4.7**	***12.9***	**1.1**	***17.3***
VSL	-3.1	*20.0*	**-5.0**	***29.1***	**2.0**	***24.0***	**-4.0**	***22.5***	**1.8**	***25.2***
OMH	1.0	*52.0*	**-0.9**	***56.2***	**6.1**	***53.7***	**0.1**	***53.0***	**5.9**	***54.3***
JV	-2.8	*24.1*	**-4.7**	***32.1***	**2.3**	***27.5***	**-3.7**	***26.2***	**2.1**	***28.6***
UME	1.2	*30.1*	**-0.7**	***36.8***	**6.3**	***32.9***	**0.3**	***31.8***	**6.1**	***33.8***
METAS	-4.0	*7.2*	**-5.9**	***22.3***	**1.1**	***15.0***	**-4.9**	***12.5***	**0.9**	***17.0***
CMI	0.4	*50.0*	**-1.5**	***54.3***	**5.5**	***51.7***	**-0.5**	***51.1***	**5.3**	***52.3***

Table 1f : Degree of equivalence at 1000 V / 10 kHz (2/4)

Voltage : 1000 V			CEM		PTB		VSL		OMH	
Frequency : 10 kHz			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
(3/4)			-2.1	*40.0*	-3.8	*8.0*	-3.1	*20.0*	1.0	*52.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-1.0	*35.0*	**1.1**	***53.2***	**2.8**	***36.0***	**2.1**	***40.4***	**-2.0**	***62.7***
BEV	0.9	*20.1*	**3.0**	***44.8***	**4.7**	***21.7***	**4.0**	***28.4***	**-0.1**	***55.8***
MIKES	-9.1	*10.0*	**-7.0**	***41.3***	**-5.3**	***12.9***	**-6.0**	***22.4***	**-10.1**	***53.0***
INETI	22.9	*40.0*	**25.0**	***56.6***	**26.7**	***40.8***	**26.0**	***44.8***	**21.9**	***65.7***
DANIAmet-AREPA	1.9	*21.1*	**4.0**	***45.3***	**5.7**	***19.6***	**5.0**	***29.1***	**0.9**	***56.2***
NPL	-5.1	*13.1*	**-3.0**	***42.1***	**-1.3**	***15.4***	**-2.0**	***24.0***	**-6.1**	***53.7***
SP	0.9	*10.1*	**3.0**	***41.3***	**4.7**	***12.9***	**4.0**	***22.5***	**-0.1**	***53.0***
IEN	-4.9	*15.3*	**-2.8**	***42.9***	**-1.1**	***17.3***	**-1.8**	***25.2***	**-5.9**	***54.3***
CEM	-2.1	*40.0*			**1.7**	***40.8***	**1.0**	***44.8***	**-3.1**	***65.7***
PTB	-3.8	*8.0*	**-1.7**	***40.8***			**-0.7**	***21.6***	**-4.8**	***52.7***
VSL	-3.1	*20.0*	**-1.0**	***44.8***	**0.7**	***21.6***			**-4.1**	***55.8***
OMH	1.0	*52.0*	**3.1**	***65.7***	**4.8**	***52.7***	**4.1**	***55.8***		
JV	-2.8	*24.1*	**-0.7**	***46.7***	**1.0**	***25.4***	**0.3**	***31.4***	**-3.8**	***57.4***
UME	1.2	*30.1*	**3.3**	***50.1***	**5.0**	***31.2***	**4.3**	***36.2***	**0.2**	***60.1***
METAS	-4.0	*7.2*	**-1.9**	***40.7***	**-0.2**	***10.8***	**-0.9**	***21.3***	**-5.0**	***52.5***
CMI	0.4	*50.0*	**2.5**	***64.1***	**4.2**	***50.7***	**3.5**	***53.9***	**-0.6**	***72.2***

Table 1g : Degree of equivalence at 1000 V / 10 kHz (3/4)

Voltage : 1000 V			JV		UME		METAS		CMI	
Frequency : 10 kHz			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
(4/4)			-2.8	*24.1*	1.2	*30.1*	-4.0	*7.2*	0.4	*50.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-1.0	*35.0*	**1.8**	***42.5***	**-2.2**	***46.2***	**3.0**	***35.8***	**-1.4**	***61.1***
BEV	0.9	*20.1*	**3.7**	***31.4***	**-0.3**	***36.2***	**4.9**	***21.4***	**0.5**	***53.9***
MIKES	-9.1	*10.0*	**-6.3**	***26.1***	**-10.3**	***31.8***	**-5.1**	***12.4***	**-9.5**	***51.0***
INETI	22.9	*40.0*	**25.7**	***46.7***	**21.7**	***50.1***	**26.9**	***40.7***	**22.5**	***64.1***
DANIAmet-AREPA	1.9	*21.1*	**4.7**	***32.1***	**0.7**	***36.8***	**5.9**	***22.3***	**1.5**	***54.3***
NPL	-5.1	*13.1*	**-2.3**	***27.5***	**-6.3**	***32.9***	**-1.1**	***15.0***	**-5.5**	***51.7***
SP	0.9	*10.1*	**3.7**	***26.2***	**-0.3**	***31.8***	**4.9**	***12.5***	**0.5**	***51.1***
IEN	-4.9	*15.3*	**-2.1**	***28.6***	**-6.1**	***33.8***	**-0.9**	***17.0***	**-5.3**	***52.3***
CEM	-2.1	*40.0*	**0.7**	***46.7***	**-3.3**	***50.1***	**1.9**	***40.7***	**-2.5**	***64.1***
PTB	-3.8	*8.0*	**-1.0**	***25.4***	**-5.0**	***31.2***	**0.2**	***10.8***	**-4.2**	***50.7***
VSL	-3.1	*20.0*	**-0.3**	***31.4***	**-4.3**	***36.2***	**0.9**	***21.3***	**-3.5**	***53.9***
OMH	1.0	*52.0*	**3.8**	***57.4***	**-0.2**	***60.1***	**5.0**	***52.5***	**0.6**	***72.2***
JV	-2.8	*24.1*			**-4.0**	***38.6***	**1.2**	***25.2***	**-3.2**	***55.6***
UME	1.2	*30.1*	**4.0**	***38.6***			**5.2**	***31.0***	**0.8**	***58.4***
METAS	-4.0	*7.2*	**-1.2**	***25.2***	**-5.2**	***31.0***			**-4.4**	***50.6***
CMI	0.4	*50.0*	**3.2**	***55.6***	**-0.8**	***58.4***	**4.4**	***50.6***		

Table 1h : Degree of equivalence at 1000 V / 10 kHz (4/4)

Voltage : 1000 V Frequency : 20 kHz (1/4)			BNM-LNE		BEV		MIKES		INETI	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-8.0	*35.0*	0.1	*24.1*	-16.8	*10.9*	29.1	*52.0*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-8.0	*35.0*			**-8.1**	***42.5***	**8.8**	***36.7***	**-37.1**	***62.7***
BEV	0.1	*24.1*	**8.1**	***42.5***			**16.9**	***26.5***	**-29.0**	***57.4***
MIKES	-16.8	*10.9*	**-8.8**	***36.7***	**-16.9**	***26.5***			**-45.9**	***53.2***
INETI	29.1	*52.0*	**37.1**	***62.7***	**29.0**	***57.4***	**45.9**	***53.2***		
DANIAmet-AREPA	0.1	*26.0*	**8.1**	***43.7***	**0.0**	***35.5***	**16.9**	***28.2***	**-29.0**	***58.2***
NPL	-10.9	*23.1*	**-2.9**	***42.0***	**-11.0**	***33.4***	**5.9**	***25.6***	**-40.0**	***56.9***
SP	-2.9	*11.1*	**5.1**	***36.8***	**-3.0**	***26.6***	**13.9**	***15.6***	**-32.0**	***53.2***
IEN	-11.8	*25.1*	**-3.8**	***43.1***	**-11.9**	***34.8***	**5.0**	***27.4***	**-40.9**	***57.8***
CEM	-6.9	*44.0*	**1.1**	***56.3***	**-7.0**	***50.2***	**9.9**	***45.4***	**-36.0**	***68.2***
PTB	-7.2	*8.0*	**0.8**	***36.0***	**-7.3**	***25.4***	**9.6**	***13.6***	**-36.3**	***52.7***
VSL	-10.1	*25.0*	**-2.1**	***43.1***	**-10.2**	***34.8***	**6.7**	***27.3***	**-39.2**	***57.7***
OMH	-20.6	*80.0*	**-12.6**	***87.4***	**-20.7**	***83.6***	**-3.8**	***80.8***	**-49.7**	***95.5***
JV	-7.6	*28.0*	**0.4**	***44.9***	**-7.7**	***37.0***	**9.2**	***30.1***	**-36.7**	***59.1***
UME	-0.6	*40.0*	**7.4**	***53.2***	**-0.7**	***46.7***	**16.2**	***41.5***	**-29.7**	***65.7***
METAS	-6.8	*7.1*	**1.2**	***35.8***	**-6.9**	***25.2***	**10.0**	***13.1***	**-35.9**	***52.5***
CMI	-1.2	*62.0*	**6.8**	***71.2***	**-1.3**	***66.6***	**15.6**	***63.0***	**-30.3**	***81.0***

Table 1i : Degree of equivalence at 1000 V / 20 kHz (1/4)

Voltage : 1000 V Frequency : 20 kHz (2/4)			DANIAmet-AREPA		NPL		SP		IEN	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			0.1	*26.0*	-10.9	*23.1*	-2.9	*11.1*	-11.8	*25.1*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-8.0	*35.0*	**-8.1**	***43.7***	**2.9**	***42.0***	**-5.1**	***36.8***	**3.8**	***43.1***
BEV	0.1	*24.1*	**0.0**	***35.5***	**11.0**	***33.4***	**3.0**	***26.6***	**11.9**	***34.8***
MIKES	-16.8	*10.9*	**-16.9**	***28.2***	**-5.9**	***25.6***	**-13.9**	***15.6***	**-5.0**	***27.4***
INETI	29.1	*52.0*	**29.0**	***58.2***	**40.0**	***56.9***	**32.0**	***53.2***	**40.9**	***57.8***
DANIAmet-AREPA	0.1	*26.0*			**11.0**	***34.8***	**3.0**	***28.3***	**11.9**	***36.2***
NPL	-10.9	*23.1*	**-11.0**	***34.8***			**-8.0**	***25.7***	**0.9**	***34.2***
SP	-2.9	*11.1*	**-3.0**	***28.3***	**8.0**	***25.7***			**8.9**	***27.5***
IEN	-11.8	*25.1*	**-11.9**	***36.2***	**-0.9**	***34.2***	**-8.9**	***27.5***		
CEM	-6.9	*44.0*	**-7.0**	***51.2***	**4.0**	***49.7***	**-4.0**	***45.4***	**4.9**	***50.7***
PTB	-7.2	*8.0*	**-7.3**	***24.8***	**3.7**	***24.5***	**-4.3**	***13.7***	**4.6**	***26.4***
VSL	-10.1	*25.0*	**-10.2**	***36.1***	**0.8**	***34.1***	**-7.2**	***27.4***	**1.7**	***35.5***
OMH	-20.6	*80.0*	**-20.7**	***84.2***	**-9.7**	***83.3***	**-17.7**	***80.8***	**-8.8**	***83.9***
JV	-7.6	*28.0*	**-7.7**	***38.3***	**3.3**	***36.3***	**-4.7**	***30.2***	**4.2**	***37.7***
UME	-0.6	*40.0*	**-0.7**	***47.8***	**10.3**	***46.2***	**2.3**	***41.6***	**11.2**	***47.3***
METAS	-6.8	*7.1*	**-6.9**	***27.0***	**4.1**	***24.2***	**-3.9**	***13.2***	**5.0**	***26.1***
CMI	-1.2	*62.0*	**-1.3**	***67.3***	**9.7**	***66.2***	**1.7**	***63.0***	**10.6**	***66.9***

Table 1j : Degree of equivalence at 1000 V / 20 kHz (2/4)

Voltage : 1000 V			CEM		PTB		VSL		OMH	
Frequency : 20 kHz			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
(3/4)			-6.9	44.0	-7.2	8.0	-10.1	25.0	-20.6	80.0
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-8.0	*35.0*	**-1.1**	***56.3***	**-0.8**	***36.0***	**2.1**	***43.1***	**12.6**	***87.4***
BEV	0.1	*24.1*	**7.0**	***50.2***	**7.3**	***25.4***	**10.2**	***34.8***	**20.7**	***83.6***
MIKES	-16.8	*10.9*	**-9.9**	***45.4***	**-9.6**	***13.6***	**-6.7**	***27.3***	**3.8**	***80.8***
INETI	29.1	*52.0*	**36.0**	***68.2***	**36.3**	***52.7***	**39.2**	***57.7***	**49.7**	***95.5***
DANIAmet-AREPA	0.1	*26.0*	**7.0**	***51.2***	**7.3**	***24.8***	**10.2**	***36.1***	**20.7**	***84.2***
NPL	-10.9	*23.1*	**-4.0**	***49.7***	**-3.7**	***24.5***	**-0.8**	***34.1***	**9.7**	***83.3***
SP	-2.9	*11.1*	**4.0**	***45.4***	**4.3**	***13.7***	**7.2**	***27.4***	**17.7**	***80.8***
IEN	-11.8	*25.1*	**-4.9**	***50.7***	**-4.6**	***26.4***	**-1.7**	***35.5***	**8.8**	***83.9***
CEM	-6.9	*44.0*			**0.3**	***44.8***	**3.2**	***50.7***	**13.7**	***91.4***
PTB	-7.2	*8.0*	**-0.3**	***44.8***			**2.9**	***26.3***	**13.4**	***80.4***
VSL	-10.1	*25.0*	**-3.2**	***50.7***	**-2.9**	***26.3***			**10.5**	***83.9***
OMH	-20.6	*80.0*	**-13.7**	***91.4***	**-13.4**	***80.4***	**-10.5**	***83.9***		
JV	-7.6	*28.0*	**-0.7**	***52.2***	**-0.4**	***29.2***	**2.5**	***37.6***	**13.0**	***84.8***
UME	-0.6	*40.0*	**6.3**	***59.5***	**6.6**	***40.8***	**9.5**	***47.2***	**20.0**	***89.5***
METAS	-6.8	*7.1*	**0.1**	***44.6***	**0.4**	***10.7***	**3.3**	***26.0***	**13.8**	***80.4***
CMI	-1.2	*62.0*	**5.7**	***76.1***	**6.0**	***62.6***	**8.9**	***66.9***	**19.4**	***101.3***

Table 1k : Degree of equivalence at 1000 V / 20 kHz (3/4)

Voltage : 1000 V			JV		UME		METAS		CMI	
Frequency : 20 kHz			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
(4/4)			-7.6	28.0	-0.6	40.0	-6.8	7.1	-1.2	62.0
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-8.0	*35.0*	**-0.4**	***44.9***	**-7.4**	***53.2***	**-1.2**	***35.8***	**-6.8**	***71.2***
BEV	0.1	*24.1*	**7.7**	***37.0***	**0.7**	***46.7***	**6.9**	***25.2***	**1.3**	***66.6***
MIKES	-16.8	*10.9*	**-9.2**	***30.1***	**-16.2**	***41.5***	**-10.0**	***13.1***	**-15.6**	***63.0***
INETI	29.1	*52.0*	**36.7**	***59.1***	**29.7**	***65.7***	**35.9**	***52.5***	**30.3**	***81.0***
DANIAmet-AREPA	0.1	*26.0*	**7.7**	***38.3***	**0.7**	***47.8***	**6.9**	***27.0***	**1.3**	***67.3***
NPL	-10.9	*23.1*	**-3.3**	***36.3***	**-10.3**	***46.2***	**-4.1**	***24.2***	**-9.7**	***66.2***
SP	-2.9	*11.1*	**4.7**	***30.2***	**-2.3**	***41.6***	**3.9**	***13.2***	**-1.7**	***63.0***
IEN	-11.8	*25.1*	**-4.2**	***37.7***	**-11.2**	***47.3***	**-5.0**	***26.1***	**-10.6**	***66.9***
CEM	-6.9	*44.0*	**0.7**	***52.2***	**-6.3**	***59.5***	**-0.1**	***44.6***	**-5.7**	***76.1***
PTB	-7.2	*8.0*	**0.4**	***29.2***	**-6.6**	***40.8***	**-0.4**	***10.7***	**-6.0**	***62.6***
VSL	-10.1	*25.0*	**-2.5**	***37.6***	**-9.5**	***47.2***	**-3.3**	***26.0***	**-8.9**	***66.9***
OMH	-20.6	*80.0*	**-13.0**	***84.8***	**-20.0**	***89.5***	**-13.8**	***80.4***	**-19.4**	***101.3***
JV	-7.6	*28.0*			**-7.0**	***48.9***	**-0.8**	***28.9***	**-6.4**	***68.1***
UME	-0.6	*40.0*	**7.0**	***48.9***			**6.2**	***40.7***	**0.6**	***73.8***
METAS	-6.8	*7.1*	**0.8**	***28.9***	**-6.2**	***40.7***			**-5.6**	***62.5***
CMI	-1.2	*62.0*	**6.4**	***68.1***	**-0.6**	***73.8***	**5.6**	***62.5***		

Table 1l : Degree of equivalence at 1000 V / 20 kHz (4/4)

Voltage : 1000 V **Frequency : 50 kHz** (1/4)			**BNM-LNE**		**MIKES**		**INETI**		**DANIAmet-AREPA**	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-31.7	*69.0*	-47.2	*23.3*	33.9	*68.0*	-18.1	*41.0*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-31.7	*69.0*			**15.5**	***72.9***	**-65.6**	***96.9***	**-13.6**	***80.3***
MIKES	-47.2	*23.3*	**-15.5**	***72.9***			**-81.1**	***71.9***	**-29.1**	***47.2***
INETI	33.9	*68.0*	**65.6**	***96.9***	**81.1**	***71.9***			**52.0**	***79.5***
DANIAmet-AREPA	-18.1	*41.0*	**13.6**	***80.3***	**29.1**	***47.2***	**-52.0**	***79.5***		
NPL	-27.1	*32.0*	**4.6**	***76.1***	**20.1**	***39.6***	**-61.0**	***75.2***	**-9.0**	***52.1***
SP	-15.1	*15.1*	**16.6**	***70.7***	**32.1**	***27.8***	**-49.0**	***69.7***	**3.0**	***43.7***
IEN	-30.9	*37.2*	**0.8**	***78.4***	**16.3**	***43.9***	**-64.8**	***77.6***	**-12.8**	***55.4***
CEM	-36.1	*64.0*	**-4.4**	***94.2***	**11.1**	***68.2***	**-70.0**	***93.4***	**-18.0**	***76.1***
PTB	-21.9	*10.0*	**9.8**	***69.8***	**25.3**	***25.4***	**-55.8**	***68.8***	**-3.8**	***39.8***
VSL	-25.2	*35.0*	**6.5**	***77.4***	**22.0**	***42.1***	**-59.1**	***76.5***	**-7.1**	***54.0***
OMH	-45.2	*120.0*	**-13.5**	***138.5***	**2.0**	***122.3***	**-79.1**	***138.0***	**-27.1**	***126.9***
JV	-19.5	*42.0*	**12.2**	***80.8***	**27.7**	***48.1***	**-53.4**	***80.0***	**-1.4**	***58.7***
UME	-13.5	*44.0*	**18.2**	***81.9***	**33.7**	***49.8***	**-47.4**	***81.0***	**4.6**	***60.2***
METAS	-21.2	*10.1*	**10.5**	***69.8***	**26.0**	***25.4***	**-55.1**	***68.8***	**-3.1**	***42.3***
CMI	-28.0	*78.0*	**3.7**	***104.2***	**19.2**	***81.5***	**-61.9**	***103.5***	**-9.9**	***88.2***

Table 1m : Degree of equivalence at 1000 V / 50 kHz (1/4)

Voltage : 1000 V **Frequency : 50 kHz** (2/4)			**NPL**		**SP**		**IEN**		**CEM**	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-27.1	*32.0*	-15.1	*15.1*	-30.9	*37.2*	-36.1	*64.0*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-31.7	*69.0*	**-4.6**	***76.1***	**-16.6**	***70.7***	**-0.8**	***78.4***	**4.4**	***94.2***
MIKES	-47.2	*23.3*	**-20.1**	***39.6***	**-32.1**	***27.8***	**-16.3**	***43.9***	**-11.1**	***68.2***
INETI	33.9	*68.0*	**61.0**	***75.2***	**49.0**	***69.7***	**64.8**	***77.6***	**70.0**	***93.4***
DANIAmet-AREPA	-18.1	*41.0*	**9.0**	***52.1***	**-3.0**	***43.7***	**12.8**	***55.4***	**18.0**	***76.1***
NPL	-27.1	*32.0*			**-12.0**	***35.4***	**3.8**	***49.1***	**9.0**	***71.6***
SP	-15.1	*15.1*	**12.0**	***35.4***			**15.8**	***40.2***	**21.0**	***65.8***
IEN	-30.9	*37.2*	**-3.8**	***49.1***	**-15.8**	***40.2***			**5.2**	***74.1***
CEM	-36.1	*64.0*	**-9.0**	***71.6***	**-21.0**	***65.8***	**-5.2**	***74.1***		
PTB	-21.9	*10.0*	**5.2**	***33.6***	**-6.8**	***18.2***	**9.0**	***38.6***	**14.2**	***64.8***
VSL	-25.2	*35.0*	**1.9**	***47.5***	**-10.1**	***38.2***	**5.7**	***51.1***	**10.9**	***73.0***
OMH	-45.2	*120.0*	**-18.1**	***124.2***	**-30.1**	***121.0***	**-14.3**	***125.7***	**-9.1**	***136.0***
JV	-19.5	*42.0*	**7.6**	***52.9***	**-4.4**	***44.7***	**11.4**	***56.2***	**16.6**	***76.6***
UME	-13.5	*44.0*	**13.6**	***54.5***	**1.6**	***46.6***	**17.4**	***57.7***	**22.6**	***77.7***
METAS	-21.2	*10.1*	**5.9**	***33.6***	**-6.1**	***18.2***	**9.7**	***38.6***	**14.9**	***64.8***
CMI	-28.0	*78.0*	**-0.9**	***84.4***	**-12.9**	***79.5***	**2.9**	***86.5***	**8.1**	***100.9***

Table 1n : Degree of equivalence at 1000 V / 50 kHz (2/4)

Voltage : 1000 V Frequency : 50 kHz (3/4)			PTB		VSL		OMH		JV	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-21.9	*10.0*	-25.2	*35.0*	-45.2	*120.0*	-19.5	*42.0*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-31.7	*69.0*	**-9.8**	***69.8***	**-6.5**	***77.4***	**13.5**	***138.5***	**-12.2**	***80.8***
MIKES	-47.2	*23.3*	**-25.3**	***25.4***	**-22.0**	***42.1***	**-2.0**	***122.3***	**-27.7**	***48.1***
INETI	33.9	*68.0*	**55.8**	***68.8***	**59.1**	***76.5***	**79.1**	***138.0***	**53.4**	***80.0***
DANIAmet-AREPA	-18.1	*41.0*	**3.8**	***39.8***	**7.1**	***54.0***	**27.1**	***126.9***	**1.4**	***58.7***
NPL	-27.1	*32.0*	**-5.2**	***33.6***	**-1.9**	***47.5***	**18.1**	***124.2***	**-7.6**	***52.9***
SP	-15.1	*15.1*	**6.8**	***18.2***	**10.1**	***38.2***	**30.1**	***121.0***	**4.4**	***44.7***
IEN	-30.9	*37.2*	**-9.0**	***38.6***	**-5.7**	***51.1***	**14.3**	***125.7***	**-11.4**	***56.2***
CEM	-36.1	*64.0*	**-14.2**	***64.8***	**-10.9**	***73.0***	**9.1**	***136.0***	**-16.6**	***76.6***
PTB	-21.9	*10.0*			**3.3**	***36.5***	**23.3**	***120.5***	**-2.4**	***43.2***
VSL	-25.2	*35.0*	**-3.3**	***36.5***			**20.0**	***125.0***	**-5.7**	***54.7***
OMH	-45.2	*120.0*	**-23.3**	***120.5***	**-20.0**	***125.0***			**-25.7**	***127.2***
JV	-19.5	*42.0*	**2.4**	***43.2***	**5.7**	***54.7***	**25.7**	***127.2***		
UME	-13.5	*44.0*	**8.4**	***45.2***	**11.7**	***56.3***	**31.7**	***127.9***	**6.0**	***60.9***
METAS	-21.2	*10.1*	**0.7**	***14.3***	**4.0**	***36.5***	**24.0**	***120.5***	**-1.7**	***43.2***
CMI	-28.0	*78.0*	**-6.1**	***78.7***	**-2.8**	***85.5***	**17.2**	***143.2***	**-8.5**	***88.6***

Table 1o : Degree of equivalence at 1000 V / 50 kHz (3/4)

Voltage : 1000 V Frequency : 50 kHz (4/4)			UME		METAS		CMI	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-13.5	*44.0*	-21.2	*10.1*	-28.0	*78.0*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\ i}$	$u(d_{adj\ i})$						
BNM-LNE	-31.7	*69.0*	**-18.2**	***81.9***	**-10.5**	***69.8***	**-3.7**	***104.2***
MIKES	-47.2	*23.3*	**-33.7**	***49.8***	**-26.0**	***25.4***	**-19.2**	***81.5***
INETI	33.9	*68.0*	**47.4**	***81.0***	**55.1**	***68.8***	**61.9**	***103.5***
DANIAmet-AREPA	-18.1	*41.0*	**-4.6**	***60.2***	**3.1**	***42.3***	**9.9**	***88.2***
NPL	-27.1	*32.0*	**-13.6**	***54.5***	**-5.9**	***33.6***	**0.9**	***84.4***
SP	-15.1	*15.1*	**-1.6**	***46.6***	**6.1**	***18.2***	**12.9**	***79.5***
IEN	-30.9	*37.2*	**-17.4**	***57.7***	**-9.7**	***38.6***	**-2.9**	***86.5***
CEM	-36.1	*64.0*	**-22.6**	***77.7***	**-14.9**	***64.8***	**-8.1**	***100.9***
PTB	-21.9	*10.0*	**-8.4**	***45.2***	**-0.7**	***14.3***	**6.1**	***78.7***
VSL	-25.2	*35.0*	**-11.7**	***56.3***	**-4.0**	***36.5***	**2.8**	***85.5***
OMH	-45.2	*120.0*	**-31.7**	***127.9***	**-24.0**	***120.5***	**-17.2**	***143.2***
JV	-19.5	*42.0*	**-6.0**	***60.9***	**1.7**	***43.2***	**8.5**	***88.6***
UME	-13.5	*44.0*			**7.7**	***45.2***	**14.5**	***89.6***
METAS	-21.2	*10.1*	**-7.7**	***45.2***			**6.8**	***78.7***
CMI	-28.0	*78.0*	**-14.5**	***89.6***	**-6.8**	***78.7***		

Table 1p : Degree of equivalence at 1000 V / 50 kHz (4/4)

Voltage : 1000 V			**BNM-LNE**		**MIKES**		**INETI**		**DANIAmet-AREPA**	
Frequency : 100 kHz			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
(1/4)			-73.6	*69.0*	-93.4	*82.1*	36.4	*102.0*	-52.6	*81.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-73.6	*69.0*			**19.8**	***107.3***	**-110.0**	***123.2***	**-21.0**	***106.5***
MIKES	-93.4	*82.1*	**-19.8**	***107.3***					**-40.8**	***115.4***
INETI	36.4	*102.0*	**110.0**	***123.2***	**129.8**	***131.0***			**89.0**	***130.3***
DANIAmet-AREPA	-52.6	*81.0*	**21.0**	***106.5***	**40.8**	***115.4***	**-89.0**	***130.3***		
NPL	-63.6	*62.0*	**10.0**	***92.8***	**29.8**	***102.9***	**-100.0**	***119.4***	**-11.0**	***102.1***
SP	-42.6	*23.1*	**31.0**	***72.8***	**50.8**	***85.3***	**-79.0**	***104.6***	**10.0**	***84.3***
IEN	-66.5	*79.4*	**7.1**	***105.2***	**26.9**	***114.3***	**-102.9**	***129.3***	**-13.9**	***113.5***
CEM	-62.6	*98.0*	**11.0**	***119.9***	**30.8**	***127.9***	**-99.0**	***141.5***	**-10.0**	***127.2***
PTB	-56.6	*30.0*	**17.0**	***75.3***	**36.8**	***87.5***	**-93.0**	***106.4***	**-4.0**	***75.3***
VSL	-61.4	*50.0*	**12.2**	***85.3***	**32.0**	***96.2***	**-97.8**	***113.6***	**-8.8**	***95.2***
OMH	-80.2	*200.0*	**-6.6**	***211.6***	**13.2**	***216.2***	**-116.6**	***224.6***	**-27.6**	***215.8***
JV	-41.5	*68.0*	**32.1**	***96.9***	**51.9**	***106.7***	**-77.9**	***122.6***	**11.1**	***105.8***
UME	-41.1	*66.0*	**32.5**	***95.5***	**52.3**	***105.4***	**-77.5**	***121.5***	**11.5**	***104.5***
METAS	-49.8	*28.0*	**23.8**	***74.5***	**43.6**	***86.8***	**-86.2**	***105.8***	**2.8**	***85.8***
CMI	-63.8	*112.0*	**9.8**	***131.6***	**29.6**	***138.9***	**-100.2**	***151.5***	**-11.2**	***138.3***

Table 1q : Degree of equivalence at 1000 V / 100 kHz (1/4)

Voltage : 1000 V			**NPL**		**SP**		**IEN**		**CEM**	
Frequency : 100 kHz			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
(2/4)			-63.6	*62.0*	-42.6	*23.1*	-66.5	*79.4*	-62.6	*98.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-73.6	*69.0*	**-10.0**	***92.8***	**-31.0**	***72.8***	**-7.1**	***105.2***	**-11.0**	***119.9***
MIKES	-93.4	*82.1*	**-29.8**	***102.9***	**-50.8**	***85.3***	**-26.9**	***114.3***	**-30.8**	***127.9***
INETI	36.4	*102.0*	**100.0**	***119.4***	**79.0**	***104.6***	**102.9**	***129.3***	**99.0**	***141.5***
DANIAmet-AREPA	-52.6	*81.0*	**11.0**	***102.1***	**-10.0**	***84.3***	**13.9**	***113.5***	**10.0**	***127.2***
NPL	-63.6	*62.0*			**-21.0**	***66.2***	**2.9**	***100.8***	**-1.0**	***116.0***
SP	-42.6	*23.1*	**21.0**	***66.2***			**23.9**	***82.7***	**20.0**	***100.7***
IEN	-66.5	*79.4*	**-2.9**	***100.8***	**-23.9**	***82.7***			**-3.9**	***126.2***
CEM	-62.6	*98.0*	**1.0**	***116.0***	**-20.0**	***100.7***	**3.9**	***126.2***		
PTB	-56.6	*30.0*	**7.0**	***68.9***	**-14.0**	***37.9***	**9.9**	***84.9***	**6.0**	***102.5***
VSL	-61.4	*50.0*	**2.2**	***79.7***	**-18.8**	***55.1***	**5.1**	***93.9***	**1.2**	***110.1***
OMH	-80.2	*200.0*	**-16.6**	***209.4***	**-37.6**	***201.4***	**-13.7**	***215.2***	**-17.6**	***222.8***
JV	-41.5	*68.0*	**22.1**	***92.1***	**1.1**	***71.9***	**25.0**	***104.6***	**21.1**	***119.3***
UME	-41.1	*66.0*	**22.5**	***90.6***	**1.5**	***70.0***	**25.4**	***103.3***	**21.5**	***118.2***
METAS	-49.8	*28.0*	**13.8**	***68.1***	**-7.2**	***36.3***	**16.7**	***84.2***	**12.8**	***102.0***
CMI	-63.8	*112.0*	**-0.2**	***128.1***	**-21.2**	***114.4***	**2.7**	***137.3***	**-1.2**	***148.9***

Table 1r : Degree of equivalence at 1000 V / 100 kHz (2/4)

Voltage : 1000 V			PTB		VSL		OMH		JV	
Frequency : 100 kHz			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
(3/4)			-56.6	*30.0*	-61.4	*50.0*	-80.2	*200.0*	-41.5	*68.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-73.6	*69.0*	**-17.0**	***75.3***	**-12.2**	***85.3***	**6.6**	***211.6***	**-32.1**	***96.9***
MIKES	-93.4	*82.1*	**-36.8**	***87.5***	**-32.0**	***96.2***	**-13.2**	***216.2***	**-51.9**	***106.7***
INETI	36.4	*102.0*	**93.0**	***106.4***	**97.8**	***113.6***	**116.6**	***224.6***	**77.9**	***122.6***
DANIAmet-AREPA	-52.6	*81.0*	**4.0**	***75.3***	**8.8**	***95.2***	**27.6**	***215.8***	**-11.1**	***105.8***
NPL	-63.6	*62.0*	**-7.0**	***68.9***	**-2.2**	***79.7***	**16.6**	***209.4***	**-22.1**	***92.1***
SP	-42.6	*23.1*	**14.0**	***37.9***	**18.8**	***55.1***	**37.6**	***201.4***	**-1.1**	***71.9***
IEN	-66.5	*79.4*	**-9.9**	***84.9***	**-5.1**	***93.9***	**13.7**	***215.2***	**-25.0**	***104.6***
CEM	-62.6	*98.0*	**-6.0**	***102.5***	**-1.2**	***110.1***	**17.6**	***222.8***	**-21.1**	***119.3***
PTB	-56.6	*30.0*			**4.8**	***58.4***	**23.6**	***202.3***	**-15.1**	***74.4***
VSL	-61.4	*50.0*	**-4.8**	***58.4***			**18.8**	***206.2***	**-19.9**	***84.5***
OMH	-80.2	*200.0*	**-23.6**	***202.3***	**-18.8**	***206.2***			**-38.7**	***211.3***
JV	-41.5	*68.0*	**15.1**	***74.4***	**19.9**	***84.5***	**38.7**	***211.3***		
UME	-41.1	*66.0*	**15.5**	***72.5***	**20.3**	***82.9***	**39.1**	***210.7***	**0.4**	***94.8***
METAS	-49.8	*28.0*	**6.8**	***41.1***	**11.6**	***57.4***	**30.4**	***202.0***	**-8.3**	***73.6***
CMI	-63.8	*112.0*	**-7.2**	***116.0***	**-2.4**	***122.7***	**16.4**	***229.3***	**-22.3**	***131.1***

Table 1s : Degree of equivalence at 1000 V / 100 kHz (3/4)

Voltage : 1000 V			UME		METAS		CMI	
Frequency : 100 kHz			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
(4/4)			-41.1	*66.0*	-49.8	*28.0*	-63.8	*112.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\,i}$	$u(d_{adj\,i})$						
BNM-LNE	-73.6	*69.0*	**-32.5**	***95.5***	**-23.8**	***74.5***	**-9.8**	***131.6***
MIKES	-93.4	*82.1*	**-52.3**	***105.4***	**-43.6**	***86.8***	**-29.6**	***138.9***
INETI	36.4	*102.0*	**77.5**	***121.5***	**86.2**	***105.8***	**100.2**	***151.5***
DANIAmet-AREPA	-52.6	*81.0*	**-11.5**	***104.5***	**-2.8**	***85.8***	**11.2**	***138.3***
NPL	-63.6	*62.0*	**-22.5**	***90.6***	**-13.8**	***68.1***	**0.2**	***128.1***
SP	-42.6	*23.1*	**-1.5**	***70.0***	**7.2**	***36.3***	**21.2**	***114.4***
IEN	-66.5	*79.4*	**-25.4**	***103.3***	**-16.7**	***84.2***	**-2.7**	***137.3***
CEM	-62.6	*98.0*	**-21.5**	***118.2***	**-12.8**	***102.0***	**1.2**	***148.9***
PTB	-56.6	*30.0*	**-15.5**	***72.5***	**-6.8**	***41.1***	**7.2**	***116.0***
VSL	-61.4	*50.0*	**-20.3**	***82.9***	**-11.6**	***57.4***	**2.4**	***122.7***
OMH	-80.2	*200.0*	**-39.1**	***210.7***	**-30.4**	***202.0***	**-16.4**	***229.3***
JV	-41.5	*68.0*	**-0.4**	***94.8***	**8.3**	***73.6***	**22.3**	***131.1***
UME	-41.1	*66.0*			**8.7**	***71.7***	**22.7**	***130.0***
METAS	-49.8	*28.0*	**-8.7**	***71.7***			**14.0**	***115.5***
CMI	-63.8	*112.0*	**-22.7**	***130.0***	**-14.0**	***115.5***		

Table 1t : Degree of equivalence at 1000 V / 100 kHz (4/4)

Voltage : 500 V Frequency : 1 kHz (1/4)			BNM-LNE		BEV		MIKES		INETI	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			3.4	*13.2*	1.6	*13.2*	0.9	*8.3*	5.6	*26.1*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	3.4	*13.2*			**1.8**	***18.7***	**2.5**	***15.6***	**-2.2**	***29.3***
BEV	1.6	*13.2*	**-1.8**	***18.7***			**0.7**	***15.6***	**-4.0**	***29.3***
MIKES	0.9	*8.3*	**-2.5**	***15.6***	**-0.7**	***15.6***			**-4.7**	***27.4***
INETI	5.6	*26.1*	**2.2**	***29.3***	**4.0**	***29.3***	**4.7**	***27.4***		
DANIAmet-AREPA	4.6	*21.1*	**1.2**	***24.9***	**3.0**	***24.9***	**3.7**	***22.7***	**-1.0**	***33.6***
NPL	0.6	*13.2*	**-2.8**	***18.7***	**-1.0**	***18.7***	**-0.3**	***15.6***	**-5.0**	***29.3***
SP	3.6	*8.3*	**0.2**	***15.6***	**2.0**	***15.6***	**2.7**	***11.8***	**-2.0**	***27.4***
IEN	1.0	*9.7*	**-2.4**	***16.4***	**-0.6**	***16.4***	**0.1**	***12.8***	**-4.6**	***27.9***
CEM	-0.4	*30.1*	**-3.8**	***32.9***	**-2.0**	***32.9***	**-1.3**	***31.3***	**-6.0**	***39.9***
PTB	-0.5	*8.0*	**-3.9**	***15.5***	**-2.1**	***15.5***	**-1.4**	***11.6***	**-6.1**	***27.3***
VSL	2.6	*15.0*	**-0.8**	***20.0***	**1.0**	***20.0***	**1.7**	***17.2***	**-3.0**	***30.2***
OMH	-0.4	*31.0*	**-3.8**	***33.7***	**-2.0**	***33.7***	**-1.3**	***32.1***	**-6.0**	***40.6***
JV	1.3	*20.1*	**-2.1**	***24.1***	**-0.3**	***24.1***	**0.4**	***21.8***	**-4.3**	***33.0***
UME	0.3	*22.1*	**-3.1**	***25.8***	**-1.3**	***25.8***	**-0.6**	***23.7***	**-5.3**	***34.2***
METAS	0.4	*6.3*	**-3.0**	***14.7***	**-1.2**	***14.7***	**-0.5**	***10.5***	**-5.2**	***26.9***
CMI	3.6	*38.1*	**0.2**	***40.4***	**2.0**	***40.4***	**2.7**	***39.0***	**-2.0**	***46.2***

Table 2a : Degree of equivalence at 500 V / 1 kHz (1/4)

Voltage : 500 V Frequency : 1 kHz (2/4)			DANIAmet-AREPA		NPL		SP		IEN	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			4.6	*21.1*	0.6	*13.2*	3.6	*8.3*	1.0	*9.7*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	3.4	*13.2*	**-1.2**	***24.9***	**2.8**	***18.7***	**-0.2**	***15.6***	**2.4**	***16.4***
BEV	1.6	*13.2*	**-3.0**	***24.9***	**1.0**	***18.7***	**-2.0**	***15.6***	**0.6**	***16.4***
MIKES	0.9	*8.3*	**-3.7**	***22.7***	**0.3**	***15.6***	**-2.7**	***11.8***	**-0.1**	***12.8***
INETI	5.6	*26.1*	**1.0**	***33.6***	**5.0**	***29.3***	**2.0**	***27.4***	**4.6**	***27.9***
DANIAmet-AREPA	4.6	*21.1*			**4.0**	***24.9***	**1.0**	***22.7***	**3.6**	***23.3***
NPL	0.6	*13.2*	**-4.0**	***24.9***			**-3.0**	***15.6***	**-0.4**	***16.4***
SP	3.6	*8.3*	**-1.0**	***22.7***	**3.0**	***15.6***			**2.6**	***12.8***
IEN	1.0	*9.7*	**-3.6**	***23.3***	**0.4**	***16.4***	**-2.6**	***12.8***		
CEM	-0.4	*30.1*	**-5.0**	***36.8***	**-1.0**	***32.9***	**-4.0**	***31.3***	**-1.4**	***31.7***
PTB	-0.5	*8.0*	**-5.1**	***19.6***	**-1.1**	***15.5***	**-4.1**	***11.6***	**-1.5**	***12.6***
VSL	2.6	*15.0*	**-2.0**	***25.9***	**2.0**	***20.0***	**-1.0**	***17.2***	**1.6**	***17.9***
OMH	-0.4	*31.0*	**-5.0**	***37.5***	**-1.0**	***33.7***	**-4.0**	***32.1***	**-1.4**	***32.5***
JV	1.3	*20.1*	**-3.3**	***29.2***	**0.7**	***24.1***	**-2.3**	***21.8***	**0.3**	***22.4***
UME	0.3	*22.1*	**-4.3**	***30.6***	**-0.3**	***25.8***	**-3.3**	***23.7***	**-0.7**	***24.2***
METAS	0.4	*6.3*	**-4.2**	***22.1***	**-0.2**	***14.7***	**-3.2**	***10.5***	**-0.6**	***11.6***
CMI	3.6	*38.1*	**-1.0**	***43.6***	**3.0**	***40.4***	**0.0**	***39.0***	**2.6**	***39.4***

Table 2b : Degree of equivalence at 500 V / 1 kHz (2/4)

Voltage : 500 V Frequency : 1 kHz (3/4)			CEM		PTB		VSL		OMH	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-0.4	*30.1*	-0.5	*8.0*	2.6	*15.0*	-0.4	*31.0*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	3.4	*13.2*	**3.8**	***32.9***	**3.9**	***15.5***	**0.8**	***20.0***	**3.8**	***33.7***
BEV	1.6	*13.2*	**2.0**	***32.9***	**2.1**	***15.5***	**-1.0**	***20.0***	**2.0**	***33.7***
MIKES	0.9	*8.3*	**1.3**	***31.3***	**1.4**	***11.6***	**-1.7**	***17.2***	**1.3**	***32.1***
INETI	5.6	*26.1*	**6.0**	***39.9***	**6.1**	***27.3***	**3.0**	***30.2***	**6.0**	***40.6***
DANIAmet-AREPA	4.6	*21.1*	**5.0**	***36.8***	**5.1**	***19.6***	**2.0**	***25.9***	**5.0**	***37.5***
NPL	0.6	*13.2*	**1.0**	***32.9***	**1.1**	***15.5***	**-2.0**	***20.0***	**1.0**	***33.7***
SP	3.6	*8.3*	**4.0**	***31.3***	**4.1**	***11.6***	**1.0**	***17.2***	**4.0**	***32.1***
IEN	1.0	*9.7*	**1.4**	***31.7***	**1.5**	***12.6***	**-1.6**	***17.9***	**1.4**	***32.5***
CEM	-0.4	*30.1*			**0.1**	***31.2***	**-3.0**	***33.7***	**0.0**	***43.3***
PTB	-0.5	*8.0*	**-0.1**	***31.2***			**-3.1**	***17.0***	**-0.1**	***32.1***
VSL	2.6	*15.0*	**3.0**	***33.7***	**3.1**	***17.0***			**3.0**	***34.5***
OMH	-0.4	*31.0*	**0.0**	***43.3***	**0.1**	***32.1***	**-3.0**	***34.5***		
JV	1.3	*20.1*	**1.7**	***36.2***	**1.8**	***21.7***	**-1.3**	***25.1***	**1.7**	***37.0***
UME	0.3	*22.1*	**0.7**	***37.4***	**0.8**	***23.6***	**-2.3**	***26.8***	**0.7**	***38.1***
METAS	0.4	*6.3*	**0.8**	***30.8***	**0.9**	***10.2***	**-2.2**	***16.3***	**0.8**	***31.7***
CMI	3.6	*38.1*	**4.0**	***48.6***	**4.1**	***39.0***	**1.0**	***41.0***	**4.0**	***49.2***

Table 2c : degree of equivalence at 500 V / 1 kHz (3/4)

Voltage : 500 V Frequency : 1 kHz (4/4)			JV		UME		METAS		CMI	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			1.3	*20.1*	0.3	*22.1*	0.4	*6.3*	3.6	*38.1*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	3.4	*13.2*	**2.1**	***24.1***	**3.1**	***25.8***	**3.0**	***14.7***	**-0.2**	***40.4***
BEV	1.6	*13.2*	**0.3**	***24.1***	**1.3**	***25.8***	**1.2**	***14.7***	**-2.0**	***40.4***
MIKES	0.9	*8.3*	**-0.4**	***21.8***	**0.6**	***23.7***	**0.5**	***10.5***	**-2.7**	***39.0***
INETI	5.6	*26.1*	**4.3**	***33.0***	**5.3**	***34.2***	**5.2**	***26.9***	**2.0**	***46.2***
DANIAmet-AREPA	4.6	*21.1*	**3.3**	***29.2***	**4.3**	***30.6***	**4.2**	***22.1***	**1.0**	***43.6***
NPL	0.6	*13.2*	**-0.7**	***24.1***	**0.3**	***25.8***	**0.2**	***14.7***	**-3.0**	***40.4***
SP	3.6	*8.3*	**2.3**	***21.8***	**3.3**	***23.7***	**3.2**	***10.5***	**0.0**	***39.0***
IEN	1.0	*9.7*	**-0.3**	***22.4***	**0.7**	***24.2***	**0.6**	***11.6***	**-2.6**	***39.4***
CEM	-0.4	*30.1*	**-1.7**	***36.2***	**-0.7**	***37.4***	**-0.8**	***30.8***	**-4.0**	***48.6***
PTB	-0.5	*8.0*	**-1.8**	***21.7***	**-0.8**	***23.6***	**-0.9**	***10.2***	**-4.1**	***39.0***
VSL	2.6	*15.0*	**1.3**	***25.1***	**2.3**	***26.8***	**2.2**	***16.3***	**-1.0**	***41.0***
OMH	-0.4	*31.0*	**-1.7**	***37.0***	**-0.7**	***38.1***	**-0.8**	***31.7***	**-4.0**	***49.2***
JV	1.3	*20.1*			**1.0**	***29.9***	**0.9**	***21.1***	**-2.3**	***43.1***
UME	0.3	*22.1*	**-1.0**	***29.9***			**-0.1**	***23.0***	**-3.3**	***44.1***
METAS	0.4	*6.3*	**-0.9**	***21.1***	**0.1**	***23.0***			**-3.2**	***38.7***
CMI	3.6	*38.1*	**2.3**	***43.1***	**3.3**	***44.1***	**3.2**	***38.7***		

Table 2d : Degree of equivalence at 500 V / 1 kHz (4/4)

Voltage : 500 V Frequency : 10 kHz (1/4)			BNM-LNE		BEV		MIKES		INETI	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-2.5	*21.1*	-0.3	*15.1*	-8.7	*7.5*	-11.3	*30.0*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-2.5	21.1			**-2.2**	***26.0***	**6.2**	***22.4***	**8.8**	***36.7***
BEV	-0.3	*15.1*	**2.2**	***26.0***			**8.4**	***16.9***	**11.0**	***33.6***
MIKES	-8.7	*7.5*	**-6.2**	***22.4***	**-8.4**	***16.9***			**2.6**	***31.0***
INETI	-11.3	*30.0*	**-8.8**	***36.7***	**-11.0**	***33.6***	**-2.6**	***31.0***		
DANIAmet-AREPA	0.7	*21.1*	**3.2**	***29.9***	**1.0**	***26.0***	**9.4**	***22.4***	**12.0**	***36.7***
NPL	-7.3	*13.1*	**-4.8**	***24.9***	**-7.0**	***20.0***	**1.4**	***15.1***	**4.0**	***32.8***
SP	0.7	*9.1*	**3.2**	***23.0***	**1.0**	***17.7***	**9.4**	***11.8***	**12.0**	***31.4***
IEN	-5.0	*9.5*	**-2.5**	***23.2***	**-4.7**	***17.9***	**3.7**	***12.2***	**6.3**	***31.5***
CEM	-3.3	*30.0*	**-0.8**	***36.7***	**-3.0**	***33.6***	**5.4**	***31.0***	**8.0**	***42.5***
PTB	-2.8	*8.0*	**-0.3**	***22.6***	**-2.5**	***17.1***	**5.9**	***11.0***	**8.5**	***31.1***
VSL	-4.3	*15.0*	**-1.8**	***25.9***	**-4.0**	***21.3***	**4.4**	***16.8***	**7.0**	***33.6***
OMH	-5.3	*36.0*	**-2.8**	***41.8***	**-5.0**	***39.1***	**3.4**	***36.8***	**6.0**	***46.9***
JV	-1.8	*22.1*	**0.7**	***30.6***	**-1.5**	***26.8***	**6.9**	***23.4***	**9.5**	***37.3***
UME	0.2	*22.1*	**2.7**	***30.6***	**0.5**	***26.8***	**8.9**	***23.4***	**11.5**	***37.3***
METAS	-3.5	*6.2*	**-1.0**	***22.0***	**-3.2**	***16.4***	**5.2**	***9.8***	**7.8**	***30.7***
CMI	-5.1	*38.0*	**-2.6**	***43.5***	**-4.8**	***40.9***	**3.6**	***38.8***	**6.2**	***48.5***

Table 2e : Degree of equivalence at 500 V /10 kHz (1/4)

Voltage : 500 V Frequency : 10 kHz (2/4)			DANIAmet-AREPA		NPL		SP		IEN	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			0.7	*21.1*	-7.3	*13.1*	0.7	*9.1*	-5.0	*9.5*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-2.5	*21.1*	**-3.2**	***29.9***	**4.8**	***24.9***	**-3.2**	***23.0***	**2.5**	***23.2***
BEV	-0.3	*15.1*	**-1.0**	***26.0***	**7.0**	***20.0***	**-1.0**	***17.7***	**4.7**	***17.9***
MIKES	-8.7	*7.5*	**-9.4**	***22.4***	**-1.4**	***15.1***	**-9.4**	***11.8***	**-3.7**	***12.2***
INETI	-11.3	*30.0*	**-12.0**	***36.7***	**-4.0**	***32.8***	**-12.0**	***31.4***	**-6.3**	***31.5***
DANIAmet-AREPA	0.7	*21.1*			**8.0**	***24.9***	**0.0**	***23.0***	**5.7**	***23.2***
NPL	-7.3	*13.1*	**-8.0**	***24.9***			**-8.0**	***16.0***	**-2.3**	***16.2***
SP	0.7	*9.1*	**0.0**	***23.0***	**8.0**	***16.0***			**5.7**	***13.2***
IEN	-5.0	*9.5*	**-5.7**	***23.2***	**2.3**	***16.2***	**-5.7**	***13.2***		
CEM	-3.3	*30.0*	**-4.0**	***36.7***	**4.0**	***32.8***	**-4.0**	***31.4***	**1.7**	***31.5***
PTB	-2.8	*8.0*	**-3.5**	***19.6***	**4.5**	***15.4***	**-3.5**	***12.2***	**2.2**	***12.5***
VSL	-4.3	*15.0*	**-5.0**	***25.9***	**3.0**	***20.0***	**-5.0**	***17.6***	**0.7**	***17.8***
OMH	-5.3	*36.0*	**-6.0**	***41.8***	**2.0**	***38.4***	**-6.0**	***37.2***	**-0.3**	***37.3***
JV	-1.8	*22.1*	**-2.5**	***30.6***	**5.5**	***25.7***	**-2.5**	***24.0***	**3.2**	***24.1***
UME	0.2	*22.1*	**-0.5**	***30.6***	**7.5**	***25.7***	**-0.5**	***24.0***	**5.2**	***24.1***
METAS	-3.5	*6.2*	**-4.2**	***22.0***	**3.8**	***14.5***	**-4.2**	***11.1***	**1.5**	***11.4***
CMI	-5.1	*38.0*	**-5.8**	***43.5***	**2.2**	***40.2***	**-5.8**	***39.1***	**-0.1**	***39.2***

Table 2f : Degree of equivalence at 500 V / 10 kHz (2/4)

Voltage : 500 V Frequency : 10 kHz (3/4)			CEM		PTB		VSL		OMH	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-3.3	*30.0*	-2.8	*8.0*	-4.3	*15.0*	-5.3	*36.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-2.5	*21.1*	**0.8**	***36.7***	**0.3**	***22.6***	**1.8**	***25.9***	**2.8**	***41.8***
BEV	-0.3	*15.1*	**3.0**	***33.6***	**2.5**	***17.1***	**4.0**	***21.3***	**5.0**	***39.1***
MIKES	-8.7	*7.5*	**-5.4**	***31.0***	**-5.9**	***11.0***	**-4.4**	***16.8***	**-3.4**	***36.8***
INETI	-11.3	*30.0*	**-8.0**	***42.5***	**-8.5**	***31.1***	**-7.0**	***33.6***	**-6.0**	***46.9***
DANIAmet-AREPA	0.7	*21.1*	**4.0**	***36.7***	**3.5**	***19.6***	**5.0**	***25.9***	**6.0**	***41.8***
NPL	-7.3	*13.1*	**-4.0**	***32.8***	**-4.5**	***15.4***	**-3.0**	***20.0***	**-2.0**	***38.4***
SP	0.7	*9.1*	**4.0**	***31.4***	**3.5**	***12.2***	**5.0**	***17.6***	**6.0**	***37.2***
IEN	-5.0	*9.5*	**-1.7**	***31.5***	**-2.2**	***12.5***	**-0.7**	***17.8***	**0.3**	***37.3***
CEM	-3.3	*30.0*			**-0.5**	***31.1***	**1.0**	***33.6***	**2.0**	***46.9***
PTB	-2.8	*8.0*	**0.5**	***31.1***			**1.5**	***17.0***	**2.5**	***36.9***
VSL	-4.3	*15.0*	**-1.0**	***33.6***	**-1.5**	***17.0***			**1.0**	***39.0***
OMH	-5.3	*36.0*	**-2.0**	***46.9***	**-2.5**	***36.9***	**-1.0**	***39.0***		
JV	-1.8	*22.1*	**1.5**	***37.3***	**1.0**	***23.6***	**2.5**	***26.8***	**3.5**	***42.3***
UME	0.2	*22.1*	**3.5**	***37.3***	**3.0**	***23.6***	**4.5**	***26.8***	**5.5**	***42.3***
METAS	-3.5	*6.2*	**-0.2**	***30.7***	**-0.7**	***10.2***	**0.8**	***16.3***	**1.8**	***36.6***
CMI	-5.1	*38.0*	**-1.8**	***48.5***	**-2.3**	***38.9***	**-0.8**	***40.9***	**0.2**	***52.4***

Table 2g : Degree of equivalence at 500 V / 10 kHz (3/4)

Voltage : 500 V Frequency : 10 kHz (4/4)			JV		UME		METAS		CMI	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-1.8	*22.1*	0.2	*22.1*	-3.5	*6.2*	-5.1	*38.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-2.5	*21.1*	**-0.7**	***30.6***	**-2.7**	***30.6***	**1.0**	***22.0***	**2.6**	***43.5***
BEV	-0.3	*15.1*	**1.5**	***26.8***	**-0.5**	***26.8***	**3.2**	***16.4***	**4.8**	***40.9***
MIKES	-8.7	*7.5*	**-6.9**	***23.4***	**-8.9**	***23.4***	**-5.2**	***9.8***	**-3.6**	***38.8***
INETI	-11.3	*30.0*	**-9.5**	***37.3***	**-11.5**	***37.3***	**-7.8**	***30.7***	**-6.2**	***48.5***
DANIAmet-AREPA	0.7	*21.1*	**2.5**	***30.6***	**0.5**	***30.6***	**4.2**	***22.0***	**5.8**	***43.5***
NPL	-7.3	*13.1*	**-5.5**	***25.7***	**-7.5**	***25.7***	**-3.8**	***14.5***	**-2.2**	***40.2***
SP	0.7	*9.1*	**2.5**	***24.0***	**0.5**	***24.0***	**4.2**	***11.1***	**5.8**	***39.1***
IEN	-5.0	*9.5*	**-3.2**	***24.1***	**-5.2**	***24.1***	**-1.5**	***11.4***	**0.1**	***39.2***
CEM	-3.3	*30.0*	**-1.5**	***37.3***	**-3.5**	***37.3***	**0.2**	***30.7***	**1.8**	***48.5***
PTB	-2.8	*8.0*	**-1.0**	***23.6***	**-3.0**	***23.6***	**0.7**	***10.2***	**2.3**	***38.9***
VSL	-4.3	*15.0*	**-2.5**	***26.8***	**-4.5**	***26.8***	**-0.8**	***16.3***	**0.8**	***40.9***
OMH	-5.3	*36.0*	**-3.5**	***42.3***	**-5.5**	***42.3***	**-1.8**	***36.6***	**-0.2**	***52.4***
JV	-1.8	*22.1*			**-2.0**	***31.3***	**1.7**	***23.0***	**3.3**	***44.0***
UME	0.2	*22.1*	**2.0**	***31.3***			**3.7**	***23.0***	**5.3**	***44.0***
METAS	-3.5	*6.2*	**-1.7**	***23.0***	**-3.7**	***23.0***			**1.6**	***38.6***
CMI	-5.1	*38.0*	**-3.3**	***44.0***	**-5.3**	***44.0***	**-1.6**	***38.6***		

Table 2h : Degree of equivalence at 500 V / 10 kHz (4/4)

Voltage : 500 V			BNM-LNE		BEV		MIKES		INETI	
Frequency : 20 kHz			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
(1/4)			-6.0	*21.1*	-2.2	*19.1*	-14.0	*8.2*	-18.2	*36.0*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-6.0	*21.1*			**-3.8**	***28.5***	**8.0**	***22.7***	**12.2**	***41.8***
BEV	-2.2	*19.1*	**3.8**	***28.5***			**11.8**	***20.8***	**16.0**	***40.8***
MIKES	-14.0	*8.2*	**-8.0**	***22.7***	**-11.8**	***20.8***			**4.2**	***37.0***
INETI	-18.2	*36.0*	**-12.2**	***41.8***	**-16.0**	***40.8***	**-4.2**	***37.0***		
DANIAmet-AREPA	-3.2	*21.1*	**2.8**	***29.9***	**-1.0**	***28.5***	**10.8**	***22.7***	**15.0**	***41.8***
NPL	-12.2	*17.1*	**-6.2**	***27.2***	**-10.0**	***25.7***	**1.8**	***19.0***	**6.0**	***39.9***
SP	-4.2	*10.2*	**1.8**	***23.5***	**-2.0**	***21.7***	**9.8**	***13.1***	**14.0**	***37.5***
IEN	-12.3	*14.1*	**-6.3**	***25.4***	**-10.1**	***23.8***	**1.7**	***16.4***	**5.9**	***38.7***
CEM	-4.2	*30.1*	**1.8**	***36.8***	**-2.0**	***35.7***	**9.8**	***31.2***	**14.0**	***47.0***
PTB	-7.0	*8.0*	**-1.0**	***22.6***	**-4.8**	***20.8***	**7.0**	***11.5***	**11.2**	***36.9***
VSL	-9.2	*20.0*	**-3.2**	***29.1***	**-7.0**	***27.7***	**4.8**	***21.7***	**9.0**	***41.2***
OMH	-7.1	*40.0*	**-1.1**	***45.3***	**-4.9**	***44.4***	**6.9**	***40.9***	**11.1**	***53.9***
JV	-5.7	*24.1*	**0.3**	***32.1***	**-3.5**	***30.8***	**8.3**	***25.5***	**12.5**	***43.4***
UME	-3.7	*26.1*	**2.3**	***33.6***	**-1.5**	***32.4***	**10.3**	***27.4***	**14.5**	***44.5***
METAS	-6.9	*6.2*	**-0.9**	***22.0***	**-4.7**	***20.1***	**7.1**	***10.3***	**11.3**	***36.6***
CMI	-8.1	*46.0*	**-2.1**	***50.7***	**-5.9**	***49.9***	**5.9**	***46.8***	**10.1**	***58.5***

Table 2i : Degree of equivalence at 500 V / 20 kHz (1/4)

Voltage : 500 V			DANIAmet-AREPA		NPL		SP		IEN	
Frequency : 20 kHz			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
(2/4)			-3.2	*21.1*	-12.2	*17.1*	-4.2	*10.2*	-12.3	*14.1*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-6.0	*21.1*	**-2.8**	***29.9***	**6.2**	***27.2***	**-1.8**	***23.5***	**6.3**	***25.4***
BEV	-2.2	*19.1*	**1.0**	***28.5***	**10.0**	***25.7***	**2.0**	***21.7***	**10.1**	***23.8***
MIKES	-14.0	*8.2*	**-10.8**	***22.7***	**-1.8**	***19.0***	**-9.8**	***13.1***	**-1.7**	***16.4***
INETI	-18.2	*36.0*	**-15.0**	***41.8***	**-6.0**	***39.9***	**-14.0**	***37.5***	**-5.9**	***38.7***
DANIAmet-AREPA	-3.2	*21.1*			**9.0**	***27.2***	**1.0**	***23.5***	**9.1**	***25.4***
NPL	-12.2	*17.1*	**-9.0**	***27.2***			**-8.0**	***20.0***	**0.1**	***22.2***
SP	-4.2	*10.2*	**-1.0**	***23.5***	**8.0**	***20.0***			**8.1**	***17.5***
IEN	-12.3	*14.1*	**-9.1**	***25.4***	**-0.1**	***22.2***	**-8.1**	***17.5***		
CEM	-4.2	*30.1*	**-1.0**	***36.8***	**8.0**	***34.7***	**0.0**	***31.8***	**8.1**	***33.3***
PTB	-7.0	*8.0*	**-3.8**	***19.6***	**5.2**	***18.9***	**-2.8**	***13.0***	**5.3**	***16.3***
VSL	-9.2	*20.0*	**-6.0**	***29.1***	**3.0**	***26.4***	**-5.0**	***22.5***	**3.1**	***24.5***
OMH	-7.1	*40.0*	**-3.9**	***45.3***	**5.1**	***43.6***	**-2.9**	***41.3***	**5.2**	***42.5***
JV	-5.7	*24.1*	**-2.5**	***32.1***	**6.5**	***29.6***	**-1.5**	***26.2***	**6.6**	***28.0***
UME	-3.7	*26.1*	**-0.5**	***33.6***	**8.5**	***31.3***	**0.5**	***28.1***	**8.6**	***29.7***
METAS	-6.9	*6.2*	**-3.7**	***22.0***	**5.3**	***18.2***	**-2.7**	***12.0***	**5.4**	***15.5***
CMI	-8.1	*46.0*	**-4.9**	***50.7***	**4.1**	***49.1***	**-3.9**	***47.2***	**4.2**	***48.2***

Table 2j : Degree of equivalence at 500 V / 20 kHz (2/4)

Voltage : 500 V Frequency : 20 kHz (3/4)			CEM		PTB		VSL		OMH	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-4.2	30.1	-7.0	8.0	-9.2	20.0	-7.1	40.0
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-6.0	*21.1*	**-1.8**	***36.8***	**1.0**	***22.6***	**3.2**	***29.1***	**1.1**	***45.3***
BEV	-2.2	*19.1*	**2.0**	***35.7***	**4.8**	***20.8***	**7.0**	***27.7***	**4.9**	***44.4***
MIKES	-14.0	*8.2*	**-9.8**	***31.2***	**-7.0**	***11.5***	**-4.8**	***21.7***	**-6.9**	***40.9***
INETI	-18.2	*36.0*	**-14.0**	***47.0***	**-11.2**	***36.9***	**-9.0**	***41.2***	**-11.1**	***53.9***
DANIAmet-AREPA	-3.2	*21.1*	**1.0**	***36.8***	**3.8**	***19.6***	**6.0**	***29.1***	**3.9**	***45.3***
NPL	-12.2	*17.1*	**-8.0**	***34.7***	**-5.2**	***18.9***	**-3.0**	***26.4***	**-5.1**	***43.6***
SP	-4.2	*10.2*	**0.0**	***31.8***	**2.8**	***13.0***	**5.0**	***22.5***	**2.9**	***41.3***
IEN	-12.3	*14.1*	**-8.1**	***33.3***	**-5.3**	***16.3***	**-3.1**	***24.5***	**-5.2**	***42.5***
CEM	-4.2	*30.1*			**2.8**	***31.2***	**5.0**	***36.2***	**2.9**	***50.1***
PTB	-7.0	*8.0*	**-2.8**	***31.2***			**2.2**	***21.6***	**0.1**	***40.8***
VSL	-9.2	*20.0*	**-5.0**	***36.2***	**-2.2**	***21.6***			**-2.1**	***44.8***
OMH	-7.1	*40.0*	**-2.9**	***50.1***	**-0.1**	***40.8***	**2.1**	***44.8***		
JV	-5.7	*24.1*	**-1.5**	***38.6***	**1.3**	***25.4***	**3.5**	***31.4***	**1.4**	***46.7***
UME	-3.7	*26.1*	**0.5**	***39.9***	**3.3**	***27.3***	**5.5**	***32.9***	**3.4**	***47.8***
METAS	-6.9	*6.2*	**-2.7**	***30.8***	**0.1**	***10.2***	**2.3**	***21.0***	**0.2**	***40.5***
CMI	-8.1	*46.0*	**-3.9**	***55.0***	**-1.1**	***46.7***	**1.1**	***50.2***	**-1.0**	***61.0***

Table 2k : Degree of equivalence at 500V / 20 kHz (3/4)

Voltage : 500 V Frequency : 20 kHz (4/4)			JV		UME		METAS		CMI	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-5.7	24.1	-3.7	26.1	-6.9	6.2	-8.1	46.0
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-6.0	*21.1*	**-0.3**	***32.1***	**-2.3**	***33.6***	**0.9**	***22.0***	**2.1**	***50.7***
BEV	-2.2	*19.1*	**3.5**	***30.8***	**1.5**	***32.4***	**4.7**	***20.1***	**5.9**	***49.9***
MIKES	-14.0	*8.2*	**-8.3**	***25.5***	**-10.3**	***27.4***	**-7.1**	***10.3***	**-5.9**	***46.8***
INETI	-18.2	*36.0*	**-12.5**	***43.4***	**-14.5**	***44.5***	**-11.3**	***36.6***	**-10.1**	***58.5***
DANIAmet-AREPA	-3.2	*21.1*	**2.5**	***32.1***	**0.5**	***33.6***	**3.7**	***22.0***	**4.9**	***50.7***
NPL	-12.2	*17.1*	**-6.5**	***29.6***	**-8.5**	***31.3***	**-5.3**	***18.2***	**-4.1**	***49.1***
SP	-4.2	*10.2*	**1.5**	***26.2***	**-0.5**	***28.1***	**2.7**	***12.0***	**3.9**	***47.2***
IEN	-12.3	*14.1*	**-6.6**	***28.0***	**-8.6**	***29.7***	**-5.4**	***15.5***	**-4.2**	***48.2***
CEM	-4.2	*30.1*	**1.5**	***38.6***	**-0.5**	***39.9***	**2.7**	***30.8***	**3.9**	***55.0***
PTB	-7.0	*8.0*	**-1.3**	***25.4***	**-3.3**	***27.3***	**-0.1**	***10.2***	**1.1**	***46.7***
VSL	-9.2	*20.0*	**-3.5**	***31.4***	**-5.5**	***32.9***	**-2.3**	***21.0***	**-1.1**	***50.2***
OMH	-7.1	*40.0*	**-1.4**	***46.7***	**-3.4**	***47.8***	**-0.2**	***40.5***	**1.0**	***61.0***
JV	-5.7	*24.1*			**-2.0**	***35.6***	**1.2**	***24.9***	**2.4**	***52.0***
UME	-3.7	*26.1*	**2.0**	***35.6***			**3.2**	***26.9***	**4.4**	***52.9***
METAS	-6.9	*6.2*	**-1.2**	***24.9***	**-3.2**	***26.9***			**1.2**	***46.5***
CMI	-8.1	*46.0*	**-2.4**	***52.0***	**-4.4**	***52.9***	**-1.2**	***46.5***		

Table 2l : Degree of equivalence at 500 V / 20 kHz (4/4)

Voltage : 500 V Frequency : 50 kHz (1/4)			BNM-LNE		BEV		MIKES		INETI	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-23.6	*36.0*	-13.9	*21.1*	-43.0	*13.1*	-37.9	*46.0*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-23.6	*36.0*			**-9.7**	***41.8***	**19.4**	***38.4***	**14.3**	***58.5***
BEV	-13.9	*21.1*	**9.7**	***41.8***			**29.1**	***24.9***	**24.0**	***50.7***
MIKES	-43.0	*13.1*	**-19.4**	***38.4***	**-29.1**	***24.9***			**-5.1**	***47.9***
INETI	-37.9	*46.0*	**-14.3**	***58.5***	**-24.0**	***50.7***	**5.1**	***47.9***		
DANIAmet-AREPA	-19.9	*21.1*	**3.7**	***41.8***	**-6.0**	***29.9***	**23.1**	***24.9***	**18.0**	***50.7***
NPL	-28.9	*24.1*	**-5.3**	***43.4***	**-15.0**	***32.1***	**14.1**	***27.5***	**9.0**	***52.0***
SP	-15.9	*14.1*	**7.7**	***38.7***	**-2.0**	***25.4***	**27.1**	***19.3***	**22.0**	***48.2***
IEN	-33.1	*20.3*	**-9.5**	***41.4***	**-19.2**	***29.3***	**9.9**	***24.2***	**4.8**	***50.3***
CEM	-26.9	*38.0*	**-3.3**	***52.4***	**-13.0**	***43.5***	**16.1**	***40.2***	**11.0**	***59.7***
PTB	-22.5	*10.0*	**1.1**	***37.4***	**-8.6**	***23.4***	**20.5**	***16.5***	**15.4**	***47.1***
VSL	-25.7	*25.0*	**-2.1**	***43.9***	**-11.8**	***32.8***	**17.3**	***28.3***	**12.2**	***52.4***
OMH	-19.0	*63.0*	**4.6**	***72.6***	**-5.1**	***66.5***	**24.0**	***64.4***	**18.9**	***78.1***
JV	-19.1	*34.0*	**4.5**	***49.6***	**-5.2**	***40.1***	**23.9**	***36.5***	**18.8**	***57.3***
UME	-18.1	*36.0*	**5.5**	***51.0***	**-4.2**	***41.8***	**24.9**	***38.4***	**19.8**	***58.5***
METAS	-21.3	*9.1*	**2.3**	***37.2***	**-7.4**	***23.0***	**21.7**	***16.0***	**16.6**	***46.9***
CMI	-38.9	*56.0*	**-15.3**	***66.6***	**-25.0**	***59.9***	**4.1**	***57.6***	**-1.0**	***72.5***

Table 2m : Degree of equivalence at 500 V / 50 kHz (1/4)

Voltage : 500 V Frequency : 50 kHz (2/4)			DANIAmet-AREPA		NPL		SP		IEN	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-19.9	*21.1*	-28.9	*24.1*	-15.9	*14.1*	-33.1	*20.3*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-23.6	*36.0*	**-3.7**	***41.8***	**5.3**	***43.4***	**-7.7**	***38.7***	**9.5**	***41.4***
BEV	-13.9	*21.1*	**6.0**	***29.9***	**15.0**	***32.1***	**2.0**	***25.4***	**19.2**	***29.3***
MIKES	-43.0	*13.1*	**-23.1**	***24.9***	**-14.1**	***27.5***	**-27.1**	***19.3***	**-9.9**	***24.2***
INETI	-37.9	*46.0*	**-18.0**	***50.7***	**-9.0**	***52.0***	**-22.0**	***48.2***	**-4.8**	***50.3***
DANIAmet-AREPA	-19.9	*21.1*			**9.0**	***32.1***	**-4.0**	***25.4***	**13.2**	***29.3***
NPL	-28.9	*24.1*	**-9.0**	***32.1***			**-13.0**	***28.0***	**4.2**	***31.6***
SP	-15.9	*14.1*	**4.0**	***25.4***	**13.0**	***28.0***			**17.2**	***24.8***
IEN	-33.1	*20.3*	**-13.2**	***29.3***	**-4.2**	***31.6***	**-17.2**	***24.8***		
CEM	-26.9	*38.0*	**-7.0**	***43.5***	**2.0**	***45.0***	**-11.0**	***40.6***	**6.2**	***43.1***
PTB	-22.5	*10.0*	**-2.6**	***18.6***	**6.4**	***26.1***	**-6.6**	***17.3***	**10.6**	***22.7***
VSL	-25.7	*25.0*	**-5.8**	***32.8***	**3.2**	***34.8***	**-9.8**	***28.8***	**7.4**	***32.3***
OMH	-19.0	*63.0*	**0.9**	***66.5***	**9.9**	***67.5***	**-3.1**	***64.6***	**14.1**	***66.2***
JV	-19.1	*34.0*	**0.8**	***40.1***	**9.8**	***41.7***	**-3.2**	***36.9***	**14.0**	***39.6***
UME	-18.1	*36.0*	**1.8**	***41.8***	**10.8**	***43.4***	**-2.2**	***38.7***	**15.0**	***41.4***
METAS	-21.3	*9.1*	**-1.4**	***23.0***	**7.6**	***25.8***	**-5.4**	***16.8***	**11.8**	***22.3***
CMI	-38.9	*56.0*	**-19.0**	***59.9***	**-10.0**	***61.0***	**-23.0**	***57.8***	**-5.8**	***59.6***

Table 2n : Degree of equivalence at 500 V / 50 kHz (2/4)

Voltage : 500 V **Frequency : 50 kHz** (3/4)			**CEM**		**PTB**		**VSL**		**OMH**	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-26.9	*38.0*	-22.5	*10.0*	-25.7	*25.0*	-19.0	*63.0*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-23.6	*36.0*	**3.3**	***52.4***	**-1.1**	***37.4***	**2.1**	***43.9***	**-4.6**	***72.6***
BEV	-13.9	*21.1*	**13.0**	***43.5***	**8.6**	***23.4***	**11.8**	***32.8***	**5.1**	***66.5***
MIKES	-43.0	*13.1*	**-16.1**	***40.2***	**-20.5**	***16.5***	**-17.3**	***28.3***	**-24.0**	***64.4***
INETI	-37.9	*46.0*	**-11.0**	***59.7***	**-15.4**	***47.1***	**-12.2**	***52.4***	**-18.9**	***78.1***
DANIAmet-AREPA	-19.9	*21.1*	**7.0**	***43.5***	**2.6**	***18.6***	**5.8**	***32.8***	**-0.9**	***66.5***
NPL	-28.9	*24.1*	**-2.0**	***45.0***	**-6.4**	***26.1***	**-3.2**	***34.8***	**-9.9**	***67.5***
SP	-15.9	*14.1*	**11.0**	***40.6***	**6.6**	***17.3***	**9.8**	***28.8***	**3.1**	***64.6***
IEN	-33.1	*20.3*	**-6.2**	***43.1***	**-10.6**	***22.7***	**-7.4**	***32.3***	**-14.1**	***66.2***
CEM	-26.9	*38.0*			**-4.4**	***39.3***	**-1.2**	***45.5***	**-7.9**	***73.6***
PTB	-22.5	*10.0*	**4.4**	***39.3***			**3.2**	***27.0***	**-3.5**	***63.8***
VSL	-25.7	*25.0*	**1.2**	***45.5***	**-3.2**	***27.0***			**-6.7**	***67.8***
OMH	-19.0	*63.0*	**7.9**	***73.6***	**3.5**	***63.8***	**6.7**	***67.8***		
JV	-19.1	*34.0*	**7.8**	***51.0***	**3.4**	***35.5***	**6.6**	***42.3***	**-0.1**	***71.6***
UME	-18.1	*36.0*	**8.8**	***52.4***	**4.4**	***37.4***	**7.6**	***43.9***	**0.9**	***72.6***
METAS	-21.3	*9.1*	**5.6**	***39.1***	**1.2**	***13.6***	**4.4**	***26.7***	**-2.3**	***63.7***
CMI	-38.9	*56.0*	**-12.0**	***67.7***	**-16.4**	***56.9***	**-13.2**	***61.4***	**-19.9**	***84.3***

Table 2o : Degree of equivalence at 500 V / 50 kHz (3/4)

Voltage : 500 V **Frequency : 50 kHz** (4/4)			**JV**		**UME**		**METAS**		**CMI**	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-19.1	*34.0*	-18.1	*36.0*	-21.3	*9.1*	-38.9	*56.0*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-23.6	*36.0*	**-4.5**	***49.6***	**-5.5**	***51.0***	**-2.3**	***37.2***	**15.3**	***66.6***
BEV	-13.9	*21.1*	**5.2**	***40.1***	**4.2**	***41.8***	**7.4**	***23.0***	**25.0**	***59.9***
MIKES	-43.0	*13.1*	**-23.9**	***36.5***	**-24.9**	***38.4***	**-21.7**	***16.0***	**-4.1**	***57.6***
INETI	-37.9	*46.0*	**-18.8**	***57.3***	**-19.8**	***58.5***	**-16.6**	***46.9***	**1.0**	***72.5***
DANIAmet-AREPA	-19.9	*21.1*	**-0.8**	***40.1***	**-1.8**	***41.8***	**1.4**	***23.0***	**19.0**	***59.9***
NPL	-28.9	*24.1*	**-9.8**	***41.7***	**-10.8**	***43.4***	**-7.6**	***25.8***	**10.0**	***61.0***
SP	-15.9	*14.1*	**3.2**	***36.9***	**2.2**	***38.7***	**5.4**	***16.8***	**23.0**	***57.8***
IEN	-33.1	*20.3*	**-14.0**	***39.6***	**-15.0**	***41.4***	**-11.8**	***22.3***	**5.8**	***59.6***
CEM	-26.9	*38.0*	**-7.8**	***51.0***	**-8.8**	***52.4***	**-5.6**	***39.1***	**12.0**	***67.7***
PTB	-22.5	*10.0*	**-3.4**	***35.5***	**-4.4**	***37.4***	**-1.2**	***13.6***	**16.4**	***56.9***
VSL	-25.7	*25.0*	**-6.6**	***42.3***	**-7.6**	***43.9***	**-4.4**	***26.7***	**13.2**	***61.4***
OMH	-19.0	*63.0*	**0.1**	***71.6***	**-0.9**	***72.6***	**2.3**	***63.7***	**19.9**	***84.3***
JV	-19.1	*34.0*			**-1.0**	***49.6***	**2.2**	***35.2***	**19.8**	***65.6***
UME	-18.1	*36.0*	**1.0**	***49.6***			**3.2**	***37.2***	**20.8**	***66.6***
METAS	-21.3	*9.1*	**-2.2**	***35.2***	**-3.2**	***37.2***			**17.6**	***56.8***
CMI	-38.9	*56.0*	**-19.8**	***65.6***	**-20.8**	***66.6***	**-17.6**	***56.8***		

Table 2p : Degree of equivalence at 500 V / 50 kHz (4/4)

Voltage : 500 V			BNM-LNE		BEV		MIKES		INETI	
Frequency : 100 kHz			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
(1/4)			-61.6	*36.1*	-40.9	*31.1*	-91.1	*36.0*	-71.9	*72.0*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-61.6	*36.1*			**-20.7**	***47.7***	**29.5**	***51.0***	**10.3**	***80.6***
BEV	-40.9	*31.1*	**20.7**	***47.7***			**50.2**	***47.6***	**31.0**	***78.5***
MIKES	-91.1	*36.0*	**-29.5**	***51.0***	**-50.2**	***47.6***			**-19.2**	***80.5***
INETI	-71.9	*72.0*	**-10.3**	***80.6***	**-31.0**	***78.5***	**19.2**	***80.5***		
DANIAmet-AREPA	-53.9	*41.1*	**7.7**	***54.8***	**-13.0**	***51.6***	**37.2**	***54.7***	**18.0**	***83.0***
NPL	-68.9	*46.1*	**-7.3**	***58.6***	**-28.0**	***55.7***	**22.2**	***58.5***	**3.0**	***85.5***
SP	-48.9	*21.1*	**12.7**	***41.9***	**-8.0**	***37.6***	**42.2**	***41.8***	**23.0**	***75.1***
IEN	-74.3	*47.7*	**-12.7**	***59.9***	**-33.4**	***57.0***	**16.8**	***59.8***	**-2.4**	***86.4***
CEM	-55.9	*50.0*	**5.7**	***61.7***	**-15.0**	***58.9***	**35.2**	***61.7***	**16.0**	***87.7***
PTB	-60.5	*22.0*	**1.1**	***42.3***	**-19.6**	***38.1***	**30.6**	***42.2***	**11.4**	***75.3***
VSL	-63.8	*40.0*	**-2.2**	***53.9***	**-22.9**	***50.7***	**27.3**	***53.9***	**8.1**	***82.4***
OMH	-61.1	*100.0*	**0.5**	***106.4***	**-20.2**	***104.8***	**30.0**	***106.3***	**10.8**	***123.3***
JV	-45.5	*48.1*	**16.1**	***60.2***	**-4.6**	***57.3***	**45.6**	***60.1***	**26.4**	***86.6***
UME	-49.9	*56.1*	**11.7**	***66.8***	**-9.0**	***64.2***	**41.2**	***66.7***	**22.0**	***91.3***
METAS	-56.0	*26.1*	**5.6**	***44.6***	**-15.1**	***40.7***	**35.1**	***44.5***	**15.9**	***76.6***
CMI	-73.0	*80.0*	**-11.4**	***87.8***	**-32.1**	***85.9***	**18.1**	***87.8***	**-1.1**	***107.7***

Table 2q : Degree of equivalence at 500 V / 100 kHz (1/4)

Voltage : 500 V			DANIAmet-AREPA		NPL		SP		IEN	
Frequency : 100 kHz			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
(2/4)			-53.9	*41.1*	-68.9	*46.1*	-48.9	*21.1*	-74.3	*47.7*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-61.6	*36.1*	**-7.7**	***54.8***	**7.3**	***58.6***	**-12.7**	***41.9***	**12.7**	***59.9***
BEV	-40.9	*31.1*	**13.0**	***51.6***	**28.0**	***55.7***	**8.0**	***37.6***	**33.4**	***57.0***
MIKES	-91.1	*36.0*	**-37.2**	***54.7***	**-22.2**	***58.5***	**-42.2**	***41.8***	**-16.8**	***59.8***
INETI	-71.9	*72.0*	**-18.0**	***83.0***	**-3.0**	***85.5***	**-23.0**	***75.1***	**2.4**	***86.4***
DANIAmet-AREPA	-53.9	*41.1*			**15.0**	***61.8***	**-5.0**	***46.2***	**20.4**	***63.0***
NPL	-68.9	*46.1*	**-15.0**	***61.8***			**-20.0**	***50.7***	**5.4**	***66.4***
SP	-48.9	*21.1*	**5.0**	***46.2***	**20.0**	***50.7***			**25.4**	***52.2***
IEN	-74.3	*47.7*	**-20.4**	***63.0***	**-5.4**	***66.4***	**-25.4**	***52.2***		
CEM	-55.9	*50.0*	**-2.0**	***64.8***	**13.0**	***68.1***	**-7.0**	***54.3***	**18.4**	***69.2***
PTB	-60.5	*22.0*	**-6.6**	***34.8***	**8.4**	***51.1***	**-11.6**	***30.5***	**13.8**	***52.6***
VSL	-63.8	*40.0*	**-9.9**	***57.4***	**5.1**	***61.1***	**-14.9**	***45.3***	**10.5**	***62.3***
OMH	-61.1	*100.0*	**-7.2**	***108.2***	**7.8**	***110.2***	**-12.2**	***102.3***	**13.2**	***110.8***
JV	-45.5	*48.1*	**8.4**	***63.3***	**23.4**	***66.7***	**3.4**	***52.6***	**28.8**	***67.8***
UME	-49.9	*56.1*	**4.0**	***69.6***	**19.0**	***72.7***	**-1.0**	***60.0***	**24.4**	***73.7***
METAS	-56.0	*26.1*	**-2.1**	***48.7***	**12.9**	***53.0***	**-7.1**	***33.6***	**18.3**	***54.4***
CMI	-73.0	*80.0*	**-19.1**	***90.0***	**-4.1**	***92.4***	**-24.1**	***82.8***	**1.3**	***93.2***

Table 2r : Degree of equivalence at 500 V / 100 kHz (2/4)

Voltage : 500 V Frequency : 100 kHz (3/4)			CEM		PTB		VSL		OMH	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-55.9	*50.0*	-60.5	*22.0*	-63.8	*40.0*	-61.1	*100.0*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-61.6	*36.1*	**-5.7**	***61.7***	**-1.1**	***42.3***	**2.2**	***53.9***	**-0.5**	***106.4***
BEV	-40.9	*31.1*	**15.0**	***58.9***	**19.6**	***38.1***	**22.9**	***50.7***	**20.2**	***104.8***
MIKES	-91.1	*36.0*	**-35.2**	***61.7***	**-30.6**	***42.2***	**-27.3**	***53.9***	**-30.0**	***106.3***
INETI	-71.9	*72.0*	**-16.0**	***87.7***	**-11.4**	***75.3***	**-8.1**	***82.4***	**-10.8**	***123.3***
DANIAmet-AREPA	-53.9	*41.1*	**2.0**	***64.8***	**6.6**	***34.8***	**9.9**	***57.4***	**7.2**	***108.2***
NPL	-68.9	*46.1*	**-13.0**	***68.1***	**-8.4**	***51.1***	**-5.1**	***61.1***	**-7.8**	***110.2***
SP	-48.9	*21.1*	**7.0**	***54.3***	**11.6**	***30.5***	**14.9**	***45.3***	**12.2**	***102.3***
IEN	-74.3	*47.7*	**-18.4**	***69.2***	**-13.8**	***52.6***	**-10.5**	***62.3***	**-13.2**	***110.8***
CEM	-55.9	*50.0*			**4.6**	***54.7***	**7.9**	***64.1***	**5.2**	***111.9***
PTB	-60.5	*22.0*	**-4.6**	***54.7***			**3.3**	***45.7***	**0.6**	***102.4***
VSL	-63.8	*40.0*	**-7.9**	***64.1***	**-3.3**	***45.7***			**-2.7**	***107.8***
OMH	-61.1	*100.0*	**-5.2**	***111.9***	**-0.6**	***102.4***	**2.7**	***107.8***		
JV	-45.5	*48.1*	**10.4**	***69.4***	**15.0**	***52.9***	**18.3**	***62.6***	**15.6**	***111.0***
UME	-49.9	*56.1*	**6.0**	***75.2***	**10.6**	***60.3***	**13.9**	***68.9***	**11.2**	***114.7***
METAS	-56.0	*26.1*	**-0.1**	***56.5***	**4.5**	***34.2***	**7.8**	***47.8***	**5.1**	***103.4***
CMI	-73.0	*80.0*	**-17.1**	***94.4***	**-12.5**	***83.0***	**-9.2**	***89.5***	**-11.9**	***128.1***

Table 2s : Degree of equivalence at 500 V / 100 kHz (3/4)

Voltage : 500 V Frequency : 100 kHz (4/4)			JV		UME		METAS		CMI	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-45.5	*48.1*	-49.9	*56.1*	-56.0	*26.1*	-73.0	*80.0*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-61.6	*36.1*	**-16.1**	***60.2***	**-11.7**	***66.8***	**-5.6**	***44.6***	**11.4**	***87.8***
BEV	-40.9	*31.1*	**4.6**	***57.3***	**9.0**	***64.2***	**15.1**	***40.7***	**32.1**	***85.9***
MIKES	-91.1	*36.0*	**-45.6**	***60.1***	**-41.2**	***66.7***	**-35.1**	***44.5***	**-18.1**	***87.8***
INETI	-71.9	*72.0*	**-26.4**	***86.6***	**-22.0**	***91.3***	**-15.9**	***76.6***	**1.1**	***107.7***
DANIAmet-AREPA	-53.9	*41.1*	**-8.4**	***63.3***	**-4.0**	***69.6***	**2.1**	***48.7***	**19.1**	***90.0***
NPL	-68.9	*46.1*	**-23.4**	***66.7***	**-19.0**	***72.7***	**-12.9**	***53.0***	**4.1**	***92.4***
SP	-48.9	*21.1*	**-3.4**	***52.6***	**1.0**	***60.0***	**7.1**	***33.6***	**24.1**	***82.8***
IEN	-74.3	*47.7*	**-28.8**	***67.8***	**-24.4**	***73.7***	**-18.3**	***54.4***	**-1.3**	***93.2***
CEM	-55.9	*50.0*	**-10.4**	***69.4***	**-6.0**	***75.2***	**0.1**	***56.5***	**17.1**	***94.4***
PTB	-60.5	*22.0*	**-15.0**	***52.9***	**-10.6**	***60.3***	**-4.5**	***34.2***	**12.5**	***83.0***
VSL	-63.8	*40.0*	**-18.3**	***62.6***	**-13.9**	***68.9***	**-7.8**	***47.8***	**9.2**	***89.5***
OMH	-61.1	*100.0*	**-15.6**	***111.0***	**-11.2**	***114.7***	**-5.1**	***103.4***	**11.9**	***128.1***
JV	-45.5	*48.1*			**4.4**	***73.9***	**10.5**	***54.8***	**27.5**	***93.4***
UME	-49.9	*56.1*	**-4.4**	***73.9***			**6.1**	***61.9***	**23.1**	***97.8***
METAS	-56.0	*26.1*	**-10.5**	***54.8***	**-6.1**	***61.9***			**17.0**	***84.2***
CMI	-73.0	*80.0*	**-27.5**	***93.4***	**-23.1**	***97.8***	**-17.0**	***84.2***		

Table 2t : Degree of equivalence at 500 V / 100 kHz (4/4)

Voltage : 200 V Frequency : 1 kHz (1/4)			BNM-LNE		BEV		MIKES		INETI	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-0.1	*12.2*	1.5	*10.2*	0.6	*7.1*	6.5	*16.2*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-0.1	*12.2*			**-1.6**	***16.0***	**-0.7**	***14.2***	**-6.6**	***20.3***
BEV	1.5	*10.2*	**1.6**	***16.0***			**0.9**	***12.5***	**-5.0**	***19.2***
MIKES	0.6	*7.1*	**0.7**	***14.2***	**-0.9**	***12.5***			**-5.9**	***17.7***
INETI	6.5	*16.2*	**6.6**	***20.3***	**5.0**	***19.2***	**5.9**	***17.7***		
DANIAmet-AREPA	3.5	*11.2*	**3.6**	***16.6***	**2.0**	***15.2***	**2.9**	***13.3***	**-3.0**	***19.7***
NPL	6.5	*12.2*	**6.6**	***17.3***	**5.0**	***16.0***	**5.9**	***14.2***	**0.0**	***20.3***
SP	3.5	*7.3*	**3.6**	***14.3***	**2.0**	***12.6***	**2.9**	***10.2***	**-3.0**	***17.8***
IEN	2.2	*8.9*	**2.3**	***15.2***	**0.7**	***13.6***	**1.6**	***11.4***	**-4.3**	***18.5***
CEM	3.5	*22.1*	**3.6**	***25.3***	**2.0**	***24.4***	**2.9**	***23.3***	**-3.0**	***27.5***
PTB	-0.5	*8.0*	**-0.4**	***14.6***	**-2.0**	***13.0***	**-1.1**	***10.7***	**-7.0**	***18.1***
JV	0.6	*18.5*	**0.7**	***22.2***	**-0.9**	***21.2***	**0.0**	***19.9***	**-5.9**	***24.6***
UME	0.3	*18.1*	**0.4**	***21.9***	**-1.2**	***20.8***	**-0.3**	***19.5***	**-6.2**	***24.3***
METAS	-1.5	*6.3*	**-1.4**	***13.8***	**-3.0**	***12.0***	**-2.1**	***9.5***	**-8.0**	***17.4***
CMI	-1.1	*24.1*	**-1.0**	***27.1***	**-2.6**	***26.2***	**-1.7**	***25.2***	**-7.6**	***29.1***

Table 3a : Degree of equivalence at 200 V / 1 kHz (1/4)

Voltage : 200 V Frequency : 1 kHz (2/4)			DANIAmet-AREPA		NPL		SP		IEN	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			3.5	*11.2*	6.5	*12.2*	3.5	*7.3*	2.2	*8.9*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-0.1	*12.2*	**-3.6**	***16.6***	**-6.6**	***17.3***	**-3.6**	***14.3***	**-2.3**	***15.2***
BEV	1.5	*10.2*	**-2.0**	***15.2***	**-5.0**	***16.0***	**-2.0**	***12.6***	**-0.7**	***13.6***
MIKES	0.6	*7.1*	**-2.9**	***13.3***	**-5.9**	***14.2***	**-2.9**	***10.2***	**-1.6**	***11.4***
INETI	6.5	*16.2*	**3.0**	***19.7***	**0.0**	***20.3***	**3.0**	***17.8***	**4.3**	***18.5***
DANIAmet-AREPA	3.5	*11.2*			**-3.0**	***16.6***	**0.0**	***13.4***	**1.3**	***14.4***
NPL	6.5	*12.2*	**3.0**	***16.6***			**3.0**	***14.3***	**4.3**	***15.2***
SP	3.5	*7.3*	**0.0**	***13.4***	**-3.0**	***14.3***			**1.3**	***11.6***
IEN	2.2	*8.9*	**-1.3**	***14.4***	**-4.3**	***15.2***	**-1.3**	***11.6***		
CEM	3.5	*22.1*	**0.0**	***24.8***	**-3.0**	***25.3***	**0.0**	***23.3***	**1.3**	***23.9***
PTB	-0.5	*8.0*	**-4.0**	***7.9***	**-7.0**	***14.6***	**-4.0**	***10.9***	**-2.7**	***12.0***
JV	0.6	*18.5*	**-2.9**	***21.7***	**-5.9**	***22.2***	**-2.9**	***19.9***	**-1.6**	***20.6***
UME	0.3	*18.1*	**-3.2**	***21.3***	**-6.2**	***21.9***	**-3.2**	***19.6***	**-1.9**	***20.2***
METAS	-1.5	*6.3*	**-5.0**	***12.9***	**-8.0**	***13.8***	**-5.0**	***9.7***	**-3.7**	***11.0***
CMI	-1.1	*24.1*	**-4.6**	***26.6***	**-7.6**	***27.1***	**-4.6**	***25.2***	**-3.3**	***25.7***

Table 3b : Degree of equivalence at 200 V / 1 kHz (2/4)

Voltage : 200 V			CEM		PTB		JV		UME	
Frequency : 1 kHz			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
(3/4)			3.5	*22.1*	-0.5	*8.0*	0.6	*18.5*	0.3	*18.1*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-0.1	*12.2*	**-3.6**	***25.3***	**0.4**	***14.6***	**-0.7**	***22.2***	**-0.4**	***21.9***
BEV	1.5	*10.2*	**-2.0**	***24.4***	**2.0**	***13.0***	**0.9**	***21.2***	**1.2**	***20.8***
MIKES	0.6	*7.1*	**-2.9**	***23.3***	**1.1**	***10.7***	**0.0**	***19.9***	**0.3**	***19.5***
INETI	6.5	*16.2*	**3.0**	***27.5***	**7.0**	***18.1***	**5.9**	***24.6***	**6.2**	***24.3***
DANIAmet-AREPA	3.5	*11.2*	**0.0**	***24.8***	**4.0**	***7.9***	**2.9**	***21.7***	**3.2**	***21.3***
NPL	6.5	*12.2*	**3.0**	***25.3***	**7.0**	***14.6***	**5.9**	***22.2***	**6.2**	***21.9***
SP	3.5	*7.3*	**0.0**	***23.3***	**4.0**	***10.9***	**2.9**	***19.9***	**3.2**	***19.6***
IEN	2.2	*8.9*	**-1.3**	***23.9***	**2.7**	***12.0***	**1.6**	***20.6***	**1.9**	***20.2***
CEM	3.5	*22.1*			**4.0**	***23.6***	**2.9**	***28.9***	**3.2**	***28.6***
PTB	-0.5	*8.0*	**-4.0**	***23.6***			**-1.1**	***20.2***	**-0.8**	***19.8***
JV	0.6	*18.5*	**-2.9**	***28.9***	**1.1**	***20.2***			**0.3**	***25.9***
UME	0.3	*18.1*	**-3.2**	***28.6***	**0.8**	***19.8***	**-0.3**	***25.9***		
METAS	-1.5	*6.3*	**-5.0**	***23.0***	**-1.0**	***10.2***	**-2.1**	***19.6***	**-1.8**	***19.2***
CMI	-1.1	*24.1*	**-4.6**	***32.7***	**-0.6**	***25.4***	**-1.7**	***30.4***	**-1.4**	***30.2***

Table 3c : Degree of equivalence at 200 V / 1 kHz (3/4)

Voltage : 200 V			METAS		CMI	
Frequency : 1 kHz			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
(4/4)			-1.5	*6.3*	-1.1	*24.1*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$				
BNM-LNE	-0.1	*12.2*	**1.4**	***13.8***	**1.0**	***27.1***
BEV	1.5	*10.2*	**3.0**	***12.0***	**2.6**	***26.2***
MIKES	0.6	*7.1*	**2.1**	***9.5***	**1.7**	***25.2***
INETI	6.5	*16.2*	**8.0**	***17.4***	**7.6**	***29.1***
DANIAmet-AREPA	3.5	*11.2*	**5.0**	***12.9***	**4.6**	***26.6***
NPL	6.5	*12.2*	**8.0**	***13.8***	**7.6**	***27.1***
SP	3.5	*7.3*	**5.0**	***9.7***	**4.6**	***25.2***
IEN	2.2	*8.9*	**3.7**	***11.0***	**3.3**	***25.7***
CEM	3.5	*22.1*	**5.0**	***23.0***	**4.6**	***32.7***
PTB	-0.5	*8.0*	**1.0**	***10.2***	**0.6**	***25.4***
JV	0.6	*18.5*	**2.1**	***19.6***	**1.7**	***30.4***
UME	0.3	*18.1*	**1.8**	***19.2***	**1.4**	***30.2***
METAS	-1.5	*6.3*			**-0.4**	***25.0***
CMI	-1.1	*24.1*	**0.4**	***25.0***		

Table 3d : Degree of equivalence at 200 V / 1 kHz (4/4)

Voltage : 200 V Frequency : 10 kHz (1/4)			BNM-LNE		BEV		MIKES		INETI	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-5.8	*13.1*	-0.6	*10.2*	-1.8	*5.9*	2.4	*16.1*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-5.8	*13.1*			**-5.2**	***16.7***	**-4.0**	***14.4***	**-8.2**	***20.8***
BEV	-0.6	*10.2*	**5.2**	***16.7***			**1.2**	***11.8***	**-3.0**	***19.1***
MIKES	-1.8	*5.9*	**4.0**	***14.4***	**-1.2**	***11.8***			**-4.2**	***17.2***
INETI	2.4	*16.1*	**8.2**	***20.8***	**3.0**	***19.1***	**4.2**	***17.2***		
DANIAmet-AREPA	0.4	*11.1*	**6.2**	***17.2***	**1.0**	***15.1***	**2.2**	***12.6***	**-2.0**	***19.6***
NPL	-7.6	*12.1*	**-1.8**	***17.9***	**-7.0**	***15.9***	**-5.8**	***13.5***	**-10.0**	***20.2***
SP	2.4	*8.2*	**8.2**	***15.5***	**3.0**	***13.1***	**4.2**	***10.2***	**0.0**	***18.1***
IEN	-3.6	*9.0*	**2.2**	***15.9***	**-3.0**	***13.7***	**-1.8**	***10.8***	**-6.0**	***18.5***
CEM	3.4	*22.1*	**9.2**	***25.7***	**4.0**	***24.4***	**5.2**	***22.9***	**1.0**	***27.4***
PTB	-3.3	*8.0*	**2.5**	***15.4***	**-2.7**	***13.0***	**-1.5**	***10.0***	**-5.7**	***18.0***
JV	-1.5	*18.5*	**4.3**	***22.7***	**-0.9**	***21.2***	**0.3**	***19.5***	**-3.9**	***24.6***
UME	-2.2	*18.1*	**3.6**	***22.4***	**-1.6**	***20.8***	**-0.4**	***19.1***	**-4.6**	***24.3***
METAS	-4.4	*6.2*	**1.4**	***14.5***	**-3.8**	***12.0***	**-2.6**	***8.6***	**-6.8**	***17.3***
CMI	-10.2	*24.1*	**-4.4**	***27.5***	**-9.6**	***26.2***	**-8.4**	***24.9***	**-12.6**	***29.0***

Table 3e : Degree of equivalence at 200 V / 10 kHz (1/4)

Voltage : 200 V Frequency : 10 kHz (2/4)			DANIAmet-AREPA		NPL		SP		IEN	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			0.4	*11.1*	-7.6	*12.1*	2.4	*8.2*	-3.6	*9.0*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-5.8	*13.1*	**-6.2**	***17.2***	**1.8**	***17.9***	**-8.2**	***15.5***	**-2.2**	***15.9***
BEV	-0.6	*10.2*	**-1.0**	***15.1***	**7.0**	***15.9***	**-3.0**	***13.1***	**3.0**	***13.7***
MIKES	-1.8	*5.9*	**-2.2**	***12.6***	**5.8**	***13.5***	**-4.2**	***10.2***	**1.8**	***10.8***
INETI	2.4	*16.1*	**2.0**	***19.6***	**10.0**	***20.2***	**0.0**	***18.1***	**6.0**	***18.5***
DANIAmet-AREPA	0.4	*11.1*			**8.0**	***16.5***	**-2.0**	***13.9***	**4.0**	***14.3***
NPL	-7.6	*12.1*	**-8.0**	***16.5***			**-10.0**	***14.7***	**-4.0**	***15.1***
SP	2.4	*8.2*	**2.0**	***13.9***	**10.0**	***14.7***			**6.0**	***12.2***
IEN	-3.6	*9.0*	**-4.0**	***14.3***	**4.0**	***15.1***	**-6.0**	***12.2***		
CEM	3.4	*22.1*	**3.0**	***24.8***	**11.0**	***25.2***	**1.0**	***23.6***	**7.0**	***23.9***
PTB	-3.3	*8.0*	**-3.7**	***7.7***	**4.3**	***14.6***	**-5.7**	***11.5***	**0.3**	***12.1***
JV	-1.5	*18.5*	**-1.9**	***21.6***	**6.1**	***22.2***	**-3.9**	***20.3***	**2.1**	***20.6***
UME	-2.2	*18.1*	**-2.6**	***21.3***	**5.4**	***21.8***	**-4.6**	***19.9***	**1.4**	***20.3***
METAS	-4.4	*6.2*	**-4.8**	***12.8***	**3.2**	***13.6***	**-6.8**	***10.3***	**-0.8**	***11.0***
CMI	-10.2	*24.1*	**-10.6**	***26.6***	**-2.6**	***27.0***	**-12.6**	***25.5***	**-6.6**	***25.8***

Table 3f : Degree of equivalence at 200 V / 10 kHz (2/4)

Voltage : 200 V Frequency : 10 kHz (3/4)			CEM		PTB		JV		UME	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			3.4	*22.1*	-3.3	*8.0*	-1.5	*18.5*	-2.2	*18.1*
			$\mathbf{D_{i,j}}$	$\boldsymbol{U_{i,j}}$	$\mathbf{D_{i,j}}$	$\boldsymbol{U_{i,j}}$	$\mathbf{D_{i,j}}$	$\boldsymbol{U_{i,j}}$	$\mathbf{D_{i,j}}$	$\boldsymbol{U_{i,j}}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-5.8	*13.1*	**-9.2**	***25.7***	**-2.5**	***15.4***	**-4.3**	***22.7***	**-3.6**	***22.4***
BEV	-0.6	*10.2*	**-4.0**	***24.4***	**2.7**	***13.0***	**0.9**	***21.2***	**1.6**	***20.8***
MIKES	-1.8	*5.9*	**-5.2**	***22.9***	**1.5**	***10.0***	**-0.3**	***19.5***	**0.4**	***19.1***
INETI	2.4	*16.1*	**-1.0**	***27.4***	**5.7**	***18.0***	**3.9**	***24.6***	**4.6**	***24.3***
DANIAmet-AREPA	0.4	*11.1*	**-3.0**	***24.8***	**3.7**	***7.7***	**1.9**	***21.6***	**2.6**	***21.3***
NPL	-7.6	*12.1*	**-11.0**	***25.2***	**-4.3**	***14.6***	**-6.1**	***22.2***	**-5.4**	***21.8***
SP	2.4	*8.2*	**-1.0**	***23.6***	**5.7**	***11.5***	**3.9**	***20.3***	**4.6**	***19.9***
IEN	-3.6	*9.0*	**-7.0**	***23.9***	**-0.3**	***12.1***	**-2.1**	***20.6***	**-1.4**	***20.3***
CEM	3.4	*22.1*			**6.7**	***23.6***	**4.9**	***28.9***	**5.6**	***28.6***
PTB	-3.3	*8.0*	**-6.7**	***23.6***			**-1.8**	***20.2***	**-1.1**	***19.8***
JV	-1.5	*18.5*	**-4.9**	***28.9***	**1.8**	***20.2***			**0.7**	***25.9***
UME	-2.2	*18.1*	**-5.6**	***28.6***	**1.1**	***19.8***	**-0.7**	***25.9***		
METAS	-4.4	*6.2*	**-7.8**	***23.0***	**-1.1**	***10.2***	**-2.9**	***19.6***	**-2.2**	***19.2***
CMI	-10.2	*24.1*	**-13.6**	***32.7***	**-6.9**	***25.4***	**-8.7**	***30.4***	**-8.0**	***30.2***

Table 3g : Degree of equivalence at 200 V / 10 kHz (3/4)

Voltage : 200 V Frequency : 10 kHz (4/4)			METAS		CMI	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-4.4	*6.2*	-10.2	*24.1*
			$\mathbf{D_{i,j}}$	$\boldsymbol{U_{i,j}}$	$\mathbf{D_{i,j}}$	$\boldsymbol{U_{i,j}}$
	$d_{adj\ i}$	$u(d_{adj\ i})$				
BNM-LNE	-5.8	*13.1*	**-1.4**	***14.5***	**4.4**	***27.5***
BEV	-0.6	*10.2*	**3.8**	***12.0***	**9.6**	***26.2***
MIKES	-1.8	*5.9*	**2.6**	***8.6***	**8.4**	***24.9***
INETI	2.4	*16.1*	**6.8**	***17.3***	**12.6**	***29.0***
DANIAmet-AREPA	0.4	*11.1*	**4.8**	***12.8***	**10.6**	***26.6***
NPL	-7.6	*12.1*	**-3.2**	***13.6***	**2.6**	***27.0***
SP	2.4	*8.2*	**6.8**	***10.3***	**12.6**	***25.5***
IEN	-3.6	*9.0*	**0.8**	***11.0***	**6.6**	***25.8***
CEM	3.4	*22.1*	**7.8**	***23.0***	**13.6**	***32.7***
PTB	-3.3	*8.0*	**1.1**	***10.2***	**6.9**	***25.4***
JV	-1.5	*18.5*	**2.9**	***19.6***	**8.7**	***30.4***
UME	-2.2	*18.1*	**2.2**	***19.2***	**8.0**	***30.2***
METAS	-4.4	*6.2*			**5.8**	***24.9***
CMI	-10.2	*24.1*	**-5.8**	***24.9***		

Table 3h : Degree of equivalence at 200 V / 10 kHz (4/4)

Voltage : 200 V Frequency : 20 kHz (1/4)			BNM-LNE		BEV		MIKES		INETI	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-7.7	*13.1*	-3.6	*12.1*	-4.7	*6.6*	-1.6	*18.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-7.7	*13.1*			**-4.1**	***17.9***	**-3.0**	***14.7***	**-6.1**	***22.3***
BEV	-3.6	*12.1*	**4.1**	***17.9***			**1.1**	***13.8***	**-2.0**	***21.7***
MIKES	-4.7	*6.6*	**3.0**	***14.7***	**-1.1**	***13.8***			**-3.1**	***19.2***
INETI	-1.6	*18.0*	**6.1**	***22.3***	**2.0**	***21.7***	**3.1**	***19.2***		
DANIAmet-AREPA	-4.6	*11.1*	**3.1**	***17.2***	**-1.0**	***16.5***	**0.1**	***13.0***	**-3.0**	***21.2***
NPL	-9.6	*14.1*	**-1.9**	***19.3***	**-6.0**	***18.6***	**-4.9**	***15.6***	**-8.0**	***22.9***
SP	-1.6	*9.1*	**6.1**	***16.0***	**2.0**	***15.2***	**3.1**	***11.3***	**0.0**	***20.2***
IEN	-11.0	*12.9*	**-3.3**	***18.4***	**-7.4**	***17.7***	**-6.3**	***14.5***	**-9.4**	***22.2***
CEM	-0.6	*22.0*	**7.1**	***25.7***	**3.0**	***25.2***	**4.1**	***23.0***	**1.0**	***28.5***
PTB	-7.3	*8.0*	**0.4**	***15.4***	**-3.7**	***14.6***	**-2.6**	***10.4***	**-5.7**	***19.7***
JV	-5.1	*20.0*	**2.6**	***24.0***	**-1.5**	***23.4***	**-0.4**	***21.1***	**-3.5**	***27.0***
UME	-8.1	*24.0*	**-0.4**	***27.4***	**-4.5**	***26.9***	**-3.4**	***24.9***	**-6.5**	***30.0***
METAS	-7.5	*6.1*	**0.2**	***14.5***	**-3.9**	***13.6***	**-2.8**	***9.0***	**-5.9**	***19.1***
CMI	-10.3	*28.0*	**-2.6**	***31.0***	**-6.7**	***30.6***	**-5.6**	***28.8***	**-8.7**	***33.3***

Table 3i : Degree of equivalence at 200 V / 20 kHz (1/4)

Voltage : 200 V Frequency : 20 kHz (2/4)			DANIAmet-AREPA		NPL		SP		IEN	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-4.6	*11.1*	-9.6	*14.1*	-1.6	*9.1*	-11.0	*12.9*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-7.7	*13.1*	**-3.1**	***17.2***	**1.9**	***19.3***	**-6.1**	***16.0***	**3.3**	***18.4***
BEV	-3.6	*12.1*	**1.0**	***16.5***	**6.0**	***18.6***	**-2.0**	***15.2***	**7.4**	***17.7***
MIKES	-4.7	*6.6*	**-0.1**	***13.0***	**4.9**	***15.6***	**-3.1**	***11.3***	**6.3**	***14.5***
INETI	-1.6	*18.0*	**3.0**	***21.2***	**8.0**	***22.9***	**0.0**	***20.2***	**9.4**	***22.2***
DANIAmet-AREPA	-4.6	*11.1*			**5.0**	***18.0***	**-3.0**	***14.4***	**6.4**	***17.1***
NPL	-9.6	*14.1*	**-5.0**	***18.0***			**-8.0**	***16.8***	**1.4**	***19.2***
SP	-1.6	*9.1*	**3.0**	***14.4***	**8.0**	***16.8***			**9.4**	***15.8***
IEN	-11.0	*12.9*	**-6.4**	***17.1***	**-1.4**	***19.2***	**-9.4**	***15.8***		
CEM	-0.6	*22.0*	**4.0**	***24.7***	**9.0**	***26.2***	**1.0**	***23.9***	**10.4**	***25.6***
PTB	-7.3	*8.0*	**-2.7**	***7.7***	**2.3**	***16.3***	**-5.7**	***12.2***	**3.7**	***15.2***
JV	-5.1	*20.0*	**-0.5**	***22.9***	**4.5**	***24.5***	**-3.5**	***22.0***	**5.9**	***23.8***
UME	-8.1	*24.0*	**-3.5**	***26.5***	**1.5**	***27.9***	**-6.5**	***25.7***	**2.9**	***27.3***
METAS	-7.5	*6.1*	**-2.9**	***12.7***	**2.1**	***15.4***	**-5.9**	***11.0***	**3.5**	***14.3***
CMI	-10.3	*28.0*	**-5.7**	***30.2***	**-0.7**	***31.4***	**-8.7**	***29.5***	**0.7**	***30.9***

Table 3j : Degree of equivalence at 200 V /20 kHz (2/4)

Voltage : 200 V Frequency : 20 kHz (3/4)			CEM		PTB		JV		UME	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-0.6	*22.0*	-7.3	*8.0*	-5.1	*20.0*	-8.1	*24.0*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-7.7	*13.1*	**-7.1**	***25.7***	**-0.4**	***15.4***	**-2.6**	***24.0***	**0.4**	***27.4***
BEV	-3.6	*12.1*	**-3.0**	***25.2***	**3.7**	***14.6***	**1.5**	***23.4***	**4.5**	***26.9***
MIKES	-4.7	*6.6*	**-4.1**	***23.0***	**2.6**	***10.4***	**0.4**	***21.1***	**3.4**	***24.9***
INETI	-1.6	*18.0*	**-1.0**	***28.5***	**5.7**	***19.7***	**3.5**	***27.0***	**6.5**	***30.0***
DANIAmet-AREPA	-4.6	*11.1*	**-4.0**	***24.7***	**2.7**	***7.7***	**0.5**	***22.9***	**3.5**	***26.5***
NPL	-9.6	*14.1*	**-9.0**	***26.2***	**-2.3**	***16.3***	**-4.5**	***24.5***	**-1.5**	***27.9***
SP	-1.6	*9.1*	**-1.0**	***23.9***	**5.7**	***12.2***	**3.5**	***22.0***	**6.5**	***25.7***
IEN	-11.0	*12.9*	**-10.4**	***25.6***	**-3.7**	***15.2***	**-5.9**	***23.8***	**-2.9**	***27.3***
CEM	-0.6	*22.0*			**6.7**	***23.5***	**4.5**	***29.8***	**7.5**	***32.6***
PTB	-7.3	*8.0*	**-6.7**	***23.5***			**-2.2**	***21.6***	**0.8**	***25.3***
JV	-5.1	*20.0*	**-4.5**	***29.8***	**2.2**	***21.6***			**3.0**	***31.3***
UME	-8.1	*24.0*	**-7.5**	***32.6***	**-0.8**	***25.3***	**-3.0**	***31.3***		
METAS	-7.5	*6.1*	**-6.9**	***22.9***	**-0.2**	***10.1***	**-2.4**	***21.0***	**0.6**	***24.8***
CMI	-10.3	*28.0*	**-9.7**	***35.7***	**-3.0**	***29.2***	**-5.2**	***34.5***	**-2.2**	***36.9***

Table 3k : Degree of equivalence at 200 V / 20 kHz (3/4)

Voltage : 200 V Frequency : 20 kHz (4/4)			METAS		CMI	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-7.5	*6.1*	-10.3	*28.0*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\ i}$	$u(d_{adj\ i})$				
BNM-LNE	-7.7	*13.1*	**-0.2**	***14.5***	**2.6**	***31.0***
BEV	-3.6	*12.1*	**3.9**	***13.6***	**6.7**	***30.6***
MIKES	-4.7	*6.6*	**2.8**	***9.0***	**5.6**	***28.8***
INETI	-1.6	*18.0*	**5.9**	***19.1***	**8.7**	***33.3***
DANIAmet-AREPA	-4.6	*11.1*	**2.9**	***12.7***	**5.7**	***30.2***
NPL	-9.6	*14.1*	**-2.1**	***15.4***	**0.7**	***31.4***
SP	-1.6	*9.1*	**5.9**	***11.0***	**8.7**	***29.5***
IEN	-11.0	*12.9*	**-3.5**	***14.3***	**-0.7**	***30.9***
CEM	-0.6	*22.0*	**6.9**	***22.9***	**9.7**	***35.7***
PTB	-7.3	*8.0*	**0.2**	***10.1***	**3.0**	***29.2***
JV	-5.1	*20.0*	**2.4**	***21.0***	**5.2**	***34.5***
UME	-8.1	*24.0*	**-0.6**	***24.8***	**2.2**	***36.9***
METAS	-7.5	*6.1*			**2.8**	***28.7***
CMI	-10.3	*28.0*	**-2.8**	***28.7***		

Table 3l : Degree of equivalence at 200 V / 20 kHz (4/4)

Voltage : 200 V Frequency : 50 kHz (1/4)			BNM-LNE		BEV		MIKES		INETI	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-28.2	*16.2*	-19.1	*16.2*	-20.2	*7.1*	-16.1	*20.1*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-28.2	*16.2*			**-9.1**	***23.0***	**-8.0**	***17.7***	**-12.1**	***25.9***
BEV	-19.1	*16.2*	**9.1**	***23.0***			**1.1**	***17.7***	**-3.0**	***25.9***
MIKES	-20.2	*7.1*	**8.0**	***17.7***	**-1.1**	***17.7***			**-4.1**	***21.4***
INETI	-16.1	*20.1*	**12.1**	***25.9***	**3.0**	***25.9***	**4.1**	***21.4***		
DANIAmet-AREPA	-23.1	*11.2*	**5.1**	***19.7***	**-4.0**	***19.7***	**-2.9**	***13.3***	**-7.0**	***23.1***
NPL	-23.1	*16.2*	**5.1**	***23.0***	**-4.0**	***23.0***	**-2.9**	***17.7***	**-7.0**	***25.9***
SP	-18.1	*13.2*	**10.1**	***20.9***	**1.0**	***20.9***	**2.1**	***15.0***	**-2.0**	***24.1***
IEN	-31.8	*18.3*	**-3.6**	***24.5***	**-12.7**	***24.5***	**-11.6**	***19.7***	**-15.7**	***27.2***
CEM	-19.1	*24.1*	**9.1**	***29.1***	**0.0**	***29.1***	**1.1**	***25.2***	**-3.0**	***31.4***
PTB	-22.7	*10.0*	**5.5**	***19.1***	**-3.6**	***19.1***	**-2.5**	***12.3***	**-6.6**	***22.5***
JV	-19.3	*26.1*	**8.9**	***30.8***	**-0.2**	***30.8***	**0.9**	***27.1***	**-3.2**	***33.0***
UME	-21.3	*30.1*	**6.9**	***34.2***	**-2.2**	***34.2***	**-1.1**	***31.0***	**-5.2**	***36.2***
METAS	-22.8	*9.2*	**5.4**	***18.7***	**-3.7**	***18.7***	**-2.6**	***11.7***	**-6.7**	***22.2***
CMI	-26.7	*36.1*	**1.5**	***39.6***	**-7.6**	***39.6***	**-6.5**	***36.8***	**-10.6**	***41.4***

Table 3m : Degree of equivalence at 200 V / 50 kHz (1/4)

Voltage : 200 V Frequency : 50 kHz (2/4)			DANIAmet-AREPA		NPL		SP		IEN	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-23.1	*11.2*	-23.1	*16.2*	-18.1	*13.2*	-31.8	*18.3*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-28.2	*16.2*	**-5.1**	***19.7***	**-5.1**	***23.0***	**-10.1**	***20.9***	**3.6**	***24.5***
BEV	-19.1	*16.2*	**4.0**	***19.7***	**4.0**	***23.0***	**-1.0**	***20.9***	**12.7**	***24.5***
MIKES	-20.2	*7.1*	**2.9**	***13.3***	**2.9**	***17.7***	**-2.1**	***15.0***	**11.6**	***19.7***
INETI	-16.1	*20.1*	**7.0**	***23.1***	**7.0**	***25.9***	**2.0**	***24.1***	**15.7**	***27.2***
DANIAmet-AREPA	-23.1	*11.2*			**0.0**	***19.7***	**-5.0**	***17.4***	**8.7**	***21.5***
NPL	-23.1	*16.2*	**0.0**	***19.7***			**-5.0**	***20.9***	**8.7**	***24.5***
SP	-18.1	*13.2*	**5.0**	***17.4***	**5.0**	***20.9***			**13.7**	***22.6***
IEN	-31.8	*18.3*	**-8.7**	***21.5***	**-8.7**	***24.5***	**-13.7**	***22.6***		
CEM	-19.1	*24.1*	**4.0**	***26.6***	**4.0**	***29.1***	**-1.0**	***27.5***	**12.7**	***30.3***
PTB	-22.7	*10.0*	**0.4**	***5.1***	**0.4**	***19.1***	**-4.6**	***16.6***	**9.1**	***20.9***
JV	-19.3	*26.1*	**3.8**	***28.5***	**3.8**	***30.8***	**-1.2**	***29.3***	**12.5**	***31.9***
UME	-21.3	*30.1*	**1.8**	***32.2***	**1.8**	***34.2***	**-3.2**	***32.9***	**10.5**	***35.3***
METAS	-22.8	*9.2*	**0.3**	***14.5***	**0.3**	***18.7***	**-4.7**	***16.1***	**9.0**	***20.5***
CMI	-26.7	*36.1*	**-3.6**	***37.8***	**-3.6**	***39.6***	**-8.6**	***38.5***	**5.1**	***40.5***

Table 3n : Degree of equivalence at 200 V / 50 kHz (2/4)

Voltage : 200 V Frequency : 50 kHz (3/4)			CEM		PTB		JV		UME	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-19.1	*24.1*	-22.7	*10.0*	-19.3	*26.1*	-21.3	*30.1*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-28.2	*16.2*	**-9.1**	***29.1***	**-5.5**	***19.1***	**-8.9**	***30.8***	**-6.9**	***34.2***
BEV	-19.1	*16.2*	**0.0**	***29.1***	**3.6**	***19.1***	**0.2**	***30.8***	**2.2**	***34.2***
MIKES	-20.2	*7.1*	**-1.1**	***25.2***	**2.5**	***12.3***	**-0.9**	***27.1***	**1.1**	***31.0***
INETI	-16.1	*20.1*	**3.0**	***31.4***	**6.6**	***22.5***	**3.2**	***33.0***	**5.2**	***36.2***
DANIAmet-AREPA	-23.1	*11.2*	**-4.0**	***26.6***	**-0.4**	***5.1***	**-3.8**	***28.5***	**-1.8**	***32.2***
NPL	-23.1	*16.2*	**-4.0**	***29.1***	**-0.4**	***19.1***	**-3.8**	***30.8***	**-1.8**	***34.2***
SP	-18.1	*13.2*	**1.0**	***27.5***	**4.6**	***16.6***	**1.2**	***29.3***	**3.2**	***32.9***
IEN	-31.8	*18.3*	**-12.7**	***30.3***	**-9.1**	***20.9***	**-12.5**	***31.9***	**-10.5**	***35.3***
CEM	-19.1	*24.1*			**3.6**	***26.1***	**0.2**	***35.6***	**2.2**	***38.6***
PTB	-22.7	*10.0*	**-3.6**	***26.1***			**-3.4**	***28.0***	**-1.4**	***31.8***
JV	-19.3	*26.1*	**-0.2**	***35.6***	**3.4**	***28.0***			**2.0**	***39.9***
UME	-21.3	*30.1*	**-2.2**	***38.6***	**1.4**	***31.8***	**-2.0**	***39.9***		
METAS	-22.8	*9.2*	**-3.7**	***25.8***	**-0.1**	***13.6***	**-3.5**	***27.7***	**-1.5**	***31.5***
CMI	-26.7	*36.1*	**-7.6**	***43.5***	**-4.0**	***37.5***	**-7.4**	***44.6***	**-5.4**	***47.1***

Table 3o : Degree of equivalence at 200 V / 50 kHz (3/4)

Voltage : 200 V Frequency : 50 kHz (4/4)			METAS		CMI	
			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
			-22.8	*9.2*	-26.7	*36.1*
			$D_{i,j}$	**$U_{i,j}$**	**$D_{i,j}$**	**$U_{i,j}$**
	$d_{adj\,i}$	$u(d_{adj\,i})$				
BNM-LNE	-28.2	*16.2*	**-5.4**	***18.7***	**-1.5**	***39.6***
BEV	-19.1	*16.2*	**3.7**	***18.7***	**7.6**	***39.6***
MIKES	-20.2	*7.1*	**2.6**	***11.7***	**6.5**	***36.8***
INETI	-16.1	*20.1*	**6.7**	***22.2***	**10.6**	***41.4***
DANIAmet-AREPA	-23.1	*11.2*	**-0.3**	***14.5***	**3.6**	***37.8***
NPL	-23.1	*16.2*	**-0.3**	***18.7***	**3.6**	***39.6***
SP	-18.1	*13.2*	**4.7**	***16.1***	**8.6**	***38.5***
IEN	-31.8	*18.3*	**-9.0**	***20.5***	**-5.1**	***40.5***
CEM	-19.1	*24.1*	**3.7**	***25.8***	**7.6**	***43.5***
PTB	-22.7	*10.0*	**0.1**	***13.6***	**4.0**	***37.5***
JV	-19.3	*26.1*	**3.5**	***27.7***	**7.4**	***44.6***
UME	-21.3	*30.1*	**1.5**	***31.5***	**5.4**	***47.1***
METAS	-22.8	*9.2*			**3.9**	***37.3***
CMI	-26.7	*36.1*	**-3.9**	***37.3***		

Table 3p : Degree of equivalence at 200 V / 50 kHz (4/4)

Voltage : 200 V			BNM-LNE		BEV		MIKES		INETI	
Frequency : 100 kHz			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
(1/4)			-70.7	*16.2*	-52.2	*21.1*	-54.5	*8.5*	-49.2	*30.1*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-70.7	*16.2*			**-18.5**	***26.7***	**-16.2**	***18.3***	**-21.5**	***34.2***
BEV	-52.2	*21.1*	**18.5**	***26.7***			**2.3**	***22.8***	**-3.0**	***36.8***
MIKES	-54.5	*8.5*	**16.2**	***18.3***	**-2.3**	***22.8***			**-5.3**	***31.3***
INETI	-49.2	*30.1*	**21.5**	***34.2***	**3.0**	***36.8***	**5.3**	***31.3***		
DANIAmet-AREPA	-66.2	*26.1*	**4.5**	***30.8***	**-14.0**	***33.6***	**-11.7**	***27.5***	**-17.0**	***39.9***
NPL	-61.2	*20.1*	**9.5**	***25.9***	**-9.0**	***29.2***	**-6.7**	***21.9***	**-12.0**	***36.2***
SP	-49.2	*19.2*	**21.5**	***25.2***	**3.0**	***28.6***	**5.3**	***21.0***	**0.0**	***35.8***
IEN	-71.5	*42.5*	**-0.8**	***45.5***	**-19.3**	***47.5***	**-17.0**	***43.4***	**-22.3**	***52.1***
CEM	-54.2	*28.9*	**16.5**	***33.2***	**-2.0**	***35.8***	**0.3**	***30.2***	**-5.0**	***41.8***
PTB	-61.9	*22.0*	**8.8**	***27.4***	**-9.7**	***30.5***	**-7.4**	***23.6***	**-12.7**	***37.3***
JV	-48.6	*36.1*	**22.1**	***39.6***	**3.6**	***41.9***	**5.9**	***37.1***	**0.6**	***47.1***
UME	-59.3	*44.1*	**11.4**	***47.0***	**-7.1**	***48.9***	**-4.8**	***45.0***	**-10.1**	***53.4***
METAS	-60.3	*24.1*	**10.4**	***29.1***	**-8.1**	***32.1***	**-5.8**	***25.6***	**-11.1**	***38.6***
CMI	-63.3	*60.0*	**7.4**	***62.2***	**-11.1**	***63.7***	**-8.8**	***60.6***	**-14.1**	***67.2***

Table 3q : Degree of equivalence at 200 V / 100 kHz (1/4)

Voltage : 200 V			DANIAmet-AREPA		NPL		SP		IEN	
Frequency : 100 kHz			$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$	$d_{adj\,j}$	$u(d_{adj\,j})$
(2/4)			-66.2	*26.1*	-61.2	*20.1*	-49.2	*19.2*	-71.5	*42.5*
			$D_{i,j}$	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***	**$D_{i,j}$**	***$U_{i,j}$***
	$d_{adj\,i}$	$u(d_{adj\,i})$								
BNM-LNE	-70.7	*16.2*	**-4.5**	***30.8***	**-9.5**	***25.9***	**-21.5**	***25.2***	**0.8**	***45.5***
BEV	-52.2	*21.1*	**14.0**	***33.6***	**9.0**	***29.2***	**-3.0**	***28.6***	**19.3**	***47.5***
MIKES	-54.5	*8.5*	**11.7**	***27.5***	**6.7**	***21.9***	**-5.3**	***21.0***	**17.0**	***43.4***
INETI	-49.2	*30.1*	**17.0**	***39.9***	**12.0**	***36.2***	**0.0**	***35.8***	**22.3**	***52.1***
DANIAmet-AREPA	-66.2	*26.1*			**-5.0**	***33.0***	**-17.0**	***32.5***	**5.3**	***49.9***
NPL	-61.2	*20.1*	**5.0**	***33.0***			**-12.0**	***27.8***	**10.3**	***47.1***
SP	-49.2	*19.2*	**17.0**	***32.5***	**12.0**	***27.8***			**22.3**	***46.7***
IEN	-71.5	*42.5*	**-5.3**	***49.9***	**-10.3**	***47.1***	**-22.3**	***46.7***		
CEM	-54.2	*28.9*	**12.0**	***39.0***	**7.0**	***35.3***	**-5.0**	***34.7***	**17.3**	***51.4***
PTB	-61.9	*22.0*	**4.3**	***14.1***	**-0.7**	***29.8***	**-12.7**	***29.2***	**9.6**	***47.9***
JV	-48.6	*36.1*	**17.6**	***44.6***	**12.6**	***41.4***	**0.6**	***40.9***	**22.9**	***55.8***
UME	-59.3	*44.1*	**6.9**	***51.3***	**1.9**	***48.5***	**-10.1**	***48.1***	**12.2**	***61.3***
METAS	-60.3	*24.1*	**5.9**	***35.6***	**0.9**	***31.4***	**-11.1**	***30.9***	**11.2**	***48.9***
CMI	-63.3	*60.0*	**2.9**	***65.5***	**-2.1**	***63.3***	**-14.1**	***63.0***	**8.2**	***73.6***

Table 3r : Degree of equivalence at 200 V / 100 kHz (2/4)

Voltage : 200 V Frequency : 100 kHz (3/4)			CEM		PTB		JV		UME	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-54.2	*28.9*	-61.9	*22.0*	-48.6	*36.1*	-59.3	*44.1*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$								
BNM-LNE	-70.7	*16.2*	**-16.5**	***33.2***	**-8.8**	***27.4***	**-22.1**	***39.6***	**-11.4**	***47.0***
BEV	-52.2	*21.1*	**2.0**	***35.8***	**9.7**	***30.5***	**-3.6**	***41.9***	**7.1**	***48.9***
MIKES	-54.5	*8.5*	**-0.3**	***30.2***	**7.4**	***23.6***	**-5.9**	***37.1***	**4.8**	***45.0***
INETI	-49.2	*30.1*	**5.0**	***41.8***	**12.7**	***37.3***	**-0.6**	***47.1***	**10.1**	***53.4***
DANIAmet-AREPA	-66.2	*26.1*	**-12.0**	***39.0***	**-4.3**	***14.1***	**-17.6**	***44.6***	**-6.9**	***51.3***
NPL	-61.2	*20.1*	**-7.0**	***35.3***	**0.7**	***29.8***	**-12.6**	***41.4***	**-1.9**	***48.5***
SP	-49.2	*19.2*	**5.0**	***34.7***	**12.7**	***29.2***	**-0.6**	***40.9***	**10.1**	***48.1***
IEN	-71.5	*42.5*	**-17.3**	***51.4***	**-9.6**	***47.9***	**-22.9**	***55.8***	**-12.2**	***61.3***
CEM	-54.2	*28.9*			**7.7**	***36.4***	**-5.6**	***46.3***	**5.1**	***52.8***
PTB	-61.9	*22.0*	**-7.7**	***36.4***			**-13.3**	***42.3***	**-2.6**	***49.3***
JV	-48.6	*36.1*	**5.6**	***46.3***	**13.3**	***42.3***			**10.7**	***57.0***
UME	-59.3	*44.1*	**-5.1**	***52.8***	**2.6**	***49.3***	**-10.7**	***57.0***		
METAS	-60.3	*24.1*	**-6.1**	***37.7***	**1.6**	***32.7***	**-11.7**	***43.5***	**-1.0**	***50.3***
CMI	-63.3	*60.0*	**-9.1**	***66.6***	**-1.4**	***64.0***	**-14.7**	***70.1***	**-4.0**	***74.5***

Table 3s : Degree of equivalence at 200 V / 100 kHz (3/4)

Voltage : 200 V Frequency : 100 kHz (4/4)			METAS		CMI	
			$d_{adj\ j}$	$u(d_{adj\ j})$	$d_{adj\ j}$	$u(d_{adj\ j})$
			-60.3	*24.1*	-63.3	*60.0*
			$D_{i,j}$	$U_{i,j}$	$D_{i,j}$	$U_{i,j}$
	$d_{adj\ i}$	$u(d_{adj\ i})$				
BNM-LNE	-70.7	*16.2*	**-10.4**	***29.1***	**-7.4**	***62.2***
BEV	-52.2	*21.1*	**8.1**	***32.1***	**11.1**	***63.7***
MIKES	-54.5	*8.5*	**5.8**	***25.6***	**8.8**	***60.6***
INETI	-49.2	*30.1*	**11.1**	***38.6***	**14.1**	***67.2***
DANIAmet-AREPA	-66.2	*26.1*	**-5.9**	***35.6***	**-2.9**	***65.5***
NPL	-61.2	*20.1*	**-0.9**	***31.4***	**2.1**	***63.3***
SP	-49.2	*19.2*	**11.1**	***30.9***	**14.1**	***63.0***
IEN	-71.5	*42.5*	**-11.2**	***48.9***	**-8.2**	***73.6***
CEM	-54.2	*28.9*	**6.1**	***37.7***	**9.1**	***66.6***
PTB	-61.9	*22.0*	**-1.6**	***32.7***	**1.4**	***64.0***
JV	-48.6	*36.1*	**11.7**	***43.5***	**14.7**	***70.1***
UME	-59.3	*44.1*	**1.0**	***50.3***	**4.0**	***74.5***
METAS	-60.3	*24.1*			**3.0**	***64.7***
CMI	-63.3	*60.0*	**-3.0**	***64.7***		

Table 3t : Degree of equivalence at 200 V / 100 kHz (4/4)

APPENDIX 2

Uncertainty budgets

UNCERTAINTY BUDGET FOR BNM-LNE (FRANCE)

STEP UP PROCEDURE			1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
PRIMARY STANDARD	**Voltage (V) :**	**3**					
(PTB 3D-MJTC)	**Standard uncertainty**		**1**	**1**	**1**	**2**	**2**
Step n° 1	Voltage (V) :	**5**					
Measurement uncertainty :		Type A	0.2	0.2	0.2	0.2	0.5
		Type B	1.5	1.5	1.5	1.5	1.5
Uncertainty arising from voltage dependence :			0	0	0	0	0
Resulting standard uncertainty			**1.9**	**1.9**	**1.9**	**2.6**	**2.6**
Step n° 2	Voltage (V) :	**10**					
Measurement uncertainty :		Type A	0.4	0.2	0.2	0.4	0.2
		Type B	1.8	1.8	1.8	1.8	1.8
Uncertainty arising from voltage dependence :			0	0	0	0	0
Resulting standard uncertainty			**2.7**	**2.7**	**2.7**	**3.2**	**3.2**
Step n° 3	Voltage (V) :	**20**					
Measurement uncertainty :		Type A	0.4	0.3	0.2	0.3	0.9
		Type B	2	2	2	2	2
Uncertainty arising from voltage dependence :			0	0	0	0	0
Resulting standard uncertainty			**3.4**	**3.4**	**3.4**	**3.8**	**3.9**
Step n° 4	Voltage (V) :	**30**					
Measurement uncertainty :		Type A	0.2	0.1	0.4	0.2	0.3
		Type B	1.1	1.1	1.1	1.1	1
Uncertainty arising from voltage dependence :			0	0	0	0	0
Resulting standard uncertainty			**3.6**	**3.6**	**3.6**	**4**	**4.1**
Step n° 5	Voltage (V) :	**50**					
Measurement uncertainty :		Type A	0.2	0.5	1	0.3	0.4
		Type B	1.3	1.3	1.3	1.3	1.3
Uncertainty arising from voltage dependence :			0	0	0	0	0
Resulting standard uncertainty			**3.9**	**3.9**	**4**	**4.3**	**4.4**
Step n° 6	Voltage (V) :	**100**					
Measurement uncertainty :		Type A	0.3	0.5	0.6	0.6	0.7
		Type B	1.9	1.9	1.9	1.9	1.9
Uncertainty arising from voltage dependence :			0	0	0	0	0
Resulting standard uncertainty			**4.4**	**4.4**	**4.5**	**4.8**	**4.9**
Step n° 7	Voltage (V) :	**200**					
Measurement uncertainty :		Type A	0.4	0.3	0.3	0.4	0.3
		Type B	2	2	2	2	2
Uncertainty arising from voltage dependence :			0	2	2	5	5
Resulting standard uncertainty			**4.9**	**5.3**	**5.4**	**7.3**	**7.3**
Step n° 8	Voltage (V) :	**300**					
Measurement uncertainty :		Type A	0.3	0.3	0.3	0.3	0.3
		Type B	1.1	1.1	1.1	1.1	1.1
Uncertainty arising from voltage dependence :			1	4	4	8	8
Resulting standard uncertainty			**5.2**	**6.8**	**6.9**	**10.9**	**10.9**
Step n° 9	Voltage (V) :	**500**					
Measurement uncertainty :		Type A	0.4	0.3	0.4	0.2	0.2
		Type B	1.4	1.4	1.4	1.4	1.4
Uncertainty arising from voltage dependence :			2	7	7	14	14
Resulting standard uncertainty			**5.8**	**9.9**	**10**	**17.8**	**17.8**
Step n° 10	Voltage (V) :	**1000**					
Measurement uncertainty :		Type A	0.6	0.6	0.4	0.5	0.5
		Type B	2	2	2	2	2
Uncertainty arising from voltage dependence :			4	14	14	29	29
Resulting standard uncertainty			**7.4**	**17.3**	**17.4**	**34.1**	**34.1**

TRAVELLING STANDARDS		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Measurement voltage (V) : 200						
Standard uncertainty of the reference standard :		4.9	5.3	5.4	7.3	7.3
Measurement uncertainty	Type A	0.2	0.7	0.9	0.6	0.6
	Type B	2	2	2	2	2
Resulting standard uncertainty (travelling standard)		5.3	5.8	5.9	7.6	7.6
Expanded uncertainty [k = 2] (travelling standard)		**10.6**	**11.6**	**11.8**	**15.2**	**15.2**
Measurement voltage (V) : 500						
Standard uncertainty of the reference standard :		5.8	9.9	10	17.8	17.8
Measurement uncertainty	Type A	0.3	0.4	0.4	0.2	0.5
	Type B	0.6	0.6	0.6	0.6	0.6
Resulting standard uncertainty (travelling standard)		5.9	10	10.1	17.9	17.9
Expanded uncertainty [k = 2] (travelling standard)		**11.8**	**20**	**20.2**	**35.8**	**35.8**
Measurement voltage (V) : 1000						
Standard uncertainty of the reference standard :		7.4	17.3	17.4	34.1	34.1
Measurement uncertainty	Type A	0.2	0.3	0.1	0.3	0.3
	Type B	0.8	0.8	0.8	0.8	0.8
Resulting standard uncertainty (travelling standard)		7.5	17.4	17.5	34.2	34.2
Expanded uncertainty [k = 2] (travelling standard)		**15**	**34.8**	**35**	**68.4**	**68.4**

Calculation of the uncertainties

The difference between the AC-DC differences d_x of the converter under test, and d_{ref} of the reference converter is given by (see the description of the measurement set up in [1]) :

$$d_x - d_{ref} = \frac{1}{n_{ref}}.[\frac{V_a}{V_c} - 1] - \frac{1}{n_x}.[\frac{k.V_a - V_{Da}}{k.V_c - V_{Dc}} - 1] = f(x_1, x_2, \ldots x_i, \ldots)$$

where :

- n_x (resp. n_{ref}) is a characteristic parameter of the converter under test (rep. reference) ;
- V_a (resp. V_c) is the measured output voltage of the reference converter in response to an AC (resp. DC) signal ;
- V_{da} (rsp. V_{Dc}) is a measured differential voltage between the outputs of both converters in response to an AC (resp. DC) signal ;
- k is the ratio of the resistive divider connected at the output of the converter under test.

For each measurement, the type B measurement uncertainty u_B is given by :

$$u_B = \sqrt{\sum_i [\frac{\partial f}{\partial x_i}]^2 . u_{Bi}^2}$$

where u_{Bi} is the uncertainty on x_i. The value of this component was taken equal to 5 parts in 10^3 for n_x and n_{ref}, 5 parts in 10^4 for k, V_a and V_c, and 5 parts in 10^6 for V_{Da} and V_{Dc}.

One determination of $d_x - d_{ref}$ is computed from a set of values of V_a, V_c, V_{da} and V_{Dc} measured during a sequence AC, DC+, DC-, AC, DC+, DC-, AC, DC+, DC-, AC, applied to the input of the converters, using a least mean square method, and then, can be associated with a standard deviation. The final value given for d_x is the weighted mean of four determinations $d_{x,i}$ (i = 1,…4), calculated using :

$$d_x = \frac{\sum_{i=1}^{i=4} d_{x,i} / u_{A,i}^2}{\sum_{i=1}^{i=4} 1/u_{A,i}^2}$$

where $u_{A,i}$ is the standard deviation calculated for $d_{x,i}$.

The type A uncertainty u_A, associated with d_x, is computed using :

$$u_A = \frac{\sum_{i=1}^{i=4} (d_{x,i} - d_x)^2 / u_{A,i}^2}{\sum_{i=1}^{i=4} 1/u_{A,i}^2}$$

The resulting standard uncertainty associated with d_x is finally given by :

$$u = \sqrt{u_A^2 + u_B^2 + u_{ref}^2 + u_{VoltDep}^2}$$

where u_{ref} is the uncertainty associated with the reference converter, and $u_{VoltDep}$, the uncertainty arising from the voltage level dependence (in the case of measurements performed in the frame of the step up procedure). This last uncertainty component was estimated from discrepancies observed between complementary measurements performed at two different voltage levels, assuming the same value of the AC-DC difference at both levels.

* * * * * * * * * *

[1] Andre POLETAEFF, "Automated Comparator for Accurate AC-DC Difference Measurement at the BNM-LCIE", *IEEE Trans. Instr. Meas.*, vol 48, n° 2, April 1999.

UNCERTAINTY BUDGET FOR BEV (AUSTRIA)

all contributions calculated as normal distribution for k=1

PTC 33 - PTC 26

frequency	PTB Cal.Cert. PTC 33 k=1 avr-98	StDev (10 meas.) sept-99	T-Connect (Spin1) juin-98	Lev.Dep (TC) sept-99	Heat.Eff. (5700;4808) avr-98	T-coup.Eff (2xK182) avr-98	Repeat sept-99 23/10/1998	uncert. PTC 26 k=1 1,5 volts
10 Hz	1	3.6	0.2	4.8	0.4	0.4	2.5	6.6
20 Hz	1	0.2	0.2	2.3	0.4	0.4	0.2	2.6
30 Hz	1	0.2	0.2	1.5	0.4	0.4	0.2	1.9
40 Hz	1	0.2	0.2	0.8	0.4	0.4	0.2	1.4
55 Hz	1	0.2	0.2	0.7	0.4	0.4	0.2	1.4
100 Hz	1	0.2	0.2	0.2	0.4	0.4	0.2	1.2
500 Hz	1	0.2	0.2	0.2	0.4	0.4	0.2	1.2
1 kHz	1	0.2	0.2	0.2	0.4	0.4	0.2	1.2
5 kHz	1	0.2	0.2	0.2	0.4	0.4	0.2	1.2
10 kHz	1	0.2	0.2	0.2	0.4	0.4	0.2	1.2
20 kHz	1	0.2	0.2	0.7	0.4	0.4	0.2	1.4
50 kHz	1.5	0.2	0.5	0.2	0.4	0.4	0.2	1.7
100 kHz	1.5	0.2	1	0.2	0.4	0.5	0.2	1.9
200 kHz	2.5	0.2	1.5	0.5	0.8	0.7	0.5	3.2
500 kHz	5	0.2	2	0.5	1.6	1.3	1.3	5.9
700 kHz	10	0.2	2.5	0.5	3.2	1.3	2	11.1
1 MHz	15	0.2	3	0.5	5	1.3	3	16.4

PTC 26 - PTC 29+250

frequency	StDev sept-99	T-Connect juin-98	Lev.Dep sept-99	Heat.Eff. avr-98	T-coup.Eff sept-99	Repeat sept-99 23/10/1998	uncert. PTC29+250 k=1 3,3 volts
10 Hz	0.5	0.2	2.6	0.4	0.4	-1.19	7.2
20 Hz	0.4	0.2	1.9	0.4	0.4	-0.71	3.4
30 Hz	0.4	0.2	1.6	0.4	0.4	-0.48	2.6
40 Hz	0.2	0.2	1.3	0.4	0.4	-0.67	2.1
55 Hz	0.3	0.2	0.6	0.4	0.4	-0.76	1.8
100 Hz	0.2	0.2	0.4	0.4	0.4	-0.7	1.6
500 Hz	0.2	0.2	0.1	0.4	0.4	-0.79	1.6
1 kHz	0.2	0.2	0.3	0.4	0.4	-0.67	1.6
5 kHz	0.2	0.2	1.0	0.4	0.4	-0.55	1.8
10 kHz	0.3	0.2	1.0	0.4	0.4	-0.64	1.8
20 kHz	0.2	0.2	0.8	0.4	0.4	-0.6	1.8
50 kHz	0.2	0.5	0.4	0.4	0.4	-0.72	2.1
100 kHz	0.2	1	0.8	0.4	0.5	-1.11	2.7
200 kHz	0.3	1.5	0.7	0.8	0.7	-2.12	4.3
500 kHz	0.2	2	1.3	1.6	1.3	-3.38	7.5
700 kHz	0.2	2.5	1.4	3.2	1.3	-7.35	14.0
1 MHz	0.2	3	1.9	5	1.3	-22.11	28.3

PTC 29+250 - PTC 26+400

frequency	StDev	T-Connect	Lev.Dep	Heat.Eff.	T-coup.Eff	Repeat	uncert. PTC26+400 k=1
		juin-98				sept-99 23/10/1998	4,5 volts
10 Hz	1.6	0.2	4.5	0.4	0.4	5	10.0
20 Hz	0.4	0.2	1	0.4	0.4	5	6.2
30 Hz	0.3	0.2	0.4	0.4	0.4	3	4.1
40 Hz	0.2	0.2	0.4	0.4	0.4	2	3.0
55 Hz	0.5	0.2	0.7	0.4	0.4	2	2.9
100 Hz	0.4	0.2	0.3	0.4	0.4	1	2.0
500 Hz	0.2	0.2	0.2	0.4	0.4	1	2.0
1 kHz	0.3	0.2	0.3	0.4	0.4	1	2.0
5 kHz	0.4	0.2	0.2	0.4	0.4	1	2.2
10 kHz	0.2	0.2	0.5	0.4	0.4	1	2.2
20 kHz	0.3	0.2	0.6	0.4	0.4	1	2.3
50 kHz	0.3	0.5	0.5	0.4	0.4	2	3.0
100 kHz	0.2	1	0.5	0.4	0.5	2	3.6
200 kHz	0.3	1.5	0.5	0.8	0.7	2	5.1
500 kHz	0.3	2	0.2	1.6	1.3	2	8.3
700 kHz	0.2	2.5	0.3	3.2	1.3	4	15.2
1 MHz	0.3	3	0.7	5	1.3	16	33.0

PTC 26+400 - PTC 29+1k EBG

frequency	StDev	T-Connect	Lev.Dep	Heat.Eff.	T-coup.Eff	Repeat	uncert. PTC29+1kE k=1
	sept-99	juin-98	sept-99	avr-98	sept-99	sept-99 23/10/1998	9 volts
10 Hz	0.3	0.2	1.6	0.4	0.4	5	11.3
20 Hz	0.4	0.2	0.5	0.4	0.4	5	8.0
30 Hz	0.2	0.2	0.3	0.4	0.4	3	5.1
40 Hz	0.2	0.2	0.4	0.4	0.4	2	3.7
55 Hz	0.2	0.2	0.2	0.4	0.4	2	3.6
100 Hz	0.2	0.2	0.2	0.4	0.4	1	2.4
500 Hz	0.2	0.2	0.2	0.4	0.4	1	2.3
1 kHz	0.2	0.2	0.4	0.4	0.4	1	2.3
5 kHz	0.3	0.2	0.6	0.4	0.4	1	2.6
10 kHz	0.2	0.2	0.3	0.4	0.4	1	2.5
20 kHz	0.2	0.2	0.2	0.4	0.4	1	2.6
50 kHz	0.2	0.5	0.5	0.4	0.4	2	3.7
100 kHz	0.2	1	0.3	0.4	0.5	2	4.3
200 kHz	0.1	1.5	0.3	0.8	0.7	2	5.8
500 kHz	0.2	2	0.7	1.6	1.3	2	9.0
700 kHz	0.3	2.5	0.7	3.2	1.3	4	16.3
1 MHz	0.3	3	0.8	5	1.3	18	38.1

PTC 29+1k EBG - PTC 26+2k EBG

frequency	StDev sept-99	T-Connect juin-98	Lev.Dep sept-99	Heat.Eff. avr-98	T-coup.Eff sept-99	Repeat sept-99 23/10/1998	uncert. PTC26+2k E k=1 16 volts
10 Hz	1.2	0.2	3.5	0.4	0.4	1.0	12.0
20 Hz	0.5	0.2	0.9	0.4	0.4	1.0	8.1
30 Hz	0.5	0.2	0.5	0.4	0.4	1.0	5.3
40 Hz	0.5	0.2	0.5	0.4	0.4	1.0	3.9
55 Hz	0.5	0.2	0.4	0.4	0.2	1.0	3.8
100 Hz	0.4	0.2	0.4	0.4	0.2	1.0	2.7
500 Hz	0.3	0.2	0.4	0.4	0.2	1.0	2.6
1 kHz	0.3	0.2	0.5	0.4	0.3	1.0	2.7
5 kHz	0.3	0.2	0.6	0.4	0.3	1.0	2.9
10 kHz	0.2	0.2	0.3	0.4	0.3	1.0	2.8
20 kHz	0.2	0.2	0.3	0.4	0.3	1.0	2.8
50 kHz	0.2	0.5	0.3	0.4	0.4	1.0	4.0
100 kHz	0.2	1	0.5	0.4	0.5	2.0	4.9
200 kHz	0.3	1.5	0.3	0.8	0.5	3.0	6.8
500 kHz	0.3	2	0.4	1.6	1.5	6.0	11.3
700 kHz	0.3	2.5	0.6	3.2	2.7	15.0	22.7
1 MHz	0.4	3	0.8	5	4.5		38.8

PTC 26+2k EBG - PTC 29+4k EBG

frequency	StDev sept-99	T-Connect juin-98	Lev.Dep sept-99	Heat.Eff. avr-98	T-coup.Eff sept-99	Repeat sept-99 23/10/1998	uncert. PTC29+4kE k=1 30 volts
10 Hz	0.5	0.2	2.20	0.4	0.5	1.0	12.3
20 Hz	0.5	0.2	0.30	0.4	0.5	1.0	8.2
30 Hz	0.5	0.2	0.30	0.4	0.5	1.0	5.5
40 Hz	0.4	0.2	0.30	0.4	0.5	1.0	4.2
55 Hz	0.4	0.2	0.50	0.4	0.5	1.0	4.0
100 Hz	0.2	0.2	0.30	0.4	0.5	1.0	3.0
500 Hz	0.2	0.2	0.30	0.4	0.5	1.0	2.9
1 kHz	0.2	0.2	0.30	0.4	0.5	1.0	3.0
5 kHz	0.2	0.2	0.30	0.4	0.6	1.0	3.2
10 kHz	0.2	0.2	0.30	0.4	0.6	1.0	3.1
20 kHz	0.2	0.2	0.30	0.4	0.7	1.0	3.1
50 kHz	0.2	0.5	0.30	0.4	0.7	1.0	4.2
100 kHz	0.2	1	0.30	0.4	0.8	2.0	5.5
200 kHz	0.2	1.5	0.30	0.8	1	3.0	7.7
500 kHz	0.2	2	0.40	1.6	1.5	6.0	13.1
700 kHz	0.2	2.5	0.50	3.2	2.7	15.0	27.6
1 MHz	0.2	3	0.70	5	4.5		39.5

PTC 29+4k EBG - PTC 26+9k7

frequency	StDev sept-99	T-Connect juin-98	Lev.Dep sept-99	Heat.Eff. avr-98	T-coup.Eff sept-99	Repeat sept-99 23/10/1998	uncert. PTC26+9k7 k=1 75 volts
10 Hz	1	0.2	6	0.4	0.5	1.0	13.7
20 Hz	1	0.2	3	0.4	0.5	1.0	8.9
30 Hz	1	0.2	3	0.4	0.5	1.0	6.4
40 Hz	1	0.2	2	0.4	0.5	1.0	4.9
55 Hz	1.5	0.2	0.7	0.4	0.5	1.0	4.5
100 Hz	1.5	0.2	0.7	0.4	0.5	1.0	3.6
500 Hz	0.6	0.2	0.7	0.4	0.5	1.0	3.3
1 kHz	0.4	0.2	0.7	0.4	0.5	1.0	3.3
5 kHz	0.3	0.2	0.5	0.4	0.6	1.0	3.4
10 kHz	0.4	0.2	0.5	0.4	0.6	1.0	3.4
20 kHz	0.5	0.2	1	0.4	0.7	1.0	3.6
50 kHz	0.8	0.5	1.5	0.4	0.7	2.0	5.1
100 kHz	0.5	1	2	0.4	0.8	3.0	6.7
200 kHz	0.5	1.5	2	0.8	1	4.0	9.1
500 kHz	0.3	2	3	1.6	1.5	6.0	15.0
700 kHz	0.3	2.5	3	3.2	2.7	15.0	32.0
1 MHz	0.5	3		5	4.5		

PTC 26+9k7 - PTC 29+19k9

frequency	StDev sept-99	T-Connect juin-98	Lev.Dep sept-99	Heat.Eff. avr-98	T-coup.Eff sept-99	Repeat sept-99 23/10/1998	uncert. PTC29+19k9 k=1 150 volts
10 Hz	0.3	0.2	2.5	1	0.5	1.0	14.0
20 Hz	0.2	0.2	1	1	0.5	1.0	9.1
30 Hz	0.2	0.2	1	1	0.5	1.0	6.7
40 Hz	0.2	0.2	1	1	0.5	1.0	5.2
55 Hz	0.2	0.2	1	1	0.5	1.0	4.9
100 Hz	0.2	0.2	1	0.5	0.5	1.0	3.9
500 Hz	0.2	0.2	1	0.5	0.5	1.0	3.7
1 kHz	0.2	0.2	1	0.5	0.5	1.0	3.7
5 kHz	0.2	0.2	1	0.5	0.6	1.0	3.8
10 kHz	0.2	0.2	1	0.5	0.6	1.0	3.8
20 kHz	0.2	0.2	1	0.5	0.7	2.0	4.3
50 kHz	0.2	0.5	2	0.5	0.7	2.0	5.9
100 kHz	0.2	1	3	1	0.8	3.0	8.1
200 kHz	0.2	1.5	4	2	1	4.0	11.1
500 kHz							
700 kHz							
1 MHz							

PTC 29+19k9 - PTC 26+35k

frequency	StDev sept-99	T-Connect juin-98	Volt.Dep sept-99	Heat.Eff. gem. avr-98	T-coup.Eff sept-99	Repeat sept-99 23/10/1998	uncert. PTC26+35k k=1 290 V
10 Hz	1.6	0.2	2.5	1	0.5	1.0	14.4
20 Hz	0.4	0.2	1	1	0.5	1.0	9.3
30 Hz	0.4	0.2	1	1	0.5	1.0	6.9
40 Hz	0.4	0.2	1	1	0.5	1.0	5.5
55 Hz	0.3	0.2	0.5	1	0.5	1.0	5.1
100 Hz	0.3	0.2	0.5	0.5	0.5	1.0	4.2
500 Hz	0.3	0.2	0.5	0.5	0.5	1.0	3.9
1 kHz	0.3	0.2	0.5	0.5	0.5	1.0	3.9
5 kHz	0.4	0.2	0.5	0.5	0.6	1.0	4.1
10 kHz	0.3	0.2	0.5	0.5	0.6	1.0	4.0
20 kHz	0.3	0.2	1	0.5	0.7	2.0	4.9
50 kHz	0.3	0.5	3	0.5	0.7	2.0	7.0
100 kHz	0.3	1	4	1	0.8	3.0	9.7
200 kHz							
500 kHz							
700 kHz							
1 MHz							

PTC 26+35k - PTC 29+68k

frequency	StDev sept-99	T-Connect juin-98	Volt.Dep sept-99	Heat.Eff. avr-98	T-coup.Eff sept-99	Repeat sept-99 23/10/1998	uncert. PTC29+68k k=1 500 volts
10 Hz							
20 Hz							
30 Hz							
40 Hz	0.8	0.2	3	3	0.5	2.0	7.3
55 Hz	1.2	0.2	3	3	0.5	2.0	7.1
100 Hz	0.8	0.2	2	3	0.5	1.0	5.7
500 Hz	0.6	0.2	2	3	0.5	1.0	5.5
1 kHz	0.4	0.2	2	3	0.5	1.0	5.5
5 kHz	0.4	0.2	3	2	0.6	1.0	5.6
10 kHz	0.4	0.2	3	3	0.6	2.0	6.2
20 kHz	0.5	0.2	4	3	0.7	4.0	8.1
50 kHz	0.4	0.5	5	3	0.7	3.0	9.6
100 kHz	0.3	1	10	3	0.8	3.0	14.6
200 kHz							
500 kHz							
700 kHz							
1 MHz							

PTC 29+68k - Best1/97+100k EBG [Step from PMJTC to SJTC]	StDev	T-Connect	Volt.Dep 02/11/1999	Heat.Eff.	T-coup.Eff	Repeat	uncert. Best1/97+ 100k EBG k=1
	sept-99	juin-98	sept-99	avr-98	sept-99	sept-99 23/10/1998	500 V
frequency							
10 Hz							
20 Hz							
30 Hz							
40 Hz	2.2	0.2	3	3	0.5	2.0	9.0
55 Hz	1.5	0.2	3	3	0.5	2.0	8.6
100 Hz	2.4	0.2	2	3	0.5	2.0	7.4
500 Hz	2.6	0.2	2	3	0.5	2.0	7.3
1 kHz	1.4	0.2	2	3	0.5	1.0	6.8
5 kHz	2.8	0.2	2	2	0.6	1.0	7.0
10 kHz	2	0.2	2	3	0.6	1.0	7.6
20 kHz	2.2	0.2	3	3	0.7	2.0	9.7
50 kHz	1.6	0.5	4	3	0.7	2.0	11.2
100 kHz	2.3	1	5	3	0.8	3.0	16.2
200 kHz							
500 kHz							
700 kHz							
1 MHz							

Best1/97+100k EBG - Best2/97+200k EBG	StDev	T-Connect	Volt.Dep	Heat.Eff.	T-coup.Eff	Repeat	uncert. Best2/97+ 200k EBG k=1
	sept-99	juin-98	sept-99	avr-98	sept-99	sept-99 23/10/1998	1000 V
frequency							
10 Hz							
20 Hz							
30 Hz							
40 Hz	3.2	0.2	1	3	0.5	3	10.5
55 Hz	3.2	0.2	1	3	0.5	3	10.2
100 Hz	3.3	0.2	1	3	0.5	3	9.2
500 Hz	3	0.2	1	3	0.5	3	9.1
1 kHz	2.1	0.2	2	3	0.5	1	8.0
5 kHz	3.2	0.2	2	2	0.6	1	8.3
10 kHz	2	0.2	3	3	0.6	1	9.0
20 kHz	1.4	0.2	4	3	0.7	1	11.0
50 kHz	3.3	0.5	5	3	0.7	3	13.4
100 kHz	3.5	1	10	3	0.8	3	19.9
200 kHz							
500 kHz							
700 kHz							
1 MHz							

SUMMARY

summary for CCEM-K9

	Volt-level		measurement uncertainty for k=1 in µV/V 1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Primary Standard (PTP/IPHT-PMJTC)	**1,5 Volts**		**1**	**1**	**1**	**1.5**	**1.5**
Step1		Type A	0.2	0.2	0.2	0.2	0.2
		Type B	0.7	0.7	0.9	0.8	1.2
Working Standard	**1,5 Volts**		**1.2**	**1.2**	**1.4**	**1.7**	**1.9**
Step2		Type A	0.2	0.3	0.2	0.2	0.2
		Type B	0.9	1.3	1.2	1.1	1.8
WS+250R	**3,3 Volts**		**1.6**	**1.8**	**1.8**	**2.1**	**2.7**
Step3		Type A	0.3	0.2	0.3	0.3	0.2
		Type B	1.2	1.3	1.3	2.2	2.4
WS+400R	**4,5 Volts**		**2**	**2.2**	**2.3**	**3**	**3.6**
Step4		Type A	0.2	0.2	0.2	0.2	0.2
		Type B	1.2	1.2	1.2	2.2	2.3
WS+1k	**9 Volts**		**2.3**	**2.5**	**2.6**	**3.7**	**4.3**
Step5		Type A	0.3	0.2	0.2	0.2	0.2
		Type B	1.2	1.2	1.2	1.3	2.4
WS+2k	**16 Volts**		**2.7**	**2.8**	**2.8**	**4**	**4.9**
Step6		Type A	0.2	0.2	0.2	0.2	0.2
		Type B	1.2	1.3	1.3	1.4	2.4
WS+4k	**30 Volts**		**3**	**3.1**	**3.1**	**4.2**	**5.5**
Step7		Type A	0.4	0.4	0.5	0.8	0.5
		Type B	1.4	1.3	1.6	2.7	3.8
WS+9k7	**75 Volts**		**3.3**	**3.4**	**3.6**	**5.1**	**6.7**
Step8		Type A	0.2	0.2	0.2	0.2	0.2
		Type B	1.6	1.6	2.4	3	4.5
WS+19k9	**150 Volts**		**3.7**	**3.8**	**4.3**	**5.9**	**8.1**
Step9		Type A	0.3	0.3	0.3	0.3	0.3
		Type B	1.2	1.3	2.2	2.2	3.4
		Volt-dep	0.5	0.5	1	3	4
WS+35k	**290 Volts**		**3.9**	**4**	**4.9**	**7**	**9.7**
Step10		Type A	0.4	0.4	0.5	0.4	0.3
		Type B	3.2	3.7	5.1	4.3	4.4
		Volt-dep	2	3	4	5	10
WS+68k	**500 Volts**		**5.5**	**6.2**	**8.1**	**9.6**	**14.6**
Step11		Type A	1.4	2	2.2	1.6	2.3
(change PMJTC to SJTC)		Type B	3.2	3.2	3.7	3.7	4.4
		Volt-dep	2	2	3	4	5
WS+100k	**500 Volts**		**6.8**	**7.6**	**9.7**	**11.2**	**16.2**
Step12		Type A	2.1	2	1.4	3.3	3.5
		Type B	3.2	3.2	3.2	4.3	4.4
		Volt-dep	2	3	4	5	10
WS+200k	**1000 Volts**		**8**	**9**	**11**	**13.4**	**19.9**

UNCERTAINTY BUDGET FOR MIKES (FINLAND)

Table I: The uncertainties of MIKES step up procedure

MIKES STEP UP PROCEDURE		**1 kHz**	**10 kHz**	**20 kHz**	**50 kHz**	**100 kHz**
PRIMARY STANDARD	Voltage (V): **1.5**					
PTB PLANAR MJTC sn 21	Standard uncertainty:	1	1	1.4	1.5	1.5
Step 1:	Voltage (V): **3**					
Measurement uncertainty:	Type A:	0.09	0.13	0.17	0.16	0.12
	Type B:	0.23	0.02	0.16	0.38	0.36
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		0	0	0	0	0
Total standard uncertainty:		1.1	1.0	1.4	1.6	1.6
Step 2:	Voltage (V): **10**					
Measurement uncertainty:	Type A:	0.90	1.65	1.35	1.45	0.85
	Type B:	1.01	0.66	0.88	0.90	0.79
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		0	0	0	0	0
Total standard uncertainty:		1.7	2.0	2.1	2.3	1.9
Step 3:	Voltage (V): **30**					
Measurement uncertainty:	Type A:	0.53	0.62	0.51	0.73	0.75
	Type B:	0.76	0.13	0.80	0.19	0.38
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		0	0	0	0	0
Total standard uncertainty:		1.9	2.1	2.3	2.4	2.1
Step 4:	Voltage (V): **100**					
Measurement uncertainty:	Type A:	0.64	0.85	0.77	0.60	0.86
	Type B:	1.62	0.30	0.17	0.19	0.39
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		0	0	0	0	0
Total standard uncertainty:		2.6	2.3	2.4	2.5	2.3
Step 5:	Voltage (V): **300**					
Measurement uncertainty:	Type A:	0.51	0.41	0.49	0.34	0.49
	Type B:	0.73	0.72	0.71	0.70	0.68
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		0	0	0	0	0
Total standard uncertainty:		2.8	2.5	2.6	2.6	2.5
Step 6:	Voltage (V): **400**					
Measurement uncertainty:	Type A:	2.08	1.56	1.75	1.60	1.89
	Type B:	1.53	1.54	1.55	1.70	2.47
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		1.42	1.54	1.95	5.13	16.92
Total standard uncertainty:		4.0	3.6	4.0	6.2	17.4

Step 7:	Voltage (V): **500**					
Measurement uncertainty:	Type A:	1.48	1.22	1.33	1.27	1.38
	Type B:	1.53	1.54	1.55	1.7	2.47
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		1.41	1.55	1.98	5.25	17.24
Total standard uncertainty:		3.8	3.5	3.8	6.2	17.6

Step 8:	Voltage (V): **1000**					
Measurement uncertainty:	Type A:	1.00	1.40	1.60	1.00	1.20
	Type B:	3.18	3.18	3.18	3.18	3.18
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		1.43	1.76	2.73	10.60	40.19
Total standard uncertainty:		4.6	4.6	5.2	11.4	40.4

Table II: The uncertainties of the CCEM-K9 comparison

TRAVELLING STANDARD			**1 kHz**	**10 kHz**	**20 kHz**	**50 kHz**	**100 kHz**
PRIMARY STANDARD	Voltage (V):	100					
RR100V + 3D_MJTC	Standard uncertainty:		2.6	2.3	2.4	2.5	2.3
	Voltage (V):	**100**					
Measurement uncertainty:	Type A:		1.86	2.05	1.80	2.00	2.09
	Type B:		0.29	0.46	0.64	1.17	2.02
Uncertainty from voltage dependence:			0	0	0	0	0
Uncertainty from power dependence:			0	0	0	0	0
Total standard uncertainty:			3.22	3.13	3.10	3.42	3.71
Expanded uncertainty (95%):			7.0	6.5	6.4	7.0	7.6

TRAVELLING STANDARD			**1 kHz**	**10 kHz**	**20 kHz**	**50 kHz**	**100 kHz**
PRIMARY STANDARD	Voltage (V):	300					
RR300V + 3D_MJTC	Standard uncertainty:		2.8	2.5	2.6	2.6	2.5
	Voltage (V):	**195**					
Measurement uncertainty:	Type A:		0.80	0.50	0.63	0.80	0.58
	Type B:		1.13	1.22	1.40	2.00	3.31
Uncertainty from voltage dependence:			0	0	0	0	0
Uncertainty from power dependence:			0	0	0	0	0
Total standard uncertainty:			3.09	2.79	3.01	3.39	4.16
Expanded uncertainty (95%):			6.7	5.6	6.5	6.8	8.2

TRAVELLING STANDARD			**1 kHz**	**10 kHz**	**20 kHz**	**50 kHz**	**100 kHz**
PRIMARY STANDARD	Voltage (V):	300					
RR300V + 3D_MJTC	Standard uncertainty:		2.8	2.5	2.6	2.6	2.5
	Voltage (V):	**300**					
Measurement uncertainty:	Type A:		0.58	0.66	0.50	0.34	1.45
	Type B:		1.11	1.34	1.61	2.58	4.80
Uncertainty from voltage dependence:			0	0	0	0	0
Uncertainty from power dependence:			0	0	0	0	0
Total standard uncertainty:			3.03	2.88	3.09	3.69	5.59
Expanded uncertainty (95%):			6.6	5.5	6.7	7.5	11.1

TRAVELLING STANDARD		**1 kHz**	**10 kHz**	**20 kHz**	**50 kHz**	**100 kHz**
PRIMARY STANDARD	Voltage (V): 1000					
RR1000V + 3D_MJTC	Standard uncertainty:	4.0	3.6	4.0	6.2	17.4
	Voltage (V): **400**					
Measurement uncertainty:	Type A:	0.48	0.34	0.25	0.40	0.40
	Type B:	0.10	0.32	0.45	0.71	1.00
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		0	0	0	0	0
Total standard uncertainty:		4.07	3.67	4.03	6.27	17.41
Expanded uncertainty (95%):		8.6	7.2	8.5	12.7	35.3

TRAVELLING STANDARD		**1 kHz**	**10 kHz**	**20 kHz**	**50 kHz**	**100 kHz**
PRIMARY STANDARD	Voltage (V): 1000					
RR1000V + 3D_MJTC	Standard uncertainty:	3.8	3.5	3.8	6.2	17.6
	Voltage (V): **500**					
Measurement uncertainty:	Type A:	0.20	0.21	0.21	0.27	0.19
	Type B:	0.10	0.32	0.45	0.71	1.00
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		0	0	0	0	0
Total standard uncertainty:		3.77	3.53	3.88	6.29	17.67
Expanded uncertainty (95%):		8.0	7.3	8.0	13.0	35.9

TRAVELLING STANDARD		**1 kHz**	**10 kHz**	**20 kHz**	**50 kHz**	**100 kHz**
PRIMARY STANDARD	Voltage (V): 1000					
RR1000V + 3D_MJTC	Standard uncertainty:	4.6	4.6	5.2	11.4	40.4
	Voltage (V): **1000**					
Measurement uncertainty:	Type A:	1.50	1.90	0.30	0.40	1.20
	Type B:	0.10	0.32	0.45	0.81	1.56
Uncertainty from voltage dependence:		0	0	0	0	0
Uncertainty from power dependence:		0	0	0	0	0
Total standard uncertainty:		4.80	4.99	5.21	11.45	40.46
Expanded uncertainty (95%):		10.0	9.9	10.8	23.2	82.1

ACDC- and ACAC voltage measurements at MIKES

1. Acdc measurements

Before the calibration the levels in the measurement sequence file at each measurement frequency for the ac calibrator were adjusted so that the thermal voltages for ac and dc match each other reasonably well. The thermal voltages of the converter pairs to be compared are adjusted at nearly the same level by loading the higher thermal voltage with an appropriate resistor. Models for the thermal voltages of both thermal converters as a function of input voltage are established by varying the input DC voltage (both positive and negative values) within ± 1% limits around the used measurement voltage, applying 2nd order regression model for the thermal voltages with the input voltages and their squares as independent variables and solving the resulting equations for the input voltages.

After a proper warmup period (some hours) with the nominal voltage applied the measurement is done in the following sequence:

- AC
- DC+
- AC
- DC-

which is repeated three times at each of the measurement frequencies. Each thermal voltage pair of the sequence is averaged from 16 individual interlaced measurement pairs after an appropriate delay from each turn of the acdc relay. The measuring algorithm also produces standard deviations (SD) of the mean of the 16 measurements for each channel. The SDs are saved to a file together with the averages, but do not propagate further into the uncertainty calculations. They are used only as a quality check (if some value is prohibitively high, the associated average is not used). The respective standard deviations of the mean are typically at $0.1\cdot10^{-6}\cdot$UT level, where UT is the thermal voltage.

The acdc differences seen by both thermal converters are calculated by first solving the input voltages u_{in_ac}, u_{in_dc} from thermal voltages by using the models measured with DC variation, and then applying Eq. 1:

$$acdc\_difference = -\frac{u_{in\_ac} - u_{in\_dc}}{u_{in\_dc}} \qquad (1)$$

where u_{in_ac} is the input voltage for ac thermal voltage calculated from the thermal voltage model and u_{in_dc} is the average of the two input voltages calculated from the model for DC+ and DC- thermal voltages. These acdc differences are calculated for both thermal converters and include the acdc difference between the two calibrators. The acdc difference of the two thermal converters is obtained at each frequency by substracting their acdc differences from each other and thus cancelling the acdc difference between the calibrators. The acdc differences are calculated for each ac measurement point that lies between either a DC+ and a DC- or a DC- and a DC+ measurements. With 3 repetitions of the above sequence this gives us six acdc results, which are partially interdependent (most of the dc points are used twice, but it is acceptable due to the low variance contribution of DC points). Note that in Eq. 1 we are dealing with the observed input voltages, which do not produce equal thermal voltages at ac and dc. If, for instance, the observed thermal voltage at ac is higher than at dc, Eq. 1 produces a negative acdc difference. This means that the observed RR-TC combination is apparently more sensitive to ac voltage than to dc voltage (apparently, because the level differences between the ac and dc generators are still included), and we should lower the ac voltage level to get equal thermal voltages. This is in harmony with the definition of acdc difference.

The procedure described produces the difference of the acdc differences of the two converters compared ("A-B"). If the subtrahend ("B") is traceable, the absolute acdc difference of the minuend ("A") is obtained simply by adding the traceable acdc difference of the subtrahend ("B") to the measured difference.

2. Acac measurements

The acac measurement is done in the same way as acdc measurement, but a frequency, the acdc difference of which is known, is used instead of dc+ and dc- voltages. The measurement sequence of the acac measurement is:

- AC_{fx}
- AC_{f0}
- AC_{fx}
- AC_{f0}

where f0 is the frequency at which the acdc differences of the devices under comparison are supposed to be known, and fx is the frequency under measurement.

Acac measurement does not need a relay, because frequency switching in a calibrator is quite fast.

The step up and CCEM-K9 at MIKES

The comparison (including the step up) was done according to Fig. 1.

The step up up to 300V was realised by using two independent step up branches (see Fig. 1). At each voltage level in both branches the uncertainty was obtained by measuring acdc difference in both directions by interchanging the devices. The uncertainty of one voltage level/one branch was obtained as follows:

$$\delta_{3x} = \sqrt{\frac{\delta_{1x}^{2} + \delta_{2x}^{2}}{2} + \frac{(\Delta_{1x} + \Delta_{2x})^{2}}{2}} \qquad (2)$$

where:

δ_{1X} and δ_{2X} are the A-type standard deviations of the measurements
Δ_{1X} and Δ_{2X} are the B-type acdc differences of the two measuring directions (their sum should be zero)

Finally, the results of the two separate branches are compared to each other to obtain the final result. As an example, the 30V level final uncertainty for branch A is obtained according to formula:

$$u_{RR30VA+246}(95\%) = k \cdot \sqrt{\delta_{3b}^{2} + \frac{\Delta_{4}^{2}}{2} + \left(\frac{u_{RR10VA+274}}{k'}\right)^{2}} \qquad (3)$$

where:

k and k' are the coverage factors obtained from Welch-Satterthwaite equation
$u_{RR30VA+246}(95\%)$ is the expanded uncertainty of the RR30VA range resistor and 3D_MJTC246
δ_{3b} is the A-type standard deviation from Eq. 2

Δ_4 is the B-type acdc difference closing error of the two measuring branches loop (the sum around the 10V/30V loop should be zero); a rectangular distribution is assumed
$u_{RR30VA+246}$ is the expanded uncertainty and k' the coverage factor of the previous level

The A- and B-type uncertainties are presented in Tables I and 2 above.

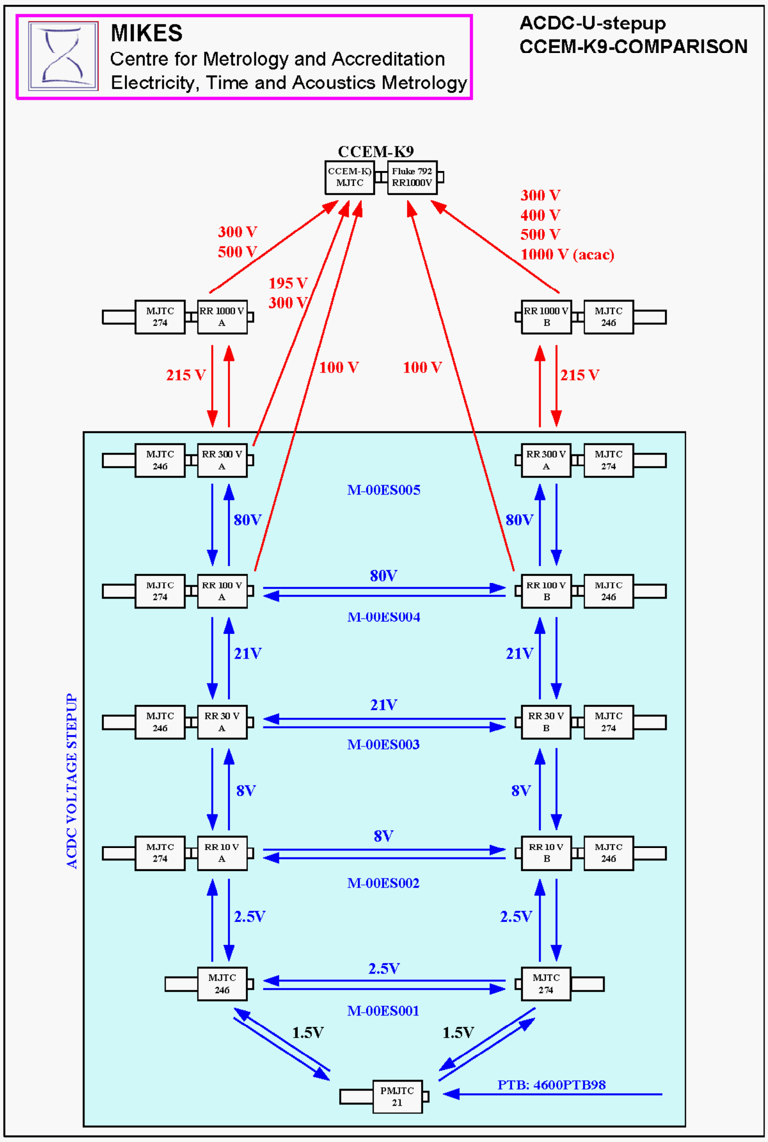

Fig. 1: CCEM-K9 comparison

In voltages above 300V the step up proceeded in the way described above, but the two branches were compared only via the common travelling standard. At 1000V level the comparison was done by using acac method with 97 Hz as a reference. Uncertainties, estimating power factors of the range resistor/thermal converter pairs were added. No measurements to obtain values for power or voltage dependencies were done.

UNCERTAINTY BUDGET FOR INETI (PORTUGAL)

Uncertainty budget of AC-DC voltage transfer standards												
Reason of deviation		*Standard deviations in µV/V at the frequencies*										*Remarks*
		10Hz	**20Hz**	**40Hz**	**1kHz**	**10 kHz**	**20kHz**	**50kHz**	**100kHz**	**500kHz**	**1MHz**	
Thermal Converter at 3 V level												
Total uncertainty u at 3 V level		1.5	1.5	1	0.5	0.5	1.0	1.0	2.5	10.0	20.0	PTB uncertainties
Step-up procedure		*Standard deviations in µV/V per step*										
per step:												
change of transfer differences												
# with current level of the converters		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	worst case ±a/?3
# with voltage level	100V	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	worst case ±a/?3
	300V	5	2	1	0.5	0.5	1	2	5			worst case ±a/?3
	1000V	10	7	5	3	5	7	10	15			worst case ±a/?3
drift during measurements		3	2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	random
comparison measurements		1	1	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	random
		Total uncertainty of the standards in µV/V: un=?[(u+?scorrel)2+?s2]										
at rated voltage												
	1V	4.4	3.4	2.3	1.7	1.7	2.1	2.1	3.6	11.0	21.0	1 step
	3 V	1.5	1.5	1.0	0.5	0.5	1.0	1.0	2.5	10.0	20.0	
	10 V	6.3	4.7	3.4	2.7	2.7	3.2	3.2	4.6	12.0	22.0	2 steps
	20 V	8.1	5.9	4.4	3.7	3.7	4.2	4.2	5.6	13.1	23.0	3 steps
	100 V	13.0	9.3	7.5	6.7	6.7	7.2	7.2	8.7			6 steps
	200 V	18.1	11.6	9.0	**7.7**	**7.7**	**8.7**	**9.7**	**14.1**			7 steps
	500 V	33.4	21.1	15.9	**12.2**	**14.2**	**17.6**	**22.6**	**35.1**			9 steps
	1000 V	43.7	28.4	21.3	**15.7**	**19.6**	**25.1**	**33.1**	**50.5**			10 steps

UNCERTAINTY BUDGET FOR DANIAMet-AREPA (DENMARK)

Uncertainty.

The overall uncertainties of the measurement results are estimated in accordance with EAL-R2 / EA-4/02. It has been distinguished between category A and B uncertainties. The category A uncertainty is stated as the estimated value of the experimental standard deviation. Estimates of the category B uncertainties are based either on experience or on stated specifications of the manufactorers. Here the limits of errors are estimated. In this case a suitable population ditribution is assumed and the standard deviation is estimated by multiplying the error estimate with the corresponding factor.

The estimated uncertainties of the measured AC-DC differences are stated in table 2, whereas table 3 contains the complete uncertainty budget.

All the uncertainty contributions (u_i) listed in table 3 are uncorrelated, and so the standard uncertainty u is calculated as:

$$u = \sqrt{\sum u_i^2}$$

The expanded uncertainty U is determined by:

$$U = ku$$

where the coverage factor k for a coverage probability of 95% is found from the effective number of degrees of freedom ν_{eff} and a t-distribution:

$$\nu_{eff} = \frac{u^4}{\sum \frac{u_i^4}{\nu_i}}$$

Measured AC-DC voltage transfer difference in 10^{-6}					
Voltage	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
200 V	2	–1	–6	–26	–72
500 V	3	0	–4	–22	–60
1000 V	4	1	–1	–20	–58

Table 1: Measurement results.

Uncertainty of the AC-DC voltage transfer difference in 10 ^{6}					
Voltage	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
200 V	11	11	11	11	26
500 V	21	21	21	21	41
1000 V	21	21	26	41	81

Table 2: Measurement uncertainties (k = 2).

Reason of deviation Standard Uncertainty u_i in 10^{-6}	Category	1kHz	10kHz	20kHz	50kHz	100kHz	Distribution Remarks
Fluke 792A traceability:	B						gaussian
200 V		5	5	5	5	12,5	
500 V		10	10	10	10	20	
1000 V		10	10	12,5	20	40	
Fluke 792A drift:	B						gaussian
200 V		2	2	2	3	5	
500 V		3	3	3	5	7	
1000 V		5	5	5	7	10	
Measurement set-up:	B						uniform
Stability, resolution, noise		2	2	2	2	2	
Standard deviation, $\nu_i > 12$:	A						gaussian
200 V		0,2	0,2	0,2	0,2	0,2	
500 V		0,1	0,1	0,1	0,1	0,2	
1000 V		0,2	0,2	0,2	- - -	- - -	
Standard uncertainty u:							$\nu_{eff} > 1000$
200 V		5,3	5,3	5,3	5,5	12,9	
500 V		10,3	10,3	10,3	10,5	20,5	
1000 V		10,5	10,5	12,9	20,5	40,5	
Expanded uncertainty U:							k = 2
200 V		11	11	11	11	26	
500 V		21	21	21	21	41	
1000 V		21	21	26	41	81	

Table 3: Uncertainty budget.

UNCERTAINTY BUDGET FOR NPL (UNITED KINGDOM)

All Type B contribtutions are considered to have infinite degrees of freedom and the divisor used is sqrt(3).

All Type A contributions are considered to have 10 Degrees of Freedom and the divisor used is 2.

	Divisor					
Frequency, kHz		**1**	**10**	**20**	**50**	**100**
SJTC Basic	Rectangular	0.00	0.00	0.00	0.00	1.00
900 ohm	Rectangular	0.00	0.00	0.00	0.00	1.00
Random Scatter from Results	Normal	1.50	1.50	1.50	1.50	1.50
MJTC Base Unc for 1 kHz	Rectangular	0.50	0.50	0.50	0.50	0.50
Cal of Freq Dependance of MJTC		1.58	1.58	1.58	1.58	2.12
Std Uncertainty / Sqrt (6)		0.65	0.65	0.65	0.65	0.87
Build up using MJTC's						
10V Level						
MJTC Uncertainty (3V)		0.65	0.65	0.65	0.65	0.87
Comparison Measurements	Rectangular	1.22	1.22	1.22	1.23	1.23
Bridge Scatter	Normal	1.00	1.00	1.00	1.00	1.00
Std Uncertainty for 10V		**1.71**	**1.71**	**1.71**	**1.71**	**1.81**
30V Level						
MJTC Uncertainty (10V)		**1.71**	**1.71**	**1.71**	**1.71**	**1.81**
Comparison Measurements	Rectangular	1.24	1.24	1.24	1.24	1.60
Bridge Scatter	Normal	1.00	1.00	1.00	1.00	1.00
Std Uncertainty for 30V		2.33	2.33	2.33	2.33	2.61
100V Level						
Cal uncertainty, $k=2$		**2.33**	**2.33**	**2.33**	**2.33**	**2.61**
Comparison Measurements	Rectangular	1.26	1.26	1.26	1.26	1.61
Resistor Voltage Coefficient	Rectangular	0.00	0.00	0.00	1.00	2.00
Bridge Scatter	Normal	2.00	2.00	2.00	2.00	2.00
Std Uncertainty for 100V		3.32	3.32	3.32	3.47	4.17
300V Level						
MJTC Uncertainty (100V)		3.32	3.32	3.32	3.47	4.17
Comparison Measurements	Rectangular	1.28	1.28	1.28	1.28	1.63
Resistor Voltage Coefficient	Rectangular	0.00	1.00	2.00	4.00	7.00
Bridge Scatter	Normal	3.00	3.00	3.00	3.00	3.00
Std Uncertainty for 300V		4.66	4.76	5.07	6.22	8.84

Comparison Measurements: Include contributions for bridge errors, Effect of T-Piece, Loss factor of heater, MJTC skin effect, Interseries adaptors, MJTC used at different levels.

Resistor Voltage Coefficient: Includes contribution for the range resistors as these are calibrated at a lower level and used at full rating.

All Type B contribtutions are considered to have infinite degrees of freedom and the divisor used is sqrt(3).

All Type A contributions are considered to have 10 Degrees of Freedom and the divisor used is 2.

200 V	**Divisor**					
Frequency, kHz		**1**	**10**	**20**	**50**	**100**
Build up using MJTC's						
Std Uncertainty for 100V		3.32	3.32	3.32	3.47	4.17
Cal of NPL SJTC						
NPL Basic Standards		**3.32**	**3.32**	**3.32**	**3.47**	**4.17**
Systematic Bridge Errors	Rectangular	1.22	1.22	1.22	1.22	1.22
Resistor Voltage Coefficient	Rectangular	0.00	0.00	2.00	4.00	7.00
Effect of T Piece	Rectangular	0.00	0.00	0.00	0.00	1.00
MJTC Different Levels	Rectangular	0.50	0.50	0.50	0.50	0.50
Interseries Adaptors	Rectangular	0.00	0.00	0.00	0.00	0.00
Bridge Scatter	Normal	3.00	3.00	3.00	3.00	3.00
Uncertainty of NPL Standards		**4.66**	**4.66**	**5.08**	**6.23**	**8.84**
Cal of Intercomparison Standard						
NPL SJTC Basic Uncertainty		**4.66**	**4.66**	**5.08**	**6.23**	**8.84**
Systematic Bridge Errors	Rectangular	1.22	1.22	1.22	1.22	1.22
Effect of T Piece	Rectangular	0.00	0.00	0.00	0.00	1.00
Bridge Scatter	Normal	3.00	3.00	4.00	4.00	4.00
Interseries Adaptors	Rectangular	0.00	0.00	0.00	0.00	1.00
Cal uncertainty, k=2		12	12	14	16	20
Degrees of Freedom		**2560**	**2560**	**1501**	**2560**	**6250**
Frequency (kHz)		**1**	**10**	**20**	**50**	**100**

All Type B contribtutions are considered to have infinite degrees of freedom and the divisor used is sqrt(3).

All Type A contributions are considered to have 10 Degrees of Freedom and the divisor used is 2.

500 V	**Divisor**					
Frequency, kHz		**1**	**10**	**20**	**50**	**100**
Build up using MJTC's						
Std Uncertainty for 300V		4.66	4.76	5.07	6.22	8.84
Cal of NPL SJTC						
NPL Basic Standards		**4.66**	**4.76**	**5.07**	**6.22**	**8.84**
Systematic Bridge Errors	Rectangular	1.22	1.22	1.22	1.22	1.22
Resistor Voltage Coefficient	Rectangular	0.00	1.00	3.00	7.50	15.00
Effect of T Piece	Rectangular	0.00	0.00	0.00	0.00	0.00
MJTC Different Levels	Rectangular	0.50	0.50	0.50	0.50	0.50
Interseries Adaptors	Rectangular	0.00	0.00	0.00	0.00	0.00
Bridge Scatter	Normal	3.00	3.00	3.00	3.00	3.00
Uncertainty of NPL Standards		**5.69**	**5.87**	**6.74**	**10.28**	**17.71**
Cal of Intercomparison Standard						
NPL SJTC Basic Uncertainty		**5.69**	**5.87**	**6.74**	**10.28**	**17.71**
Systematic Bridge Errors	Rectangular	1.22	1.22	1.22	1.22	1.22
Effect of T Piece	Rectangular	0.00	0.00	0.00	0.00	0.00
Bridge Scatter	Normal	1.00	1.00	1.00	1.00	1.00
Interseries Adaptors	Rectangular	0.00	0.00	0.00	0.00	1.00
Cal uncertainty, *k*=2		12	13	14	21	36
Degrees of Freedom		**207360**	**285610**	**384160**	**1944810**	**16796160**
Frequency (kHz)		**1**	**10**	**20**	**50**	**100**

All Type B contribtutions are considered to have infinite degrees of freedom and the divisor used is sqrt(3).						
All Type A contributions are considered to have 10 Degrees of Freedom and the divisor used is 2.						
1000 V	**Divisor**					
Frequency, kHz		**1**	**10**	**20**	**50**	**100**
Build up using MJTC's						
Std Uncertainty for 300V		4.66	4.76	5.07	6.22	8.84
Cal of NPL SJTC						
NPL Basic Standards		**4.66**	**4.76**	**5.07**	**6.22**	**8.84**
Systematic Bridge Errors	Rectangular	1.22	1.22	1.22	1.22	1.22
Resistor Voltage Coefficient	Rectangular	0.00	1.00	5.00	12.50	25.00
Effect of T Piece	Rectangular	0.00	0.00	0.00	0.00	0.00
MJTC Different Levels	Rectangular	0.50	0.50	0.50	0.50	0.50
Interseries Adaptors	Rectangular	0.00	0.00	0.00	0.00	0.00
Bridge Scatter	Normal	3.00	3.00	3.00	3.00	3.00
Uncertainty of NPL Standards		**5.69**	**5.87**	**7.84**	**14.34**	**26.72**
Cal of Intercomparison Standard						
NPL SJTC Basic Uncertainty		**5.69**	**5.87**	**7.84**	**14.34**	**26.72**
Systematic Bridge Errors	Rectangular	1.22	1.22	1.22	1.22	1.22
Effect of T Piece	Rectangular	0.00	0.00	0.00	0.00	0.00
Bridge Scatter	Normal	1.00	1.00	1.00	1.00	1.00
Interseries Adaptors	Rectangular	0.00	0.00	0.00	0.00	1.00
Cal uncertainty, *k*=2		12	13	16	29	54
Degrees of Freedom		**12960**	**17851**	**40960**	**442051**	**5314410**
Frequency (kHz)		**1**	**10**	**20**	**50**	**100**

UNCERTAINTY BUDGET FOR SP (SWEDEN)

1.Uncertainty of the travelling standard

It was observed that the ac-dc transfer difference of the travelling standard was changing during the warm up. The travelling standard was warmed up until steady state before measurement, but the final temperature of the travelling standard, and then also its ac-dc difference, will depend on how the TVC is supported. The support will influence the convection of heat.

The measured ac-dc transfer difference d_T of the travelling standard is determined as:

$$d_T = d_A + d_B + d_{Sr} + d_{Sd} + d_{STC} - d_{TTC} \qquad (7)$$

where

d_A indicated ac-dc transfer difference between the standard and the travelling standard

d_B correction for the error in the indicated ac-dc transfer difference due to the measurement set-up

d_{Sr} ac-dc transfer difference of the standard of SP at the time and temperature of the determination

d_{Sd} correction for the drift of the ac-dc transfer difference of the standard of SP

d_{STC} correction due to the temperature of the ac-dc transfer difference of the standard of SP

d_{TTC} correction due to the temperature of the ac-dc transfer difference of the travelling standard

The variance of the measured ac-dc transfer difference $u^2(d_T)$ is:

$$u^2(d_T) = u^2(d_A) + u^2(d_B) + u^2(d_{Sr}) + u^2(d_{Sd}) + u^2(d_{STC}) + u^2(d_{TTC}) \qquad (8)$$

Indicated ac-dc transfer difference (d_A): The indicated value is the mean of a set of determinations of the ac-dc transfer difference between the standard and the test. The standard uncertainty $u(d_A)$ is the standard deviation of the mean. Normal distribution.

Measurement set-up (d_B): The correction d_B is estimated to zero. The following sources of uncertainty are considered to contribute to the uncertainty of the correction: non-linearity and resolution of nV-amplifiers and DVMs, non-linearity of the drift in output voltages and back-off voltage sources and the uncertainty in the scale factors. Normal distribution.

Ac-dc transfer difference of the standard (d_S): The used ac-dc transfer differences of the standards were determined at the time and temperature of the voltage build-up in Jan-April 2001 and the above described determination at 200 V. Normal distribution.

Drift of the standard (d_{Sd}): The correction d_{Sd} is estimated to zero. The uncertainty due to the drift of the ac-dc transfer difference is estimated on the history of the standards and the time between this measurement and the voltage build-up. Rectangular distribution.

Temperature of the standard (d_{STC}): The correction d_{STC} is estimated to zero. The uncertainty is based on an estimate of the difference in temperature of the standard between the determination and the use of its ac-dc transfer differences and the temperature coefficient of the standard. Rectangular distribution.

Temperature of the travelling standard (d_{TTC}): The correction d_{TTC} is estimated to zero. The uncertainty is based on an estimate of the difference between the temperature of the travelling standard at our determination and an average temperature of all participants determinations and the influence of this temperature difference on the ac-dc transfer difference of the travelling standard. Rectangular distribution.

The uncertainties due to the following reasons are estimated to be negligible: T-connector and reference plane, difference in ac- and dc-voltage levels, reversal errors, non-pure spectra of ac- and dc-sources, common mode currents, potential difference between the output low and input low of TVCs, switching time and time constants of the TVCs, external fields and relative humidity in the laboratory.

The uncertainty budgets of the travelling standard at 200 V, 500 V and 1000V are given in table 7, 8 and 9. The standard deviations of the mean of the indicated ac-dc transfer differences are from table 2, 3 and 4.

Table 7. Uncertainty budget of the travelling standard at 200 V.

Quantity	u	Standard uncertainty in µV/V at the frequency					Eq. deg. freedom
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	
Ac-dc diff of standard, 200 V	$u(d_S)$	3,2	3,6	4,4	6,0	9,0	117
Drift of standard	$u(d_{Sd})$	0,2	0,2	0,3	0,7	1,0	10
Temperature of standard	$u(d_{STC})$	0,0	0,1	0,1	0,2	0,4	10
Corr. measurement set-up	$u(d_B)$	0,6	0,6	0,6	0,6	0,6	10
Temperature of travelling std	$u(d_{TTC})$	0,0	0,1	0,1	0,2	0,4	10
Indicated ac-dc difference	$u(d_A)$	0,2	0,2	0,3	0,4	0,4	5
Standard uncertainty	$u(d_T)$	3,3	3,7	4,5	6,1	9,2	127
Expanded uncertainty	U = 2u	7	8	9	13	19	

Table 8. Uncertainty budget of the travelling standard at 500 V.

Quantity	u	Standard uncertainty in µV/V at the frequency					Eq. deg. freedom
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	
Ac-dc diff of standard, 500 V	$u(d_S)$	3,7	4,0	4,8	6,5	10,0	121
Drift of standard	$u(d_{Sd})$	0,2	0,2	0,4	1,0	2,0	10
Temperature of standard	$u(d_{STC})$	0,0	0,1	0,2	0,5	1,0	10
Corr. measurement set-up	$u(d_B)$	0,9	0,9	0,9	0,9	0,9	10
Temperature of travelling std	$u(d_{TTC})$	0,0	0,1	0,2	0,5	1,0	10
Indicated ac-dc difference	$u(d_A)$	0,1	0,1	0,1	0,1	0,3	5
Standard uncertainty	$u(d_T)$	3,9	4,2	5,0	6,7	10,4	138
Expanded uncertainty	U = 2u	8	9	10	14	21	

Table 9. Uncertainty budget of the travelling standard at 1 kV.

Quantity	u	Standard uncertainty in µV/V at the frequency					Eq. deg. freedom
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	
Ac-dc diff of standard, 1 kV	$u(d_S)$	4,1	4,4	5,1	7,0	10,5	143
Drift of standard	$u(d_{Sd})$	0,2	0,2	0,4	1,0	2,0	10
Temperature of standard	$u(d_{STC})$	0,1	0,2	0,4	1,0	2,0	10
Corr. measurement set-up	$u(d_B)$	0,9	0,9	0,9	0,9	0,9	10
Temperature of travelling std	$u(d_{TTC})$	0,1	0,2	0,4	1,0	2,0	10
Indicated ac-dc difference	$u(d_A)$	0,1	0,1	0,2	0,1	0,1	5
Standard uncertainty	$u(d_T)$	4,3	4,6	5,3	7,3	11,1	169
Expanded uncertainty	U = 2u	9	10	11	15	23	

Uncertainty budget for the voltage ac-dc transfer standards in SP

Voltage build-up

The primary standard for ac-dc transfer difference is a group of multijunction thermal converters (MJTC) of PTB type traceable to PTB. The ac-dc transfer difference of the MJTCs due to dc-effects has been evaluated by fast reversed dc (FRDC). The equivalence of the primary standard for ac-dc transfer difference maintained by SP to the standards of other national laboratories is verified by an international key comparison [2]. To establish traceability at higher voltage levels a method called phase controlled voltage build-up (PVB) is used [3]. This method allows a voltage build-up without introducing errors due to level dependence of the thermal converters used. The ac-dc transfer difference of a thermal voltage converter (TVC) is compared to two thermal voltage converters in series. Hence, the thermal converters are calibrated and used as reference at the same voltage level.

In the voltage build-up two thermal transfer standards (TTS) of type Fluke 792A are used as TTS1 and TTS2. From 4 V to 256 V a set of Holt 11 is used as TVC3. Above 256 V an early design of Fluke 792 range resistor in combination with a 400 Ω planar multijunction converter (PMJTC) of PTB type is used as TVC3. The ac-dc transfer difference of TTS1 at 2 V is determined by comparison to the primary standard.

The measurement procedure consists of three measurements for each step in the voltage build-up, fig. A1.

1. The ac-dc transfer difference of TTS2 is measured by a 1:1 comparison with TTS1 as the reference standard, using type N T-connector
2. The ac-dc transfer difference of TVC3 is measured by a 2:1 comparison with TTS1 and TTS2 in series as the reference standard, using special T-connector
3. The ac-dc transfer difference of TTS1 is measured by a 1:1 comparison with TVC3 as the reference standard, using special T-connector with output to TTS2 short circuited

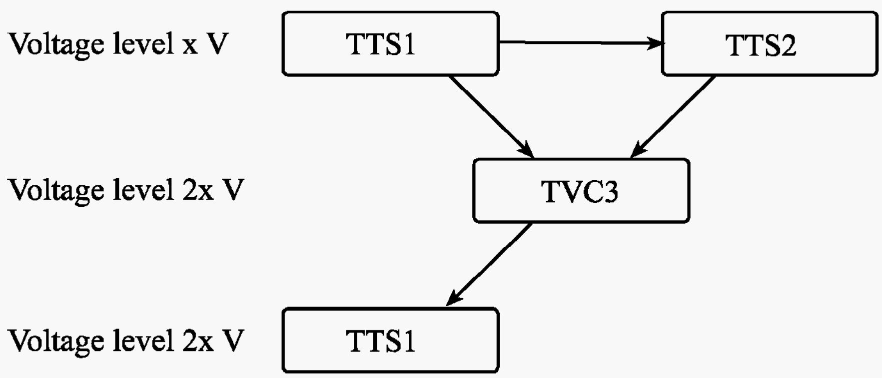

Fig. A1. Scheme for one step in the phase controlled voltage build-up using three thermal voltage converters.

The voltage build-up is made in a sequence 2 V, 4 V, 8 V, 16 V, 32 V, 64 V, 128 V, 256 V and then from 250 V to 500 V and 1000 V. The TVC3 calibrated at 256 V is used as reference at 250 V. This will introduce an error due to the level dependence of TVC3, which is considered in the uncertainty budget.

Uncertainty budget for the voltage build-up procedure

The model equations for the three measurements of a step in the voltage build-up procedure are based on the more detailed analysis of the 1:1 comparison and the 2:1 comparison in appendix B and C.

1. Comparison of TTS2 to TTS1

The measured ac-dc transfer difference d_{T2} of the test TTS2 at the voltage level x V is determined as:

$$d_{T2} = d_{A12} + d_{B12} + d_{S1} \quad \text{(A1)}$$

where

- d_{A12} indicated ac-dc transfer difference between the standard TTS1 and the test TTS2
- d_{B12} correction for the error in the indicated ac-dc transfer difference due to the measurement set-up
- d_{S1} Ac-dc transfer difference of the standard TTS1

The variance of the measured ac-dc transfer difference $u^2(d_{T2})$ is

$$u^2(d_{T2}) = u^2(d_{A12}) + u^2(d_{B12}) + u^2(d_{S1}) \quad \text{(A2)}$$

But the variance of interest in the next measurement is $u^2(d_{S12})$, which is the variance of the mean of d_{S1} and d_{S2}. As d_{S1} and d_{S2} are correlated the variance $u^2(d_{S12})$ is:

$$u^2(d_{S12}) = u^2(d_{A12})/4 + u^2(d_{B12})/4 + u^2(d_{S1}) \quad \text{(A4)}$$

2. Comparison of TVC3 to TTS1 and TTS2 in series

The measured ac-dc transfer difference d_{T3} of the test TVC3 at the voltage level 2x V is determined as:

$$d_{T3} = d_{A123} + d_{B123} + d_a + d_g + d_{S12} \quad \text{(A5)}$$

where

- d_{A123} indicated ac-dc transfer difference between the standards TTS1 and TTS2 in series and the test TVC3
- d_{B123} correction for the error in the indicated ac-dc transfer difference due to the PVB-measurement set-up, excluding phase angle error and guarding
- d_a correction for the error in the indicated ac-dc transfer difference due to phase angle error
- d_g correction for the error in the indicated ac-dc transfer difference due to guarding
- d_{S12} mean ac-dc transfer difference of the standards TTS1 and TTS2

The variance of the measured ac-dc transfer difference $u^2(d_{T3})$ is

$$u^2(d_{T3}) = u^2(d_{A123}) + u^2(d_{B123}) + u^2(d_a) + u^2(d_g) + u^2(d_{S12}) \quad \text{(A6)}$$

3. Comparison of TTS1 to TVC3

The measured ac-dc transfer difference d_{T1} of the test TTS1 at the voltage level 2x V is determined as:

$$d_{T1} = d_{A31} + d_{B31} + d_c + d_{S3} + d_{TC} \quad \text{(A7)}$$

where

d_{A31} indicated ac-dc transfer difference between the standard TVC3 and the test TTS1

d_{B31} correction for the error in the indicated ac-dc transfer difference due to the measurement set-up, excluding the T-connector and reference plane

d_c correction for the error in the ac-dc transfer difference due to the T-connector and reference plane

d_{S3} ac-dc transfer difference of the standard TVC3 at the temperature of the determination

d_{TC} correction for the error in the ac-dc transfer difference of the standard TVC3 due to its temperature coefficient

The variance of the measured ac-dc transfer difference $u^2(d_{T1})$ is

$$u^2(d_{T1}) = u^2(d_{A31}) + u^2(d_{B31}) + u^2(d_c) + u^2(d_{S3}) + u^2(d_{TC}) \qquad \text{(A8)}$$

I the following uncertainty budget the uncertainty contributions are based on the calibration conditions given in appendix B and C and also:

- The maximum uncertainty due to non-linearity and resolution of a nV-amplifier and DVM is 5 nV and of a DVM 0,2 µV, rectangular distribution.
- The maximum uncertainty due to non-linear drift in the output is for Fluke 792A 0,15 µV/V below 100 V and 0,3 µV/V at 100 V and above and for other thermal converters 0,5 µV/V below 100 V and 1 µV/V at 100 V and above, rectangular distribution.
- The maximum drift in the output voltage from the time of determination of the scale factor to the time of the ac-dc transfer measurement is for Fluke 792A 0,05 % below 100 V, then 0,1 % up to 500 V and 0,15 % at 500 V and above and for other thermal converters 0,1 % below 50 V, then 0,15 % up to 250 V and 0,3 % at 250 V and above, rectangular distribution.
- The output voltages of the ac-sources are within 100 µV/V of the output voltages of the dc-sources.
- The measured ac-dc transfer differences are <100 µV/V.
- The phase angle error is <0,15° at 1 kHz and <0,2° at other frequencies, rectangular distribution.
- The maximum uncertainty due to the special T-connector is estimated to 3 µV/V at 4 V, 100 kHz, rectangular distribution.
- The uncertainty due to the temperature coefficient of TVC3 is estimated from warm-up measurements but in the range 64 V to 256 V there is also an uncertainty included due to a drift in the measured value of TVC3 during the voltage build-up measurements. The reason for this drift is unknown but can possibly be caused by changes of the humidity in the range resistors due to the repeated measurements (heat treatments) [4].
- Due to the change in voltage level of TVC3 from 256 V to 250 V an uncertainty contribution due to the level dependence is added in that step to the uncertainty due to the temperature coefficient of TVC3. The uncertainty contribution is evaluated in a similar way as the determination of the ac-dc transfer difference at 200 V.

Table A1. Uncertainty budget for the ac-dc transfer standards of SP based on the voltage build-up procedure.

Quantity	u	Standard uncertainties in uV/V at frequency					Eq. deg.
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	freedom
1:1 comparison							
Ac-dc difference MJTC 2 V	$u(d_S)$	0,5	1,2	1,6	1,8	2,0	100
Measurement set-up	$u(d_B)$	0,3	0,3	0,3	0,3	0,3	10
Indicated ac-dc difference	$u(d_A)$	0,2	0,2	0,2	0,2	0,2	2
Ac-dc difference TTS1 2 V	$u(d_T)$	0,62	1,25	1,64	1,84	2,03	106
Standard uncertainty 2 V	$u(d_{2V})$	**0,7**	**1,3**	**1,7**	**1,9**	**2,1**	**106**

Quantity	u	Standard uncertainties in uV/V at frequency					Eq. deg.
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	freedom
From 2 V to 4 V							
1:1 comparison							
Ac-dc difference TTS1 2 V	$u(d_{S1})$	0,7	1,3	1,7	1,9	2,1	106
Measurement set-up	$u(d_{B12})$	0,2	0,2	0,2	0,2	0,2	10
Indicated ac-dc difference	$u(d_{A12})$	0,2	0,2	0,2	0,2	0,2	2
Ac-dc difference TTS2 2 V	$u(d_{T2})$	0,75	1,33	1,72	1,92	2,12	109
2:1 comparison							
Ac-dc difference TTS1&TTS2 4 V	$u(d_{S12})$	0,71	1,31	1,71	1,91	2,10	106
Phase angle error	$u(d_a)$	0,3	0,5	0,5	0,5	0,5	10
Guarding	$u(d_g)$	0,1	0,2	0,4	1,0	2,0	10
Measurement set-up	$u(d_{B123})$	0,4	0,4	0,4	0,4	0,4	10
Indicated ac-dc difference	$u(d_{A123})$	0,2	0,2	0,2	0,2	0,2	2
Ac-dc difference TVC3 4 V	$u(d_{T3})$	0,90	1,48	1,88	2,25	2,98	44
1:1 comparison							
Ac-dc difference TVC3 4 V	$u(d_{S3})$	0,90	1,48	1,88	2,25	2,98	44
Temperature coefficient TVC3	$u(d_{TC})$	0	0,05	0,1	0,25	0,5	10
T-connector and reference plane	$u(d_c)$	0,2	0,6	0,9	1,4	2,0	10
Measurement set-up	$u(d_{B31})$	0,4	0,4	0,4	0,4	0,4	10
Indicated ac-dc difference	$u(d_{A31})$	0,2	0,2	0,2	0,2	0,2	2
Ac-dc difference TTS1 4 V	$u(d_{T1})$	1,02	1,66	2,13	2,70	3,65	52
Standard uncertainty 4 V	$\mathbf{u(d_{4V})}$	**1,1**	**1,7**	**2,2**	**2,7**	**3,7**	**52**
From 4 V to 8 V							
1:1 comparison							
Ac-dc difference TTS1 4 V	$u(d_{S1})$	1,1	1,7	2,2	2,7	3,7	52
Measurement set-up	$u(d_{B12})$	0,2	0,2	0,2	0,2	0,2	10
Indicated ac-dc difference	$u(d_{A12})$	0,2	0,2	0,2	0,2	0,2	2
Ac-dc difference TTS2 4 V	$u(d_{T2})$	1,14	1,72	2,22	2,71	3,71	53
PVB							
Ac-dc difference TTS1&TTS2 4 V	$u(d_{S12})$	1,12	1,71	2,21	2,71	3,71	53
Phase angle error	$u(d_a)$	0,3	0,3	0,5	0,5	0,5	10
Guarding	$u(d_g)$	0,1	0,2	0,4	1,0	2,0	10
Measurement set-up	$u(d_{B123})$	0,4	0,4	0,4	0,4	0,4	10
Indicated ac-dc difference	$u(d_{A123})$	0,4	0,4	0,4	0,4	0,4	2
Ac-dc difference TVC3 8 V	$u(d_{T3})$	1,29	1,84	2,37	2,98	4,28	64
1:1 comparison							
Ac-dc difference TVC3 8 V	$u(d_{S3})$	1,29	1,84	2,37	2,98	4,28	64
T-connector and reference plane	$u(d_{TC})$	0,1	0,2	0,2	0,3	0,4	10
Temperature coefficient TVC3	$u(d_c)$	0	0,05	0,1	0,25	0,5	10
Measurement set-up	$u(d_{B31})$	0,4	0,4	0,4	0,4	0,4	10
Indicated ac-dc difference	$u(d_{A31})$	0,3	0,3	0,3	0,3	0,3	2
Ac-dc difference TTS1 8 V	$u(d_{T1})$	1,39	1,92	2,43	3,05	4,35	69
Standard uncertainty 8 V	$\mathbf{u(d_{8V})}$	**1,4**	**2,0**	**2,5**	**3,1**	**4,4**	**69**

Quantity	u	Standard uncertainties in uV/V at frequency					Eq. deg. freedom
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	
From 8 V to 16 V							
1:1 comparison							
Ac-dc difference TTS1 8 V	$u(d_{S1})$	1,4	2,0	2,5	3,1	4,4	69
Measurement set-up	$u(d_{B12})$	0,3	0,3	0,3	0,3	0,3	10
Indicated ac-dc difference	$u(d_{A12})$	0,3	0,3	0,3	0,3	0,3	2
Ac-dc difference TTS2 8 V	$u(d_{T2})$	1,46	2,04	2,54	3,13	4,42	70
2:1 comparison							
Ac-dc difference TTS1&TTS2 16 V	$u(d_{S12})$	1,42	2,01	2,51	3,11	4,41	69
Phase angle error	$u(d_a)$	0,3	0,5	0,5	0,5	0,5	10
Guarding	$u(d_g)$	0,1	0,2	0,4	1,0	2,0	10
Measurement set-up	$u(d_{B123})$	0,4	0,4	0,4	0,4	0,4	10
Indicated ac-dc difference	$u(d_{A123})$	0,4	0,4	0,4	0,4	0,4	2
Ac-dc difference TVC3 16 V	$u(d_{T3})$	1,56	2,16	2,65	3,35	4,90	81
1:1 comparison							
Ac-dc difference TVC3 16 V	$u(d_{S3})$	1,56	2,16	2,65	3,35	4,90	81
Temperature coefficient TVC3	$u(d_{TC})$	0	0,05	0,1	0,25	0,5	10
T-connector and reference plane	$u(d_c)$	0,1	0,2	0,2	0,3	0,4	10
Measurement set-up	$u(d_{B31})$	0,4	0,4	0,4	0,4	0,4	10
Indicated ac-dc difference	$u(d_{A31})$	0,3	0,3	0,3	0,3	0,3	2
Ac-dc difference TTS1 16 V	$u(d_{T1})$	1,64	2,22	2,71	3,41	4,96	86
Standard uncertainty 16 V	$\mathbf{u(d_{16V})}$	**1,7**	**2,3**	**2,8**	**3,5**	**5,0**	**86**
From 16 V to 32 V							
1:1 comparison							
Ac-dc difference TTS1 16 V	$u(d_{S1})$	1,7	2,3	2,8	3,5	5,0	86
Measurement set-up	$u(d_{B12})$	0,2	0,2	0,2	0,2	0,2	10
Indicated ac-dc difference	$u(d_{A12})$	0,3	0,3	0,3	0,3	0,3	2
Ac-dc difference TTS2 16 V	$u(d_{T2})$	1,74	2,33	2,82	3,52	5,01	86
PVB							
Ac-dc difference TTS1&TTS2 32 V	$u(d_{S12})$	1,72	2,31	2,81	3,51	5,01	86
Phase angle error	$u(d_a)$	0,3	0,3	0,5	0,5	0,5	10
Guarding	$u(d_g)$	0,1	0,2	0,4	1,0	2,0	10
Measurement set-up	$u(d_{B123})$	0,4	0,4	0,4	0,4	0,4	10
Indicated ac-dc difference	$u(d_{A123})$	0,4	0,4	0,4	0,4	0,4	2
Ac-dc difference TVC3 32 V	$u(d_{T3})$	1,84	2,41	2,94	3,73	5,44	98
1:1 comparison							
Ac-dc difference TVC3 32 V	$u(d_{S3})$	1,84	2,41	2,94	3,73	5,44	98
T-connector and reference plane	$u(d_{TC})$	0,1	0,1	0,1	0,2	0,2	10
Temperature coefficient TVC3	$u(d_c)$	0	0,05	0,1	0,25	0,5	10
Measurement set-up	$u(d_{B31})$	0,4	0,4	0,4	0,4	0,4	10
Indicated ac-dc difference	$u(d_{A31})$	0,4	0,4	0,4	0,4	0,4	2
Ac-dc difference TTS1 32 V	$u(d_{T1})$	1,92	2,48	3,00	3,78	5,50	102
Standard uncertainty 32 V	$\mathbf{u(d_{32V})}$	**2,0**	**2,5**	**3,0**	**3,8**	**5,5**	**102**

Quantity	u	Standard uncertainties in uV/V at frequency					Eq. deg. freedom
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	
From 32 V to 64 V							
1:1 comparison							
Ac-dc difference TTS1 32 V	$u(d_{S1})$	2,0	2,5	3,0	3,8	5,5	102
Measurement set-up	$u(d_{B12})$	0,2	0,2	0,2	0,2	0,2	10
Indicated ac-dc difference	$u(d_{A12})$	0,4	0,4	0,4	0,4	0,4	2
Ac-dc difference TTS2 32 V	$u(d_{T2})$	2,05	2,54	3,03	3,83	5,52	104
2:1 comparison							
Ac-dc difference TTS1&TTS2 64 V	$u(d_{S12})$	2,01	2,51	3,01	3,81	5,50	103
Phase angle error	$u(d_a)$	0,3	0,5	0,5	0,5	0,5	10
Guarding	$u(d_g)$	0,1	0,2	0,4	1,0	2,0	10
Measurement set-up	$u(d_{B123})$	0,5	0,5	0,5	0,5	0,5	10
Indicated ac-dc difference	$u(d_{A123})$	0,5	0,5	1,0	1,5	2,0	2
Ac-dc difference TVC3 64 V	$u(d_{T3})$	2,16	2,66	3,27	4,27	6,23	81
1:1 comparison							
Ac-dc difference TVC3 64 V	$u(d_{S3})$	2,16	2,66	3,27	4,27	6,23	81
Temperature coefficient TVC3	$u(d_{TC})$	0,05	0,2	0,4	1,0	2,0	10
T-connector and reference plane	$u(d_c)$	0,1	0,1	0,1	0,1	0,1	10
Measurement set-up	$u(d_{B31})$	0,5	0,5	0,5	0,5	0,5	10
Indicated ac-dc difference	$u(d_{A31})$	0,5	0,5	1,0	1,5	2,0	2
Ac-dc difference TTS1 64 V	$u(d_{T1})$	2,27	2,76	3,48	4,66	6,86	79
Standard uncertainty 64 V	$\mathbf{u(d_{64V})}$	**2,3**	**2,8**	**3,5**	**4,7**	**6,9**	**79**
From 64 V to 128 V							
1:1 comparison							
Ac-dc difference TTS1 64 V	$u(d_{S1})$	2,3	2,8	3,5	4,7	6,9	79
Measurement set-up	$u(d_{B12})$	0,2	0,2	0,2	0,2	0,2	10
Indicated ac-dc difference	$u(d_{A12})$	0,4	0,4	0,4	0,4	0,4	2
Ac-dc difference TTS2 64 V	$u(d_{T2})$	2,34	2,84	3,53	4,72	6,91	79
PVB							
Ac-dc difference TTS1&TTS2 128 V	$u(d_{S12})$	2,32	2,82	3,51	4,71	6,91	79
Phase angle error	$u(d_a)$	0,3	0,3	0,5	0,5	0,5	10
Guarding	$u(d_g)$	0,1	0,2	0,4	1,0	2,0	10
Measurement set-up	$u(d_{B123})$	0,7	0,7	0,7	0,7	0,7	10
Indicated ac-dc difference	$u(d_{A123})$	0,5	0,5	1,0	1,5	2,0	2
Ac-dc difference TVC3 128 V	$u(d_{T3})$	2,50	2,97	3,77	5,12	7,51	83
1:1 comparison							
Ac-dc difference TVC3 128 V	$u(d_{S3})$	2,50	2,97	3,77	5,12	7,51	83
T-connector and reference plane	$u(d_{TC})$	0,1	0,1	0,1	0,1	0,1	10
Temperature coefficient TVC3	$u(d_c)$	0,05	0,2	0,4	1,0	2,0	10
Measurement set-up	$u(d_{B31})$	0,7	0,7	0,7	0,7	0,7	10
Indicated ac-dc difference	$u(d_{A31})$	0,5	0,5	1,0	1,5	2,0	2
Ac-dc difference TTS1 128 V	$u(d_{T1})$	2,64	3,10	3,99	5,47	8,06	88
Standard uncertainty 128 V	$\mathbf{u(d_{128V})}$	**2,7**	**3,1**	**4,0**	**5,5**	**8,1**	**88**

Quantity	u	Standard uncertainties in uV/V at frequency					Eq. deg. freedom
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	
From 128 V to 250 V (256 V)							
1:1 comparison							
Ac-dc difference TTS1 128 V	$u(d_{S1})$	2,7	3,1	4,0	5,5	8,1	88
Measurement set-up	$u(d_{B12})$	0,3	0,3	0,3	0,3	0,3	10
Indicated ac-dc difference	$u(d_{A12})$	0,5	0,5	0,5	0,5	0,5	2
Ac-dc difference TTS2 128 V	$u(d_{T2})$	2,76	3,15	4,04	5,53	8,12	89
2:1 comparison							
Ac-dc difference TTS1&TTS2 256 V	$u(d_{S12})$	2,72	3,11	4,01	5,51	8,11	88
Phase angle error	$u(d_a)$	0,3	0,5	0,5	0,5	0,5	10
Guarding	$u(d_g)$	0,1	0,2	0,4	1,0	2,0	10
Measurement set-up	$u(d_{B123})$	0,7	0,7	0,7	0,7	0,7	10
Indicated ac-dc difference	$u(d_{A123})$	1,0	1,0	1,0	1,5	2,0	2
Ac-dc difference TVC3 256 V	$u(d_{T3})$	2,99	3,39	4,24	5,86	8,63	94
1:1 comparison							
Ac-dc difference TVC3 256 V	$u(d_{S3})$	2,99	3,39	4,24	5,86	8,63	94
Temperature coefficient TVC3	$u(d_{TC})$	0,2	0,4	0,7	1,5	2,7	10
T-connector and reference plane	$u(d_c)$	0,1	0,1	0,1	0,1	0,1	10
Measurement set-up	$u(d_{B31})$	0,7	0,7	0,7	0,7	0,7	10
Indicated ac-dc difference	$u(d_{A31})$	1,0	1,0	1,0	1,5	2,0	2
Ac-dc difference TTS1 250 V	$u(d_{T1})$	3,24	3,62	4,47	6,27	9,29	103
Standard uncertainty 250 V	$u(d_{250V})$	**3,3**	**3,7**	**4,5**	**6,3**	**9,3**	**103**
From 250 V to 500 V							
1:1 comparison							
Ac-dc difference TTS1 250 V	$u(d_{S1})$	3,3	3,7	4,5	6,3	9,3	103
Measurement set-up	$u(d_{B12})$	0,4	0,4	0,4	0,4	0,4	10
Indicated ac-dc difference	$u(d_{A12})$	1,0	1,0	1,0	1,5	2,0	2
Ac-dc difference TTS2 250 V	$u(d_{T2})$	3,47	3,85	4,63	6,49	9,52	102
PVB							
Ac-dc difference TTS1&TTS2 500 V	$u(d_{S12})$	3,39	3,78	4,56	6,39	9,41	107
Phase angle error	$u(d_a)$	0,3	0,3	0,5	0,5	0,5	10
Guarding	$u(d_g)$	0,1	0,2	0,4	1,0	2,0	10
Measurement set-up	$u(d_{B123})$	0,7	0,7	0,7	0,7	0,7	10
Indicated ac-dc difference	$u(d_{A123})$	0,5	0,5	0,5	0,5	0,5	2
Ac-dc difference TVC3 500 V	$u(d_{T3})$	3,51	3,89	4,69	6,55	9,67	117
1:1 comparison							
Ac-dc difference TVC3 500 V	$u(d_{S3})$	3,51	3,89	4,69	6,55	9,67	117
T-connector and reference plane	$u(d_{TC})$	0,1	0,1	0,1	0,1	0,1	10
Temperature coefficient TVC3	$u(d_c)$	0,05	0,1	0,2	0,5	1,0	10
Measurement set-up	$u(d_{B31})$	0,7	0,7	0,7	0,7	0,7	10
Indicated ac-dc difference	$u(d_{A31})$	0,5	0,5	0,5	0,5	0,5	2
Ac-dc difference TTS1 500 V	$u(d_{T1})$	3,61	3,99	4,77	6,62	9,76	121
Standard uncertainty 500 V	$u(d_{500V})$	**3,7**	**4,0**	**4,8**	**6,7**	**9,8**	**121**

Quantity	u	Standard uncertainties in uV/V at frequency					Eq. deg.
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	freedom
From 500 V to 1 kV							
1:1 comparison							
Ac-dc difference TTS1 500 V	$u(d_{S1})$	3,7	4,0	4,8	6,7	9,8	121
Measurement set-up	$u(d_{B12})$	0,5	0,5	0,5	0,5	0,5	10
Indicated ac-dc difference	$u(d_{A12})$	0,5	0,5	0,5	0,5	0,5	2
Ac-dc difference TTS2 500 V	$u(d_{T2})$	3,77	4,06	4,85	6,74	9,83	123
2:1 comparison							
Ac-dc difference TTS1&TTS2 1 kV	$u(d_{S12})$	3,72	4,02	4,81	6,71	9,81	122
Phase angle error	$u(d_a)$	0,3	0,5	0,5	0,5	0,5	10
Guarding	$u(d_g)$	0,1	0,2	0,4	1,0	2,0	10
Measurement set-up	$u(d_{B123})$	0,7	0,7	0,7	0,7	0,7	10
Indicated ac-dc difference	$u(d_{A123})$	1,0	1,0	1,0	1,0	1,0	2
Ac-dc difference TVC3 1 kV	$u(d_{T3})$	3,92	4,23	5,01	6,91	10,09	133
1:1 comparison							
Ac-dc difference TVC3 1 kV	$u(d_{S3})$	3,92	4,23	5,01	6,91	10,09	133
Temperature coefficient TVC3	$u(d_{TC})$	0,05	0,2	0,4	1,0	2,0	10
T-connector and reference plane	$u(d_c)$	0,1	0,1	0,1	0,1	0,1	10
Measurement set-up	$u(d_{B31})$	0,7	0,7	0,7	0,7	0,7	10
Indicated ac-dc difference	$u(d_{A31})$	0,5	0,5	0,5	0,5	0,5	2
Ac-dc difference TTS1 1 kV	$u(d_{T1})$	4,02	4,32	5,10	7,04	10,33	143
Standard uncertainty 1 kV	**$u(d_{1kV})$**	**4,1**	**4,4**	**5,1**	**7,1**	**10,4**	**143**

DETERMINATION OF THE UNCERTAINTY OF THE IEN STEP-UP

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The uncertainty of the basic reference group at 4 V is given by combination of:

- $u(x_1(f_i)$ estimated uncertainty of the mean value of the reference group at 3 V, which takes into account the uncertainty of ac-dc transfer difference of the multijunction.converters and the optimization of the measurement values in the reference group, obtained by least square adjustment.

$$u'(x_1(f_i)) = \sqrt{\frac{\sum_{i=1}^{N} R_i}{N - C + 1}} \quad (1)$$

where:
R_i is residual of the measurements
N number of independent measurements
C number of standards in the steps

- $u(x_2(f_i))$ uncertainty of the determination of the variation of the ac-dc transfer difference between 3 and 4 V.

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_1(f_i))$	0.4	0.6	0.7	1.1	1.7
$u(x_2(f_i))$	0.08	0.08	0.08	0.08	0.08

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u_C(Y)$	0.4	0.6	0.7	1.1	1.7

The uncertainty of the other steps are:

Step	**Voltage (V)**	
	Lower value	**Nominal value**
1	4	6
2	6	10
3	10	12
4	12	20
5	20	30
6	30	40
7	40	60
8	60	100
9	100	200
10	200	500
11	500	1000

The value of the ac-dc transfer difference in each step $Y_p(f_i)$ is given by:

$$Y_p(f_i) = X_{1,p}(f_i) + X_{2,p}(f_i) + X_{3,p}(f_i) + X_{4,p}(f_i) \quad (2)$$

where:

$X_{1,p}(f_i)$ is the ac-dc transfer difference of the converters at the lower voltage level in the previous step;

$X_{2,p}(fi)$ is the difference between the ac-dc transfer difference evaluated by the measurements and the optimization of the results;

$X_{3,p}(f_i)$ is the variation of the ac-dc transfer difference of the reference converter as function of the applied voltage in the transition between the lower value and the nominal value. This component, which is due only to the thermal element, is evaluated;

$X_{4,p}(f_i)$ is the variation of the ac-dc transfer difference of the reference converter as function of the applied voltage in the transition between the lower value and the nominal value. This component, which is due only to the resistor, has been estimated only for voltages higher than 100 V and has been assumed to be zero for other voltages.

In the 11 steps of the step-up procedure up to 1000 V the relation:

$$X_{1,p+1}(f_i) = Y_p(f_i) \qquad (3)$$

is applied.

- $u(x_{2,p}(f_i))$ is evaluated on the basis of the measurements performed at that voltage level by applying to them the least square adjustment.
- $u(x_{3,p}(f_i))$ is evaluated by combination of the uncertainties in the determination of the ac-dc transfer differences of the thermal element in the two voltage levels.
- $u(x_{4,p}(f_i))$ due to the voltage dependence of the range resistors, is evaluated from the differences between the ac-dc transfer differences at nominal voltage and at reduced voltage in comparison with a thermal converter having a higher nominal voltage (for example the dependence of the 200 V thermal converters has been estimated from the difference between the ac-dc transfer differences of such converters at 200 V and at 100 V measured in comparison with a 500 V nominal voltage thermal converter). In this determination the variation of the power in all the converters and of the ac-dc transfer difference due to the thermal element have also been taken into account. The uncertainty of the voltage dependence on the 1000 V converter has been obtained by extrapolation assuming a behavior proportional to the power supplied to the converter.

Step 1 (form 4V to 6V)

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,1}(f_i))$	0.10	0.33	0.45	0.90	1.28
$u(x_{3,1}(f_i))$	0.14	0.14	0.14	0.14	0.14
$u(x_{4,1}(f_i))$	0.05	0.05	0.09	0.14	0.35

Step 2 (from 6V to 10V)

f_i	1kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,2}(f_i))$	0.06	0.21	0.27	0.26	0.30
$u(x_{3,2}(f_i))$	1.1	1.1	1.1	1.1	1.1
$u(x_{4,2}(f_i))$	0.05	0.05	0.09	0.13	0.33

Step 3 (from 10V to 12V)

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,3}(f_i))$	0.19	0.25	0.27	0.45	0.61
$u(x_{3,3}(f_i))$	0.26	0.26	0.26	0.26	0.26
$u(x_{4,3}(f_i))$	0.11	0.11	0.20	0.30	0.76

Step 4 (form 12V to 20V)

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,4}(f_i))$	0.14	0.33	0.37	0.36	0.35
$u(x_{3,4}(f_i))$	0.16	0.16	0.16	0.16	0.16
$u(x_{4,4}(f_i))$	0.19	0.19	0.35	0.52	1.3

Step 5 (form 20V a 30V)

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,5}(f_i))$	0.22	0.05	0.16	0.61	0.31
$u(x_{3,5}(f_i))$	0.82	0.82	0.82	0.82	0.82
$u(x_{4,5}(f_i))$	0.12	0.12	0.23	0.34	0.87

Step 6 (from 30V to 40V)

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,6}(f_i))$	0.20	0.43	0.61	0.89	1.14
$u(x_{3,6}(f_i))$	0.30	0.30	0.30	0.30	0.30
$u(x_{4,6}(f_i))$	0.51	0.51	0.95	1.4	3.6

Step 7 (from 40V to 60V)

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,7}(f_i))$	0.16	0.24	0.18	0.11	0.13
$u(x_{3,7}(f_i))$	0.14	0.14	0.14	0.14	0.14
$u(x_{4,7}(f_i))$	0.49	0.49	0.91	1.4	3.5

Step 8 (from 60V to 100V)

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,8}(f_i))$	0.40	0.10	0.13	0.61	0.78
$u(x_{3,8}(f_i))$	1.1	1.1	1.1	1.1	1.1
$u(x_{4,8}(f_i))$	0.47	0.47	0.87	1.3	3.3

Step 9 (from 100V to 200V)

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,9}(f_i))$	0.25	0.12	0.22	0.41	0.53
$u(x_{3,9}(f_i))$	0.25	0.25	0.25	0.25	0.25
$u(x_{4,9}(f_i))$	2.2	2.2	4.1	6.1	16

Step 10 (from 200V to 500V)

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,10}(f_i))$	0.33	0.17	0.34	1.3	2.1
$u(x_{3,10}(f_i))$	0.95	0.95	0.95	0.95	0.95
$u(x_{4,10}(f_i))$	1.5	1.5	2.9	4.3	11

Step 11 (from 500V to 1000V)

f_i	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
$u(x_{2,11}(f_i))$	1.3	1.4	1.3	2.1	2.2
$u(x_{3,11}(f_i))$	1.2	1.2	1.2	1.2	1.2
$u(x_{4,11}(f_i))$	5.5	5.5	10	15	31

The determination of the $u_{i,p}$ (fi) is obtained by collecting the different components on the basis of the first index j, which displays the type of the component.

For j = 2, $\overline{u_{2,p}}(f_i)$ are evaluated by the quadratic sum of the single components of the same index for the different steps.

$$\overline{u_{2,p}}(f_i)=\sqrt{\sum_{k=1}^{p}\left(u(X_{2,p}(f_i))\right)^2} \quad (4)$$

For j = 3, where the correlation for the steps that use the same thermoelement is assumed to be 1,

$$\overline{u_{3,p}}(f_i)=\sqrt{\sum_{t=1}^{nt}\left(\sum_{k=1}^{nl(t)}u(X_{3,t,k}(f_i))\right)^2} \quad (5)$$

where:
nt is the number of thermoelements used to reach the step *p;*
nl(t) is the number of steps where the same thermoelement *t* is used

For j = 3, where the correlation is 1 for the steps that use the same range resistors:

$$\overline{u_{4,p}}(f_i)=\sqrt{\sum_{r=1}^{nr}\left(\sum_{k=1}^{nl(r)}u(X_{4,r,k}(f_i))\right)^2} \quad (6)$$

where:
nr is the number of range resistor used to reach the step *p;*
nl(r) is the number of steps where the same range resistor *r* is used.

The total uncertainty at the step *p* and the frequency f_i is given by:

$$u_{c,p}(f_i)=\sqrt{(u_C(f_i))^2+(\overline{u_{2,p}}(f_i))^2+(\overline{u_{3,p}}(f_i))^2+(\overline{u_{4,p}}(f_i))^2} \quad (7)$$

$u_{c,p}(f_i)$ (parts in 10^6)						
f_i		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
p =1	6 V	0.46	0.74	0.82	1.5	2.2
p=2	10 V	1.2	1.3	1.4	1.8	2.5
p=3	12 V	1.2	1.4	1.5	2.0	2.8
p=4	20 V	1.3	1.5	1.6	2.1	3.2
p=5	30 V	2.0	2.1	2.2	2.7	3.7
p=6	40 V	2.2	2.4	2.7	3.5	6.4
p=7	60 V	2.3	2.5	3.0	3.9	7.7
p=8	100 V	3.3	3.4	3.8	4.7	8.7
p=9	200 V	4.2	4.3	6.2	8.7	20.6
p=10	500 V	4.6	4.6	6.9	9.8	23.3
p=11	1000 V	7.4	7.5	12.4	18.3	38.9

Extracts from:"COMPARISON CCEM-K9 High Voltage AC-DC transfer Report of the measurements at IEN" **U. Pogliano and G. C. Bosco,** IEN Report N. 624March 2001

7. UNCERTAINTIES

The uncertainties of the AC/DC transfer differences are evaluated in Table 8, Table 9 and Table 10.

Table 8 *Assigned uncertainties of the transfer differences at 200 V (1σ in parts in 10^6).*

Unc. components	Type	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Reference standard		4.2	4.3	6.2	8.7	20.6
Repetitions of meas.	A	0.3	0.4	0.8	1.1	0.6
EMFs comparator	B	0.5	0.5	0.5	0.5	0.5
Measurement system additional uncertainty	B	0.5	0.8	1	2.5	5
Total uncertainty		**4.3**	**4.4**	**6.4**	**9.1**	**21.2**

Table 9 *Assigned uncertainties of the transfer differences at 500 V (1σ in parts in 10^6).*

Unc. components	Type	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Reference standard		4.6	4.6	6.9	9.8	23.3
Repetitions of meas.	A	0.4	0.3	0.3	0.4	0.5
EMFs comparator	B	0.3	0.3	0.3	0.3	0.3
Measurement system additional uncertainty	B	0.5	0.8	1	2.5	5
Total uncertainty		**4.7**	**4.7**	**7.0**	**10.1**	**23.8**

Table 10 *Assigned uncertainties of the transfer differences at 1000 V (1σ in parts in 10^6).*

Unc. components	Type	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Reference standard		7.4	7.5	12.4	18.3	38.9
Repetitions of meas.	A	0.1	0.4	0.2	0.3	0.6
EMFs comparator	B	0.1	0.1	0.1	0.1	0.1
Measurement system additional uncertainty	B	0.5	1.2	1.5	3.5	8
Total uncertainty		**7.4**	**7.6**	**12.5**	**18.6**	**39.7**

The uncertainty component due to the electromotive-force comparator was evaluated from the differences obtained by connecting the output of the same thermal converter to both channels and applying the usual measurement procedure. The additional component due to the system was evaluated by repeating the comparisons in different conditions, for example: using different type of T–connectors, changing the positions of the mechanical supports of the converters and using different cables.

UNCERTAINTY BUDGET FOR CEM (SPAIN)

Uncertainty of measurement.

An analysis of the uncertainties of measurement for the CEM-standards has been performed in accordance with the CIPM Recommendation 1 (CI-1981).

We enclose, tables 1, 2 and 3, an uncertainty budget with the reason of the deviation, type of distribution and standard deviations in 10^{-6} at measurement frequencies. We provide a list of type A and type B contributions. It also provides an overall uncertainty with the root squares of all contributions.

The study of the uncertainties contains all contributions from the PTB-MJTC basis; these reference values are based on the CCEM-K6.a. All type B contributions with rectangular distribution. We include the reference in the estimation of the uncertainty at level of 3 V. The standards for higher voltages are calibrated by a "step up" procedure with 10 steps. The uncertainties owing to the current level of the MJTC and owing to the voltage level of the voltage dropping resistors are correlated.

The calibration of the travelling standard is carried out by direct comparison against the CEM standards. Standard deviations smaller than 1 10^{-6} at 200 V and 500 V and up to 4 10^{-6} at 1000 V are obtained, which does not increase the uncertainty of the measurement results notably.

At the end we represent a combined value. All uncertainties are given at 1 σ. The degrees of freedom ν, for the uncertainty contribution of the 12 measurements is 11 (type A evaluation). The uncertainties obtained from a type B evaluation, dominate in the final combined standard uncertainty, and they can be treated as exactly known,

$\nu_i \longrightarrow \infty$, so the number of effective degrees of freedom of our results, $\nu_{eff} \longrightarrow \infty$, too ($\nu_{eff}$ >25000).

Uncertainty of the primary ac-dc voltage transfer standard. MJTC at 3V level											
		Standard measurement uncertainty, u, in 10^{-6} at the frequencies,									
Influence quantity	u	10 Hz	20 Hz	40 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	500 kHz	1 MHz
Thomson effect.	$u(\delta_{TH})$	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Reactive components and loss factor of the heater	$u(\delta_{LGC})$	0	0	0	0,01	0,1	0,4	0,7	1	5	10
Low frequency effects	$u(\delta_{LF})$	2,5	1,5	1	0,1	0	0	0	0	0	0
Skin effect	$u(\delta_{Skin})$	0	0	0	0,01	0,01	0,01	0,01	0,1	2	5
Connectors and T	$u(\delta_{conn})$	0	0	0	0,5	0,5	0,5	0,6	0,7	1	3
Reference standard	$\mathbf{u(\delta_S)}$	**2,5**	**1,5**	**1**	**0,5**	**0,5**	**0,6**	**1**	**1,2**	**5,5**	**11,6**

Table 1. $\mathbf{u^2(\delta_S) = u^2(\delta_{TH}) + u^2(\delta_{LGC}) + u^2(\delta_{Skin}) + u^2(\delta_{conn}) + u^2(\delta_{LF})}$

UNCERTAINTY BUDGET OF AC/DC VOLTAGE TRANSFER STANDARDS AT CEM

Reason of deviation	Standard uncertainty in 10^{-6} at the frequencies: 10 Hz	20 Hz	40 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	500 kHz	1 MHz	Remarks/ distribution
Standard uncertainty $u(\delta_s)$ (1σ) at 3 V level.	2,5	1,5	1	0,5	0,5	0,6	1	1,2	5,5	11,6	Reference
Step-up procedure. Standard deviations per step, change of transfer differences :											Worst case $\pm X/\sqrt{3}$ correl.
- With current level of the converters $u(\delta_n)$	1	0,8	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	
- With voltage $u(\delta s_i)$:											
up to 10 V	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	1,5	1,5	
up to 30 V	2	1	1	1	1	1	1	1	2	2	
up to 100 V	2	1	1	1	1	1	1	1	-	-	
up to 300 V	3	2	1,5	1	1	1	2	3	-	-	
up to 500 V	5	4	3	1,5	1,5	2	4	6	-	-	
up to 1000 V	7	6	5	3	5	6	12	24	-	-	-----------------
Drift during measurement	2	1	0,5	0,5	0,5	0,5	0,5	0,5	1	2	$u(\delta_d)$
Comparison measurement	1,5	1	1	0,5	0,5	0,5	0,5	1	2	3	$u(\delta m)$
Standard uncertainty per additional steps $u(\delta c_i)$:											
to 5 V, 10 V	2,9	1,9	1,5	1,2	1,2	1,2	1,2	1,5	3	4,1	steps 1-2
20 V, 30 V	3,9	2,3	1,9	1,7	1,7	1,7	1,7	1,9	3,4	4,4	steps 3-4
50 V, 100 V	3,9	2,3	1,9	1,7	1,7	1,7	1,7	1,9	-	-	steps 5-6
200 V, 300 V	4,7	3,1	2,3	1,7	1,7	1,7	2,6	3,7	-	-	steps 7-8
500 V	6,5	5	3,7	2,1	2,1	2,6	4,6	6,6	-	-	step 9
1000 V	8,4	6,9	5,6	3,6	5,5	6,5	12,5	24,5	-	-	step 10
Total uncertainty $u(\delta_V)$ (1σ) of the standards :											
3 V	2,5	1,5	1	0,5	0,5	0,6	1	1,2	5,5	11,6	
5 V	3,8	2,4	1,8	1,3	1,3	1,3	1,6	1,9	6,3	12,3	1 step
10 V	6,3	4,1	3,2	2,5	2,5	2,5	2,6	3,2	8,1	14,2	2 steps
20 V	10	6,3	5	4,1	4,1	4,1	4,2	5	10,9	17,1	3 steps
30 V	13,8	8,5	6,9	5,8	5,8	5,8	5,9	6,9	-	-	4 steps
50 V	17,7	10,8	8,8	7,5	7,5	7,5	7,6	8,8	-	-	5 steps
100 V	21,5	13,1	10,6	9,2	9,2	9,2	9,3	10,7	-	-	6 steps
200 V	**26,2**	**16,2**	**12,9**	**10,9**	**10,9**	**10,9**	**11,8**	**14,4**	-	-	7 steps
300 V	30,9	19,3	15,2	12,6	12,6	12,6	14,4	18	-	-	8 steps
500 V	**37,4**	**24,2**	**18,9**	**14,7**	**14,7**	**15,2**	**19**	**24,6**	-	-	9 steps
1000 V	**45,8**	**31,1**	**24,5**	**18,3**	**20,2**	**21,7**	**31,5**	**49,1**	-	-	10 steps

$$u(\delta_{ci}) = \sqrt{(u(\delta n) + u(\delta si))^2 + u(\delta d)^2 + u(\delta m)^2}$$

$$u(\delta_V) = \sqrt{u(\delta s)^2 + \left(\sum u(\delta_{ci})\right)^2}$$

Table 2. Uncertainty budget of the ac-dc voltage transfer standards at CEM.

Uncertainty on the comparison of the reference of CEM with the travelling standard						
Standard measurement uncertainty, u, in 10^{-6} at the frequencies,						
	u	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Reference standard 200 V 500 V 1000 V	$u(\delta_V)$	 10,9 14,7 18,3	 10,9 14,7 20,2	 10,9 15,2 21,7	 11,8 19 31,5	 14,4 24,6 49,1
Drift during measurements	$u(\delta_d)$	0,5	0,5	0,5	0,5	0,5
Comparison measurements	$u(\delta_C)$	0,5	0,5	0,5	0,5	1
standard deviation of the measurements 200 V 500 V 1000 V	$u(\delta_A)$	 1 1 2	 1 1 3	 1 1 3,2	 1 1 3,,2	 1 1 4
Standard meas. Uncertainty **200 V** **500 V** **1000 V**	$\mathbf{u(\delta_x)}$	 **11** **14,8** **18,4**	 **11** **14,8** **20,4**	 **11** **15,2** **22**	 **12** **19** **31,7**	 **14,4** **24,6** **49,3**

Table 3. $u^2(\delta_x) = u^2(\delta_V) + u^2(\delta_d) + u^2(\delta_C) + u^2(\delta_A)$

UNCERTAINTY BUDGET FOR PTB (GERMANY)

influence quantity	u	standard measurement uncertaintyies u in 10^{-6} at the frequencies				
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
MJTC at 5-V-level						
Thomson effect at dc	$u(\delta_{TH})$	0,01	0,01	0,01	0,01	0,01
reactive components and loss factor of the heater	$u(\delta_{L,G,C})$	0,00	0,02	0,02	0,05	0,13
skineffect	$u(\delta_{SKIN})$	0,00	0,00	0,00	0,00	0,03
low frequency effect	$u(\delta_{LF})$	0,00	0,00	0,00	0,00	0,00
connector and T	$u(\delta_{Connect})$	0,00	0,10	0,10	0,30	0,50
measurements between different converters	$u(\delta_{d})$	0,10	0,10	0,10	0,10	0,50
standard uncertainty 5-V	$u(\delta_{S\,5\text{-}V})$	**0,1**	**0,1**	**0,1**	**0,3**	**0,7**
Step-up procedure						
10-V-level						
standard uncertainty 5 V	$u(\delta_{S\,5\,V})$	0,1	0,1	0,1	0,3	0,7
comparison measurements	$u(\delta_{d})$	0,1	0,1	0,1	0,1	0,5
resistor voltage coefficient	$u(\delta_{U\text{voltage coefficient}})$	0,4	0,4	0,4	0,4	1,0
standard uncertainty 10 V	$u(\delta_{S\,10\,V})$	**0,4**	**0,4**	**0,4**	**0,5**	**1,3**
20-V-level						
standard uncertainty 10 V	$u(\delta_{S\,10\,V})$	0,4	0,4	0,4	0,5	1,3
comparison measurements	$u(\delta_{d})$	0,1	0,1	0,1	0,1	0,5
resistor voltage coefficient	$u(\delta_{U\text{voltage coefficient}})$	0,4	0,4	0,4	0,4	1,0
standard uncertainty 20 V	$u(\delta_{S\,20\,V})$	**0,6**	**0,6**	**0,6**	**0,7**	**1,7**
100-V-level						
standard uncertainty 20 V	$u(\delta_{S\,20\,V})$	0,6	0,6	0,6	0,7	1,7
comparison measurements	$u(\delta_{d})$	0,1	0,1	0,1	0,1	0,5
resistor/converter combination	$u(\delta_{U\text{standards}})$	1,9	1,9	1,9	1,9	1,9
resistor voltage coefficient	$u(\delta_{U\text{voltage coefficient}})$	1,0	1,0	1,0	1,0	1,0
standard uncertainty 100 V	$u(\delta_{S\,100\,V})$	**2,2**	**2,2**	**2,2**	**2,3**	**2,8**
200-V-level						
standard uncertainty 100 V	$u(\delta_{S\,100\,V})$	2,2	2,2	2,2	2,3	2,8
comparison measurements	$u(\delta_{d})$	0,1	0,1	0,1	0,1	0,5
resistor/converter combination	$u(\delta_{U\text{standards}})$	1,2	1,2	1,2	1,2	2,8
resistor voltage coefficient	$u(\delta_{U\text{volt. coefficient}})$	1,5	1,5	1,5	1,6	4,1
with high voltage amplifiers	$u(\delta_{U\text{amplifiers}})$	2,3	2,3	2,9	3,5	9,0
standard uncertainty 200 V	$u(\delta_{S\,200\,V})$	**3,7**	**3,7**	**4,1**	**4,6**	**11**

influence quantity	u	standard measurement uncertaintyies u in 10^{-6} at the frequencies				
		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
500-V-level						
standard uncertainty 100 V	$u(\delta_{S\ 100\ V})$	2,2	2,2	2,2	2,3	2,8
comparison measurements	$u(\delta_{d})$	0,1	0,1	0,1	0,1	0,5
resistor/converter combination	$u(\delta_{U standards})$	0,5	0,5	0,5	1	4,5
resistor voltage coefficient	$u(\delta_{U volt.\ coefficient})$	0,6	0,6	0,8	0,4	2,3
high voltage amplifiers	$u(\delta_{U amplifiers})$	0,7	0,7	0,7	2,1	8,1
standard uncertainty 500 V	$\boldsymbol{u(\delta_{S\ 500\ V})}$	**2,5**	**2,5**	**2,5**	**3,3**	**10**
600-V-level						
standard uncertainty 500 V	$u(\delta_{S\ 500\ V})$	2,5	2,5	2,5	3,3	10
comparison measurements	$u(\delta_{d})$	0,1	0,1	0,1	0,1	0,5
resistor/converter combination	$u(\delta_{U standards})$	0,5	0,5	0,5	1	4,5
resistor voltage coefficient	$u(\delta_{U volt.\ coefficient})$	0,6	0,6	0,8	0,4	2,3
high voltage amplifiers	$u(\delta_{U amplifiers})$	0,9	0,9	0,8	2,1	8,8
standard uncertainty 600 V	$\boldsymbol{u(\delta_{S\ 600\ V})}$	**2,7**	**2,7**	**2,8**	**4,0**	**14**
1000-V-level						
standard uncertainty 500 V	$u(\delta_{S\ 500\ V})$	2,5	2,5	2,5	3,3	10,0
comparison measurements	$u(\delta_{d})$	0,1	0,1	0,1	0,1	0,5
resistor/converter combination	$u(\delta_{U standards})$	0,5	0,5	0,5	1	4,5
resistor voltage coefficient	$u(\delta_{U volt.\ coefficient})$	0,4	0,4	0,9	0,3	5,5
high voltage amplifiers	$u(\delta_{U amplifiers})$	1,0	1,0	1,0	3,2	4,7
standard uncertainty 1000 V	$\boldsymbol{u(\delta_{S\ 1000\ V})}$	**2,7**	**2,7**	**2,9**	**4,7**	**13**

As at 100 kHz the standard measurement uncertainty at 600 V is larger than at 1000 V, the larger value is taken for the uncertainty at 1000 V.

All uncertainties are calculated as a mean of more than 40 measurements. Therefore the degrees of freedom can be taken as large enough to use k=2 for the calculation of the expanded measurement uncertainty at a confidence level of 95 %.

Table III. Standard measurement uncertainties

voltage	standard measurement uncertainties u in 10^{-6} at the frequencies				
	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
200 V, 500 V	4	4	4	5	11
1000 V	4	4	4	5	15

UNCERTAINTY BUDGET FOR VSL (THE NETHERLANDS)

Detailed uncertainty budget for CCEM-K9

Institute: NMi VSL B.V.

Date: 25 August 2004
By: E.F. Dierikx and J.T. Dessens

Measurements performed in May / June 2001

The AC/DC transfer difference of thermal voltage converters up to 1000 V in the frequency range from 1 kHz to 100 kHz is determined by a step-up method. The starting point of this step-up is a multi junction thermal converter (MJTC-6) with a nominal input voltage of 2.4 V, which has been calibrated at PTB. Two 1 V planar multi junction thermal converters (PM1 and PM2) are used to step-up from 3 V to 200 V by using different range resistors as shown in the diagram below. The whole range from 200 V up to 1000 V is covered by PM5B (a 2V PMJTC) in combination with a Fluke 792 range resistor of about 200 kΩ.

1000 V			TS-K9 @ 1000 V
900 V			
800 V			
700 V			
600 V			
500 V			TS-K9 @ 500 V
400 V			
300 V			
200 V		PM5B+ 200 kΩ @ 200 V	
100 V			PM2 + 18 kΩ @ 100 V
90 V			
80 V			
70 V			
60 V			
50 V		PM1 + 9,0 kΩ @ 50 V	
40 V			
30 V			PM2 + 4,4 kΩ @ 30 V
20 V		PM1 + 2,8 kΩ @ 20 V	
10 V			PM2 + 1,9 kΩ @ 10 V
9 V			
8 V			
7 V			
6 V			
5 V		PM1 + 810 Ω @ 5,0 V	
4 V			
3 V		MJTC-5 @ 3,0 V	PM2 + 360 Ω @ 3,0 V
2 V	PTB MJTC-6 @ 2,4 V		
1 V			

Figure 1 Schematic diagram of the AC-DC transfer difference step-up from 3 V up to 1000 V at NMi-VSL

For each step, the AC-DC transfer difference, $\delta_{x,step(i)}$ is calculated by:

$$\delta_{x,step(i)} = \delta_{x,step(i-1)} + \delta_{lev} + \delta_{diff}$$

where, for each step:

$\delta_{x,step(i)}$: is the unknown AC-DC difference from the converter/resistor combination under test.

$\delta_{x,step(i-1)}$: is the known reference AC-DC difference from the converter/resistor combination in the previous step.

δ_{lev}: is the voltage/current level dependence of the reference converter/resistor combination.

δ_{diff}: is the measured AC-DC difference between the reference and the unknown.

The uncertainty in each step, u_x is given by the root sum square of the individual contributions:

$$u_x = \sqrt{u_{ref}^2 + u_{lev}^2 + u_{diff}^2 + u_{std}^2}$$

where

u_{ref}: is the uncertainty of the reference converter (or converter/resistor combination)
For PTB-MJTC-6, the uncertainties are given on the PTB calibration certificate. The effective degrees of freedom ν_{ref} for PTB-MJTC-6 are estimated to be at least 1000. For all other steps, the uncertainty in de reference and the corresponding values of ν_{ref} are obtained from the previous step.

u_{lev}: is the voltage and current level dependence of the converter and range resistor.
For measurements below 30 V, this contribution is estimated to be very small; < 0.1 µV/V at all frequencies. In the range from 30 V up to 200 V, u_{lev} is typical 1 µV/V or 2 µV/V. Above 200 V the contributions are somewhat higher, but less than 10 µV/V. All of the values have been estimated from experience with these standards.
ν_{lev} is estimated to be at least 1000 for all steps.

u_{diff}: is the combined uncertainty of contributions resulting from the AC/DC difference measurement. This contains contributions for:

- drift during the measurements
- sensitivity measurement
- output voltage readout
- temperature
- reproducibility
- electromagnetic interference
- t-connector
- systematic effects from the set-up (sources, amplifiers, grounding, guarding, etc.)

All these contributions are estimate by a type B evaluation with a rectangular distribution. The combined uncertainty of these contributions is expected to have a more or less normal distribution. ν_{diff} is estimated to be at least 1000.

u_{std}: is the standard deviation of the mean of the measured values.
This contribution is estimated by a type A evaluation with a normal distribution.
In the step-up from 3 V up to 200 V each measurement is repeated at least 5 times, so $\nu_{std} > 4$. The measurements of the travelling standard at 500 V and 1000 V were each repeated more than 7 times, so in the last step $\nu_{std} > 6$.

A table for these different uncertainty contributions at each step is given below.
The total effective degrees of freedom ν_{eff} have been calculated for each step by the Welch-Satterthwaite formula according to the GUM. Only the values for ν_{eff} in the measurements at 500 V and 1000 V are shown in the table below.

Table 1 Uncertainty budget table for the NMi-VSL AC-DC difference step-up from 3 V up to 1000 V. All values are expressed as standard uncertainties in µV/V (k = 1) unless specified otherwise.

					1 kHz	10 kHz	20 kHz	50 kHz	100 kHz			
Applied Voltage V	Thermal converter	Range resistor Ω	Max. Voltage V		unc. k = 1 µV/V	unc. k = 1 µV/V	unc. k = 1 µV/V	unc. k = 1 µV/V	unc. k = 1 µV/V			
2.4	MJTC-6		3		0.5	0.5	1.0	1.0	2.5			
3	MJTC-5		3		0.5	0.5	1.0	1.0	2.5	type B	normal	u_ref
					1	1	2	2	5	k=2		
					1	1	1	2	3	type B	rectangular	u_diff
					0.1	0.1	0.1	0.1	0.1	type B	rectangular	u_lev
					1	1	1	1	1	type A	normal	u_std
3	PM2	360	5		1.5	1.5	1.7	2.5	4.0	type B	normal	u_ref
					3.0	3.0	3.5	4.9	8.1	k=2		
					1	1	1	2	3	type B	rectangular	u_diff
					0.1	0.1	0.1	0.1	0.1	type B	rectangular	u_lev
					1	1	1	1	1	type A	normal	u_std
5	PM1	810	10		2.1	2.1	2.2	3.3	5.1	type B	normal	u_ref
					4.1	4.1	4.5	6.6	10.3	k=2		
					1	1	1	2	3	type B	rectangular	u_diff
					0.1	0.1	0.1	0.1	0.1	type B	rectangular	u_lev
					1	1	1	1	1	type A	normal	u_std
10	PM2	1k9	20		2.5	2.5	2.7	4.0	6.0	type B	normal	u_ref
					5.0	5.0	5.3	8.0	12.0	k=2		
					1	1	1	2	3	type B	rectangular	u_diff
					0.1	0.1	0.1	0.1	0.1	type B	rectangular	u_lev
					1	1	1	1	1	type A	normal	u_std
20	PM1	2k8	30		2.9	2.9	3.0	4.6	6.8	type B	normal	u_ref
					5.8	5.8	6.0	9.2	13.6	k=2		
					1	1	1	2	3	type B	rectangular	u_diff
					1	1	1	2	2	type B	rectangular	u_lev
					1	1	1	1	1	type A	normal	u_std
30	PM2	4k4	50		3.4	3.4	3.5	5.5	7.8	type B	normal	u_ref
					6.7	6.7	6.9	11.0	15.5	k=2		
					1	1	1	2	3	type B	rectangular	u_diff
					1	1	1	2	2	type B	rectangular	u_lev
					1	1	1	1	1	type A	normal	u_std
50	PM1	9k0	100		3.8	3.8	3.9	6.2	8.6	type B	normal	u_ref
					7.6	7.6	7.8	12.5	17.2	k=2		
					1	1	1	2	3	type B	rectangular	u_diff
					1	1	1	2	2	type B	rectangular	u_lev
					1	1	1	1	1	type A	normal	u_std
100	PM2	18k	200		4.2	4.2	4.2	6.9	9.4	type B	normal	u_ref
					8.3	8.3	8.5	13.9	18.8	k=2		
					1	1	1	2	3	type B	rectangular	u_diff
					1	1	1	2	2	type B	rectangular	u_lev
					1	1	1	1	1	type A	normal	u_std
200	PM5B	200k	1000		4.5	4.5	4.6	7.6	10.1	type B	normal	u_ref
					9.0	9.0	9.2	15.1	20.2	k=2		

					1 kHz	10 kHz	20 kHz	50 kHz	100 kHz			
Applied Voltage V	Thermal converter	Range resistor Ω	Max. Voltage V		unc. k = 1 µV/V	unc. k = 1 µV/V	unc. k = 1 µV/V	unc. k = 1 µV/V	unc. k = 1 µV/V			
	PM5B	200k	1000		4.5	4.5	4.6	7.6	10.1	type B	normal	u_ref
					2	2	6	7	14	type B	rectangular	u_diff
					3	3	5	5	10	type B	rectangular	u_lev
					1	1	1	1	1	type A	normal	u_std
500	TS-K9		1000		5.9	5.9	9.1	11.5	20.0	type B	normal	u_ref
					517	517	1682	3237	3106	ν_eff		
					11.7	11.7	18.2	23.0	40.0	k=2		
					15.0	15.0	20.0	25.0	40.0	Reported unc. k = 2		
	PM5B	200k	1000		4.5	4.5	4.6	7.6	10.1	type B	normal	u_ref
					4	4	7	13	17	type B	rectangular	u_diff
					5	5	6	7	9	type B	rectangular	u_lev
					1	1	1	1	1	type A	normal	u_std
1000	TS-K9		1000		7.9	7.9	10.3	16.6	21.8	type B	normal	u_ref
					1621	1621	2199	2333	2426	ν_eff		
					15.8	15.8	20.7	33.2	43.5	k=2		
					20.0	20.0	25.0	35.0	50.0	Reported unc. k = 2		

The tables below were submitted to the pilot laboratory in the original measurement report from NMi-VSL. However, there was a mistake in the uncertainties for the reference standard for the measurement of TS-K9 at 1000 V. (The total uncertainties and expanded uncertainties were correct in the original table). The table below give the correct values for the uncertainty in the reference standard. (The total uncertainties k = 1 are slightly different from the values above, probably due to rounding errors.)

Travelling standard: TS-K9 at 500 V

Contribution of:	Unc. f: 1 kHz	Unc. f: 10 kHz	Unc. f: 20 kHz	Unc. f: 50 kHz	Unc. f: 100 kHz	Type A or B	Shape
St. dev. of mean	< 1	< 1	< 1	< 1	< 1	A	N
Reference standard	5	5	5	9	11	B	N
Level dependence	3	3	5	5	10	B	R
Measurement set-up	2	2	10	10	20	B	R
Connectors	2	2	4	4	10	B	R
Reproducibility	1	1	1	3	5	B	R

total unc (*k*=1):	5.7	5.7	8.6	11.5	18.2
exp. unc (*k*=2):	11.3	11.3	17.1	23.0	36.4
Reported uncertainty (*k*=2)	15	15	20	25	40

Travelling standard: TS-K9 at 1000 V

Contribution of:	Unc. f: 1 kHz	Unc. f: 10 kHz	Unc. f: 20 kHz	Unc. f: 50 kHz	Unc. f: 100 kHz	Type A or B	Shape
St. dev. of mean	< 1	< 1	< 1	< 1	< 1	A	N
Reference standard	5	5	5	9	11	B	N
Level dependence	8	8	8	12	15	B	R
Measurement set-up	4	4	10	20	25	B	R
Connectors	2	2	4	4	10	B	R
Reproducibility	1	1	1	3	5	B	R

total unc (*k*=1):	7.4	7.4	9.3	16.5	21.4
exp. unc (*k*=2):	14.7	14.7	18.6	33	42.3
Reported uncertainty (*k*=2)	20	20	25	35	50

CCEM K-9 (Euromet project no. 557) comparison
AC/DC transfer devices at AC frequencies (1-100kHz)

Report on the measurements by the National Office of Measures, Hungary

Measuring procedure

AC/DC transfer difference measurement of the travelling standard:

The AC/DC transfer difference determination of the transfer standard against the Hungarian national standards for 500V and 1000V were carried out at 1 kHz, 10 kHz, 20 kHz, 50 kHz and 100kHz frequencies.

The standards to be compared were used in a two channel automatic measuring system for thermal voltage converter comparison. During the substitution process instead of achieving a perfect balance the system uses DC or reference frequency (1 kHz) input value giving nearly balanced thermal output voltage for both converters simultaneously. Correction are made in the input voltage in dependence of the measured ΔE thermal voltage unbalance on the basis of the

$$E_{out}+\Delta E_{out}=k(V_{in}+\Delta V_{in})^n$$

theoretical function. The n exponent for each converter was determined before or after the actual measurement in a separate measuring phase using known input voltage step.

The results are the mean value of at least 10 measurements.

Measuring conditions:

1. Connection of the standards

   The converters were connected to the corresponding arm of a special T (N male/female).

2. Environment parameters.

   Ambient temperature: 23 °C ±1 K

   Relative humidity: 40% ±10%

3. Signal parameters.

   Accuracy of the AC signal frequency: ±10ppm

Measurement setup for the AC/DC transfer difference measurement

The setup for the comparison of the AC/DC transfer difference of two thermal voltage converters is shown on Fig. 1.

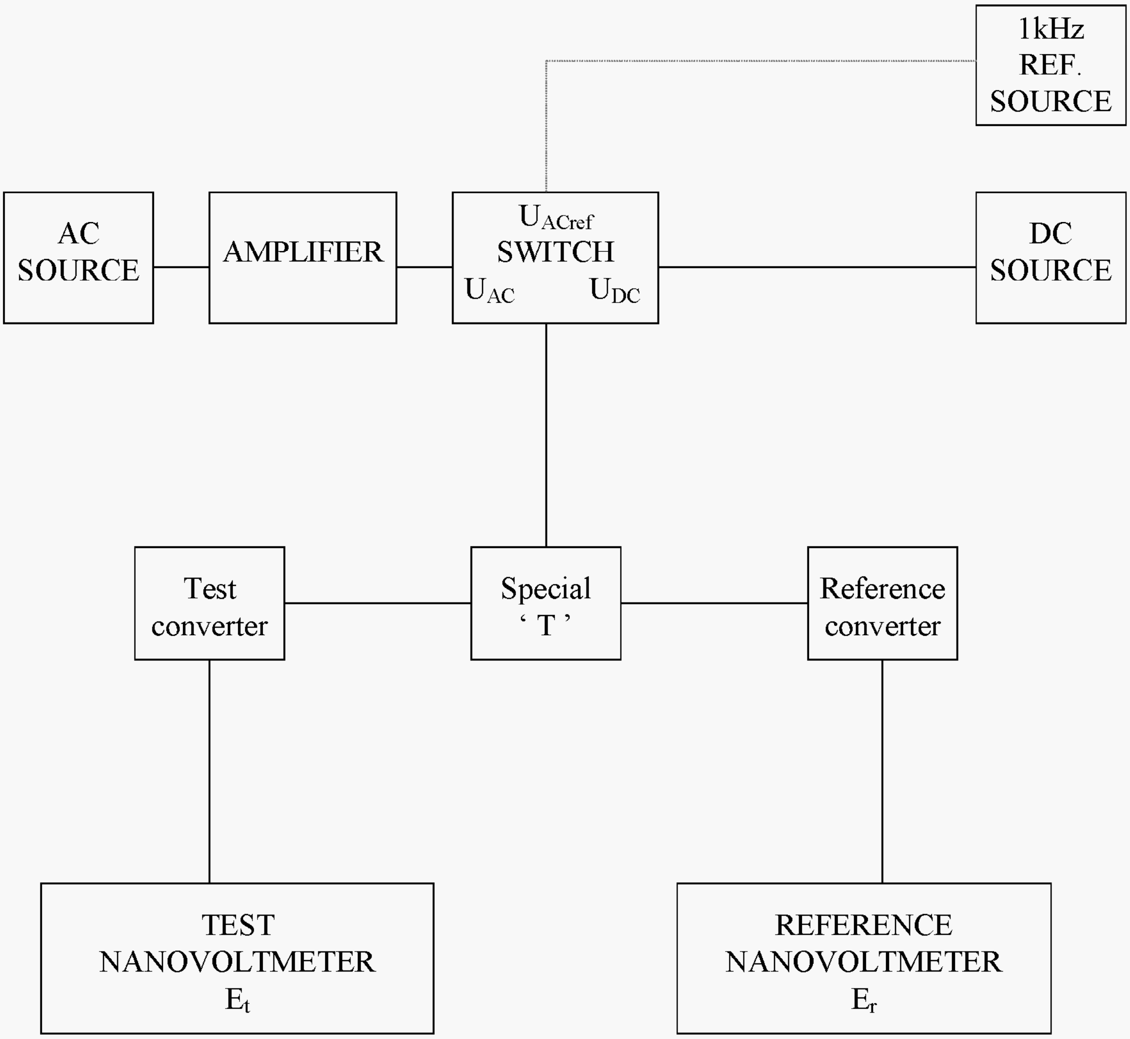

Figure 1.

The same setup was used to measure the n exponent of the converter thermal voltage -input voltage function.

Results of CCEM K-9 Comparison

Institute : National Office of Measures
Hungary
Date : October 2001.

Remarks :
The calibrations are valid in the reference plane of the supplied T connector (N male/female connectors)

Travelling standard:
1000V resistor (for Fluke 792, s/n 30) – NIST
Planar multijunction converter (no 91 PTB/IPHT MJTC 1997) - PTB

Input voltage: 500V

frequency	1	10	20	50	100
# meas.	10	10	10	10	10
δ [ppm]	-0,4	-5,3	-7,1	-19,0	-61,1
u [ppm]	31	36	40	63	100

Input voltage: 1000V

frequency [kHz]	1	10	20	50	100
# meas.	10	10	10	10	10
δ [ppm]	-0,6	1,0	-20,6	-45,2	-80,2
u [ppm]	43	52	80	120	200

Also, the measurement results of the travelling standard on this form with:
δ is the AC/DC difference
u is the total uncertainty of the measurements (at **k=2**).
A detailed uncertainty budget see Appendix 1 and Appendix 2

Appendix 1

Uncertainty budget for the calibration of the travelling standard

TRAVELLING STANDARD		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Measurement Voltage (V):	**200**					
Standard uncertainty of the reference standard:						
Measurement uncertainty	Type A					
	Type B					
Resulting standard uncertainty (k=2) (traveling standard)						
Expanded uncertainty (k=2) (traveling standard)						
Measurement Voltage (V):	**500**					
Standard uncertainty of the reference standard:		14,4	16,9	18,9	30,8	48,1
Measurement uncertainty	Type A	4	5	5	5	10
	Type B	3	4	4	4	5
Resulting standard uncertainty (k=2) (traveling standard)		15,2	18,0	19,9	31,5	49,4
Expanded uncertainty (k=2) (traveling standard)		**31**	**36**	**40**	**63**	**100**
Measurement Voltage (V):	**1000**					
Standard uncertainty of the reference standard:		20,6	25,2	37,2	59,8	98,7
Measurement uncertainty	Type A	4	5	10	5	10
	Type B	3	4	4	4	5
Resulting standard uncertainty (k=2) (traveling standard)		21,2	26,0	38,7	60,1	99,3
Expanded uncertainty (k=2) (traveling standard)		**43**	**52**	**80**	**120**	**200**

The resulting standard uncertainty was calculated by:

$$u = \sqrt{u_A^2 + u_B^2 + u_{ref}^2}$$

where

u_{ref} is is the uncertainty of the appropriate reference standard converter (see Appendix 2).

Appendix 2

Uncertainty budget for step-up procedure (OMH-Hungary)

STEP UP Procedure			1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Primary Standard	Voltage (V):	1,45					
(PTB MJTC-25)	Standard uncertainty		1,5	2	2	2	3,5
Step n° 1	Voltage (V):	3					
Measurement uncertainty:		Type A	2	2	2	2	2
		Type B	2	2	2	2	2
Uncertainty arising from voltage dependence:			0	0	0	0	0
Resulting standard uncertainty			3,2	3,5	3,5	3,5	4,5
Step n° 2	Voltage (V):	5					
Measurement uncertainty:		Type A	2	2	2	2	2
		Type B	2	2	2	2	2
Uncertainty arising from voltage dependence:			0	0	0	0	0
Resulting standard uncertainty			4,3	4,5	4,5	4,5	5,3
Step n° 3	Voltage (V):	10					
Measurement uncertainty:		Type A	2	2	2	2	2
		Type B	2	2	2	2	2
Uncertainty arising from voltage dependence:			0	0	0	0	0
Resulting standard uncertainty			5,1	5,3	5,3	5,3	6,0
Step n° 4	Voltage (V):	20					
Measurement uncertainty:		Type A	2	2	2	2	2
		Type B	2	2	2	2	2
Uncertainty arising from voltage dependence:			0	0	0	0	0
Resulting standard uncertainty			5,9	6,0	6,0	6,0	6,7
Step n° 5	Voltage (V):	30					
Measurement uncertainty:		Type A	2	2	2	2	2
		Type B	2	2	2	2	2
Uncertainty arising from voltage dependence:			0	0	0	0	0
Resulting standard uncertainty			6,5	6,6	6,6	6,6	7,2
Step n° 6	Voltage (V):	50					
Measurement uncertainty:		Type A	2	2	2	2	4
		Type B	2	2	2	2	2
Uncertainty arising from voltage dependence:			0	0	0	0	0
Resulting standard uncertainty			7,1	7,2	7,2	7,2	8,5
Step n° 7	Voltage (V):	100					
Measurement uncertainty:		Type A	4	4	4	4	6
		Type B	3	5	5	5	5
Uncertainty arising from voltage dependence:			0	0	0	0	5
Resulting standard uncertainty			8,7	9,6	9,6	9,6	12,6
Step n° 8	Voltage (V):	200					
Measurement uncertainty:		Type A	4	4	4	4	8
		Type B	5	5	5	5	5
Uncertainty arising from voltage dependence:			0	3	5	10	15
Resulting standard uncertainty			10,8	12,0	12,6	15,3	21,7
Step n° 9	Voltage (V):	300					
Measurement uncertainty:		Type A	4	4	4	4	8
		Type B	5	5	5	5	5
Uncertainty arising from voltage dependence:			3	5	5	15	20
Resulting standard uncertainty			12,9	14,5	15,0	22,4	31,0

Step n° 10	Voltage (V):	500					
Measurement uncertainty:		Type A	4	5	5	5	10
		Type B	4	5	5	5	5
Uncertainty arising from voltage dependence:			3	5	9	20	35
Resulting standard uncertainty			14,4	16,9	18,9	30,8	48,1
Step n° 11	Voltage (V):	1000					
Measurement uncertainty:		Type A	4	5	5	5	10
		Type B	10	10	10	10	10
Uncertainty arising from voltage dependence:			10	15	30	50	85
Resulting standard uncertainty			20,6	25,2	37,2	59,8	98,7

The voltage dependence was estimated from the differences calculated between measurements performed at two different voltages (ratio 1:2) and assuming that the values of the AC-DC difference are the same at both voltage levels.

The resulting standard uncertainty in each step is calculated by:

$$u = \sqrt{u_A^2 + u_B^2 + u_{ref}^2 + u_{VoltDep}^2}$$

where

u_{ref} is the uncertainty of the former reference standard converter.

UNCERTAINTY BUDGET FOR JV (NORWAY)

Step-up and calibration of the standards used

The step-up to obtain the values for the standards can be divided into two parts:

1. Step-up from ~2 V to 200 V, using coaxial range resistors in combination with single junction thermal converters (sjtcs). Two separate, complete sets of range resistors (800 Ω (RX1), 3.6 kΩ (RX2), 11.6 kΩ (RX3), 39.6 kΩ (RX4) and 120 kΩ (RX5, where X is either 1 or 2)) in different combinations with a 2.5 mA or 5 mA single junction thermal converters were used. The step-up to 200 V were performed in 8 steps: 2-3 V, 3-6V, 6-10 V, 10-20 V, 20-30 V, 30-60 V, 60-100 V and 100-200 V. Using a fast reversed DC-source[4], level dependencies in the sjtcs have been found. The final values of the AC-DC differences in the step-up have been corrected for this effect. A schematic of the step-up "chain" is presented in figure 2. Comparisons between pairs of TVCs with different ranges are always performed at the highest possible voltage, given by the converter with the smaller voltage range.
2. Step-up from 200 V to 1 kV, performed using a 1000 V range resistor (R7002), originally designed for a Fluke 792A AC-DC thermal transfer standard, in combination with a sjtc (200-500 V) or a pmjtc (500 V to 1 kV). This resistor is capacitively matched to the 2.2 V range of the specific Fluke 792A it belongs to. To be able to keep the calibration history of the 792A, this was not changed. Passive interface boxes, to be inserted between the resistor and the TVCs, were made to match the impedance of the sjtc and the pmjtc. The step-up was performed in such a way to give the maximum, independent, number of ways to get the value for the standards at 500 V (T23+R7002) and 1000 V (TVC14+R7002). To step up to 500 V four different ways were possible, to 1000 V seven. The coaxial resistors (R41 and R42) were only used for step-up from 100 to 200 V. These resistors are believed to have some level dependence, and this has been taken into account in the uncertainty budget. A schematic of the step-up "chain" is presented in figure 3.

The level dependence of the R7002 resistor has not been tested specifically. This type of resistor has been tested by other groups and found to have fairly low level dependencies[5,6]. No level dependency correction is therefore applied, but since the specific unit has not been tested, an additional uncertainty is added. The resistor also has an instability. For higher frequencies the AC-DC differences obtained from the step-up is divided into two groups, where the differences between these is frequency dependent. The final AC-DC differences is the average of these and an extra uncertainty has been added to the uncertainties from the step-up procedure.

The estimated uncertainties of the primary standards and the step-up procedures to 1000V are given in table 1.

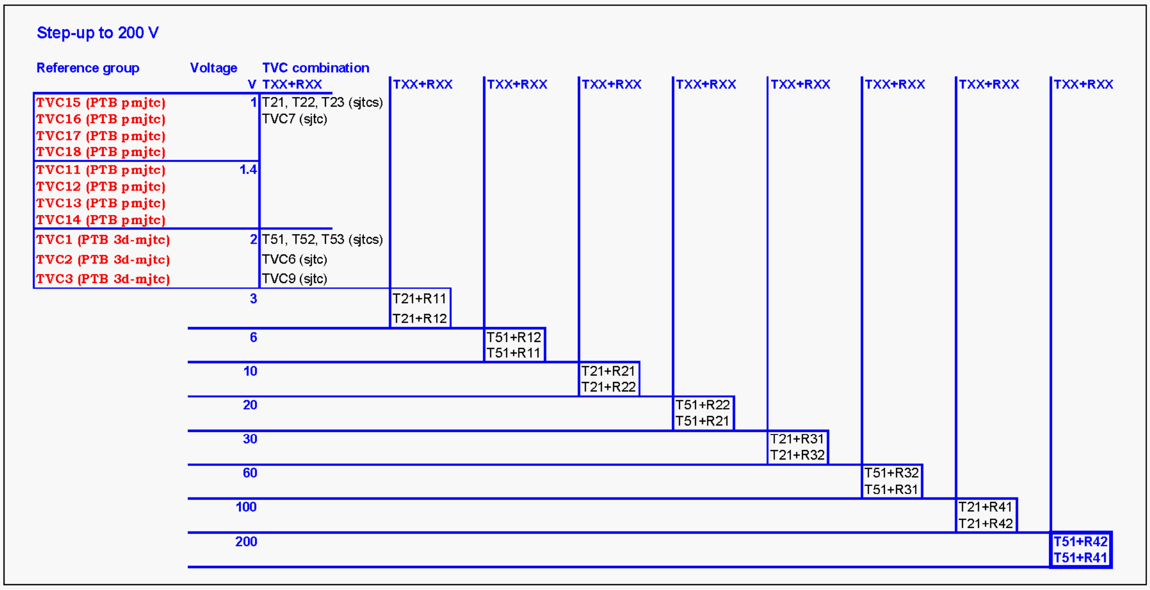

Figure 2 Schematic of the step-up procedure to 200 V.

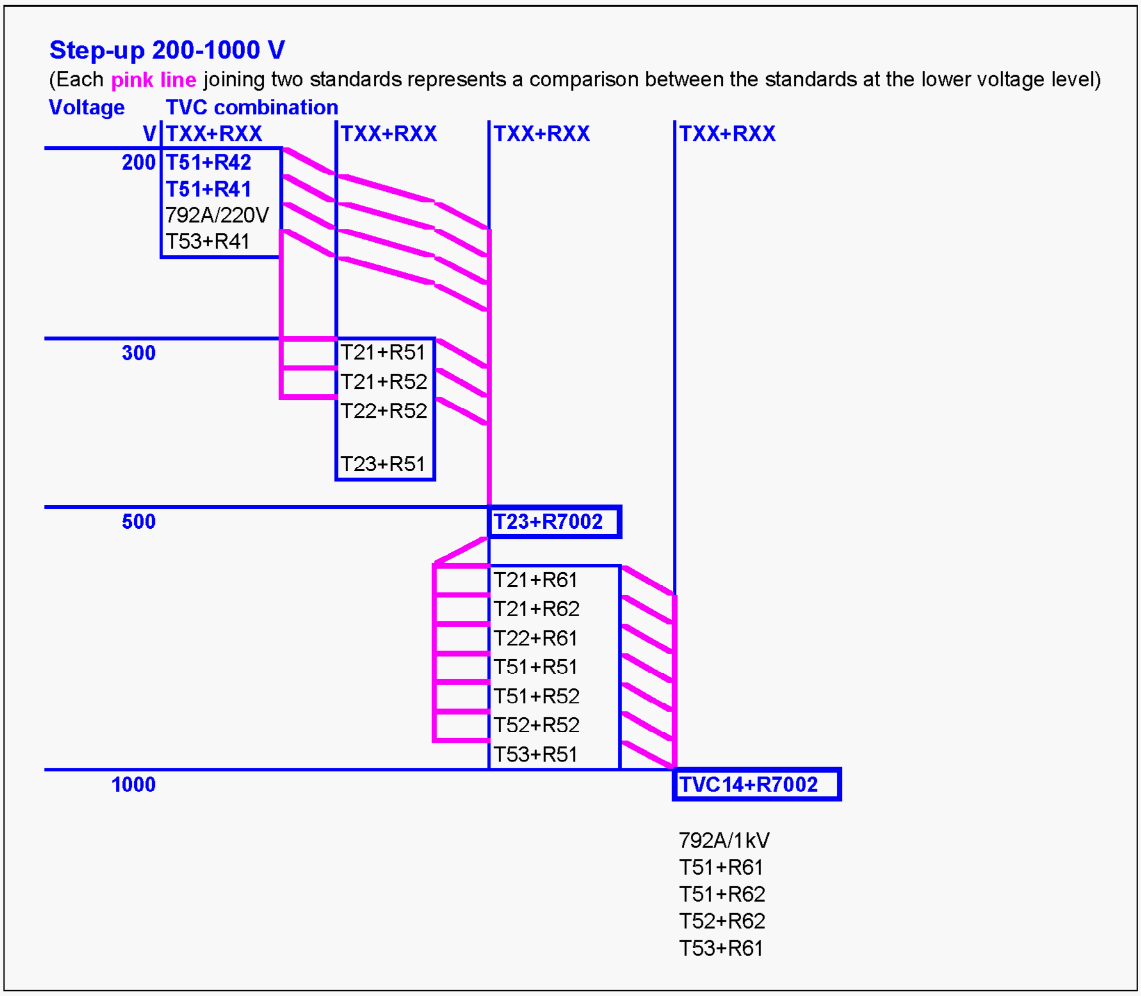

Figure 3 Schematic of the step-up procedure from 200 V to 1000 V.

Influence quantity	Standard uncertainties in µV/V at the frequencies (in Hz)					Comments
	1 000	10 000	20 000	50 000	100 000	
3V level						
Uncertainty of standard at 2V (from CCEM-K6a)	0.5	0.5	0.5	1.5	1.5	Standards: group of planar and 3d mjtcs
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	
sjtc level dependence unc., half to full range	0.3	0.3	0.3	0.3	0.3	Uncertainty of correction measured with FRDC.
Range resistor voltage coefficient	1.0	1.0	1.2	1.5	2.0	
Standard uncertainty 3V	**3.1**	**3.1**	**3.3**	**4.1**	**4.8**	Standard: 2.5mA sjtc + coaxial RR
6V level						
Uncertainty of standard at 3V	3.1	3.1	3.3	4.1	4.8	Standard: 2.5mA sjtc + coaxial RR
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	
sjtc level dependence unc., half to full range	0.5	0.5	0.5	0.5	0.5	Uncertainty of correction measured with FRDC.
Range resistor voltage coefficient	1.0	1.0	1.2	1.5	2.0	
Standard uncertainty 6V	**4.3**	**4.3**	**4.6**	**5.6**	**6.7**	Standard: 5mA sjtc + coaxial RR
10 V level						
Uncertainty of standard at 6V	4.3	4.3	4.6	5.6	6.7	
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	
sjtc level dependence unc., half to full range	0.3	0.3	0.3	0.3	0.3	Uncertainty of correction measured with FRDC.
Range resistor voltage coefficient	1.0	1.0	1.2	1.5	2.0	
Standard uncertainty 10V	**5.3**	**5.3**	**5.7**	**6.7**	**8.1**	Standard: 2.5mA sjtc + coaxial RR
20 V level						
Uncertainty of standard at 10V	5.3	5.3	5.7	6.7	8.1	
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	
sjtc level dependence unc., half to full range	0.5	0.5	0.5	0.5	0.5	Uncertainty of correction measured with FRDC.
Range resistor voltage coefficient	1.0	1.0	1.2	1.5	2.0	
Standard uncertainty 20V	**6.1**	**6.1**	**6.5**	**7.7**	**9.3**	Standard: 5mA sjtc + coaxial RR
30 V level						
Uncertainty of standard at 20V	6.1	6.1	6.5	7.7	9.3	Standard: 5mA sjtc + coaxial RR
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	
sjtc level dependence unc., half to full range	0.2	0.2	0.2	0.2	0.2	Uncertainty of correction measured with FRDC.
Range resistor voltage coefficient	0.5	0.5	0.7	1.5	2.5	
Standard uncertainty 30V	**6.7**	**6.7**	**7.2**	**8.6**	**10**	Standard: 2.5mA sjtc + coaxial RR
60 V level						
Uncertainty of standard at 30V	6.7	6.7	7.2	8.6	10.5	Standard: 2.5mA sjtc + coaxial RR
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	
sjtc level dependence unc., half to full range	0.5	0.5	0.5	0.5	0.5	Uncertainty of correction measured with FRDC.
Range resistor voltage coefficient	1.0	1.0	1.2	2.5	3.0	
Standard uncertainty 60V	**7.4**	**7.4**	**7.9**	**10**	**12**	Standard: 5mA sjtc + coaxial RR
100 V level						
Uncertainty of standard at 60V	7.4	7.4	7.9	9.6	11.7	Standard: 5mA sjtc + coaxial RR
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	
sjtc level dependence unc., half to full range	0.3	0.3	0.3	0.3	0.3	Uncertainty of correction measured with FRDC.
Range resistor voltage coefficient	1.5	1.5	2.0	4.0	5.0	Level dependence of RR not tested.
Standard uncertainty 100V	**8.0**	**8.0**	**8.7**	**11**	**13**	Standard: 2.5mA sjtc + coaxial RR
200 V level						
Uncertainty of standard at 100V	8.0	8.0	8.7	11.0	13.4	Standard: 2.5mA sjtc + coaxial RR
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	
sjtc level dependence unc., half to full range	0.5	0.5	0.5	0.5	0.5	Uncertainty of correction measured with FRDC.
Range resistor voltage coefficient	2.0	2.0	3.0	5.0	10.0	Level dependence of RR not tested.
Standard uncertainty 200V	**8.8**	**8.8**	**10**	**13**	**17**	Standard: 5mA sjtc + coaxial RR
500 V level						
Uncertainty of standard at 200V	8.8	8.8	9.7	12.6	17.2	Standard: 5mA sjtc + coaxial RR
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	
sjtc level dependence unc., third to full range	0.5	0.5	0.5	0.5	0.5	Uncertainty of correction measured with FRDC.
Range resistor voltage coefficient	2.0	2.0	2.0	4.0	7.0	Level dependence of RR not tested.
Uncertainty due to diff. HV-amplifiers	2.5	2.5	3.0	4.0	6.0	
Instability of range resistor	0.5	2.5	4.0	8.0	11.0	
Standard uncertainty 500V	**9.8**	**10**	**12**	**16**	**23**	Standard: 2.5mA sjtc + Fluke 7002 resistor
1000 V level						
Uncertainty of standard at 500V	9.8	10.1	11.5	16.3	22.8	Standard: 2.5mA sjtc + Fluke 7002 resistor
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	
pmjtc level dependence unc., half to full range	0.0	0.0	0.0	0.0	0.0	Zero level dependence of pmjtc verified with FRDC-meas.
Range resistor voltage coefficient	2.0	2.0	2.0	5.0	10.0	Level dependence of RR not tested.
Uncertainty due to diff. HV-amplifiers	2.5	2.5	3.0	4.0	6.0	
Instability of range resistor	0.5	3.0	6.0	11.0	22.0	
Standard uncertainty 1000V	**11**	**11**	**14**	**21**	**34**	Standard: 180Ω planar mjtc + Fluke 7002 resistor

Table 1 **Estimated uncertainties in the primary AC-DC transfer standards and the step-up to 1000 V for k=1.**

Results and uncertainties

The measured AC-DC differences and the corresponding uncertainties of the audit TVC are given in table 2.

The estimated uncertainties of the primary standards and the step-up procedure to 1000V were given in table 1 in the previous chapter.

Uncertainty budgets for the measured AC-DC differences at 200 V, 500 V and 1000 V are given in table 3, 4 and 5. The low standard deviation of the mean at 1000 V compared to at 200 and 500 V, is because at 200 and 500 V comparisons with more than four different standards were performed, but at 1000 V only with one. The number of effective degrees of freedom is high because each "run" (see "Set-up and measurements") has seven degrees of freedom and more than fifteen runs were performed for each frequency and voltage combination. The measurements performed with the audit TVC are illustrated in figure 4.

	200 V		500 V		1000V	
	δabs	u (k=1)	δabs	u (k=1)	δabs	u (k=1)
1 kHz	**0.3**	9.2	**0**	10	**-1**	11
10 kHz	**3.7**	9.2	**3**	11	**2**	12
20 kHz	**14**	10	**13**	12	**11**	14
50 kHz	**91**	13	**91**	17	**90**	21
100 kHz	**352**	18	**351**	24	**352**	34

Table 2 Measured AC-DC differences of the audit TVC from 200 V to 1000 V. All AC-DC differences and uncertainties are in µV/V.

Quantity	Standard uncertainty at frequency					Units	Prob.distrib. / method of evaluation	Sensitivity coefficient	Uncertainty contribution at frequency					Degrees of freedom
Xi	u(xi)	u(xi)	u(xi)	u(xi)	u(xi)	–	–	ci	ui(δ)	ui(δ)	ui(δ)	ui(δ)	ui(δ)	–
	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz				1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	
Uncertainty of standard at 200V	8.8	8.8	10	13	17	µV/V	Gaussian / B	1	8.8	8.8	10	13	17	Infinite
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	µV/V	Gaussian / B	1	2.8	2.8	3.0	3.5	4.1	Infinite
Std.dev. of mean	0.2	0.6	0.6	1.2	2.2	µV/V	Gaussian / A	1	0.2	0.6	0.6	1.2	2.2	> 100
														veff
Total uncertainty in calibration of δ (at the frequency)						µV/V			**9.2**	**9.2**	**10**	**13**	**18**	>1*10^5

Table 3 Uncertainty budget for the measured AC-DC differences at 200 V.

Quantity	Standard uncertainty at frequency					Units	Prob.distrib. / method of evaluation	Sensitivity coefficient	Uncertainty contribution at frequency					Degrees of freedom
Xi	u(xi)	u(xi)	u(xi)	u(xi)	u(xi)	–	–	ci	ui(δ)	ui(δ)	ui(δ)	ui(δ)	ui(δ)	–
	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz				1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	
Uncertainty of standard at 500V	9.8	10	12	16	23	µV/V	Gaussian / B	1	9.8	10	12	16	23	Infinite
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	µV/V	Gaussian / B	1	2.8	2.8	3.0	3.5	4.1	Infinite
Std.dev. of mean	0.5	1.0	1.9	3.7	8.0	µV/V	Gaussian / A	1	0.5	1.0	1.9	3.7	8.0	> 100
														veff
Total uncertainty in calibration of δ (at the frequency)						µV/V			**10**	**11**	**12**	**17**	**24**	>1*10^4

Table 4 Uncertainty budget for the measured AC-DC differences at 500 V.

Quantity	Standard uncertainty at frequency					Units	Prob.distrib. / method of evaluation	Sensitivity coefficient	Uncertainty contribution at frequency					Degrees of freedom
Xi	u(xi)	u(xi)	u(xi)	u(xi)	u(xi)	–	–	ci	ui(δ)	ui(δ)	ui(δ)	ui(δ)	ui(δ)	–
	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz				1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	
Uncertainty of standard at 1000V	11	11	14	21	34	µV/V	Gaussian / B	1	11	11	14	21	34	Infinite
Uncertainty of comparator measurements	2.8	2.8	3.0	3.5	4.1	µV/V	Gaussian / B	1	2.8	2.8	3.0	3.5	4.1	Infinite
Std.dev. of mean	0.0	0.1	0.1	0.3	0.5	µV/V	Gaussian / A	1	0.0	0.1	0.1	0.3	0.5	> 100
														veff
Total uncertainty in calibration of δ (at the frequency)						µV/V			**11**	**12**	**14**	**21**	**34**	>1*10^8

Table 5 **Uncertainty budget for the measured AC-DC differences at 1000 V.**

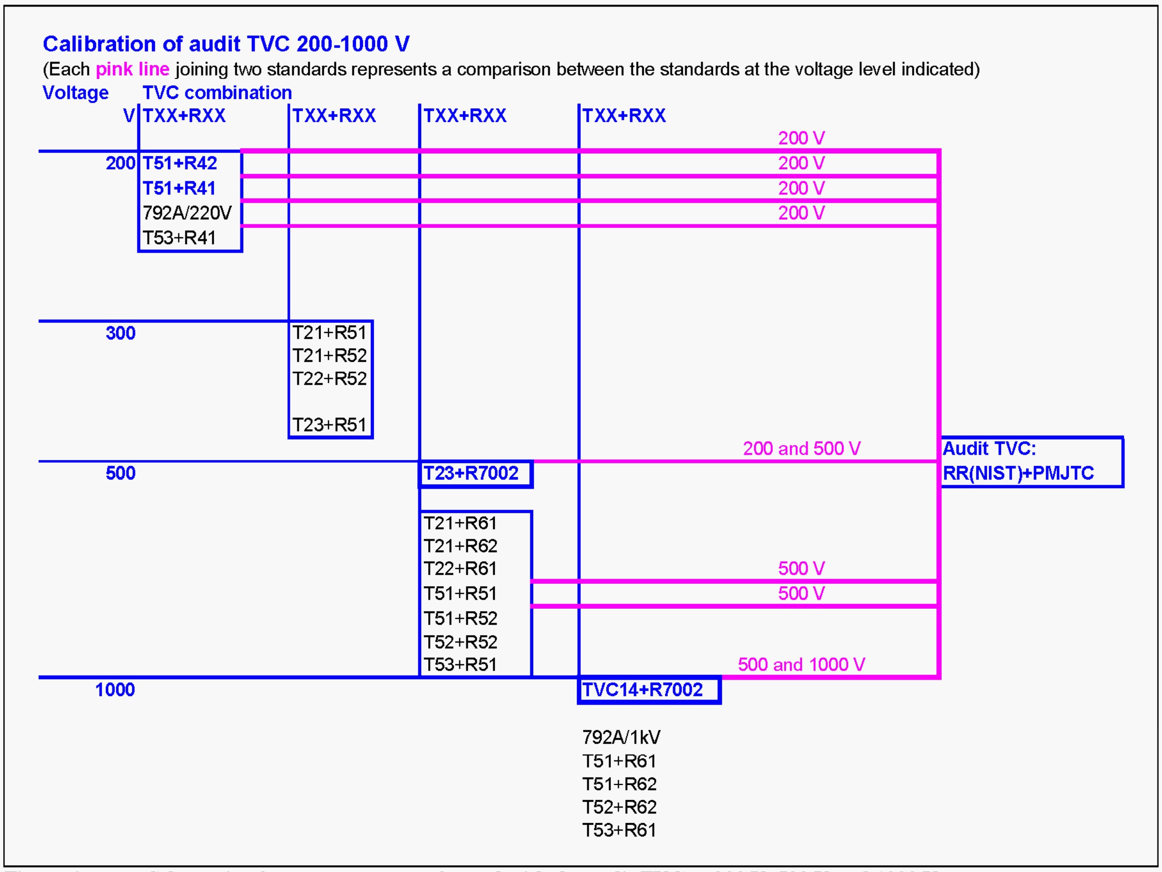

Figure 4 **Schematic of measurements performed with the audit TVC at 200 V, 500 V and 1000 V.**

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UNCERTAINTY BUDGET FOR UME (TURKEY)

Step-up Procedure in UME

Primary standards used in UME for AC voltage is group of Planar Multijunction Thermal Converters (PMJTC) of nominal voltage 1, 1.5, 2 and 3 V and are calibrated by PTB. Other AC voltages are established by step-up procedure. Converters used at higher voltages consist of range resistors and PMJTC modules. Standards for AC Voltages used in UME are summarized in table 1.

Table 1. ACV Standards Used at UME

ACV Standard Converter	Resistor	Useful Range
1 V	90 Ω heater	100 mV – 1 V
1.5 V	180 Ω heater	0.5 – 1.5 V
2 V	400 Ω heater	0.7 – 2 V
3 V	900 Ω heater	1 – 3 V
10 V	90 Ω MJTC + 900 Ω	3 – 10 V
20 V	90 Ω MJTC + 1.9 kΩ	6 – 20 V
30 V	90 Ω MJTC + 2.9 kΩ	10 – 30 V
50 V	90 Ω MJTC + 4.9 kΩ	15 – 50 V
100 V	90 Ω MJTC + 10 kΩ	20 – 100 V
300 V	90 Ω MJTC + 30 kΩ	80 – 300 V
1000 V	400 Ω MJTC + 100 kΩ	200 – 1000 V

Step-up measurements are summarized in Figure 2.

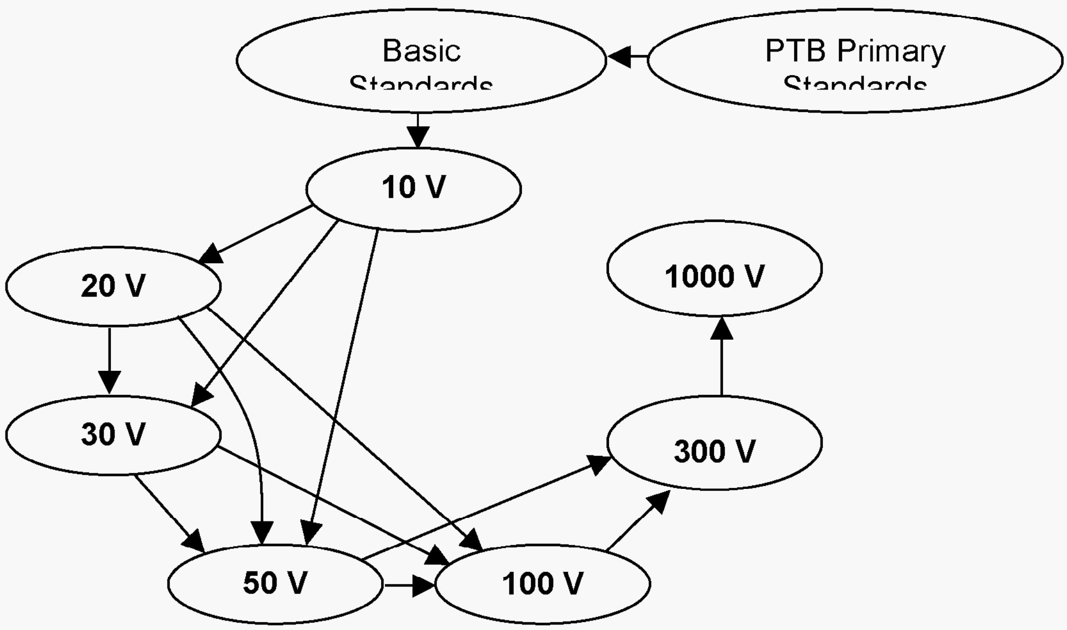

Figure 2. Set-up Comparisons Chain in UME

Due to high sensitivity of the PMJTC, stadards are used in step-up procedure with 5:1 ratio to improve reliability of the step-up.
There is 7 steps required to rich 1000 V level. Dropping resistors used in high voltage converters up to 300 V are high-quality stable, coaxial metal film type, and it is assumed that their resistance doesn't depend significantly on voltage level. Several measurements are performed to examine this hypothesis. 100 V standard, assuming to be level independent from 20 V to 30 V is used to check level dependence of 30 V converter from 20 V to 30 V. Similar comparisons can be made for other ranges. Obtained differences were smaller than standard deviation of these measurements, which normally is not higher than 1 ppm. In technical papers relating this topic, it is widely accepted that level dependence of the range resistors up to 200 V is not higher than 1 ppm. This is considered in uncertainty estimation given below.
Voltage converter used from 200 V to 1000 V consists of commercial high voltage resistor (Fluke 7002) and 400 Ω PMJTC. Two such resistors are used in UME to transfer from 200 V level to 1000 V.
Design of these resistors includes most of the necessary aspects pointed out in work of the ac-dc experts in several last years. It is frequency compensated, use planar resistor technology and has very low impact of temperature on the voltage characteristic. Although no attempt is done at UME so far to determine voltage coefficient of these resistors, estimation given in uncertainty budget is based on consultation with Dr. Klonz and researches mentioned above.

Uncertainty Budget

Basic Standards for AC Voltage in UME are PMJTC, which are calibrated by PTB in range 1 – 3 V. Uncertainty of these standards is taken from certificate (*Ust*).
Voltage converters for higher voltages are calibrated in a step-up procedure. Uncertainty for each step (*Ustep*) is calculated from the following components:

Url – Estimated resistor level uncertainty
Um – Uncertainty of measurement set-up (method, connections, drifts)
Uh – Uncertainty arise from using different equipment
U_A – Type A uncertainty
Ust(i)-1 – Uncertainty of the previous step (or 3 V standard at 10 V)

$$Ustep = \sqrt{U_{rl}^2 + U_m^2 + U_A^2 + Uh + U_{st(i)-1}}$$

Summarized Uncertainties of the AC Voltage at UME are given in Table 2.

Uncertainty of the comparison of the UME standard with the traveling standard is calculated by using the following equation:

$$Ucmp = \sqrt{U_{std}^2 + U_m^2 + U_{eq}^2 + U_A^2 + U_{rep}^2}$$

where
Um - uncertainties due to measurement set-up (method, connections, drifts)
Uh - uncertainty arise from using different equipment
U_A - Type A uncertainty of the measurements
Ustd- uncertainty of the UME standards

Urep- uncertainty related with long time stability, which is maximum difference of the measurements made during 1.5 month

Estimation of the uncertainty of the 1000 V standard at 500 V is done by decreasing uncertainty component coming from voltage coefficient of the 1000 V resistor. Results are given in table 3.

Table 2. Uncertainty Budget of the Step-up Procedure in UME

Quantity	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	Comment
3 V Standard (U_s)	1	1	1	1.5	1.5	PTB, k=1
Resistor Level						Rectangular
10 V	0,5	0,5	0,5	0,5	0,5	
20 V	0,8	0,8	0,8	0,8	0,8	
30 V	1,0	1,0	1,0	1,0	1,0	
50 V	1,2	1,2	1,2	1,5	2,0	
100 V	1,5	1,5	1,5	2,0	2,5	
300 V	3,0	3,0	3,0	4,0	8,0	
1000 V	10	10	10	10	20	
Type A (U_A)						Normal
<100 V	1,0	1,0	1,0	1,0	1,0	
>100 V	2,0	2,0	2,0	3,0	5,0	
Set-up (U_m)	1,0	1,0	1,0	2,0	3,0	Normal
Different Equipment (U_{eq})						Rectangular
<100 V	0,5	0,5	0,5	2,0	5,0	
>100 V	5,0	5,0	7,0	10,0	15,0	
Total Uncertainty at each step (U_{step})						k=1
10 V	1,8	1,8	1,8	2,4	2,7	
20 V	2,5	2,5	2,5	3,1	3,6	
30 V	3,0	3,0	3,0	3,8	4,4	
50 V	3,3	3,3	3,3	4,2	4,9	
100 V	3,9	3,9	3,9	5,0	5,9	
300 V	6,1	6,1	6,8	9,6	14,1	
1000 V	12,3	12,3	12,9	19,0	26,5	

Table 3. Uncertainty budget of the comparison with traveling standard

Quantity	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	Comment
Different Equipment	5,0	5,0	7,0	10,0	15,0	Rectangular
Type A (U_A)	2,0	2,0	2,0	2,0	3,0	Normal
Set-up (U_m)	1,0	1,0	1,0	2,0	3,0	Normal
Long Term (U_{lt})						Rectangular
200 V	2,0	2,0	2,0	3,0	5,0	
500 V	2,0	2,0	2,0	2,0	10	
1000 V	2,0	2,0	2,0	2,0	10	
Std. Uncertainty (U_{std})						Normal
200 V	6,1	6,1	6,8	9,6	14,1	
500 V	8,7	8,7	9,6	13,6	20,0	
1000 V	12,3	12,3	12,9	19,0	26,5	
Total Uncertainty						k=1
200V	8,4	8,4	11,3	14,5	21,6	
500 V	10,5	10,5	12,4	17,2	27,3	
1000 V	14,2	14,2	19,9	21,7	32,3	

Results of the Measurements

200 V	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
ac-dc difference (μV/V)	0	3	11	89	343
Uncertainty (1σ)	9	9	12	15	22
500 V	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
ac-dc difference (μV/V)	-1	5	15	92	348
Uncertainty (1σ)	11	11	13	18	28
1000 V	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
ac-dc difference (μV/V)	1	6	18	96	355
Uncertainty (1σ)	15	15	20	22	33

UNCERTAINTY BUDGET FOR METAS (SWITZERLAND)

Institute : METAS / Marc Flueli 19 August 2004
Country : Switzerland All uncertainty values in microV/V étalon:

STEP-UP PROCEDURE		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	étalon
PRIMARY STANDARD	Voltage (V) : 2.8						MJTC #115 (MJ2)
	Standard uncertainty :	**0.5**	**0.5**	**1.0**	**1.0**	**2.5**	
Step n° 1	**Voltage (V) :** 3.2						RS2+US3
Measurement uncertainty		0.2	0.3	0.3	0.2	0.2	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**0.8**	**0.8**	**1.2**	**1.5**	**4.3**	
Step n° 2	**Voltage (V) :** 5.6						RS3+US4
Measurement uncertainty		0.6	0.6	0.4	0.4	0.4	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**1.1**	**1.2**	**1.4**	**2.0**	**5.5**	
Step n° 3	**Voltage (V) :** 10						RS4+US5
Measurement uncertainty		0.5	0.8	0.5	0.3	0.5	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**1.4**	**1.5**	**1.6**	**2.3**	**6.5**	
Step n° 4	**Voltage (V) :** 18						RS5+US2
Measurement uncertainty		0.6	0.5	0.4	0.4	0.6	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**1.6**	**1.7**	**1.7**	**2.6**	**7.4**	
Step n° 5	**Voltage (V) :** 32						RS7+US4
Measurement uncertainty		0.5	0.3	0.4	0.6	0.5	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**1.7**	**1.8**	**1.9**	**2.9**	**8.2**	
Step n° 6	**Voltage (V) :** 56						RS9+US2
Measurement uncertainty		0.6	0.5	0.9	0.8	0.6	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**1.9**	**2.0**	**2.1**	**3.2**	**8.9**	
Step n° 7	**Voltage (V) :** 100						RS10+US3
Measurement uncertainty		0.7	0.6	0.6	0.5	0.5	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**2.1**	**2.2**	**2.3**	**3.5**	**9.6**	
Step n° 8	**Voltage (V) :** 178						RS11+US4
Measurement uncertainty		0.3	0.5	0.5	0.3	0.6	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**2.2**	**2.3**	**2.4**	**3.7**	**10.2**	
Step n° 9	**Voltage (V) :** 316						RS13+US2
Measurement uncertainty		0.7	0.9	0.6	0.4	0.7	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**2.4**	**2.5**	**2.6**	**3.9**	**10.8**	
Step n° 10	**Voltage (V) :** 562						RS15+US4
Measurement uncertainty		0.5	0.5	0.5	0.3	0.6	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**2.5**	**2.6**	**2.7**	**4.0**	**11.4**	
Step n° 11	**Voltage (V) :** 1000						RS17+US2
Measurement uncertainty		0.5	0.3	0.6	1.0	1.7	
Uncertainty arising from voltage dependence		0.6	0.6	0.6	1.2	3.5	
Resulting standard uncertainty		**2.6**	**2.7**	**2.8**	**4.3**	**12.0**	

TRAVELLING STANDARDS		1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Measurement voltage (V) : 200						
Standard uncertainty of reference standard		2.4	2.5	2.6	3.9	10.8
Measurement uncertainty ……………….	Type A	1.0	1.0	1.0	1.0	1.0
	Type B	0.1	0.1	0.1	0.2	0.3
Resulting standard uncertainty (travelling standard)		2.6	2.8	2.8	4.0	11
Number of effective degrees of freedom		(34)	(31)	(40)	(20)	(13)
Expended uncertainty [U95] (travelling standard)		**6**	**6**	**6**	**9**	**24**
Measurement voltage (V) : 500						
Standard uncertainty of reference standard		2.5	2.6	2.7	4.0	11.4
Measurement uncertainty ……………….	Type A	1.0	1.0	1.0	1.0	1.0
	Type B	1.0	0.2	0.2	0.3	0.3
Resulting standard uncertainty (travelling standard)		2.9	2.9	2.9	4.2	12
Number of effective degrees of freedom		(31)	(29)	(36)	(19)	(15)
Expended uncertainty [U95] (travelling standard)		**6**	**6**	**6**	**9**	**26**
Measurement voltage (V) : 1000				0.0		
Standard uncertainty of reference standard		2.6	2.7	2.8	4.3	12.0
Measurement uncertainty ……………….	Type A	1.0	1.0	1.0	1.0	1.0
	Type B	0.1	0.1	0.1	0.2	0.3
Resulting standard uncertainty (travelling standard)		2.9	3.0	3.0	4.5	13
Number of effective degrees of freedom		(29)	(31)	(33)	(19)	(17)
Expended uncertainty [U95] (travelling standard)		**6**	**7**	**7**	**10**	**28**

UNCERTAINTY BUDGET FOR CMI (CZECH REPUBLIC)

1.1 Uncertainties of the step-up process

Measured difference between converters:

$$\delta = \delta_A + \delta_{step-up} \qquad (2)$$

where δ_A means value calculated from set of δ and $\delta_{step\text{-}up}$ contribution from the calibration set-up.

The ac-dc transfer differences of the TVCs for higher voltages are determined by step-up chain:

$$\delta_{step\_k} = \delta_{step\_k-1} + \delta_I + \delta_{res} + \delta_{ac\_ampl} + \delta_U + \delta_{low} + \delta \qquad (3)$$

δ_{step_k}	is ac-dc voltage transfer difference of the standard at the voltage step *k*
δ_{step_k-1}	is ac-dc voltage transfer difference of the standard at the voltage step *k-1*
δ_I	is ac-dc voltage transfer difference due to the current level effect of the TVCs
δ_{res}	is ac-dc voltage transfer difference with different resistor/TVC combination
δ_{ac_ampl}	is ac-dc voltage transfer difference with different level of AC voltages
δ_U	is ac-dc voltage transfer difference with different voltage coefficient of the serial resistor in the step-up procedure
δ_{low}	is ac-dc voltage transfer difference due to the thermal effect of the lower voltage by the switching on the high voltages
δ	is measured ac-dc voltage transfer difference of the Dut / Ref

The variance of the standard uncertainty of the ac-dc difference between two TVC is:

$$u^2(\delta) = u^2(\delta_A) + u^2(\delta_{step-up}) \qquad (4)$$

where $u^2(\delta_A)$ is uncertainty of A-type calculated from set of determination δ; $u^2(\delta_{step\text{-}up})$ standard uncertainty of the step-up

$u(\delta_I)$	is uncertainty of the ac-dc voltage transfer difference due to the current level effect of the TVCs (no contribution to the uncertainty for PMJTC)
$u(\delta_{res})$	is uncertainty of the ac-dc voltage transfer difference with different resistor/TVC combination, rectangular contribution
$u(\delta_{ac\_ampl})$	is uncertainty of the ac-dc voltage transfer difference with different level of AC voltages, rectangular contribution
$u(\delta_U)$	is uncertainty of the ac-dc voltage transfer difference with different voltage coefficient of the serial resistor in the step-up, the maximum differences are estimated experimentally, rectangular contribution
$u(\delta_{low})$	is uncertainty of the ac-dc voltage transfer difference with different voltage coefficient due the thermal effect of the lower voltage by the switching on the high voltages
u(δ)	is uncertainty of the measured difference of the Dut / Ref

Uncertainty budget for k= 1

Quantity		Standard measurement uncertainty in 10^{-6}				
		1kHz	10kHz	20kHz	50kHz	100kHz
1V						
traceable to PTB		1	1	1	2	2
k=1	$u(\delta)$	1	1	1	2	3
Sum		2	2	2	3	4
3V	$u(\delta\_1V)$	2	2	2	3	4
	$u(\delta)$	1	1	1	2	3
	$u(\delta U)$	1	1	1	2	2
Sum		3	3	3	4	5
10V	$u(\delta\_3V)$	3	3	3	4	5
	$u(\delta)$	1	1	1	2	3
	$u(\delta U)$	1	1	1	2	2
Sum		3	3	3	5	6
30V	$u(\delta\_10V)$	3	3	3	5	6
	$u(\delta)$	1	1	1	2	3
	$u(\delta U)$	1	1	1	2	2
	$u(\delta_{res})$	2	2	2	2	3
Sum		4	4	4	6	8
100V	$u(\delta\_30V)$	4	4	4	6	8
	$u(\delta)$	1	1	1	2	5
	$u(\delta U)$	3	3	3	5	7
	$u(\delta_{res})$	5	5	6	8	10
Sum		7	7	8	11	15
300V	$u(\delta\_100V)$	7	7	8	11	15
	$u(\delta)$	2	2	3	3	5
	$u(\delta U)$	3	3	3	5	7
	$u(\delta_{res})$	8	8	10	12	20
	$u(\delta_{ac\_ampl})$	4	4	5	8	12
	$u(\delta_{low})$	2	2	2	5	7
Sum		12	12	15	20	30
500V	$u(\delta\_300V)$	12	12	15	20	30
	$u(\delta)$	2	2	3	3	5
	$u(\delta U)$	3	3	3	5	7
	$u(\delta_{low})$	5	5	5	7	8
	$u(\delta_{res})$	10	10	13	13	18
	$u(\delta_{ac\_ampl})$	5	5	5	8	12
Sum		18	18	22	27	39
1000V	$u(\delta\_500V)$	18	18	22	27	39
	$u(\delta)$	2	2	3	3	5
	$u(\delta U)$	3	3	3	5	7
	$u(\delta_{low})$	10	10	10	15	15
	$u(\delta_{res})$	10	10	15	17	25
	$u(\delta_{ac\_ampl})$	5	5	5	8	15
Sum		24	24	30	37	52

Results of the measurement

Ambient temperature: (23 ± 0.5) °C

Ambient humidity: (30 ± 10) %

Ambient atmospheric pressure: 980 - 1020 hPa

<u>Transfer standard MJTC 92 + R500V Fluke:</u>

	Ac-dc difference in 10^{-6} on the frequency; for k=1				
	1kHz	10kHz	20kHz	50kHz	100kHz
200V	**- 1 ± 12**	**- 7 ± 12**	**- 3 ± 14**	**3 ±18**	**35 ± 30**
500V	**2 ± 19**	**- 6 ± 19**	**- 3 ± 23**	**2 ± 28**	**30 ± 40**

Note: One of the four lamellas from the shield of the GR 874 type input connector, placed on the F792A resistor, was broken.

<u>Transfer standard SJTC U + R1000V OFMET:</u>

	Ac-dc difference in 10^{-6} on the frequency; for k=1				
	1kHz	10kHz	20kHz	50kHz	100kHz
500V	**2 ± 19**	**0 ± 19**	**8 ± 23**	**42 ± 28**	**221 ± 40**
1000V	**8 ± 25**	**6 ± 25**	**15 ± 31**	**53 ± 39**	**227 ± 56**

APPENDIX 3

Technical protocol

COMPARISON CCEM-K9

High voltage AC-DC transfer

TECHNICAL PROTOCOL

Scope of the comparison

The purpose of the comparison is to check the agreement between the NMIs in the field of high voltage AC-DC transfer (500 V and 1000 V), in the frequency range from 1 kHz to 100 kHz. The main difficulty in this field is to take correctly into account the voltage level dependence of the AC-DC transfer difference due to the range resistor of the thermal converter. This voltage dependence impairs the calibration of the reference standards.

Definition of the AC-DC transfer difference

The relative AC-DC transfer difference δ of a thermal converter is defined as:

$$\delta = \frac{V_{AC} - V_{DC}}{V_{DC}}$$

where: V_{AC} is the RMS value of the applied AC voltage.

V_{DC} is the mean value of the direct and reversed DC voltages which produce the same output voltage of the converter as V_{AC}.

Travelling standards

The comparison will be performed in two parallel loops with two different travelling standards.

One standard will circulate among the participating laboratories of countries where no ATA-carnet is needed. It consists of a 1000 V range resistor for a FLUKE 792 A AC/DC thermal voltage transfer standard (s/n 030) provided by the NIST associated with a PTB/IPHT planar multijonction thermal converter (n° 91 PTB/IPHT MJTC 1997).

For the second loop two other standards will circulate in countries where an ATA-carnet is needed. The first one is a 1000 V standard developed and provided by the OFMET (ref. RS1000/E + US6), consisting of a 1000 V range resistor associated with a single junction thermal converter. The second one consists of a 500 V range resistor for a FLUKE 792 A (s/n 034), provided by the NIST, associated with a PTB/IPHT planar multijonction thermal converter (n° 92 PTB/IPHT MJTC 1997).

Several laboratories will take part in both loops to ensure reliable links between the measurements made on both sets of standards.

The preliminary reference values for the OFMET standard are determined from calibrations performed at OFMET (Switzerland), SP (Sweden), NIST (USA) and BNM-LCIE (France) before starting the comparison. The preliminary reference values for the NIST/PTB standards are determined from calibrations performed at PTB (Germany), OFMET and BNM-LCIE.

Measurements

The laboratories participating in the loop without ATA-carnet are asked to measure the AC-DC transfer difference of the NIST/PTB 1000 V standard at 1000 V, 500 V and 200 V.

The laboratories participating in the loop with ATA-carnet are asked to measure the AC-DC transfer difference of :

- the OFMET 1000 V standard at 1000 V and 500 V;
- the NIST/PTB 500 V standard at 500 V and 200 V.

All of these measurements are to be performed at 1 kHz, 10 kHz, 20 kHz, 50 kHz and 100 kHz.

Note: Measurements at 200 V are intended to check the agreement between the participants at a voltage where no significant voltage level dependence is assumed to come from the range resistors.

Measurement conditions

The input and the output of the thermal converter have to be earthed in order to protect the insulation between the heater and the thermocouple(s).

It is advisable that all the participants perform the measurements at the reference temperature, 23 °C. In any case temperature, humidity and atmospheric pressure should be measured and mentioned in the report.

The participants are asked to use their usual best measurement procedure.

Report

Each laboratory must send its report to the pilot laboratory within a delay of 3 months after finishing its measurements. This report must contain:

- a detailed description of the measurement set-up, including schematic diagrams, if necessary;
- a detailed description of the measurement procedure;
- the results of the measurements with their associated uncertainty (1 σ);
- a description of the procedure used to calibrate the high voltage reference standards. This is usually a so-called step-up procedure. In particular, a **detailed description** should be given of how the **voltage level dependence** of the AC-DC transfer difference was estimated;

- a detailed uncertainty budget in accordance with the CIPM recommendations. A list of the main uncertainty components which have to be taken into account is given in the appendix. This list is not exhaustive. In the final uncertainty associated with the AC-DC transfer difference of the high voltage reference standards, the uncertainty arising from each step of the step-up procedure should be clearly expressed.

Transportation

The travelling standards should be carried by car, train or plane, whichever appears to be the most appropriate way to assure their safety.

Each participating laboratory is responsible for arranging the transportation of the travelling standard to the next laboratory. It has to **inform the pilot laboratory** as soon as it **receives the standard** from the previous laboratory **and** again when **it sends the standard** to the next participant.

Customs

Inside the European Community no customs papers are necessary. For the participants outside the European Community, an ATA-carnet will be provided.

Organisation

The pilot laboratory for this comparison is BNM-LCIE. For any questions, the person to contact at the pilot laboratory is:

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APPENDIX

About the uncertainty budget

The guidelines for CIPM key comparison (March 1st, 1999) specify that the technical protocol has to include a list of the main components of uncertainty common to all the participants. All these components must be evaluated by each participant and appear in the report.

List of the main components of the uncertainty budget which must be taken into account by each participant:

1 -) Uncertainty of the primary AC-DC transfer standard (for example MJTC at the 1 V or 3 V level):

If the AC-DC transfer difference of the primary standard has been calculated, all the influence quantities have to be estimated and the resulting standard uncertainty reported. If it has been calibrated in another NMI (which should be identified), only the combined standard uncertainty given by this institute has to be reported.

2 -) Uncertainty arising from the step-up procedure:

This component includes the change of the AC-DC transfer difference with the voltage level and the type-A uncertainty of the measurements. The uncertainty must be estimated and reported for each part of the step-up procedure. The combined uncertainty resulting from the full step-up procedure must also be reported.

3 -) Uncertainty on the reference standard used in the comparison (deduced from the two previous components):

In particular, detailed information should be given about the step-up procedure between 500 V and 1000 V, the estimation or measurement of the voltage level dependence and the estimation or calculation of the associated uncertainty.

4 -) Uncertainty on the comparison of the reference of the laboratory with the travelling standard:

This component includes the type-A uncertainty for a series of measurements of the AC-DC transfer difference (reproducibility of the measurements) and the short term stability of the travelling standard and the reference over the period of time the travelling standard stays at the participating laboratory.

In addition to the above mentioned components, individual participants may add any component they feel relevant for the evaluation of their uncertainty.

Uncertainties have to be evaluated at a level of one standard deviation (see the “Guidelines for CIPM key comparisons”, March 1st, 1999) and information must be given on the number of effective degrees of freedom. This is required for a proper estimate of the confidence level.