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Pneumatic gauge pressure proficiency test in the range from -70 kPa to 0 kPa for Mexican accredited laboratories

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Abstract

With the purpose to establish deviations and concordance levels for negative pressure measurements in Mexico, and by a request from the Mexican Accreditation Body (ema), the pressure and vacuum group in CENAM (the Mexican National Metrology Institute) organized a proficiency test among laboratories from the National System of Calibrations (SNC). In this proficiency test most of the Mexican secondary laboratories with the capabilities to perform calibrations in this measurement range participated.

This document presents the results and the concordance level obtained among the laboratories which participated in the proficiency test. The measurements performed by the pilot laboratory (CENAM) are also presented. CENAM established the reference values (error and uncertainty) and determined the drift of the transfer standard during the period of the proficiency test.

The concordance of the results obtained by the laboratories was evaluated by means of the normalized error equation method.

Keywords: Pressure, proficiency tests, pneumatic gauge pressure.

1. Introduction

CENAM's pressure and vacuum group organized a proficiency test among laboratories from the National System of Calibrations (SNC) for negative pressure from -70 kPa to 0 kPa. The proficiency test was carried out from October 2006 until March 2007. In this proficiency test 28 laboratories participated.

1.1 Participating Laboratories

The participants were accredited Mexican pressure calibration secondary laboratories, or laboratories which were in the process of obtaining their accreditation. The participant laboratories should also have pressure measurement systems which could, at least, measure 4 pressure points from the calibration range proposed for this proficiency test i.e. within -70 kPa and -0.7 kPa.

The proficiency test was performed in two comparison rounds. *Table 1* presents the participating laboratories and the proficiency test program.

Table 1
Proficiency test program

CENAM	Queretaro	25 to 26 Oct.		Aguascalientes	4 to 5 Dec.
SICAMT.	Toluca	27 to 28 Oct.	METGOSA	Tampico	6 to 7 Dec.
ASIC	Toluca	30 to 31 Oct.	Tamoxlab	Tampico	8 to 11 Dec.
IMP	Mexico City	1 to 2 Nov.	Certifik	Monterrey	12 to 14 Dec.
CVC-México	Mexico City	3 to 4 Nov.	MYPASA	Nogales	15 to 18 Dec.
SIMCA	Mexico City	6 to 7 Nov.	Metas	Jalisco	19 to 21 Dec.
CCCISA	Mexico City	8 to 9 Nov.	SECEI	Mexico State	22 to 23 Dec.
CALPRO	Mexico State	10 to 11 Nov.	MANINASA	Mexico City	2 to 3 Jan.
Metrotecnica	Mexico State	13 to 14 Nov.	VAMET	Mexico City	4 to 5 Jan.
Caltest	Mexico State	15 to 16 Nov.	Caltechnix	Mexico City	6 to 8 Jan.
José Luz	Mexico State	17 to 18 Nov.	NSPA y DEI	Mexico City	9 to 11 Jan.
METEC	Mexico State	20 to 21 Nov.	Ind. Seico	Orizaba	12 to 13 Jan.
CIDESI	Queretaro	22 to 23 Nov.	TACSA	Orizaba	15 to 16 Jan.
CENAM	Queretaro	24 to 27 Nov.	SICA	Mexico State	18 to 19 Jan.
LAPEM	Irapuato	28 to 29 Nov.	CVC-México	Mexico City	22 to 23 Jan.
CIATEC	León	30 Nov to 2 Dec	CENAM	Queretaro	24 to 26 Jan.

1.2 General Guidelines and Procedure

The manometer calibration method was proposed by CENAM in accordance to other national proficiency tests [1] and international comparisons [2, 3, 4, 5, 6], as well as international recommendations [7]. The procedure consisted on taking 10 measurements distributed within the fixed pressure range from -70 kPa to 0.7 kPa. Each pressure target point was measured 3 times in ascending order and 3 times in descending order.

1.3 Transfer Standard

A digital manometer, Druck model DPI 104 serial number 2422875, with a measuring range from -70 kPa to 2 100 kPa; with 0.05% of the measurement range accuracy class, and resolution of 0.01 kPa, property of CENAM, was used as transfer standard for this proficiency test.

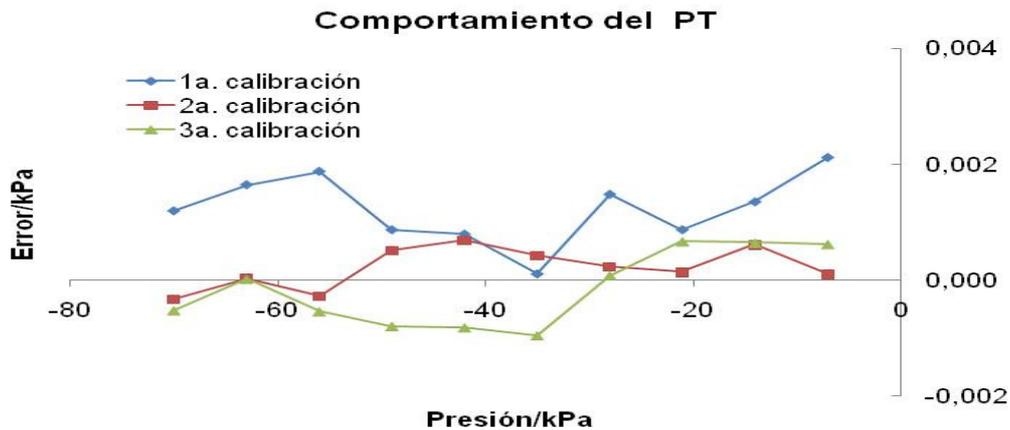
2. Results

2.1 Stability of the Transfer Standard

The transfer standard (PT) showed good stability during the measurements period, the three calibrations performed by CENAM had a maximum standard deviation of 156×10^{-6} ; inside the accuracy class of the manometer. Considering that the maximum deviation was only in the first point, the rest of the range the standard deviation was less than 32×10^{-6} .

The first calibration was made before any of the laboratories started their measurements, the second one was approximately at half of the test program, and the third was after the last laboratory had taken its measurements.

The transfer standard calibrations made by CENAM are shown in *Graph 1*.



Graph 1. Stability of the Transfer Standard.

2.2 Results

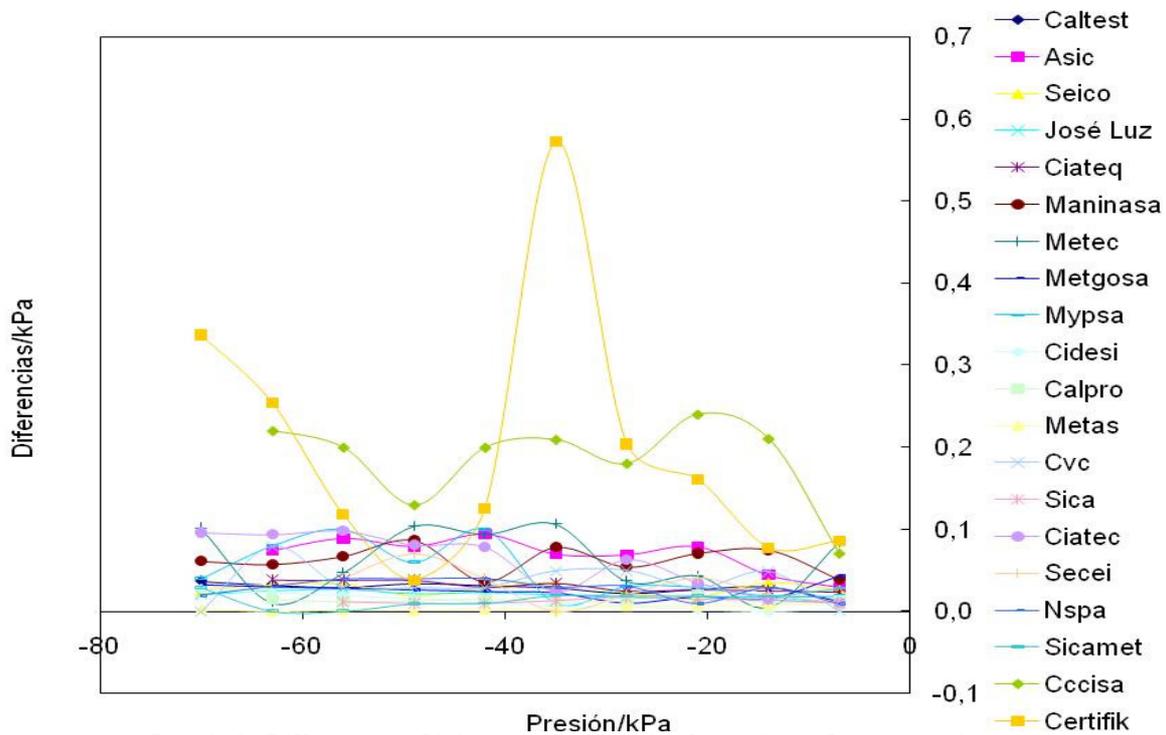
From the 28 participating laboratories 20 laboratories accepted the publication of their results. Table 2 presents their results.

Table 2
Error found for each measured pressure point

Pn kPa	Caltest kPa	Asic kPa	Seico kPa	J. Luz kPa	Ciateq kPa	Manina kPa	Metec kPa	Metgosa kPa	Mypsa kPa	Cidesi kPa
-7	0.013	0.029	0.026	0.010	0.024	0.039	0.085	0.085	0.019	0.004
-14	0.030	0.044	0.035	0.018	0.026	0.075	0.005	0.005	0.019	0.000
-21	0.028	0.079	0.019	0.016	0.027	0.071	0.043	0.043	0.029	0.003
-28	0.023	0.069	0.023	0.018	0.026	0.054	0.037	0.037	0.031	0.007
-35	0.029	0.070	0.035	0.021	0.035	0.078	0.107	0.107	0.010	0.007
-42	0.032	0.095	0.029	0.024	0.030	0.036	0.094	0.094	0.100	0.011
-49	0.035	0.080	0.019	0.022	0.039	0.087	0.104	0.104	0.060	0.016
-56	0.030	0.090	0.033	0.028	0.039	0.067	0.047	0.047	0.100	0.020
-63	0.033	0.074	0.033	0.026	0.039	0.057	0.010	0.010	0.079	0.024
-70	0.037		0.026	0.021		0.061	0.102	0.102	0.040	0.027

Pn kPa	Calpro kPa	Metas kPa	Cvc kPa	Sica kPa	Ciatec kPa	Secei kPa	Nspa kPa	Sicamet kPa	Ccci kPa	Certifik kPa
-7	0.013	0.010	0.001	0.010	0.011	0.011	0.009	0.029	0.071	0.086
-14	0.011	0.008	0.049	0.014	0.016	0.021	0.029	0.019	0.211	0.078
-21	0.021	0.008	0.029	0.014	0.035	0.041	0.009	0.019	0.241	0.162
-28	0.014	0.008	0.051	0.017	0.064	0.021	0.031	0.019	0.181	0.205
-35	0.012	0.003	0.050	0.013	0.025	0.000	0.030	0.020	0.210	0.573
-42	0.015	0.004	0.030	0.010	0.079	0.040	0.040	0.010	0.200	0.126
-49	0.013	0.002	0.030	0.010	0.082	0.070	0.040	0.010	0.130	0.039
-56	0.012	0.002	0.030	0.012	0.099	0.040	0.040	0.000	0.200	0.119
-63	0.015	0.001	0.079		0.094		0.031	0.001	0.221	0.255
-70		0.004	0.000		0.097		0.020	0.030		0.337

Graph 2 presents the difference obtained by each laboratory against the reference value.



Graph 2. Difference of laboratories results from the reference values.

The expanded uncertainty reported by the laboratories is shown in *table 3*.

Table 3
Expanded uncertainty reported by the laboratories ($k = 2$)

Pn kPa	Caltest ±kPa	Asic ±kPa	Seico ±kPa	J. Luz ±kPa	Ciateq ±kPa	Manina ±kPa	Metec ±kPa	Metgosa ±kPa	Mypsa ±kPa	Cidesi ±kPa
-7	5.4E-1	1.5E-1	9.0E-2	9.8E-2	9.9E-2	1.5E-1	4.8E-1	4.0E-2	2.2E-1	3.1E-2
-14	5.4E-1	2.6E-1	9.0E-2	1.0E-1	9.9E-2	1.5E-1	4.8E-1	4.0E-2	3.4E-1	3.1E-2
-21	5.4E-1	2.1E-1	9.4E-2	9.7E-2	9.9E-2	1.5E-1	4.8E-1	4.0E-2	2.3E-1	3.1E-2
-28	5.4E-1	1.9E-1	9.6E-2	9.7E-2	1.0E-1	1.6E-1	4.8E-1	4.0E-2	2.9E-1	3.1E-2
-35	5.4E-1	1.4E-1	1.0E-1	9.8E-2	1.1E-1	1.6E-1	4.8E-1	4.0E-2	3.7E-1	3.1E-2
-42	5.4E-1	2.3E-1	1.1E-1	1.0E-1	1.1E-1	1.6E-1	4.8E-1	4.0E-2	1.9E-1	3.1E-2
-49	5.4E-1	1.6E-1	1.1E-1	1.0E-1	1.1E-1	1.6E-1	4.8E-1	4.0E-2	2.0E-1	3.1E-2
-56	5.4E-1	1.4E-1	1.2E-1	1.0E-1	1.2E-1	1.6E-1	4.8E-1	4.0E-2	1.9E-1	3.1E-2
-63	5.4E-1	4.4E-1	1.2E-1	1.0E-1	1.2E-1	1.5E-1	4.8E-1	4.0E-2	2.2E-1	3.1E-2
-70	5.4E-1		1.3E-1	1.0E-1		1.4E-1	4.8E-1	4.0E-2	2.5E-1	3.1E-2

Pn kPa	Calpro ±kPa	Metas ±kPa	Cvc ±kPa	Sica ±kPa	Ciatec ±kPa	Secei ±kPa	Nspa ±kPa	Sicamet ±kPa	Ccci ±kPa	Certifik ±kPa
-7	1.2E-2	1.2E-2	1.2E0	3.2E-2	1.1E-1	3.7E-1	1.1E-1	1.6E-1	1.7E-1	5.5E-1
-14	1.2E-2	1.2E-2	1.2E0	2.8E-2	1.1E-1	3.7E-1	1.3E-1	1.6E-1	4.0E-1	5.5E-1
-21	1.3E-2	1.2E-2	1.2E0	2.4E-2	1.1E-1	3.7E-1	1.2E-1	1.6E-1	2.5E-1	5.5E-1
-28	1.5E-2	8.0E-3	1.2E0	2.4E-2	1.1E-1	3.7E-1	1.2E-1	1.6E-1	1.8E-1	5.5E-1
-35	1.3E-2	8.0E-3	1.2E0	2.0E-2	1.1E-1	3.7E-1	1.2E-1	1.6E-1	2.3E-1	6.0E-1
-42	1.3E-2	8.0E-3	1.2E0	2.2E-2	1.2E-1	3.7E-1	1.2E-1	1.6E-1	2.2E-1	5.5E-1
-49	1.3E-2	9.0E-3	1.2E0	2.4E-2	1.2E-1	3.7E-1	1.1E-1	1.6E-1	1.5E-1	6.3E-1
-56	1.3E-2	8.0E-3	1.2E0	2.6E-2	1.2E-1	3.7E-1	1.1E-1	1.6E-1	2.1E-1	5.5E-1
-63	1.4E-2	8.0E-3	1.2E0		1.1E-1		1.2E-1	1.6E-1	3.4E-1	5.5E-1
-70		1.0E-2	1.2E0		1.1E-1		1.1E-1	1.6E-1		5.6E-1

3. Analysis of Results

The evaluation of the laboratories performance was based on the normalized error equation method. Equation 1 was used to obtain the normalized error values for each pressure point measured by each participating laboratory.

$$E_n = \frac{E_L - E_R}{\sqrt{U_L^2 + U_R^2}} \quad (1)$$

Where:

- E_n Normalized error calculated at each calibration pressure
- E_L Estimated error by a laboratory
- E_R Reference value (average estimated error from the 3 CENAM's measurements)
- U_L Laboratory's reported expanded uncertainty
- U_R Reference expanded uncertainty assigned by CENAM.

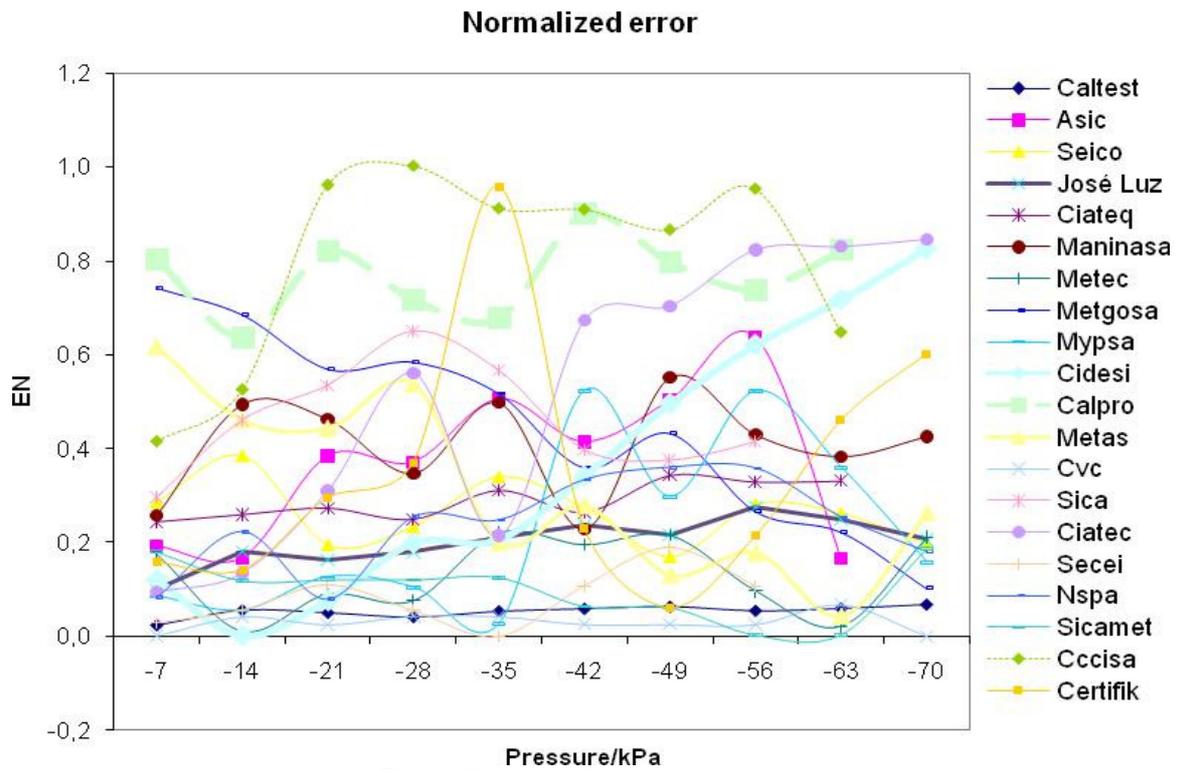
Table 4 presents the results obtained by the participating laboratories for the normalized error according to equation 1.

Table 4
Normalized error of the laboratories

Pn kPa	E_N Caltest	E_N Asic	E_N Seico	E_N J. Luz	E_N Ciateq	E_N Manina	E_N Metec	E_N Metgosa	E_N Mypsa	E_N Cidesi
-7	0.0	0.2	0.3	0.1	0.2	0.3	0.2	0.7	0.1	0.1
-14	0.1	0.2	0.4	0.2	0.3	0.5	0.0	0.7	0.1	0.0
-21	0.1	0.4	0.2	0.2	0.3	0.5	0.1	0.6	0.1	0.1
-28	0.0	0.4	0.2	0.2	0.3	0.3	0.1	0.6	0.1	0.2
-35	0.1	0.5	0.3	0.2	0.3	0.5	0.2	0.5	0.0	0.2
-42	0.1	0.4	0.3	0.2	0.3	0.2	0.2	0.4	0.5	0.3
-49	0.1	0.5	0.2	0.2	0.3	0.6	0.2	0.4	0.3	0.5
-56	0.1	0.6	0.3	0.3	0.3	0.4	0.1	0.3	0.5	0.6
-63	0.1	0.2	0.3	0.2	0.3	0.4	0.0	0.2	0.4	0.7
-70	0.1		0.2	0.2		0.4	0.2	0.1	0.2	0.8

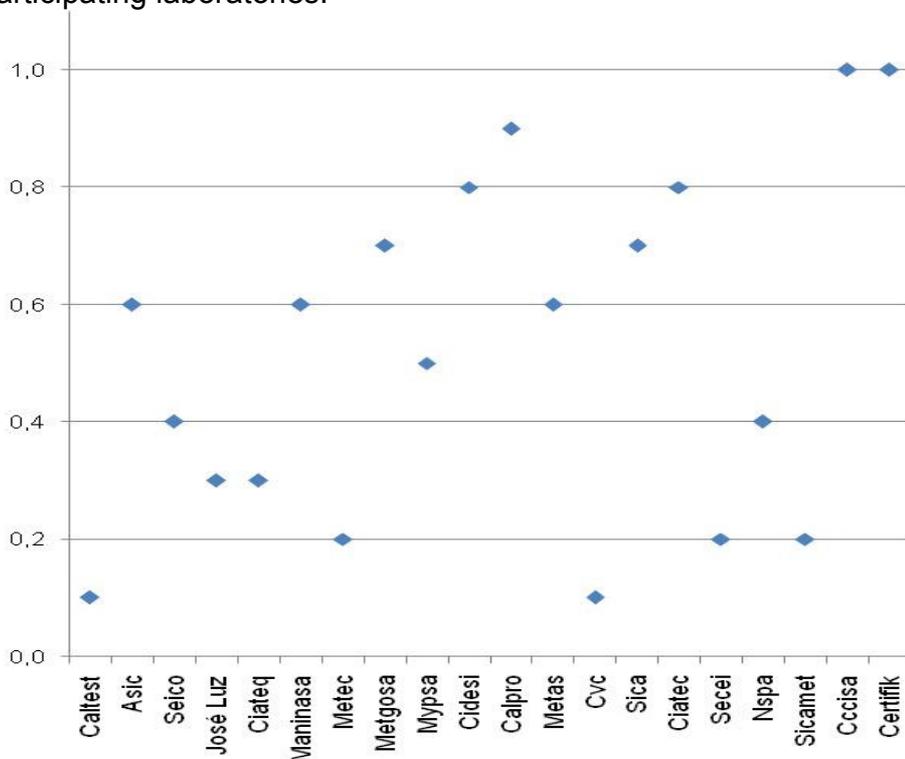
Pn kPa	E_N Calpro	E_N Metas	E_N Cvc	E_N Sica	E_N Ciatec	E_N Secei	E_N Nspa	E_N Sicamet	E_N Ccci	E_N Certifik
-7	0.8	0.6	0.0	0.3	0.1	0.0	0.1	0.2	0.4	0.2
-14	0.6	0.5	0.0	0.5	0.1	0.1	0.2	0.1	0.5	0.1
-21	0.8	0.4	0.0	0.5	0.3	0.1	0.1	0.1	1.0	0.3
-28	0.7	0.5	0.0	0.7	0.6	0.1	0.3	0.1	1.0	0.4
-35	0.7	0.2	0.0	0.6	0.2	0.0	0.2	0.1	0.9	1.0
-42	0.9	0.3	0.0	0.4	0.7	0.1	0.3	0.1	0.9	0.2
-49	0.8	0.1	0.0	0.4	0.7	0.2	0.4	0.1	0.9	0.1
-56	0.7	0.2	0.0	0.4	0.8	0.1	0.4	0.0	1.0	0.2
-63	0.8	0.0	0.1		0.8		0.3	0.0	0.6	0.5
-70		0.3	0.0		0.8		0.2	0.2		0.6

Graph 3 presents the normalized error equation graph results for the participating laboratories.



Graph 3. Normalized error values.

Graph 4 shows the maximum normalized error values obtained by each one of the participating laboratories.



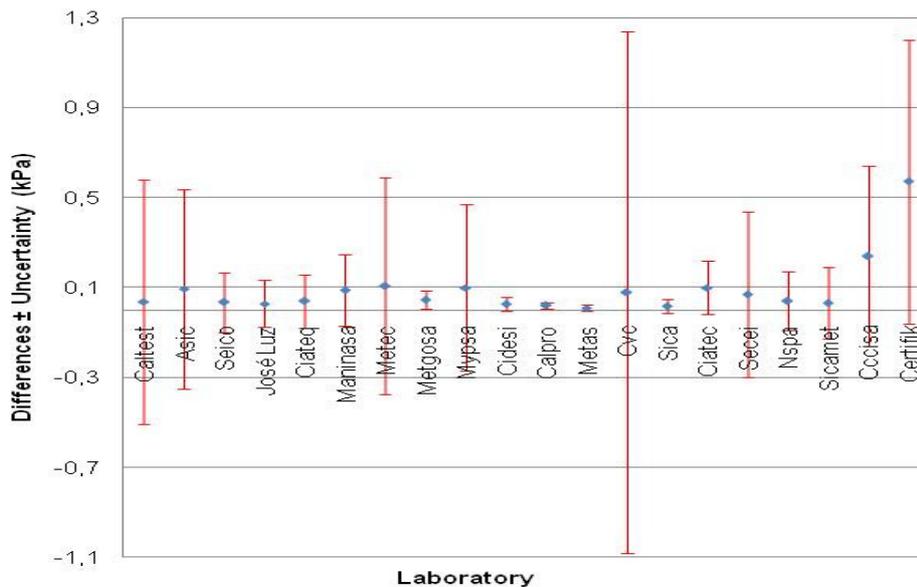
Graph 4. Maximum normalized error values found by the laboratories.

4. Conclusions

The results showed a concordance level among all of the participating laboratories. Table 5 and Graph 5 show the maximum values obtained by the laboratories on the proficiency test.

Table 5
Maximum value obtained by the laboratories on the proficiency test

Laboratory	Maximum normalized error	Maximum deviation kPa	Maximum uncertainty \pm kPa
Caltest	0.1	0.037	5.4E-1
Asic	0.6	0.095	4.4E-1
Seico	0.4	0.035	1.3E-1
José Luz	0.3	0.028	1.0E-1
Ciateq	0.3	0.039	1.2E-1
Maninasa	0.6	0.087	1.6E-1
Metec	0.2	0.107	4.8E-1
Metgosa	0.7	0.044	4.0E-2
Mypsa	0.5	0.100	3.7E-1
Cidesi	0.8	0.027	3.1E-2
Calpro	0.9	0.021	1.5E-2
Metas	0.6	0.010	1.2E-2
Cvc	0.1	0.079	1.2E+0
Sica	0.7	0.017	3.2E-2
Ciatec	0.8	0.099	1.2E-1
Secei	0.2	0.070	3.7E-1
Nspa	0.4	0.040	1.3E-1
Sicamet	0.2	0.030	1.6E-1
Cccisa	1.0	0.241	4.0E-1
Certifik	1.0	0.573	6.3E-1



Graph 5. Maximum deviations and uncertainty found by each laboratory.

The measurement results allowed the participating laboratories to identify improvement opportunities concerning their calibration standards and procedures as well as uncertainty evaluation method.

As a conclusion, we consider this proficiency test to be very positive as there was a very good laboratories participation (having 28). Also, from those 71.4% (20) obtained satisfactory results (within an absolute value of 1, of the normalized error); 7.1 %, (2) obtained questionable normalized error values (between 1 and 2, absolute values) and only 6 (21.4 %) laboratories obtained one or more pressure target points with a normalized error value bigger than 2.

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