BIPM Capacity Building & Knowledge Transfer Programme

2024 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Transducer-Aided-Crossfloat Calibration
Description	Use of a precise transducer as an alternative transfer standard method for cross float calibration
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Introduction

A piston gauge is critical devices for the realization and dissemination of the SI unit of pressure, the pascal (Pa). They make use of the simple relationship of pressure to the units force and length, pressure being an intrinsic property that is equal to the amount of force divided to a unit area. The key part of a piston gauge is the piston cylinder unit (PCU), for which the effective cross-sectional area is the metrological quantity. The calibration of a piston gauge can determine its generated pressure and effective area by cross-float measurements against a standard piston gauge. The traditional cross-float measurement achieves a balance condition of equal pressure between the standard and the test piston gauges by adjusting the trim masses loaded on one of gauges. However, this process requires significant expertise and is time consuming.

it requires many hours of attention from an experienced metrologist who must assess the state of the gauges during a cross-float (by measuring the fall rate of the piston in the cylinder) and add or remove tiny trim masses by hand to achieve the balance condition. We propose a modification to the cross-float calibration method where a pressure transducer is used as a very short-term transfer standard between the two piston gauges. It will allow for a much less stringent balance condition and lends itself to automation. this will enable automation of piston gauge calibrations and safe time for calibration. In this project, we compare Transducer -Aided crossfloat calibration method with a traditional cross-float method. In this study project, a new method was used in which a precise transducer was connected first to the standard and then to the test device. The method for estimating the fractional mass to be placed on the pressure balance in order to obtain the equivalent pressure of two pressure balances is also discussed Our findings indicate that we will be able to achieve effective area of piston comparable to those from the traditional cross-float method.

1. Method

The reference standard and test piston gauges are placed on a calibration table, leveled and plumbed into a manifold with gas supply, gas is pumped and all line was checked if there any leaks, and shut-off valves to isolate the various components as necessary

The connection between the reference piston gauge and the piston gauge under test is done via a transducer (Paroscientific, model 745). Before this transducer, there are two valves, a valve for the reference piston gauge and a valve for the device under test. These two valves operate via air and control the process of any path that enters the transducer and controls the oil, its volume and stability. When the calibration begins, the appropriate weights are loaded to reach the required pressure on both the reference piston gauge and the piston gauge under test (in the case of starting, the pistons is warmed up).

Step 1: When loading the required weights for each pressure point, the calibration is done in the A B B A method as in the calibration of weights.

Step 2: Where the appropriate pressure is loaded, then the valve is opened from the reference piston gauge to the transducer and waiting from two to five minutes for the reading to stabilize, then taking the reading.

Step 3: In case B, the valve for the reference piston gauge is closed and the valve for the piston gauge under test is opened and waiting from two to five minutes for the reading to stabilize, then recording it.

Step 4: In case B, the previous case B is repeated.

Step 5: In case A, the valve for the piston gauge under test is closed and the valve for the reference piston gauge is opened and waiting from two to five minutes for the reading to stabilize, then recording it.

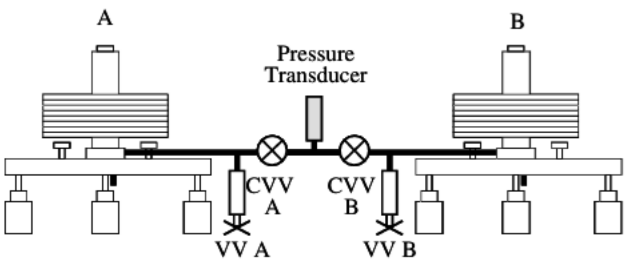

Fig 1. Transducer-Aided-Crossfloat Calibration setup

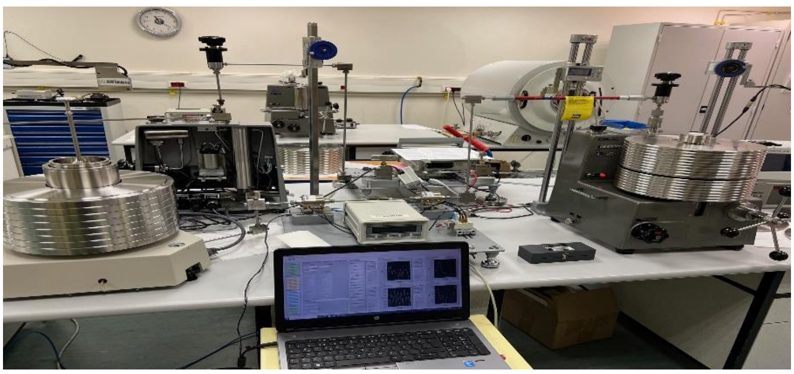

Fig 2. Transducer-Aided-Crossfloat Calibration setup in lab

In a traditional cross-float, a pressure metrologist adds or removes trim masses until balance is achieved between the two piston gauges to within the resolution of the differential pressure cell. In the transducer aided crossfloat (TAC) method this is unnecessary. Instead, the pressure of the reference piston gauge is sampled by the transducer. The transducer is then closed to the reference gauge and opened to the test gauge. If the transducer reading is sufficiently reproducible and linear, it can be employed as an immediate, short-lived transfer standard. gauge calibrates the transducer, and that calibration is immediately transferred to the test gauge. If the transducer reading is a linear function of the actual pressure, it can be expressed in the usual way, $P_{trans} = lP_{actual} + b$, [omit X for times here and throughout] where the slope l and zero-offset b are properties of the transducer that are ideally but not necessarily independent of pressure

In equation (1), the offset between the transducer reading and the reference piston gauge is adjusted for linearity and added to the reading of the test gauge to find the actual pressure on the test gauge,

$$P_{balance,test} = \frac{\Delta P}{l} + P_{balance,std}\ , \quad \Delta P = \frac{P_{transducer,test} - P_{transducer,std}}{l} \qquad (1)$$

Applied force on the cross floated gauges is given by:

$$F = PA_{eff} = \frac{\sum_i m_i g\left(1-\frac{\rho_a}{\rho_b}\right)+\gamma C}{1+(\alpha_p+\beta_c)\,(T-T_r)} \qquad (2)$$

Where ρ_a is the air density, ρ_b is the density of the pressurizing medium, T_r is the reference temperature (typically 23 °C) α_c and α_p are the thermal expansion coefficients of the cylinder and piston, respectively. Note that the surface tension term, γC, is zero for gas pressurizing media, the term ( ) is to correct for buoyancy, and the denominator is correction for deviation of the actual temperature from the reference temperature the term $(1- \rho_a/\rho_b)$, is to correct for buoyancy, and the divisor terms are correction for deviation of the actual calibration temperature from the reference temperature. The measurement equation pressure PT, of the test gauge using the TAC method is the relation given by;

$$P_T = \frac{\Delta P}{l} + \left(\frac{1}{A_{eff}}\right)\frac{\sum_i m_i g\left(1-\frac{\rho_a}{\rho_b}\right)}{1+(\alpha_p+\beta_c)\,(T-T_r)} \qquad (3)$$

The effective area of a general piston gauge is related to the force by eq(4)

$$A_{eff} = A_0(1 + b_1 P + b_2 P^2) - \frac{t}{P} \qquad (4)$$

where the coefficients A0, b1, b2, and t are determined by calibration The terms A_0, b_1, b_2, and t are determined by calibration, equations (2) and (4) are combined to calculate the actual pressure generated by the reference piston gauge, and the actual pressure on the test piston gauge is calculated using Eq. (1).

2. Experiment Details

this method was tested by using Tubitak UME piston gauge and test DHI PG 7601 , one used as a Reference (Ruska: ---) and one was used as a test gauge (DHI PG 7601). The gauges were set up and connected in with the transducer (Paroscientific 745) with air-actuated valves. A laser distance meter was placed into the same manifold to allow real-time cross checking (determining the piston fall rates) of the traditional method against the TAC method. The system was set up and allowed to thermally equilibrate. At every 6 pressure points, pressure were taken using the transducer (TAC method). We compared the results from these two methods .

2.1 Traditional Cross-Float

Considering first the traditional cross-float, the test gauge was floated against the standard gauge at six pressure points. The temperature-corrected forces were calculated in the usual way using Eq. (2). The effective area of the test gauge could then be calculated from the pressure generated by the standard gauge using known masses and pre-determined calibration coefficients for the gauge in Eq. (4)—at each pressure point. The data were fitted to a linear function and extrapolated to zero to get a final value for the effective area of A_{eff}, crossfloat = 4.90130850E-05 m2

2.2 Transducer-Aided Cross-Float

The test gauge was calibrated at seven pressure points covering the range (10,20,40,60,80,90,100 MPa). At each of these pressures, fifteen (15) points were taken without changing pressure between the standard and test gauges (ΔP) and repeated in five cycles of measurements. Typical data are plotted below at a pressure around 90 MPa.

Fig 3. Number of point taken in the calibration

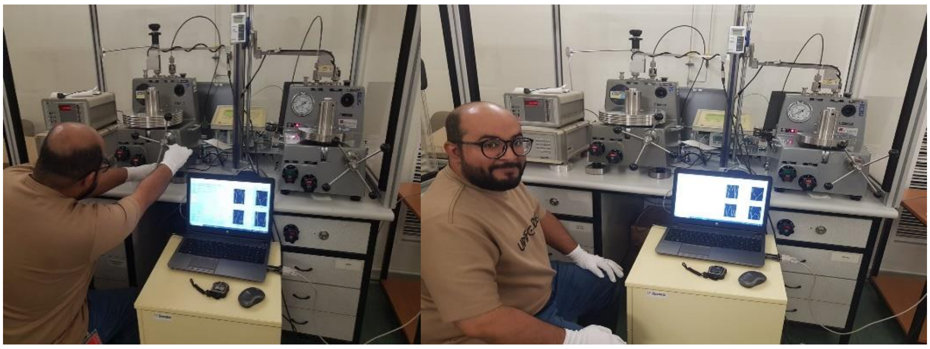

Fig 4. The Participant in the calibration time

3. Experimental Results

The results for the effective area at zero pressure of Test Device piston gauge, Fluke PG, from the two methods under comparison are Aeff,A_0;crossfloat = 9.806775E-06 m2 for the traditional cross float, Aeff,A_0 TAC;real slope = 9.806897E-06 m2 and Aeff, A_0 TAC; ideal slope = 9.806919E-06 m2 for the transducer-aided calibration. The difference in Area A_0 in ppm between the manufacture certificate and Area from cycle calibration shown in table

Cycle number	A_0 manufacturer	A_0 from cycles	diff ppm
C1	9.806775E-06	9.806897E-06	12.5
C2	9.806775E-06	9.806964E-06	19.3
C3	9.806775E-06	9.806866E-06	9.3
C4	9.806775E-06	9.806908E-06	13.6
C5	9.806775E-06	9.806963E-06	19.2

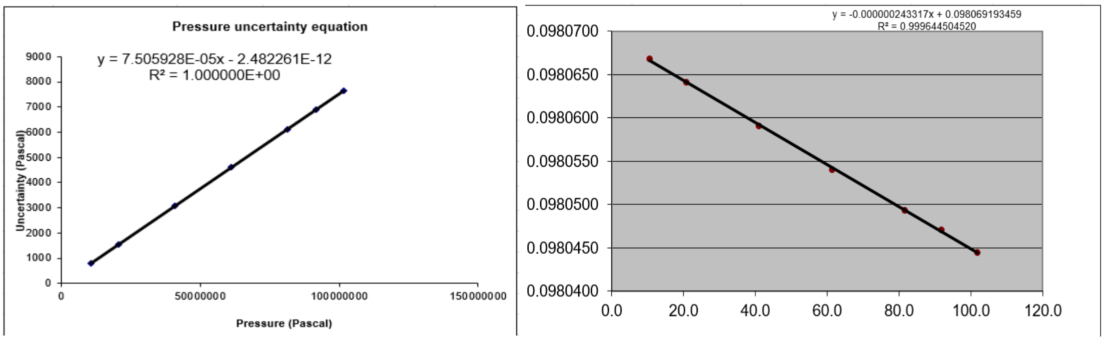

Fig 5. a -Pressure uncertainty equation b -ideal slope for the transducer-aided calibration Area vis pressure

Aeff, A_0 TAC; ideal slope is 9.806919E-06 m2 and the difference in ppm between the traditional cross-float and TAC Area is 15 ppm . It is shown that the results from the different methods are in very good agreement.

4. Conclusions and Future Work

In this project the study the calibration conducted in hydraulic media with Transducer-Aided-Cross-float Calibration method are found to be compatible with the cross-float method when the measurement result are compared , the average of difference were of the 15 ppm . Adoption of the Transducer-Aided-Cross-float Calibration method in the performed measurement is very useful in reducing the Operator dependency and necessary expertise for this calibration of devices and Preventing possible errors and significantly reducing the calibration time and also it lead to automation in future

The transducer chosen should have sufficiently good resolution, linearity, and stability characteristics in the pressure range of interest . It is important to note that transducer behavior has been observed in some cases to change over time, the behavior of the transducer should be monitored for long-term consistency Further experiments and studies are required to investigate this parameter. I intend to further this study in pressure laboratory at my institute and implement transducer aided Cross float using a commercially acquired known precise transducer

5. Acknowledgements

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