Palestine Technical University – Kadoorie
College of Engineering and Technology
Department of Mechanical Engineering
Fluid mechanics & thermal lab. (12210341)

Experiment No. 2: Calibration of a pressure gauge

Introduction:

Many techniques have been developed for the measurement of pressure and vacuum. Instruments used to measure pressure are called pressure gauges or vacuum gauges.

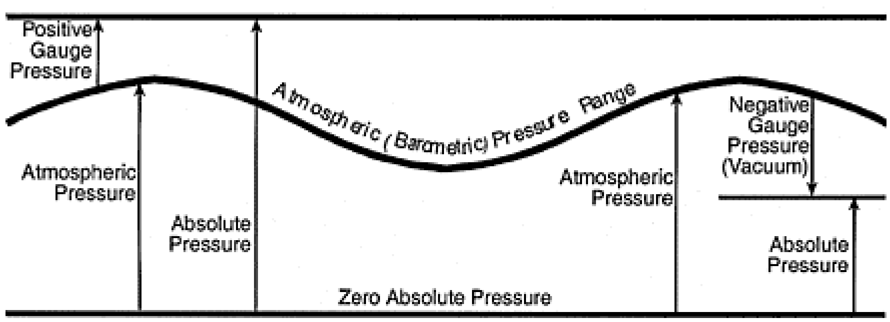
A manometer could also be referring to a pressure measuring instrument, usually limited to measuring pressures near to atmospheric. The term manometer is often used to refer specifically to liquid column hydrostatic instruments.

Although no pressure is an absolute quantity, everyday pressure measurements, such as for tire pressure, are usually made relative to ambient air pressure. In other cases measurements are made relative to a vacuum or to some other specified reference. When distinguishing between the pressure references, the following terms are used:

• **Absolute pressure** is zero referenced against a perfect vacuum, so it is equal to gauge pressure plus atmospheric pressure.

• **Gauge pressure** is zero referenced against ambient air pressure, so it is equal to absolute pressure minus atmospheric pressure. Negative signs are usually omitted.

• **Differential pressure** is the difference in pressure between two points.



Atmospheric pressure is typically about 100 kPa at sea level, but is variable with altitude and weather. If the absolute pressure of a fluid stays constant, the gauge pressure of the same fluid will vary as atmospheric pressure changes. For example, when a car drives up a mountain (atmospheric air pressure decreases), the (gauge) tire pressure goes up. Some standard values of atmospheric pressure such as 101.325 kPa or 100 kPa have been defined, and some instruments use one of these standard values as a constant zero reference instead of the actual variable ambient air pressure. This impairs the accuracy of these instruments, especially when used at high altitudes. Use of the atmosphere as reference is usually signified by a (g) after the ressure unit e.g. 30 psi g, which means that the pressure measured is the total pressure minus atmospheric pressure.

Units

1 Pa = 1 N/m2 or (kg/m·s^2).

= 10−5 bar

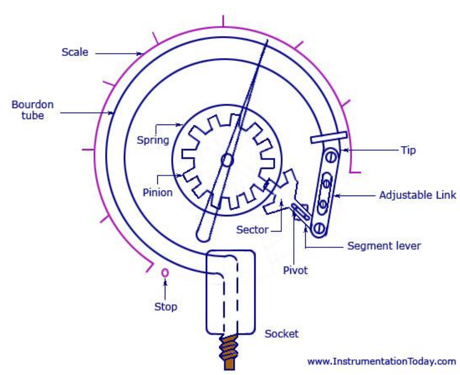
= 9.8692×10−6 atm

= 145.04×10−6 psi

A 10 m high column of clean water at 4 C will produce 98 kpa (0.98 kN/m^2) of pressure.

When indicated, the zero reference is stated in parenthesis following the unit, for example 101 kPa (abs). The pound per square inch (psi) is still in widespread use in the US and Canada, notably for cars. A letter is often appended to the psi unit to indicate the measurement's reference; Psia for absolute, psig for gauge, psid for differential.

The transparent dial of the experimental instrument allows you to see the workings of the gauge. A thin-walled tube with oval cross section forms a 270 degree circular arc tube has one end fixed and open to the applied pressure. Its other end is sealed but free to move. As pressure enters the fixed end, the tube tries to straighten. This cause movement at free end which moves a mechanical system connected to a pointer. The pointer moves around a graduated scale in proportion to the pressure applied. The sensitivity of the gauge depends on the material and dimensions of the bourdon tube. A piston and cylinder assembly to the side of the gauge allows you to add known values of accurately calibrated weights, which force water towards the gauge, increasing the pressure in the bourdon tube. The pressure shown by the bourdon gauge should match the pressure calculated from the force created by the weights, with an accuracy determined by experiment.



Bourdon Tube Pressure Gauge

Pressure Gauge Calibration is necessary for maintaining precision and accuracy when the instrument is used. Calibration is usually required when you purchase the instrument newly. It's also required when there is questionable output after using the instrument. You may also calibrate the pressure gauge after it has suffered a shock or adverse weather conditions. The calibration process is also necessary for keeping the instrument in good order. When seeking for accurate pressure reports, you need to calibrate the pressure gauge from time to time. The calibration process is also very vital for maintaining a safe and healthy working environment.

Objectives:

This experiment allows the student to:

1. Know the construction of the bourdon tube pressure gauge.
2. Learn the principle of work of the bourdon tube pressure gauge.
3. calibrate the bourdon gauge using a dead weight tester and a known weights.
4. Identify the sources of error which leads to inaccurate pressure reading.

Theory:

Normal gauges (such as the gauge in this equipment) show pressure with respect to atmosphere, so when the gauge shows zero pressure, its input is open to atmospheric pressure or at a pressure equivalent to atmospheric. The pressure shown by these gauges is termed ' gauge pressure'.

The weights are converted from units of kilogram-force (kgf) to Newton (N) simply by multiplying by the acceleration due to gravity (9.81 m/s^2), and the applied pressure equals the dividing of this figure by the piston area.

W = mg (kg * m/s^2) or (N)

and

P = W/A (N/m^2)

P = mg/A

or

P = m * k

where k = a constant found from g/A, (calibration constant).

For example, for a piston area of 315 mm^2 (315 * 10^-6 m^2) and g = 9.81 m/s^2 , then k = 31143. Therefore:

Pressure (in N/m^2) = mass (in kg) * 31143

or

Pressure (in kN/m^2) = mass (in kg) * 31.143

Subtract the applied pressure from the Average pressure to find the average error.

Divide the average error by the full scale reading of the gauge and multiply by 100 to convert this into percentage of full scale.

Parts needed:

1. Bourdon gauge scale: Graduated in 0 to 200 kN.m^2 in 5 kN.m^2 intervals.
2. dead weight tester: piston mass = 1 kgf
   piston area = 315mm^2
3. masses: 1 kg (four pieces)
   0.5 kg (two pieces)
   0.2 kg (one piece)

Procedure:

1.Create a blank table of results, similar to table 1.

Piston Area (A) =							
Mass(M) (kg)	**Force W (N)**	**Applied pressure P (kN/m^2)**	**Gauge Reading (kN/m^2)**			**Average Error (kN/m^2)**	**Error (%of full scale)**
			Increasing	**Decreasing**	**Average**		

Table 1 blank results table

2. Set out the apparatus on a level surface.
3. remove the piston from the pressure gauge dead weight tester.
4. Fill the cylinder of the dead weight tester with water, and remove the trapped air in the transparent tube by tilting the unit and gently tapping it. A small amount of air in the system will not affect the experiment or results.
5. Check that the gauge reads zero pressure. You may need to gently 'tap' the gauge to make the indicator settle down to zero.
6. Carefully insert the piston into the cylinder, allowing air and excess water to discharge through the top hole of the cylinder. Allow the piston to settle.

Caution: take care to insert the piston perpendicular and square to the bore, or you accidentally scratch the surfaces and the equipment may leak or not work correctly.

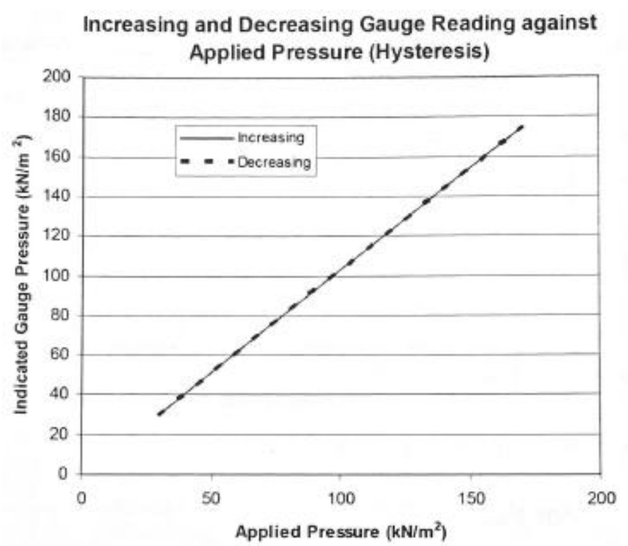
7. Record the gauge reading in the 'increasing' column of your results table.
8. Add the weights to the loading platform. Of the piston in at least 8 steps up to an indicated reading of around 170 kN/m^2 or a maximum applied mass of around 6 kg including the mass of the piston.

9. At each step, gently rotate the piston to help prevent the piston sticking and record the gauge reading in the 'increasing' column.

   Caution: Add and remove the weights carefully. Do not drop them on to the platform. Do not add more than the 5.2 kg masses (supplied) to the platform. To avoid reading errors, look directly at the gauge, not at an angle.

10. Reverse the procedure, reducing the weights and record the gauge readings as the pressure decreases in the 'decreasing ' column.

Typical results:



Gauge Reading Hysteresis

Mechanical gauges normally have three main causes of error:

1. Hysteresis caused by friction in the mechanical movement in the gauge.

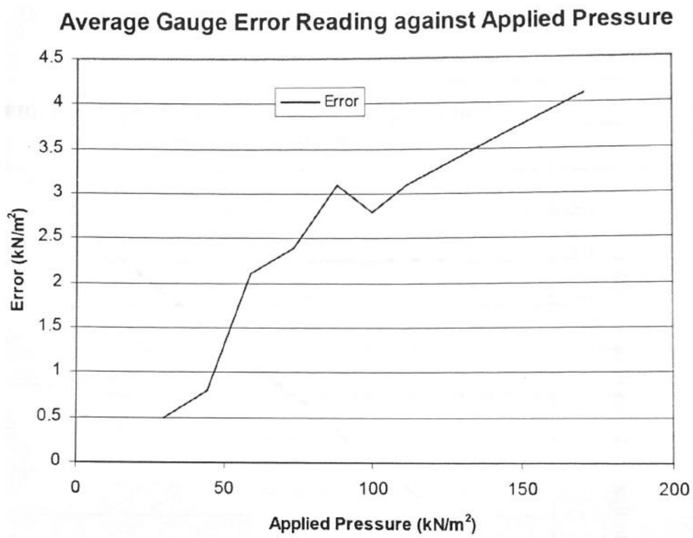
The results (Figure 3) show only a small hysteresis for this gauge, typically less than 1 kN/m^2 across the entire range. In normal use, you would gently 'tap' the gauge between readings to help relieve this friction - often called 'stiction'.

2. Accuracy of the printed scale.

The results (Figure 4) show an indicated pressure error trend that increases with the applied pressure. When converted into percentage of full scale you can expect a maximum error of around 2.5%. This is acceptable for many engineering purposes, although some manufacturers can supply gauges with an error of only 0.5% of the full-scale reading. However, greater accuracy usually means higher unit costs of the gauge.

3. Reading error.

If the user does not look directly through the printed scale at the pointer at a position perpendicular to the gauge face, then the reading may be subject to parallax error.



Average Gauge Error Reading

Questions for further discussion:

1. What suggestions do you have for improving the apparatus?
2. No correction has been allowed for the slight variations in height of the piston and therefore pressure head with respect to the gauge while you add weights. This is because the errors caused by this difference are too small to measure with this equipment. Remember that 10 mm of water = 9.8 N/m^2 = 0.0098 kN/m^2.
   However, if the centre of the gauge were 200 mm (0.2 m) higher than the base of the piston, should a correction be made and, if so, how big would it be?
3. How would you change the dimensions of the piston to use it for calibrating a gauge having a full scale reading of 3500 kN/m^2 using the same weights?

Conclusion:

Conclusion is to be done by the student upon his results and analysis.