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Review Article

Pressure Measurement and Calibration Setup (TH2)

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Abstract: The work investigated the responses of measuring and calibrating the pressure in the range of 200 to 2000 millibar using a setup of TH2.The setup of TH2 utilizes a deadweight pressure calibrator unit (DPC) to generate a number of reference pressures through a Bourdon gauge.An electrical pressure sensor was connected with Bourdon gauge which incorporated a semiconductor diaphragm that deflects when pressure is generatedthrough the working fluid. The water has been used as a pressure generating fluid. The operating range of dead weight reference pressure calibrator is 200-2000 millilbar, with a piston design diameter of 0.017655 m and a cross sectional area of 0.000245m^2. A corrected reference pressure has been evaluated according to the data of NIST which indicated the effect of the elevation and the latitude on the set of applied weights and final pressure. The percentage error of deviation between the actual and the corrected Bourdon pressure, was provided a value of 0.25%.The sensitivity of the applied weights, pressure of Bourdon and electrical sensor provided values of 0.25 kg/millibar and 0.062kg/millibarrespectively. The calibrationerror of the electrical sensor according to experimental data reached a maximum value of2.5%**.**
Keywords: TH2 utilizes a deadweight pressure calibrator unit (DPC) to generate a number of reference pressures through a Bourdon gauge.

INTRODUCTION

In manyengineering applications, pressure is the most important variable for a wide a range of instrumentation processes. For example different types of industrial measurement are inferred from pressure, such as flow, liquid level, liquid density and weight measurement. Even temperature may be inferred from pressure measurement in such industrial applications, the pressure variable is a very important quantity to be measured accurately (Tony, R. K. 2015).This pressureis defined as the force exerted by gases and liquids due to their weight, the pressure of the atmosphere on the surface of the earth and the pressure containerized liquids exert on the bottom and walls of a container are major examples (Dunn, W. C. 2005; Tony, R. K. 2015; Dunn, P. F. 2010; Morris, A. S. 2001and Webster, J.G. 1999).

In this work, the Armfield temperature measurement and calibration setup TH2 (TH Armfield series thermodynamics. 2018 Feb, 25; TH2 Armfield, 2012) was executed for measuring and calibrating the pressure profile in the range of p=200to2000 millibar. In this setup TH2, pressure is exerted by apiston on a column of water. The pressure applied is equal to the force exerted by a piston over the cross-sectional area of the fluid. Generally the use of the piston and masses with the cylinder generates a measurable reference pressure, P_a. According to the SI units, P_a is described in Newtons per square meter which is known as Pascals and the diameter of the piston is in meters. The setup was based on the reality of the direct proportionality of the pressure and the masses applied to the moving piston. The function of the apparatus has been widen to investigate and calibrate the pressure sensing units based on a deadweight tester principles (TH Armfield series thermodynamics. 2018 feb, 25; TH2 Armfield, 2012).Thus the piston pressure is created by a downward force acting over theequivalent area Aof the piston. The weight of the piston plus the additional weight ofcalibrated masses are used to provide this external force F_a.A Bourdon type pressure guage consists of acurved tube was loaded as a reference sensor with known pressures using a dead weight tester for the purpose of calibrating the measuring devices. The pressure is finally converted to an electrical transducer connected with an electrical console. The Known pressure of the Bourdon and the electronic was

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used for calibration. The characteristics of the system including the accuracy and linearity were determined.

II. EXPERIMENTAL SETUP

The setup of TH2 equipment utilizes a deadweight pressure calibrator unit (DPC) to generate a number of reference pressures. This is connected to a Bourdon gauge and electronic pressure sensor to enable an accurate measurement. As described in Fig.1,2 the DPC consists of a precision ground piston and matching cylinder with a set of weights giving an operating range of 200to 2000millibar.The Bourdon gauge and pressure sensor are mounted on a manifold block with a separate reservoir to contain the hydraulic fluid. In this work water was used for its safety and ease of use properties. A priming valve located between the reservoir and the manifold block enabled easy priming, restricted flow of water to demonstrate the application of damping and the connection of alternative devices for calibration.The priming vessel of the setup has a capacity of 150 ml. In addition the setup supplied with a precise ground piston and matching cylinder with a set of different weights (TH Armfield series thermodynamics. 2018 feb, 25; TH2 Armfield, 2012). The manifold block supplied with an additional isolating valve allows the water to be drained and alternative devices to be connected for calibration.The reference pressure has been indicated by a Burdon guage with a rotary scale and mechanical indicator.The operating range of dead weight pressure calibrator is 200-2000 millilbar, with a piston design diameter of 0.017655 m and a cross sectional area of 0.000245m^2 (TH Armfield series thermodynamics. 2018 feb, 25; TH2 Armfield, 2012).

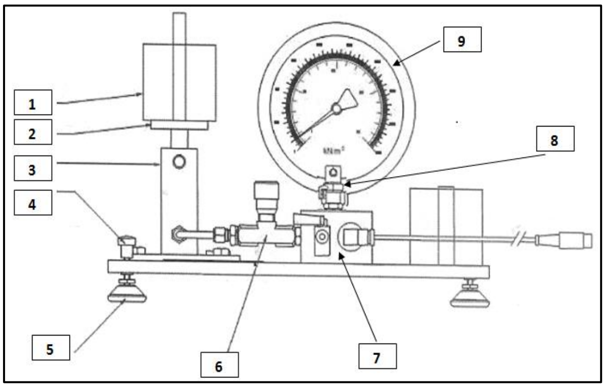

Fig.1: Front overview of TH2 setup (TH Armfield series thermodynamics. 2018 feb, 25; TH2 Armfield, 2012).

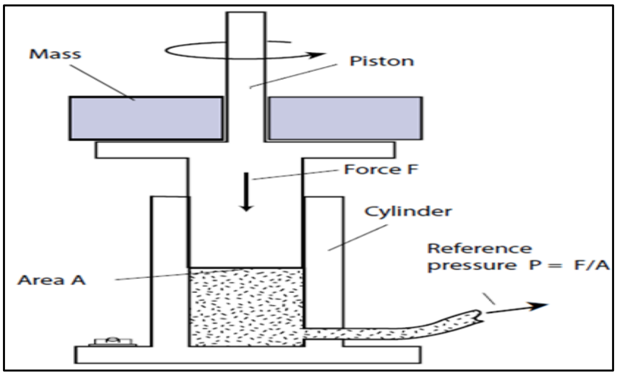

Fig.2: Deadweight pressure calibrator unit (DPC) (TH Armfield series thermodynamics. 2018 feb, 25; TH2 Armfield, 2012).

No.	Equipment name	No.	Equipment name
1	Set of weights	**6**	Damping valve
2	Precision ground piston	**7**	Manifold block
3	Matching cylinder	**8**	Quick coupling valve
4	Fine height controller	**9**	Bourdon gauge
5	Base valve		

TH2 setup, equipment list (TH Armfield series thermodynamics. 2018 feb, 25; TH2 Armfield, 2012)

The gauge supplied is a six inch diameter fitted with a graded rotary scale to enable observation of the Bourdon tube and the conversion of motion into needle rotation.In addition this scale is calibrated in degrees of rotation beside the usual scale calibrated in units of kNm^{-2}to indicate the pressure.The electronic pressure sensor incorporates a semiconductor diaphragm that deflects when pressure is generatedthrough the working fluid. This deflection generates a voltage output that is proportional to the applied pressure.Fig.3 describes the installation of the setup in the lab.

Fig.3: TH2 setup existing in the lab.

Power supplies and signal conditioning circuitries were contained in an electrical console .The output voltage generated from the pressure sensor was displayed on a digital meter. An additional conditioning circuit with user-adjustable zero and span control enables the output to be displayed as a direct reading pressure meter calibrated in units of pressure (TH Armfield series thermodynamics. 2018 feb, 25; TH2 Armfield, 2012).The weight was applied carefully to the top of the piston ensuring the generation of the predetermined pressure, while the piston is spinning to reduce the friction.

III. RESULTS AND DISCUSSIONS

The reference of Bourdon gauge has been testified with data of NIST for the purpose of accurate measuring and calibrating the pressure. The general equation described the pressure as a function of applied mass, gravity and size parameters of dead weight. The actual pressure was measured according to the reference pressure of the Bourdon gauge. The actual pressure was then compared to the pressure of the semiconductor sensor outputs over a range of 200-2000 millibar.Fig.4 shows thevariation of actual setup reference gauge pressure (Bourdon) with corrected pressure of NIST data, which was described by the following equation (Morris, A.S., & Langari, R. 2012; Figliola, R.S. *et al.*, 2011; Czichos, H. & Cliffs, NJ. 2015; and Baird, D.C. 1995):

$$P_a = \frac{F_a}{A} + \sum error = \frac{M_a g}{A} + \sum error \quad (1)$$

Number of considerable errorscontribute to equation (1), such as air buoyancy effects, variations in local gravity, uncertainty in the known mass of the piston, added masses, shear effects, thermal expansion of the piston area, and elastic deformation of the piston.In this work, the indicated reference and Bourdonguage pressure P_i, was corrected for gravity effects, e_1, and for air buoyancy effects, e_2, according to NIST gravity error equation (Figliola, R.S. *et al.*, 2011).

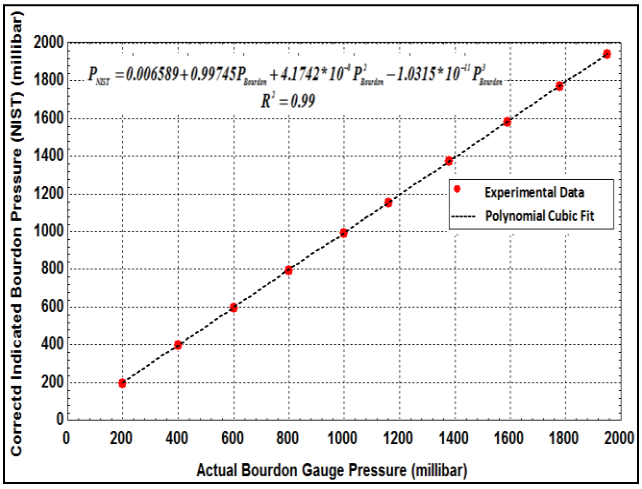

Fig.4: Variation of reference gauge pressure (Bourdon) with corrected pressure of NIST.

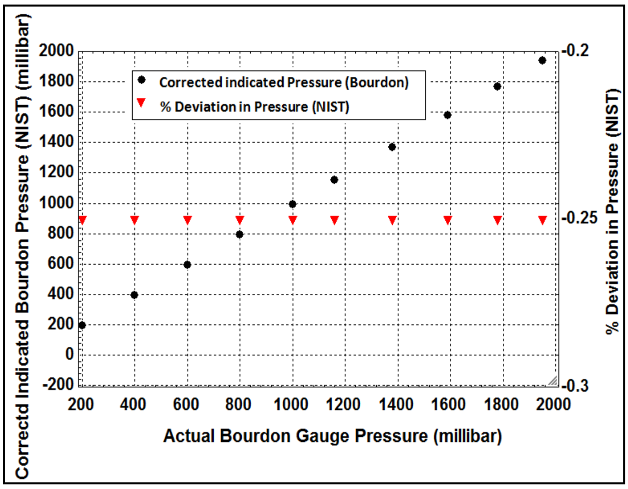

Fig.5: Variation of actual gauge reference pressure (Bourdon) with percentage error and corrected pressure of NIST.

The Bourdon measuring data exhibited an absolute linear variation with data of NIST, as described in Fig.4. The relation between the corrected pressure and the pressure of NIST has been turned to a polynomial cubic data of:

Table. (1): Polynomial cubic data of actual and corrected Bourdon pressure.

a_0	a_1	a_2	a_3
0.006589	0.99745	4.1742*10^{-8}	-1.0315*10^{-11}

Fig.5 described the percentage error of deviation between the actual and the corrected Bourdon pressure, which resulted nearly a constant fluctuation values with a maximum absolute deviation of 0.25%. The corrected equation used an elevation z equal to local condition of 380.589 m and a latitude of 15.6°. The measurement has been executed under normal atmospheric pressure P_{atm}. Fig.6,7 described the behavior of the DPC unit amid loading the applied mass and its effect on output of electrical sensor and deflection angle of Bourdon gauge.The weight of the piston plus the additional weight of calibrated masses are used to provide this externalforce F. The masses' weight ranges between 0.5-4.50 kg.

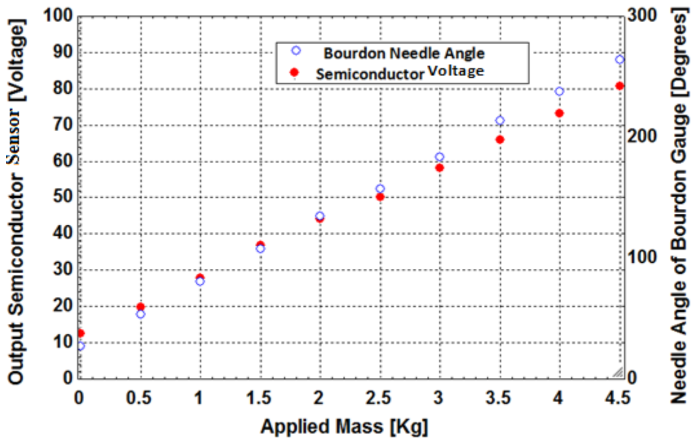

Fig.6: Variation of applied mass with output of electrical sensor and deflection angle of Bourdon gauge.

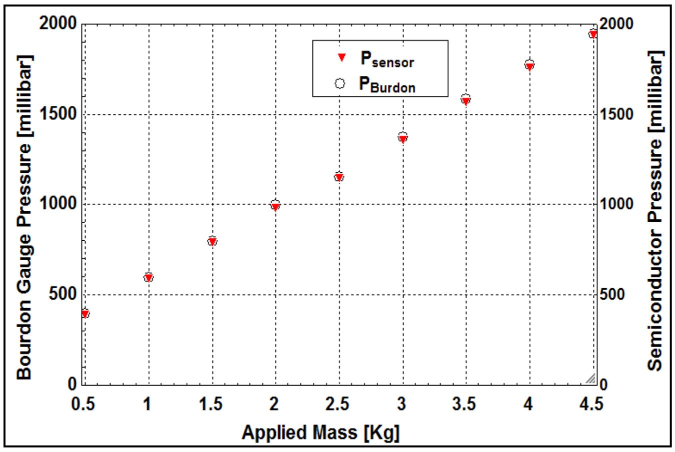

Fig.7: Calibration curve of applied mass varied with pressure of Bourdon gauge and electrical sensor.

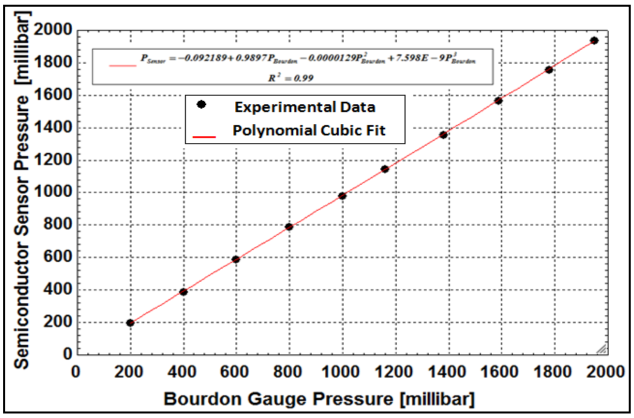

Fig.8: Calibration curve of Bourdon gauge pressure varied with electrical sensor pressure.

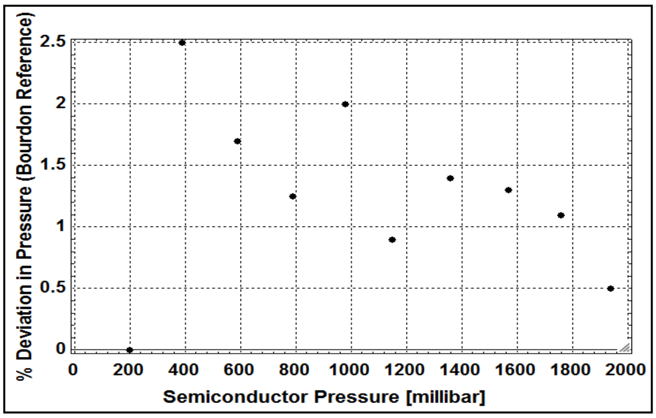

Fig.9: Variation of semiconductor pressure with percentage deviation in pressure (Bourdon).

The relation confirmed an increase of all measuring variables with increasing the load of the piston mass.The sensitivity of the pressure is the slope of the calibration curve, which provided values of0.250 kg/millibar and0.0625 kg/millibar for the Bourdon pressure gauge and the electrical sensor respectively. The calibration gauge pressure of the Bourdon and the output voltage of the semiconductor sensor is presented in Fig.8.The relation provided an absolute linear variation, with a cubic polynomial data of table (2).

Table. (2): Polynomial cubic fit for calibration data of Bourdon gauge and electrical sensor.

a_0	a_1	a_2	a_3
-0.092189	0.9897	-0.0000129	$7.598*10^{-9}$

The calibration data of the electrical sensor is described in Fig.9. The error of calibrationreached a maximum value of less than 2.5%.

CONCLUSIONS

The experimental setup exhibit the responses of measuring and calibrating the pressure. The setup confirms a very accurate measuring data. The study of the effect of gravity and air buoyancy on measuring and calibrating the data has been evaluated. The sensitivity and error of measuring and calibrating data was identified.

NOMENCLATURE

Pa	Actual pressure (bar)	a_0	First polynomial fit constant
P_{atm}	Ambient pressure of surroundings (bar)	a_1	Second polynomial fit constant
F_A	Applied force (kN)	a_2	Third polynomial fit constant
A	Area of the piston (m^2)	a_3	Fourth polynomial fit constant
M_A	Applied Mass (kg)	g	Acceleration due to gravity (m/sec^2)

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