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# Hydraulic gauge pressure proficiency test in the range from 7 MPa to 70 MPa for Mexican accredited laboratories

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**Abstract**

At the end of 2006, the Pressure Group of the Centro Nacional de Metrología CENAM, *Mexican National Metrology Institute*, organized and piloted a proficiency test in hydraulic gauge pressure in the range from 7 MPa to 70 MPa for accredited laboratories by the Entidad Mexicana de Acreditación (ema), *Mexican Accreditation Body*. For the proficiency test, the pilot laboratory (CENAM) carried out three calibrations of the transfer standard; the first one at the beginning of the proficiency test, the second at the middle and the last one at the end of the program.

With the measurements made by CENAM the reference values were established, including error and uncertainty. The deviations for each laboratory were compared against the reference values and the compatibility of results was calculated, for each participating laboratory, by means of the normalized error equation method.

The measurements were carried out by each participant laboratory with their own resources (personnel, calibration systems, environmental conditions and in their installations). Laboratories located all around the country participated and most of the laboratories with this range of measurement participated. The proficiency test started in November 2006 and finished in March 2007.

*Keywords*: Pressure, proficiency tests, hydraulic gauge pressure.

## 1. Introduction

Proficiency tests among accredited laboratories are carried out in order to demonstrate their performance in measuring and/or calibrating with confidence and accuracy within their declared best measurement capability [1]. The participant laboratories in this proficiency test belong to the National System of Calibration (SNC), and are accredited laboratories or in the processes to be so. For the proficiency test, each laboratory carried out a calibration of a transfer standard (TS), and its results were compared with the reference values set by the Mexican National Metrology Institute (CENAM). The compatibility of results was assessed by means of the normalized error equation method [2, 3, 4, 5].

The proficiency test can be used by the accreditation body as part of the assessment processes, to evaluate the ability of the laboratories to knowledgeably carry out tasks for which its accreditation has been applied for. This test is a complement of the laboratory assessment carried out by technical experts *in situ*.

## 2. Scope of Work

The purpose of this proficiency test was to evaluate the level of compatibility of results between the measurements carried out by CENAM and those obtained by each participant laboratory in the range of hydraulic pressure from 7 MPa up to 70 MPa, using the normalized error equation as the equivalence parameter.

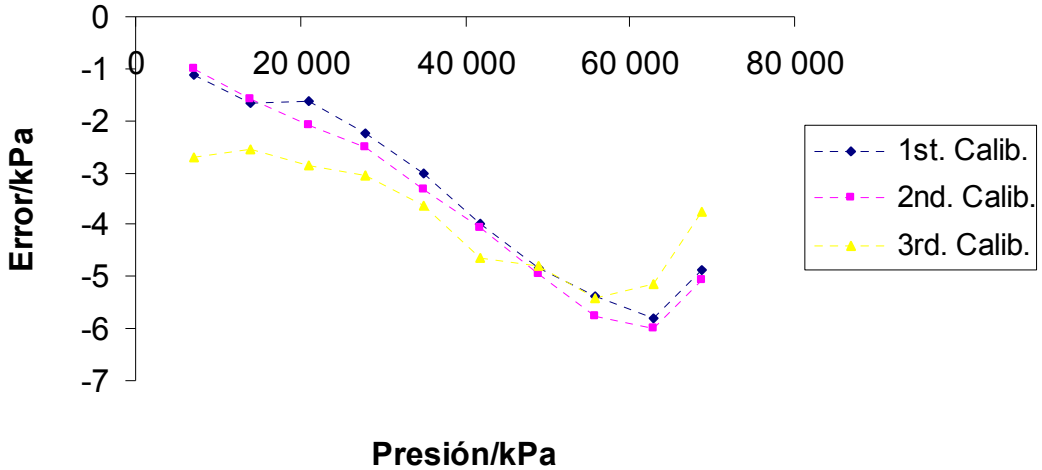
### *2.1 Transfer standard (TS)*

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

Table 1
Transfer standard data

| | |
|---|---|
| Instrument Type: | Digital manometer |
| Range: | 0 to 70 000 |
| Units: | kPa |
| Resolution: | 0.01 |
| Accuracy Class: | 0.05 % of F. S. |
| Manufacturer: | Druck |
| Model: | DPI-104 |
| Serial number: | 2329116 |

The transfer standard was calibrated three times by CENAM, the first one before starting the exercise, another one half way of the program and the last one at the end of the proficiency test. The TS had good performance during the proficiency test; the maximum standard deviation was 1 kPa, which is within the instruments accuracy class, equivalent to ±35 kPa (0.05 % F. S.). The behavior of the TS during the whole test is shown in graph 1.




Graph 1. Transfer standard behavior.

### *2.2 Comparison program*

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

Table 2
Names and dates of the calibrations performed by the participating laboratories

| No. | Laboratory | City | Reception date | Calibration date |
|---|---|---|---|---|
| | CENAM | Querétaro | 25-Oct | 26-Oct |
| 1 | Sicamet | Toluca | 27-Oct | 28-Oct |
| 2 | Asic | Toluca | 30-Oct | 31-Oct |
| 3 | Imp | Mexico City | 01-Nov | 02-Nov |
| 4 | Simca | Mexico City | 06-Nov | 07-Nov |
| 5 | Calpro | Mexico State | 10-Nov | 11-Nov |
| 6 | Metrotecnia | Mexico State | 13-Nov | 14-Nov |
| 7 | Caltest | Mexico State | 15-Nov | 16-Nov |
| 8 | José Luz | Mexico State | 17-Nov | 18-Nov |
| 9 | Metec | Mexico State | 20-Nov | 21-Nov |
| | CENAM | Querétaro | 24-Nov | 27-Nov |
| 10 | Lapem | Irapuato | 28-Nov | 29-Nov |
| 11 | Ciateq | Aguascalientes | 4-Dec | 05-Dec |
| 12 | Met golfo | Tampico | 06-Dec | 07-Dec |
| 13 | Tamoxlab | Tampico | 08-Dec | 11-Dec |
| 14 | Alteq | Monterrey | 12-Dec | 14-Dec |
| 15 | Mypsa | Nogales | 15-Dec | 18-Dec |
| 16 | Sica | Mexico State | 02-Jan | 04-Jan |
| 17 | Conmed | Mexico City | 05-Jan | 08-Jan |
| 18 | Aeronáutica | Mexico City | 19-Jan | 22-Jan |
| | CENAM | Querétaro | 23-Jan | |

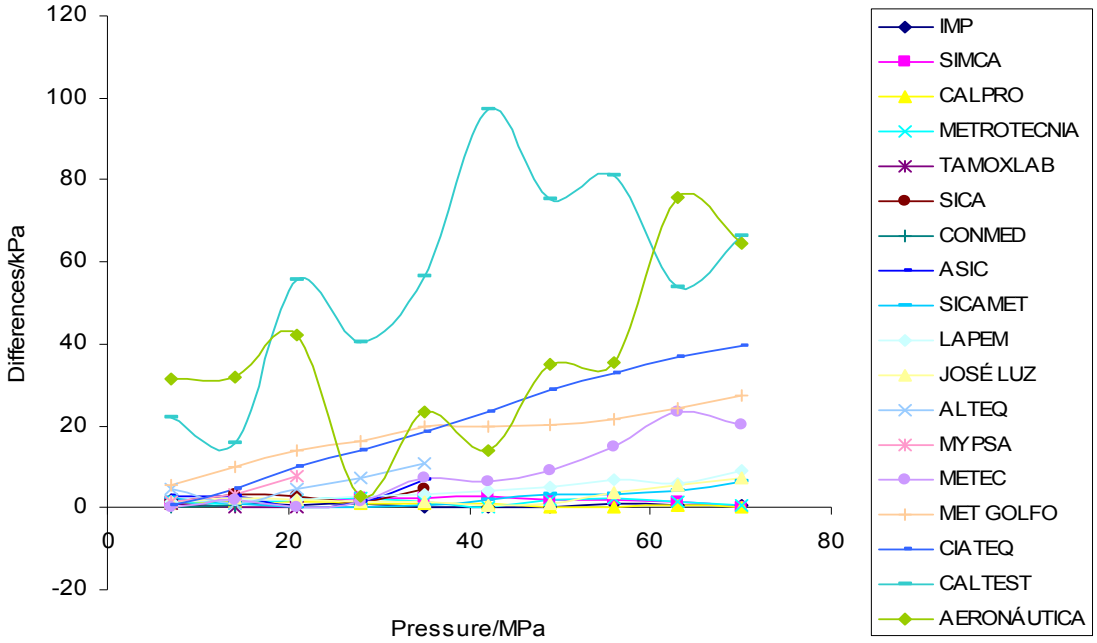
### *2.3 General Guidelines and Procedure*

The Proficiency test's followed international procedures [6, 7]. The most important considerations were:

a) To take ten points evenly distributed on the digital manometer measuring range (transfer standard, TS). Measured target pressure points: 7 MPa, 14 MPa, 21 MPa, 28 MPa, 35 MPa, 42 MPa, 49 MPa, 56 MPa, 63 MPa and 70 MPa.
b) To perform four measurements in each pressure point, by carrying out four series, two in ascending order and two in descending order.
c) To use hydraulic fluid (oil) as manometric fluid.

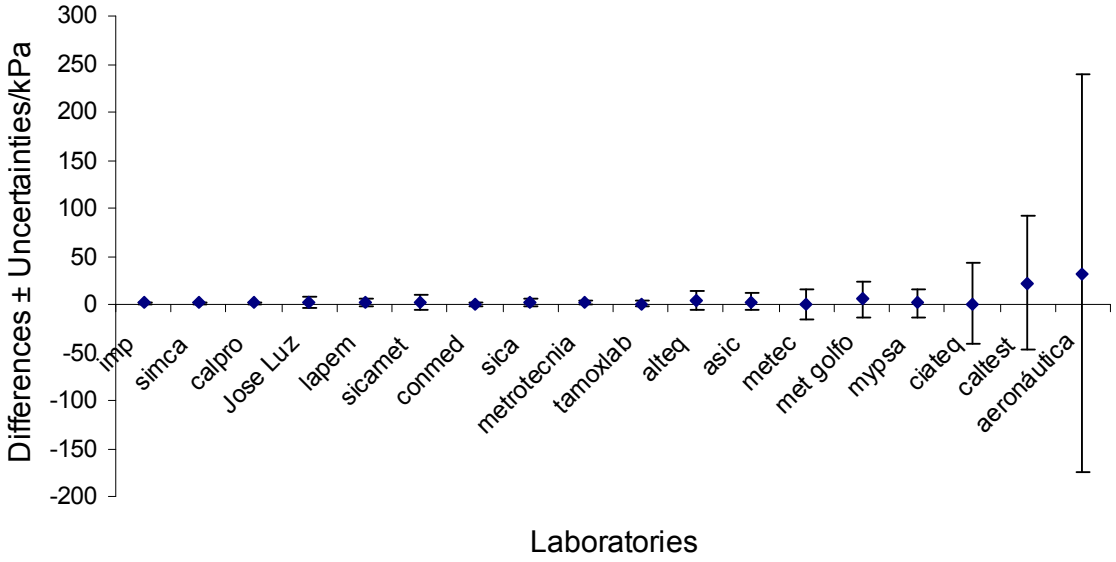
## 3. Results

Graph 2 shows the differences between the errors found for the TS by each laboratory against the reference value set by CENAM.



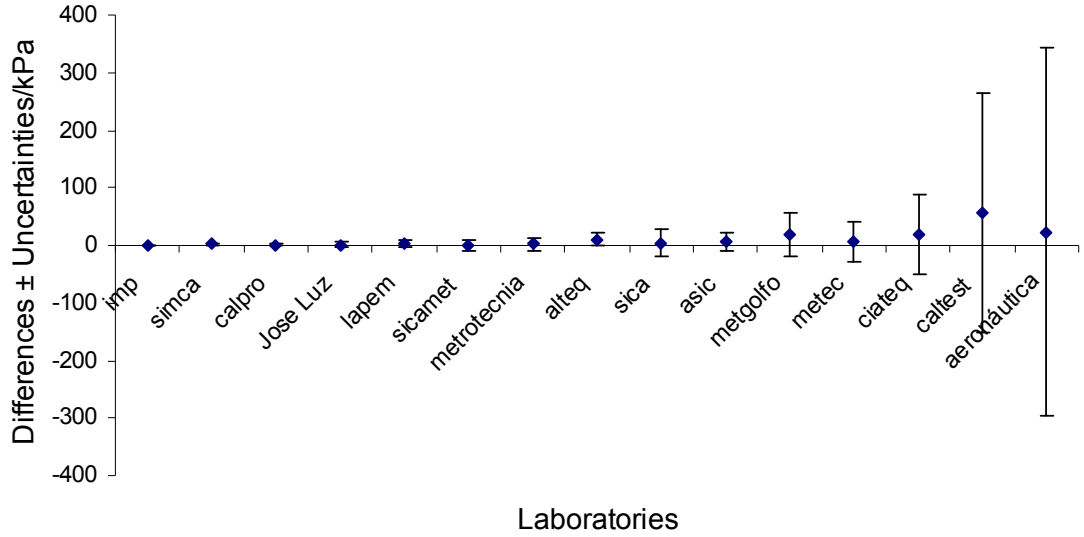

Graph 2. Differences between the errors reported by the laboratories and those set by CENAM as reference values for each measured pressure (absolute values).

Graph 3 presents the differences between the error at 7 MPa found by CENAM and the error reported by the participant laboratories; the uncertainty assigned by each laboratory for this pressure point is also included.



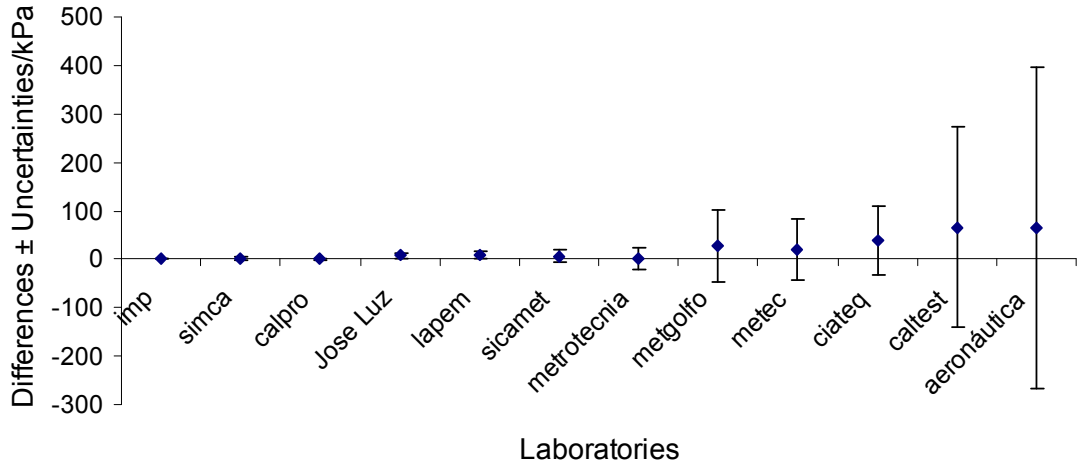

Graph 3. Differences between the errors reported by the laboratories and those set by CENAM as reference value for 7 MPa (absolute values). The uncertainty reported by each laboratory for this pressure is included.

In Graph 4, the difference of the errors found by each laboratory against the reference value established by CENAM at 35 MPa are shown; the uncertainty in each pressure point measured is also included.




Graph 4. Differences between the errors reported by the laboratories and those set by CENAM as reference value for 35 MPa (absolute values). The uncertainty reported by each laboratory for this pressure is included.

Graph 5 presents the differences of the errors at 70 MPa between CENAM's error reference value and the participant laboratories reported error values; the uncertainty assigned by each laboratory for this pressure point is also included.




Graph 5. Differences between the errors reported by the laboratories and those set by CENAM as reference value for 70 MPa (absolute values). The uncertainty reported by each laboratory for this pressure is included.

## 4. Discussion

The degree of equivalence between the results of the measurements made by the laboratories was evaluated using the normalized error equation according to the expression of Equation 1.

$$E_N = \frac{|E_L - E_R|}{\sqrt{U_L^{\,2} + U_R^{\,2}}} \qquad (1)$$

Where,

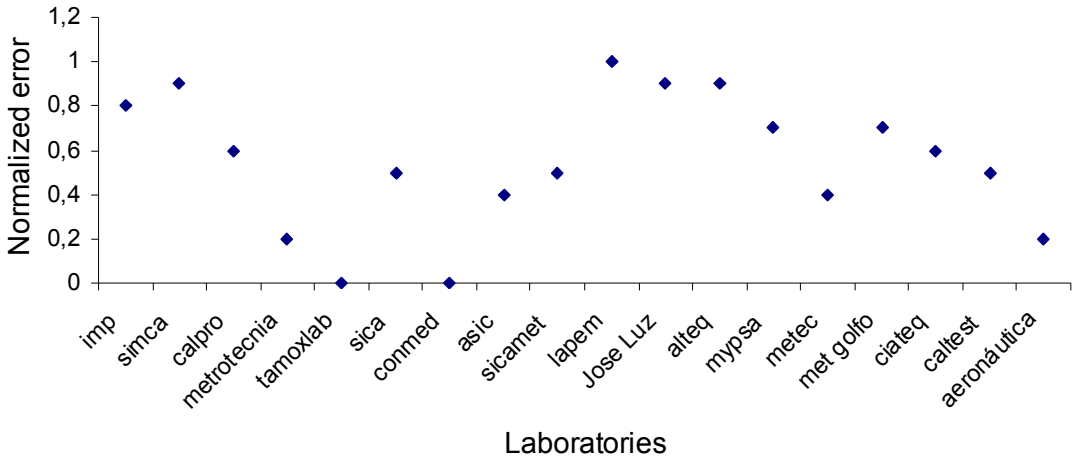
$E_N$ Normalized error calculated at each calibration pressure,
$E_R$ CENAM's estimated error,
$E_L$ Laboratory's estimated error,
$U_R$ CENAM's estimated expanded uncertainty,
$U_L$ Laboratory's estimated expanded uncertainty.

The results of the application of the normalized error equation to the calibrations made by the Laboratories are shown in Table 3. Also, the maximum difference for each laboratory in all measuring range and maximum uncertainty ($k$ = 2) found for the range are included.

Table 3
Normalized error equation values of the Laboratories

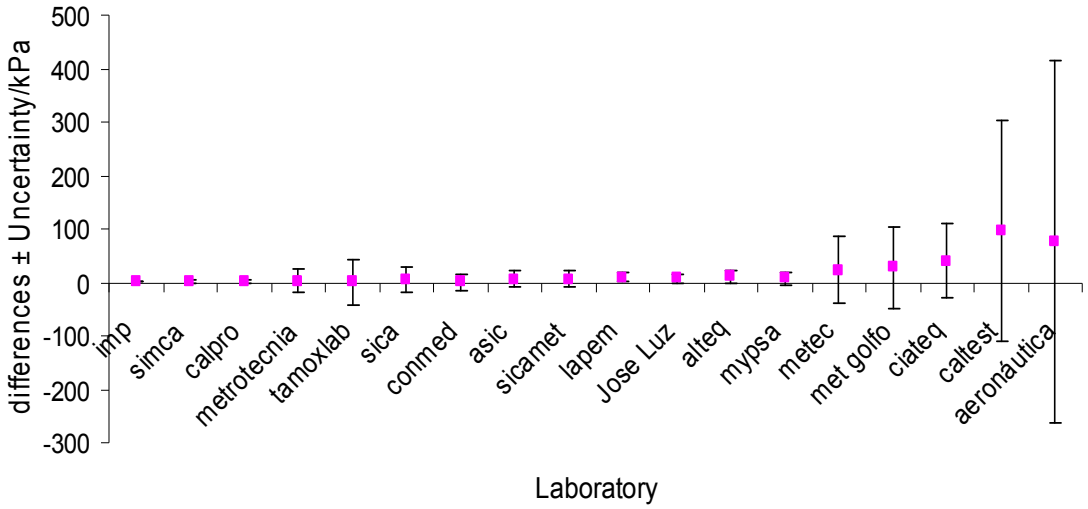
| Laboratory | Normalized error value | Maximum difference kPa | Maximum uncertainty ($k$=2) kPa |
|---|---|---|---|
| Imp | 0.8 | 1.8 | ± 1.0 |
| Simca | 0.9 | 2.8 | ± 3.2 |
| Calpro | 0.6 | 1.3 | ± 3.0 |
| Metrotecnia | 0.2 | 2.5 | ± 22 |
| Tamoxlab | 0.0 | 0.9 | ± 42 |
| Sica | 0.5 | 4.7 | ± 25 |
| Conmed | 0.0 | 0.5 | ± 16 |
| Asic | 0.4 | 6.7 | ± 15 |
| Sicamet | 0.5 | 6.4 | ± 14 |
| Lapem | 1.0 | 9.1 | ± 8 |
| Jose Luz | 0.9 | 7.2 | ± 7 |
| Alteq | 0.9 | 10.7 | ± 11 |
| Mypsa | 0.7 | 7.8 | ± 11 |
| Metec | 0.4 | 23.4 | ± 63 |
| Met Golfo | 0.7 | 27.4 | ± 76 |
| Ciateq | 0.6 | 39.7 | ± 70 |
| Caltest | 0.5 | 97.2 | ± 207 |
| Aeronáutica | 0.2 | 75.6 | ± 340 |

In Graph 6, the maximum normalized error values found by each laboratory are shown.



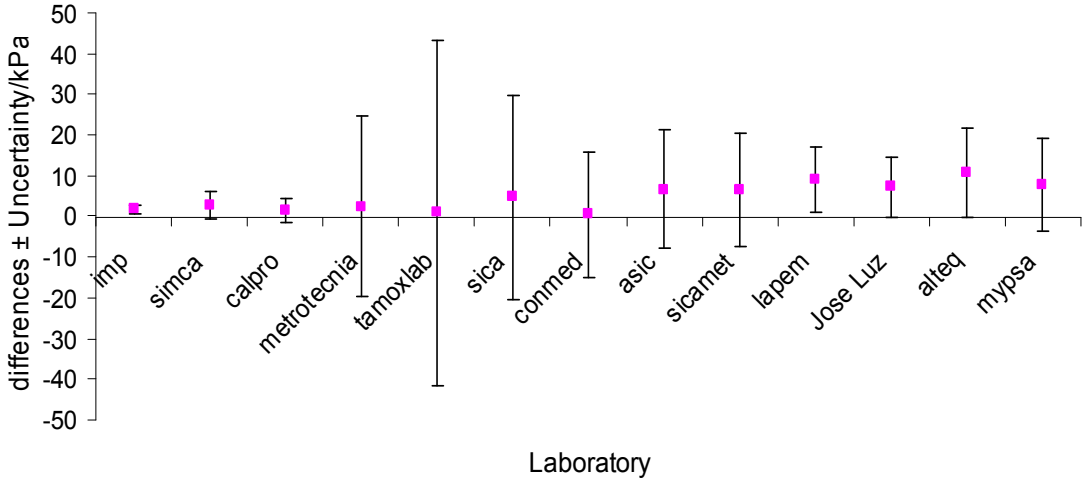
Graph 6. Maximum normalized error found by each laboratory.

In Graph 7, the maximum differences found for the whole range by each laboratory are shown. Also, the maximum uncertainty is included.




Graph 7. Maximum differences found by each laboratory.

In Graph 8, after filtering the laboratories which had too high uncertainty, the maximum differences found for the whole range by each laboratory are shown. Also, the maximum uncertainty is included.




Graph 8. Maximum differences found by each laboratory, after filtering laboratories with too high uncertainties.

## 5. Conclusions

A proficiency test is an adequate tool to estimate the level of confidence of the measurements carried out by secondary calibration laboratories. In a given proficiency test, it is also possible to verify different classes of laboratories, low level of uncertainties and high level of uncertainties.

In this proficiency test, all participating laboratories demonstrated good agreement with the reference values, taking into account the uncertainties declared in their best measurement capability used for their accreditation.

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