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Lab. Manual
of
Fluid Mechanics
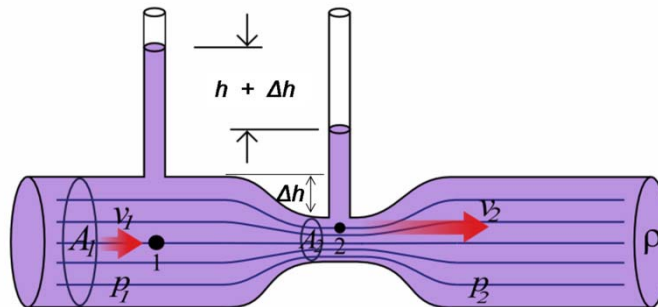
The Department of Civil and Architectural Engineering

General Safety rules to be followed in Fluid Mechanics Lab:

1. Always wear shoes before entering lab.

2. Do not touch anything without the permission of instructor/lab assistant.

3. Read carefully the lab manual before performing experiments.

4. Check electrical connections before starting the equipment.

5. Do not put your hands while the machine is in operation.

6. Do not tamper measuring instruments.

7. Do not open the casing of the equipment.

8. Do not unplug any electrical connection.

9. Switch off the power supply to the experimental setup on completion of the experiment.

10. Do not leave chemical containers on the working tables.

11. Use safety goggles wherever necessary.

List of Experiment

Experiment No: 1 Calibration of a Bourdon Pressure Gage

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Experiment No: 3 Center of Pressure on Submerged Plane Surface

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Experiment No: 1 Calibration of a Bourdon Pressure Gage

Objective:

To calibrate a Bourdon type pressure gage and to establish the calibration curve of Bourdon Gage. Also determine the gage errors.

1. Apparatus:

  i.   Dead Weight Calibrator.
  ii.   Set of Test weights
  iii. Weight balance.
  iv.   Bourdon pressure gage.

1.1 Introduction

Instrument calibration is one of the primary processes used to maintain instrument accuracy. It is the process of configuring an instrument to provide results within an acceptable range. Known weights have been applied on a Dead Weight Calibrator to apply pressure to a fluid for checking the accuracy of readings from a pressure gage.

Various types of pressure measuring instrument have been used to measure the pressure intensity at any point in static or moving fluid. One of these devices is the Bourdon tube pressure gage. Bourdon-tube pressure gages are most widely used now-a-days because of their reliability, compactness, low cost and ease of use. It consists of a curved tube (Figure 1) of elliptical cross-section bent into a circular arc.

Figure 1: Dead Weight Calibrator

When pressure is applied to the tube, it tends to straighten out, and the deflection of the end of the tube is communicated through a system of levers to a recording pointer. This gauge is widely used for steam and compressed gases. The pressure indicated is the difference between the system pressure and to the external (ambient) pressure, and is usually referred to as the gauge pressure

1.2 Related Theory:

The bourdon gage is the most popular pressure measuring device for both liquids and gasses. It can be connected to any source of pressure such as a pipe or vessel containing a pressurized fluid.

I. Bourdon Gage:

The Bourdon Gauge (Figure 2) is fitted with a transparent dial, which lets you see the internal workings of the gauge. The gauge consists of a thin walled closed ended tube which is oval in cross section. This tube is bent through an angle of about 270° along its long axis. The open end of the tube is welded to a hollow mounting block which allows the pressurized fluid to reach the tube. This causes the pressure from the source to be transmitted directly to the inside of the bourdon tube. The applied pressure causes the oval tube to become rounder (since a round cross section has the maximum area for a given circumference). As it becomes rounder, the bourdon tube tends to uncurl which causes its free end to move. A system of linkages and levers transmits this motion to the gauge needle which moves over the scale.
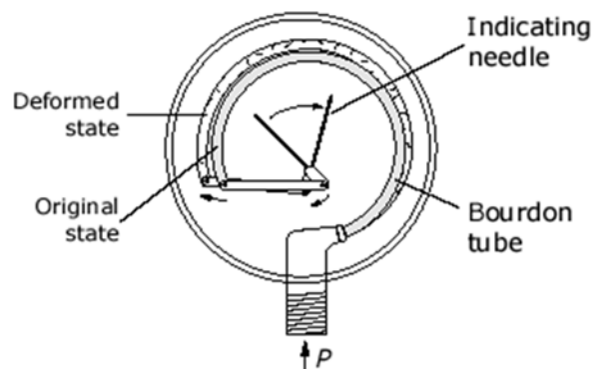

Figure 2: Bourdon Gage

II. Dead Weight Calibrator:

In order to obtain very accurate pressure measurements, it is essential to regularly re-calibrate the gauge. This is because the tube tends to become weaker with extended use. The usual procedure is to apply a known pressure to the gauge using a device called a Dead Weight Calibrator. The normal calibration procedure is to load the gauge for known pressures, using a dead weight calibrator including a liquid of known specific gravity (use water as the liquid). This dead weight tester uses a simple piston and cylinder arrangement to provide a source of pressurized liquid (in the experiment water will produced a better result than oil) which is transmitted to the gauge. Since the true pressure of the liquid can be easily calculated, the value can be compared directly to the reading on the gauge over the complete scale range. (The scale range is the range of pressures from zero to the full-scale deflection value). The dead weight tester consists of a cylindrical piston which is free to move vertically in a close fitting cylinder.

A *Platen* is attached to the piston which can be loaded with a series of accurate weights. The pressure developed in the cylinder is transmitted via a transparent tube to the gauge under test. The cylinder is mounted on a base board which is supported on leveling screws and fitted with a spirit level.

1.3 Governing Equations:

The use of the piston and weights with the cylinder generates a measurable reference pressure:

$$P = \frac{F}{A} \; , \qquad F = Mg$$

Where,

F =   Force applied to the liquid in the calibrator cylinder in Newton (N).

M =   Total mass including the mass of the piston in kilogram (kg).

A =   Cross-sectional area of the piston in square meter (m²).

g =   Acceleration due to gravity in meter per square second (m/s²).

1.4 Equipment Set Up:

- Position the calibrator without the piston on the hydraulic bench top and ensure that the base is horizontal by adjusting the feet and using the spirit level. This is necessary to ensure vertical transfer of the applied load and free rotation of the piston.
- Open all cocks on the pressure gage base.
- Connect the inflow cock to the bench flow connector and the outflow cock to the lower tube from the calibrator cylinder.
- Open slowly the bench valve to produce a flow, tilt the pressure gage to ensure that air is driven out from the manifold and then close the middle cock on the manifold.
- When there is no further air emerging and the calibrator cylinder is full, close the bench valve and the inflow cock on the manifold.

1.4.1 Data for the Piston:

a. Mass of the piston (M_p) = 498g
b. Diameter of the piston (d) = 0.01767m

1.5 Procedure:

1. Measure the weight of the calibration masses.

2. Note down the weight of the piston and it's cross sectional area.

3. Remove the piston and pour the water into the cylinder until it is full to overflow level. Any air trapped in the tube may be cleared by tilting and gently tapping the apparatus.

4. Insert the piston carefully and spin it to minimize any friction effects.

5. Note the pressure reading from the gage.

6. Add the weights in convenient increments, and at each increment, observe the pressure gage reading.

7. Take the similar sets of readings with decreasing weights.

Note: **If due to the slight leakage, piston reaches the cylinder bottom, more water must be added to the cylinder.**

1.6 Table of Observations and Calculations:

All readings and calculations are to be tabulated as follows:

Mass (kg)	Actual Pressure (kPa)	Gage Reading (kPa)		Percent Error (%)	
		Loading	Unloading	Loading	Unloading

Relative Error = (Measured Value – Actual Value) /Actual Value

Percent Error = │Relative Error│ × 100

Note: Also, show the sample calculation to calculate the Relative Error and Percent Error.

1.7 Graphical Relationship:

Plot the following graphs:

1) Actual Pressure against Measured Pressure (Gage Reading).

2) Percent Error against Measured Pressure (Gage Reading).

1.8 Conclusion and Recommendations:

- Comment on the accuracy of the gage.
- Is the relative height between the calibrator and the gage important in calibration?
- General comments about the experiment
- Your recommendations.

Experiment No: 2 Pressure Measurement Bench

Objective

To get familiar with different pressure measuring instruments and to verify the theoretical manometer equation for measurement of pressure.

2. Apparatus

   i.   Pressure measurement bench
   ii.   U- tube Manometer filled with mercury
   iii. Bourdon pressure gauge
   iv.   Pressure transducer

2.1 Related Theory

Pressure of a fluid is the normal force exerted by a fluid on a unit area. The pressure designated will be either an absolute pressure or a gauge pressure. Absolute pressure is measured relative to a perfect vacuum (absolute zero pressure), whereas gauge pressure is measured relative to the local atmospheric pressure. Absolute pressures are positive, but gauge pressure can be either positive (above atmospheric pressure) or negative (below atmospheric pressure) as shown in figure 1.
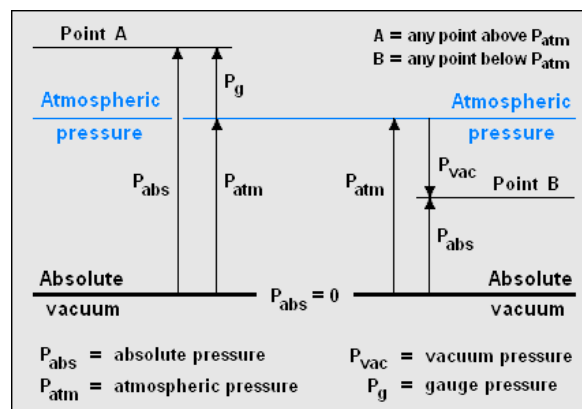

Figure 1: Graphical Representation of Gage & Absolute Pressure

U-tube manometers, bourdon gauge and the pressure transducer used in this experiment to measure the pressure.

2.2 Description of the Instruments

2.2.1 Manometer:

It is a widely used device for measurement of fluid pressure under steady state and laboratory conditions. This method involves balancing the unknown pressure against the pressure produced by a fluid column of known density. The manometer gives directly the gauge pressure. In order to improve the resolution on very low-pressure manometers, the indicating tube is inclined to cause a greater linear movement than a vertical tube. U-tube and inclined manometers are shown in the figure 2.
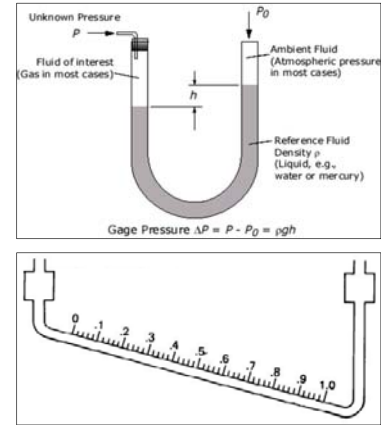

Figure 1 U-tube & Inclined Manometers

2.2.2 Bourdon Pressure Gauge:

The Bourdon tube is usually an elliptical cross-section tube having a 'C' shape configuration. When pressure is admitted to the inside of the tube, an elastic deformation results, which tries to straighten up the tube. One end of the tube is fixed and the other end is free to move and is connected to a spring-loaded linkage, which amplifies the displacement and transforms it into an angular rotation of the pointer.
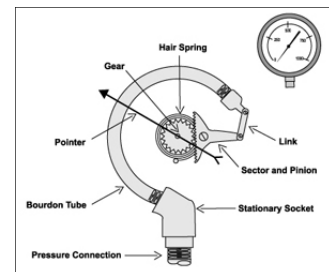
Figure 2 Bourdon Gauge

2.2.3 Pressure Transducer:

The operation of this device is based on the principle of elastic deformation of a sensitive element. The commonly used transducer is the strain-gage base transducer. It converts pressure into an analog electrical signal by the physical deformation of strain gages. Pressure applied to the transducer produces a deflection of the diaphragm which introduces strain to the gages. The strain will produce an electrical resistance changes proportionally to the pressure.

2.3 Procedure

1. Familiarize with adjusting the pressure of the pump using the control knobs.

2. Check the range of pressures to which each instrument can be exposed.

3. Connect the U-tube manometer and the pressure transducer to the network.

4. Get multiple pressure readings by increasing the pressure gradually.

5. Repeat steps 3 and 4 but connect the U-tube manometer with the Bourdon gauge instead of the pressure transducer.

2.4 Observations and Calculations

Table.1: Max operating range of used instruments

Instrument	Transducer		Bourdon Gauge		U-Tube Mercury Manometer	
Unit	Bar	Pascal	Bar	Pascal	mm Mercury	Pascal
Reading						

Table.2: Comparison of various instruments

Transducer Reading		U-Tube Manometer			
P_1		h_1	h_2	h (Level Diff.)	P_2
Bar	kPa	mm	mm	m	kPa

Bourdon Gauge		U-Tube Manometer			
P_3		h_1	h_2	h (Level Diff.)	P_4
Bar	kPa	mm	mm	m	kPa

Table.3: Error percentages

P_1	P_2	Error %	P_3	P_4	Error %

Note:

- $P = \gamma h$
- $1\, Bar = 101.3\, kPa, \gamma_w = 9.789\, kN/m^3 @ 20°C, SG_{Hg} = 13.6$

2.5 Graphical Relationships:

Plot the graphs between P1 and P2 as well as between P3 and P4.

2.6 Discussion and Recommendations:

- Discuss the different areas of application of the various instruments.
- Comment on the error percentages.

Experiment No: 3 Center of Pressure on Submerged Plane Surface

Objective:

To calculate the hydrostatic force a fluid exerts on a submerged plane surface and then compare the experimental hydrostatic force to the theoretical hydrostatic force.

3. Apparatus:

   i.   Hydrostatic Pressure Apparatus
   ii. Set of Test Weights
   iii. Water

3.1 Related Theory:

The basic theory to calculate the hydrostatic force for partially and fully submerged plane is same. So, the two cases will be discussed separately. Figure 1 is a sketch of the device used to measure the center of pressure on submerged vertical surface.
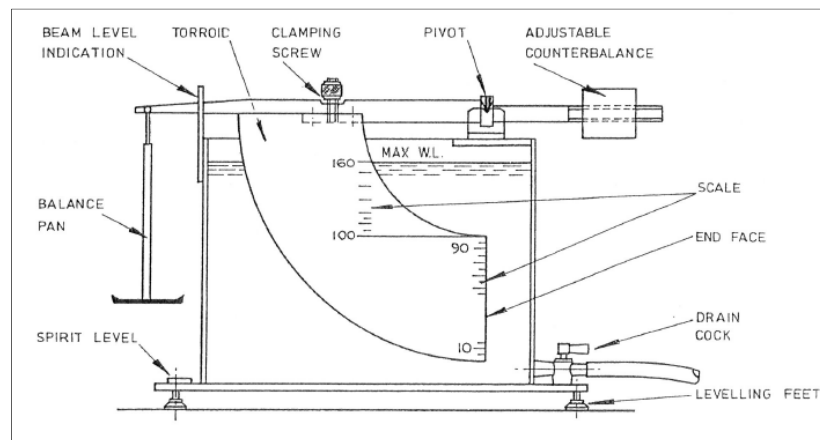

Figure 1: Hydrostatic pressure apparatus

1. Partially submerged vertical plane surface

The magnitude of hydrostatic force acting on the rectangular face and the depth of center of pressure can be computed from Eq. 1 and Eq. 2 respectively.

$$F = g\rho h_c A \tag{1}$$

$$y_R = y_c + \frac{I_G}{y_c A} \tag{2}$$
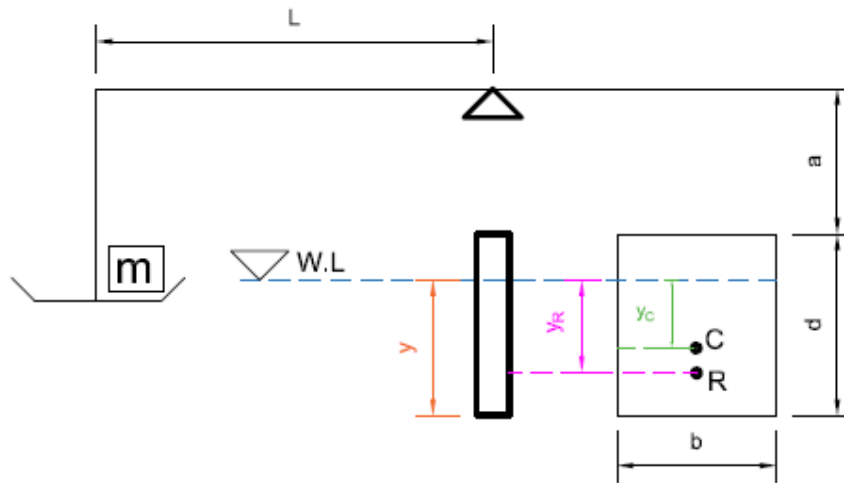
The partially submerged surface is shown in Figure 2.

Figure 2: Partially submerged

Where

$$h_c = y_c = \frac{y}{2} \;\; and \;\; A = by \tag{3}$$

Substituting the value of h_c and A in Eq. 1

$$F = \frac{1}{2} g\rho b y^2 \tag{4}$$

The second moment of inertia formula is as follows, where b is the length of the base of the submerged plane and y is the height of the submerged plane.

$$I_{xc} = \frac{1}{12} b y^3 \tag{5}$$

Therefore Eq. 2 will become

$$y_R - y_c = \frac{by^3/12}{by^2/2} = \frac{y}{6} \tag{6}$$

Moment about knife-edge axis is given by Eq. 8

$$M = \frac{1}{2} g\rho b y^2 \left(a + d - \frac{y}{2} + \frac{y}{6} \right) \tag{7}$$

$$M = \frac{1}{2} g\rho b y^2 \left(a + d - \frac{y}{3} \right) \tag{8}$$

A balancing moment (Eq. 9) is produced by the weight (w) applied to the hanger at the end of the balance arm.

Also $M = w \times L$ (9)

Where   **w** = mg and **m** is the mass added to balance pan. **L** is the distance from knife-edge axis to balance pan suspension rod axis.

For static equilibrium, the two moments governed from Eq. 8 and Eq. 9 are equal

$$mL = \frac{1}{2}\rho by^2 \left(a + d - \frac{y}{3}\right)$$ (10)

2. Fully submerged vertical plane surface

The magnitude of hydrostatic force acting on the rectangular face and the y-direction position of center of pressure can be computed from Eq. 1 and Eq. 2 respectively.

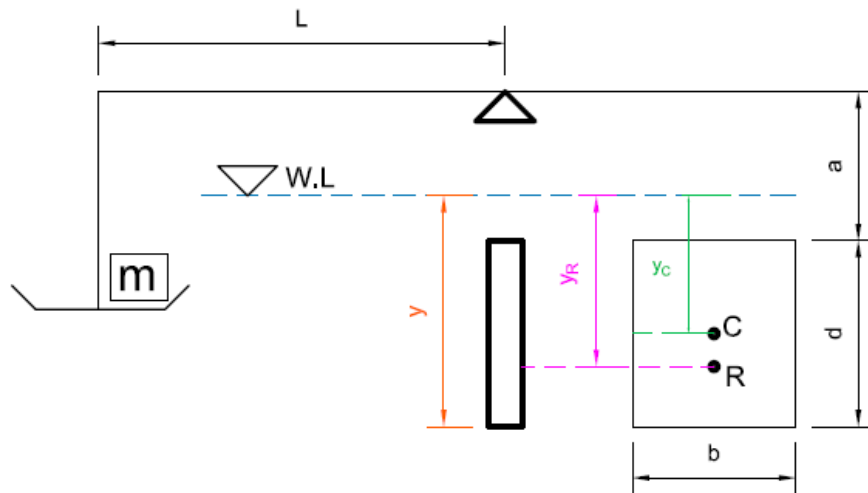The partially submerged surface is shown in Figure 3.

Figure 3: Fully submerged

Where

$$h_C = y_C = y - \frac{d}{2} \ , \ A = bd$$ (11)

Substituting the value of h_c and A in Eq. 1

$$F = \rho g \left(y - \frac{d}{2}\right) bd$$ (12)

The second moment of inertia formula is as follows (Eq. 13), where b is the length of the base of the submerged plane and d is the height of the submerged plane.

$$I_{xc} = \frac{1}{12} bd^3 \qquad\qquad (13)$$

Therefore Eq. 2 will become

$$y_R - y_C = \frac{bd^3/12}{bdy_C} = \frac{d^2}{12y_C} \qquad\qquad (14)$$

Moment about knife-edge axis is given by Eq. 15

$$M = g\rho bdy_C \left(a + \frac{d}{2} + \frac{d^2}{12y_C} \right) \qquad\qquad (15)$$

For static equilibrium, the two moments governed from Eq. 9 and Eq. 15 are equal

$$mL = \rho bdy_C \left(a + d + \frac{d^2}{12y_C} \right) \qquad\qquad (16)$$

3.2 Procedure:

1. Place the center of pressure apparatus on a level surface. This is important for obtaining an accurate force balancing scenario.
2. Measure the dimensions a, b, d, and the distance L from the knife-edge axis to the balance pan axis.
3. Position the Perspex tank on work surface and locate the balance arm on the knife edges.
4. Attach a hose to the drain cock and direct the other end of the hose to the sink. Attach a hose to the tap and place the free end on the top of the Perspex tank. Level the tank using the adjustable feet in conjunction with the spirit level.
5. Adjust the counter-balance weight until the balance arm is horizontal. This is indicated on a gate adjacent to the balance arm.
6. Open the valve to fill water into the Perspex tank, until the water is level with the bottom edge of the toroid.
7. Place a mass on the balance pan. Fill the tank until the balance arm is horizontal. Note the water level on the scale. Fine adjustment of the water level may be achieved by over-filling and slowly draining, using the drain cock.
8. Repeat step No.7 for different masses and note the corresponding water level.

3.3 Observations and Calculations

3.3.1 Table of Observations:

Sr. No	Description	Values
1	a (cm)	
2	b (cm)	
3	d (cm)	
4	L (cm)	

3.3.2 Table of Observations:

Case	m(g)	y(cm)
Partially submerged		
y < d		
Fully submerged		
y > d		

3.4 Graphical Relationships:

Case: 1- Partially submerged (y < d)

1- Tabulate $\frac{m}{y^2}$

2- Plot $\frac{m}{y^2}$ against y

Note: The slope of this graph should be $-\frac{\rho b}{6L}$ and the intercept should be $\frac{\rho b(a+d)}{2L}$

<u>Case: 2 – Fully submerged (y > d)</u>

1- Tabulate $y_c = y - \dfrac{d}{2}$, $\dfrac{m}{y_c}$ and $\dfrac{1}{y_c}$

2- Plot $\dfrac{m}{y_c}$ against $\dfrac{1}{y_c}$

The slope of this graph should be $\dfrac{\rho b d^3}{12L}$ and the intercept should be $\dfrac{\rho b d}{L}\left(a + \dfrac{d}{2}\right)$

3.5 Discussions and Recommendations:

- Give reasons for the discrepancies, if any, between the measured and predicted values of the above expressions for the graph parameters.
- Discuss about the percentage of error obtained in both of the cases and some guidelines for the improvement.

Experiment No: 4 Coefficient of Discharge for a Rectangular Notch

Objective:

To determine the coefficient of discharge of a rectangular notch

4. Apparatus:

i.   Hydraulic Bench
ii.   Stop Watch
iii.   Rectangular Notch
iv.   Hook and Point Gauge

4.1 Introduction

There are many devices to measure fluid velocities and flow rates using principles involved in Bernoulli equation. A Notch is a device used for measuring the rate of flow of a liquid through a small channel or a tank.
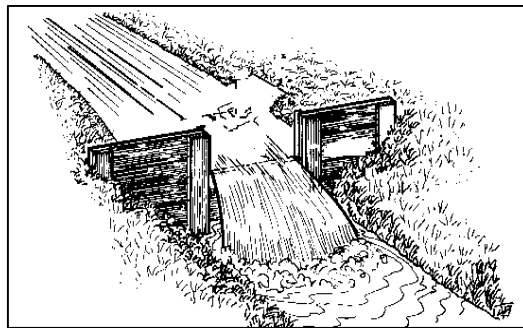

Figure 1: Open channel

4.2 Related Theory

- **Rectangular Notch:**

It is a plate having a rectangular shaped cut in it and used to measure the rate of flow of a liquid.

- **Hook Guage:**

It is used to determine the depth of flow of open channel and over the notches.

- **Co-efficient of Discharge:**

It is the coefficient or ratio between the actual discharge and the theoretical discharge. It is denoted by C_d.

$$C_d = \frac{Actual\ Discharge}{Theoretical\ Discharge}$$

The value ranged from 0.96 to 0.98

- **Derivation:**

To find the discharge of water flowing over notch, consider an elementary horizontal strip of water of thickness 'dh' shown below.
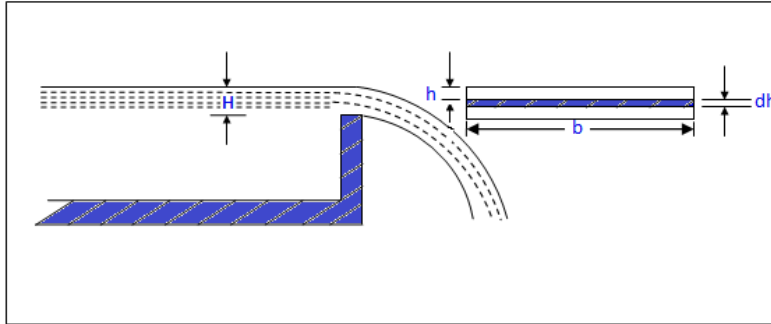

Figure 2: Rectangular notch

$Q = AV$

The area of strip $dA = b \times dh$

Theoretical velocity $V_{Th} = \sqrt{2gh}$

Discharge through strip:

$dQ = V_{Th} \times dA$

$dQ = b \times \sqrt{2g} \sqrt{h} \, dh$

Total theoretical discharge $(Q_{theo}) = b \sqrt{2g} \int_0^H h \, dh = \frac{2}{3} b \sqrt{2g} H^{3/2}$

As, $C_d = \frac{Actual\ Discharge}{Theoretical\ Discharge}$

$(Q_{act}) = Q_{theo} \times C_d$ where $Q_{act} = V/t$ (m³/sec)

$(Q_{act}) = \frac{2}{3} b \sqrt{2g} H^{3/2} \times C_d$

Rearranging the terms,

$(Q_{act}) = C_d \times \frac{2}{3} b \sqrt{2g} \times H^{3/2}$

$(Q_{act}) = K H^n$ where, $K = C_d \times \frac{2}{3} b \sqrt{2g}$ and n= 1.5

Where,

b: Width of the notch in m = 5cm = 0.05m

H: Head of the water above bottom of notch in m.

g: Acceleration due to gravity in m/s^2 = 9.81 m/sec^2

C$_d$: Coefficient of discharge.

4.3 Procedure

1. Fix the plate having rectangular notch in the water passage of Hydraulic bench.
2. Turn the hydraulic bench on; water will accumulate in the channel.
3. When the water level reaches the Crest or sill of notch stop the inflow and level the Point Gauge to be at zero.
4. Restart the bench and note the volume and time of water that accumulates in the volumetric tank of bench, from this find the discharge, and also note the height of water at this point.
5. Take different readings by changing the discharge head over the notch, using the control valve.

4.4 Observations and Calculations

All observations & calculations tabulated are as follows:

Sr. No	Head (H)		Time (t)	Volume (V)	Q_{act} (V /t)	Q_{theo}	$C_d = \dfrac{Q_{act}}{Q_{theo}}$	Log H	Log Q_{act}
	(mm)	(m)	(sec)	(m³)	(m^3/s)	$C_d = \dfrac{Q_{act}}{Q_{theo}}$			
1									
2									
3									
4									
5									
6									
7									
8									

4.5 Graphical Relationships

- Plot a graph of actual discharge against the theoretical discharge and find C_d value.
- Can the Q-H relationship be described by an empirical relationship $Q = KH^n$. If so, find values of k and n.
- Tabulate Log Q_{act} against Log H.
- Plot Log Q_{act} against Log H and find C_d value.

4.6 Conclusions and Recommendations

Experiment No: 5 Coefficient of Discharge for a Venturi

Objective

To determine the coefficient of discharge for a venturi.

5. Apparatus:

i.   Hydraulic Bench
ii.   Stop Watch
iii. Venturimeter
iv.   Differential manometer

5.1 Introduction

Many devices have been developed to measure fluid velocities and flow rates using principles involved in Bernoulli equation.
Venturimeter is a device used to measure the flowrate through a pipe. It consists of a short length of gradual convergence and a long length of gradual divergence.

5.2 Related Theory

- **Differential Manometer:**

It is used to measure the difference of pressure between the two tubes.

- **Co-efficient of Discharge:**

It is the coefficient or ratio between the actual discharge and the theoretical discharge. It is denoted by C_d.

$$C_d = \frac{Actual\ Discharge}{Theoretical\ Discharge}$$

It ranges from 0.96 to 0.98. It depends upon manufacturer or internal roughness.

- **Derivation:**

To measure the flowrate through a pipe, the pressure difference between the low-velocity, high pressure upstream at section 1 and the high velocity, low pressure downstream at section 2 will be measured.
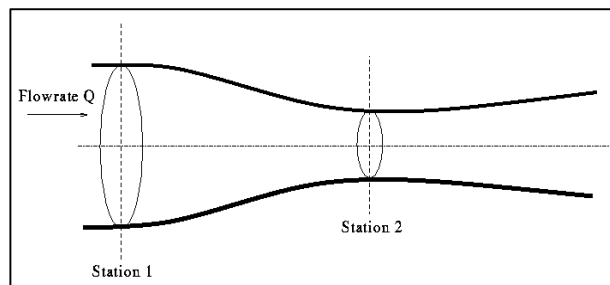

Figure 1: Venturi

Using Bernoulli equation and the continuity equation, an expression can be derived to calculate the theoretical discharge.

$$P_1 + \gamma Z_1 + \frac{1}{2}\rho V_1^2 = P_2 + \gamma Z_2 + \frac{1}{2}\rho V_2^2$$

$Z_1 = Z_2 = zero\ since\ the\ flow\ is\ horizontal.$

$$\frac{P_1}{\gamma} - \frac{P_2}{\gamma} = \frac{1}{2g}(V_2^2 - V_1^2)$$

$$H = \frac{1}{2g}(V_2^2 - V_1^2) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

From equation of continuity,

$Q = A_1 V_1 = A_2 V_2$

$$V_2 = \frac{A_1 V_1}{A_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Putting the the value of V_2 in eq (1).

$$H = \frac{1}{2g}\left(\left(\frac{A_1 V_1}{A_2}\right)^2 - V_1^2\right)$$

$$2gH = V_1{}^2 \left(\frac{A_1^2}{A_2^2} - 1\right)$$

$$\sqrt{2gH} = V_1{}^2 \sqrt{\left(\frac{A_1^2}{A_2^2} - 1\right)}$$

$$V_1 = \frac{A_2\sqrt{2gH}}{\sqrt{A_1^2 - A_2^2}}$$

As,

$Q = A_1 V_1 = A_2 V_2$

$$Q_T = \frac{A_1 A_2 \sqrt{2gH}}{\sqrt{A_1^2 - A_2^2}}$$

$$\rightarrow Q_{theo} = A_2 \sqrt{\frac{2gh}{1 - \left(\frac{A_2}{A_1}\right)^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Actual discharge $(Q_{act}) = Q_{theo} \times C_d$

Where,

A_1: Cross-sectional area of section 1

A_2: Cross-sectional area of section 2

h: Differential head $(h_1 - h_2)$ between sections 1 & 2 in m.

g: Acceleration due to gravity in m/s^2.

C$_d$: Coefficient of discharge.

Note:

- $d_1 = 38$mm.
- $d_2 = 24$mm.
- $g = 9.81$ m/s^2
- $\gamma_w = 9.789 \, kN/m^3 \, @ \, 20°C, SG_{Hg} = 13.6$

$$SG_{Hg} = \frac{\gamma_{mer}}{\gamma_{water}} = 13.6$$

$$H = Y\left(\frac{\gamma_{mer}}{\gamma_{water}} - 1\right)$$

$$H = Y\left(\frac{13.6 \times \gamma_{water}}{\gamma_{water}} - 1\right)$$

$$H = 12.6 \, Y$$

5.3 Procedure

1. Fix the Venturimeter through the pipe.
2. Turn the hydraulic bench on; water will flow through the venturi.
3. Measure the flow rates using the volumetric tank.
4. Measure the differential head between the two sections using the manometer.
5. Take different readings by changing the discharge using the control valve.

5.4 Observations and Calculations

All observations and calculations tabulated are as follows:

Table 1: Observations and Calculations:

Sr. No	h_1	h_2	$Y=\frac{h2-h1}{1000}$	H=13.6 Y	Time (t)	Volume (V)	Q_{act} (V/t)
	mm Hg	mm Hg	mm Hg	m of fluid	(sec)	(m^3)	(m^3/s)
1							
2							
3							
4							
5							
6							
7							
8							

Table 1: Observations and Calculations (continued):

Sr. No	Q_{theo} (m^3/s)	$C_d=\frac{Q_{act}}{Q_{theo}}$	Log H	Log Q_{act}
1				
2				
3				
4				
5				
6				
7				
8				

5.5 Graphical Relationships

- Plot a graph of actual discharge against the theoretical discharge and find C_d value.
- Can the Q-h relationship be described by an empirical formula $Q = Kh^n$. If so, find values of k and n.
- Tabulate Log Q_{act} against Log h.
- Plot Log Q_{act} against Log h and find C_d value.

5.6 Conclusions and Recommendations

Experiment No: 6 Head Loss due to Friction in a Smooth Pipe

Objective

To confirm the head loss predicted by a pipe friction equation associated with flow of water through a smooth pipe.

6. Apparatus

 i. Fluid Friction Apparatus
 ii. Stop Watch

6.1 Introduction

Pressure losses occur during the flow of real fluids due to friction and turbulence. Pressure losses in pipes, piping elements, fittings and measuring instruments cause pressure losses and must therefore be taken into account when designing piping systems. HM 150.11 allows to study the pressure losses in pipes and piping elements.

The experimental unit contains six different pipe sections capable of being shut off individually. The pipe sections are equipped with piping elements such as bends, elbows and branches. The pressures are measured with tube manometers. The main elements of the apparatus are shown in Figure 1.

The experimental unit is positioned easily and securely on the work surface of the HM 150 base module which provides the basic equipment for individual experiments:

- Supply of water in the closed circuit.
- Determination of volumetric flow rate.
- Positioning of the experimental unit on the working surface of the base module and the collection of dripping water.

The closed water circuit consists of the underlying storage tank with a powerful submersible pump and the measuring tank arranged above, in which the returning water is collected. The measuring tank is stepped, for larger and smaller volumetric flow rates. The volumetric flow rates are measured using a stopwatch.
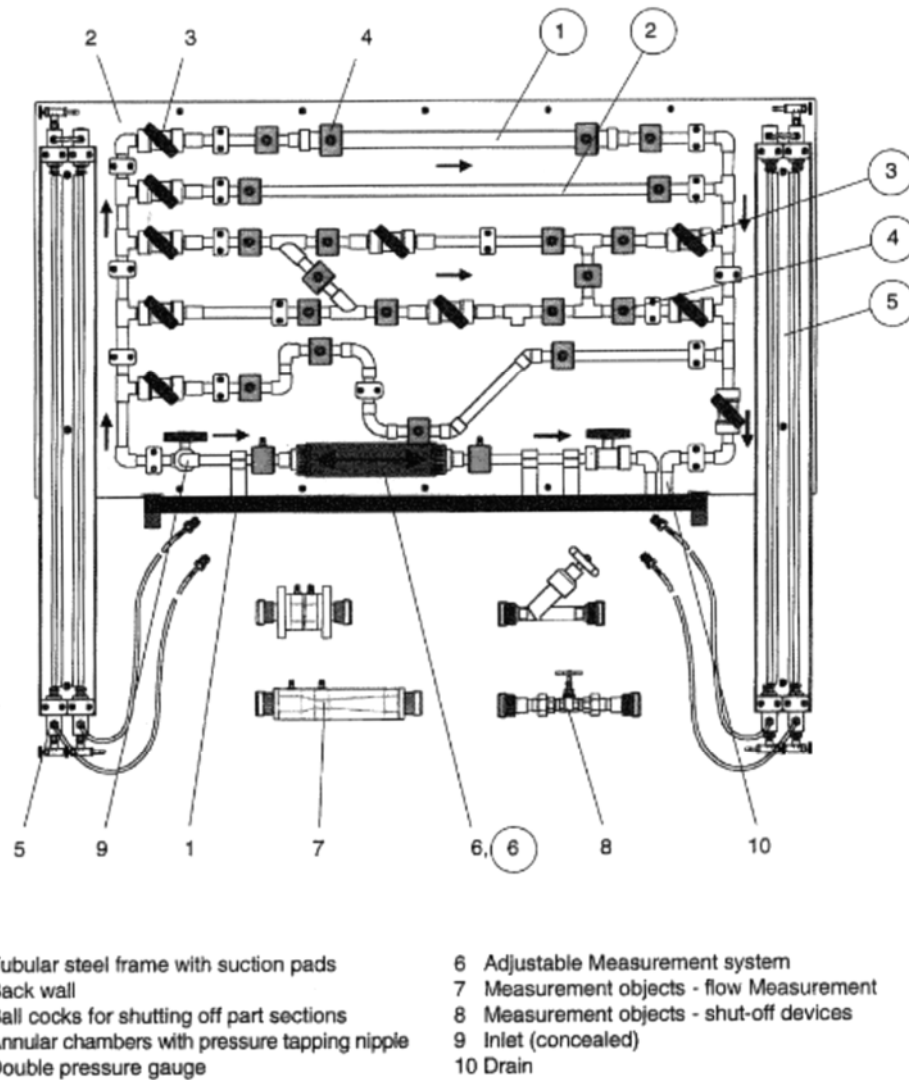
1 Tubular steel frame with suction pads
2 Back wall
3 Ball cocks for shutting off part sections
4 Annular chambers with pressure tapping nipple
5 Double pressure gauge
6 Adjustable Measurement system
7 Measurement objects - flow Measurement
8 Measurement objects - shut-off devices
9 Inlet (concealed)
10 Drain

Figure 1: Gunt HM150.11 Fluid Friction Apparatus

6.2 Method

To obtain a series of readings of head loss at different flow rates through one or more of the smooth test pipes.

6.3 Related Theory

For a circular pipe flowing full, the head loss due to friction may be calculated from the formula:

$$h_{L_f} = \frac{fLu^2}{2gd}$$

Where,

L: Length of the pipe between tapings (*L= 0.8 m*).

d: Internal diameter of the pipe (*d= 16.5 mm*).

u: Mean velocity of water through the pipe in m/s.

g: Acceleration due to gravity in m/s².

f: Pipe friction coefficient.

Reynolds' number, Re, can be found using the following equation:

$$R_e = \frac{\rho u d}{\mu}$$

Where μ is the dynamic viscosity (*1.15 x 10⁻³ Ns/m² at 15°C*) and ρ is the density (*999 kg/m³ at 15°C*).

Having established the value of Reynolds' number for flow in the pipe, the value of f may be determined using *Moody diagram*. (**Page 288 of your Text Book**).

6.4 Procedure

- Prime the pipe network with water. Open and close the appropriate valves to obtain flow of water through the required test pipe.
- Take readings at a number of different flow rates, altering the flow using the control valve on the apparatus.
- Measure flow rates using the volumetric tank. Measure head loss between the tappings using the pressurized water manometer.

6.5 Observations and Calculations

All readings & calculations to be tabulated are as follows:

Sr. No	Volume V		Time T	Flow Rate Q	Velocity u	Reynolds No. Re	Friction Factor f	Calculated Head Loss h$_c$	Measured Head Loss h$_m$
	(L)	(m^3)	(sec)	(m^3/s)	(m/s)			(m)	(m H$_2$O)
1									
2									
3									
4									
5									
6									
7									
8									

6.6 Graphical Relationships

Plot a graph between the Calculated Head Loss and Measured Head Loss.

6.7 Conclusions and Recommendations

- Compare the values of head loss determined by calculation with those measured using the manometer.
- Confirm that the head loss can be predicted using the pipe friction equation provided the velocity of the fluid, the value for f and the pipe dimensions are known.
- General comments about the Experiment.