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THE CHARACTERIZATION OF FPG (FORCE-BALANCED PISTON GAUGE) IN ABSOLUTE MODE IN TUBITAK UME PRESSURE LABORATORY

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Abstract – TUBITAK UME has been using FPG system which was developed by DH Instruments Inc. since 2013. FPG system covers the range of gauge and absolute pressure from less than 1 Pa to 15 kPa. The system uses a mass comparator to measure the force resulting from differential pressure across a non-rotating piston in a close fitting cylinder. Resolution is up to 1 mPa and measurement uncertainty as low as ± (5 mPa + 3.10^{-5}·p) is estimated. The most important advantage of FPG is the fact that a conventional pressure balance can be used to determine the effective area. However, the measurement is not straight forward due to the lubrication gas flow in the FPG. The validation and metrological characterization of the new instrument is a challenge for UME and it's more convenient to join international comparison to provide the traceability of measurement results.

This paper describes the metrological characterization of FPG in gauge and in absolute modes.

Keywords: FPG,comparator, pressure balance, CDG

1. INTRODUCTION

The centre of National Metrology Institute of Turkey (UME) purchased a force-balanced piston gauge (FPG system) which is manufactured by DH Instruments in 2006. Working pressure of the system is from a few pascal to 15 kPa in gauge, negative gauge and absolute modes. Main purpose was for getting FPG was doing measurements for low pressure scales where the classical pressure balances can not be used.

2. WORKING PRINCIPLE OF THE FPG SYSTEM

The FPG system consists of two main parts as in give in Fig. 1. The pressure measuring part at left side and the pressure controlling parts is at right. The overall system is interfaced with and controlled by a dedicated personal computer running specialized software. The pressure measuring portion operates on the piston gauge principle. However, the force resulting from pressure on the piston is measured by a force balanced load cell rather than balanced against masses subjected to the acceleration due to gravity as seen in Fig. 2. For this reason, the measuring portion is designated a force balanced piston gauge (FPG). The piston-cylinder is suspended below the load cell. There are two independent, symmetrical chambers at either end of the piston-cylinder. The lower chamber is held at atmosphere or vacuum while the pressure to be measured is applied to the upper chamber. The net force resulting from the difference in pressure between the two chambers is transmitted to the load cell through the coupling. The value of the pressure is calculated from the effective area of the piston-cylinder and the net force value [1].

Fig. 1. Force balanced piston gauge system [1]

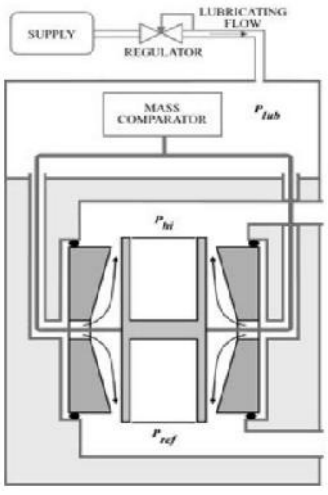

Fig. 2. Non-rotating piston principle [1]

3. CALCULATION OF THE PRESSURE IN FPG

Before the measurements, to find the calibration coefficient of the load cell, K_{cal}, load cell calibration was done by hanging up some reference masses on to the load cell using a special apparatus and corresponding output count values vs. mass were read from the controlling computer. Calibration setup is as in Fig. 3.

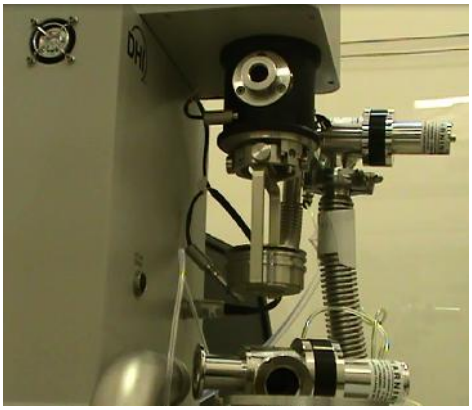

Fig. 3. Loadcell calibration, output counts vs. applied force due to reference mass

Force F_{cal} applied on the load cell generates the reading N_{cal}. The calibration constant for the load cell K_{cal} is now

$$K_{cal} = \frac{F_{cal}}{N_{cal}} \quad (1)$$

Differential pressure p over the FPG piston is defined as

$$\Delta p = \frac{F}{A}$$

$$\Delta p = \frac{F}{A} = \frac{(N + \delta N1 + \delta N2 + \delta N3) \cdot Kcal}{A_{eff,\,20°C}[1 + (\sim_{piston} + \sim_{cylinder})(t - 20°C)]} \quad (2)$$

where F is force, A is effective area, N is number of counts in the load cell reading, δN1 to δN3 are corrections taking into account the changes in pressure and temperature of the lubricating gas, Aeff 20 ˚C is effective area at 20 ˚C, α_{piston} is linear thermal expansion coefficient of the piston, $\alpha_{cylinder}$ is linear thermal expansion coefficient of the cylinder and t is temperature of the piston–cylinder assembly [2].

4. METROLOGICAL CHARACTERIZATION OF THE FPG STANDARD

The characterization of the FPG, piston-cylinder calibration done in gauge and absolute mode using conventional pressure balance. Gauge measurement setup is seen in Fig. 4 and absolute measurement setup is seen in Fig. 5.

Fig. 4. Calibration of the FPG using by the conventional pressure balance in gauge mode

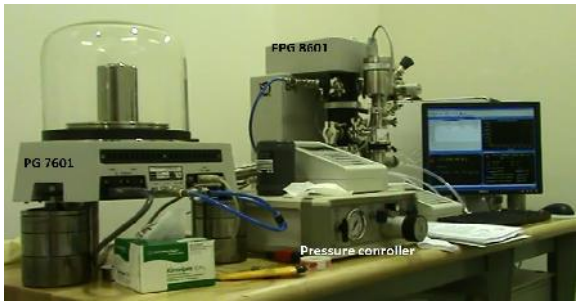

Fig. 5. Calibration of the FPG using by the conventional pressure balance in absolute mode

The PG7607 piston gauge is used to define gauge reference pressures between 5 and 15 kPa with a step size of 2.5 kPa. While PG7607 cylinder floats, FPG is isolated from PG7607by closing the ball valve. In this position pressure readout and rate of change is monitored and manipulated with a special vacuum metering valve in such a way that the FPG pressure readout stabilizes around the pressure defined by PG7607. Controlling computer display and measurement data at 15 kPa are given in Fig. 6 and Fig. 7.

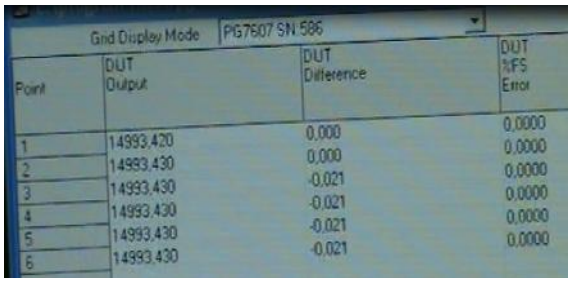

Fig. 6. Calibration data of the FPG at 15 kPa

Fig. 7. Calibration of the FPG at 15 kPa

Stabilization of the FPG pressure at 10 kPa around the pressure defined by PG7607 is given in Fig. 8.

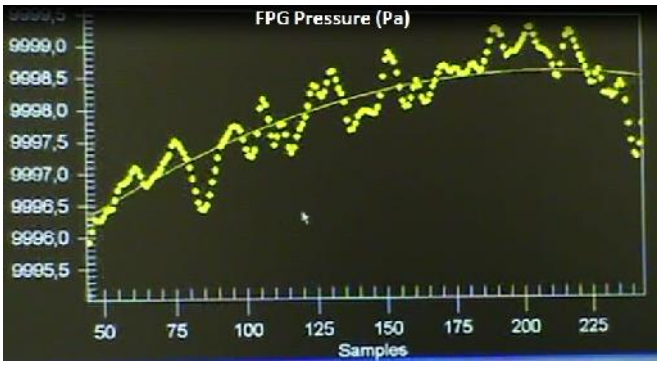

Fig. 8. Calibration of the FPG at 10 kPa

4. CONCLUSIONS

In this paper, work has been done at UME laboratrory for the metrological characterization of FPG, was presented. Calculated effective area has changed about 7 ppm from the original effective area determined by DH Intruments. Taken into account a stated uncertainty of 30 ppm + 5 mPa in pressure, the found disagreement is well within expectations.

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