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# Continuous improvement of a Mexican pressure calibration secondary laboratory

F. J. Cedillo, R. L. Villeda.

Calibraciones Profesionales e Ingeniería S.A. de C.V.

**Abstract**

The present article has as main objective showing the evolution of a Mexican pressure calibration secondary laboratory based on comparisons. This could be thought to be a reflection of the maturity and metrological culture dissemination from the Centro Nacional de Metrología (Mexican National Centre of Metrology, CENAM). The participation in a total of 10 comparisons through one decade as a secondary laboratory is analyzed in 4 subintervals. Due to the big measurement range covered, from -70 kPa up to 70 000 kPa, to analyzed in only one graph would be a little illustrative.

*Keywords:* secondary laboratory, pressure, comparison, normalized error, uncertainty.

## 1. Introduction

CalPro was born as a secondary calibration laboratory on May 27th 1999, previously the trade name was Habinsa, company, name used in participation 1 of 10 comparisons analyzed in this paper:

| Comparison Date | Range | Transfer Standard | Publication results | Report |
|---|---|---|---|---|
| From 97-08-13 to 98-04-21 | 0,7 MPa to 35 MPa | Pressure Balance Ametek Accuracy: ±0,025% of R. | 1998-06-12 Ref. : DMM721-024-98 | No Satisfactory |
| From 99-07-20 to 99-09-13 | -100 kPa to 0 kPa | Vacuum Gauge Druck Accuracy: ±0,025% F.S. | 1999-12-10 Ref. DMM721-069-99 | No Satisfactory |
| From 02-12 to 03-01-07 | 5 MPa to 50 MPa | Pressure Balance DH Accuracy: ±0,005% of R. | 2003-01-10 Ref.: Inf. De Comp. Cenam | Satisfactory |
| From 03-05-28 to 03-06-25 | 20 MPa to 50 MPa | Pressure Standard Paroscientific Accuracy: ±0,01% E.T. | 2003-07-08 Ref.: Inf. Comp. Cenam | Satisfactory |
| From 03-05-06 to 03-10-01 | 0,21 MPa to 2,1 MPa | Pressure Standard Paroscientific Accuracy: ±0,01 E.T | 2003-10 Ref.: Simposio de Metrología 2003 | Satisfactory |
| From 04-10-21 to 04-12-25 | 0,7 MPa to 7 MPa | Pressure Standard DH Accuracy: ±0,01%L | 2005-10-17 Ref.: SNC. P-7 | No Satisfactory |
| From 05-08-12 to 05-11-11 | 7 MPa to 50 MPa | Pressure Balance Ametek Accuracy: ±0,1%L | 2006-07-10 Ref.: CNM-EA-720-010/2006 | Satisfactory |

| | | | | |
|---|---|---|---|---|
| From 05-08-12 to 06-01-17 | 0,27 MPa to 2,7 MPa | Pressure Standard Paroscientific Accuracy: ±0,01 E.T | 2006-07-10 Ref.: CNM-EA-720-01/2006 | Satisfactory |
| From 06-10-25 to 07-01-18 | -70 kPa to -7 kPa | Pressure Gauge Druck Accuracy: ± 0,05% E.T | 2007-05-02 Ref.: CNM-EA-720-024/2007 | Satisfactory |
| From 06-10-25 to 07-01-12 | 7 MPa to 70 MPa | Pressure Gauge Druck Accuracy: ± 0,05% E.T | 2007-05-02 Ref.: CNM-EA-720-044/2007 | Satisfactory |

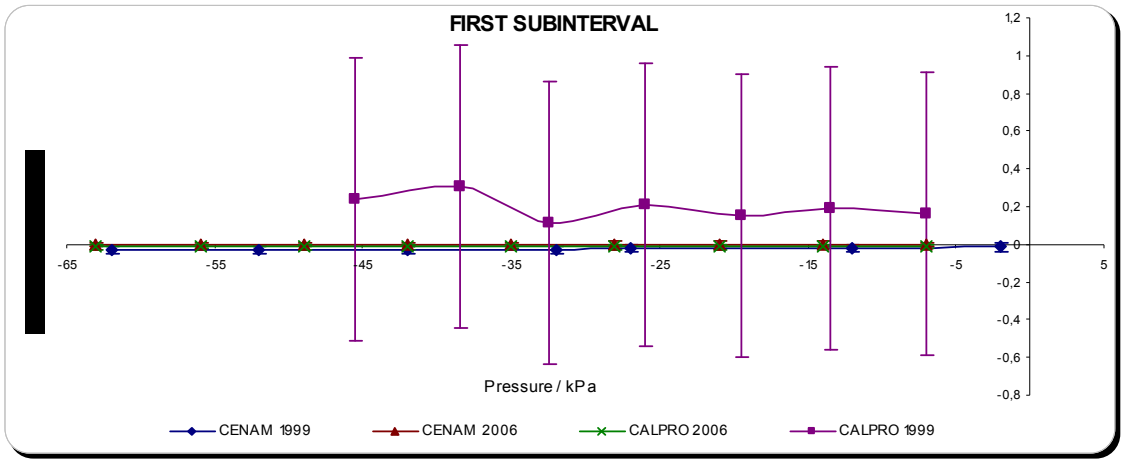
*1.1 Justification*

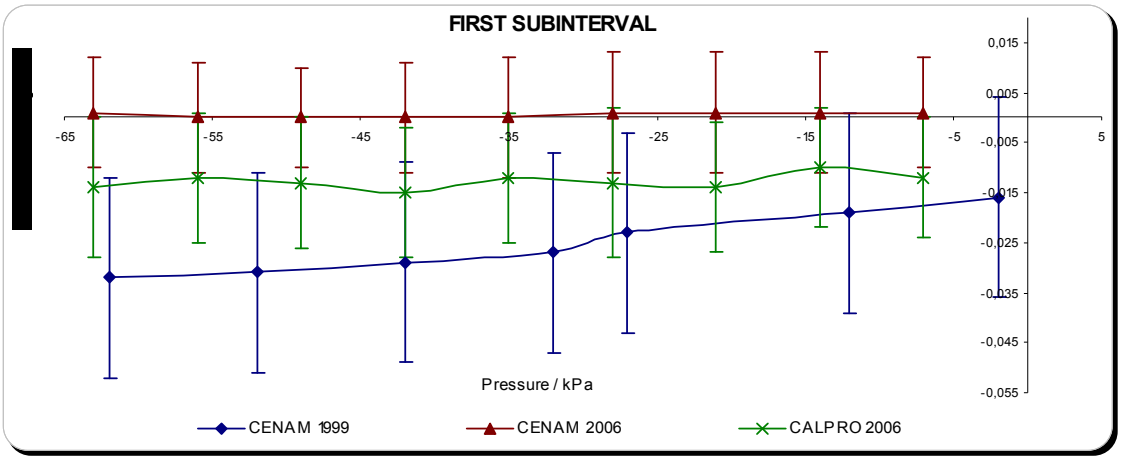
The present article has as main objective showing the evolution of a secondary laboratory based on the comparisons, which could be a reflection of the dissemination of the metrological culture according to the National Center of Metrology. From this total of 10 comparisons through one decade as secondary laboratory is analyzed in 4 subintervals, due to wide range of measurement, participating from -70 kPa to 70 000 kPa.

The subintervals to analyze will be:
First Subinterval: 2 Comparisons in Negative gauge pressure (Vacuum) with digital pressure manometer as transfer standard (- 63 kPa to -2 kPa).
Second Subinterval: 3 Comparisons in Pneumatic gauge pressure with digital pressure manometer as transfer standard (210 kPa to 6 300 kPa).
Third Subinterval: 2 Comparisons in Hydraulic gauge Pressure with digital pressure manometer as transfer standard (7 MPa to 70 MPa)
Fourth Subinterval: 3 Comparisons in Hydraulic gauge pressure with pressure dead weight tester as transfer standard (5 MPa to 50 MPa)

## 2. Results

*2.1 First Subinterval. Comparisons in Negative Pressure dated 1999-07 and 2006-11*






Because in the comparison of 1999 the results by standard normalized error were not analyzed, after that the analysis of both cases by this method is made to be able to observe the improvement in the calibration systems.

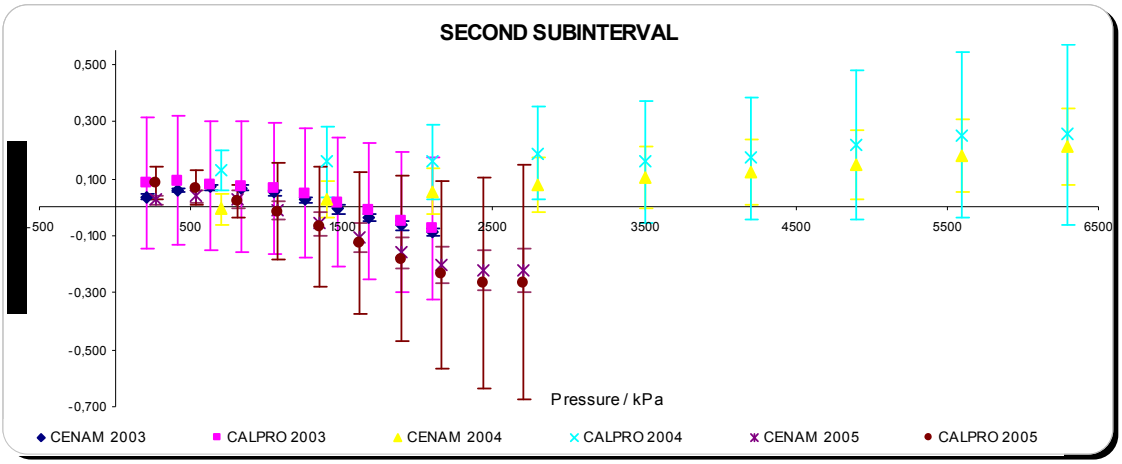
| 1999-07-27 | | | | | | | 2006-11-10 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pn (kPa) | Ecnm | Ucnm | Pn (kPa) | Elab | Ulab | En | Pn (kPa) | Ecnm | Ucnm | Elab | Ulab | En |
| -2 | -0,016 | 0,020 | -7,0 | 0,16 | 0,75 | 0,2 | -7 | 0,001 | 0,011 | -0,012 | 0,012 | -0,8 |
| -12 | -0,019 | 0,020 | -13,5 | 0,19 | 0,75 | 0,3 | -14 | 0,001 | 0,012 | -0,010 | 0,012 | -0,6 |
| -27 | -0,023 | 0,020 | -19,5 | 0,15 | 0,75 | 0,2 | -21 | 0,001 | 0,012 | -0,014 | 0,013 | -0,8 |
| -32 | -0,027 | 0,020 | -26,0 | 0,21 | 0,75 | 0,3 | -28 | 0,001 | 0,012 | -0,013 | 0,015 | -0,7 |
| -42 | -0,029 | 0,020 | -32,5 | 0,11 | 0,75 | 0,2 | -35 | 0,000 | 0,012 | -0,012 | 0,013 | -0,7 |
| -52 | -0,031 | 0,020 | -38,5 | 0,31 | 0,75 | 0,5 | -42 | 0,000 | 0,011 | -0,015 | 0,013 | -0,9 |
| -62 | -0,032 | 0,020 | -45,5 | 0,24 | 0,75 | 0,4 | -49 | 0,000 | 0,010 | -0,013 | 0,013 | -0,8 |
| | | | | | | | -56 | 0,000 | 0,011 | -0,012 | 0,013 | -0,7 |
| | | | | | | | -63 | 0,001 | 0,011 | -0,014 | 0,014 | -0,8 |

Where:
Pn Is the Nominal Pressure of the comparison point.
Ecnm: It is the error average reported by CENAM
Ucnm: It is the uncertainty reported by CENAM
Elab: It is the error average reported by CalPro
Ulab: It is the uncertainty reported by CalPro
En: It is the standard normalized error considering that: $-1 \leq En \leq 1$ Satisfactory; $En > 1$ non Satisfactory

It is important to emphasize that at CalPro we had a better standard than at 1999, nevertheless the cause of the no consistent results was our lack of metrological culture at that moment, when not applying the pertinent corrections to the standard, which origin in bad results, nowadays is possible to accentuate that the results emitted by our laboratory count on uncertainties of up to 1.05 more times that the uncertainty reported by CENAM.

Detected and Implemented Points of Improvement: Qualification and Equipment Pattern in This Interval

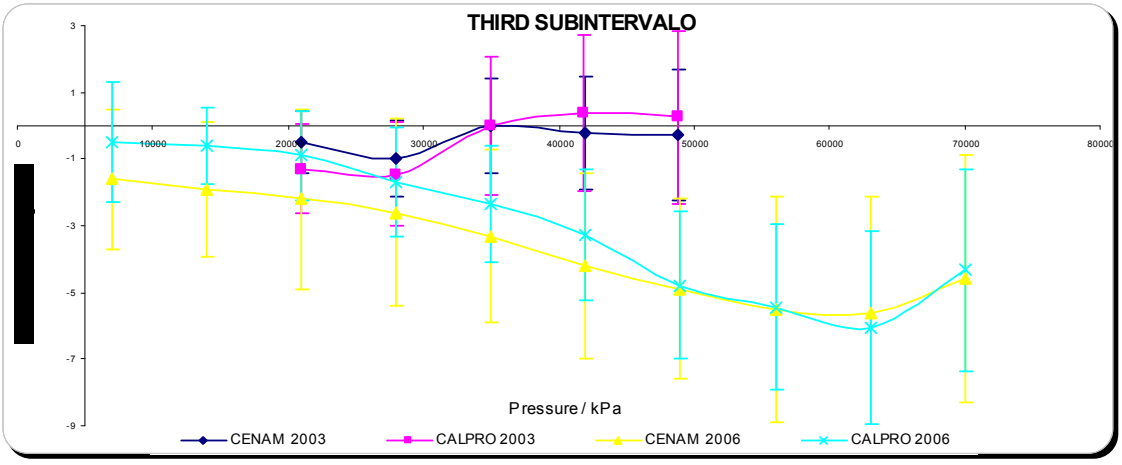
*2.2 Second Subinterval: Comparisons in pneumatic positive pressure dated to the 2003-06, 2004-11 and 2005-09*




In the previous graph it is observed that in the 2003, CalPro's uncertainty reported by CENAM was of 17 to 28 times, in 2004 CalPro reports uncertainties of 1.4 to 2.4 times and in 2005 CalPro reports uncertainties of 2 to 5.4 times. In 2004 was when CalPro has 1 point with a standard normalize error from 1.57 to 700 kPa, which implies an analysis of causes. For these three CalPro calibrations uses as standard a Pressure Balance of high exactitude manufacturer DH Instruments with a piston and cylinder of 100 MPa of calibrated hydraulic operation in effective area in the interval of 10 MPa to 100 MPa, which if we analyzed this standard this being used from 0,21% to 6,3% of the scope of the standard. It is possible to indicate that for the calibration in the three comparisons, an interphase of liquid to gas was used manufacturer DH Instruments.

Detected and Implemented points of Improvement: Calibration of the piston and cylinder in effective area in the interval of 0.2 MPa to 8 MPa.

*2.3 Third Subinterval Comparisons in hydraulic positive pressure dated in 2003-05 and 2006-11*



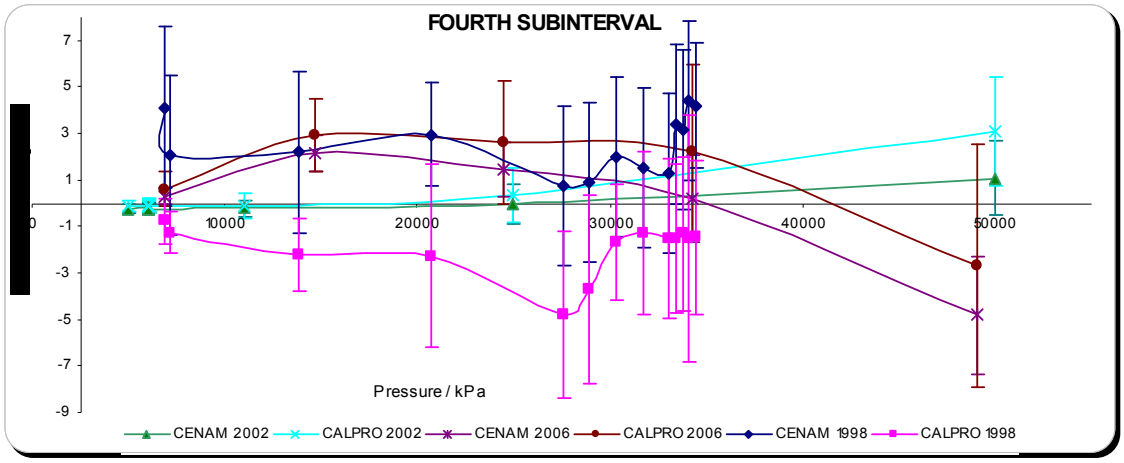

As seen in the previous graph the uncertainty of CalPro reported in the 2006 goes up to 0.85 0.49 times that CENAM uncertainty case in opposition to the comparison of the 2003. For both comparisons we used the same standard that was used in the second interval comparisons.

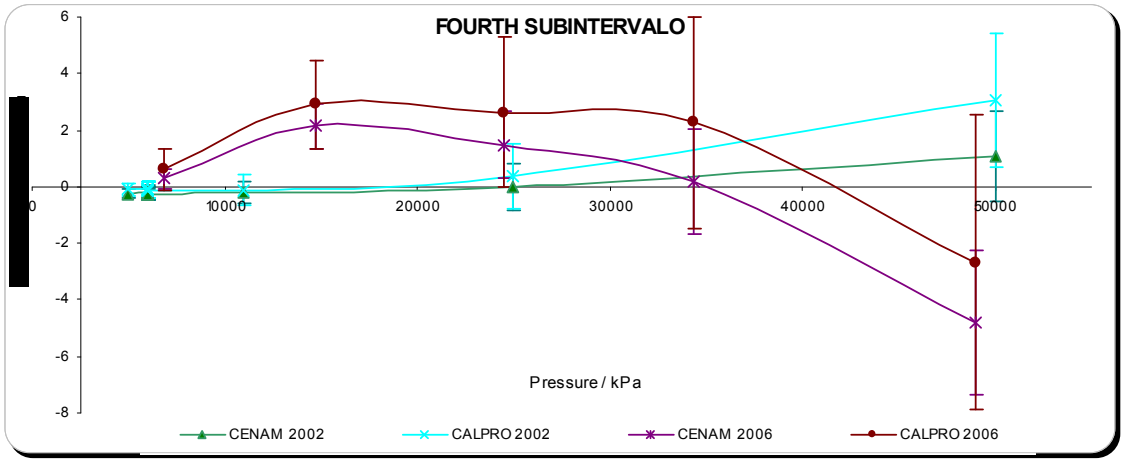
| 2003-05-14 | | | | | | | 2006-11-10 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pn (kPa) | Ecnm | Ucnm | Pn (kPa) | Elab | Ulab | En | Pn(kPa) | Ecnm | Ucnm | Elab | Ulab | En |
| 20945 | -0,49 | 0,91 | 20941 | -1,28 | 1,35 | -0,49 | 7000 | -1,6 | 2,10 | -0,5 | 1,789 | 0,40 |
| 27926 | -0,97 | 1,16 | 27921 | -1,45 | 1,56 | -0,25 | 14000 | -1,9 | 2,00 | -0,59 | 1,161 | 0,57 |
| 34908 | 0,02 | 1,42 | 34901 | -0,02 | 2,07 | -0,02 | 21000 | -2,2 | 2,70 | -0,89 | 1,33 | 0,44 |
| 41889 | -0,2 | 1,69 | 41881 | 0,386 | 2,35 | 0,20 | 28000 | -2,6 | 2,80 | -1,69 | 1,626 | 0,28 |
| 48871 | -0,26 | 1,95 | 48861 | 0,252 | 2,6 | 0,16 | 35000 | -3,3 | 2,60 | -2,33 | 1,737 | 0,31 |
| | | | | | | | 42000 | -4,2 | 2,80 | -3,29 | 1,963 | 0,27 |
| | | | | | | | 49000 | -4,9 | 2,70 | -4,79 | 2,208 | 0,03 |
| | | | | | | | 56000 | -5,5 | 3,40 | -5,44 | 2,49 | 0,01 |
| | | | | | | | 63000 | -5,6 | 3,50 | -6,05 | 2,907 | -0,10 |
| | | | | | | | 70000 | -4,6 | 3,70 | -4,33 | 3,024 | 0,06 |

The 2003 results served to demonstrate the request for uncertainty of 50 ppm in the accreditation. The comparison at 2006 reaffirms the accountability of the measurements of CalPro in the interval where it counts on better ability of measurement.

Detected and Implemented points of Improvement: Theoretical preparation of the personnel who takes measurements since practically they demonstrated technical competition.

*2.4 Fourth Subinterval. Comparisons in hydraulic positive pressure to Balances of Pressure by the method of cross float dated to the 1998-02-20, 2002-12 and 2005-09-30*




In the calibration of Pressure Balances by cross float method where CalPro has demonstrated the best ability of measurement, since in 2002 and 2006

consistent results were obtained at least, in 1998 greater gradient is observed between the errors, nevertheless the uncertainties reported by CalPro in some cases are smaller to the reported ones by CENAM as it is in the following table, but we compared the uncertainties of 2002 and 1998 and there is a relation of up to 20 to 1 between the values of uncertainty reported by CENAM.

| 1998-02-20 | | | | | | 2002-12 | | | | | | 2005-09-30 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pn (kPa) | Ecnm | Ucnm | Elab | Ulab | En | Pn (kPa) | Ecnm | Ucnm | Elab | Ulab | En | Pn (kPa) | Ecnm | Ucnm | Elab | Ulab | En |
| 6900 | 4,14 | 3,45 | -0,76 | 0,965 | -1,4 | 5000 | -0,235 | 0,166 | -0,09 | 0,236 | 0,5 | 6865 | 0,294 | 0,353 | 0,598 | 0,735 | 0,37 |
| 7200 | 2,07 | 3,45 | -1,24 | 0,896 | -0,9 | 6000 | -0,174 | 0,198 | -0,09 | 0,282 | 0,2 | 14710 | 2,157 | 0,794 | 2,903 | 1,569 | 0,42 |
| 13800 | 2,21 | 3,45 | -2,21 | 1,586 | -1,2 | 6000 | -0,193 | 0,198 | -0,11 | 0,282 | 0,2 | 24517 | 1,471 | 1,177 | 2,638 | 2,648 | 0,40 |
| 20700 | 2,96 | 2,21 | -2,28 | 3,93 | -1,2 | 6000 | -0,185 | 0,198 | -0,11 | 0,282 | 0,2 | 34323 | 0,196 | 1,863 | 2,265 | 3,727 | 0,50 |
| 27600 | 0,76 | 3,45 | -4,76 | 3,585 | -1,1 | 6000 | -0,233 | 0,198 | -0,13 | 0,282 | 0,3 | 49033 | -4,805 | 2,550 | -2,677 | 5,198 | 0,37 |
| 28900 | 0,90 | 3,45 | -3,72 | 4,068 | -0,9 | 6000 | -0,233 | 0,198 | -0,12 | 0,282 | 0,3 | | | | | | |
| 30300 | 2,00 | 3,45 | -1,65 | 2,482 | -0,9 | 6000 | -0,203 | 0,198 | -0,1 | 0,282 | 0,3 | | | | | | |
| 31700 | 1,52 | 3,45 | -1,31 | 3,516 | -0,6 | 6000 | -0,252 | 0,198 | -0,1 | 0,282 | 0,4 | | | | | | |
| 33100 | 1,31 | 3,45 | -1,52 | 3,447 | -0,6 | 6000 | -0,234 | 0,198 | -0,09 | 0,282 | 0,4 | | | | | | |
| 33400 | 3,38 | 3,45 | -1,52 | 3,172 | -1,0 | 6000 | -0,236 | 0,198 | -0,11 | 0,282 | 0,4 | | | | | | |
| 33800 | 3,17 | 3,45 | -1,31 | 3,309 | -0,9 | 11000 | -0,201 | 0,356 | -0,11 | 0,518 | 0,1 | | | | | | |
| 34100 | 4,41 | 3,45 | -1,52 | 5,309 | -0,9 | 25000 | -0,037 | 0,832 | 0,37 | 1,178 | 0,3 | | | | | | |
| 34500 | 4,21 | 2,69 | -1,45 | 3,309 | -1,3 | 50000 | 1,096 | 1,61 | 3,08 | 2,362 | 0,7 | | | | | | |

Note: The comparison at 2002 in its original report, the analysis this fact with a factor of cover of k=1 but, for this revision occurred a factor of cover of k=2. As it is observed the results of the standard normalized error are satisfactory in 2002 and 2006.

Detected and Implemented Points of Improvement: The uncertainty reported in the comparison of the 2006 is approximately of 100 x $10^{-6}$ counting our laboratory with 50 x $10^{-6}$ as better ability of measurement, same that would also offer satisfactory results but this takes us to analyze the model of propagation of uncertainties for industrial pressure balances type since one of the variables of 100 influence which I include myself and I help to ppm is the contribution by exactitude class of calibrating equipment.

## 3. Conclusions

Due to the experience gain on these 10 comparisons, we can say that improvement opportunities are always detected and if they are taken care of there is guarantee that better results will be obtained for the future. Finally, we trusted fully that there is not a better way to validate a method than a comparison with a solid reference and the best is undoubtedly that given by CENAM, the National Centre of Metrology in Mexico, our natural reference and the millstone for our traceability.

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