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Cross-floating calibration study. Trim masses: on the standard balance or on the balance under calibration

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ABSTRACT
The pressure balances are used as reference standards to calibrate secondary manometers and other balances. There are different types and models of pressure balances that cover measuring ranges from 3 kPa to 1 GPa. The pressure balances are designed to measure relative, absolute or differential pressure and some balances can measure all types of pressure. This paper presents the results of a study of high accuracy pressure balances cross-floating calibration comparing trim masses on the standard balance or on the balance under calibration.

Section: TECHNICAL NOTE

Keywords: pressure balances; cross-floating calibration; trim masses

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1. INTRODUCTION

The pressure balances are used as reference standards to calibrate secondary manometers and other balances. There are different types of pressure balances covering ranges from 3 kPa to 1 GPa. The pressure balances measure relative, absolute or differential pressure and some measure all types of pressure. This paper is a part of a project within Mexico to aid secondary calibration laboratories to better use their high accuracy pressure balances for calibration and internal traceability. The calibration of pressure balances or dead weight balances is of high importance in secondary laboratories, as well as in industry. This type of calibrations is performed by the cross-floating method. The method is for two pressure balances, connected together using a manometric fluid (i.e. gas or liquid) which transmits the pressure between them; the equilibrium must be achieved by adding or removing trim masses (small masses), either in the standard balance or in the balance under calibration. The piston-cylinder of each balance must be located at its floating level.

In Mexico, more than 12 secondary laboratories have high accuracy pressure balances as calibration standards. This paper presents the results of a study of high accuracy pressure balances cross-floating calibration comparing the use of the trim masses on the standard balance or on the balance under calibration [1]-[3].

2. STUDY

Two piston-cylinder calibrations (DH Instruments, 5300 model, 8666 serial number, 20 MPa maximum range, CENAMs property) were made (Table 1). The reference standard used was a DH Instruments, 5300 model, 5716 serial number piston-cylinder, 100 MPa maximum range. On the first calibration, the trim masses were added on the pressure balance under

Table 1. Standards used.

Description	Balance Under Calibration	Standard Balance
Manufacturer	DH Instruments	DH Instruments
Model	5300	5300
Serial number	8666	5716
Range	0.04 MPa to 20 MPa	0.2 MPa to 100 MPa

Calibration (Table 2). In the second calibration, the trim masses were added on the standard pressure balance (Table 3).

3. RESULTS

To evaluate the results obtained from the two calibrations the criteria used was the normalized error equation method.

$$E_\mathrm{n} = \frac{x_\mathrm{cal} - x_\mathrm{ref}}{\sqrt{U_\mathrm{cal}^2 - U_\mathrm{ref}^2}} \qquad (1)$$

where:

E_n is the normalized error;

x_cal is the area obtained by one method of calibration;

x_ref is the area obtained by the other method of calibration;

U_cal is the expanded uncertainty estimated for one method of calibration, (k = 2);

U_ref is the expanded uncertainty estimated for the other method of calibration, (k = 2).

From the normalized error equation model, if:

$|E_\mathrm{n}| \leq 1$ the results are compatible,

$|E_\mathrm{n}| > 1$ the results are not compatible.

By means of the results included in Tables 2 and 3, we can obtain the effective area and its uncertainty, for each type of calibrations as shown in Tables 4 and 5.

Figure 1 shows the results obtained in Tables 4 and 5 for the effective area A_effe and its uncertainty.

Normalized error equation method results can be calculated by means of the data in Tables 4 and 5, as presented in Table 6.

Figure 2 graphs the results included in Table 6.

Additionally to the calibrations made with the Mexican National Standard shown before (Figures 1 and 2), using the results from the original calibration made by the manufacturer for A_0, we can compare the results from both calibrations for A_0, as shown in Table 7, where A_0 is the effective area at zero pressure.

Table 2. Adding trim masses to the balance under calibration.

Nominal pressure / MPa	Masses, Standard balance / kg	Masses, Balance under calibration / kg
2.0	2.0	10.004 050
4.0	4.0	20.004 570
6.0	6.0	30.004 910
10.0	10.0	50.005 100
14.0	14.0	70.005 060
18.0	18.0	90.006 250
20.0	20.0	100.007 120

Table 3. Adding trim masses to the standard balance.

Nominal pressure / MPa	Masses, Standard balance / kg	Masses, Balance under calibration / kg
2.0	1.998 900	10.0
4.0	3.998 870	20.0
6.0	5.998 940	30.0
10.0	9.998 930	50.0
14.0	13.998 770	70.0
18.0	17.998 750	90.0
20.0	19.998 730	100.0

Table 4. Results adding trim masses to the balance under calibration.

Pressure / kPa	A_effe (20 °C) / m^2	Uncertainty / m^2	Relative uncertainty / A_effe	Pressure due to the trim masses / kPa
1 995.560	4.902 72 E-05	± 1.8 E-09	± 37 E-06	0.835
3 990.331	4.902 82 E-05	± 1.7 E-09	± 35 E-06	1.343
5 985.121	4.902 81 E-05	± 1.7 E-09	± 35 E-06	1.700
9 974.638	4.902 78 E-05	± 1.7 E-09	± 35 E-06	0.880
13 964.110	4.902 79 E-05	± 1.7 E-09	± 35 E-06	1.131
17 953.648	4.902 82 E-05	± 1.7 E-09	± 35 E-06	1.134
19 948.393	4.902 85 E-05	± 1.7 E-09	± 35 E-06	1.413

Table 5. Results adding trim masses to the standard balance.

Pressure / kPa	A_effe (20 °C) / m^2	Uncertainty / m^2	Relative uncertainty / A_effe	Pressure due to the trim masses / kPa
1 994.499	4.903 35 E-05	± 1.8 E-09	± 37 E-06	1.473
3 989.208	4.903 08 E-05	± 1.7 E-09	± 35 E-06	1.658
5 984.078	4.902 86 E-05	± 1.7 E-09	± 35 E-06	1.733
9 973.585	4.902 80 E-05	± 1.7 E-09	± 35 E-06	1.718
13 962.929	4.902 83 E-05	± 1.7 E-09	± 35 E-06	1.575
17 952.378	4.902 82 E-05	± 1.7 E-09	± 35 E-06	1.548
19 947.078	4.902 82 E-05	± 1.7 E-09	± 35 E-06	1.523

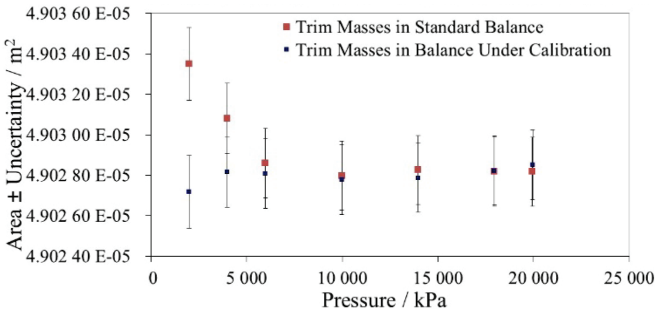

Figure 1. Results of effective area and its uncertainty for both calibrations made.

Table 6. Results adding trim masses to the standard balance.

Pressure / kPa	Trim masses on the standard balance A_effe (20 °C) / m^2	Trim masses on the balance under calibration A_effe (20 °C) / m^2	E_n
1 994.499	4.903 35 E-05	4.902 72 E-05	2.5
3 989.208	4.903 08 E-05	4.902 82 E-05	1.1
5 984.078	4.902 86 E-05	4.902 81 E-05	0.22
9 973.585	4.902 80 E-05	4.902 78 E-05	0.08
13 962.929	4.902 83 E-05	4.902 79 E-05	0.16
17 952.378	4.902 82 E-05	4.902 82 E-05	0.02
19 947.078	4.902 82 E-05	4.902 85 E-05	0.14

4. DISCUSSION

During the calibrations, all considerations for effective area pressure balance procedure were taken into account. From the two calibrations made, there are only one point bigger than one, E_n, with not compatible results. The form to realize the

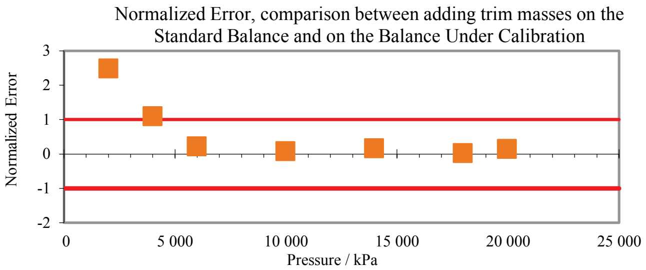

Figure 2. Normalized error equation results for the two calibrations.

Table 7. Normalized error equation results of the two calibrations using the manufacturer's first calibration information as reference.

Description	A_0 (20 °C) / m²	Uncertainty / m²	Relative uncertainty / m²	E_n
Manufacturer	4.902 67 E-05	± 3.9 E-09	± 80 E-06	---
Trim masses on the Standard Balance	4.903 17 E-05	± 2.1 E-09	± 42 E-06	1.1
Trim masses on the Balance Under Calibration	4.902 76 E-05	± 1.8 E-09	± 37 E-06	0.20

adjustment with trim masses is compatible using one or the other method for most of the target points calibrated.

As shown in Figures 1 and 2, comparing both results, the most significant difference for high accuracy pressure balances is in the low range of the calibration. On the other hand, the pressure generated by the trim masses, as shown in Tables 4 and 5, is in the order of 1.7 kPa, which is less than 0.009 % of the minimum range measured.

5. CONCLUSIONS

When comparing the A_0 results between the two methods with the Mexican national standard and alternatively with the results from the original calibration made by the manufacturer, both methods are compatible. Although, slightly better results were obtained by the method using the trim masses on the standard balance.

There is still more experiments to be carried out to discriminate other possible effects (i. e. different ranges, uncertainties, etc.). As general recommendation, it is better to use the minimum possible number of masses and trim masses.

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