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FORCE TRANSDUCER CALIBRATION COMPARISON BETWEEN PTB (GERMANY), CEM (SPAIN) AND LABORATORIO CUSTODIO DE PATRONES NACIONALES DE FUERZA (CHILE)

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Abstract - A force transducer calibration comparison was carried out between Laboratorio Custodio de Patrones Nacionales de Fuerza (in Chile), Centro Español de Metrología (in Spain) and Physikalisch-Technische Bundesanstalt (in Germany), in order to compare and to evaluate the results of the calibrations of force transducers. The calibration comparison was carried out for the range of 100 kN.
The calibrations was made in conformity with the standard ISO 376:99. The results obtained, the deviation graphs that include the uncertainty for each laboratory are presented in this document.

1. INTRODUCTION

Within the framework of the Physikalisch- Technische Bundesanstalt (PTB, Germany)- Centro Español de Metrología (CEM, Spain) and Laboratorio Custodio de Patrones Nacionales de Fuerza (Chile) collaboration, a calibration force comparison was carried out in order to estimate the level of agreement of the results, and the uncertainty associated to their measurements. This constitutes the first exercise of comparison between the three institutions.

1.1 Scope of work

The ISO publication "International Vocabulary of Basic and General Terms of Metrology" (VIM), and the International System of Units, SI, were used for the comparison and for writing this document. The recommendations in the Guide to the expression of Uncertainty in Measurements and the Guidelines for key comparison carried out by consultative Committees were followed (1,2,3,4).

1.2 Program objectives

To compare the results of the calibration of a 100 kN force transducer in compression.

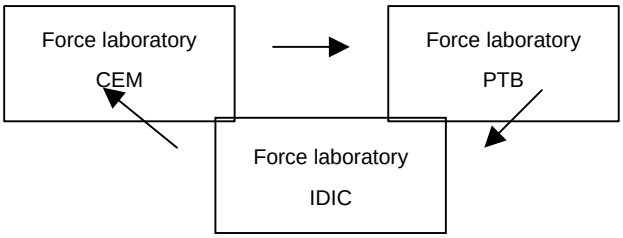
2. COMPARISON

2.1 Comparison standard

In this comparison one force transducer was used, and each laboratory used it's own means (digital amplifier, force standard machine).

2.2 Comparison round

The comparison was performed including initial measurements at the IDIC force laboratory, measurements at CEM and PTB and final measurements at IDIC, as it is shown in the next figure.



2.3 General guidelines and procedure

The most relevant aspects of the measurement procedure and comparison conditions were developed in agreement with the standard ISO 376:99. The measurement uncertainty was evaluated according to ISO guide "expression of Uncertainty in Measurements" and to the document EA-10/04 "Uncertainty of calibration results in force measurements".(10)
As IDIC made two calibrations, at the beginning and at the end, the reference value assumed for it, was the average value of these two measurements.
From the measurement results obtained by each laboratory, are determined the following parameters: deformation (Xr), reproducibility (b), repeatability (b') and reversibility (v).
To determine the quality of measurement results between labs, normalized error is evaluated:

$$E_n = \frac{\left(\bar{X}_r\right)_{lab1} - \left(\bar{X}_r\right)_{lab2}}{\sqrt{U_{lab1}^2 + U_{lab2}^2}} \leq 1$$

3. COMPARISON STANDARDS

The force standard machines of CEM and PTB are dead-weight type (DWM) and a comparison type in the case of IDIC.

The information of the standards used by each laboratory is presented in table 1

Instrument	IDIC	CEM	PTB
Digital Amplifier	DMP40 HBM	DMP40 HBM	DMP40 HBM
Standards Laboratories	Comparison force calibration machine 500 kN Ref: STFR Morehouse 500 kN - N° 7339	Dead-weight force standard machine 500 kN Ref: 5.1-01.01-001	Dead-weight force standard machine 100 kN Ref: DWM-100K
Force Transducer	100 kN HBM	100 kN HBM	100 kN HBM

1. RESULTS

IDIC carried out the stability analysis of the force transducer previous the comparison. Due to IDIC made two calibration measurements, at the beginning and at the end, the reference value assumed was the average value.

TABLE 1. Xr values (mV/V)

kN	1ª IDIC	2ª IDIC	ref IDIC	CEM	PTB
10	0,199954	0,199968	**0,199961**	0,199914	0,199925
20	0,399913	0,399936	**0,399925**	0,399827	0,399836
30	0,599855	0,599867	**0,599861**	0,599726	0,599737
40	0,799758	0,799781	**0,799770**	0,799610	0,799619
50	0,999630	0,999604	**0,999617**	0,999477	0,999486
60	1,199478	1,199454	**1,199466**	1,199328	1,199335
70	1,399321	1,399281	**1,399301**	1,399165	1,399163
80	1,599093	1,599089	**1,599091**	1,598980	1,598974
90	1,798907	1,798859	**1,798883**	1,798772	1,798764
100	1,998658	1,998601	**1,998630**	1,998537	1,998526

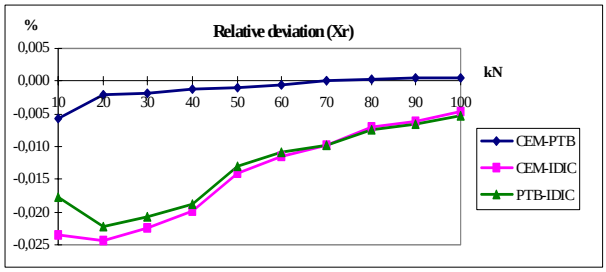


Fig. 1. Relative deviation (Xr) between labs

Following graphs and tables show differences between participant laboratories relating to metrological parameters:

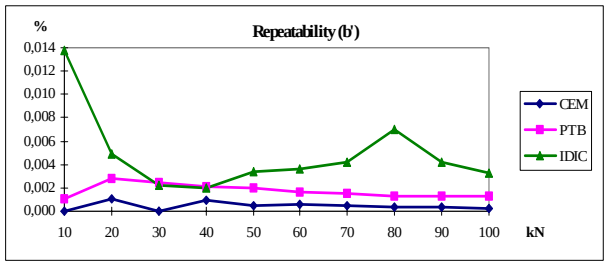


Fig. 2. Repeatability of the force transducer calibration

TABLE 2. Repeatability (%)

kN	CEM	PTB	IDIC
10	0,0000	0,0010	0,0138
20	0,0010	0,0028	0,0049
30	0,0000	0,0025	0,0023
40	0,0009	0,0021	0,0019
50	0,0005	0,0020	0,0034
60	0,0006	0,0016	0,0036
70	0,0005	0,0015	0,0043
80	0,0004	0,0013	0,0070
90	0,0003	0,0013	0,0042
100	0,0003	0,0013	0,0032

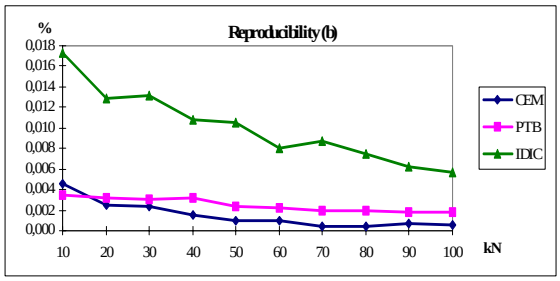


Fig. 3. Reproducibility of the force transducer calibration

TABLE 3. Reproducibility (%)

kN	CEM	PTB	IDIC
10	0,0045	0,0035	0,0173
20	0,0025	0,0033	0,0129
30	0,0023	0,0030	0,0132
40	0,0015	0,0031	0,0108
50	0,0009	0,0023	0,0105
60	0,0009	0,0022	0,0080
70	0,0004	0,0019	0,0088
80	0,0004	0,0019	0,0075
90	0,0007	0,0018	0,0063
100	0,0005	0,0019	0,0056

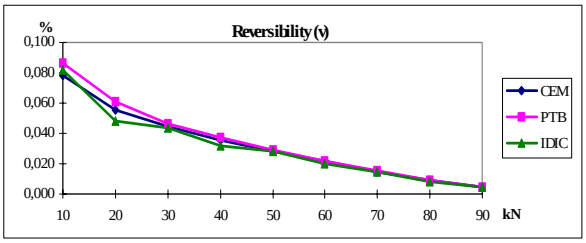


Fig. 4. Reversibility of the force transducer calibration

TABLE 4. Reversibility (%)

kN	CEM	PTB	IDIC
10	0,0783	0,0865	0,0818
20	0,0555	0,0605	0,0485
30	0,0443	0,0467	0,0435
40	0,0355	0,0368	0,0322
50	0,0280	0,0288	0,0286
60	0,0215	0,0216	0,0201
70	0,0149	0,0151	0,0144
80	0,0093	0,0093	0,0086
90	0,0043	0,0043	0,0043

Expanded Uncertainty for each laboratory. Values in % F

kN	CEM	PTB	IDIC
10	0,0455	0,0502	0,0707
20	0,0324	0,0353	0,0584
30	0,0259	0,0274	0,0569
40	0,0210	0,0219	0,0541
50	0,0167	0,0173	0,0533
60	0,0131	0,0133	0,0518
70	0,0096	0,0099	0,0513
80	0,0068	0,0072	0,0508
90	0,0049	0,0053	0,0505
100	0,0042	0,0047	0,0504

Values of Normalized Error:

kN	CEM-PTB	CEM-IDIC	PTB-IDIC
10	0,084	0,279	0,205
20	0,045	0,364	0,325
30	0,047	0,360	0,328
40	0,037	0,343	0,322
50	0,037	0,250	0,233
60	0,031	0,215	0,204
70	0,012	0,186	0,189
80	0,036	0,136	0,143
90	0,061	0,122	0,131
100	0,087	0,092	0,102

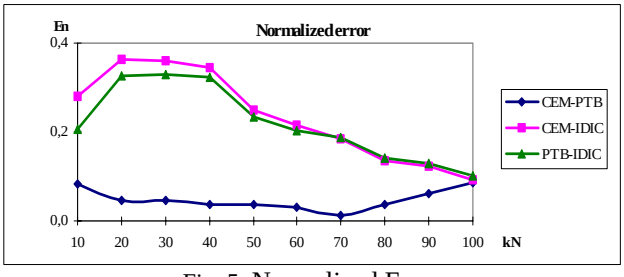


Fig. 5. Normalized Error

5. CONCLUSIONS AND DISCUSSIONS

From the graphs, it can be observed that the uncertainties were calculated by each laboratory according to EA 10/04, showing that is an easy and practical guide for the calibration of commercial force transducers.

IDIC, CEM and PTB have compared their results of the force calibration by means of one commercial force transducer of 100 kN without performing preliminary measurements. The transducer behavior was such that it has facilitated the comparison. The results have demonstrated a good agreement between the three laboratories. The normalized error obtained allow to assess the compatibility between the three laboratories in the 100 kN force range in compression.

These results may be useful for the calibration laboratories which look for traceability to national standards.

6. REFERENCES

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(6) EAP-P7, EAL Interlaboratory Comparisons 1996.
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(10) EA 10/04 guide : Uncertainty of calibration results in force measurements

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