INTERNATIONAL COMPARISON OF VOLUME MEASUREMENT STANDARDS AT 20 LITERS AMONG SIM MEMBERS

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ABSTRACT

The results of the comparison of volume measurements at 20 L are presented below. The transfer standard was a 20 L graduated neck volumetric test measure. CENAM was the pilot laboratory. Participants were the national laboratories of Argentina, Brazil, Canada, Costa Rica, Jamaica, Mexico, Peru, Uruguay and the USA, all of which are members of the Sistema Interamericano de Metrología (SIM).

The maximum and the minimum reported volumes differ by only 0,015 percent. There is significant overlap in the uncertainty of all participants.

INTRODUCTION

Volume measurements have been the basis for custody transfer in commercial transactions of valuable fluids, hence, the comparison of volume measurement systems is important for countries whose economies are heavily dependent on oil production as well as for large scale importers of this commodity. The objectives pursued in a comparison of this nature are mainly focused on the mutual recognition of calibration services among participating laboratories, as well as on the identification of problems related to measurement instruments and/or measurement procedures. In the last two years three different volume measurement comparisons have been organized. In 1998, a volume measurement comparison for 50L was organized, in which MC, NIST, CENAM and the

Physikalisch Technische Bundesanstalt (PTB) took part [1]. The comparison at 20 L, described in this paper, was carried out in 1999. There have also been comparisons at 50 ml and 100 ml with Gay-Lussac pycnometers as transfer standards [2].

CENAM, NIST, MC, ONNUM, JBS, INDECOPI, LATU, INMETRO and INTI are the laboratories responsible for maintaining and disseminating the accuracy of volume reference standards in: Mexico, the USA, Canada, Costa Rica, Jamaica, Peru, Uruguay, Brazil and Argentina respectively. All these countries have completed the activities related to this comparison, by volume content determination of a 20 L, graduated neck, volumetric reference standard.

Figure 1 shows a photograph of this volumetric transfer standard.

CALIBRATION METHOD

All the laboratories taking part in the comparison used the gravimetric method, which has been recognized as the primary method for volume determination. All participants determined the mass of water in the container, subtracting the mass of the container from the total mass of water and container, and correcting for air buoyancy. The transfer standard was calibrated as “to contain” by all participants.

Various weighing techniques were used for the determination of the mass value of the water held in the container. Some countries used the double substitution method, others used the simple substitution method and others used direct readings.

The mathematical model used by each participant takes into account the specific aspects of the calibration processes; however, the following equation represents the generic model for calculation of the volume contained in the volumetric standard at a reference temperature of 20 ºC.

$$V_{20^{\circ}C} = \left(\frac{(m_2 - m_1) * \left(1 - \frac{r_{air}}{r_s}\right)}{r_{water} - r_{air}} \right) * \left(1 - a\,(t - 20)\right) \qquad (1)$$

where :

r_{air} : density of air, [kg/m^3], which is determined using the values of temperature, atmospheric pressure and relative humidity that prevail during the calibration process, and by applying experimental expressions, such as those proposed by Davis [3], Giacomo [4], Jaeger and Davis [5]

r_{water} : density of water contained in the volumetric standard, [kg/m^3]. It is calculated by means of the Patterson and Morris equation [6] or that of G. S. Kell [7]

a: volumetric thermal expansion coefficient of 304 stainless steel (α = $47{,}7 \cdot 10^{-6}$ $^{o}C^{-1}$)

r_s : density of the weights, [kg/m^3]

t : temperature of water in the volumetric standard, [^{o}C]

m_1 : mass of the empty transfer standard, [kg]

m_2 : mass of both the water and the transfer standard, [kg]

RESULTS

The volume and corresponding uncertainty reported by each laboratory are given in table 1. All of the uncertainties are expressed with a coverage factor of 2 (k=2). CENAM, as the pilot laboratory, set the uncertainty for the reading of the neck scale, to be assumed by all participants, at 1,4 ml (= resolution/$\sqrt{12}$; = 5/$\sqrt{12}$)

The sight glass was broken during shipment after the measurement at MC. The difference in the inner diameter of the new and old sight glasses increased the volume at 2,02 ml. The shift in volume is evident in the CENAM volumes plotted in figure 2 where the reported volumes are plotted in chronological order.

Figure 3 is a plot of the deviations of the reported volumes from the appropriate average. The measurement performed by CENAM, NIST and MC are graphed with respect to their average; on the other hand, the remaining measurements CENAM2, ONNUM, CENAM3, JBS, CENAM4, INDECOPI, LATU, CENAM5, INTI and CENAM6, are graphed with respect to their average.

The maximum and minimum volumes reported by the participating laboratories differ by only 0,015 %. Figure 3 show there is significant overlap in the uncertainties of all participants.

Laboratory	Date	Volume [ml]	Uncertainty ± ml	weighing method	Data
CENAM1	September 1998	20 026,17	3,1	DS	5
NIST	September 1998	20 024,97	3,1	DS	5
(NRC/MC)	September 1998	20 026,80	3,0	SS	4
CENAM2	May 1999	20 027,77	3,1	DS	12
ONNUM	June 1999	20 026,90	3,0	DS	5
CENAM3	June 1999	20 027,59	3,1	DS	4
JBS	July 1999	20 027,26	3,6	SS	5
CENAM4	August 1999	20 027,68	3,0	DS	4
INDECOPI	October 1999	20 029,80	3,2	DR	10
LATU	October 1999	20 026,90	3,0	SS	10
INMETRO	October 1999	20 027,30	3,3	DR	13
CENAM5	November 1999	20 028,05	3,3	DS	3
INTI	December 1999	20 028,93	2,9	SS	7
CENAM6	February 2000	20 027,41	3,1	DS	4

Table 1 Calibration results of the 20 L standard.

DS: double substitution; SS: simple substitution; DR: direct reading

REFERENCES:

1. *International Comparison of Volume Measurement Standards at 50 Liters at CENAM, PTB, Measurement Canada, and NIST*. DRAFT.
2. Measurement Canada was the pilot laboratory under the direction of Dr. Claude Jacques, (NRC).
3. R. S. Davis, *Equation for the Determination of the Density of Moist Air*, Metrologia, 29, 1992, 67-70
4. P. Giacomo, *Equation for the Determination of Density of Moist Air*, Metrologia, 18, 1982,33 -40.
5. K. B. Jaeger and R. S. Davis, *A Primer for Mass Metrology*, National Bureau of Standards (US) NBS Special Publication 700-1, Industrial Measurement Series, 1984, 79 p.

6. J. B. Patterson and E. C. Morris, *Measurement of Absolute Water Density, 1 °C to 40 °C*, Metrologia, 31, 1994, 277- 288.
7. G. S. Kell, Density, *Thermal Expansions and Tables for Atmospheric Pressure and Saturation. Reviewed and Expressed on 1968 Temperature Scale*, J. Chem. Eng. Data, 20, 1975, 97-105.

Figure 1.- Transfer standard for volume comparison at 20 L.

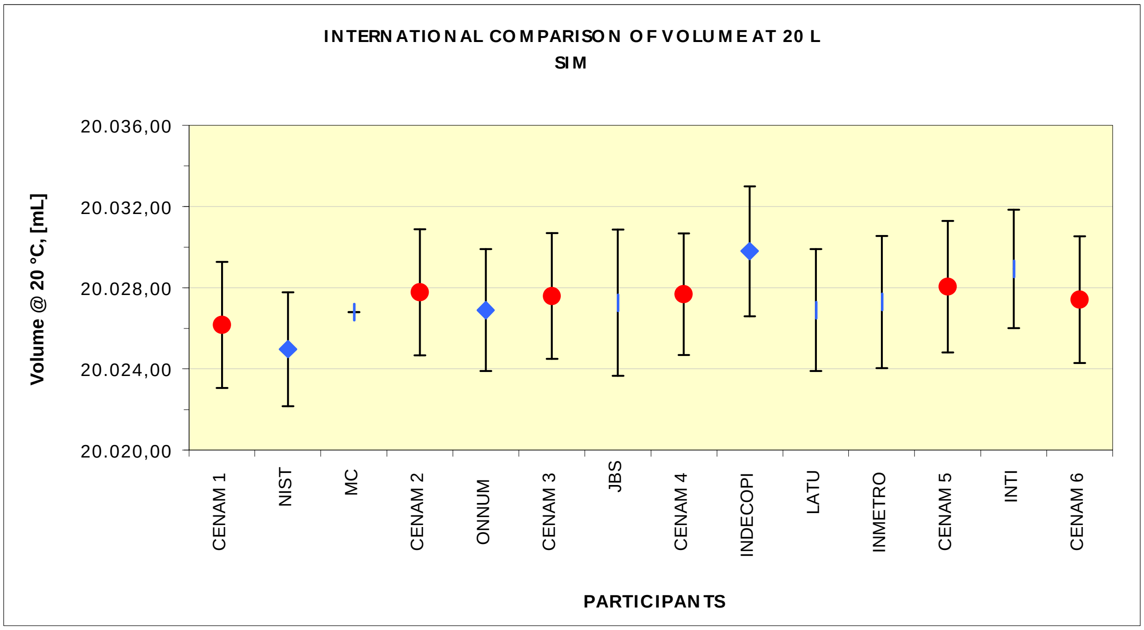

Figure 2.- Calibration results provided by each participant.

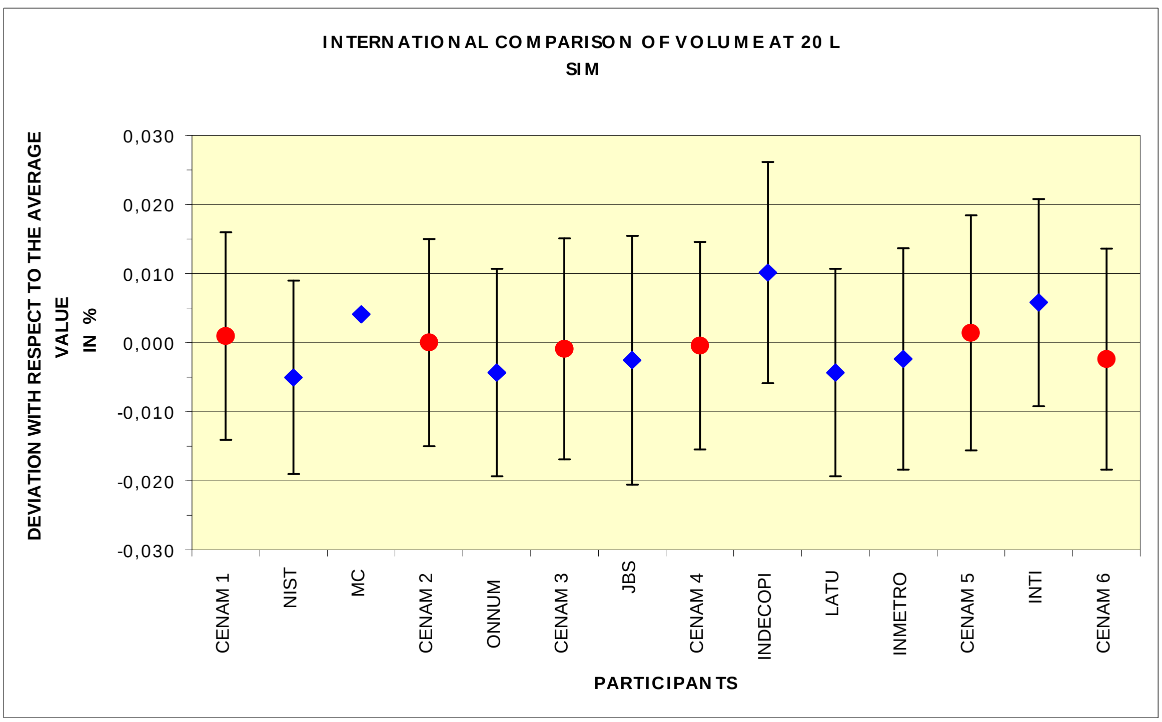

Figure 3.- Deviation with respect to the appropriate average value.