FINAL REPORT OF COMPARISON OF THE CALIBRATIONS OF HYDROMETERS FOR LIQUID DENSITY DETERMINATION BETWEEN SIM LABORATORIES SIM.M.D-K4

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1. Introduction

Hydrometers are instruments widely used for different levels of precision to measure density, specific gravity, alcoholic strength, sugar concentration, milk density etc. of a liquid.

The aim of this SIM comparison is to check the stated uncertainty levels and degrees of equivalence of NMI laboratories for hydrometer calibrations in the density range between 600 kg/m^3 and 1 300 kg/m^3 at 20 ºC and to check liquid density measuring instruments used for this purpose.

This comparison followed the guidelines of the Euromet project 702 “Comparison of the calibration of high resolution hydrometers for liquid density determinations” carried out in 2003-2004.

The comparison is intended to be a regional key comparison according to the Mutual Recognition Arrangements. It should also support provisional entries for the CMC tables in this sub-field and anticipate the planned CMC key comparison on hydrometers CCM.D-K4.

The participating laboratories were invited to participate as proposed by CENAM, taking into account their intention to participate in this exercise expressed in the Questionnaire of density circulated in 2004.

CENAM accepted to act as the pilot laboratory in this SIM comparison.

2. Participant laboratories

The participant laboratories are listed in table 1. NMIs from all SIM sub-regions participated in this comparison.

Table 1. Participants of hydrometer comparison

National Institute of Metrology	Acronym	Country/ SIM Subregion	Technical Contact(s)
Bureau of Standards of Jamaica, Kingston Jamaica	**BSJ**	Jamaica / CARIMET	Sheldon Walker Tweedsmuir Mitchell Mairy Sanz
Centro Nacional de Metrología, Querétaro, México	**CENAM**	Mexico / NORAMET	Luis Omar Becerra Arturo Daued Luis Manuel Peña

Centro Nacional de Metrología de Panamá Panamá, Rep. de Panamá	**CENAMEP**	Panama / CAMET	Saul García
CESMEC Ltda. Santiago, Chile	**CESMEC**	Chile / SURAMET	Francisco García Raúl Hernández Fernando Leyton
Instituto Boliviano de Metrología, La Paz, Bolivia	**IBMETRO**	Bolivia / ANDIMET	María del Carmen Vega Orlando Alvarez Gerson Vallejos John Zurita
Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual, Lima, Perú	**INDECOPI**	Peru / ANDIMET	Abed Morales Juan Villadeza
Instituto Ecuatoriano de Normalización, Quito, Ecuador	**INEN**	Ecuador / ANDIMET	Manuel Salazar Wilson Gallegos
Instituto Nacional de Metrologia, Normalização e Qualidade Industrial, Xerem, Brazil	**INMETRO**	Brazil / SURAMET	Dalni Malta José Julio Pinheiro Paulo Roberto Marteleto
Instituto Nacional de Tecnologia Industrial Buenos Aires, Argentina	**INTI**	Argentina / SURAMET	Héctor Méndez
Laboratorio Costarricense de Metrología, San José, Costa Rica	**LACOMET**	Costa Rica / CAMET	Sandra M. Rodríguez Olman Ramos
Laboratorio Tecnológico del Uruguay, Montevideo, Uruguay	**LATU**	Uruguay / SURAMET	Claudia Santo Joselaine Cáceres
National Institute of Standards and Technology, Gaithersburg, United States	**NIST**	United States / NORAMET	John D. Wright
National Research Council, Institute for National Measurement Standards, Ottawa, Canada	**NRC**	Canada / NORAMET	Claude Jacques
Superintendencia de Industria y Comercio, Bogota, Colombia	**SIC**	Colombia / ANDIMET	Luis Carlos Castro

3 Transfer standards (hydrometer samples)

For the comparison, CENAM supplied two similar sets of four different hydrometers with the following characteristics,

Table 2. Data of the traveling standards for the SIM density comparison

	Hydrometer 1	**Hydrometer 2**	**Hydrometer 3**	**Hydrometer 4**
Manufacturer	Stevenson Reeves Ltd	Stevenson Reeves Ltd	Stevenson Reeves Ltd	Stevenson Reeves Ltd
Range	600 kg/m^3 – 610 kg/m^3	800 kg/m^3 – 810 kg/m^3	990 kg/m^3 – 1 000 kg/m^3	1 290 kg/cm^3 – 1 300 kg/m^3
Resolution	0.1 kg/m^3	0.1 kg/m^3	0.1 kg/m^3	0.1 kg/m^3
Surface Tension:	15 mN/m	25 mN/m	35 mN/m	55 mN/m
Reference temperature	20ºC	20ºC	20ºC	20ºC
Hydrometer weight (approx.)*:	82.71 g	108.87 g	136.46 g	188.45 g
Hydrometer Length:	400 mm	400 mm	400 mm	400 mm
Diameter of the stem (approx.)*:	5 mm	3 mm	3 mm	3 mm
Diameter of the bulb (approx.):	28 mm	28 mm	28 mm	28 mm

Figure 1. Set of transfer standards (Hydrometers)

4. Circulation and date of measurements

Participants were divided in two loops for the circulation of the travelling standards. Travelling standards were hand transported between participants according to the schedule of table 3.

CENAM as the pilot laboratory made the measurements of the travelling standards at the beginning and at the end of the circulation of the hydrometers,

Table 3. Dates of measurement of the travelling standards

Loop 1		Loop 2	
Acronym	**Date**	**Acronym**	**Date**
CENAM	Apr-07	CENAM	Apr-07
NRC	Jun-07	IBMETRO	Jun-07
NIST	Jul-07	LATU	Aug-07
BSJ	Aug-07	INEN	Sep-07
LACOMET	Oct-07	INDECOPI	Oct-07
CENAMEP	Nov-07	SIC	Nov-07
INMETRO	Dec-07	INTI	Jan-08
CENAM	Oct-08	CESMEC	Mar-08
		CENAM	Oct-08

5. Traceability of results reported by participants

For the calibration of the hydrometers, all laboratories used their own hydrostatic weighing system, and all laboratories determined the corrections to the specific indications (at 20ºC) of the travelling standards by Cuckow's method [6].

In table 4 are the liquids used by participants as density standards for the calibration of the travelling standards, the mean value of the densities and the surface tensions reported by the participants, the sources of traceability reported by participants and the balance used by participants for weighing in liquid.

Table 4. Liquids used by participants in their hydrostatic weighing system

Acronym	Liquid	Density Standard	Traceability	Balance used for weighing in liquid
BSJ	Water 998 kg/m^3 73 mN/m	Water	Tanaka's formula	Sartorius Type RC250S d=0.1 mg
CENAM	Pentadecane 769 kg/m^3 27 mN/m	Density standard made of zerodur. Sphere shape	PTB-Germany	Mettler-Toledo Type AT400 d=0.1 mg
CENAMEP	Water 998 kg/m^3 73 mN/m	Water	Tanaka's formula	Mettler-Toledo Type AB204-S d=0.1 mg
CESMEC	Cyclohexane 779 kg/m^3 25 mN/m	Density standard made of fused silica. Cylinder shape	PTB-Germany	AND Type HA202M d=0.1 mg
IBMETRO	Water 998 kg/m^3 73 mN/m	Water	Tanaka's formula	Sartorius Type BP 221S d=0.1 mg

INDECOPI	Water 998 kg/m^3 73 mN/m	Water	Kell's formula	Mettler-Toledo Type AE 163 d=0.1 mg
INEN	Water 998 kg/m^3 XXX mN/m[1]	Water	Tanaka's formula	Mettler-Toledo Type XP8002S d=10 mg
INMETRO	Alcohol 806 kg/m^3 23 mN/m	Density standard made of silicon. Ring shape	NMIJ-Japan	Sartorius Type CC3000 d=0.1 mg
INTI	Water 998 kg/m^3 56 mN/m	Water	Tanaka's formula	Sartorius Type BP 301S d=0.1 mg
LACOMET	Iso octane 692 kg/m^3 20 mN/m (for the range of 600 to 610 kg/m^3); Water 998 kg/m^3 73 mN/m (for the others ranges)	Vibrating tube Density meter, Water	Density meter calibrated with liquid density standards with traceability to DKD, Tanaka's formula	Mettler-Toledo Type AT261 d=0.1 mg
LATU	n-Tridecane 756 kg/m^3 27 mN/m	Solid density standard	PTB-Germany	Mettler-Toledo Type AG204 d=0.1 mg
NIST	n-Tridecane 756 kg/m^3 25 mN/m	Solid density standard made of stainless steel. Sphere shape	Formula of Patterson and Morris for the Water's density	Mettler-Toledo Type AT201 d=0.1 mg
NRC	Water 998 kg/m^3 61 mN/m	Water	Tanaka's formula	Mettler-Toledo Type XP205DR d=0.01 mg
SIC	Nonane 718 kg/m^3 26 mN/m	Density standard made of fused silica. Cylinder shape	Tanaka's formula	Mettler-Toledo Type AT400 d=0.1 mg

6. Results and uncertainties

6.1 Results reported by participants

For each hydrometer, the protocol specified three nominal values for which the participants had to report the density corrections and the associated uncertainties at the specific temperature of 20 ºC.

The pilot laboratory made the measurements at the beginning and at the end of the circulation of the travelling standards.

The corrections and their uncertainties reported by participants are listed in table 5. The rows with successive entries of “CENAM” in Table 5 divide data from the two loops and the two hydrometers of each loop.

[1] Surface tension of the reference liquid used was not reported by the participant.

Table 5. Corrections and associated uncertainties reported by participants.

	601 kg/m^3		605 kg/m^3		609 kg/m^3	
NMIs	Correction kg/m^3	U, k=2 kg/m^3	Correction kg/m^3	U, k=2 kg/m^3	Correction kg/m^3	U, k=2 kg/m^3
CENAM	0.000	0.025	-0.012	0.025	-0.005	0.026
IBMETRO	0.340	0.061	0.340	0.061	0.390	0.061
SIC	0.007	0.047	0.000	0.047	0.028	0.047
LATU	0.030	0.033	-0.005	0.033	-0.007	0.033
INEN	0.140	0.054	0.200	0.054	0.200	0.054
INDECOPI	0.010	0.053	0.000	0.053	-0.010	0.053
CESMEC	0.000	0.050	-0.020	0.050	-0.020	0.050
INTI	-0.010	0.060	-0.040	0.060	-0.050	0.060
CENAM	0.005	0.027	-0.019	0.027	-0.031	0.028
CENAM	0.077	0.025	0.069	0.025	0.064	0.025
NIST	0.085	0.023	0.072	0.023	0.076	0.023
INMETRO	0.040	0.030	0.068	0.030	0.122	0.030
LACOMET	-0.200	0.069	-0.147	0.069	-0.181	0.070
NRC	Withdraw					
CENAMEP	0.144	0.035	0.137	0.035	0.136	0.035
BSJ	-0.19	0.07	-0.25	0.07	-0.01	0.07
CENAM	Broken					
	801 kg/m^3		805 kg/m^3		809 kg/m^3	
	Correction kg/m^3	U, k=2 kg/m^3	Correction kg/m^3	U, k=2 kg/m^3	Correction kg/m^3	U, k=2 kg/m^3
CENAM	0.019	0.031	0.008	0.031	0.019	0.032
IBMETRO	1.020	0.080	1.030	0.080	1.020	0.080
SIC	0.037	0.056	0.038	0.056	0.059	0.056
LATU	0.039	0.034	0.027	0.034	0.037	0.034
INEN	0.120	0.054	0.030	0.054	0.030	0.054
INDECOPI	0.120	0.065	0.090	0.065	0.100	0.065
CESMEC	0.080	0.030	0.110	0.030	0.110	0.030
INTI	0.100	0.067	0.030	0.067	0.030	0.067
CENAM	0.060	0.032	0.049	0.032	0.046	0.033
CENAM	0.033	0.030	0.033	0.031	0.048	0.031
NIST	0.061	0.026	0.052	0.026	0.067	0.026
INMETRO	-0.081	0.034	-0.090	0.034	-0.034	0.034
LACOMET	-0.043	0.068	-0.089	0.068	-1.177	0.068
NRC	-0.012	0.110	0.033	0.110	0.109	0.110
CENAMEP	0.106	0.037	0.094	0.037	0.092	0.037
BSJ	-0.09	0.12	0.05	0.12	-0.02	0.12
CENAM (*PL*)	0.042	0.032	0.040	0.032	0.037	0.033
	991		995		999	
	Correction kg/m^3	U, k=2 kg/m^3	Correction kg/m^3	U, k=2 kg/m^3	Correction kg/m^3	U, k=2 kg/m^3
CENAM	0.048	0.037	0.073	0.038	0.080	0.037
IBMETRO	-0.216	0.052	-0.229	0.052	-0.224	0.052

SIC	0.030	0.066	0.003	0.066	0.023	0.066
LATU	0.009	0.036	0.023	0.036	0.038	0.036
INEN	-0.120	0.054	-0.020	0.054	0.010	0.054
INDECOPI	0.090	0.078	0.080	0.078	0.060	0.078
CESMEC	0.130	0.040	0.130	0.040	0.140	0.040
INTI	-0.054	0.069	-0.045	0.069	-0.054	0.069
CENAM	0.036	0.037	0.042	0.037	0.056	0.037
CENAM	0.119	0.036	0.127	0.036	0.142	0.036
NIST	0.109	0.033	0.108	0.033	0.136	0.033
INMETRO	-0.090	0.040	-0.120	0.040	0.040	0.040
LACOMET	-0.001	0.078	0.035	0.078	-0.042	0.078
NRC	0.053	0.123	0.077	0.123	0.057	0.123
CENAMEP	0.161	0.034	0.169	0.034	0.174	0.034
BSJ	-0.03	0.09	-0.20	0.09	-0.06	0.09
CENAM	0.096	0.037	0.097	0.037	0.117	0.037
	1 291 kg/m^3		**1 295 kg/m^3**		**1 299 kg/m^3**	
	Correction kg/m^3	**U, k=2 kg/m^3**	**Correction kg/m^3**	**U, k=2 kg/m^3**	**Correction kg/m^3**	**U, k=2 kg/m^3**
CENAM	0.082	0.049	0.078	0.049	0.095	0.049
IBMETRO	**Broken**					
SIC	0.096	0.081	0.123	0.081	0.120	0.081
LATU	0.063	0.040	0.077	0.040	0.090	0.040
INEN	-0.010	0.054	-0.040	0.054	0.080	0.054
INDECOPI	0.060	0.090	0.070	0.090	0.100	0.090
CESMEC	0.070	0.040	0.050	0.040	0.050	0.040
INTI	0.075	0.080	0.045	0.080	0.065	0.080
CENAM	0.127	0.046	0.116	0.046	0.123	0.046
CENAM	0.114	0.047	0.089	0.046	0.119	0.046
NIST	0.064	0.039	0.068	0.039	0.103	0.039
INMETRO	-0.180	0.054	-0.050	0.054	-0.020	0.054
LACOMET	-0.169	0.067	-0.166	0.067	-0.121	0.067
NRC	0.000	0.151	-0.005	0.151	0.006	0.151
CENAMEP	0.073	0.031	0.078	0.031	0.086	0.031
BSJ	-0.06	0.13	-0.07	0.13	-0.05	0.13
CENAM	0.053	0.046	0.053	0.046	0.086	0.047

In order to compare results reported by participants from both loops, differences between results reported by participants and results reported by the pilot laboratory were calculated,

$$d_{ji} = X_{ji} - PL_j \qquad (1$$

were

d_{ji} Difference between the result reported by laboratory "i" of loop "j" and the pilot laboratory

X_{ji} Correction reported by laboratory "i" of loop "j"

PL_j Mean correction reported by the pilot laboratory of the hydrometer of loop "j"

As the pilot laboratory measured the travelling standards at the beginning and at the end of the circulation, the value of the pilot laboratory (PL) is the mean of both measurements (at the beginning and at the end of the circulation).

The uncertainty of the difference d_{ji} was calculated as following,

$$u(d_{ji}) = \sqrt{u^2(X_{ji}) + u^2(rep, PL_j)} \quad (2$$

where

$u(d_{ji})$ standard uncertainty of the difference

$u(X_{ji})$ standard uncertainty reported by the participant[2]

$u(rep, PL_j)$[3] uncertainty contribution due to the reproducibility of the measurements done by the pilot laboratory

The standard uncertainty due to the reproducibility of the pilot laboratory was calculated considering the difference of the measurements of the pilot laboratory (at the beginning and at the end of the circulation of the travelling standards) and taking this difference as an interval of uniform probability density.

$$u(rep, PL_j) = \frac{PL_{1j} - PL_{2j}}{\sqrt{12}} \quad (3$$

The standard uncertainties due to the reproducibility of the pilot laboratory measurements are listed in table 6.

Table 6. Standard uncertainties due to the reproducibility of the pilot laboratory

Nominal Value	*u (rep, PL),* kg/m^3 (k=1)	
kg/m^3	Loop 1	Loop 2
601	0.002	0.002
605	0.002	0.002
609	0.008	0.008
801	0.003	0.012
805	0.002	0.012
809	0.003	0.008
991	0.007	0.004
995	0.009	0.009

[2] Uncertainties related to the transfer standard itself other than reproducibility, i.e. uncertainty in the thermal expansion coefficient of the hydrometer glass, were included in the uncertainty analyses of each participating laboratory, are already included in $u(X_{ji})$, or were negligible, and therefore are not listed separately in formula 2.

[3] The pilot laboratory made a slight change in the hydrostatic weighing system between measurements, which consisted in the change of the source of light (the use of LEDs instead of a fluorescent bulb) for the optical system for positioning the mark of the hydrometers). The differences between both measurements of the pilot laboratory were within the calibration uncertainty; however these differences were taken into account for the analysis of uncertainty.

999	0.007	0.007
1291	0.018	0.013
1295	0.011	0.011
1299	0.010	0.008

All differences are reported in tables 7 to 10 and plotted in figures 2 to 5.

6.2 Contributions to the uncertainties

The accuracy of the values reported by the participants depends on all their systems, and as this SIM comparison was performed with hydrometers of high accuracy (resolution of 0.1 kg/m^3), participants should take special attention to these contributions to uncertainties that are usually hidden by the resolution of the instruments.

Some of the input quantities for the hydrometers calibration by Cuckow's method are:

- Density of the transfer liquid
  - Thermal expansion coefficient of the transfer liquid
  - Isothermal compressibility coefficient of the transfer liquid
  - Temperature of the transfer liquid
    - Characteristics of the measurement instrument
    - Stability of the liquid temperature
    - Temperature gradients in the liquid
  - Pressure of the transfer liquid
    - Characteristics of the measurement instrument
    - Pressure gradients in the liquid
- Surface tension of the transfer liquid
- Diameter of the stem
- Mass measurements of the hydrometer (both in air and in liquid)
  - Repeatability and reproducibility of the mass measurements
  - Resolution of the balance
  - Indication error of the balance
- Positioning of the mark
  - Resolution of the hydrometer
  - Alignment of the hydrometer
- Air density
  - Air Temperature
    - Characteristics of the measurement instrument
    - Stability of the air temperature
  - Atmospheric pressure
    - Characteristics of the measurement instrument
  - Relative humidity
    - Characteristics of the measurement instrument
    - Stability of the relative humidity
- Local gravity
- Others

7. Reference values

The proposed reference values (for each nominal value) were evaluated using procedure A (weighted mean), procedure B (median) according to Cox [2002] [1] and the weighted mean of the largest consistent subset according to Cox [2007] [2].

7.1 Weighted mean (Procedure A)

The use of the weighted mean as a reference value could be applied only if all values reported by participants are consistent.

The consistency of results reported by participants was evaluated by the chi-squared test, $\Pr\left\{\chi^2(\upsilon) > \chi^2_{obs}\right\} < 0.05$.

No consistency among participants was found for all nominal values. Some values reported by participants were found as “anomalous” according to chi-squared test at an approx. 95% of confidence level.

7.2 Median (Procedure B)

As some of the values reported by participants were found as “anomalous”, a proposed reference value was calculated using procedure B of Cox [2002] [1].

This proposed reference value was evaluated by numerical simulation as the median of the differences of results reported by participants and results reported by pilot laboratory. Each reference value calculated by numerical simulation (Monte Carlo method [5]) was evaluated with 1×10^6 trials.

For the numerical simulation, the inputs are the probability density functions (pdfs) of the differences between reported values by participants and reported values by the pilot laboratory and their associated uncertainties as the mean and the standard deviations of normal pdfs $N(\bar{x}, s)$.

Those pdfs were combined according to the mathematical model (median) and the mean and the standard deviation of the pdf resulting from the numerical simulation were taken as the reference value and its associated uncertainty for each nominal value.

Proposed reference values by procedure B (medians) are reported in tables 7 to 10 and shown in figures 2 to 5.

7.3 Weighted mean of the largest consistent subset (WM of the LCS)

As was pointed out in 7.1, no consistency among participants was found for all nominal values, and because of that, “anomalous” values (according to the chi-squared test) were eliminated in order to have the largest consistent subset of values [2] for the calculation of the proposed reference value as the weighted mean (formula 4), and its uncertainty (formula 5), similar to procedure A of [1].

This procedure was done for each nominal value. Proposed reference values calculated as the weighted mean (of the differences of results reported by participants and results reported by pilot laboratory) are listed in tables 7 to 10 and shown in figures 2 to 5.

$$RV_{mean} = \frac{\sum d_{ji} / u^2(d_{ji})}{\sum 1/u^2(d_{ji})} \quad (4$$

$$\frac{1}{u^2(RV_{mean})} = \sum \frac{1}{u^2(d_{ji})} \quad (5$$

8. Degree of equivalence

8.1 Degree of equivalence between participants and the reference value

8.1.1 Degree of equivalence using the weighted mean as the reference value

In order to evaluate the degree of equivalence between the values reported by participants and the proposed reference value (calculated as the weighted mean), the differences between reported values by participants (actually differences between reported values of participants and the value of the pilot laboratory, formula 1) and the mean values were evaluated as follows,

$$D_{di-RV} = d_{ji} - RV_{mean} \quad (6,$$

with the associated uncertainty (with an approximated level of confidence of approx. 95%),

for the values reported by participants that contributed to the reference value,

$$U(D_{di-RV}) = 2\sqrt{u_{dji}^2 - u_{RVmean}^2} \quad (7$$

and as follows for the values reported by participants that did not contributed for the reference value,

$$U(D_{di-RV}) = 2\sqrt{u_{dji}^2 + u_{RVmean}^2} \quad (8$$

The differences and their associated uncertainties between values reported by participants and reference values are listed in tables from 11 to 14.

The normalized error was calculated for each reported value of participants, as follows,

if the reported value of the participant contributed to the reference value,

$$E_{n(mean)} = \frac{\left| d_{ji} - RV_{mean} \right|}{2\sqrt{u_{dji}^2 - u_{RVmean}^2}} \quad (9$$

If the reported value of the participant did not contribute for the reference value,

$$E_{n(mean)} = \frac{\left| d_{ji} - RV_{mean} \right|}{2\sqrt{u_{dji}^2 + u_{RVmean}^2}} \quad (10$$

The normalized errors calculated with formulae 9 and 10 are listed in tables 7 to 10.

8.1.2 Degree of equivalence using the median as the reference value

In order to evaluate the differences between the values reported by participants and the proposed reference value evaluated as the median, a numerical simulation of Monte Carlo method was done [5]. Each difference calculated by numerical simulation was evaluated with $1x10^6$ trials.

For the numerical simulation, the inputs are the probability density functions (pdfs) of the differences between reported values by participants and reported values by the pilot laboratory and their associated uncertainties as the mean and the standard deviations of normal pdfs $N(\bar{x}, s)$.

Those pdfs were combined according to the mathematical model of the difference between the difference between the reported value of the participant and the pilot laboratory and the median evaluated by numerical simulation for the corresponding nominal value,

$$D_{di-RV} = d_{ji} - RV_{median} \quad (11$$

From the pdfs resulting for each difference (D_{di-RV}) we obtained the mean value and the interval of confidence for an approx. level of confidence of 95%, $\overline{D}_{di-RV}, \left[d_{low}(2{,}5\%), d_{high}(97{,}5\%) \right]$.

The differences and their confidence intervals associated between values reported by participants and reference values are listed in tables 11 to 14.

Even when the pdfs of the differences D_{di-RV} evaluated by numerical simulation are slightly asymmetrical, the normalized errors were calculated assuming symmetry in pdfs of the differences,

$$E_{n(median)} = \left| \frac{d_{ji} - RV_{median}}{\frac{1}{2}\left(d_{high} - d_{low}\right)} \right| \quad (12$$

The normalized errors calculated with formula 12 are listed in tables 7 to 10.

8.2 Degree of equivalence between participants

The degree of equivalence among participant laboratories was calculated as the difference between the values reported by participants. In order to do this the values reported by the pilot laboratory were used as pivot values.

Degree of equivalence between participant laboratories of the same loop is,

$$\begin{aligned} D_{A-B} &= d_{jA} - d_{jB} \\ D_{A-B} &= \left(X_{jA} - PL_j\right) - \left(X_{jB} - PL_j\right) \\ D_{A-B} &= X_{jA} - X_{jB} \end{aligned} \quad (13$$

with the expanded uncertainty as follows,

$$u\left(D_{A-B}\right) = 2\sqrt{u^2\left(d_{jA}\right) + u^2\left(d_{jB}\right) - u^2\left(rep, PL_j\right)} \quad (14$$

Degree of equivalence between participant laboratories of different loops is,

$$\begin{aligned} D_{A-C} &= d_{jA} - d_{kC} \\ D_{A-C} &= \left(X_{jA} - PL_j\right) - \left(X_{kC} - PL_k\right) \\ D_{A-C} &= X_{jA} - X_{kC} \end{aligned} \quad (15$$

with the expanded uncertainty as follows,

$$D\left(d_{A-C}\right) = 2\sqrt{u^2\left(d_{jA}\right) + u^2\left(d_{kC}\right) - \frac{u^2\left(rep, PL_j\right) + u^2\left(rep, PL_k\right)}{2}} \quad (16$$

The degrees of equivalence between participants are listed in tables 15 to 26.

9. Conclusions

The main objectives of this SIM comparison were:

- to evaluate the degree of equivalence between SIM NMIs in the calibration of hydrometers of high accuracy within the range of 600 kg/m^3 to 1 300 kg/m^3,and
- to anticipate to the CCM KC on hydrometers calibration and eventually to link the results of SIM NMIs with Key Comparison Reference Value (KCRV) of CCM.D-K4

In order to reach such objectives, two sets of four hydrometers each were circulated between fourteen NMIs of SIM. For the circulation of the travelling standards the NMIs were divided in two petals, linked only by the results of the pilot laboratory. All measurements were carried out from April 2007 to October 2008.

For the measurements each laboratory used their own hydrostatic weighing system with their own respective standard liquid such as: water, pentadecane, cyclohexane, alcohol, iso-octane and n-tridecane.

The traceabilities of the density standard liquids are either from PTB's density standard, from NMIJ's density Standard, or from different formulae to calculate the density of water (Tanaka's formula and others formulae).

The degree of equivalence between participants in the scope of this comparison are calculated from the results reported by each participants in table 5. They are reported in tables 15 to 26.

Two sets of reference values, for each nominal value, were proposed to the participants: the weighed mean of the largest consistent subset [2] and the median [1].

The participant laboratories agreed to use of the weighed mean of the largest consistent subset as the reference value for this comparison.

The differences (and its associated uncertainty) between the participant laboratories and the agreed reference value D_{di}-RV_{mean}, for each nominal value are listed in tables 11 to 14 and shown in figures 6 to 9.

The normalized errors calculated for each result reported by participants are listed in tables 7 to 10. These normalized errors were calculated with a level of confidence of approximately 95% (k=2).

The distributions of the normalized errors to the reference values calculated from all participants are,

- **63.6 %** below to **1**, for the four ranges, from 600 kg/m^3 to 1 300 kg/m^3,
- **80.3 %** below to **2** for the four ranges, from 600 kg/m^3 to 1 300 kg/m^3,
- **85.2 %** below to **3** for the four ranges, from 600 kg/m^3 to 1 300 kg/m^3,
- **56.4 %** below to **1** within the range of 600 kg/m^3 to 610 kg/m^3,
- **69.1 %** below to **1** within the range of 800 kg/m^3 to 810 kg/m^3,

- **50.0 %** below to **1** within the range of 990 kg/m^3 to 1 000 kg/m^3,
- **79.5 %** below to **1** within the range of 1 290 kg/m^3 to 1 300 kg/m^3.

Reference

[1] Cox, M. - The evaluation of key comparison data - Metrologia, 2002, 39, 589-595

[2] Cox, M. – The evaluation of the key comparison data: determining the largest consistent subset – Metrologia 44 (2007) 187-200

[3] Lorefice, S et al. – EUROMET.M.D-K4 / EUROMET Project 702: Comparison of the calibration of high resolution hydrometers for liquid density determinations – Metrologia, 2008, 45, Tech. Suppl., 07008. EUROMET.M.D-K4 Final Report, 2008.

[4] JCGM 100:2008 - Evaluation of measurement data — Guide to the expression of uncertainty in measurement -

[5] JCGM 101:2008 - Evaluation of measurement data — Supplement 1 to the “Guide to the expression of uncertainty in measurement” — Propagation of distributions using a Monte Carlo method

[6] Cuckow F W - A new method of high accuracy for the calibration of reference standard hydrometers J. Soc. Chem. Indust. 68 44–9, 1949

Table 7. Differences between results reported by participant laboratories and pilot laboratory for the hydrometer with range 600 kg/m^3 to 610 kg/m^3 . The normalized errors calculated against the mean and against the median are listed too. Values are reported in kg/m^3

	601 kg/m^3				605 kg/m^3				609 kg/m^3			
	d	U, k=2	En (W. Mean)	En (Median)	*d*	U, k=2	En (W. Mean)	En (Median)	*d*	U, k=2	En (W. Mean)	En (Median)
CENAM	**0.000**	**0.027**	0.30	0.18	**0.000**	**0.028**	0.15	0.21	**0.000**	**0.032**	0.29	0.49
IBMETRO	0.338	0.062	5.25	5.28	0.356	0.062	5.59	5.61	0.408	0.063	6.14	6.01
SIC	**0.005**	**0.047**	0.06	0.02	**0.016**	**0.047**	0.27	0.21	**0.046**	**0.049**	0.80	0.63
LATU	**0.028**	**0.033**	0.68	0.66	**0.011**	**0.033**	0.23	0.14	**0.011**	**0.036**	0.09	0.13
INEN	0.138	0.054	2.34	2.36	0.216	0.054	3.80	3.77	0.218	0.056	3.61	3.45
INDECOPI	**0.008**	**0.053**	0.01	0.05	**0.016**	**0.053**	0.24	0.19	**0.008**	**0.055**	0.00	0.15
CESMEC	**-0.002**	**0.050**	0.20	0.16	**-0.004**	**0.050**	0.17	0.21	**-0.002**	**0.052**	0.20	0.36
INTI	**-0.012**	**0.060**	0.33	0.31	**-0.024**	**0.060**	0.48	0.52	**-0.032**	**0.062**	0.67	0.81
NIST	**0.008**	**0.023**	0.03	0.09	**0.003**	**0.023**	0.01	0.10	**0.012**	**0.028**	0.16	0.13
INMETRO	**-0.037**	**0.030**	1.64	1.23	**-0.001**	**0.030**	0.15	0.21	**0.058**	**0.034**	1.34	1.08
LACOMET	-0.277	0.069	4.05	4.03	-0.216	0.069	3.12	3.19	-0.245	0.072	3.46	3.58
NRC												
CENAMEP	0.067	0.035	1.60	1.59	0.068	0.035	1.74	1.66	0.072	0.038	1.56	1.33
BSJ	-0.268	0.074	3.64	3.64	-0.317	0.074	4.24	4.33	**-0.078**	**0.076**	1.16	1.22
W. mean	**0.007**	**0.013**			**0.004**	**0.013**			**0.008**	**0.015**		
median	**0.005**	**0.019**			**0.006**	**0.016**			**0.016**	**0.020**		

The values in bold were taken into account for the calculation of the reference value according to WM of the LCS (weighted mean).
For the reference value calculated by procedure B (median) were taking into account values reported by all participants.

Table 8. Differences between results reported by participant laboratories and pilot laboratory for the hydrometer with range 800 kg/m^3 to 810 kg/m^3 . The normalized errors calculated against the mean and against the median are listed too. Values are reported in kg/m^3

	801 kg/m^3				805 kg/m^3				809 kg/m^3			
	d	U, k=2	En (W. Mean)	En (Median)	*d*	U, k=2	En (W. Mean)	En (Median)	*d*	U, k=2	En (W. Mean)	En (Median)
CENAM	**0.000**	**0.040**	0.68	0.50	**0.000**	**0.040**	0.70	0.32	**0.000**	**0.036**	0.90	0.49
IBMETRO	0.981	0.083	11.29	11.46	1.001	0.083	11.52	11.65	0.988	0.081	11.60	11.76
SIC	**-0.002**	**0.061**	0.46	0.38	**0.009**	**0.061**	0.29	0.06	**0.027**	**0.058**	0.06	0.17
LATU	**0.000**	**0.041**	0.66	0.49	**-0.002**	**0.042**	0.71	0.34	**0.005**	**0.037**	0.72	0.34
INEN	**0.081**	**0.059**	0.98	1.03	**0.001**	**0.059**	0.43	0.20	**-0.002**	**0.056**	0.59	0.37
INDECOPI	**0.081**	**0.069**	0.83	0.92	**0.061**	**0.069**	0.52	0.72	**0.068**	**0.067**	0.58	0.78
CESMEC	**0.041**	**0.038**	0.45	0.59	**0.081**	**0.038**	1.54	1.57	**0.078**	**0.034**	1.54	1.54
INTI	**0.061**	**0.071**	0.52	0.63	**0.001**	**0.071**	0.36	0.17	**-0.002**	**0.069**	0.48	0.30
NIST	**0.024**	**0.026**	0.05	0.18	**0.015**	**0.026**	0.50	0.08	**0.024**	**0.026**	0.25	0.23
INMETRO	-0.118	0.034	3.81	3.48	-0.127	0.034	4.13	3.46	-0.077	0.035	2.88	2.38
LACOMET	-0.081	0.068	1.51	1.43	-0.125	0.068	2.18	1.96	-1.220	0.068	17.96	17.68
NRC	**-0.049**	**0.111**	0.68	0.66	**-0.004**	**0.111**	0.27	0.16	**0.066**	**0.111**	0.33	0.46
CENAMEP	0.069	0.037	1.10	1.21	**0.057**	**0.037**	0.91	1.07	**0.049**	**0.037**	0.55	0.82
BSJ	-0.126	0.119	1.26	1.23	**0.009**	**0.119**	0.15	0.04	**-0.067**	**0.119**	0.82	0.75
W. mean	**0.025**	**0.015**			**0.026**	**0.014**			**0.030**	**0.013**		
median	**0.019**	**0.021**			**0.013**	**0.023**			**0.018**	**0.021**		

The values in bold were taken into account for the calculation of the reference value according to WM of the LCS (weighted mean).
For the reference value calculated by procedure B (median) were taking into account values reported by all participants.

Table 9. Differences between results reported by participant laboratories and pilot laboratory for the hydrometer with range 990 kg/m^3 to 1000 kg/m^3 . The normalized errors calculated against the mean and against the median are listed too. Values are reported in kg/m^3

	991 kg/m^3				995 kg/m^3				999 kg/m^3			
	d	U, k=2	En (W. Mean)	En (Median)	*d*	U, k=2	En (W. Mean)	En (Median)	*d*	U, k=2	En (W. Mean)	En (Median)
CENAM	**0.000**	**0.039**	0.40	0.92	**0.000**	**0.042**	0.73	0.95	**0.000**	**0.040**	0.46	1.03
IBMETRO	-0.258	0.052	4.38	3.45	-0.287	0.055	4.45	3.85	-0.292	0.054	4.83	3.97
SIC	**-0.012**	**0.066**	0.03	0.53	**-0.054**	**0.068**	0.41	0.12	**-0.045**	**0.067**	0.44	0.08
LATU	**-0.033**	**0.037**	0.61	0.29	**-0.034**	**0.040**	0.20	0.28	**-0.030**	**0.039**	0.40	0.47
INEN	-0.162	0.054	2.57	1.85	**-0.077**	**0.057**	0.93	0.55	**-0.058**	**0.056**	0.79	0.15
INDECOPI	**0.048**	**0.078**	0.82	1.12	**0.023**	**0.080**	0.64	0.88	**-0.008**	**0.079**	0.11	0.56
CESMEC	0.088	0.041	2.27	2.52	0.073	0.044	2.08	2.24	0.072	0.042	1.91	2.36
INTI	**-0.096**	**0.069**	1.24	0.78	**-0.102**	**0.071**	1.09	0.79	-0.121	0.070	1.45	0.99
NIST	**0.001**	**0.036**	0.50	0.98	**-0.004**	**0.037**	0.73	0.94	**0.006**	**0.036**	0.73	1.20
INMETRO	-0.198	0.042	3.97	2.85	-0.232	0.044	4.31	3.50	-0.090	0.042	1.58	0.85
LACOMET	-0.109	0.079	1.17	0.84	**-0.077**	**0.080**	0.64	0.41	-0.172	0.079	1.90	1.46
NRC	**-0.054**	**0.124**	0.33	0.09	**-0.035**	**0.124**	0.06	0.10	**-0.073**	**0.124**	0.47	0.21
CENAMEP	0.053	0.037	1.63	1.97	0.057	0.038	1.98	2.13	0.044	0.037	1.46	1.98
BSJ	-0.140	0.089	1.39	1.06	-0.309	0.090	3.07	2.81	-0.190	0.089	1.90	1.51
W. mean	**-0.014**	**0.019**			**-0.027**	**0.019**			**-0.016**	**0.019**		
median	**-0.044**	**0.035**			**-0.047**	**0.032**			**-0.049**	**0.031**		

The values in bold were taken into account for the calculation of the reference value according to WM of the LCS (weighted mean).
For the reference value calculated by procedure B (median) were taking into account values reported by all participants.

Table 10. Differences between results reported by participant laboratories and pilot laboratory for the hydrometer with range 1290 kg/m^3 to 1300 kg/m^3 . The normalized errors calculated against the mean and against the median are listed too. Values are reported in kg/m^3

	1 291 kg/m^3				1 295 kg/m^3				1 299 kg/m^3			
	d	U, k=2	En (W. Mean)	En (Median)	*d*	U, k=2	En (W. Mean)	En (Median)	*d*	U, k=2	En (W. Mean)	En (Median)
CENAM	**0.000**	**0.058**	0.65	0.81	**0.000**	**0.053**	0.31	0.77	**0.000**	**0.052**	0.48	0.70
IBMETRO												
SIC	**-0.009**	**0.085**	0.33	0.48	**0.026**	**0.084**	0.51	0.85	**0.011**	**0.083**	0.42	0.59
LATU	**-0.042**	**0.048**	0.13	0.13	**-0.020**	**0.046**	0.11	0.45	**-0.019**	**0.043**	0.10	0.37
INEN	**-0.115**	**0.060**	1.39	1.01	-0.137	0.058	1.99	1.42	-0.029	0.056	-0.10	0.12
INDECOPI	**-0.045**	**0.094**	0.09	0.04	**-0.027**	**0.093**	0.13	0.18	**-0.009**	**0.092**	0.16	0.31
CESMEC	**-0.035**	**0.048**	0.03	0.27	**-0.047**	**0.046**	0.75	0.09	**-0.059**	**0.043**	0.90	0.52
INTI	**-0.030**	**0.084**	0.08	0.23	**-0.053**	**0.083**	0.46	0.12	**-0.045**	**0.082**	0.27	0.11
NIST	**-0.019**	**0.053**	0.34	0.53	**-0.003**	**0.044**	0.32	0.82	**0.000**	**0.043**	0.59	0.81
INMETRO	-0.263	0.064	3.38	3.06	-0.121	0.058	1.73	1.18	-0.123	0.057	-1.67	1.39
LACOMET	-0.252	0.075	2.79	2.55	-0.236	0.070	3.06	2.53	-0.223	0.069	-2.81	2.56
NRC	**-0.083**	**0.155**	0.31	0.24	**-0.076**	**0.152**	0.40	0.23	**-0.096**	**0.152**	0.48	0.41
CENAMEP	**-0.010**	**0.047**	0.60	0.76	**0.007**	**0.038**	0.69	0.99	**-0.017**	**0.037**	0.20	0.48
BSJ	**-0.143**	**0.134**	0.81	0.74	**-0.143**	**0.131**	0.98	0.80	**-0.150**	**0.130**	0.98	0.91
g												
W. mean	**-0.036**	**0.019**			**-0.016**	**0.018**			**-0.023**	**0.017**		
median	**-0.048**	**0.032**			**-0.043**	**0.035**			**-0.036**	**0.028**		

The values in bold were taken into account for the calculation of the reference value according to WM of the LCS (weighted mean).
For the reference value calculated by procedure B (median) were taking into account values reported by all participants.

Table 11. Degree of equivalence between results reported by participant laboratories and proposed RV for the hydrometer with range 600 kg/m^3 to 610 kg/m^3 .

	601					605					609				
	$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$			$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$			$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$		
	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)
CENAM	**-0.007**	0.024	**-0.005**	-0.036	0.022	**-0.004**	0.024	**-0.006**	-0.036	0.022	**-0.008**	0.028	**-0.016**	-0.052	0.013
IBMETRO	**0.331**	0.063	**0.332**	0.269	0.395	**0.352**	0.063	**0.350**	0.287	0.412	**0.400**	0.065	**0.392**	0.327	0.457
SIC	**-0.002**	0.045	**-0.001**	-0.046	0.045	**0.012**	0.045	**0.010**	-0.035	0.056	**0.038**	0.047	**0.030**	-0.014	0.082
LATU	**0.021**	0.030	**0.022**	-0.008	0.059	**0.007**	0.030	**0.005**	-0.028	0.039	**0.003**	0.033	**-0.005**	-0.042	0.030
INEN	**0.131**	0.056	**0.132**	0.076	0.188	**0.212**	0.056	**0.210**	0.154	0.265	**0.210**	0.058	**0.202**	0.144	0.261
INDECOPI	**0.001**	0.051	**0.002**	-0.048	0.053	**0.012**	0.051	**0.010**	-0.040	0.061	**0.000**	0.053	**-0.008**	-0.061	0.043
CESMEC	**-0.009**	0.048	**-0.008**	-0.057	0.039	**-0.008**	0.048	**-0.010**	-0.060	0.037	**-0.010**	0.050	**-0.018**	-0.070	0.029
INTI	**-0.019**	0.059	**-0.018**	-0.077	0.038	**-0.028**	0.059	**-0.030**	-0.090	0.025	**-0.040**	0.060	**-0.048**	-0.111	0.006
NIST	**0.001**	0.019	**0.002**	-0.023	0.029	**0.000**	0.019	**-0.002**	-0.028	0.022	**0.004**	0.023	**-0.004**	-0.035	0.024
INMETRO	**-0.044**	0.027	**-0.043**	-0.077	-0.008	**-0.004**	0.027	**-0.006**	-0.038	0.023	**0.050**	0.030	**0.042**	0.003	0.080
LACOMET	**-0.285**	0.070	**-0.283**	-0.353	-0.213	**-0.219**	0.070	**-0.222**	-0.291	-0.152	**-0.253**	0.073	**-0.261**	-0.334	-0.188
NRC															
CENAMEP	**0.060**	0.037	**0.061**	0.023	0.100	**0.065**	0.037	**0.063**	0.025	0.100	**0.064**	0.041	**0.056**	0.014	0.098
BSJ	**-0.275**	0.076	**-0.273**	-0.348	-0.198	**-0.320**	0.076	**-0.323**	-0.397	-0.248	**-0.086**	0.074	**-0.094**	-0.171	-0.017

Table 12. Degree of equivalence between results reported by participant laboratories and proposed RV for the hydrometer with range 800 kg/m^3 to 810 kg/m^3 .

	801					805					809				
	$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$			$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$			$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$		
	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)
CENAM	**-0.025**	0.037	**-0.019**	-0.061	0.014	**-0.026**	0.038	**-0.013**	-0.057	0.026	**-0.030**	0.034	**-0.018**	-0.057	0.015
IBMETRO	**0.956**	0.085	**0.962**	0.878	1.046	**0.975**	0.085	**0.988**	0.904	1.073	**0.958**	0.083	**0.970**	0.888	1.053
SIC	**-0.027**	0.059	**-0.021**	-0.081	0.031	**-0.017**	0.059	**-0.004**	-0.081	0.031	**-0.003**	0.057	**0.009**	-0.045	0.066
LATU	**-0.025**	0.038	**-0.019**	-0.063	0.015	**-0.028**	0.039	**-0.015**	-0.059	0.025	**-0.025**	0.035	**-0.013**	-0.053	0.022
INEN	**0.056**	0.057	**0.062**	0.003	0.123	**-0.025**	0.057	**-0.012**	-0.071	0.044	**-0.032**	0.055	**-0.020**	-0.076	0.031
INDECOPI	**0.056**	0.067	**0.062**	-0.002	0.132	**0.035**	0.068	**0.048**	-0.015	0.119	**0.038**	0.066	**0.050**	-0.010	0.118
CESMEC	**0.016**	0.035	**0.022**	-0.011	0.063	**0.055**	0.036	**0.068**	0.025	0.112	**0.048**	0.031	**0.060**	0.021	0.099
INTI	**0.036**	0.069	**0.042**	-0.020	0.113	**-0.025**	0.070	**-0.012**	-0.081	0.056	**-0.032**	0.067	**-0.020**	-0.087	0.043
NIST	**-0.001**	0.021	**0.005**	-0.021	0.034	**-0.011**	0.022	**0.003**	-0.028	0.034	**-0.006**	0.023	**0.007**	-0.021	0.038
INMETRO	**-0.143**	0.038	**-0.137**	-0.177	-0.098	**-0.153**	0.037	**-0.139**	-0.180	-0.099	**-0.107**	0.037	**-0.094**	-0.134	-0.055
LACOMET	**-0.105**	0.070	**-0.100**	-0.169	-0.030	**-0.152**	0.070	**-0.138**	-0.209	-0.068	**-1.250**	0.070	**-1.237**	-1.307	-1.167
NRC	**-0.074**	0.110	**-0.068**	-0.177	0.030	**-0.030**	0.110	**-0.017**	-0.124	0.088	**0.036**	0.110	**0.049**	-0.054	0.157
CENAMEP	**0.044**	0.040	**0.050**	0.009	0.091	**0.031**	0.034	**0.045**	0.003	0.087	**0.019**	0.035	**0.032**	-0.004	0.073
BSJ	**-0.151**	0.120	**-0.145**	-0.263	-0.027	**-0.017**	0.118	**-0.004**	-0.118	0.110	**-0.097**	0.118	**-0.085**	-0.202	0.025

Table 13. Degree of equivalence between results reported by participant laboratories and proposed RV for the hydrometer with range 990 kg/m^3 to 1000 kg/m^3 .

	991					995					999				
	$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$			$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$			$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$		
	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)
CENAM	**0.014**	0.034	**0.044**	0.000	0.096	**0.027**	0.037	**0.047**	0.001	0.099	**0.016**	0.035	**0.049**	0.003	0.099
IBMETRO	**-0.244**	0.056	**-0.213**	-0.275	-0.151	**-0.260**	0.058	**-0.240**	-0.302	-0.177	**-0.276**	0.057	**-0.242**	-0.303	-0.181
SIC	**0.002**	0.064	**0.033**	-0.021	0.103	**-0.027**	0.066	**-0.008**	-0.074	0.054	**-0.029**	0.065	**0.005**	-0.056	0.069
LATU	**-0.019**	0.031	**0.012**	-0.024	0.056	**-0.007**	0.036	**0.012**	-0.027	0.060	**-0.014**	0.034	**0.020**	-0.017	0.067
INEN	**-0.148**	0.058	**-0.117**	-0.180	-0.053	**-0.050**	0.054	**-0.031**	-0.093	0.019	**-0.042**	0.052	**-0.008**	-0.064	0.042
INDECOPI	**0.062**	0.076	**0.093**	0.011	0.177	**0.050**	0.078	**0.069**	-0.005	0.153	**0.008**	0.077	**0.042**	-0.025	0.123
CESMEC	**0.102**	0.045	**0.133**	0.081	0.186	**0.100**	0.048	**0.119**	0.067	0.173	**0.088**	0.046	**0.122**	0.070	0.173
INTI	**-0.083**	0.067	**-0.052**	-0.127	0.007	**-0.075**	0.069	**-0.055**	-0.131	0.009	**-0.105**	0.073	**-0.072**	-0.147	-0.002
NIST	**0.015**	0.030	**0.046**	0.002	0.096	**0.023**	0.032	**0.043**	0.000	0.091	**0.022**	0.031	**0.056**	0.010	0.103
INMETRO	**-0.184**	0.046	**-0.153**	-0.206	-0.099	**-0.205**	0.048	**-0.185**	-0.238	-0.132	**-0.074**	0.047	**-0.040**	-0.092	0.003
LACOMET	**-0.095**	0.082	**-0.064**	-0.148	0.004	**-0.050**	0.078	**-0.030**	-0.111	0.039	**-0.156**	0.082	**-0.122**	-0.206	-0.038
NRC	**-0.041**	0.123	**-0.010**	-0.121	0.099	**-0.008**	0.123	**0.011**	-0.103	0.129	**-0.057**	0.123	**-0.024**	-0.142	0.089
CENAMEP	**0.067**	0.041	**0.098**	0.049	0.148	**0.084**	0.043	**0.104**	0.056	0.153	**0.060**	0.041	**0.094**	0.047	0.141
BSJ	**-0.126**	0.091	**-0.096**	-0.189	-0.008	**-0.282**	0.092	**-0.263**	-0.356	-0.169	**-0.173**	0.091	**-0.140**	-0.233	-0.047

Table 14. Degree of equivalence between results reported by participant laboratories and proposed RV for the hydrometer with range 1290 kg/m^3 to 1300 kg/m^3 .

	1291					1295					1299				
	$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$			$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$			$D_{di\text{-}RV(mean)}$		$D_{di\text{-}RV(median)}$		
	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)	diff	U, (k=2)	diff	x1 (2.5%)	x2 (97.5%)
CENAM	**0.036**	0.055	**0.048**	-0.005	0.113	**0.016**	0.050	**0.043**	-0.005	0.106	**0.023**	0.049	**0.036**	-0.010	0.093
IBMETRO															
SIC	**0.027**	0.083	**0.039**	-0.038	0.126	**0.042**	0.082	**0.069**	-0.005	0.157	**0.034**	0.081	**0.047**	-0.028	0.131
LATU	**-0.006**	0.044	**0.006**	-0.043	0.059	**-0.004**	0.042	**0.023**	-0.021	0.079	**0.004**	0.040	**0.017**	-0.025	0.066
INEN	**-0.079**	0.057	**-0.067**	-0.132	0.000	**-0.121**	0.061	**-0.094**	-0.160	-0.027	**-0.006**	0.059	**0.007**	-0.048	0.064
INDECOPI	**-0.009**	0.092	**0.003**	-0.086	0.094	**-0.011**	0.091	**0.016**	-0.070	0.106	**0.014**	0.090	**0.027**	-0.057	0.118
CESMEC	**0.001**	0.044	**0.013**	-0.034	0.068	**-0.031**	0.042	**-0.004**	-0.056	0.044	**-0.036**	0.040	**-0.023**	-0.072	0.017
INTI	**0.006**	0.082	**0.018**	-0.060	0.101	**-0.037**	0.081	**-0.010**	-0.091	0.068	**-0.021**	0.080	**-0.008**	-0.088	0.069
NIST	**0.017**	0.049	**0.029**	-0.020	0.088	**0.013**	0.040	**0.040**	-0.001	0.096	**0.024**	0.040	**0.036**	-0.003	0.087
INMETRO	**-0.227**	0.067	**-0.215**	-0.285	-0.144	**-0.105**	0.061	**-0.078**	-0.144	-0.011	**-0.099**	0.060	**-0.087**	-0.149	-0.024
LACOMET	**-0.216**	0.078	**-0.204**	-0.284	-0.124	**-0.221**	0.072	**-0.194**	-0.270	-0.117	**-0.200**	0.071	**-0.187**	-0.260	-0.114
NRC	**-0.047**	0.154	**-0.035**	-0.185	0.110	**-0.061**	0.151	**-0.033**	-0.181	0.108	**-0.073**	0.151	**-0.060**	-0.209	0.082
CENAMEP	**0.026**	0.043	**0.038**	-0.006	0.094	**0.023**	0.033	**0.050**	0.000	0.101	**0.007**	0.032	**0.019**	-0.016	0.065
BSJ	**-0.107**	0.132	**-0.095**	-0.229	0.028	**-0.127**	0.129	**-0.100**	-0.232	0.018	**-0.127**	0.129	**-0.114**	-0.244	0.006

Table 15. Degree of equivalence between participant laboratories for the nominal value of 601 kg/m^3.

601	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		-0.338	-0.005	-0.028	-0.138	-0.008	0.002	0.012	-0.008	0.037	0.277		-0.067	0.268
IBMETRO			0.333	0.310	0.200	0.330	0.340	0.350	0.330	0.375	0.615		0.271	0.606
SIC				-0.023	-0.133	-0.003	0.007	0.017	-0.003	0.042	0.282		-0.062	0.273
LATU					-0.110	0.020	0.030	0.040	0.020	0.065	0.305		-0.039	0.296
INEN						0.130	0.140	0.150	0.130	0.175	0.415		0.071	0.406
INDECOPI							0.010	0.020	0.000	0.045	0.285		-0.059	0.276
CESMEC								0.010	-0.010	0.035	0.275		-0.069	0.266
INTI									-0.020	0.025	0.265		-0.079	0.256
NIST										0.045	0.285		-0.059	0.276
INMETRO											0.240		-0.104	0.231
LACOMET													-0.344	-0.010
NRC														
CENAMEP														0.335
BSJ														
601	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.067	0.054	0.043	0.061	0.059	0.057	0.066	0.036	0.041	0.074		0.044	0.079
IBMETRO			0.077	0.070	0.082	0.081	0.079	0.086	0.066	0.068	0.092		0.071	0.096
SIC				0.058	0.072	0.071	0.069	0.076	0.052	0.056	0.084		0.058	0.088
LATU					0.063	0.062	0.060	0.069	0.040	0.045	0.077		0.048	0.081
INEN						0.075	0.074	0.081	0.059	0.062	0.088		0.064	0.092
INDECOPI							0.073	0.080	0.057	0.061	0.087		0.063	0.091
CESMEC								0.078	0.055	0.058	0.085		0.061	0.090
INTI									0.064	0.067	0.092		0.069	0.096
NIST										0.038	0.073		0.042	0.078
INMETRO											0.075		0.046	0.080
LACOMET													0.077	0.101
NRC														
CENAMEP														0.082
BSJ														

Table 16. Degree of equivalence between participant laboratories for the nominal value of 605 kg/m^3.

605	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		-0.356	-0.016	-0.011	-0.216	-0.016	0.004	0.024	-0.003	0.001	0.216		-0.068	0.317
IBMETRO			0.340	0.345	0.140	0.340	0.360	0.380	0.352	0.356	0.571		0.287	0.672
SIC				0.005	-0.200	0.000	0.020	0.040	0.012	0.016	0.231		-0.053	0.332
LATU					-0.205	-0.005	0.015	0.035	0.007	0.011	0.226		-0.058	0.327
INEN						0.200	0.220	0.240	0.212	0.216	0.431		0.147	0.532
INDECOPI							0.020	0.040	0.012	0.016	0.231		-0.053	0.332
CESMEC								0.020	-0.008	-0.004	0.211		-0.073	0.312
INTI									-0.028	-0.024	0.191		-0.093	0.292
NIST										0.004	0.219		-0.065	0.320
INMETRO											0.215		-0.069	0.316
LACOMET													-0.284	0.101
NRC														
CENAMEP														0.385
BSJ														
605	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.067	0.055	0.043	0.061	0.059	0.057	0.066	0.036	0.041	0.074		0.044	0.079
IBMETRO			0.078	0.070	0.082	0.081	0.079	0.086	0.066	0.069	0.093		0.071	0.097
SIC				0.058	0.072	0.071	0.069	0.076	0.053	0.056	0.084		0.059	0.088
LATU					0.064	0.062	0.060	0.069	0.040	0.045	0.077		0.048	0.081
INEN						0.076	0.074	0.081	0.059	0.062	0.088		0.064	0.092
INDECOPI							0.073	0.080	0.057	0.061	0.087		0.063	0.091
CESMEC								0.078	0.055	0.059	0.085		0.061	0.090
INTI									0.064	0.067	0.092		0.069	0.096
NIST										0.038	0.073		0.042	0.078
INMETRO											0.075		0.046	0.080
LACOMET													0.077	0.102
NRC														
CENAMEP														0.082
BSJ														

Table 17. Degree of equivalence between participant laboratories for the nominal value of 609 kg/m^3.

609	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		-0.408	-0.046	-0.011	-0.218	-0.008	0.002	0.032	-0.012	-0.058	0.245		-0.072	0.078
IBMETRO			0.362	0.397	0.190	0.400	0.410	0.440	0.396	0.350	0.653		0.336	0.486
SIC				0.035	-0.172	0.038	0.048	0.078	0.034	-0.012	0.291		-0.026	0.124
LATU					-0.207	0.003	0.013	0.043	-0.001	-0.047	0.256		-0.061	0.089
INEN						0.210	0.220	0.250	0.206	0.160	0.463		0.146	0.296
INDECOPI							0.010	0.040	-0.004	-0.050	0.253		-0.064	0.086
CESMEC								0.030	-0.014	-0.060	0.243		-0.074	0.076
INTI									-0.044	-0.090	0.213		-0.104	0.046
NIST										-0.046	0.257		-0.060	0.090
INMETRO											0.303		-0.014	0.136
LACOMET													-0.317	-0.167
NRC														
CENAMEP														0.150
BSJ														
609	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.070	0.058	0.048	0.064	0.063	0.061	0.069	0.041	0.046	0.078		0.049	0.082
IBMETRO			0.080	0.073	0.084	0.083	0.082	0.088	0.069	0.071	0.095		0.073	0.099
SIC				0.061	0.074	0.073	0.072	0.079	0.056	0.059	0.087		0.062	0.090
LATU					0.066	0.065	0.063	0.071	0.045	0.049	0.080		0.052	0.084
INEN						0.078	0.077	0.083	0.062	0.065	0.091		0.067	0.094
INDECOPI							0.075	0.082	0.061	0.064	0.090		0.066	0.093
CESMEC								0.081	0.059	0.062	0.088		0.064	0.092
INTI									0.067	0.070	0.094		0.072	0.098
NIST										0.043	0.076		0.046	0.080
INMETRO											0.079		0.050	0.083
LACOMET													0.081	0.104
NRC														
CENAMEP														0.084
BSJ														

Table 18. Degree of equivalence between participant laboratories for the nominal value of 801 kg/m^3.

801	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		-0.981	0.002	0.000	-0.081	-0.081	-0.041	-0.061	-0.024	0.118	0.081	0.049	-0.069	0.126
IBMETRO			0.983	0.981	0.900	0.900	0.940	0.920	0.957	1.099	1.061	1.030	0.912	1.107
SIC				-0.002	-0.083	-0.083	-0.043	-0.063	-0.026	0.116	0.078	0.047	-0.071	0.124
LATU					-0.081	-0.081	-0.041	-0.061	-0.024	0.118	0.080	0.049	-0.069	0.126
INEN						0.000	0.040	0.020	0.057	0.199	0.161	0.130	0.012	0.207
INDECOPI							0.040	0.020	0.057	0.199	0.161	0.130	0.012	0.207
CESMEC								-0.020	0.017	0.159	0.121	0.090	-0.028	0.167
INTI									0.037	0.179	0.141	0.110	-0.008	0.187
NIST										0.142	0.104	0.073	-0.045	0.150
INMETRO											-0.038	-0.069	-0.187	0.008
LACOMET												-0.031	-0.149	0.046
NRC													-0.118	0.077
CENAMEP														0.195
BSJ														
801	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.091	0.071	0.056	0.070	0.079	0.054	0.080	0.047	0.052	0.078	0.117	0.054	0.125
IBMETRO			0.102	0.092	0.101	0.108	0.091	0.109	0.087	0.090	0.107	0.138	0.091	0.145
SIC				0.072	0.084	0.091	0.071	0.093	0.065	0.069	0.091	0.126	0.071	0.133
LATU					0.071	0.080	0.055	0.081	0.048	0.053	0.079	0.118	0.055	0.126
INEN						0.090	0.070	0.091	0.064	0.068	0.090	0.125	0.069	0.132
INDECOPI							0.078	0.098	0.073	0.077	0.097	0.130	0.078	0.137
CESMEC								0.080	0.045	0.051	0.078	0.117	0.052	0.125
INTI									0.075	0.078	0.098	0.131	0.080	0.138
NIST										0.043	0.073	0.114	0.045	0.122
INMETRO											0.076	0.116	0.050	0.124
LACOMET												0.130	0.078	0.137
NRC													0.117	0.162
CENAMEP														0.125
BSJ														

Table 19. Degree of equivalence between participant laboratories for the nominal value of 805 kg/m^3.

805	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		-1.001	-0.009	0.002	-0.001	-0.061	-0.081	-0.001	-0.015	0.127	0.125	0.004	-0.057	-0.009
IBMETRO			0.992	1.003	1.000	0.940	0.920	1.000	0.986	1.128	1.127	1.005	0.944	0.993
SIC				0.011	0.008	-0.052	-0.072	0.008	-0.006	0.136	0.135	0.013	-0.048	0.001
LATU					-0.003	-0.063	-0.083	-0.003	-0.017	0.125	0.124	0.002	-0.059	-0.010
INEN						-0.060	-0.080	0.000	-0.014	0.128	0.127	0.005	-0.056	-0.007
INDECOPI							-0.020	0.060	0.046	0.188	0.187	0.065	0.004	0.053
CESMEC								0.080	0.066	0.208	0.207	0.085	0.024	0.073
INTI									-0.014	0.128	0.127	0.005	-0.056	-0.007
NIST										0.142	0.141	0.019	-0.042	0.007
INMETRO											-0.001	-0.123	-0.184	-0.135
LACOMET												-0.122	-0.183	-0.134
NRC													-0.061	-0.013
CENAMEP														0.049
BSJ														
805	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.092	0.072	0.057	0.070	0.079	0.054	0.081	0.047	0.052	0.079	0.117	0.054	0.125
IBMETRO			0.103	0.092	0.102	0.108	0.091	0.109	0.087	0.090	0.107	0.138	0.091	0.145
SIC				0.073	0.084	0.092	0.071	0.093	0.066	0.069	0.091	0.126	0.071	0.133
LATU					0.071	0.080	0.055	0.082	0.048	0.053	0.079	0.118	0.055	0.126
INEN						0.090	0.070	0.092	0.064	0.068	0.090	0.125	0.069	0.132
INDECOPI							0.078	0.099	0.074	0.077	0.097	0.130	0.078	0.137
CESMEC								0.080	0.046	0.051	0.078	0.117	0.053	0.125
INTI									0.075	0.079	0.098	0.131	0.080	0.138
NIST										0.043	0.073	0.114	0.045	0.122
INMETRO											0.076	0.116	0.050	0.124
LACOMET												0.130	0.077	0.137
NRC													0.117	0.162
CENAMEP														0.124
BSJ														

Table 20. Degree of equivalence between participant laboratories for the nominal value of 809 kg/m^3.

809	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		-0.988	-0.027	-0.005	0.002	-0.068	-0.078	0.002	-0.024	0.077	1.220	-0.066	-0.049	0.067
IBMETRO			0.961	0.983	0.990	0.920	0.910	0.990	0.964	1.065	2.208	0.922	0.939	1.055
SIC				0.022	0.029	-0.041	-0.051	0.029	0.003	0.104	1.247	-0.039	-0.022	0.094
LATU					0.007	-0.063	-0.073	0.007	-0.019	0.082	1.225	-0.061	-0.044	0.072
INEN						-0.070	-0.080	0.000	-0.026	0.075	1.218	-0.068	-0.051	0.065
INDECOPI							-0.010	0.070	0.044	0.145	1.288	0.002	0.019	0.135
CESMEC								0.080	0.054	0.155	1.298	0.012	0.029	0.145
INTI									-0.026	0.075	1.218	-0.068	-0.051	0.065
NIST										0.101	1.244	-0.042	-0.025	0.091
INMETRO											1.143	-0.143	-0.126	-0.010
LACOMET												-1.286	-1.269	-1.153
NRC													0.017	0.133
CENAMEP														0.116
BSJ														
809	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.089	0.068	0.051	0.066	0.076	0.049	0.077	0.044	0.050	0.077	0.116	0.051	0.124
IBMETRO			0.100	0.089	0.099	0.105	0.088	0.106	0.085	0.088	0.106	0.137	0.089	0.144
SIC				0.069	0.080	0.088	0.067	0.090	0.064	0.067	0.089	0.125	0.069	0.132
LATU					0.067	0.076	0.050	0.078	0.045	0.051	0.078	0.117	0.052	0.125
INEN						0.087	0.066	0.088	0.062	0.066	0.088	0.124	0.067	0.131
INDECOPI							0.075	0.096	0.072	0.075	0.095	0.129	0.076	0.136
CESMEC								0.076	0.042	0.048	0.076	0.116	0.050	0.124
INTI									0.073	0.077	0.097	0.130	0.078	0.137
NIST										0.043	0.073	0.114	0.046	0.122
INMETRO											0.077	0.116	0.051	0.124
LACOMET												0.130	0.078	0.137
NRC													0.117	0.162
CENAMEP														0.125
BSJ														

Table 21. Degree of equivalence between participant laboratories for the nominal value of 991 kg/m^3.

991	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.258	0.012	0.033	0.162	-0.048	-0.088	0.096	-0.001	0.198	0.109	0.054	-0.053	0.140
IBMETRO			-0.246	-0.225	-0.096	-0.306	-0.346	-0.162	-0.259	-0.060	-0.149	-0.203	-0.311	-0.118
SIC				0.021	0.150	-0.060	-0.100	0.084	-0.013	0.186	0.097	0.043	-0.065	0.128
LATU					0.129	-0.081	-0.121	0.063	-0.034	0.165	0.076	0.022	-0.086	0.107
INEN						-0.210	-0.250	-0.066	-0.163	0.036	-0.053	-0.107	-0.215	-0.022
INDECOPI							-0.040	0.144	0.047	0.246	0.157	0.103	-0.005	0.188
CESMEC								0.184	0.087	0.286	0.197	0.143	0.035	0.228
INTI									-0.098	0.101	0.013	-0.042	-0.150	0.044
NIST										0.199	0.110	0.056	-0.052	0.142
INMETRO											-0.089	-0.143	-0.251	-0.057
LACOMET												-0.054	-0.162	0.031
NRC													-0.108	0.086
CENAMEP														0.194
BSJ														
991	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.065	0.077	0.053	0.067	0.087	0.056	0.080	0.053	0.057	0.088	0.130	0.053	0.097
IBMETRO			0.085	0.064	0.076	0.094	0.066	0.087	0.063	0.067	0.095	0.135	0.064	0.103
SIC				0.076	0.086	0.102	0.078	0.096	0.075	0.078	0.103	0.141	0.076	0.111
LATU					0.066	0.086	0.055	0.078	0.051	0.056	0.087	0.129	0.052	0.096
INEN						0.095	0.068	0.088	0.065	0.069	0.096	0.135	0.065	0.104
INDECOPI							0.088	0.104	0.086	0.089	0.111	0.146	0.086	0.118
CESMEC								0.080	0.054	0.058	0.089	0.130	0.054	0.098
INTI									0.078	0.081	0.105	0.142	0.078	0.113
NIST										0.055	0.087	0.129	0.051	0.096
INMETRO											0.090	0.131	0.055	0.099
LACOMET												0.147	0.087	0.119
NRC													0.129	0.153
CENAMEP														0.096
BSJ														

Table 22. Degree of equivalence between participant laboratories for the nominal value of 995 kg/m^3.

995	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.287	0.054	0.034	0.077	-0.023	-0.073	0.102	0.004	0.232	0.077	0.035	-0.057	0.309
IBMETRO			-0.232	-0.252	-0.209	-0.309	-0.359	-0.185	-0.283	-0.055	-0.210	-0.252	-0.344	0.022
SIC				-0.020	0.023	-0.077	-0.127	0.048	-0.051	0.177	0.023	-0.019	-0.112	0.255
LATU					0.043	-0.057	-0.107	0.068	-0.031	0.197	0.043	0.001	-0.092	0.275
INEN						-0.100	-0.150	0.025	-0.074	0.154	0.000	-0.042	-0.135	0.232
INDECOPI							-0.050	0.125	0.026	0.254	0.100	0.058	-0.035	0.332
CESMEC								0.175	0.076	0.304	0.150	0.108	0.015	0.382
INTI									-0.098	0.130	-0.025	-0.067	-0.159	0.207
NIST										0.228	0.073	0.031	-0.061	0.305
INMETRO											-0.155	-0.197	-0.289	0.077
LACOMET												-0.042	-0.134	0.232
NRC													-0.092	0.274
CENAMEP														0.366
BSJ														
995	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.069	0.080	0.057	0.070	0.090	0.060	0.082	0.055	0.060	0.090	0.131	0.056	0.099
IBMETRO			0.087	0.068	0.079	0.097	0.070	0.090	0.066	0.070	0.097	0.136	0.066	0.105
SIC				0.079	0.089	0.105	0.081	0.099	0.077	0.081	0.105	0.142	0.078	0.113
LATU					0.069	0.089	0.059	0.082	0.054	0.059	0.089	0.131	0.055	0.098
INEN						0.098	0.072	0.091	0.068	0.071	0.098	0.137	0.068	0.106
INDECOPI							0.091	0.107	0.088	0.090	0.113	0.148	0.088	0.120
CESMEC								0.083	0.057	0.061	0.091	0.132	0.058	0.100
INTI									0.080	0.083	0.107	0.143	0.080	0.114
NIST										0.057	0.088	0.130	0.053	0.097
INMETRO											0.091	0.132	0.057	0.100
LACOMET												0.148	0.088	0.120
NRC													0.130	0.153
CENAMEP														0.097
BSJ														

Table 23. Degree of equivalence between participant laboratories for the nominal value of 999 kg/m^3.

999	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.292	0.045	0.030	0.058	0.008	-0.072	0.121	-0.006	0.090	0.172	0.073	-0.044	0.190
IBMETRO			-0.247	-0.262	-0.234	-0.284	-0.364	-0.170	-0.298	-0.202	-0.120	-0.218	-0.336	-0.102
SIC				-0.015	0.013	-0.037	-0.117	0.077	-0.051	0.045	0.127	0.029	-0.089	0.145
LATU					0.028	-0.022	-0.102	0.092	-0.036	0.060	0.142	0.044	-0.074	0.160
INEN						-0.050	-0.130	0.064	-0.064	0.032	0.114	0.016	-0.102	0.132
INDECOPI							-0.080	0.114	-0.014	0.082	0.164	0.066	-0.052	0.182
CESMEC								0.194	0.066	0.162	0.244	0.146	0.028	0.262
INTI									-0.128	-0.032	0.050	-0.048	-0.166	0.068
NIST										0.096	0.178	0.079	-0.038	0.196
INMETRO											0.082	-0.017	-0.134	0.100
LACOMET												-0.098	-0.216	0.018
NRC													-0.117	0.116
CENAMEP														0.234
BSJ														
999	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM		0.067	0.078	0.055	0.068	0.088	0.058	0.081	0.053	0.058	0.089	0.130	0.054	0.098
IBMETRO			0.086	0.066	0.077	0.095	0.068	0.088	0.064	0.068	0.096	0.135	0.065	0.104
SIC				0.077	0.087	0.104	0.079	0.097	0.076	0.079	0.104	0.141	0.077	0.112
LATU					0.067	0.088	0.057	0.080	0.052	0.057	0.088	0.130	0.053	0.097
INEN						0.096	0.070	0.090	0.066	0.070	0.097	0.136	0.066	0.105
INDECOPI							0.089	0.106	0.086	0.089	0.112	0.147	0.087	0.119
CESMEC								0.082	0.055	0.060	0.090	0.131	0.056	0.099
INTI									0.079	0.082	0.106	0.142	0.079	0.114
NIST										0.055	0.087	0.129	0.051	0.096
INMETRO											0.090	0.131	0.056	0.099
LACOMET												0.147	0.087	0.119
NRC													0.129	0.153
CENAMEP														0.096
BSJ														

Table 24. Degree of equivalence between participant laboratories for the nominal value of 1291 kg/m^3.

1291	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM			0.009	0.042	0.115	0.045	0.035	0.030	0.019	0.263	0.252	0.083	0.010	0.143
IBMETRO														
SIC				0.033	0.106	0.036	0.026	0.021	0.011	0.255	0.244	0.075	0.002	0.135
LATU					0.073	0.003	-0.007	-0.012	-0.022	0.222	0.211	0.042	-0.031	0.102
INEN						-0.070	-0.080	-0.085	-0.095	0.149	0.138	-0.031	-0.104	0.029
INDECOPI							-0.010	-0.015	-0.025	0.219	0.208	0.039	-0.034	0.099
CESMEC								-0.005	-0.015	0.229	0.218	0.049	-0.024	0.109
INTI									-0.010	0.234	0.223	0.054	-0.019	0.113
NIST										0.244	0.233	0.064	-0.009	0.124
INMETRO											-0.011	-0.180	-0.253	-0.120
LACOMET												-0.169	-0.242	-0.109
NRC													-0.073	0.060
CENAMEP														0.133
BSJ														
1291	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM			0.102	0.074	0.083	0.110	0.074	0.101	0.077	0.086	0.094	0.165	0.073	0.145
IBMETRO														
SIC				0.096	0.103	0.126	0.096	0.119	0.099	0.105	0.112	0.176	0.096	0.158
LATU					0.075	0.104	0.066	0.096	0.069	0.079	0.088	0.161	0.065	0.141
INEN						0.110	0.076	0.102	0.078	0.087	0.095	0.165	0.074	0.145
INDECOPI							0.104	0.125	0.106	0.113	0.119	0.180	0.104	0.162
CESMEC								0.096	0.069	0.079	0.088	0.161	0.065	0.141
INTI									0.098	0.105	0.112	0.175	0.095	0.157
NIST										0.081	0.090	0.162	0.068	0.142
INMETRO											0.097	0.167	0.078	0.147
LACOMET												0.171	0.087	0.152
NRC													0.161	0.204
CENAMEP														0.140
BSJ														

Table 25. Degree of equivalence between participant laboratories for the nominal value of 1295 kg/m^3.

1295	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM			-0.026	0.020	0.137	0.027	0.047	0.053	0.003	0.121	0.236	0.076	-0.007	0.143
IBMETRO														
SIC				0.046	0.163	0.053	0.073	0.078	0.029	0.147	0.262	0.102	0.019	0.169
LATU					0.117	0.007	0.027	0.032	-0.017	0.101	0.216	0.056	-0.027	0.123
INEN						-0.110	-0.090	-0.085	-0.134	-0.016	0.099	-0.061	-0.144	0.006
INDECOPI							0.020	0.025	-0.024	0.094	0.209	0.049	-0.034	0.116
CESMEC								0.005	-0.044	0.074	0.189	0.029	-0.054	0.096
INTI									-0.050	0.068	0.184	0.024	-0.060	0.090
NIST										0.118	0.234	0.073	-0.010	0.140
INMETRO											0.116	-0.045	-0.128	0.022
LACOMET												-0.160	-0.244	-0.094
NRC													-0.083	0.067
CENAMEP														0.150
BSJ														
1295	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM			0.099	0.069	0.078	0.107	0.069	0.098	0.069	0.078	0.087	0.161	0.064	0.141
IBMETRO														
SIC				0.095	0.102	0.125	0.095	0.117	0.094	0.101	0.109	0.173	0.091	0.155
LATU					0.073	0.103	0.064	0.094	0.063	0.073	0.083	0.158	0.058	0.138
INEN						0.109	0.074	0.101	0.072	0.081	0.090	0.163	0.069	0.143
INDECOPI							0.103	0.124	0.102	0.109	0.116	0.178	0.100	0.160
CESMEC								0.094	0.063	0.073	0.083	0.158	0.058	0.138
INTI									0.093	0.101	0.108	0.173	0.090	0.154
NIST										0.072	0.082	0.158	0.057	0.137
INMETRO											0.090	0.162	0.068	0.142
LACOMET												0.167	0.079	0.148
NRC													0.156	0.200
CENAMEP														0.135
BSJ														

Table 26. Degree of equivalence between participant laboratories for the nominal value of 1299 kg/m^3.

1299	Difference between values reported by participant laboratories (D_{A-B}), kg/m^3													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM			-0.011	0.019	0.029	0.009	0.059	0.045	0.000	0.123	0.223	0.096	0.017	0.150
IBMETRO														
SIC				0.030	0.040	0.020	0.070	0.055	0.010	0.133	0.234	0.107	0.027	0.161
LATU					0.010	-0.010	0.040	0.025	-0.020	0.103	0.204	0.077	-0.003	0.131
INEN						-0.020	0.030	0.015	-0.030	0.093	0.194	0.067	-0.013	0.121
INDECOPI							0.050	0.035	-0.010	0.113	0.214	0.087	0.007	0.141
CESMEC								-0.015	-0.060	0.063	0.164	0.037	-0.043	0.091
INTI									-0.045	0.078	0.179	0.052	-0.028	0.105
NIST										0.123	0.224	0.097	0.017	0.150
INMETRO											0.101	-0.026	-0.106	0.027
LACOMET												-0.127	-0.207	-0.074
NRC													-0.080	0.054
CENAMEP														0.133
BSJ														
1299	Expanded uncertainty, kg/m^3 (k=2)													
	CENAM	IBMETRO	SIC	LATU	INEN	INDECOPI	CESMEC	INTI	NIST	INMETRO	LACOMET	NRC	CENAMEP	BSJ
CENAM			0.097	0.067	0.076	0.105	0.067	0.096	0.067	0.077	0.086	0.160	0.063	0.140
IBMETRO														
SIC				0.093	0.100	0.123	0.093	0.116	0.093	0.100	0.107	0.173	0.090	0.154
LATU					0.071	0.101	0.061	0.092	0.061	0.071	0.081	0.158	0.056	0.137
INEN						0.107	0.071	0.099	0.071	0.080	0.089	0.162	0.067	0.142
INDECOPI							0.101	0.122	0.101	0.108	0.114	0.177	0.098	0.159
CESMEC								0.092	0.061	0.071	0.081	0.158	0.056	0.137
INTI									0.092	0.099	0.107	0.172	0.089	0.153
NIST										0.071	0.081	0.158	0.056	0.137
INMETRO											0.089	0.162	0.067	0.142
LACOMET												0.167	0.078	0.147
NRC													0.156	0.200
CENAMEP														0.135
BSJ														

Figure 2. Difference between results reported by participant laboratories and pilot laboratory for the hydrometer with range 600 kg/m^3 to 610 kg/m^3

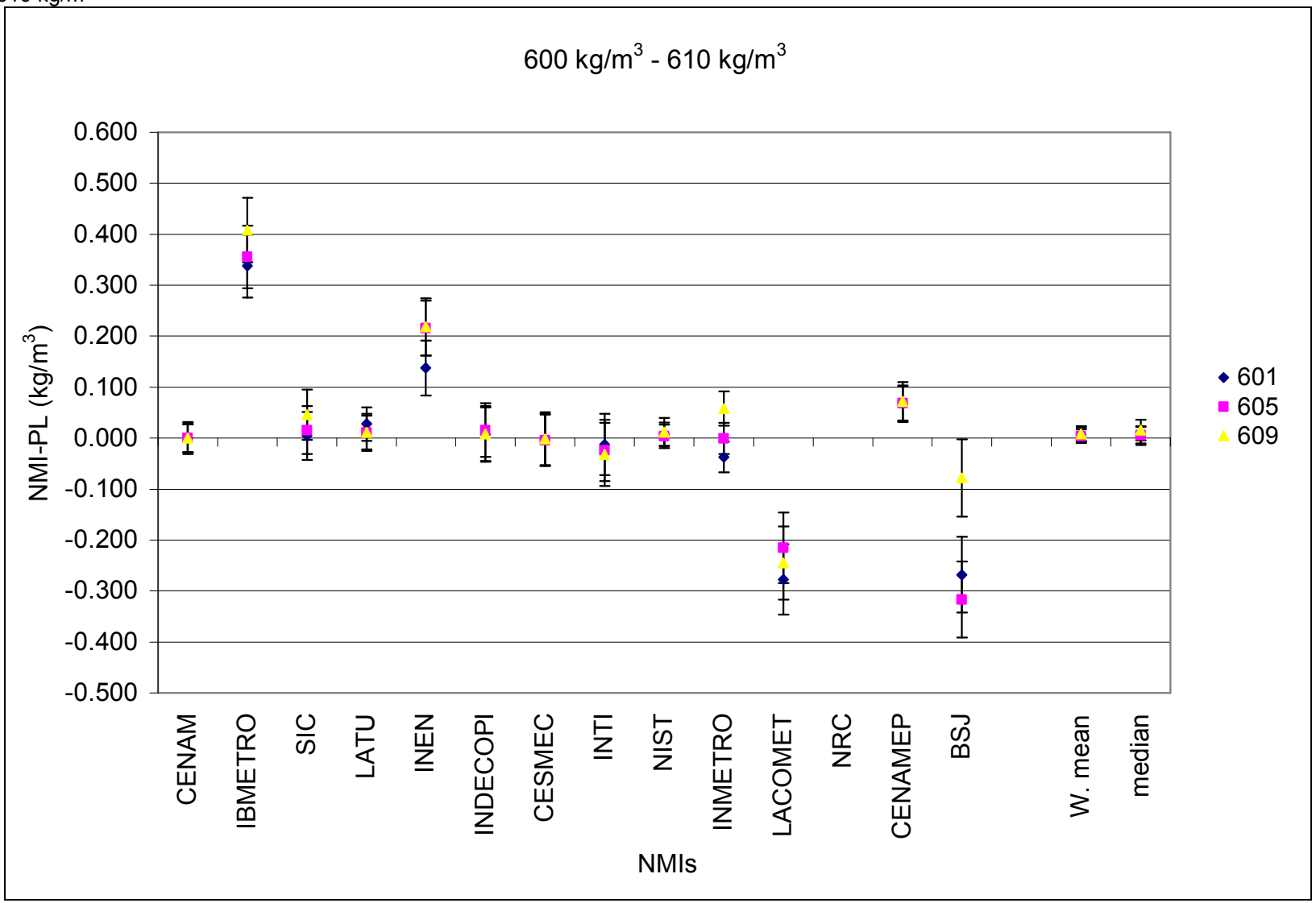

Figure 2A. Difference between results reported by participant laboratories and pilot laboratory for the hydrometer with range 600 kg/m^3 to 610 kg/m^3 (the scale of the graph is limited to ± two times the resolution of the hydrometer).

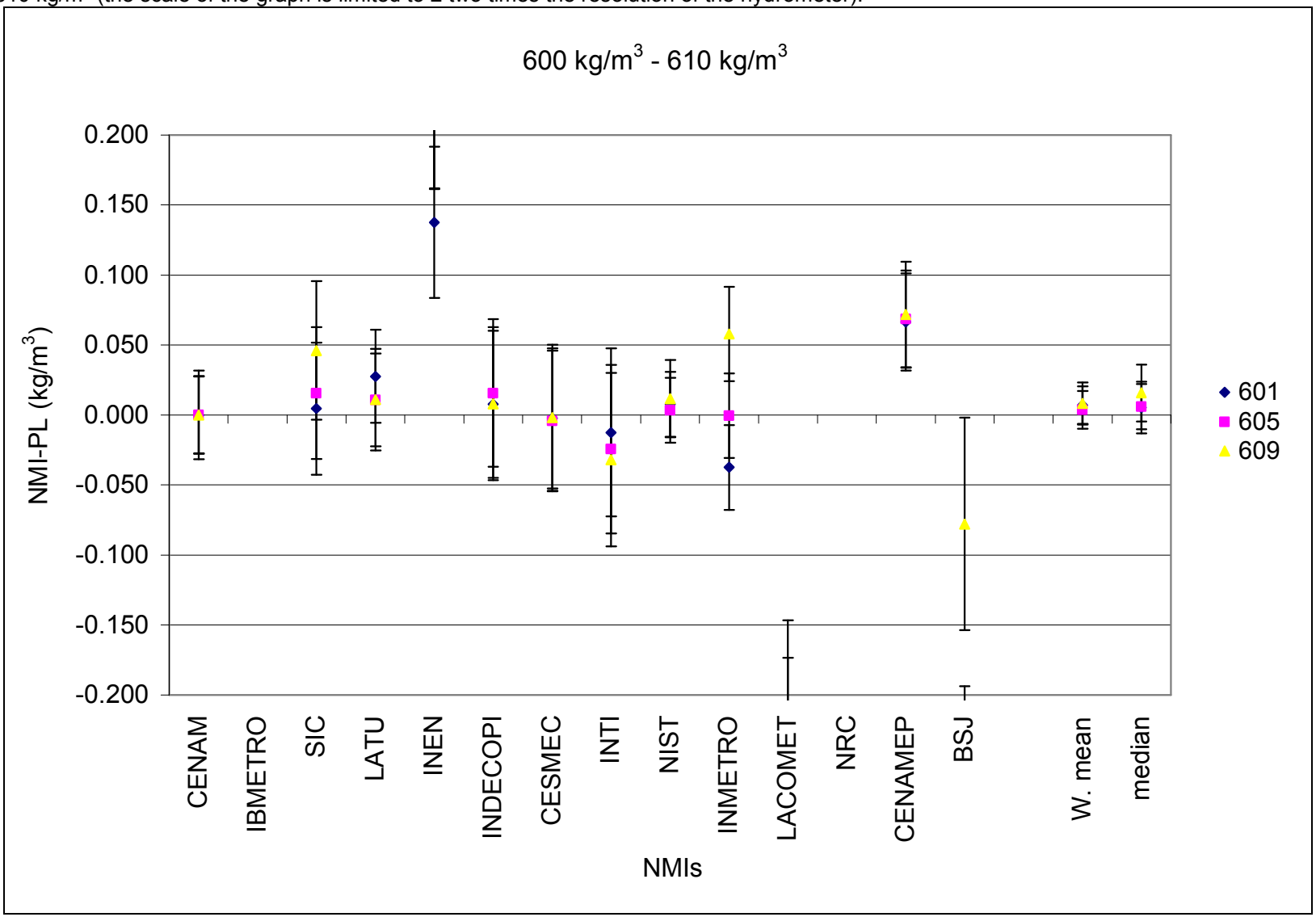

Figure 3. Difference between results reported by participant laboratories and pilot laboratory for the hydrometer with range 800 kg/m^3 to 810 kg/m^3

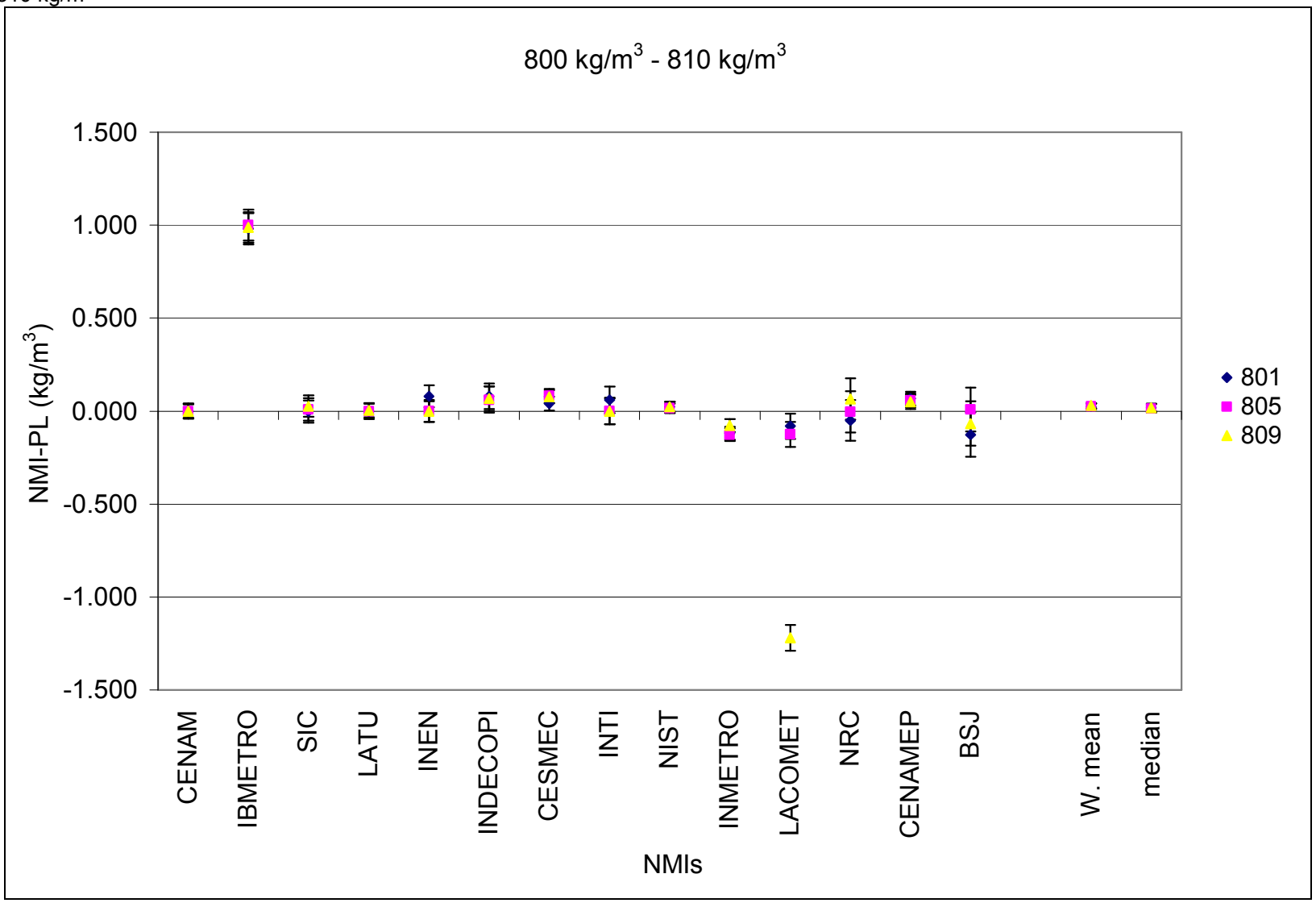

Figure 3A. Difference between results reported by participant laboratories and pilot laboratory for the hydrometer with range 800 kg/m^3 to 810 kg/m^3 (the scale of the graph is limited to ± two times the resolution of the hydrometer).

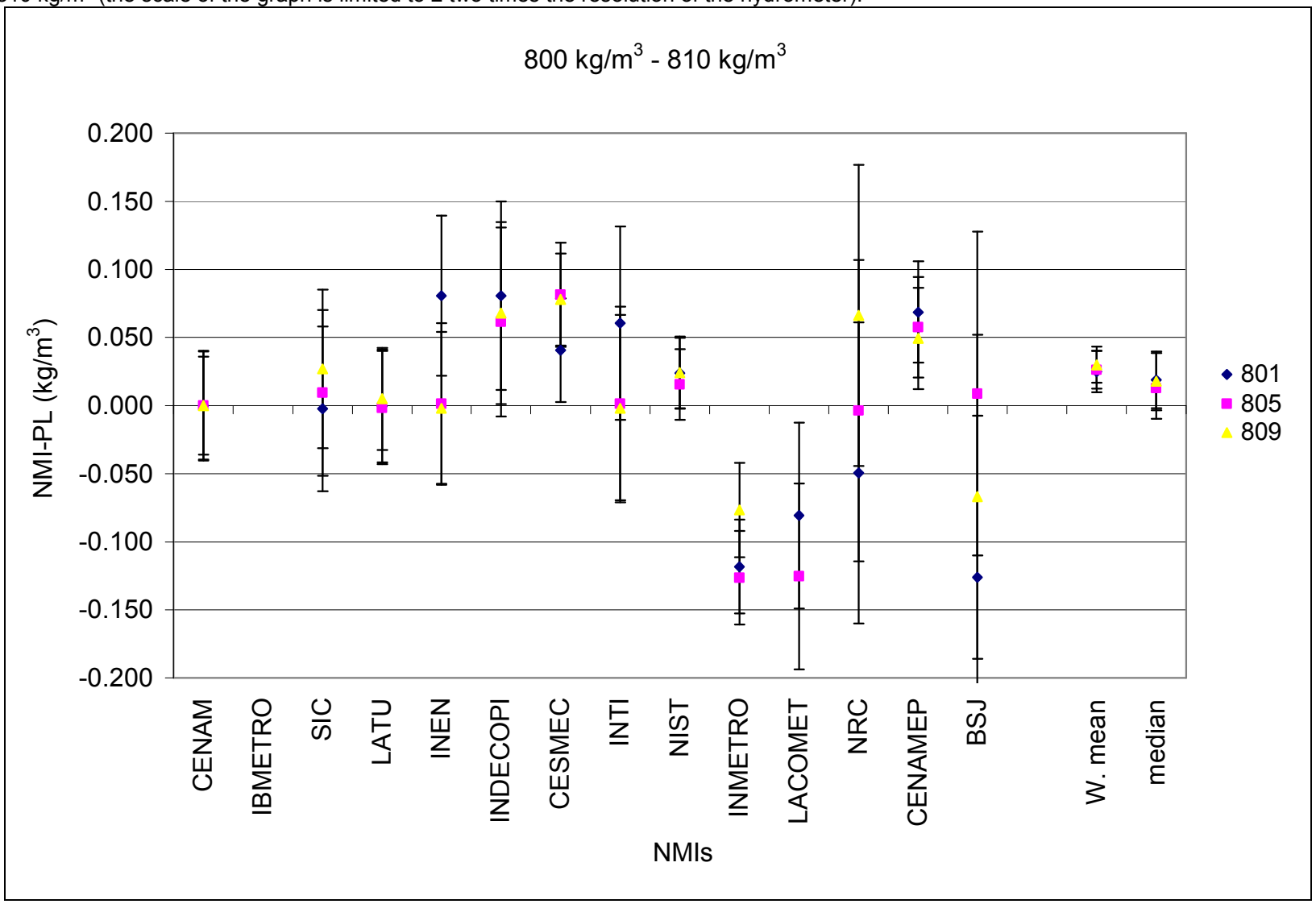

Figure 4. Difference between results reported by participant laboratories and pilot laboratory for the hydrometer with range 990 kg/m^3 to 1000 kg/m^3

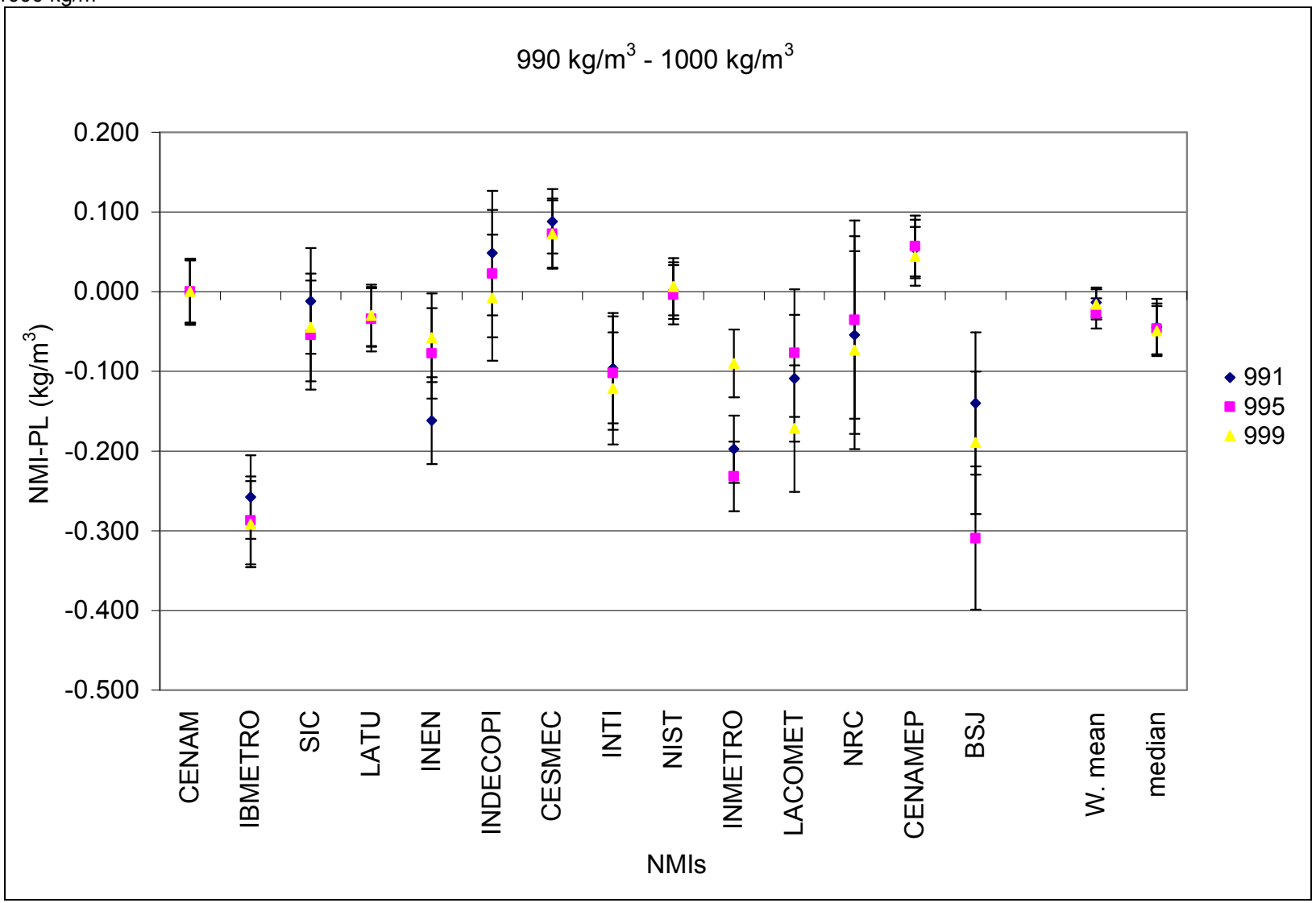

Figure 4A. Difference between results reported by participant laboratories and pilot laboratory for the hydrometer with range 990 kg/m^3 to 1000 kg/m^3 (the scale of the graph is limited to ± two times the resolution of the hydrometer).

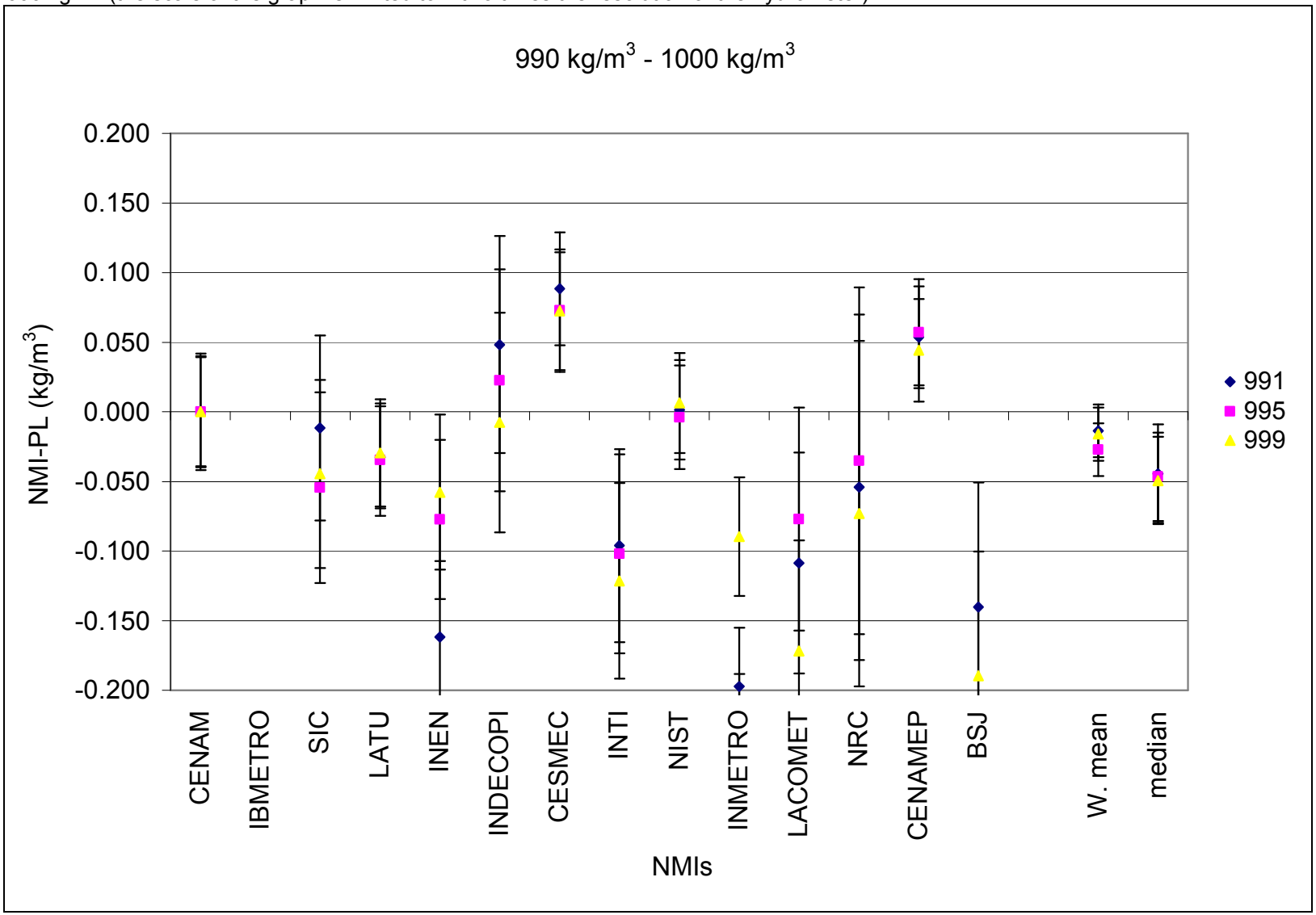

Figure 5. Difference between results reported by participant laboratories and pilot laboratory for the hydrometer with range 1 290 kg/m^3 to 1 300 kg/m^3

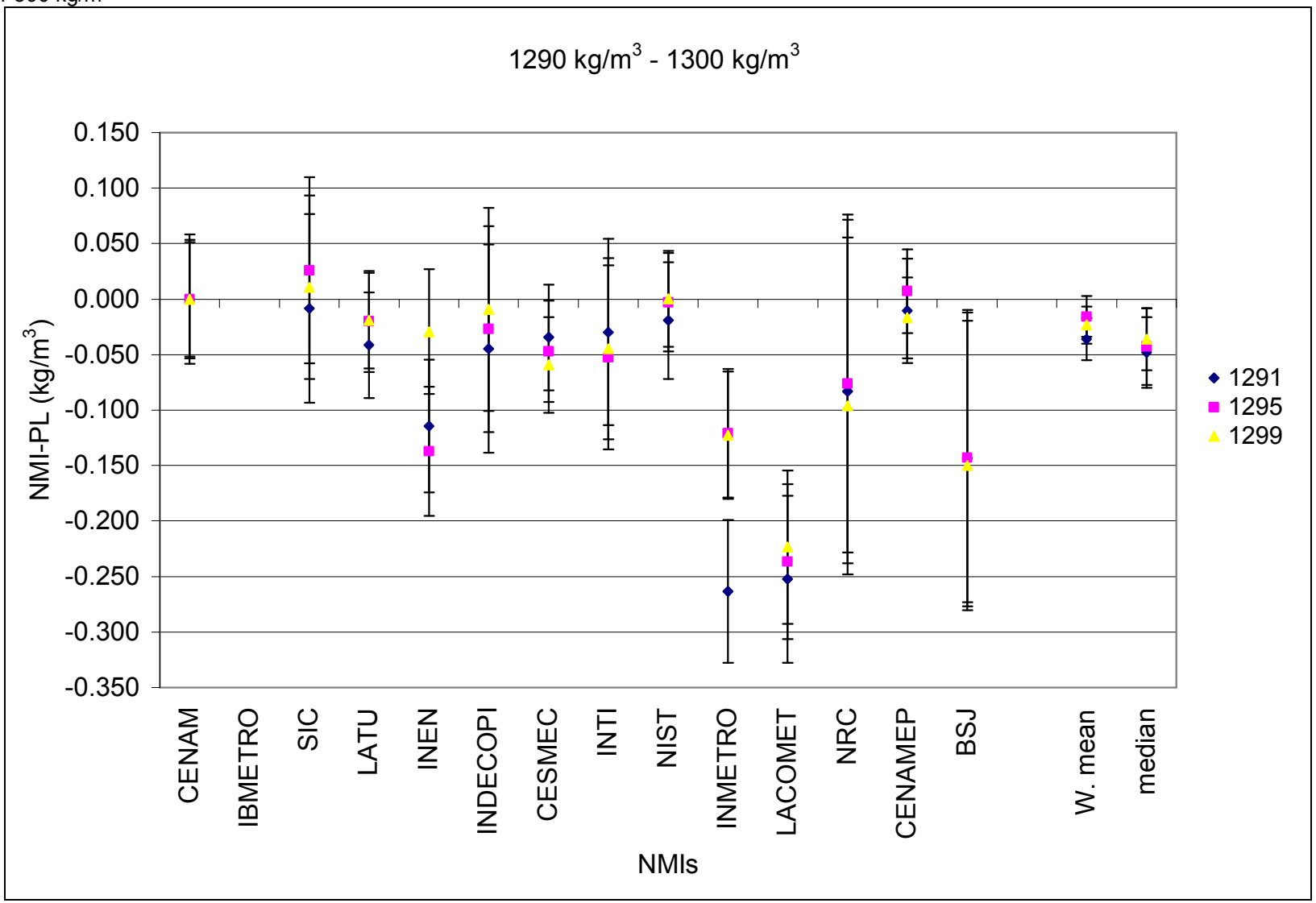

Figure 5A. Difference between results reported by participant laboratories and pilot laboratory for the hydrometer with range 1 290 kg/m^3 to 1 300 kg/m^3 (the scale of the graph is limited to ± two times the resolution of the hydrometer).

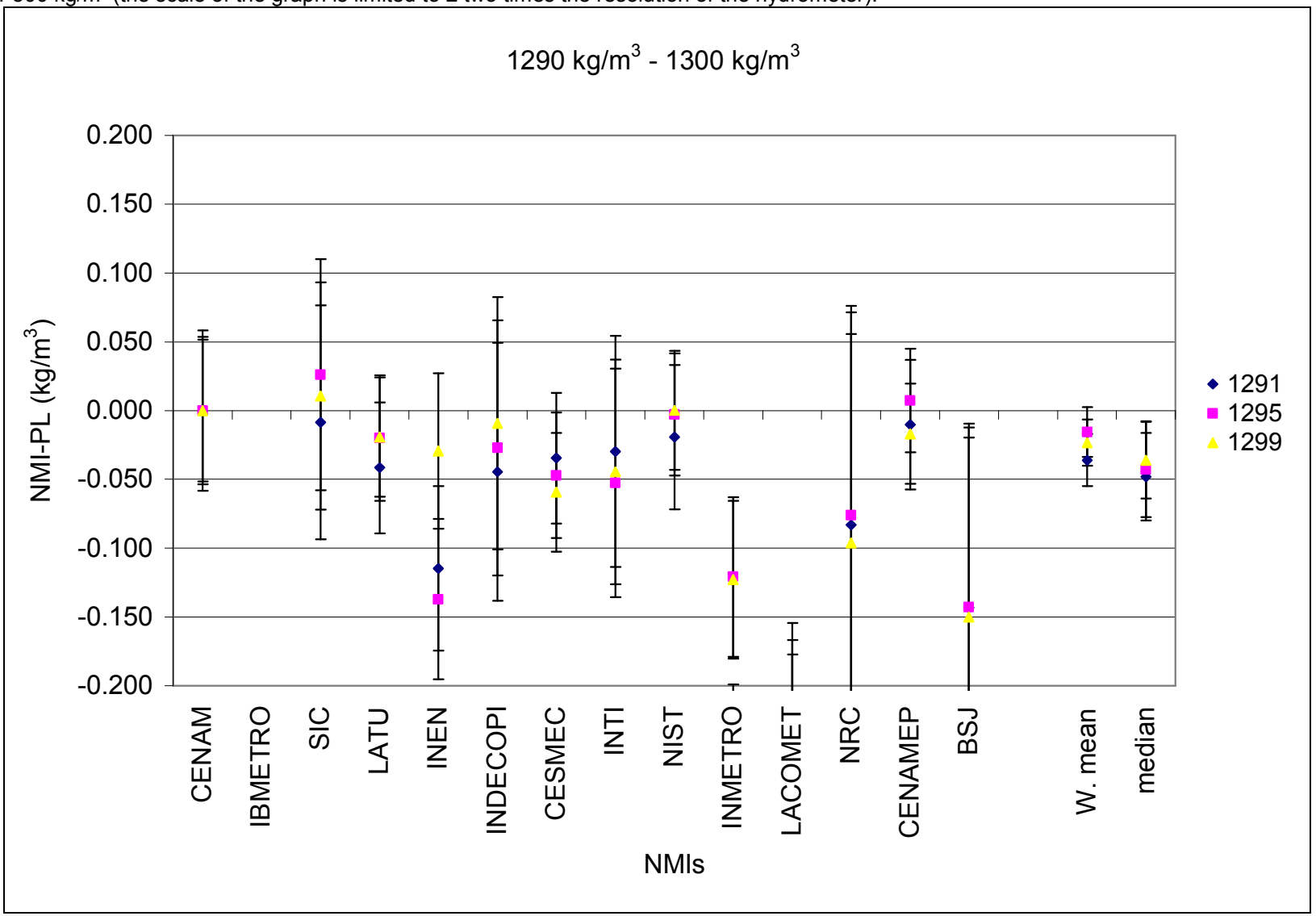

Figure 6. Difference between results reported by participant laboratories and the Reference Value for the hydrometer with range 600 kg/m^3 to 610 kg/m^3

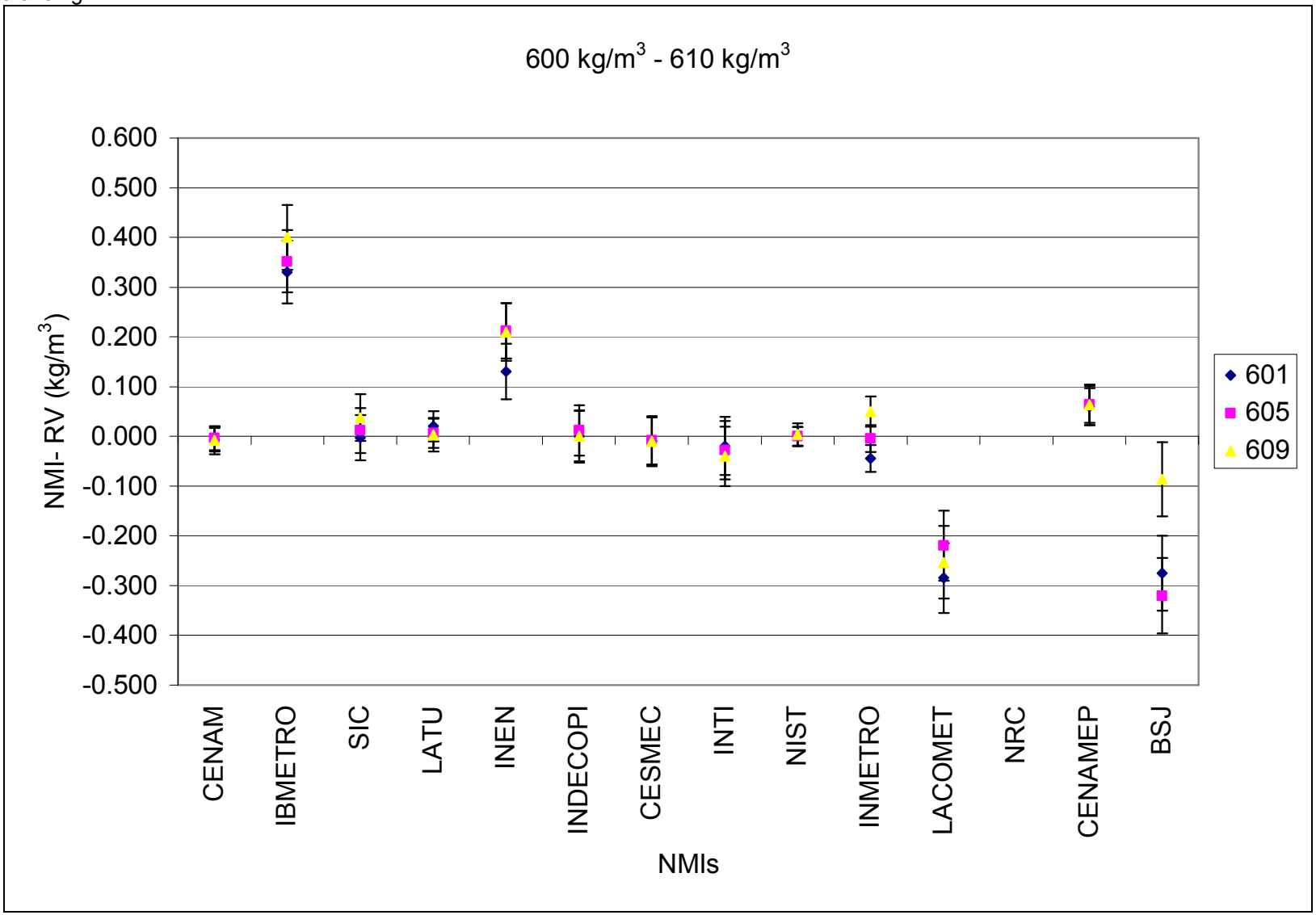

Figure 6A. Difference between results reported by participant laboratories and the Reference Value for the hydrometer with range 600 kg/m^3 to 610 kg/m^3 (the scale of the graph is limited to ± two times the resolution of the hydrometer).

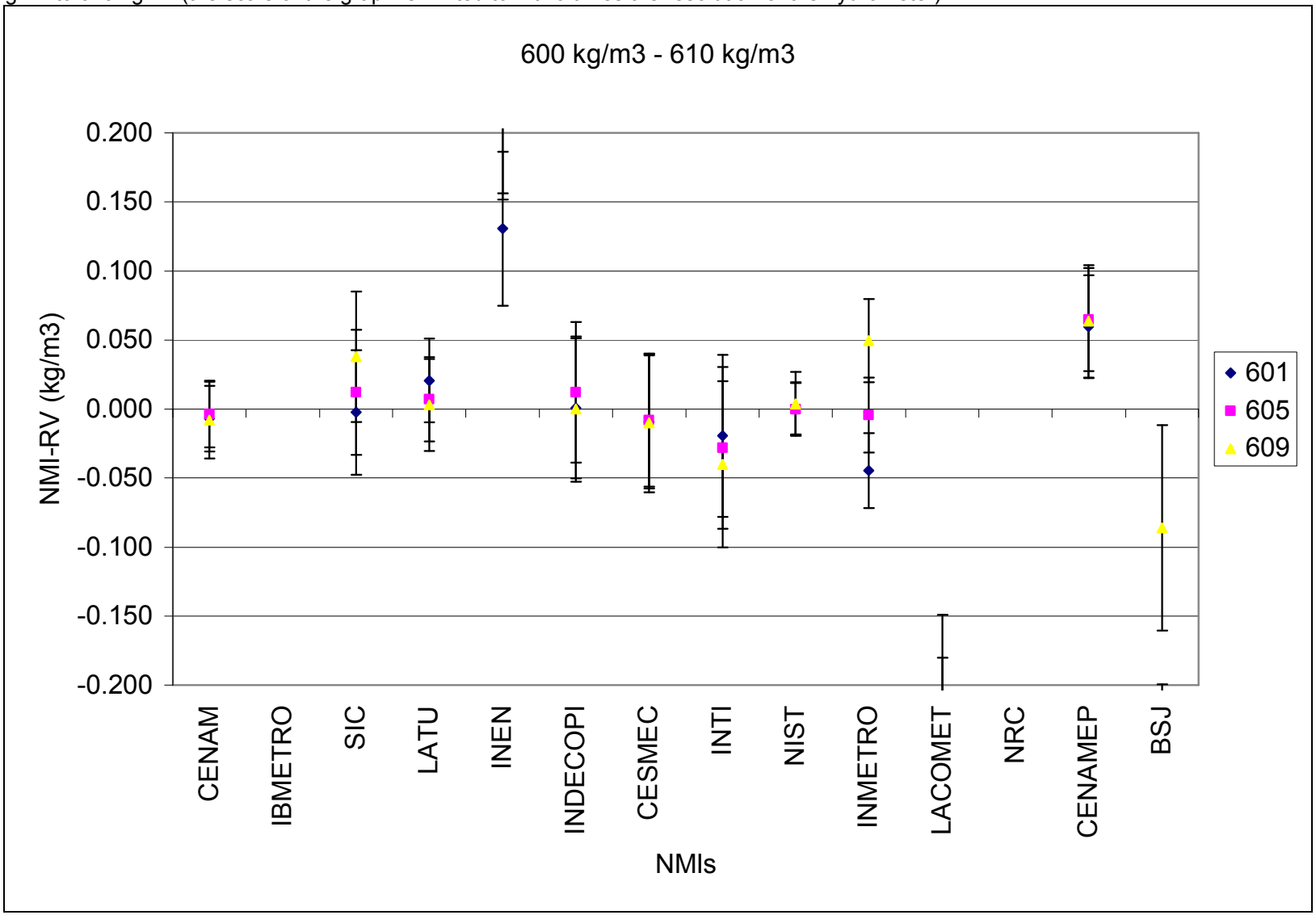

Figure 7. Difference between results reported by participant laboratories and the Reference Value for the hydrometer with range 800 kg/m^3 to 810 kg/m^3

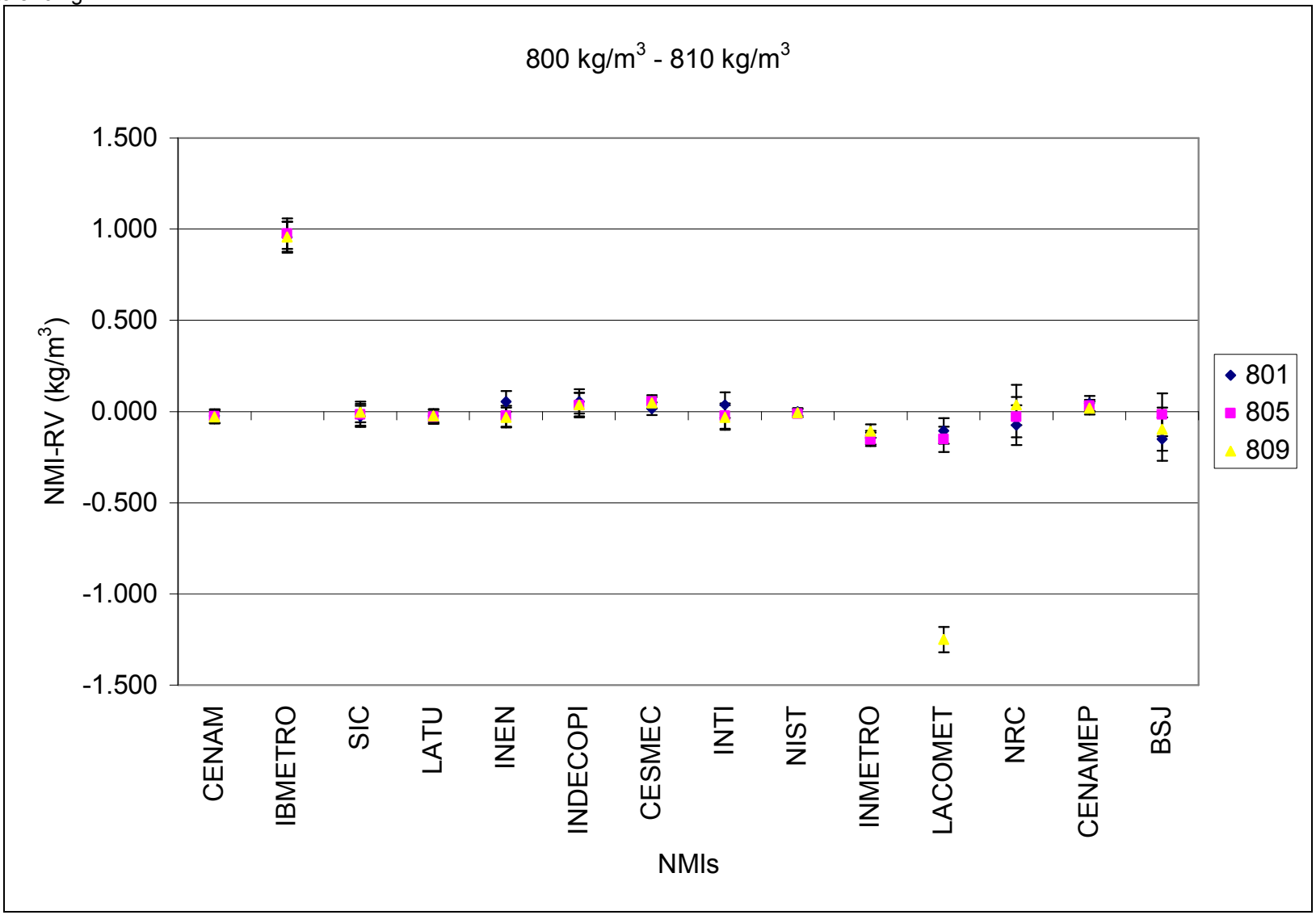

Figure 7A. Difference between results reported by participant laboratories and the Reference Value for the hydrometer with range 800 kg/m^3 to 810 kg/m^3 (the scale of the graph is limited to ± two times the resolution of the hydrometer).

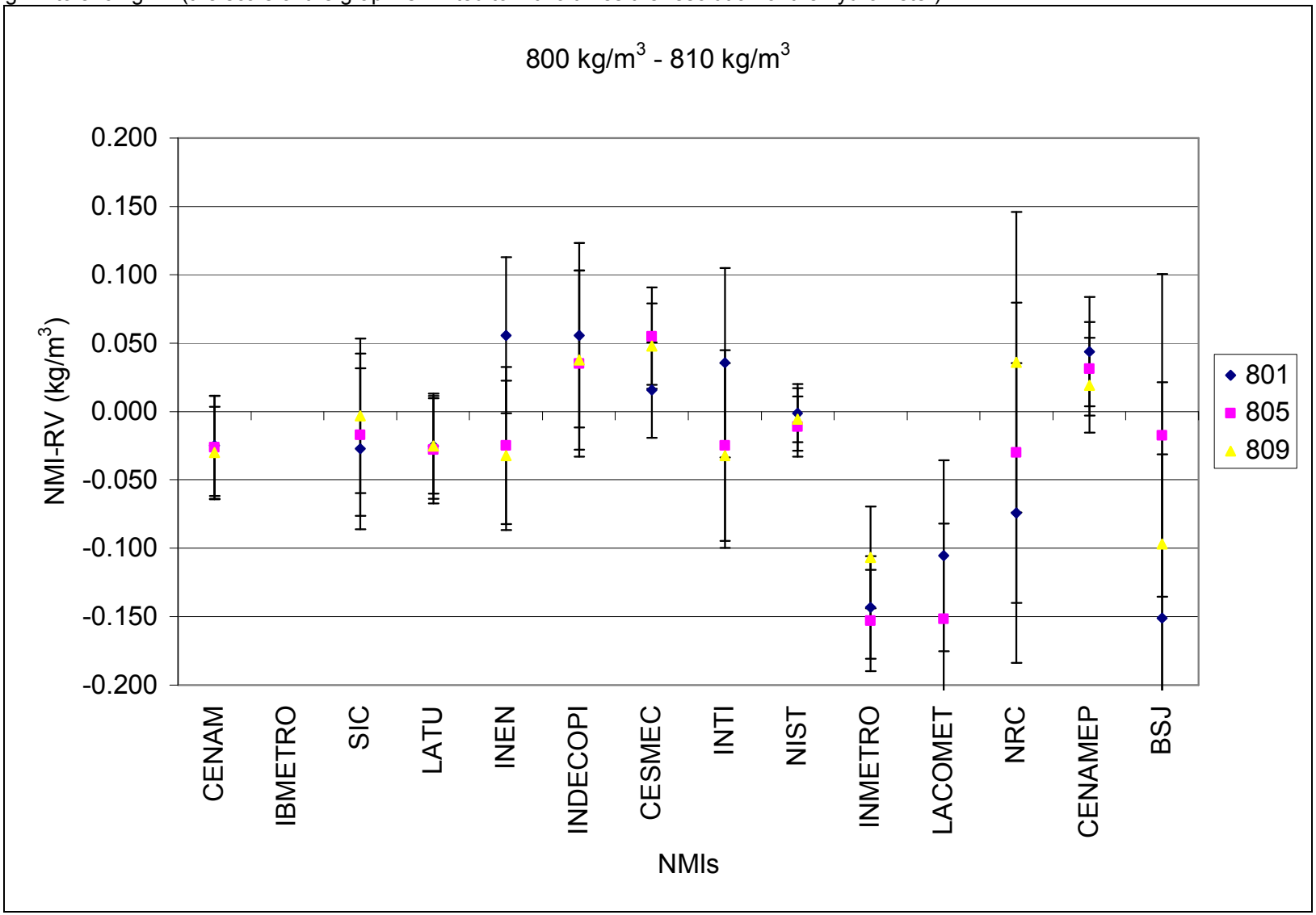

Figure 8. Difference between results reported by participant laboratories and the Reference Value for the hydrometer with range 990 kg/m^3 to 1 000 kg/m^3

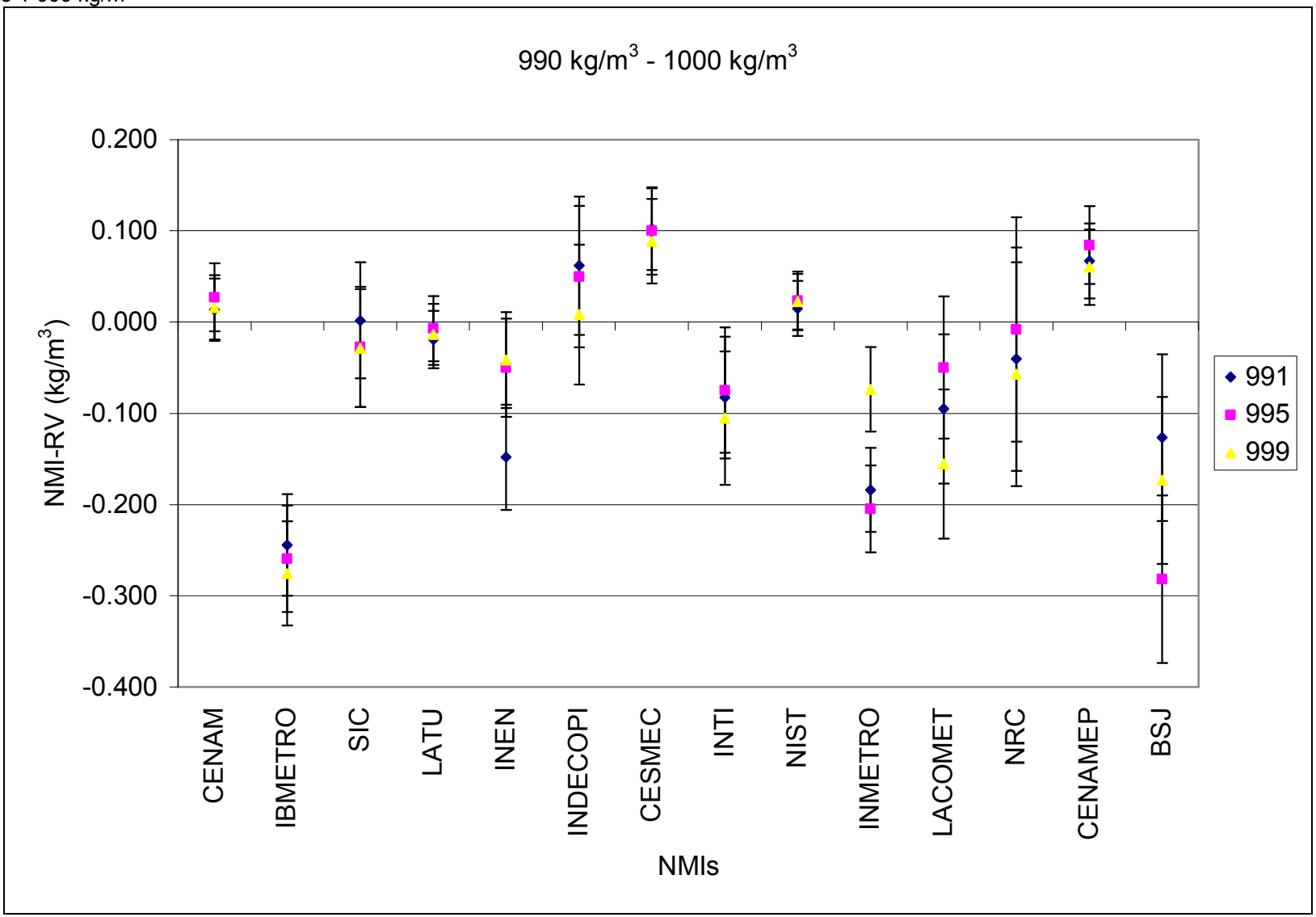

Figure 8A. Difference between results reported by participant laboratories and the Reference Value for the hydrometer with range 990 kg/m^3 to 1 000 kg/m^3 (the scale of the graph is limited to ± two times the resolution of the hydrometer).

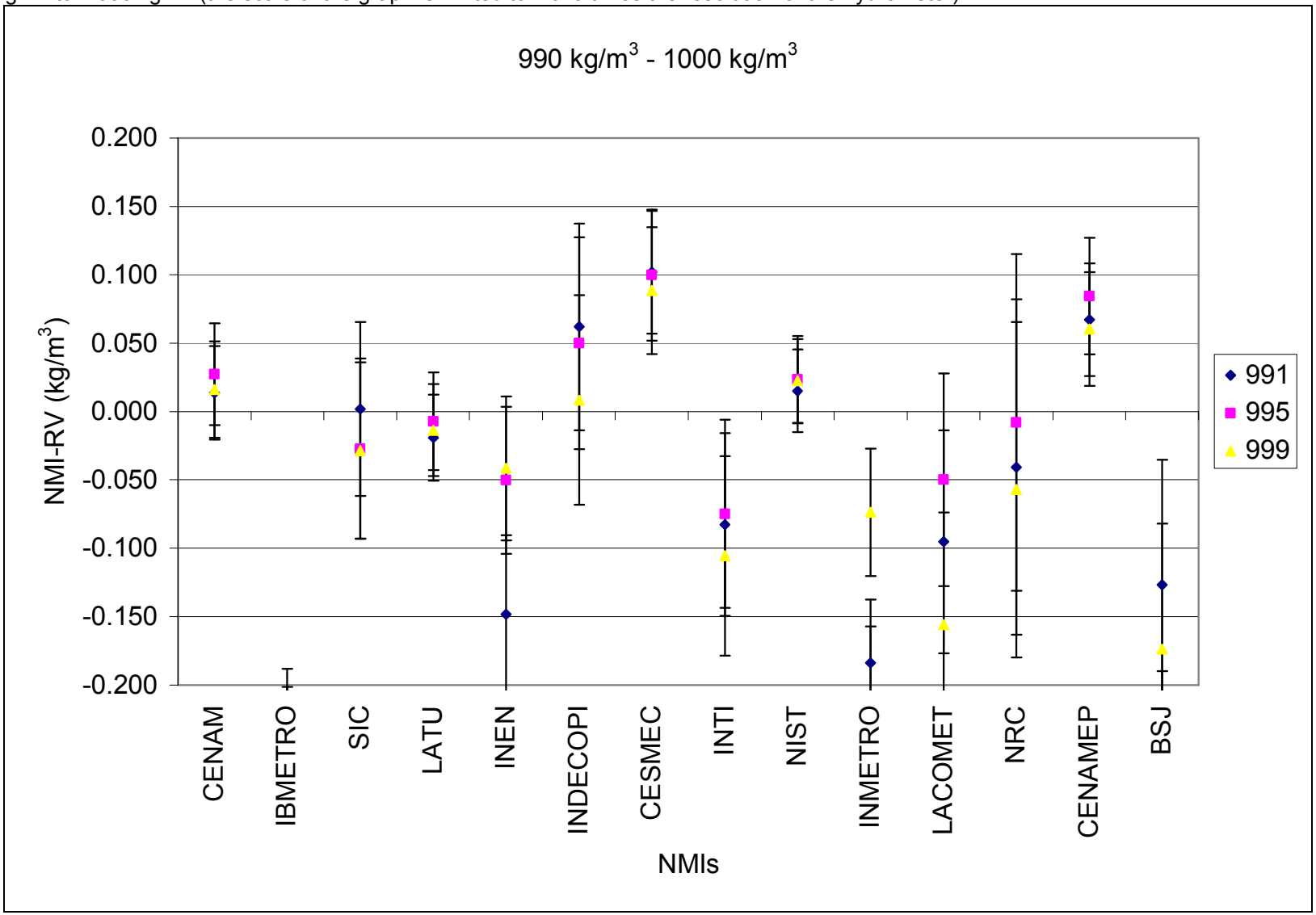

Figure 9. Difference between results reported by participant laboratories and the Reference Value for the hydrometer with range 1 290 kg/m^3 to 1 300 kg/m^3

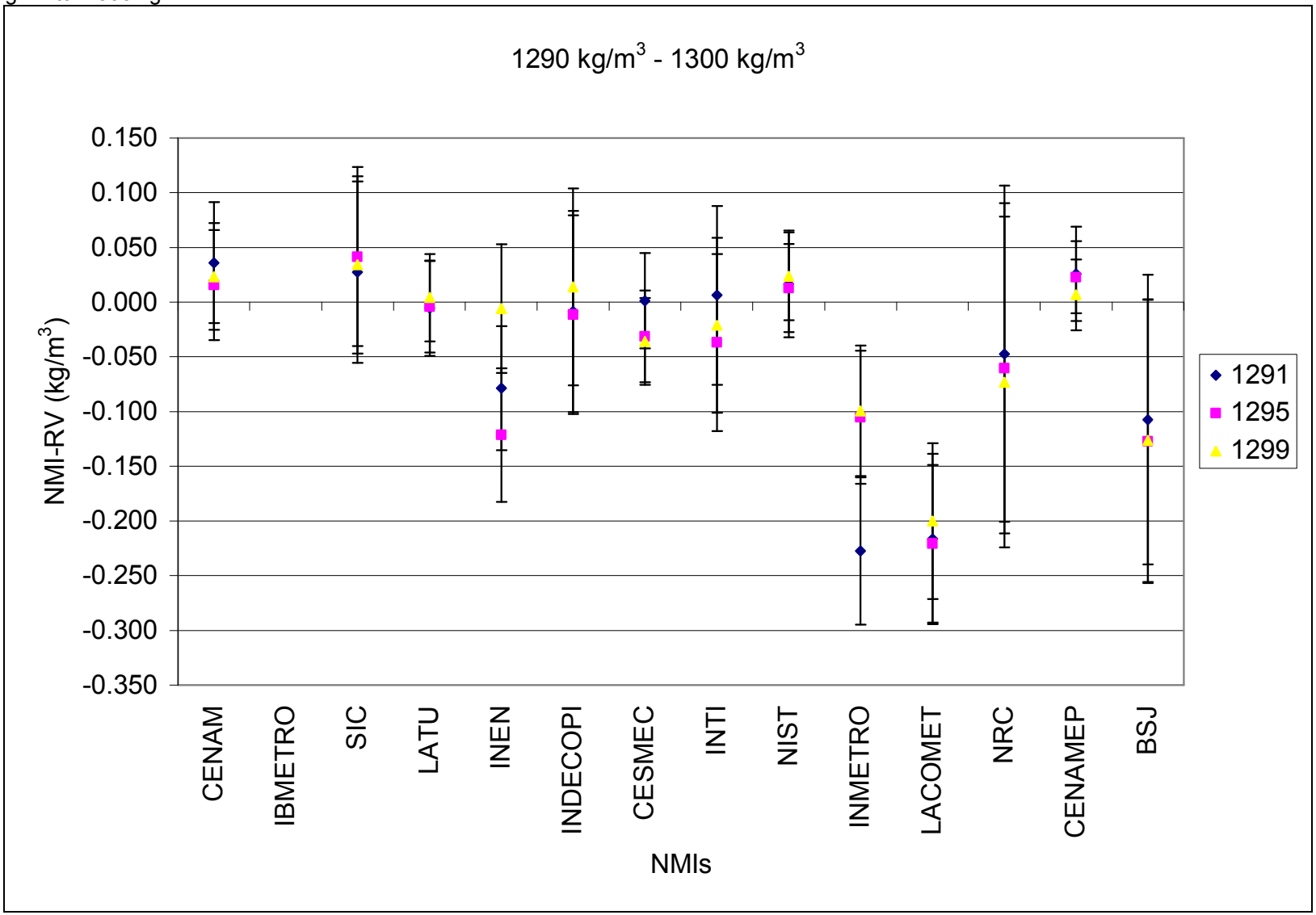

Figure 9A. Difference between results reported by participant laboratories and the Reference Value for the hydrometer with range 1 290 kg/m^3 to 1 300 kg/m^3 (the scale of the graph is limited to ± two times the resolution of the hydrometer).