DRAFT B - REPORT OF THE BILATERAL COMPARISON OF THE CALIBRATIONS OF HYDROMETERS FOR LIQUID DENSITY DETERMINATION BETWEEN CENAM-MEXICO AND INRIM-ITALY
SIM.M.D-S1

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Introduction

Hydrometers are instruments usually made of glass that are 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 bilateral comparison was to check the stated uncertainty levels and degrees of equivalence between CENAM and INRIM for hydrometer calibrations in the density range of 800 kg/m^3 to 1 200 kg/m^3 at 20 ºC.

This supplementary comparison is intended to link the SIM.M.D-K4 and the EURAMET.D-K4 due to the fact of CENAM acted as pilot laboratory at the SIM key comparison SIM.M.D-K4 and INRIM acted as pilot laboratory at the Euramet key comparison EURAMET.M.D-K4.

Participant laboratories

The data of the participant laboratories are listed in table 1. CENAM belonging to SIM metrological region and INRIM belonging to EURAMET metrological region.

Table 1. Participants of hydrometer comparison

National Metrology Institute	Acronym	Country	Technical Contact(s)
Centro Nacional de Metrología, km. 4,5 Carretera a los Cués, Mpio. El Marqués Querétaro, México	**CENAM**	**MEXICO**	Luis Omar Becerra Arturo Daued Luis Manuel Peña
Istituto Nazionale di Ricerca Metrologica Strada delle Cacce 91, Turin, Italy	**INRIM**	**ITALY**	Salvatore Lorefice F. Penecchi

Transfer standards (hydrometer samples)

For the bilateral comparison, INRIM supplied two hydrometers with the following characteristics,

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

	Hydrometer 1	Hydrometer 2
Manufacturer	G.H. Zeal Ltd. (UK)	G.H. Zeal Ltd. (UK)
Range	800 kg/m^3 – 820 kg/m^3	1 180 kg/m^3 – 1 200 kg/m^3
Resolution	0.2 kg/m^3	0.2 kg/m^3
Surface Tension:	25.5 mN/m	35 mN/m
Reference temperature	20 ºC	20 ºC

Figure 1. Set of transfer standards (Hydrometers)

Circulation and date of measurements

The travelling standards were measured first at INRIM and them at CENAM according to the dates of table 3.

Table 3. Dates of measurement of the travelling standards

Acronym	Date
INRIM	June, 2007
CENAM	August, 2007

Traceability of results reported by participants

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

In table 4 are the liquids used by participants as density standard for the calibration of the travelling standards, the mean density and the surface tension reported by the participants, also the source of traceability reported by participants and the balance used by participants for weighing in liquid are listed in table 4.

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

Acronym	Liquid	Density Standard	Traceability	Balance used for weighing in liquid
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
INRIM	N-nonane 718 kg/m^3 23 mN/m	Density standard made of silicon. Sphere shape	INRIM-Italy	Mettler-Toledo Type AT405 d=0.1/0.01 mg

Results

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

Corrections and their associated uncertainties reported by participants are listed in table 5.

Table 5. Corrections and associated uncertainties reported by participants.

	802 kg/m^3		**807 kg/m^3**		**813 kg/m^3**		**818 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	Correction kg/m^3	U, k=2 kg/m^3
CENAM	-0.076	0.052	-0.087	0.052	-0.091	0.052	-0.041	0.052
INRIM	-0.067	0.026	-0.077	0.026	-0.077	0.026	-0.037	0.026
	1 182 kg/m^3		**1 187 kg/m^3**		**1 193 kg/m^3**		**1 198 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	Correction kg/m^3	U, k=2 kg/m^3
CENAM	0.093	0.064	0.136	0.064	0.158	0.064	0.170	0.064
INRIM	0.098	0.030	0.136	0.030	0.160	0.030	0.174	0.030

Figure 2. Results reported by participant laboratories within the range of 800 kg/m^3 to 820 kg/m^3.

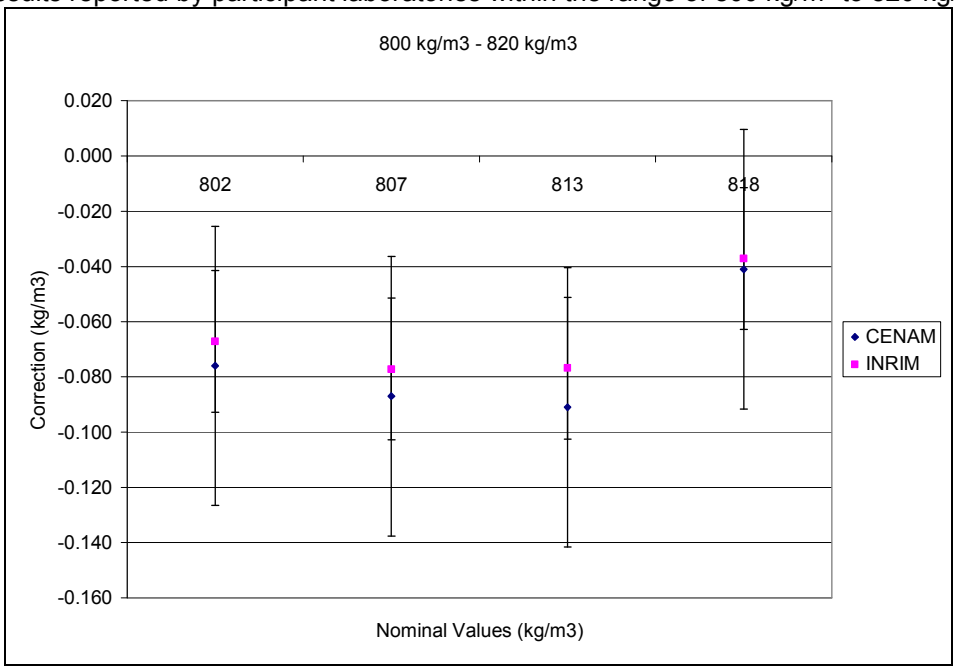
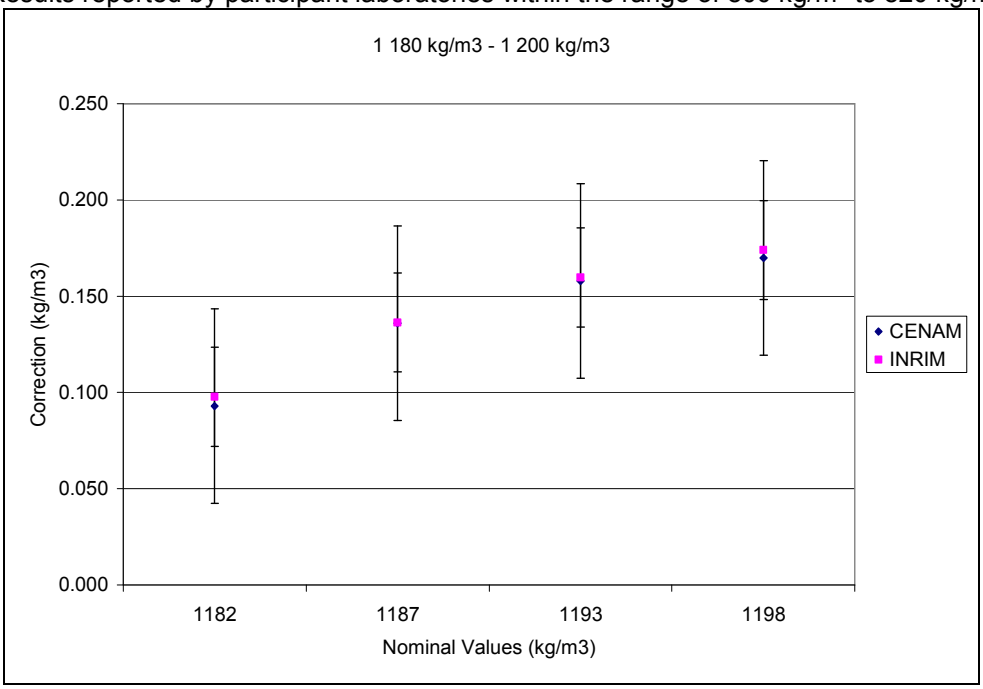


Figure 3. Results reported by participant laboratories within the range of 800 kg/m^3 to 820 kg/m^3.



Degree of equivalence between participants

The degree of equivalence among participant laboratories was calculated as the difference between the values reported by participants.

$$D_{CENAM-INRIM} = X_{CENAM} - X_{INRIM} \quad (1$$

with the expanded uncertainty as follows,

$$U\left(D_{CENAM-INRIM}\right) = 2\sqrt{u^2\left(X_{CENAM}\right) + u^2\left(X_{INRIM}\right)} \quad (2$$

For the above formula, the correlation between results reported by CENAM and INRIM are considered not significant.

From this difference and corresponding uncertainty, the normalized errors were calculated for each nominal value as follows,

$$En = \frac{\left|D_{CENAM-INRIM}\right|}{U\left(D_{CENAM-INRIM}\right)} \quad (3$$

In the table 6 are listed the degrees of equivalence between CENAM and INRIM for the selected values within the ranges of 800 kg/m^3 to 1 200 kg/m^3,

Table 6. Degree of equivalence between CENAM and INRIM for the selected nominal values within the range of 800 kg/m^3 to 1 200 kg/m^3

Scale Reading kg/m^3	Difference CENAM-INRIM $D_{CENAM-INRIM}$ kg/m^3	Expanded uncertainty (approx. 95%) $U(D_{CENAM-INRIM})$ kg/m^3	Normalized Error En
802	-0.009	0.057	0.16
807	-0.010	0.057	0.17
813	-0.014	0.057	0.25
818	-0.004	0.057	0.07
1 182	-0.005	0.072	0.07
1 187	0.000	0.072	0.01
1 193	-0.002	0.072	0.02
1 198	-0.004	0.072	0.06

Conclusions

The main objectives of this SIM comparison were:

- to evaluate the degree of equivalence between CENAM-Mexico and INRIM-Italy in the calibration of hydrometers of high accuracy within the range of 800 kg/m^3 to 1 200 kg/m^3 and,
- to offer a possibility to link the SIM key comparison SIM.M.D-K4 with the Euramet key comparison EURAMET.M.D-K4

In order to reach such objectives, two hydrometers were measured in both laboratories from June to August to 2007.

For the measurements each laboratory used their own hydrostatic weighing system and procedures.

The traceability of the measurements done by the laboratories are to PTB's density standard (for CENAM), and INRIM's density Standard (for INRIM).

From results reported by participants (see table 5), there were calculated the degree of equivalence between participants in the scope range of this comparison as well as the normalized errors, results are reported in table 6.

From data of table 6, it can be noted that results reported by both participants are consistent within the reported uncertainty. The largest normalized error calculated for this comparison was 0.25.

Acknowledge

The technical contacts of participant laboratories wish to thank to **Francisco García** of CESMEC-Chile for acting as a third laboratory which received results from both participants and checked consistency before to share the results with CENAM and INRIM.

Reference

[1] 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.

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

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