Palestine technical university – khadoorie
Collage of engineering and technology
Mechanical engineering department
Fluid Mechanics and Thermodynamics Laboratory

Experiment 3: Pressure and vacuum measurements

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.

One of the earliest pressure measuring instruments is still in wide use today because of its inherent accuracy and simplicity of operation. It's the U-tube manometer, which is a U-shaped glass tube partially filled with liquid. This manometer has no moving parts and requires no calibration. Manometry measurements are functions of gravity and the liquid's density, both physical properties that make the U-tube manometer a NIST standard for accuracy.

Inclined manometers provide greater readability by stretching a vertical differential along an inclined indicating column, giving more graduations per unit of vertical height. This effectively increases the instruments sensitivity and accuracy.

Objectives:

1. To learn the concept of pressure measurement using U-tube and inclined manometers.
2. To calibrate a bourdon tube pressure gauge using a U-tube and inclined manometers.
3. To identify the sources of error which leads to inaccurate pressure reading.

Parts needed:

1. H30 pressure measurement bench.
2. Syringe 10 ml
3. Nylon Tubes
4. ‘ T’ pieces
5. Funnel
6. Artery clamps
7. Colored water

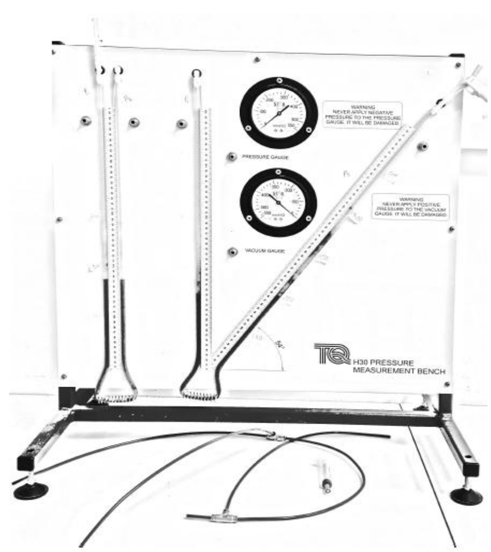


Fig.1 H30 pressure measurement bench.

Theory:

As in Figure2.A, each leg of a U-tube manometer exposed to the atmosphere, the height of liquid in the columns is equal. Using this point as a reference and connecting each leg to an unknown pressure, the difference in column heights indicates the difference in pressures (see Figure 2.B).

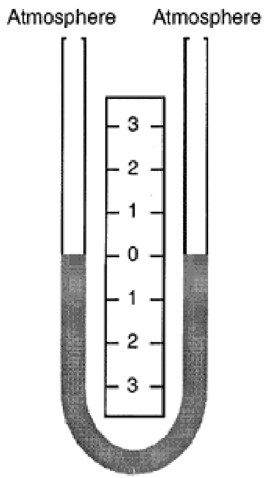


Figure 2.A

With both legs of a U-tube manometer open to the atmosphere or subjected to the same pressure, the liquid maintains the same level in each leg, establishing a zero reference.

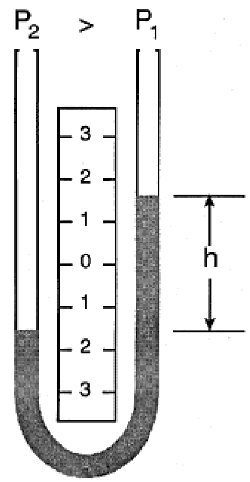


Figure 3. B

With a greater pressure applied to the left side of a U-tube manometer, the liquid lowers in the left leg and rises in the right leg. The liquid moves until the unit weight of the liquid, as indicated by h, exactly balances the pressure.

The fundamental relationship for pressure expressed by a liquid column is:

$\Delta p = P_2 - P_1 = \rho g h$ (for U – tube manometer), and

$\Delta p = P_2 - P_1 \sin ø = \rho g h \sin ø$ (for the inclined manometer)

where: Δp = differential pressure

- P_1 = pressure at the low-pressure connection
- P_2 = pressure at the high-pressure connection
- ρ = density of the fluid (at a specific temperature)
- g = acceleration of gravity (at a specific latitude and elevation)
- h = difference in column heights

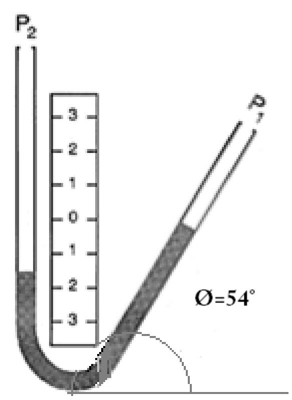
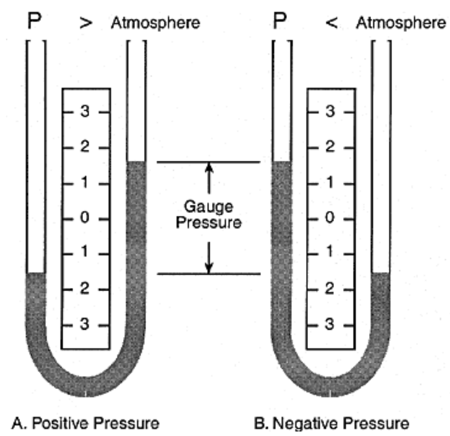


Figure 2.C: Inclined manometer (with p2 > p1)

The resulting pressure is the difference between forces exerted per unit of surface area of the liquid columns, with pounds per square inch (psi) or newtons per square meter (pascals) as the units. The manometer is so often used to measure pressure that the difference in column heights is also a common unit. This is expressed in inches, centimeters, or millimeters of water or mercury at a specific temperature, which can be changed to standard units of pressure with a conversion table.
All pressure measurements are differential. The reference can be zero absolute pressure (a total vacuum), atmospheric pressure (the barometric pressure), or another pressure. With one leg of a manometer open to the atmosphere (see Figure 3A), the measured pressure is that which exceeds atmospheric pressure, which at sea level is 14.7 psi, 101.3 kPa, or 76 cmHg.

Figure 3. Gauge pressure is a measurement relative to atmospheric pressure and it varies with the barometric reading. A gauge pressure measurement is positive when the unknown pressure exceeds atmospheric pressure (A), and is negative when the unknown pressure is less than atmospheric pressure(B).

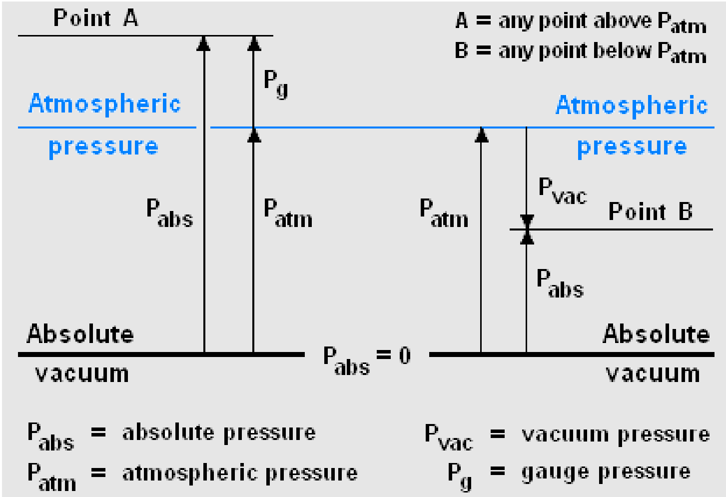


This measurement is called gauge pressure, and the relationship is expressed by:

absolute pressure = atmospheric pressure + positive gauge pressure (for a positive pressure).
and the relationship is expressed by:

absolute pressure = atmospheric pressure + negative gauge pressure (For a negative pressure - vacuum) measurement (see Figure 3B), the column heights reverse. These pressure relationships are shown in Figure 4.

Fig. 4
Relationships between gauge pressure, absolute pressure, and atmospheric pressure



A manometer can be designed to directly measure absolute pressure. The manometer in Figure 5 measures the pressure compared to zero absolute pressure in a sealed leg above a mercury column. The most common form of this manometer is the conventional mercury barometer used to measure atmospheric pressure. With just one connection, this configuration can measure pressures above and below atmospheric pressure.

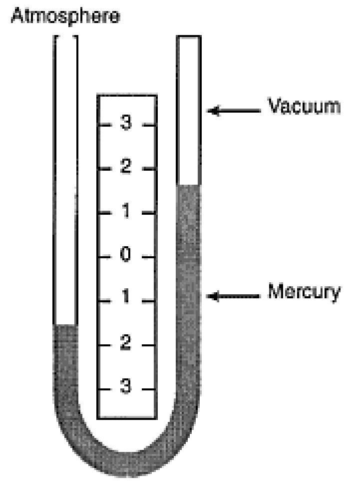


Figure 5. In a sealed-tube manometer, the pressure reference is a vacuum, or zero absolute pressure. The most common form of a sealed-tube manometer is the conventional mercury barometer used to measure atmospheric pressure.

Variations on the U-Tube Manometer: The differential pressure is always the difference in column heights, regardless of the size or shape of the tubes. As shown in Figure 6A, the legs of both manometers are open to the atmosphere and the indicating fluids are at the same level. Connecting the same pressure to the left leg of each manometer causes its level to lower. Because of the variation in volume in the manometer legs, the fluid in each column moves a different distance. However, the difference between the fluid levels in both manometers is identical (see Figure 6B).

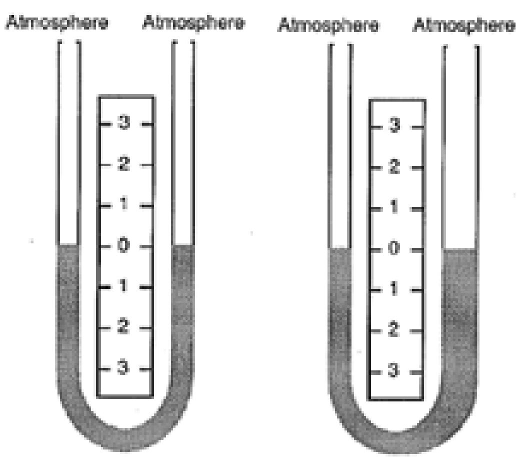


Fig.6A: Open to atmosphere

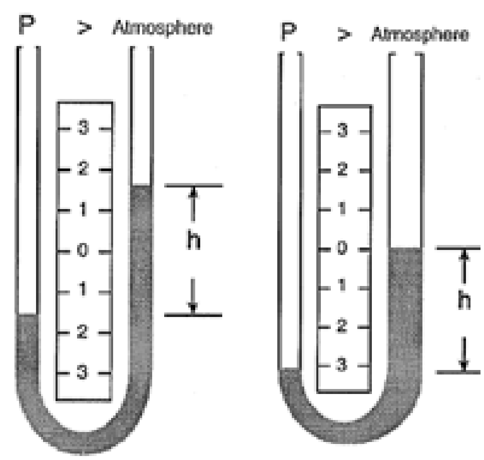


Fig.6B: Equal positive pressure applied

Indicating Fluids

Liquid manometers measure differential pressure by balancing the weight of a liquid between two pressures. Light liquids such as water can measure small pressure differences; mercury or other heavy liquids are used for large pressure differences. For an indicating fluid 3 times heavier than water, the pressure measurement range is 3 times greater, but the resolution is reduced.

Indicating fluids can be colored water, oil, benzenes, bromides, and pure mercury. When selecting an indicating fluid, check the specifications for specific gravity, operating temperature range, vapor pressure, and flash point. Corrosive properties, solubility, and toxicity are also considerations.

Procedure:

1. Use the funnel to fill the manometers with the colored water.
2. Construct a working circuit using the syringe assembly with the tubes and tee pieces, so that the pressure gauge and manometer can be used at the same time.
3. Note that For vacuum tests the syringe should be fully depressed prior to fitting to the circuit, and for pressure tests the syringe should be fully extended before fitting to the system, (read all notes labeled on the panel before doing the tests).
4. Complete the working circuit by Pressing the tube home firmly to ensure a leak proof joint is made.
5. Slowly move the syringe and note the change in both the gauge reading and manometer reading simultaneously.
6. Carefully ensure the range of the manometer is not exceeded or fluid could be spilt.
7. Record your results according to the following tables.

Pressure						
Pressure Gauge	Vertical Manometer			Inclined Manometer		
mm H2O	P1 mm H2O	P2 mmH2O	Δ mm H2O	P1 mm H2O	P2 mm H2O	Adjusted mm H2O
50						
100						
150						
200						
250						
300						

Vacuum						
Vacuum Gauge	Vertical Manometer			Inclined Manometer		
mm H2O	P1 mm H2O	P2 mm H2O	Δ mm H2O	P1 mm H2O	P2 mm H2O	Adjusted mm H2O
-50						
-100						
-150						
-200						
-250						
-300						

Results and analyses:

Manometers have an error due to inaccuracies in manufacturing the scale and user error in reading the level of water.

It will be found that this error increases to a maximum of around 2.5% of the full scale reading. This is acceptably small for many engineering purposes although gauges with an error of only 0.5% of the full scale reading are commercially obtainable.

A graph as in fig. 7 can be plotted showing the error on either the Bourdon gauge or the manometer.

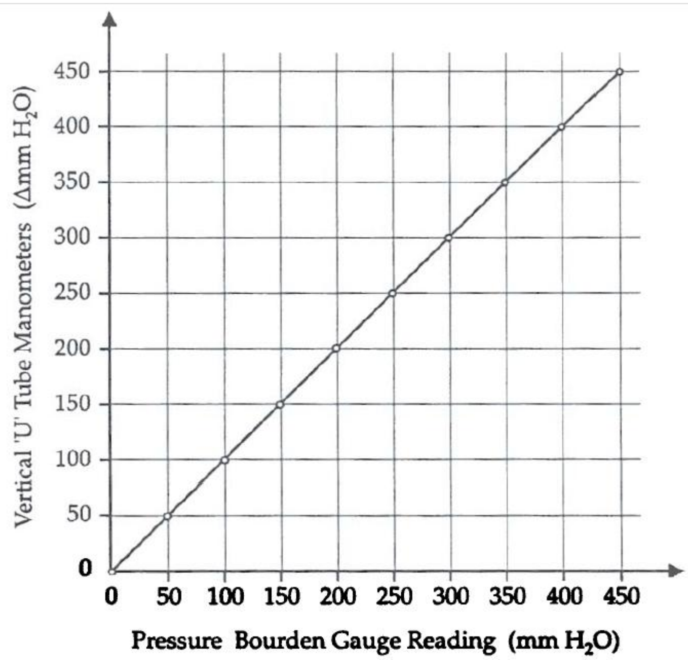


Fig.7: Typical calibration graph of bourdon pressure gauge and vertical U tube manometer.

Questions for further discussion:

1. Express one of your results as absolute pressure in (mm H2O).
2. Express one of your results in (N/m^2 or Pa)
3. Plot a chart for calibration of each gauge (pressure and vacuum) with the U tube manometer.
4. Plot a chart for the gauge error on y-axis with the applied pressure (from manometer) on x-axis of each gauge.
5. Discuss the error and the sources of error in your experiment?

Conclusion:

Student should write a conclusion upon his results and the objectives achievement.