Laboratory Report

Pressure & Refrigeration

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Contribution Table

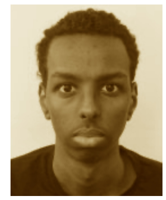
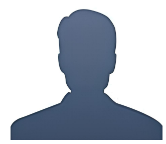
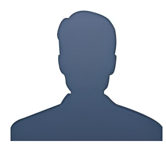
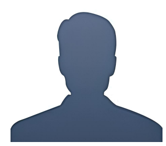
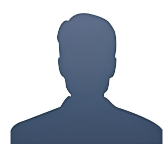
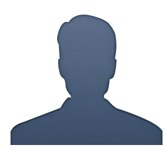
Student	Course	Contribution	Picture
Sakariye Abiikar	Mechanical Engineering		
Alireza Alishahi	Mechanical Engineering		
Naim Alrifai	Mechanical Engineering		
Munachi J Atuegbu	Mechanical Engineering		
Ehsan Haque	Mechanical Engineering		
Abdul Mueed	Mechanical Engineering		
Abdelrahman Shehata	Mechanical Engineering		
Varley, Freddie	Mechanical Engineering		

Table of Contents

1 Abstract

In this experiment, we calibrated and compared the performance of multiple pressure-measuring devices, including two Bourdon gauges, a Budenberg pressure gauge and a Hg glass manometer, in tandem with a reference pressure calibrator (DPI-603 Portable Pressure Calibrator), which served as the baseline for pressure measurements and as the source of the applied pressure. The devices were connected to the DPI-603 Portable Pressure Calibrator, enabling us to apply both positive and negative pressures in increments of approximately ±5 kPa. Through this process, we were able to get an exhaustive dataset that demonstrated notable differences in the pressure-measuring devices' performance. [Placeholder breif results findings]. These results highlighted the importance of selecting appropriate devices based on precision requirements and operating conditions, as well as the potential impact of human error in reading analog instruments like the Bourdon gauges and Hg manometer.

2 Introduction

In engineering and scientific applications, pressure measurement is essential, playing a critical role in fields such as fluid dynamics, meteorology, and industrial control. Over time, pressure-measuring instruments have evolved, from early liquid column manometers to modern mechanical and digital gauges, each designed to provide accurate measurements under varying conditions.

A key distinction in pressure measurement is between **absolute** and **gauge** pressure [1].
Absolute pressure is measured relative to a vacuum, while gauge pressure is measured relative to atmospheric pressure. This distinction influences the design and function of pressure-measuring devices.

Historically, the invention of the Bourdon gauge by Eugène Bourdon in 1849 marked a significant advancement in pressure measurement. It provided a robust and reliable means of monitoring pressure in industrial settings, where durability and consistency were paramount. On the other hand, liquid column manometers, particularly those using mercury, have been essential in laboratory settings due to their precision in measuring small pressure differences.

Despite the advantages of different pressure-measuring devices, each has limitations, such as calibration errors and environmental influences.

Previous studies have highlighted various challenges and findings related to pressure measurement devices. For example, a study by Hodgkinson et al. (2020) found that the accuracy of home blood pressure monitors varied significantly, with validated monitors showing a higher pass rate in static pressure tests compared to unvalidated ones. This emphasizes the importance of validation and calibration in ensuring the accuracy of pressure-measuring devices.

In this experiment, we aimed to evaluate the performance and accuracy of various pressure-measuring devices under controlled conditions, comparing their responses to varying pressure levels.

[1] **differential** pressure i decided to redact in the context of our lab though it would be among this list

3 Method & Experimental Procedures

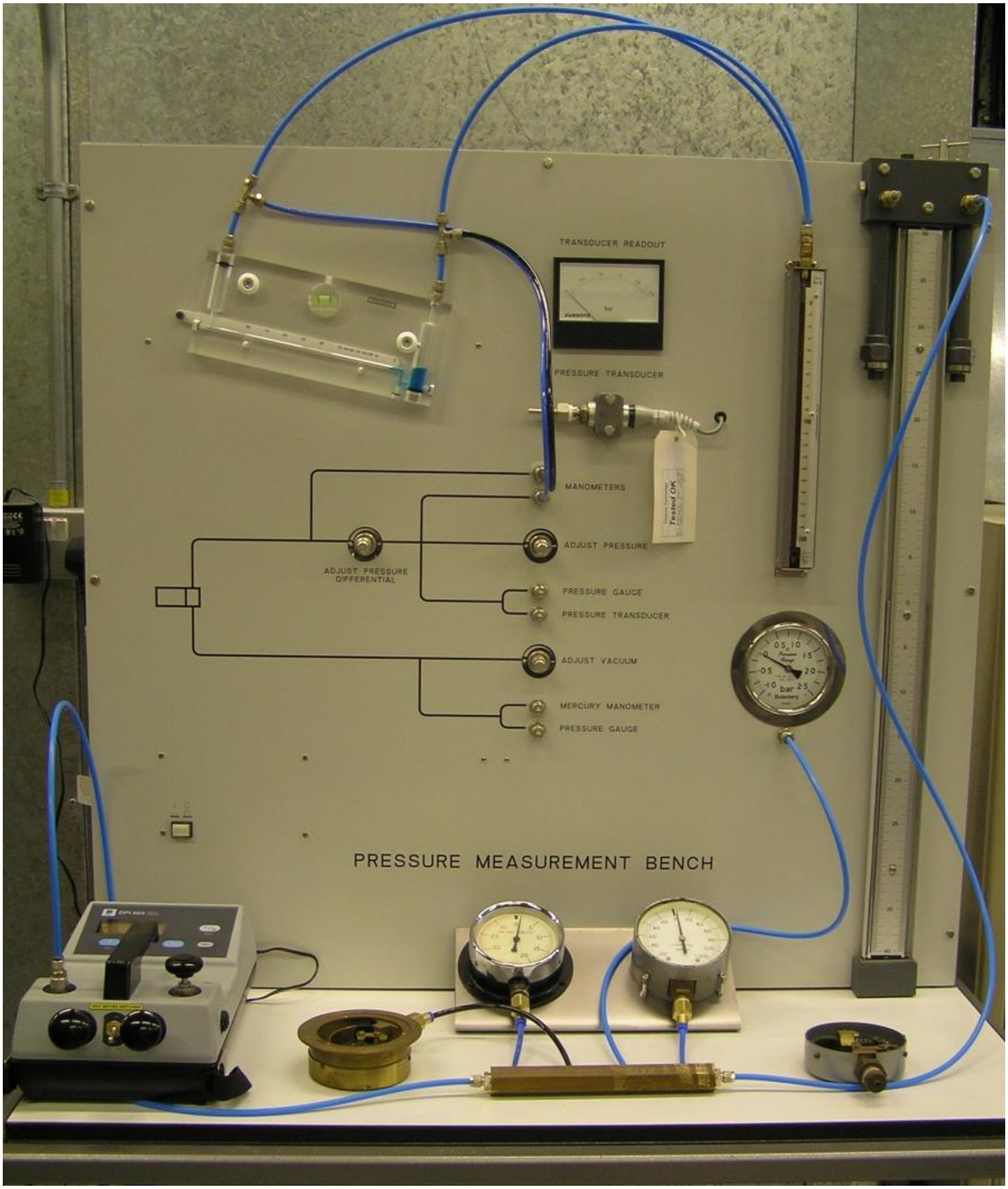


Figure 1: Setup

POSITIVE															
#	Reference Value	Pressure Calibrator MAX 75 kPa			Bourdon Gauge 1			Bourdon Gauge 2			Bundenberg Pressure Gauge		Hg Glass Manometer (+) MAX 32 cm Hg		
		kPa	bar	bar P_{abs}	**psi**	bar	bar P_{abs}	**kN/m²**	bar	bar P_{abs}	**bar**	bar P_{abs}	**cm Hg**	bar	bar P_{abs}
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															

NEGATIVE															
#	Reference Value	Pressure Calibrator MAX 75 kPa			Bourdon Gauge 1			Bourdon Gauge 2			Bundenberg Pressure Gauge		Hg Glass Manometer (+) MAX 32 cm Hg		
		kPa	bar	bar P_{abs}	**psi**	bar	bar P_{abs}	**kN/m²**	bar	bar P_{abs}	**bar**	bar P_{abs}	**cm Hg**	bar	bar P_{abs}
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															

Mercury manometer Pressure = Density × Gravity × Height in metres = $13600 \times 9.81 \times$Hg height in metres

Atmospheric Pressure (Patm) from the Digital Manometer This is a fill-in line with a specific length: ___________.mbar (1000 mbar = 1 bar)

Bordon Gauge 1, Bourden Gauge 2, and Bundenberg Gauge offsets

Figure 2: Form for recording pressure measurements

The experiment **summary** is as follows:

The instructor guided us through operating the equipment, demonstrating how to use the pressure calibrator and interpret the gauge readings. Before diving in, we received crucial instructions on what to avoid to prevent major issues—such as compromising our data, ensuring safety, and other key considerations.

After carefully analyzing the gauge readings as a team, we recorded the pressure measurements in the designated table (Figure 2).

A detailed breakdown of the **exact steps** we followed is provided on the next page.

3.1 Operating Procedure

1. Visual check test rigs pneumatic connections.
2. Open the instruments vent valve.
3. Select between positive (+) or negative (-) as required. (This is the selector on the front of the DPI-603 (±VE on Figure 3), located between the hand pump and the volume adjuster.)

   We started with the positive pressure (Excess).
4. Switch on the unit, pressing the power.
5. Select Pressure Units, i.e., in Hg or bar, etc, by cycling through clicking the button shown in Figure 3, we went with kPa.
6. Close Vent valve and zero instrument using Vent Valve.

   It was determined that due to the sensitivity of the vent valves, the instructure must perform this.

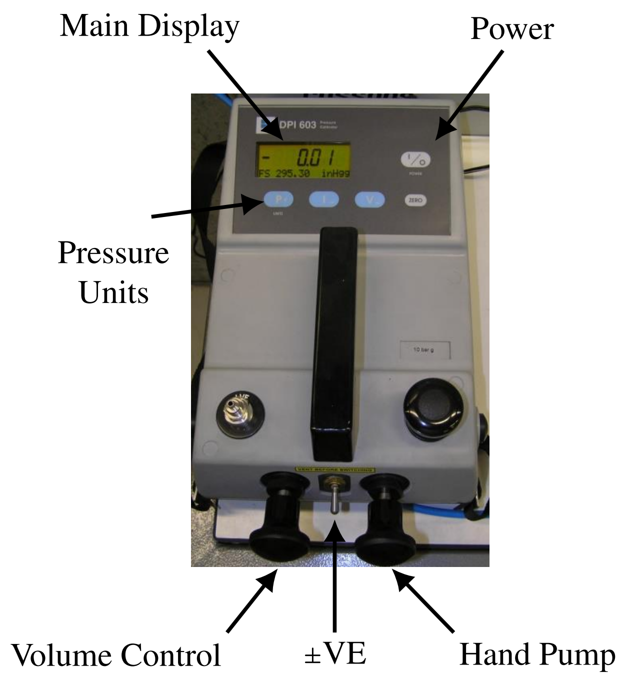


Figure 3: DPI-603 Portable Pressure Calibrator

7. Using the hand pump pressurize the system to the required value ($\approx \pm 5$ kPa).[2] Vent air using the vent valve and adjust pressure by pumping air using the hand pump. Use the volume control to fine-tune the pressure.
7. Once the required Obtain data from all relevant pressure gauges.
9. Reverse procedure for Vacuum.

[2] Caution is required when using the mercury (Hg) glass manometer. The maximum pressure should not exceed 32 cm Hg to prevent damage to the glass. In this experiment, pressure increments of 5 kPa were recorded, totaling 50 kPa, which remains safely within both the 32 cm Hg limit and the 75 kPa threshold. Therefore, the calibration was performed without exceeding the safe pressure limits.

4 Theory

4.1 Pressure

When we talk about pressure, the first thing that comes to mind is its physical definition. It refers to the effect or various types of deflection when a force is applied to a surface.

$$P = \frac{F}{A} \qquad \text{Eq. 1}$$

- P = Pressure (Pa, Pascal)
- F = Force applied (N, Newton)
- A = Surface area (m^2)

”Pressure is the force per unit area exerted normal to the surface.”

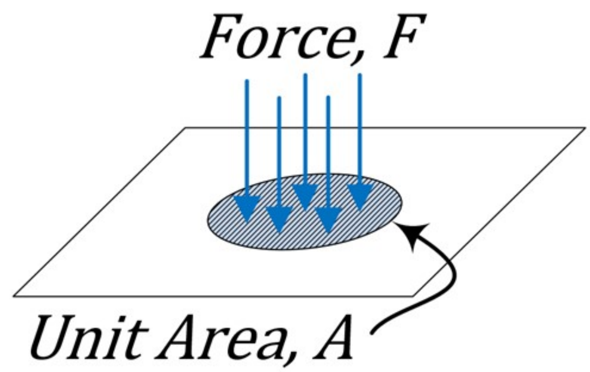


Figure 4: Illustration of pressure application

The type of deflection caused by pressure depends on its magnitude and the duration of application. Pressure has numerous examples and applications, such as vehicle tires and press machines.

The most effective way to estimate applied pressure is by measuring its effects, for example, by observing changes in the dimensions of an elastic object or the height of a liquid column, as shown in the following image.

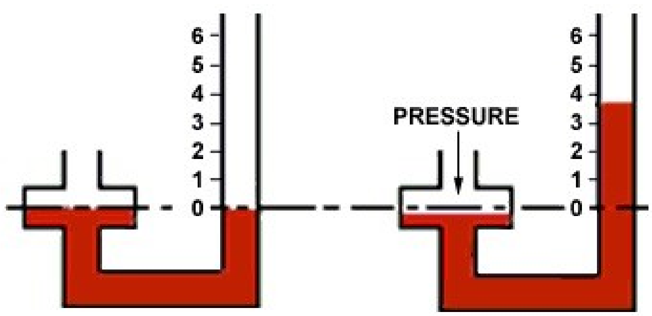


Figure 5: Pressure measurement using a liquid column

Pressure is categorized into two main groups: **gauge pressure** and **absolute pressure**, explained in the following diagram.

4.2 Absolute Pressure

Absolute pressure, or absolute zero pressure, is the lowest possible pressure measurable. Consequently, all measured pressures are positive in comparison to this reference point. Achieving absolute zero pressure is practically impossible unless calculated or represented through an extremely accurate curve.

4.3 Gauge Pressure

Gauge pressure, also known as relative pressure, is measured relative to local atmospheric pressure. Since we live under constant atmospheric pressure, it is often convenient to measure the difference between actual pressure and atmospheric pressure, which is referred to as gauge pressure. This measurement is commonly used in industrial applications.

It is important to note that:

- Any pressure between local atmospheric pressure and absolute zero pressure is called **vacuum pressure**.
- Any pressure higher than local atmospheric pressure is considered **positive pressure**.

The relationship between absolute and gauge pressure is given by:

$$P_{\text{absolute}} = P_{\text{atmosphere}} + P_{\text{gauge}} \qquad \text{Eq. 2}$$

The following diagram illustrates the definitions of pressure more clearly.

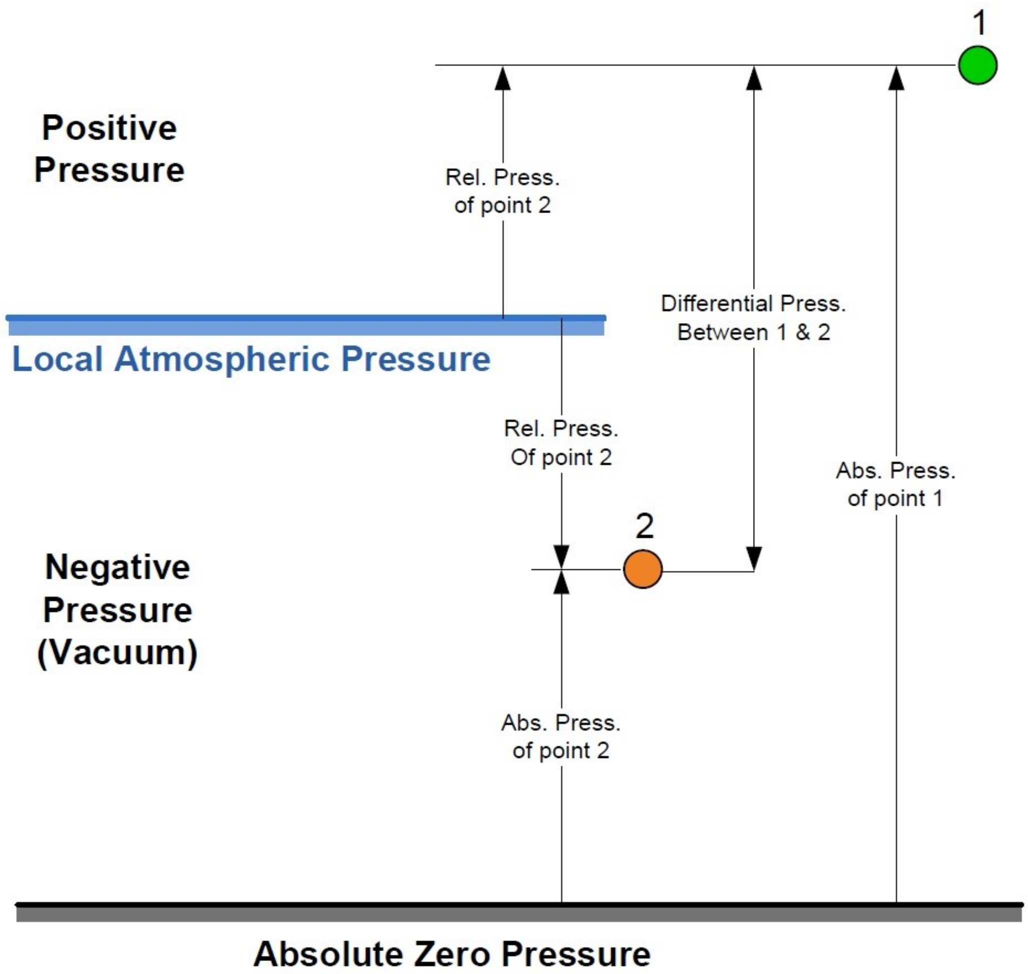


Figure 6: Pressure categories and their relationships

4.4 Other Types of Pressure in Flow Measurement

Additionally, different interpretations of pressure are applicable in flow measurement. The most common types of pressure in this context are **total**, **static**, and **dynamic** pressures.

4.4.1 Total Pressure

Total pressure is the force per unit area felt when a flowing fluid is brought to rest. It is typically measured using a Pitot tube, as shown in the figure below. Total pressure is the sum of static pressure and dynamic pressure:

$$P_{\text{total}} = P_{\text{static}} + P_{\text{dynamic}} \qquad \text{Eq. 3}$$

Total pressure is also referred to as stagnation pressure.

4.4.2 Static Pressure

Static pressure is the force exerted on a fluid particle from all directions when the fluid is at rest or when measured in a moving reference frame. It is commonly measured using gauges or transmitters attached to the side of a pipe or tank wall. In most discussions, the term ”pressure” generally refers to static pressure.

4.4.3 Dynamic Pressure

Dynamic pressure represents the kinetic energy of a flowing fluid and is the difference between total and static pressure. It is given by:

$$P_{\text{dynamic}} = \frac{\rho v^2}{2g} \qquad \text{Eq. 4}$$

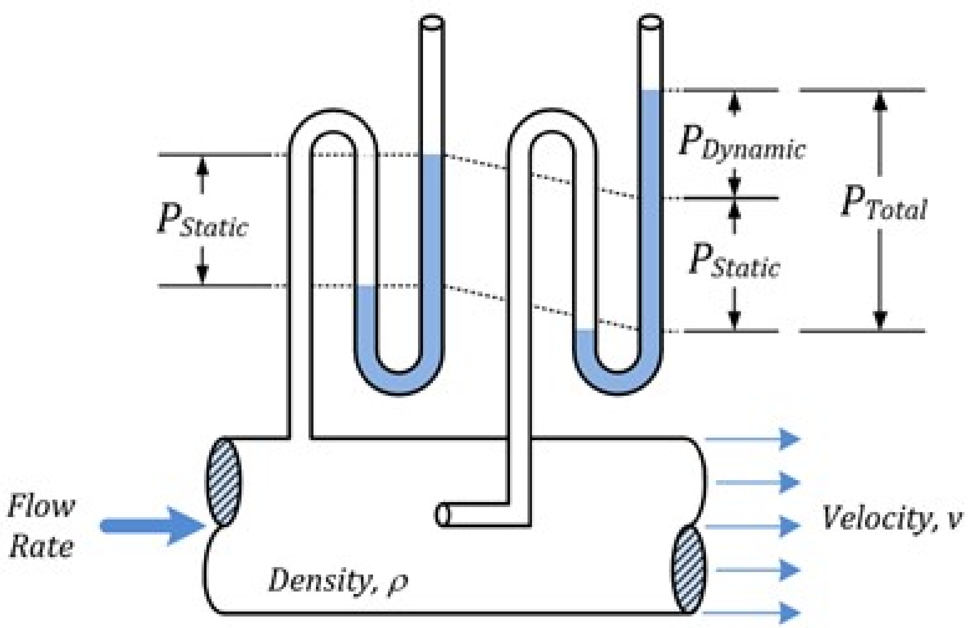


Figure 7: Measurement of dynamic pressure in fluid flow

Pressure Units

The SI unit for pressure is the Pascal (Pa), which is defined as one Newton per square meter (N/m^2). In other unit systems, pressure is often measured in pounds per square inch (psi). However, one of the most widely used units is the bar or millibar (mbar). Some common pressure units and their equivalents are listed below:

- 1 bar = 10^5 Pa
- 1 atm = 101325 Pa
- 1 psi = 6894.76 Pa
- 1 mmHg = 133.322 Pa

5 Data, Calculations and Results

Thus, as explained in the Method & Experimental Procedures Section 3, we have gathered a simple dataset for the corresponding pressure gauges. Our goal now is to make calculations, illustrate trends, etc., and simply produce another dataset from which we can draw fair conclusions from. Here, I first describe the baseline data that was collected and recorded on the table that was made available for use in the lab (Figure **??**).

5.1 Pressure Calibrator Readings

kPa

+	-
0.0	0.0
5.7	-5.6
10.4	-12.1
16.0	-18.0
21.1	-21.8
27.7	-25.4
34.2	-29.3
40.0	-33.6
46.1	-37.6
52.2	-41.7

Table 1: Pressure Calibrator

psi

+	-
1.0	1.2
2.0	0.4
2.6	-0.5
3.4	-2.0
4.1	-2.8
5.0	-4.0
6.0	-6.0
6.8	-7.1
7.6	-8.3
8.5	-9.5

Table 2: Bourdon Gauge 1

kN/m^2

+	-
1.0	2.5
8.0	-1.0
14.0	-9.0
20.0	-15.0
25.0	-20.0
30.0	-23.0
39.0	-27.0
45.0	-32.0
50.0	-36.0
57.0	-40.0

Table 3: Bourdon Gauge 2

bar

+	-
-0.05	-0.05
0.00	-0.10
0.04	-0.16
0.10	-0.24
0.15	-0.27
0.22	-0.30
0.29	-0.35
0.35	-0.40
0.40	-0.44
0.47	-0.49

Table 4: Budenberg Pressure Gauge

cm Hg

+	-
0.4	0.4
3.5	-0.7
5.3	-3.7
7.4	-5.4
9.4	-6.8
11.6	-8.2
14.2	-9.6
16.4	-11.3
18.7	-12.8
21.0	-14.4

Table 5: Hg Glass Manometer

6 Discussion of Results

7 Conclusions

8 Recommendations

9 References

1. Hodgkinson, J.A. et al. (2020). *Accuracy of blood-pressure monitors owned by patients with hypertension (ACCU-RATE study): a cross-sectional, observational study in central England*. British Journal of General Practice, [online] 70(697), pp.e548–e554. Available at: https://bjgp.org/content/70/697/e548.

10 Appendix