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COMPARISON BETWEEN INMETRO (BRAZIL) AND CENAM (MEXICO) ON BAROMETRIC PRESSURE, RANGE FROM 80 kPa UP TO 115 kPa

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Abstract. This paper presents the comparison between the Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO, Brazil) and the Centro Nacional de Metrología (CENAM, Mexico) on barometric pressure in the range from 80 kPa up to 115 kPa. This comparison was carried out at the end of 2004 and has been entered within the data base of the Sistema Interamericano de Metrología (Interamerican Metrology System, SIM) as comparison SIM.7.25 P. The pilot laboratory was CENAM. The standards used by the national laboratories were pressure balances, operated in free deformation. The transfer standard used for the comparison was a digital barometer, accuracy class of 0,01 % of full scale. Eight points of pressures were selected and each pressure was measured four times. The results obtained by the two laboratories were in agreement.

Keywords: Comparison, pressure, barometric pressure, pressure balance, SIM.

1. INTRODUCTION

The state of the art for primary standards in absolute pressure, for the measurement of barometric pressures, is mercury columns and pressure balances. Due to this, where possible, these instruments are used as national standards.

The comparison between National Metrology Institutes (NMI) is carried out in order to evaluate the level of agreement of its measurements and could be realized either, directly with primary standards or by means of an adequate transfer standard (TS) [1, 2]. The most common method is by using TS.

This bilateral comparison was carried out between the Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO, Brazil) and the Centro Nacional de Metrología (CENAM, Mexico). INMETRO and CENAM have performed other comparisons [3, 4] in pressure but this one is the first in barometric pressure, not only between this two NMIs but within the Sistema Interamericano de Metrología (Interamerican Metrology System, SIM).

2. SCOPE OF WORK

The purpose of this bilateral comparison is to evaluate the degree of equivalence between the measurements carried out by CENAM and INMETRO in the range of barometric pressure from 80 kPa up to 115 kPa, using the normalized error equation as the equivalence parameter [5, 6].

This bilateral comparison has been entered within the data base of the Sistema Interamericano de Metrología (SIM) as a pilot comparison with the reference number SIM.7.25 P.

2.1 Transfer standard (TS)

A digital manometer was used as TS. The characteristics of the digital barometer are:

Table 1. Transfer standard data.

Transducer Type:	Digital barometer
Range:	800 hPa to 1 150 hPa
Units:	hPa
Resolution:	1 Pa
Accuracy Class:	0,01% of F. S.
Manufacturer:	Druck
Model:	DPI-145
Serial number:	1040/99-05
Code number	007181/82088

2.2 Comparison dates

The dates of the calibrations performed by the participating laboratories are shown in Table 2.

Table 2. Dates of the calibrations by the NMIs.

National Metrology Institute	*Calibration date*	*Standard used*
INMETRO	2004-11-25	Ruska pressure balance
CENAM	2004-12-07	DHI pressure balance

2.3 General Guidelines and Procedure

The comparison's most important considerations are:

a) To take eight points over the measuring range of the digital barometer, (Transfer Standard, TS); measured pressure points 80 kPa, 85 kPa, 90 kPa, 95 kPa, 100 kPa, 105 kPa, 110 kPa and 115 kPa.
b) To perform four measurements in each pressure point, by carrying out four series, two in ascending mode and two in descending mode.
c) To evacuate the atmospheric pressure over the masses with a vacuum pump.
d) To use as the reference temperature 20 °C.
e) To use nitrogen as manometric fluid.

The model used for absolute pressure is described in Equation 1.

$$p = \frac{\sum_{i=1}^{n} m_i g_l}{A_0\left(1+\left(\alpha_p+\alpha_c\right)\left(t-t_r\right)\right)\left(1+b p_n\right)} - \rho g_l h + p_{res.} \quad (1)$$

Where:

p = pressure over transfer Standard, Pa
m_i = mass, kg
g_l = local gravity, m/s^2
A_0 = Effective area, m^2
α_p = Thermal coefficient of piston, °C^{-1}
α_c = Thermal coefficient of cylinder, °C^{-1}
t = Temperature of piston – cylinder assembly, °C
t_r = Reference temperature of piston – cylinder assembly, °C
b = Pressure distortion coefficient of piston – cylinder assembly, Pa^{-1}
p_n = Nominal pressure, Pa
ρ = Manometric fluid used, kg/m^3
h = Height of de column of manometric fluid, m
p_{res} = Residual pressure in the bell jar, Pa.

3. PARTICIPATING LABORATORIES' STANDARDS

The comparison was carried out using a pressure balance, operating in free deformation, as the reference standard of each of the participating laboratories. The TS was calibrated by both NMIs using their national standard (primary standard) for the comparison measuring range.

3.1 Characteristics of CENAM's pressure balance

Manufacturer: DH Instruments
Model: PG-7607
Serial number of pressure balance: 122
Serial number of piston cylinder assembly: 231
Serial number of mass set: 2003/2004
Range: 2,5 kPa to 175 kPa
Accuracy class: 0,002 % of reading
Traceability: Dimensional and mass to CENAM
Uncertainty: ±14 x 10^{-6} relative to the reading.

3.2 Characteristics of INMETRO's pressure balance

Manufacturer: Ruska
Model: 2465-752
Serial number of piston cylinder assembly: TL-1505
Range: 1,5 kPa to 175 kPa
Accuracy class: 0,002 % of reading
Traceability: PTB

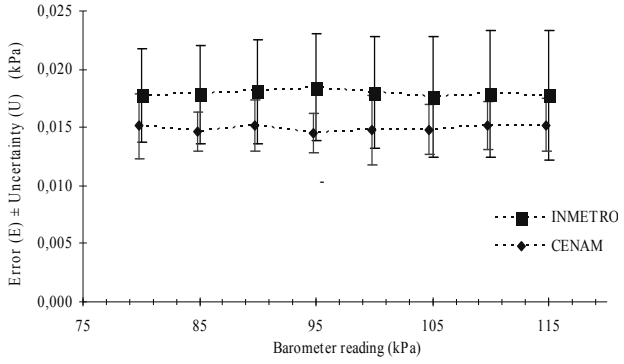
4. RESULTS

The results of the measurements made to the TS by CENAM and INMETRO, for each calibration pressure, are presented in Table 3.

Table 3. Results of the TS calibration by the NMIs.

	CENAM		INMETRO	
Pressure	Error	U	Error	U
kPa	kPa	$k = 2$	kPa	$k = 2$
80	0,015 1	0,002 8	0,017 7	0,004 0
85	0,014 6	0,001 7	0,017 8	0,004 2
90	0,015 1	0,002 2	0,018 1	0,004 5
95	0,014 5	0,001 7	0,018 5	0,004 6
100	0,014 8	0,003 0	0,017 9	0,004 8
105	0,014 8	0,002 1	0,017 7	0,005 2
110	0,015 1	0,002 1	0,017 9	0,005 4
115	0,015 2	0,002 3	0,017 8	0,005 6

In Graph 1, the errors of the TS found by each NMI is shown, the uncertainty in each pressure point measured is also included.



Graph 1. INMETRO and CENAM measurements results. The least squares best-fit lines have been superimposed over each laboratory's measurement results.

5. DISCUSSION

The degree of equivalence between the results of the measurements made by both laboratories was evaluated using the normalized error equation according to the expression of Equation 2.

$$e_n = \frac{E_{INMETRO} - E_{CENAM}}{\sqrt{(U_{INMETRO})^2 + (U_{CENAM})^2}} \quad (2)$$

Where,

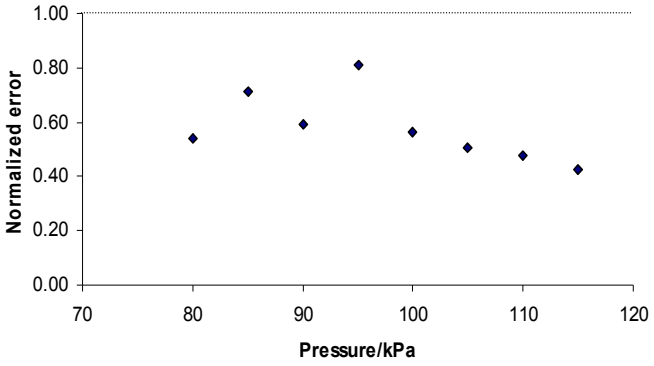
e_n - normalized error calculated at each calibration pressure,
E_{CENAM} - CENAM's estimated error,
$E_{INMETRO}$ - INMETRO's estimated error,
U_{CENAM} - CENAM's estimated expanded uncertainty,
$U_{INMETRO}$ - INMETRO's estimated expanded uncertainty.

The results of the application of the normalized error equation to the calibrations made by CENAM and INMETRO are showed in Table 4.

Table 4. Normalized error equation degree of equivalence between INMETRO and CENAM.

Pressure kPa	e_n
80	0,54
85	0,72
90	0,59
95	0,81
100	0,56
105	0,51
110	0,48
115	0,43

The data included in Table 4 is presented in Graph 2 in a more convenient way to make the equivalence between the two laboratories easier to distinguish.



Graph 2. Graphical representation of the normalized error equation. The dotted horizontal line is the limit for equivalence.

This graph provides a better view of the comparison results and of the equivalence of measurements between CENAM and INMETRO. In Table 4 and Graph 2, it is important to notice that no measured pressure point in this comparison has a value of the normalized error equation greater than 0,81.

6. CONCLUSIONS

The behavior of the calibrations made by both laboratories showed a constant difference of around 3 Pa, this difference is within the uncertainties claimed by the NMIs.

The normalized error equation values were, throughout the entire comparison measuring pressure range, below one. From these results, according to the normalized error equation analysis, it can be concluded that a good agreement exists between the measurements carried out at CENAM and INMETRO in the range of barometric pressure chosen for this comparison.

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