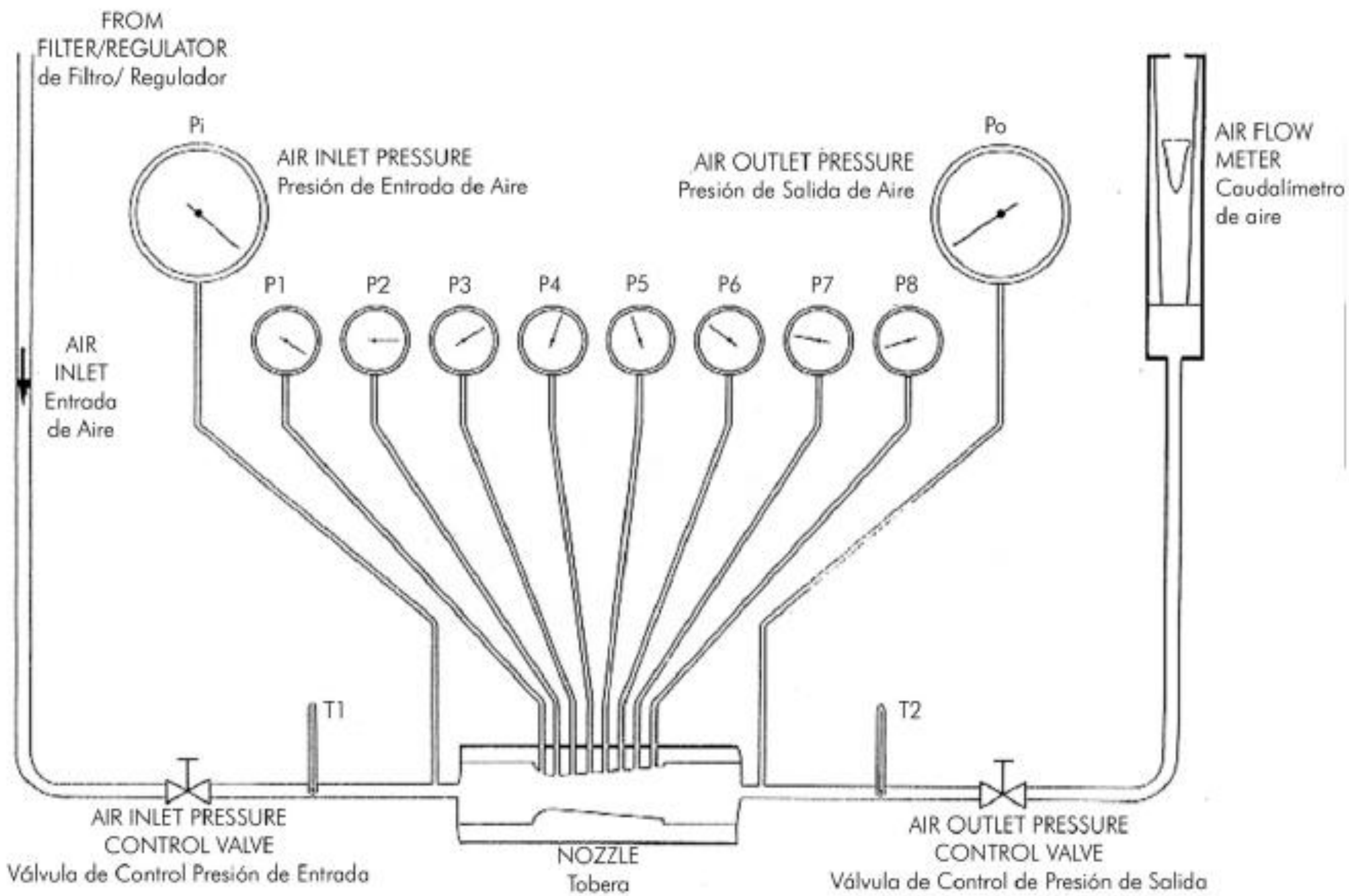
<u>Experiment No. 01:</u> To test that Pressure is an intensive property.

Apparatus: Nozzle Distribution Unit

PROCESS DIAGRAM AND ELEMENTS ALLOCATION



Note: P= Pressure meter. T=Thermometer

APPARATUS DESCRIPTION:

- This unit has been specifically designed to demonstrate the phenomena associated to fluxes through nozzles and to allow the quick investigation of the pressure distribution in it.
- Besides, it allows the investigation of the mass flow rate through convergent-divergent and convergent nozzles.
- Since the unit works with ambient temperature air, it is stabilized quickly and its energy consumption is only the necessary one to impulse a relatively small compressor.
- Compressed air at a 7 to 9 bars pressure, supplied from an external service. It passes through the filter/regulator, located on the back part of the unit.

APPARATUS DESCRIPTION:

- In the unit, the air passes through a control valve, which allows an accurate control of the pressure at the inlet of the nozzle.
- The pressure and inlet temperature are measured and then the air is expanded through the nozzle chosen.
- When discharging from the nozzle, the pressure is controlled by other valve, and the air goes finally through a flow meter to the atmosphere.
- The nozzles have been made of brass, have been mechanised accurately and several pressure tappings are available, being each one connected to its own manometer to indicate the static pressure.

APPARATUS SPECIFICATIONS:

- Bench-top unit. Anodized aluminium structure and panels in painted steel. Diagram in the front panel with similar distribution to the elements in the real unit.
- Nozzles: Convergent type (conical), with 6 pressure tappings. Convergent-divergent type, with 5 pressure tappings, for a design pressure ratio of 0.25. Convergent- divergent, with 8 pressure tappings, for a design pressure ratio of 0.1. Nozzles can be changed quickly and easily.
- 2 Pressure meters (manometers), 100 mm. diameter, to measure air inlet and outlet pressures (range: 0 to 10 bar). 8 Pressure meters (manometers), 60 mm. diameter, to determine the pressure at the nozzle tappings (range: -1 to 8 bar).

APPARATUS SPECIFICATIONS:

- Variable area type flow meter to indicate air flow at standard conditions (p= 1.2kg/m^3). (Correction factors for other pressures and temperatures are provided). Range 0 to 9 g/s. 2 Glass temperature meters, to indicate air temperature before and after nozzle(range: 0 to 50^{o}C).Valves to give a fine control of air inlet pressure and outlet pressure.
- Air filter and pressure regulator to provide constant pressure, clean and water free air to the unit. This is to be installed by the customer in the pipe between his compressed air service and the unit, and must be drained regularly.
- Works a ambient temperature- stabilises immediately. Allows students to make a comprehensive investigation in a normal laboratory period. Gives students an opportunity to calibrate equipment. Cables and accessories, for normal operation.

PROCEDURE:

Students are advised to deeply observe the apparatus operation during experimentation and then write down the procedure for the experiment in their own words.

OBSERVATIONS AND CALCULATIONS

No. of Obs.	Pressure before distribution	P1	P2	P3	P4	P5	P6	Pressure after distribution
---	Bars	Bars	Bars	Bars	Bars	Bars	Bars	Bars
1.	3.0							
2.	2.5							
3.	2.0							
4.	1.5							
5.	1.0							

Results:

Students are advised to deeply check that either all the gages are showing the same values or not. If all the values are same the what it is showing? Similarly if all the values in all gages are not same that what that are showing, and why all that are not same.

Comments:

This is the most important part of your experimental work. In this portion of your experiment you give the comments about your observations, calculations, experimental results etc. If there are some variations in experimental results then discuss why they are, and how it can be removed. Also observe that what were the errors generated during due to environmental effects, human error or by any other source. Keep in mind every student has different mind, different thinking and different approach to observe the things.

Experiment No. 02: Calibration of Bourdon Manometer Gauge and determination of Hysteresis curve.

Apparatus: Dead Weight Calibrator, Set of Masses

PROCESS DIAGRAM AND ELEMENTS ALLOCATION

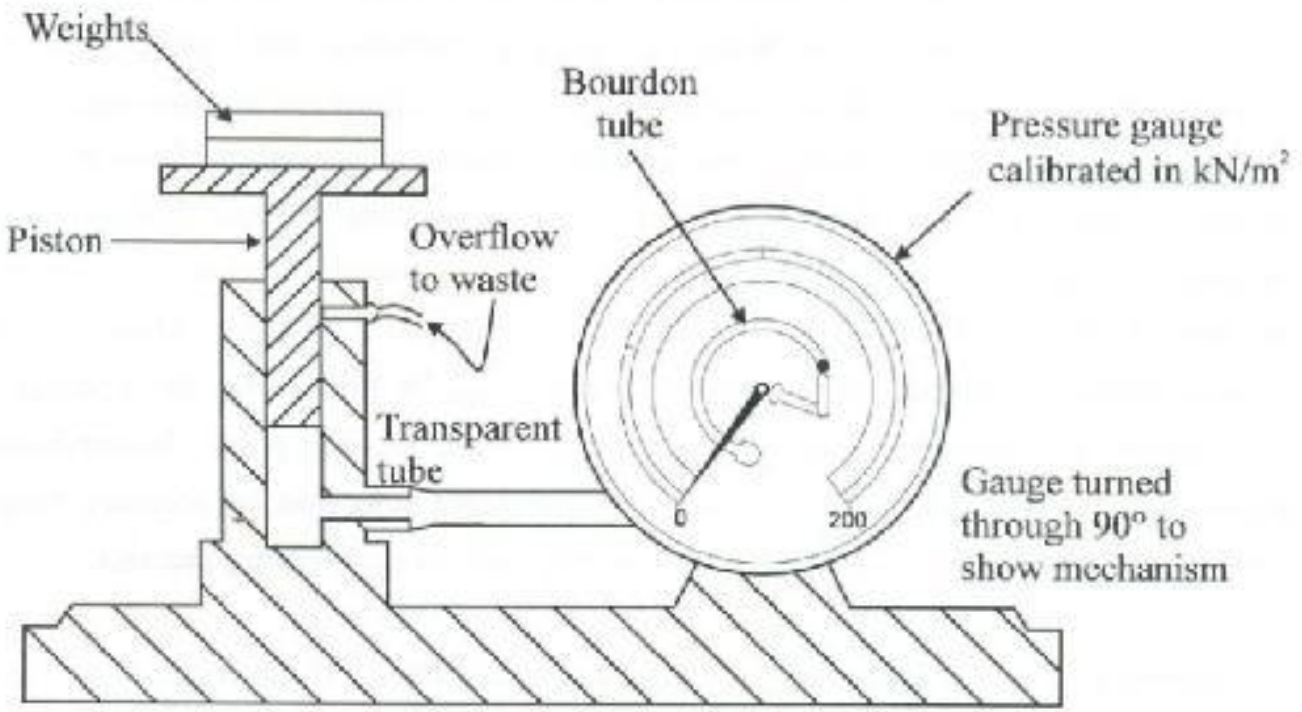


Fig 3.1 Apparatus for calibration of pressure gauge

Glycerine filled pressure gauge

APPARATUS DESCRIPTION:

- This unit enables a wide range of investigations and studies into pressure measurement techniques, using Bourdon type pressure gauges to understand the operation the characteristic of the devices, and to study the principles of calibration and to do practical exercises and experiments about it.
- Pressure Measurement and Calibration Unit is designed to study pressure and how different methods and techniques can be used to measure this variable.
- This unit introduces students to pressure, pressure scales and common devices available to measure pressure.
- It comprises a dead-weight pressure calibrator to generate a number of predetermined pressures, connected to a Bourdon type manometer to allow their characteristics, including accuracy and linearity, to be determined.

APPARATUS DESCRIPTION:

- Using the dead-weight pressure calibrator different fixed pressures are generated for calibrating the measuring elements. The dead-weight pressure calibrator consists of a precision piston and cylinder with a set of weights.
- The Bourdon type manometer is mounted on a manifold block with a separate reservoir to contain the water.
- Valves allow for easy priming, restricted flow of water to demonstrate the application of damping and the connection of alternative devices for calibration.

APPARATUS SPECIFICATIONS:

Bourdon gauge with dead-weight calibrator module:

- Anodized aluminum structure and panel in painted steel (epoxy paint), and main metallic elements in stainless steel.
- Diagram in the panel with similar distribution to the elements in the real unit.
- Dead-weight calibrator consists of a piston, with is free to move vertically, in cylinder. Flexible hose connects the cylinder with the Bourdon pressure gauge. A set of weights are included.
- Bourdon type gauge with internal mechanism clearly visible through the transparent dial.
- The module can be leveled with the help of adjustable feet.

Calibration:

It is defined as the process of comparison of specific values of input and output of instrument with the corresponding reference standards.

Concept Structure:

Calibration

↓

Process of comparison of specific values of input and output of instrument

↓ With

Corresponding reference standard

Calibration must be performed periodically to test the validity of performance of device or system.

Calibration

To be Performed

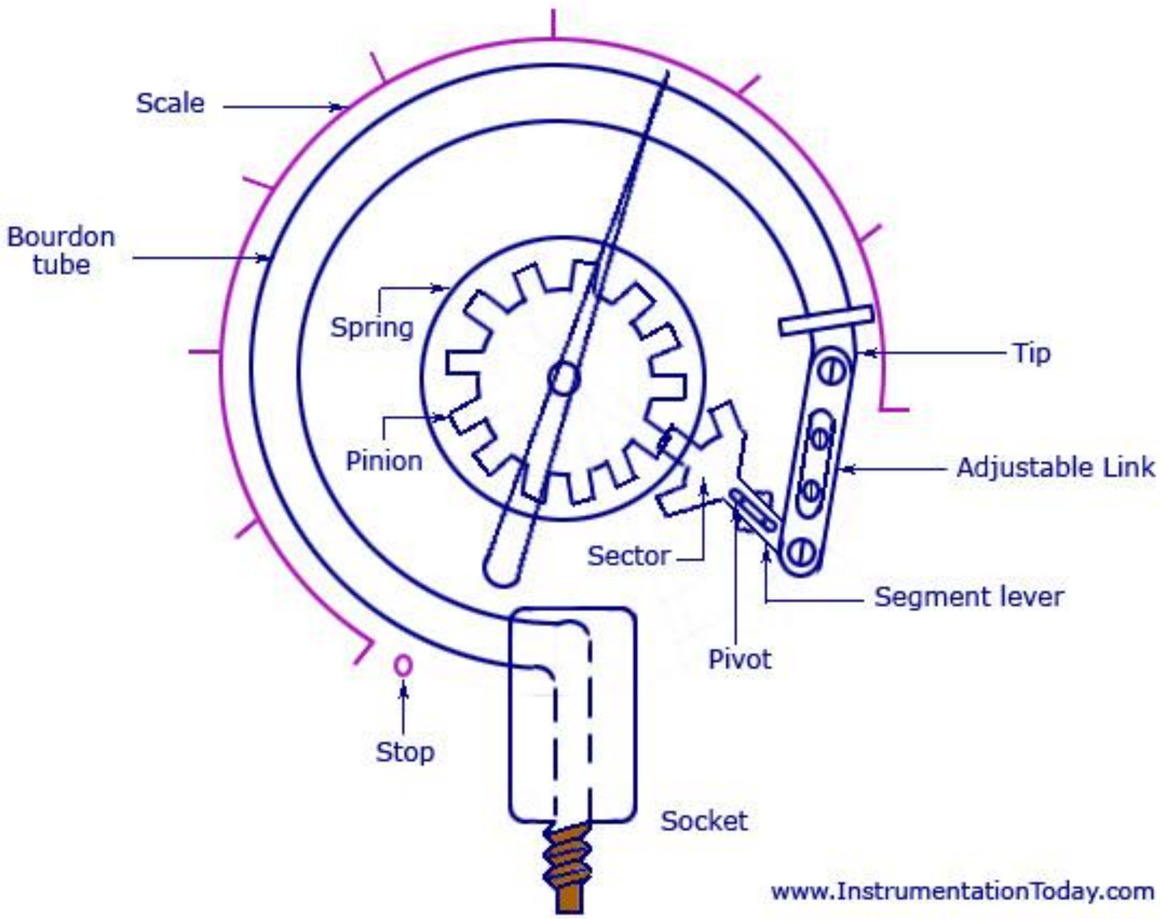
Periodically

To test the validity of performance of device or system

BOURDON TUBE

- Bourdon Tubes are known for its very high range of differential **pressure measurement** in the range of almost 100,000 psi (700 MPa). It is an elastic type pressure transducer.
- The device was invented by Eugene Bourdon in the year 1849. The basic idea behind the device is that, cross-sectional tubing when deformed in any way will tend to regain its circular form under the action of pressure.
- The bourdon pressure gauges used today have a slight elliptical cross-section and the tube is generally bent into a C-shape or arc length of about 27 degrees. The detailed diagram of the bourdon tube is shown below.

BOURDON TUBE



Bourdon Tube Pressure Gauge

BOURDON TUBE

- As seen in the figure, the pressure input is given to a socket which is soldered to the tube at the base. The other end or free end of the device is sealed by a tip. This tip is connected to a segmental lever through an adjustable length link. The lever length may also be adjustable. The segmental lever is suitably pivoted and the spindle holds the pointer as shown in the figure. A hair spring is sometimes used to fasten the spindle of the frame of the instrument to provide necessary tension for proper meshing of the gear teeth and thereby freeing the system from the backlash.
- Any error due to friction in the spindle bearings is known as lost motion. The mechanical construction has to be highly accurate in the case of a Bourdon Tube Gauge. If we consider a cross-section of the tube, its outer edge will have a larger surface than the inner portion. The tube walls will have a thickness between 0.01 and 0.05 inches.

BOURDON TUBE

Working:

- As the fluid pressure enters the bourdon tube, it tries to be reformed and because of a free tip available, this action causes the tip to travel in free space and the tube unwinds. The simultaneous actions of bending and tension due to the internal pressure make a non-linear movement of the free tip.
- This travel is suitable guided and amplified for the measurement of the internal pressure. But the main requirement of the device is that whenever the same pressure is applied, the movement of the tip should be the same and on withdrawal of the pressure the tip should return to the initial point.

BOURDON TUBE

Working:

- A lot of compound stresses originate in the tube as soon as the pressure is applied. This makes the travel of the tip to be non-linear in nature. If the tip travel is considerably small, the stresses can be considered to produce a linear motion that is parallel to the axis of the link. The small linear tip movement is matched with a rotational pointer movement. This is known as multiplication, which can be adjusted by adjusting the length of the lever.
- For the same amount of tip travel, a shorter lever gives larger rotation. The approximately linear motion of the tip when converted to a circular motion with the link-lever and pinion attachment, a one-to-one correspondence between them may not occur and distortion results. This is known as angularity which can be minimized by adjusting the length of the link.

BOURDON TUBE

Working:

- Other than C-type, bourdon gauges can also be constructed in the form of a helix or a spiral. The types are varied for specific uses and space accommodations, for better linearity and larger sensitivity. For thorough repeatability, the bourdon tubes materials must have good elastic or spring characteristics.
- The surrounding in which the process is carried out is also important as corrosive atmosphere or fluid would require a material which is corrosion proof. The commonly used materials are phosphor-bronze, silicon-bronze, beryllium-copper, inconel, and other C-Cr-Ni-Mo alloys, and so on.

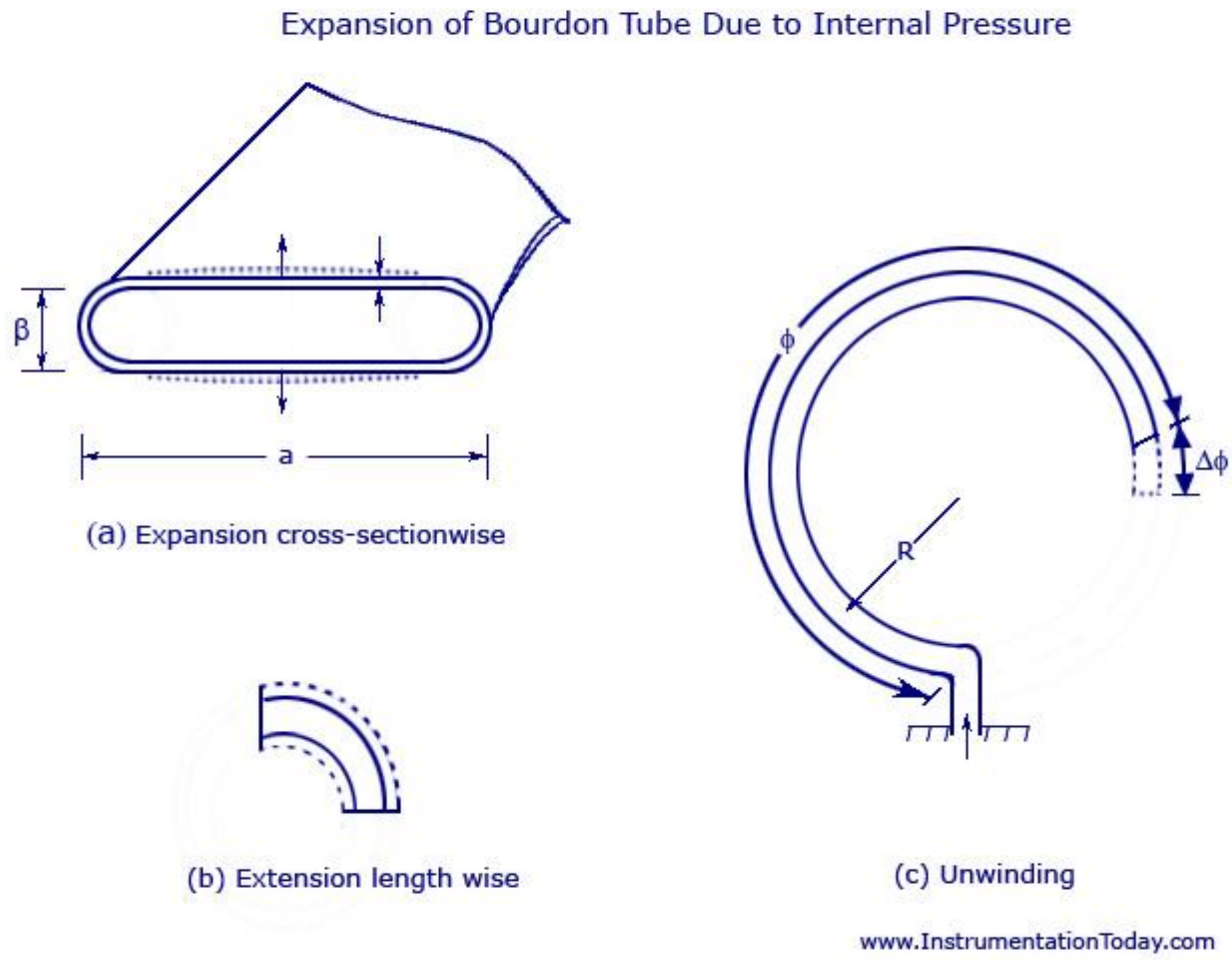
BOURDON TUBE

Working:

- In the case of forming processes, empirical relations are known to choose the tube size, shape and thickness and the radius of the C-tube. Because of the internal pressure, the near elliptic or rather the flattened section of the tube tries to expand as shown by the dotted line in the figure below (a). The same expansion lengthwise is shown in figure (b). The arrangement of the tube, however forces an expansion on the outer surface and a compression on the inner surface, thus allowing the tube to unwind. This is shown in figure (c).

BOURDON TUBE

Expansion of Bourdon Tube Due to Internal Pressure



BOURDON TUBE

Working:

- Like all elastic elements a bourdon tube also has some hysteresis in a given pressure cycle. By proper choice of material and its heat treatment, this may be kept to within 0.1 and 0.5 percent of the maximum pressure cycle.
- Sensitivity of the tip movement of a bourdon element without restraint can be as high as 0.01 percent of full range pressure reducing to 0.1 percent with restraint at the central pivot.

PROCEDURE:

Students are advised to deeply observe the apparatus operation during experimentation and then write down the procedure for the experiment in their own words.

OBSERVATIONS AND CALCULATIONS

Diameter of Piston = d= 18 mm = 0.018 m.

Area of Piston = A =$\pi d^2/4$ = $3.142(0.018)^2/4$ = 0.000255 m^2

We will find the Pressure in the Cylinder by using the formula P = F/A

We convert bars into KN/m^2 by;

1 bar = $10^5\ N/m^2 = 10^2 KN/m^2$

OBSERVATIONS AND CALCULATIONS

FOR ASCENDING ORDER OF MASS OF PISTON

No. of obs.	Mass of Piston	Pressure in Cylinder	Manometer Reading	Manometer Reading	Absolute Error	Relative Error
---	M (Kg)	X (KN/m^2)	X_0 (Bars)	X_0 (KN/m^2)	$X-X_0$ (KN/m^2)	$(X-X_0)/X$ (KN/m^2)
1						
2						
3						
4						
5						
6						

OBSERVATIONS AND CALCULATIONS

FOR DESCENDING ORDER OF MASS OF PISTON

No. of obs.	Mass of Piston	Pressure in Cylinder	Manometer Reading	Manometer Reading	Absolute Error	Relative Error
---	M (Kg)	X (KN/m^2)	X_0 (Bars)	X_0 (KN/m^2)	$X-X_0$ (KN/m^2)	$(X-X_0)/X$ (KN/m^2)
1						
2						
3						
4						
5						
6						

OBSERVATIONS AND CALCULATIONS

AVERAGE OF ASCENDING & DESCENDING VALUES OF MASS OF PISTON

No. of obs.	Mass of Piston	Pressure in Cylinder	Manometer Reading	Manometer Reading	Absolute Error	Relative Error
---	M (Kg)	X (KN/m^2)	X_0 (Bars)	X_0 (KN/m^2)	$X-X_0$ (KN/m^2)	$(X-X_0)/X$ (KN/m^2)
1						
2						
3						
4						
5						
6						

GRAPH:

- Graph between absolute error in a function of the real pressure in the manometer.
- Graph between relative error in a function of the real pressure in the manometer.

DETERMINATION OF HYSTERISIS CURVE

Hysteresis is the dependence of a system not only on its current environment but also on its past environment. This dependence arises because the system can be in more than one internal state. To predict its future development, either its internal state or its history must be known.[1] If a given input alternately increases and decreases, the output tends to form a loop as in the figure. However, loops may also occur because of a dynamic lag between input and output. Often, this effect is also referred to as hysteresis, or *rate-dependent hysteresis*. This effect disappears as the input changes more slowly, so many experts[*who?*] do not regard it as true hysteresis.

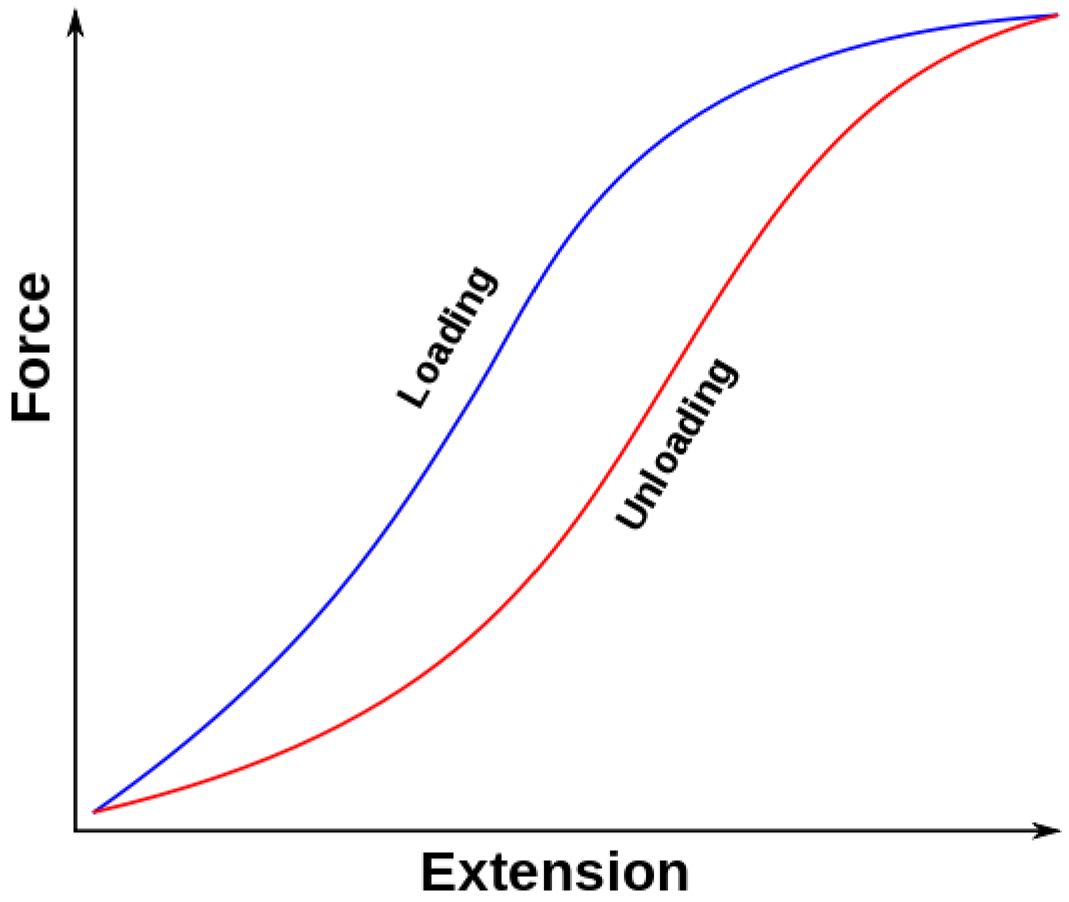
DETERMINATION OF HYSTERISIS CURVE

Hysteresis occurs in ferromagnetic materials and ferroelectric materials, as well as in the deformation of some materials in response to a varying force. In natural systems hysteresis is often associated with irreversible thermodynamic change. Many artificial systems are designed to have hysteresis: for example, in thermostats hysteresis is produced by positive feedback to avoid unwanted rapid switching. Hysteresis has been identified in many other fields, including economics and biology.

DETERMINATION OF HYSTERISIS CURVE

- Draw a graph between real pressure in KN/m^2 and manometer pressure in KN/m^2 for ascending and descending readings. If a loop is formed in the graph this means hysteresis take place.

DETERMINATION OF HYSTERISIS CURVE



Results:

Students are advised to deeply check that either the applied pressure on the piston comprises the pressure shown on the Bourdon Pressure Gauge. If both of the values are same then tell what it is showing of. If there is a difference in the actual pressure and the pressure shown on the gauge then why does it so… What are the reasons of it. What are your conclusions from this experiment.

Comments:

This is the most important part of your experimental work. In this portion of your experiment you give the comments about your observations, calculations, experimental results etc. If there are some variations in experimental results then discuss why they are, and how it can be removed. Also observe that what were the errors generated during due to environmental effects, human error or by any other source. Keep in mind every student has different mind, different thinking and different approach to observe the things.