COLLEGE OF ENGINEERING & TECHNOLOGY

LABORATORY MANUAL

FLUID MECHANICS AND HYDRAULIC MACHINES

SUBJECT CODE: 3141906

MECHANICAL ENGINEERING DEPARTMENT

B.E. 4th SEMESTER

NAME:____________________

ENROLLMENT NO: ____________________

BATCH NO: ____________________

YEAR: ____________________

Amiraj College of Engineering and Technology,
Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

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COLLEGE OF ENGINEERING & TECHNOLOGY

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Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

CERTIFICATE

This is to certify that Mr. / Ms. ____

Of class___________________Enrolment No __________________________has Satisfactorily completed the course in Fluid Mechanics and Hydraulic Machines as by the Gujarat Technological University for 2nd Year (B.E.) semester 4 of Mechanical Engineering in the Academic year____________.

Date of Submission:-

Faculty Name and Signature
(Subject Teacher)

Head of Department
(Mechanical)

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SUBJECT: FLUID MECHANICS & HYDRAULIC MACHINES

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List of Experiments

Sr. No.	Title	Date of Performance	Date of submission	Sign	Remark
1	To Validate Bernoulli's Theorem				
2	To determine the Metacentric height of a given floating body				
3	To calibrate and find the co-efficient of discharge for a given Venturimeter, Orifice meter and Rotameter				
4	To determine co-efficient of discharge for flow through Notch				
5	To Visualize flow regimes by Reynold's Experiment				
6	To determine the friction factor for pipes of different sizes and materials and their comparison				
7	To determine the loss co-efficient of different pipe fittings viz. Bend, elbow, valve, sudden contraction and sudden expansion				
8	Experimental performance evaluation on Pelton Wheel				
9	Experimental performance determination of Kaplan turbine				
10	Experimental performance prediction on Francis turbine				

EXPERIMENT NO.: 1 **DATE:**

AIM: To validate Bernoulli's theorem

Introduction and Theory

Bernoulli's principle is named after the Dutch-Swiss mathematician Daniel Bernoulli who published his principle in his book Hydrodynamica in 1738.

Bernoulli's principle in its simplest form states that "the pressure of a fluid [liquid or gas] decreases as the speed of the fluid increases." The principle behind Bernoulli's theorem is the law of conservation of energy. It states that energy can be neither created nor destroyed, but merely changed from one form to another.

The energy, in general, may be defined as the capacity to do work. Though the energy exists in many forms, yet the following are important from the subject point of view:

1) Potential Energy
2) Kinetic Energy and
3) Pressure Energy

Potential energy of a Liquid in Motion:

It is the energy possessed by a liquid particle, by virtue of its position. If a liquid particle is Z meters above the horizontal datum (arbitrary chosen), the potential energy of the particle will be Z meter-kilogram (briefly written as mkg) per kg of liquid. Potential head of the liquid, at that point, will be Z meters of the liquid.

Kinetic Energy of a liquid Particle in Motion

It is the energy, possessed by a liquid particle, by virtue of its motion or velocity. If a liquid particle is flowing with a mean velocity of v meter per second, then the kinetic energy of the particle will be $v^2/2g$ meter of the liquid. Velocity head of the liquid, at that velocity, will be $v^2/2g$ meter of liquid.

Pressure Energy of a liquid Particle in Motion:

It is the energy, possessed by a liquid particle, by virtue of its existing pressure. If a liquid particle is under a pressure of p kg/m^2, then the pressure energy of the particle will be p/w mkg per kg of liquid, where w is the specific weight of the liquid. Pressure head of the liquid under that pressure will be p/w meter of the liquid.

Total Energy of a liquid Particle in Motion:

The total energy of a liquid particle, in motion, is the sum of its potential energy, kinetic energy and pressure energy. Mathematically,

Total Energy,

$$E = Z + \frac{v^2}{2g} + \frac{p}{w} \quad \text{mkg/kg of liquid}$$

Bernoulli's Equation

It states, "For a perfect incompressible liquid, flowing in a continuous stream, the total energy of a particle remains the same; while the particle moves from one point to another." This statement is based on the assumption that there are no losses due to friction in pipe. Mathematically,

$$E = Z + \frac{v^2}{2g} + \frac{p}{w} = \text{constant}$$

Apparatus Description

The apparatus is made from transparent acrylic and has both the convergent and divergent sections. Water is supplied from the constant head tank attached to the test section.

Constant level is maintained in the supply tank. Piezometric tubes are attached at different distance on the test section. Water discharges to the discharge tank attached at the far end of the test section and from there it goes to the measuring tank through valve. The entire setup is mounted on a stand.

Experimental Procedure

1. Note down the area of cross-section of the conduit at sections where piezometers have been fixed.
2. Open the supply valve and adjust the flow in the conduit so that the water level in the inlet tank remains at a constant level (i.e., the flow becomes steady).
3. Measure the height of water level (above an arbitrarily selected suitable horizontal plane) in different piezometer tubes.
4. Measure the discharge by calculating time taken for 10 liters flow.
5. Repeat steps (2) to (4) for other discharges.

Observations Table

Piezometer tube number		1	2	3	4	5	6	7	8
Diameter of Cross-Section (mm)		34.0	27.5	22.9	25.0	28.1	31.1	34.2	37.2
Area of cross-section, A		9.08×10^{-4}	5.94×10^{-4}	4.12×10^{-4}	4.91×10^{-4}	6.20×10^{-4}	7.6×10^{-4}	9.19×10^{-4}	10.87×10^{-4}
Distance of piezometer from 1st tube (mm)		0	25	50	75	100	125	150	
Run No.1 Discharge $Q_1 = 0.01/t$ =	V=Q/A								
	$V^2/2g$								
	$(p/\rho g) + z$								
	E								
Run No.2 Discharge $Q_2 = 0.01/t$ =	V=Q/A								
	$V^2/2g$								
	$(p/\rho g) + z$								
	E								
Run No.3 Discharge $Q_3 = 0.01/t$ =	V=Q/A								
	$V^2/2g$								
	$(p/\rho g) + z$								
	E								

Plot the following on an ordinary graph paper for all the runs taken.

1. {(p/ρg) + z} v/s distance (x) of piezometer tubes from some reference point. Draw a smooth curve passing through the plotted points. This is known as the hydraulic gradient line.
2. $E = \{(p/\rho g) + z + V^2/2g\}$ v/s distance (x) of piezometer tubes on the graph {(p/ρg) + z} v/s distance. Draw a smooth curve passing through the plotted points. This is the total energy line.

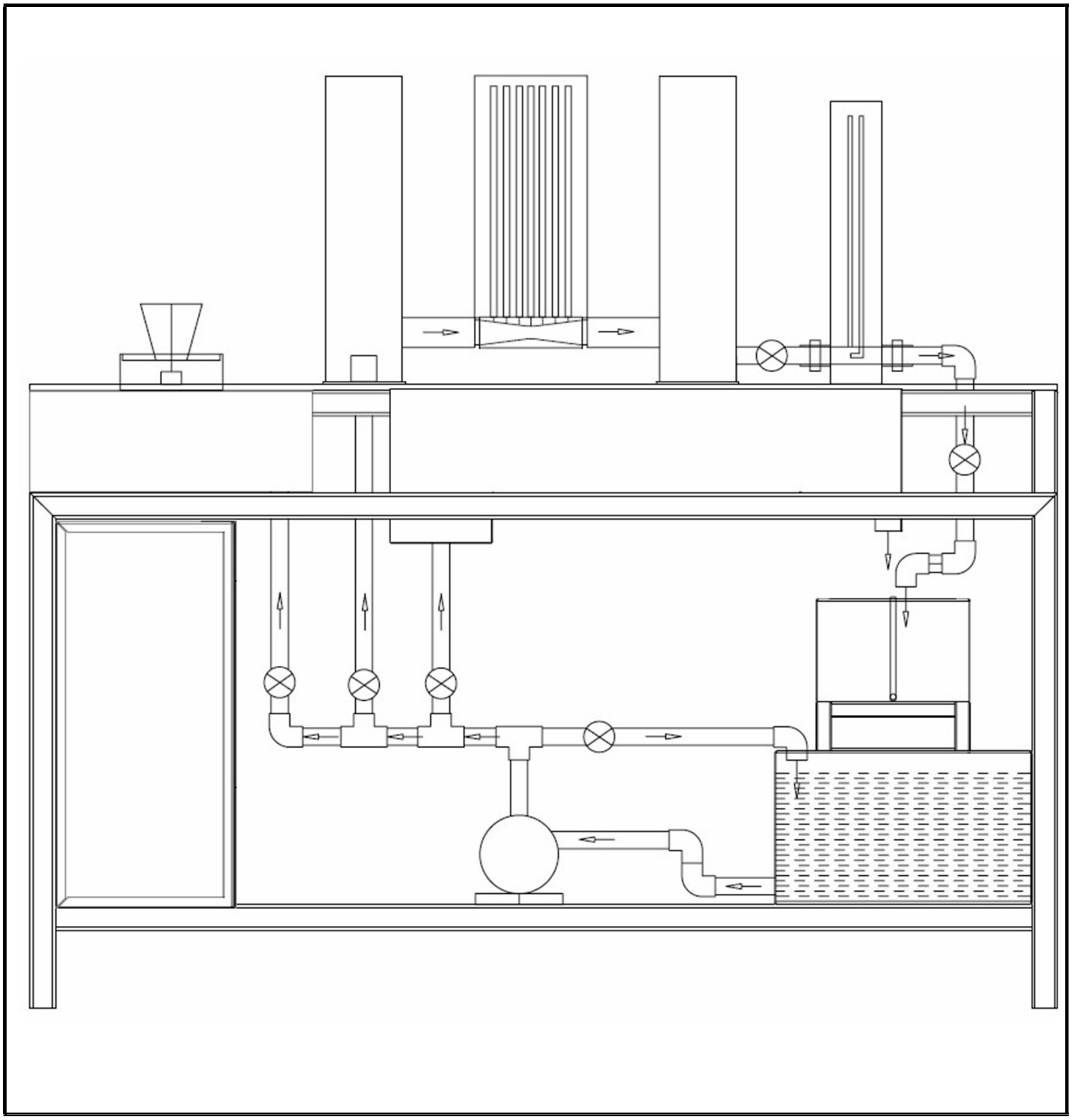
Conclusion

The Total Energy remains the same at different sections of the conduit.

- **Reference Video links**
  https://youtu.be/wR0AlZddJtY
  https://youtu.be/3wfUev6TQv0

EXPERIMENT NO.: 2 **DATE:**

AIM: To determine the Metacentric height of a given floating body

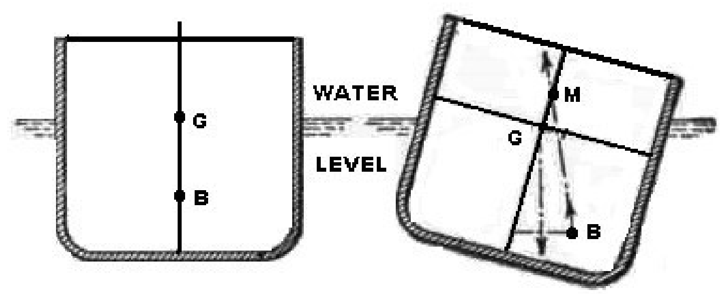


Introduction and Theory

Buoyancy
When a body is completely submerged in a fluid, or it is floating or partially submerged, the resultant fluid force acting on the body is called the buoyant force. It is also known as the net upward vertical force acting on the body. A net upward vertical force results because pressure increases with depth and the pressure forces acting from below are larger than the pressure forces acting above.

The *Center of buoyancy* is the center of gravity of the displaced water. It lies at the geometric center of volume of the displaced water.

Metacentre
For the investigation of stability of floating body, it is necessary to determine the position of its metacentre with respect to its centre of gravity. Consider a floating ship model, the weight of the ship acts through its centre of gravity and is balanced by an equal and opposite buoyant force acting upwards through the centre of buoyancy i.e. the centre of gravity of liquid displaced by the floating body.



A small angular displacement shifts the centre of buoyancy and the intersection of the line of action of the buoyant force passing through the new centre of buoyancy and the extended line would give the metacentre.

The distance between centre of gravity (G) and metacentre (M) is known as Metacentric height (GM).

There are three conditions of equilibrium of a floating body

Stable Equilibrium -	Metacentre lies above the centre of gravity
Unstable Equilibrium-	Metacentre lies below the centre of gravity
Neutral Equilibrium -	Metacentre coincides with centre of gravity

The Metacentric height (GM) is given by

$$\mathbf{GM} = (m * X) / (W * \tan\theta)$$

Where,
W = weight of the floating body
m = movable weight
X = distance through which the movable load is shifted
θ = Angle of Heel

Apparatus Description

The apparatus consist of a SS tank and is provided with a drain cock. The floating body is made from Clear Transparent Acrylic. It is provided with movable weights, protractor to measure the angle of Heel and pointer. Weights are also provided to increase the weight of floating body by known amount.

Experimental Procedure

1) Fill the SS tank to about 2/3 levels
2) Place the floating body in the tank.
3) Apply momentum to the floating body by moving one of the adjustable weights (m) through a known distance.
5) Note down the angle of heel corresponding to this shifts of weight with the help of protractor and pointer.
6) Take about 4-5 such readings by changing the position of the adjustable weight and find out centre of gravity in each case

Observation Table:

Weight of the ship model = 1.9 X 9.81 =18.64 N
Given Movable Weights = 100 gm = 0.981 N

Sr. No.	Movable Weight (m) N	Distance moved (X) M	Angle of Tilt θ	Tan θ	Metacentric Height GM M

Conclusion

Thus Metacentre is the point about which a body starts oscillating when the body is tilted by a small angle.

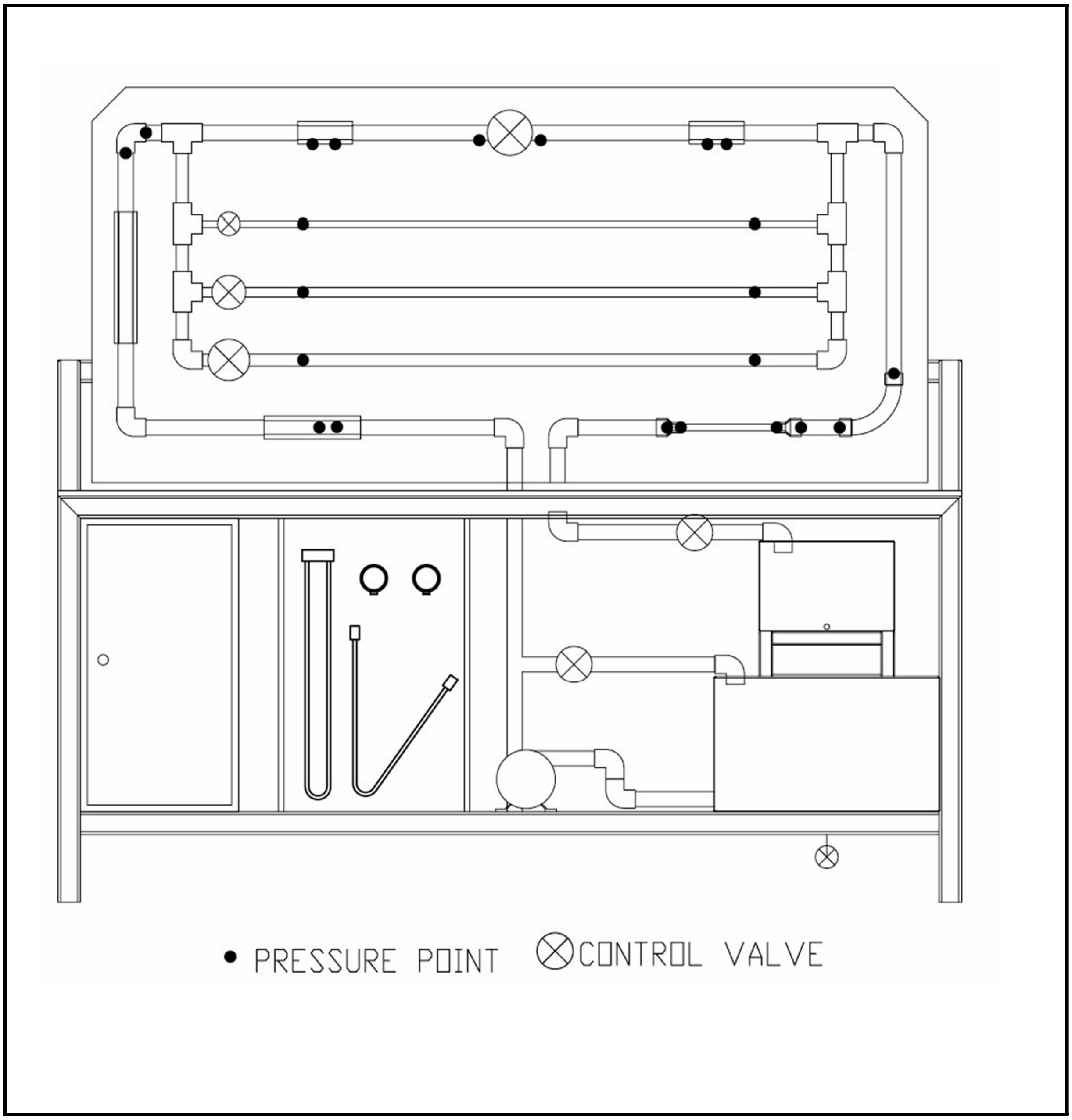
Metacentric Height of the given ship model is ___________

- **Reference video links**
  https://youtu.be/jaONNtysP4Q

EXPERIMENT NO.: 3 **DATE:**

AIM:

To calibrate and find the co-efficient of discharge for a given Venturimeter.
To calibrate and find the co-efficient of discharge for a given Orificemeter.
To calibrate and find the co-efficient of discharge for a given Rotameter.



Introduction and Theory

The most important class of flow meter is that in which the flow is either accelerated or retarded at the measuring sections by reducing the flow area, and the change in the kinetic energy is measuring sections by reducing the flow area and the change in the kinetic energy is measured by recording the pressure difference produced.

This class includes

1) The Pitot tube
2) The Orifice meter
3) The Venturimeter
4) The Nozzle
5) The Notch or Weir
6) The variable Areameter or Rotameter

However from apparatus point of view let us study a few in little detail.

1) Orifice Meter

A circular Opening in a plate which is fitted suitably in a pipeline is a simple device to measure the discharge flowing in the pipeline. Such a device is known as orifice meter and is as shown in the figure. the opening is normally at the centre of the plate as shown in figure. Applying Bernoulli's equation between section 1 and 2 and using continuity equation, it can be shown that,

$$Qa = Cd \; x A_2 \left[\frac{2g\,(h_1 - h_2)}{1 - (A_2/A_1)^2} \right]^{0.5}$$

where A_2 is the area of cross section of the orifice, and $(h_1 - h_2)$ is the difference in the piezometeric heads at section 1 and 2

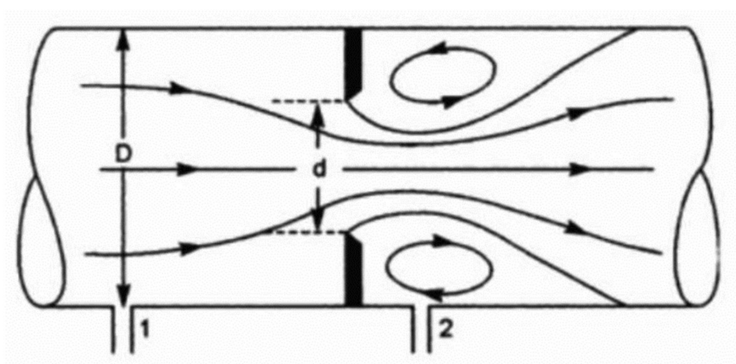


Fig: Simple Orifice Meter

2) Venturi Meter

Like orifice meter, a venturimeter is also used for the measurement of discharge in a pipeline. Since head loss caused due to installation of venturi meter in a pipeline is less than that caused due to installation of orficemeter, the former is usually preferred particularly for higher flow rates. A venturimeter consists of a converging tube which is followed by a diverging tube. The junction of the two is termed as 'throat' which is the section of minimum cross-section.

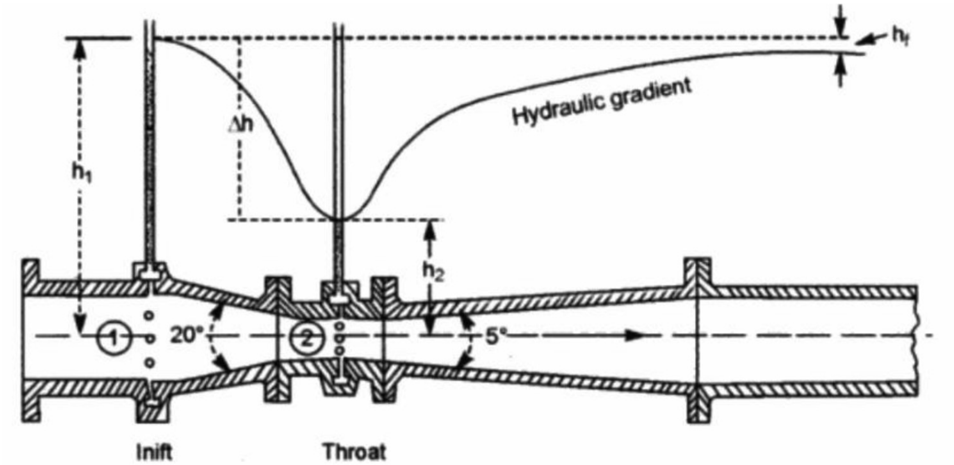


Fig: Venturi Meter

3) Rotameter
The rotameter is an industrial flowmeter used to measure the flowrate of liquids and gases. The rotameter consists of a tube and float. The float response to flowrate changes is linear. The rotameter is popular because it has a linear scale, a relatively long measurement range, and low pressure drop. It is simple to install and maintain.

The rotameter's operation is based on the variable area principle: fluid flow raises a float in a tapered tube, increasing the area for passage of the fluid. The greater the flow, the higher the float is raised. The height of the float is directly proportional to the flowrate. With liquids, the float is raised by a combination of the buoyancy of the liquid and the velocity head of the fluid. With gases, buoyancy is negligible, and the float responds to the velocity head alone.

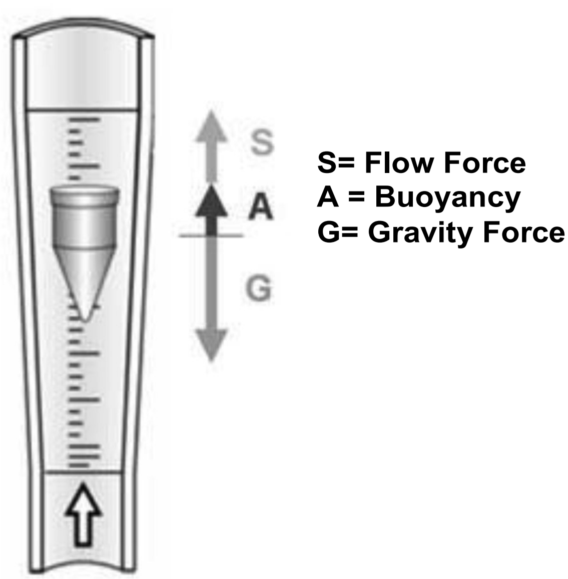


Fig: Rota meter

Apparatus Description

All flowmeters are mounted along a pipeline with sufficient distance to stabilze flow between two meters. The pressure taps are provided at sections as given in the fig. Pressure head difference between sections can be read on manometer having mercury as the manometer fluid. A valve, fitted at the end of the pipeline, is used for regulating the discharge in the pipeline.

Technical Specifications:-

Orificemeter:

Size	= 26 mm
Orifice Size	= 16 mm
Dia Ratio	= 0.615

Venturimeter:

Size	= 26 mm
Throat Size	= 16 mm
Dia Ratio	= 0.615

Rotameter:

Size	= 1- 1000 LPH
Type	= Thread Ends

Experimental Procedure

1) Fill the storage tank/sump with the water.
2) Switch on the pump and keep the control valve fully open and close the bypass valve to have maximum flow rate through the meter.
3) To calibrate Orificemeter open control valve of the same.
4) Open the vent cocks provided at the top of the manometer to drive out the air from the manometer limbs and close both of them as soon as water start coming out.
5) Note down the difference of level of mercury in the manometer limbs.
6) Keep the drain valve of the collection tank closed till its time to start collecting the water.
7) Close the drain valve of the collection tank and note down the initial level of the water in the collection tank.
8) Collect known quantity of water in the collection tank and note down the time required for the same.
9) Change the flow rate of water through the meter with the help of control valve and repeat the above procedure.
10) To calibrate Venturimeter and Nozzlemeter repeat the same procedure indicated in step 4-9
11) Rotameter readings can be directly verified from flow marking provided by manufacturer
12) Take about 2-3 readings for different flow rates.

Observations:

For Orificemeter

Diameter at inlet D_1 = 26 mm; Area $A_1 = 5.31 \times 10^{-4}\ m^2$

Diameter at orfice D_2 = 16 mm; Area $A_2 = 2.01 \times 10^{-4}\ m^2$

Sr. No	Manometer Difference In mm of Hg	Flowrate (time for 10 lit) t in secs

For Venturimeter

Diameter at inlet D_1 = 26 mm; Area $A_1 = 5.31 \times 10^{-4}\ m^2$

Diameter at throat D_2 = 16 mm; Area $A_2 = 2.01 \times 10^{-4}\ m^2$

Sr. No	Manometer Difference In mm of Hg	Flowrate (time for 10 lit) t in secs

For Rotameter

Sr. No	Rotameter Scale (in LPH)	Flowrate (time for 10 lit) t in secs

Calculations:

For Orificemeter and Venturimeter:

Actual Discharge , $Q_a = \frac{0.01}{t}\ m^3/sec$ =

We Know as per the theory:-

$$Qa = Cd \times A_2 \left[\frac{2g\,(h_1 - h_2)}{1 - (A_2/A_1)^2} \right]^{0.5}$$

Before Substituting Values of Qact and $(h_1 - h_2)$ into the above equation, it will simpler to establish the value of

$$A_2 \left[\frac{2g}{1-(A_2/A_1)^2} \right]^{0.5}$$

This value is

$= 2.0096 \times 10^{-4} [(2* 9.81)/ (1- (0.378^2)]^{0.5} = 9.65 \text{ X } 10^{-4}$

Therefore, $Qa = C_d \text{ X } 9.65 \text{ X } 10^{-4} (h_1-h_2)^{0.5}$

So, $C_d = 1036.26 * Q / (h_1 h_2)^{0.5}$

Put the values of Q and (h_1-h_2) from observations

$C_d =$ __________

For Rotameter:

Discharge from Rotameter in LPH =

Actual Discharge , $Q_a = \frac{0.01}{t}$ m^3/sec =

In LPH Qa * 3600000 =

Conclusion

Average values of the co-efficient of discharge for various flowmeters, as obtained experimentally, are as follows:

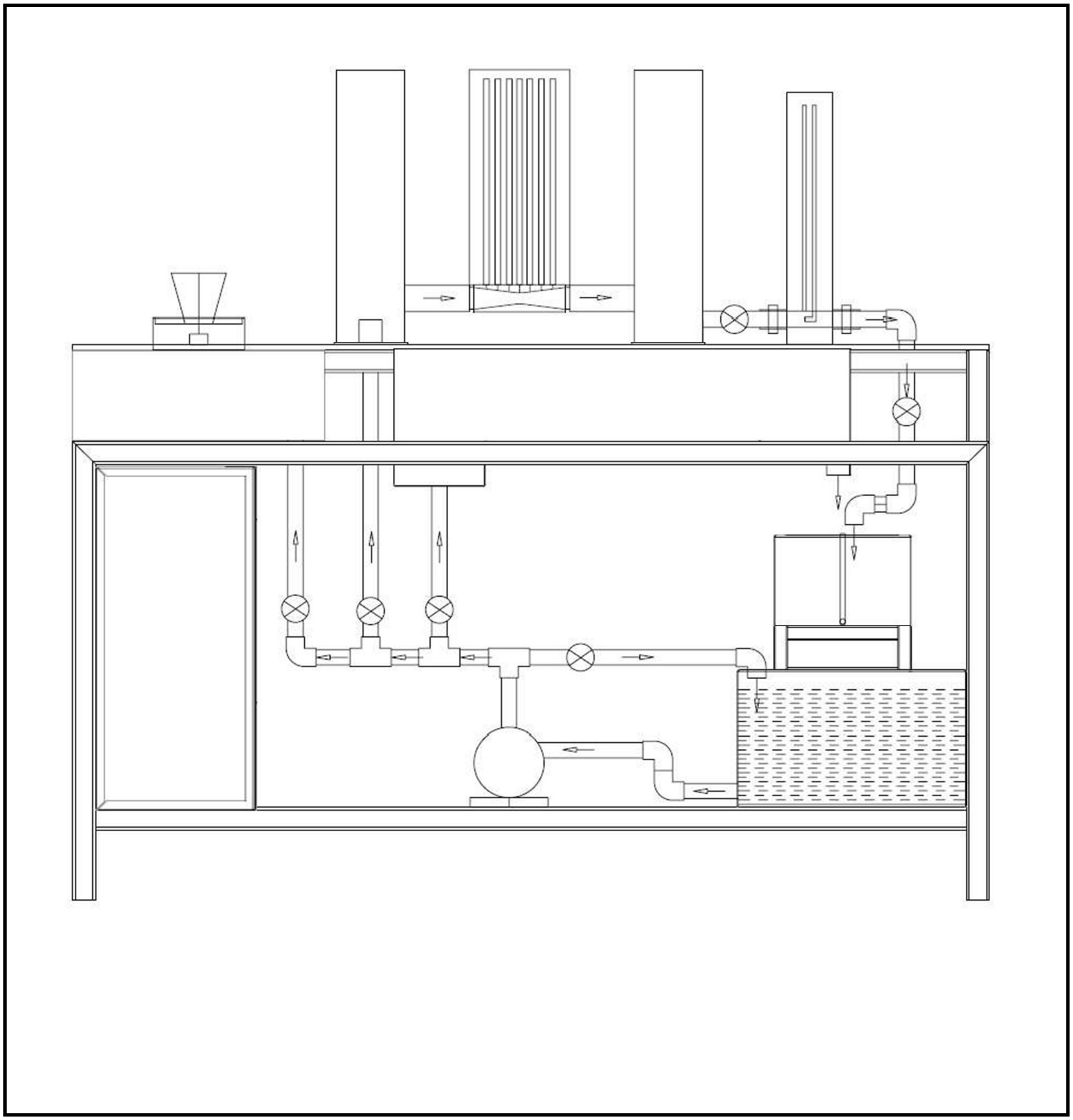
	Flow Meter	Discharge Co-efficient, C_d
1)	Orificemeter	____________________
2)	Venturimeter	____________________
3)	Rotameter	____________________

- **Reference Video links**

https://youtu.be/NsW-8FjgjpY
https://youtu.be/ljMVt7T4HQM
https://youtu.be/Xx16olP_BwE
https://youtu.be/6CdO9inzSRQ

EXPERIMENT NO.: 4 **DATE:**

AIM: To determine co-efficient of discharge for flow through rectangular, triangular and trapezoidal Notch.



Introduction and Theory

Measurement of flow in open channel is essential for better management of supplies of water. Hydraulic structures such as weirs are emplaced in the channel. They are used to determine the discharge indirectly from measurements of the flow depth.

A notch is an opening in the side of a measuring tank or reservoir extending above the free surface. A weir is a notch on a large scale, used, for the measurement of discharge in free surface flows like a river. A weir is an orifice placed at the water surface so that the head on its upper edge is zero. Hence, the upper edge can be eliminated, leaving only the lower edge named as weir crest. A weir can be of different shapes - rectangular, triangular, trapezoidal etc. A triangular weir is particularly suited for measurement of small discharges.

Rectangular Notch

The discharge over an unsubmerged rectangular sharp-crested notch is defined as:

$$Q = 2/3.\ C_d.\ (2g)^{0.5}\ L.\ H^{3/2}$$

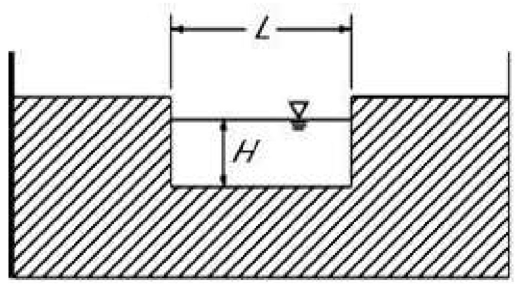


Fig: Rectangular Notch

Triangular Notch

The rate of flow over a triangular weir mainly depends on the head H, relative to the crest of the notch; measured upstream at a distance about 3 to 4 times H from the crest. For triangular notch with apex angle θ , the rate of flow Q is obtained from the equation,

$$Q = C_d\ .\ (8 / 15)\ (2g)^{0.5}\ \tan(\theta/2)\ H^{5/2}$$

Here, C_d is termed the coefficient of discharge of triangular notch

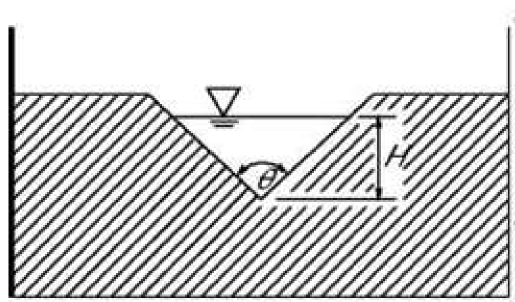


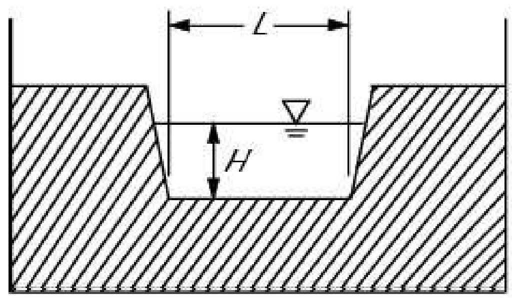
Fig: Triangular Notch

Trapezoidal Notch

Also known as Cipolletti weirs, are trapezoidal with 1:4 slopes to compensate for end contraction losses. The equation generally accepted for computing the discharge through an unsubmerged sharp-crested Cipolletti weir with complete contraction is:

$$Q = 1.84.C_d.L.H^{3/2}$$

Where, Q = Discharge over notch (m^3/sec); L = Bottom of notch width; H = Head above bottom of opening (m)

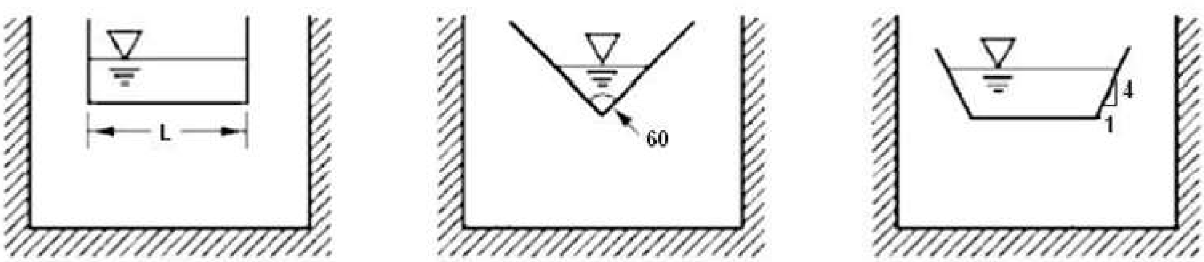


Apparatus Description

The pump sucks the water from the sump tank, and discharges it to a small flow channel. The notch is fitted at the end of channel. All the notches and weirs are interchangeable. The water flowing over the notch falls in the collector. Water coming from the collector is directed to the measuring tank for the measurement of flow.

The following notches are provided with the apparatus:-

1) Rectangular notch (Crest length L = 0.050m)
2) Triangular notch (Notch Angle – 60^o ; 45^o)
3) Trapezoidal notch (Crest length L = 0.030m; Slope = 4V:1H)



(1) (2) (3)

Experimental Procedure

1) Fit the required notch in the flow channel.
2) Fill up the water in the sump tank.
3) Open the water supply gate valve to the channel and fill up the water in the channel upto sill level.
4) Take down the initial reading of the crest level (sill level)
5) Now start the pump and open the gate valve slowly so that water starts flowing over the notch

6) Let the water level become stable and note down the height of water surface at the upstream side by the sliding depth gauge.
7) Close the drain valve of measuring tank, and measure the discharge.
8) Take the reading for different flow rates.
9) Repeat the same procedure for other notch also.

Observations:

Notch Type:- Triangular

Sr. No.	Still level reading 's' mts	Water height on upstream side 'h' mtrs	Discharge time for 10 litres 't' sec

Notch Type:- Rectangular

Sr. No.	Still level reading 's' mts	Water height on upstream side 'h' mtrs	Discharge time for 10 litres 't' sec

Notch Type:- Trapezoidal

Sr. No.	Still level reading 's' mts	Water height on upstream side 'h' mtrs	Discharge time for 10 litres 't' sec

Calculations:-

A) Rectangular Notch-
1. Head over the notch, $H = | h-s |$ m
2. Actual Discharge , $Q_a = \frac{0.01}{t}$ m^3/sec

   Crest length of notch = 0.05 m

3. Now theoretical discharge
   $Q_{th} = 2/3\ (2g)^{0.5}\ L.\ H^{3/2}$

4. coefficient of discharge

   $$C_d = \frac{Q_a}{Q_{th}}$$

B) Triangular notch-

1. Head over the notch, $H = |\ h\text{-}s\ |$ m

2. Actual Discharge , $Q_a = \frac{0.01}{t}$ m^3/sec

   Crest length of notch = 0.075 m

3. Now theoretical discharge
   $Q_{th} = (8\ /\ 15)\ (2g)^{0.5} \tan(60/2)\ H^{5/2}$

4. Coefficient of discharge

   $$C_d = \frac{Q_a}{Q_{th}}$$

C) Trapezoidal Notch (or Cipolletti Weir)

a. Head over the notch, $H = |\ h\text{-}s\ |$ m

b. Actual Discharge , $Q_a = \frac{0.01}{t}$ m^3/sec

   Crest length of notch (L) = 0.030 m

c. Now theoretical discharge
   $Q_{th} = 1.84.L.H^{3/2}$

d. coefficient of discharge

   $$C_d = \frac{Q_a}{Q_{th}}$$

Conclusion

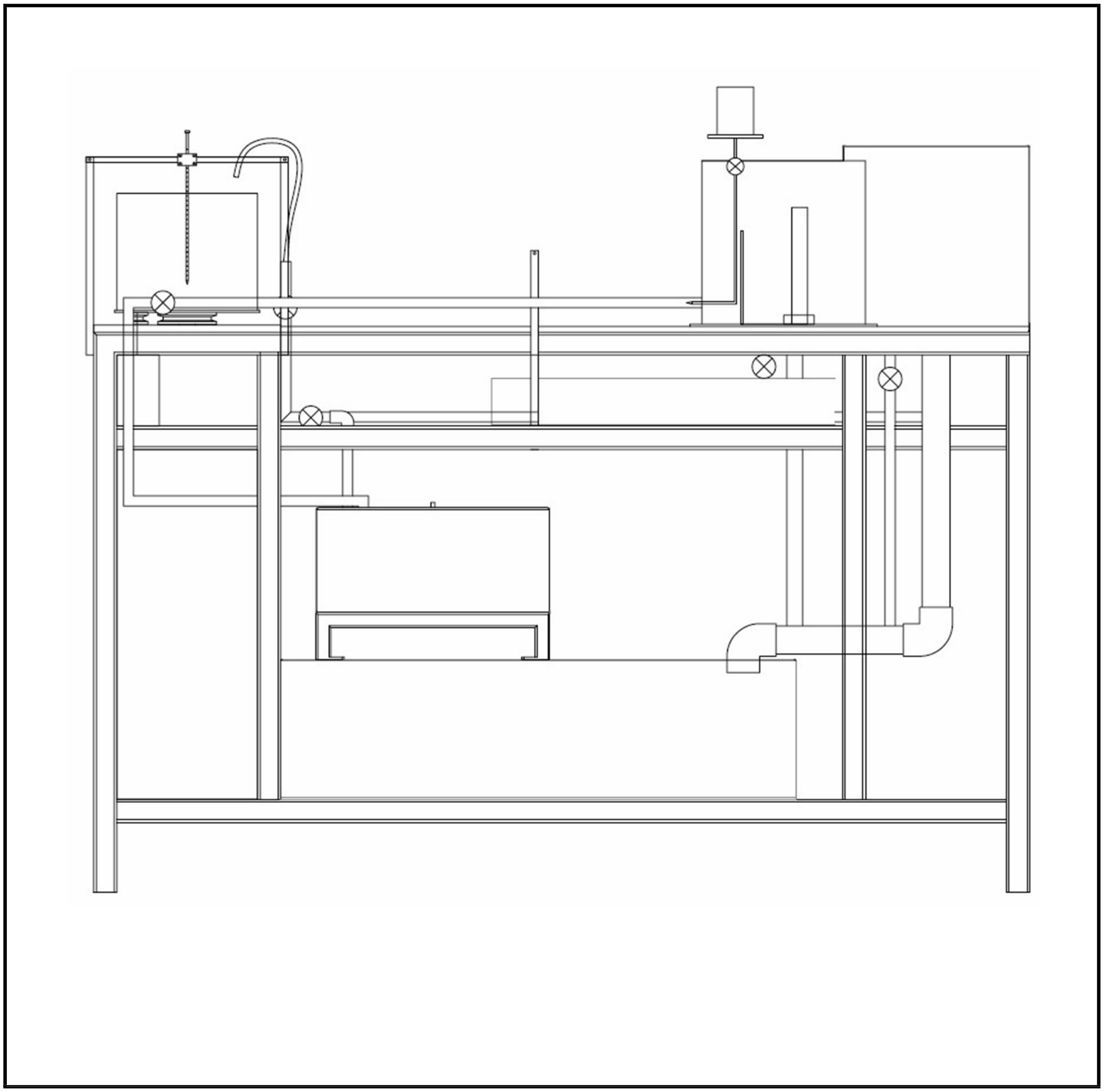
1) Average C_d of given Triangular notch is ___________
2) Average C_d of given Rectangular notch is ________
3) Average C_d of given Trapezoidal notch is ________

❖ Reference video Links

https://www.youtube.com/watch?v=q1O8IW19Pv0
https://www.youtube.com/watch?v=r7QAOhME7y0

EXPERIMENT NO.: 5 **DATE:**

AIM: To study and visualize flow regimes by Reynolds's Experiment.



Introduction and Theory

The properties of density and specific gravity are measures of the "heaviness" of fluid. These properties are however not sufficient to uniquely characterize how fluids behave since two fluids (such as water and oil) can have approximately the same value of density but behave quite differently when flowing. There is apparently some additional property that is needed to describe the "fluidity" of the fluid.

Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid. It is an inherent property of each fluid. Its effect is similar to the frictional resistance of one body sliding over other body. As viscosity offers frictional resistance to the motion of the fluid consequently. In order to maintain the flow, extra energy is to be supplied to overcome effect of viscosity. The frictional energy generated comes out in form of heat and dissipated to the atmosphere through boundary surfaces.

Types of flow and Reynolds number

Laminar flow:-

Laminar flow is that type of flow in which the particle of the fluid moves along well defined parts or streamlines. In laminar flow all streamlines are straight and parallel. In laminar flow one layer of fluid is sliding over another layer, whenever the Reynolds number is less than 2000, the flow is said to be laminar. In laminar `flow, energy loss is low and it is directly proportional to the velocity of the fluid. The following reasons are for the laminar flow, fluid has low velocity, fluid has high viscosity and diameter of pipe is large

Turbulent Flow:-

The flow is said to be turbulent flow it he flow moves in a zigzag way. Due to movement of the particles in a zigzag way the eddies formation take place which are responsible of high-energy losses.

In turbulent flow, energy loss is directly proportional to the square of velocity of fluid. If Reynolds number is greater than 4000, then flow is said to be turbulent flow.

Reynold's Number

Reynold was first to determine the translation from laminar to turbulent depends not only on the mean velocity but on the quality

$$\frac{\rho VD}{\mu}$$

Where

ρ = Density of Fluid

D = Diameter of pipe

μ =Dynamic Viscosity

The term is dimensionless and it is called Reynolds Number (Re). It is the ration of the inertia force to the viscous force

$$Re = \frac{\text{Intertia force}}{\text{Viscous Force}}$$

$$Re = (\rho V^2) / \mu(V/D)$$

$$= \rho VD / \mu$$

This indicates that it is non-dimensional number.

Apparatus Description

The apparatus consists of
1. A tank containing water at constant head
2. Die container
3. A glass tube
4. The water from the tank is allowed to flow through the glass tube. The velocity of flow can be varied by regulating valve. A liquid die having same specific weight as that of water has to be introduced to glass tube.

Additional materials or Equipments required:-
1. Stop Watch
2. Measuring Flask
3. Colour Dye
4. Water Supply

Experimental Procedure

1) Switch on the pump and fill the head tank. Manually also fill the dye tank with some amount of bright dye liquid provided.
2) Open the control valve slowly at the bottom of the tube and release small flow of dye.
3) Observe the flow in the tube.
4) Note down the time for 1 litre of discharge with the help of stopwatch and measuring flask.
5) Repeat the above process for various discharges

Observations:

The following observations are made:
(i) When the velocity of flow is low, the die filament in the glass tube is in the form of a straight line of die filament is parallel to the glass tube which is the case of laminar flow as shown in fig1.
(ii) With the increase of velocity of flow the die filament is no longer straight line but it becomes wavy one as shown in fig2. This is shown that flow is no longer laminar. This is transition flow.
(iii) With further increase of velocity of the way die filament is broken and finally mixes in water as shown in fig3.

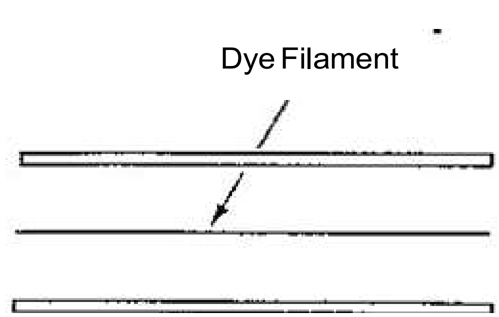


Fig .1 LAMINAR

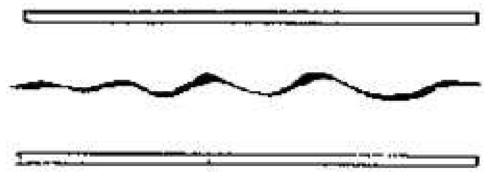


Fig.2 TRANSITION

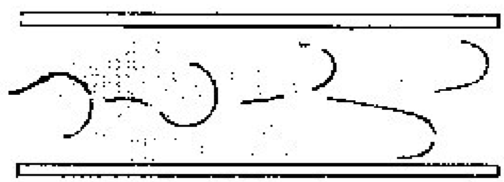


Fig. 3 TURBULENT

Observation Table:

Sr. No.	Time for 500 ml discharge (Sec)	Discharge Q (m^3/s)	Velocity V (m/s)	Reynolds No. Re	Observe the flow (Laminar, Transition, Turbulent)
1					
2					
3					
4					
5					

Calculations:-

$Re = (\rho \times V \times D) / \mu$

$Re = (V \times D) / \nu$

Where: ν is Kinematic viscosity of water which in m^2/s
V is Velocity of Water in m/s
D is diameter of pipe is 0.030 m

Conclusion

Laminar flow

* Re < 2000
* Observed at 'low' velocity
* Dye does not mix with water
* Fluid particles move in straight lines
* Simple mathematical analysis possible
* Rare in practice in water systems.

Transitional flow

* 2000 < Re < 4000
* Observed at 'medium' velocity
* Dye stream wavers in water - mixes slightly.

Turbulent flow

* Re > 4000
* Observed at 'high' velocity
* Dye mixes rapidly and completely
* Particle paths completely irregular
* Average motion is in the direction of the flow
* Cannot be seen by the naked eye
* Changes/fluctuations are very difficult to detect.
* Mathematical analysis very difficult - so experimental measures are used
* Most common type of flow.

Appendix:

Dynamic and Kinematic Viscosity of Water in SI Units:-

Temperature - *t* - (^oC)	Dynamic Viscosity - μ - ($N\ s/m^2$) x 10^{-3}	Kinematic Viscosity - ν - (m^2/s) x 10^{-6}
0	1.787	1.787
5	1.519	1.519
10	1.307	1.307
20	1.002	1.004
30	0.798	0.801
40	0.653	0.658
50	0.547	0.553
60	0.467	0.475
70	0.404	0.413
80	0.355	0.365
90	0.315	0.326
100	0.282	0.294

Conversion Factors:-

1 litre/sec = 0.001 m^3/sec

0.5 litre/sec = 0.0005 m^3/sec

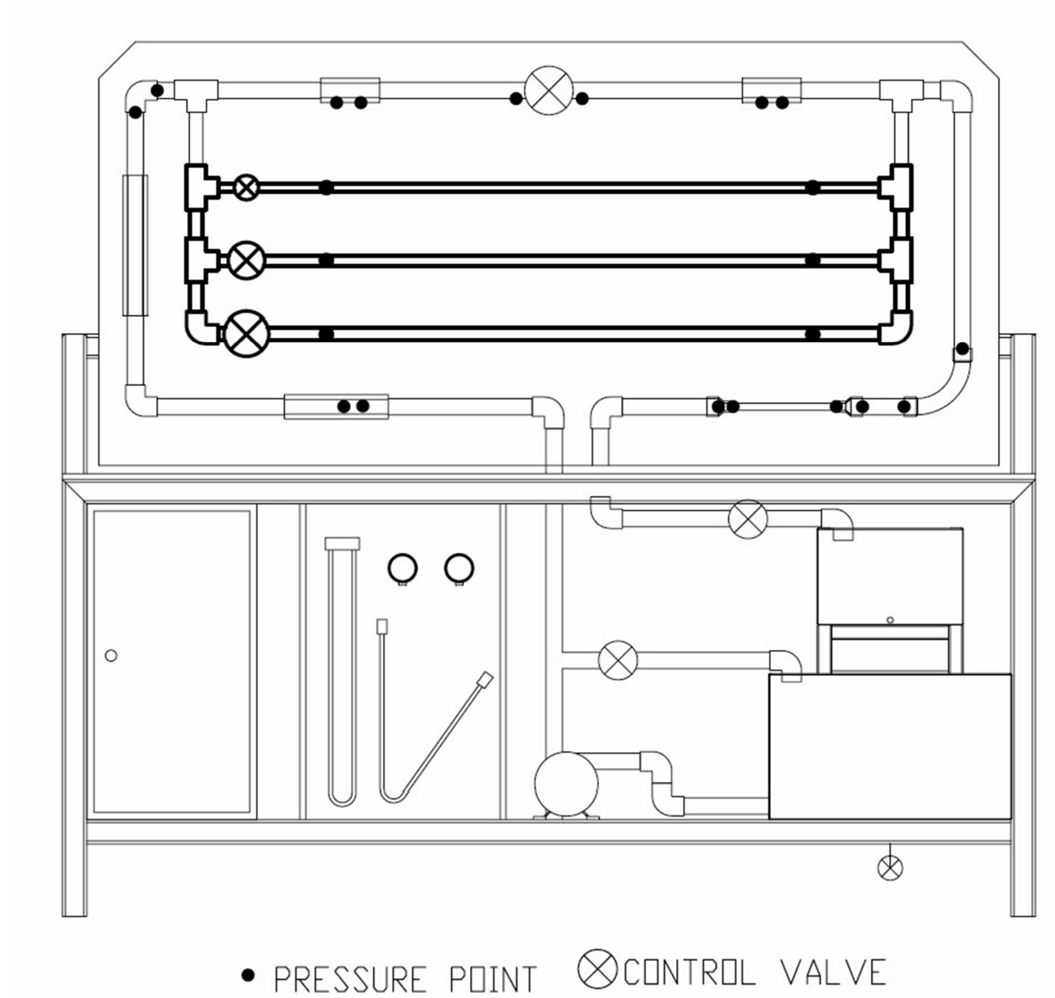
❖ Reference Video Links:

https://www.youtube.com/watch?v=xiX5PfFxmIs

https://www.youtube.com/watch?v=xiX5PfFxmIs

EXPERIMENT NO.: 6 **DATE:**

AIM: To determine the friction factor for pipes of different sizes and materials and their comparison.



Introduction and Theory

The flow of liquid through a pipe is resisted by viscous shear stresses within the liquid and the turbulence that occurs along the internal walls of the pipe, created by the roughness of the pipe material. This resistance is usually known as pipe friction and is measured is meters head of the fluid, thus the term head loss is also used to express the resistance to flow.

Many factors affect the head loss in pipes, the viscosity of the fluid being handled, the size of the pipes, the roughness of the internal surface of the pipes, the changes in elevations within the system and the length of travel of the fluid.

The resistance through various valves and fittings will also contribute to the overall head loss. In a well designed system the resistance through valves and fittings will be of minor significance to the overall head loss and thus are called Major losses in fluid flow.

The Darcy-Weisbach equation

Weisbach first proposed the equation we now know as the Darcy-Weisbach formula or Darcy-Weisbach equation:

$$h_f = f\,(L/D) \times (v^2/2g)$$

where:

h_f = head loss (m)
f = Darcy friction factor
L = length of pipe work (m)
d = inner diameter of pipe work (m)
v = velocity of fluid (m/s)
g = acceleration due to gravity (m/s^2)

The Darcy Friction factor used with Weisbach equation has now become the standard head loss equation for calculating head loss in pipes where the flow is turbulent.

Apparatus Description

The experimental set up consists of a large number of pipes of different diameters. The pipes have tapping at certain distance so that a head loss can be measure with the help of a U – Tube manometer. The flow of water through a pipeline is regulated by operating a control valve which is provided in main supply line. Actual discharge through pipeline is calculated by collecting the water in measuring tank and by noting the time for collection.

TECHNICAL SPECIFICATION:

Pipe:

MOC = P.U.
Test length = 1000 mm

Pipe Diameter:

Pipe 1: ID: 13.9 mm (1/2” UPVC 80 Schedule)
Pipe 2: ID: 16.2 mm (1/2” GI)
Pipe 3: ID: 27.4 mm (1” GI)

Experimental Procedure

1) Fill the storage tank/sump with the water.
2) Switch on the pump and keep the control valve fully open and close the bypass valve to have maximum flow rate through the meter.
3) To find friction factor of pipe 1 open control valve of the same and close other to valves
4) Open the vent cocks provided for the particular pipe 1 of the manometer.
5) Note down the difference of level of mercury in the manometer limbs.
6) Keep the drain valve of the collection tank open till its time to start collecting the water.
7) Close the drain valve of the collection tank and collect known quantity of water
8) Note down the time required for the same.
9) Change the flow rate of water through the meter with the help of control valve and repeat the above procedure.
10) Similarly for pipe 2 and 3 . Repeat the same procedure indicated in step 4-9
11) Take about 2-3 readings for different flow rates.

Observations Table

Length of test section (L) = 1000 mm = 1 m

Pipe 1
Internal Diameter of Pipe , D= 13.9 mm
Cross Sectional Area of Pipe = 15.18×10^{-4} m^2

Sr. No.	Qty (litre)	t (sec)	h_1 _ h_2 (mm)	V (m/s)
1				
2				
3				

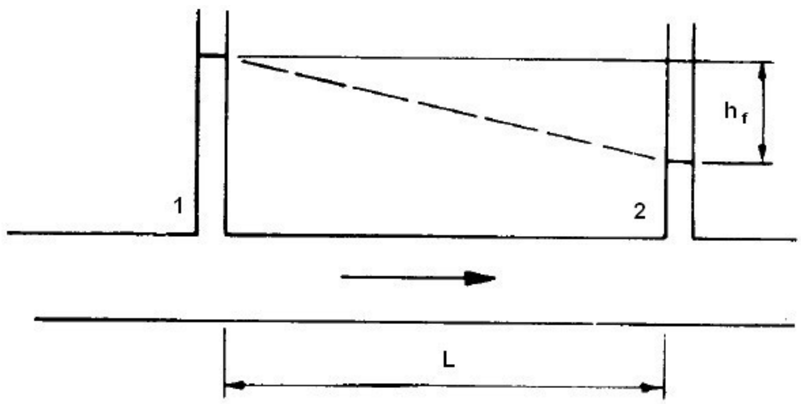
Pipe 2
Internal Diameter of Pipe , D= 16.2 mm
Cross Sectional Area of Pipe = 2.06×10^{-4} m^2

Sr. No.	Qty(litre)	t (sec)	h_1 _ h_2 (mm)	V (m/s)
1				
2				
3				

Pipe 3
Internal Diameter of Pipe , D= 27.4 mm
Cross Sectional Area of Pipe = 5.9×10^{-4} m^2

Sr. No.	Qty(litre)	t (sec)	$h_1 - h_2$ (mm of hg)	V (m/s)
1				
2				
3				

Calculations



Mean velocity of flow, V = Q/A m/s

Where, Q = 0.01/time required for 10 lit in m^3/sec

According to Darcy- Weisbach Equation for frictional loss of head due to pipe friction:-

$$h_f = h_1 - h_2 = \frac{f.L.V^2}{D \times 2g}$$

In the above equation, everything is known to us except "*f*"

Conversion Factor :- 1 mm of Hg = 0.0126 m of water

Conclusion

1) The friction factor for pipe is as follows:
    - Pipe 1 =
    - Pipe 2 =
    - Pipe 3 =

2) Friction factor decreases with increase in diameter for same material of construction.

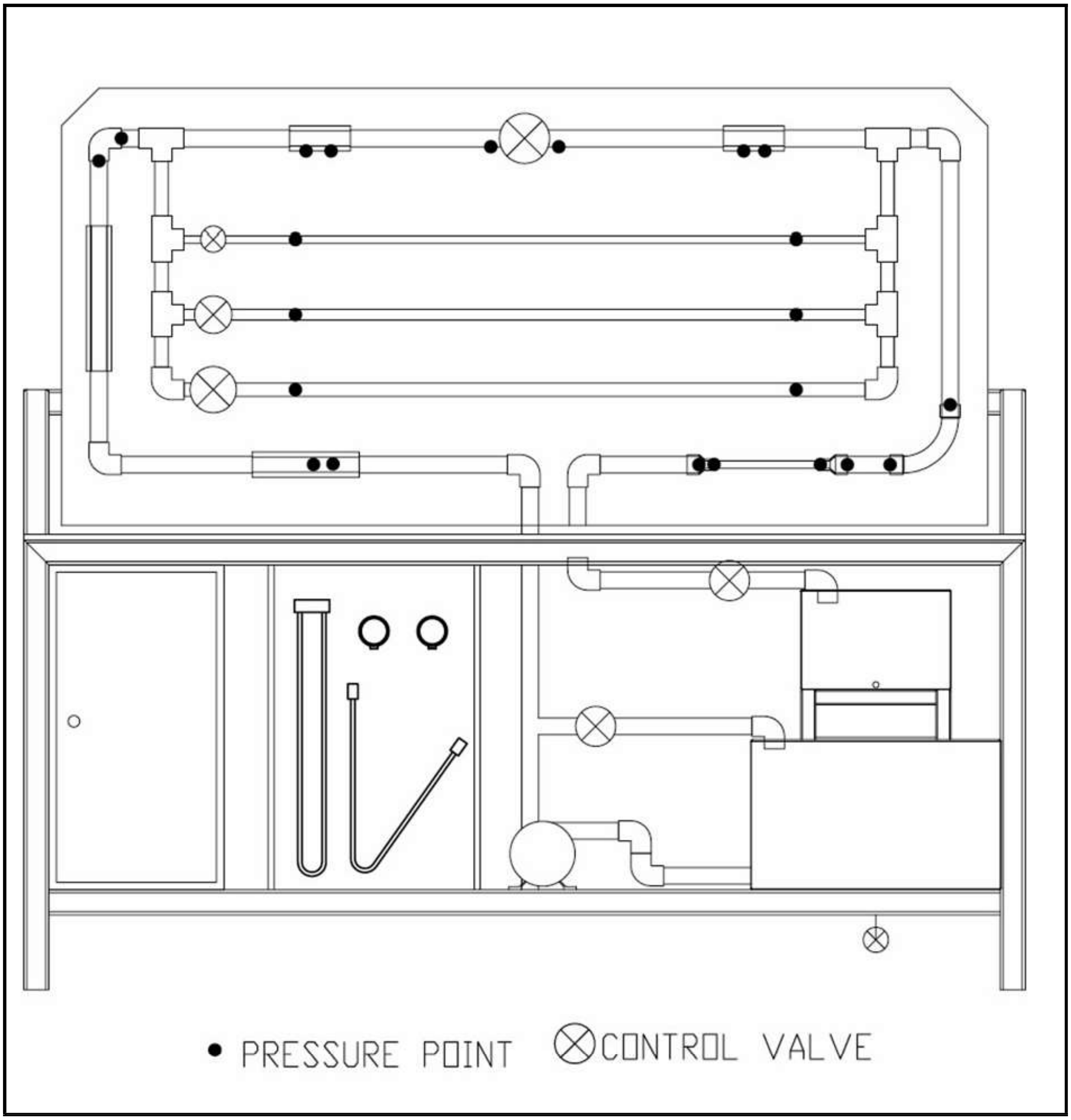
3) For same size pipes, GI/PU has more friction compared to GI/PU.

- ❖ Reference Video Links:

https://www.youtube.com/watch?v=_hSL9_eo4n8
https://www.youtube.com/watch?v=w7n0srAzm8g

EXPERIMENT NO.: 7 **DATE:**

AIM: To determine the loss co-efficient of different pipe fittings viz. Bend, elbow, valve, sudden contraction and sudden expansion.



Introduction and Theory

While installing a pipeline for conveying a fluid, it is generally not possible to install a long pipeline of same size all over a straight for various reasons, like space restrictions, aesthetics, location of outlet etc. Hence, the pipe size varies and it also changes its direction. Also, various fittings are required to be used. All these variations of sizes and the fittings cause the loss of fluid head.

Losses due to change in cross-section, bends, elbows, valves and fittings of all types fall into the category of minor losses in pipelines. In long pipeline, the friction losses are much larger than these minor losses and hence, the latter are often neglected. But, in shorter pipelines, their consideration is necessary for the correct estimate of losses.

The minor loses are, generally expressed as

$$H_L = K_L (V^2/2g)$$

Where, H_L is the minor loss (i.e. head loss) and K_L, the loss coefficient, which is practically constant at high Reynold's number for a particular flow geometry. V is the velocity of flow in the pipe (incase of sudden contraction, V is the velocity of flow in the contracted section).

For an abrupt enlargement of the pipe section, however, use of the continuity equation, Bernoulli's equation and Momentum equation yields

$$h_L = \frac{(V-V_2)^2}{2g} = \left\{1 - \left(\frac{d}{D}\right)^2\right\} \frac{V^2}{2g} = K_L \frac{V^2}{2g}$$

Here, V_2 and V are the velocities of flow in the larger diameter (= D) and the smaller diameter (=d) pipes respectively.

Apparatus Description

The experimental set-up consists of a pipe of diameter about 24.3 mm fitted with
(a) a right angle bend
(b) an elbow
(c) a Gate Valve
(d) a sudden expansion (larger pipe having diameter of about 24.3 mm) and
(e) a sudden contraction (from about 24.3 mm to about 13.8 mm)

Sufficient length of the pipeline is provided between various pipe fittings. The pressure taps on either side of these fittings are suitably provided and the same may be connected to a mutitube manometer bank. Supply to the line is made through a storage tank and discharge is regulated by means of outlet valve provided near the outlet end.

Experimental Procedure

1) Fill up sufficient clean water in the sump tank
2) Fill up mercury in the manometer
3) Connect the electric supply. See that the flow control valve and bypass valve are fully open and all the manometer cocks are closed. Keep the water collecting funnel in the sump tank side
4) Start the pump and adjust the flow rate. Now slowly open the manometer tapping connection of small bend. Open both the cocks simultaneously

5) Open air vent cocks. Remove air bubbles and slowly & simultaneously close the cocks. Note down the manometer reading and flow rate.
6) Close the cocks and similarly, note down the readings for other fittings. Repeat the procedure for different flow rates.

Observations:

Type of fitting – Elbow

Sr. No.	Manometer diff. mm of Hg	Flow rate (Time for 10 lits of water) t sec

Type of fitting – Bend

Sr. No.	Manometer diff. mm of Hg	Flow rate (Time for 10 lits of water) t sec

Type of fitting – Valve

Sr. No.	Manometer diff. mm of Hg	Flow rate (Time for 10 lits of water) t sec

Type of fitting – Sudden Contraction

Sr. No.	Manometer diff. mm of Hg	Flow rate (Time for 10 lits of water) t sec

Type of fitting – Sudden Expansion

Sr. No.	Manometer diff. mm of Hg	Flow rate (Time for 10 lits of water) t sec

Calculations:

1) Elbow

In elbow, there is no change in the magnitude of velocity of water but there is change in the direction of water, hence head loss exists

Diameter of the elbow, d = 21.34 mm = 0.02134 m

For elbow, mean area A= $(\pi/4)\ d^2 = 3.58 \times 10^{-4}\ m^2$

Mean velocity of flow, V = Q/A m/s

Where, Q = 0.01/time required for 10 lit in m^3/sec

Therefore, Loss of head at elbow

$h_L = K_L\ (V^2 / 2g)$ m of water

Where, h_L = Manometer diff (m) X 12.6

2) Pipe Bend

Similar to elbow, loss of head at bend is due to change in the direction of water. But unlike the elbow, change of direction is not abrupt hence loss if head is les compared to elbow

Diameter of bend d = 21.34 mm = 0.02134 m

For bend, mean area A= $(\pi/4)\ d^2 = 3.58 \times 10^{-4}\ m^2$

Mean Velocity of flow V = Q/A m/sec.

Where Q = 0.01/time required for 10 lit. m^3/sec

Loss of Head at bend, $h_L = K_L\ (V^2 / 2\ g)$

Where, h_L = Manometer Diff. (m) X 12.6

3) Valve

For Gate Valve, mean area A= $(\pi/4)\ d^2 = 3.58 \times 10^{-4}\ m^2$

Diameter of valve opening d = 21.34 mm = 0.02134 m

Mean Velocity of flow V = Q/A m/sec.

Where Q = 0.01/time required for 10 lit. m^3/sec

Loss of Head at bend, $h_L = K_L\ (V^2 / 2\ g)$

Where, h_L = Manometer Diff. (m) X 12.6

4) Sudden Contraction

At sudden contraction, velocity of water increases which causes pressure head to drop (according top Bernoulli's Theorem) in addition to this there is loss of head due to sudden contraction.

Hence,

Manometer reading = (Head drop due to increment of velocity) + (head loss due to sudden contraction)
Assuming no loss to be there due to contraction and applying Bernoulli's theorem at inlet and outlet of the section

$$\frac{P_i}{w} + \frac{V_i^2}{2.g} = \frac{P_o}{w} + \frac{V_o^2}{2.g}$$

Inlet size (dia.) = 33.4 mm = 0.0334 m

Therefore Ai = 8.76×10^{-4} m^2

Outlet size (dia.) d = 21.34 mm = 0.02134 m

Therefore $A_0 = (\pi/4)\, d^2 = 3.58 \times 10^{-4}$ m^2

$V_i = Q/A_i$ m/s
$V_o = Q/A_o$ m/s

Where, Q = discharge = (0.01)/time required for 10 lit. m^3/sec
Ai and Ao = inlet and outlet area respectively m^2

Drop of Head due to velocity increment,

$$h_v = \frac{V_i^2}{2.g} - \frac{V_o^2}{2.g}$$

Actual drop, h = (manometer reading x 12.6)

Loss of head due to sudden contraction is largely dependent on the smaller pipe i.e. inlet diameter
$h_{Lc} = h - h_v$
Theoretically, $h_{Lc} = K_L (V_i^2/2.g)$

5) Sudden Expansion
At sudden expansion of flow, pressure increases due to reduction in velocity, but there is pressure drop due to sudden expansion also. Hence at sudden expansion one rise of pressure lesser than that predicated theoretically.
Assuming no loss of head and applying Bernoulli's equation at inlet and outlet, similar to equation used for sudden contraction,

Inlet size (dia.) = d_i = 21.34 mm = 0.02134 m

Therefore $A_i = (\pi/4)\, d^2 = 3.58 \times 10^{-4}$ m^2

Outlet size (dia.) d_o= 33.4 mm = 0.0334 m

Therefore $A_o = 8.76 \times 10^{-4}$ m^2

Where, Q = discharge = (0.01)/time required for 10 lit. m^3/sec
Ai and Ao = inlet and outlet area respectively m^2

Rise of pressure

$$h_v = \frac{V_i^2}{2.g} - \frac{V_o^2}{2.g}$$

Loss of head due to sudden expansion, is largely dependent on the outer pipe i.e. outlet diameter

Actual, $h_{Le} = h_v - $ (manometer (m) X 12.6)

Therotical, $h_{Le} = K_L (V_o)^2 / 2g$

Result Table

Sr No.	Bend		Elbow		Valve		Sudden Contraction		Sudden Expansion	
	h_L	K_L	h_L	K_L	h_L	K_L	h_{Lc}	K_L	h_{Le}	K_L
1										
2										
3										

Conclusion

Average values of the loss coeeficients for various pipe fittings, as obtained experimentally, are as follows:

	Pipe Fitting	**Loss Coefficient, K_L**
1)	Bend	________________
2)	Elbow	________________
3)	Valve	________________
4)	Sudden Contraction	________________
5)	Sudden Expansion	________________

- Reference Video Links:

https://www.youtube.com/watch?v=GxaAcpDyIxM

https://www.youtube.com/watch?v=c0GIe5bAiQk

Experiment No: 8

OPERATING INSTRUCTION MANUAL OF

Pelton wHeel tURbIne test RIG

PRODUCT

EIE INSTRUMENTS PVT. LTD.

(MFR. OF HIGH CLASS LABORATORY EQUIPMENTS)

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WEB: WWW.EIEINSTRUMENTS.COM

CUSTOMER CARE: (079) 660 40 660-760(100 LINES)

Note : Please Read the Instructions before Operation

 AIM: - To conduct load test on pelton wheel turbine and to study the characteristics of pelton wheel turbine.

 APPARATUS:-

1. Pelton Wheel Turbine
2. Nozzle
3. RPM Indicator with proxy
4. Pressure Gauges (2 no. Range = 0 – 4.2 kg/cm^2)
   (1 no. Range = 0 – 7 kg/cm^2)

 THEORY:

Pelton wheel turbine is an impulse turbine, which is used to act on high loads and for generating electricity. All the available heads are classified in to velocity energy by means of spear and nozzle arrangement. Position of the jet strikes the knife- edge of the buckets with least relative resistances and shocks. While passing along the buckets the velocity of the water is reduced and hence an impulse force is supplied to the cups which in turn are moved and hence shaft is rotated
.

 PROCEDURE:

1. Fill the storage tank/sump with the water.
2. Keep the nozzle opening at the required position
3. Do the priming & start the pump.
4. Switch on the pump and keep the control valve fully open and close the bypass valve to have maximum flow rate.
5. Allow the water in the turbine to rotate it.
6. Note down the speed of the turbine.
7. Take the respective readings in the respective pressure gauges.
8. Load the turbine by increasing weight of spring balance.
9. Note down the spring balance difference.
10. Also note down the Head level and RPM.
11. Repeat the same procedure for different loading conditions.

 OBSERVATION:-

1. Diameter of Drum = 18cm=0.18m
2. Diameter of Rope = 5mm = 0.005 m
3. Total diameter (D) = 415 mm = 0.185 m

Sr no	Orifice meter		Pressure difference.	Discharge	Net head	RPM	torsion T=T2-T1 Kg
	P1 (kg/cm²)	P2 (kg/cm²)	h=(P2-P1) (kg/cm²)	Q=0.00135*(h)^0.5 (m³/sec)	H=P3*10 Mtr		
1							
2							
3							
4							
5							
6							

- OBSERVATION TABLE:-

Brake horse power	Indicated horse power	Efficiency
BHP=(3.14*D*N*T)/(60*75) HP	IHP=(1000*Q*H)/75 HP	%Л=(BHP/IHP)*100

- Calculation:-

1. VENTURIMETER READING:

   h = (P1 - P2) x10 (m of water)

   Where, P1, P2 = Venturimeter reading in Kg /cm²

2. DISCHARGE:

   Q = 0.00135(h) ^0.5 (m³/ s)

3. BRAKE HORSE POWER:

   BHP = (3.14x D x N x T) / (60 x75) (hp)

   Where, N = Speed of the turbine in (rpm)
   D = Effective diameter of brake drum = 0.185m T =
   Torsion in (T1 – T2) (Kg) =

4. INDICATED HORSE POWER:

IHP = (1000 x Q x H) / 75 (hp)

Where, H = Total head (m)

5. PERCENTAGE EFFICIENCY:

% Л = (B.H.P / I.H.P x 100) (%)

 RESULT:

From Observations:

1. Maximum Efficiency of the Pelton Wheel Turbine = ...%

2. Actual Discharge (Q) = ………

3. Head at inlet of turbine (H) = ……..

4. B.H.P. (output) = ………….

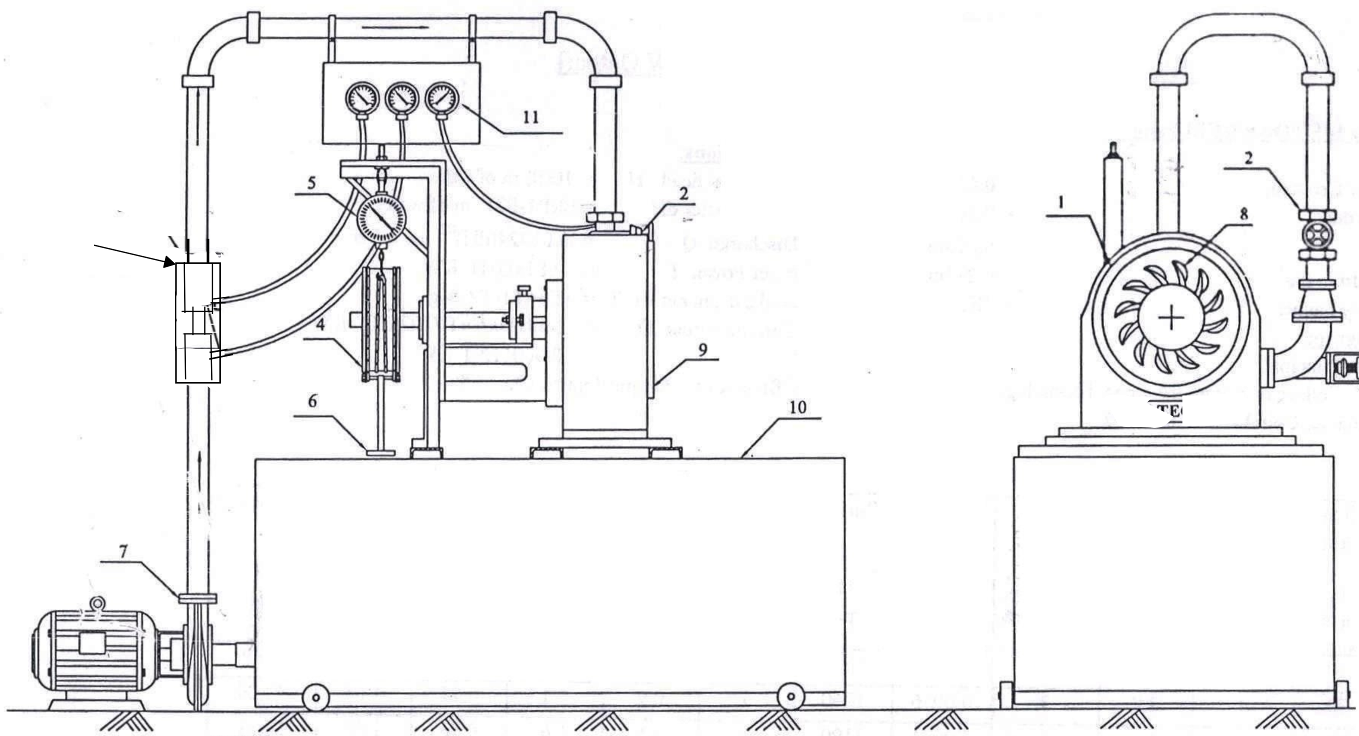
 GRAPHS:

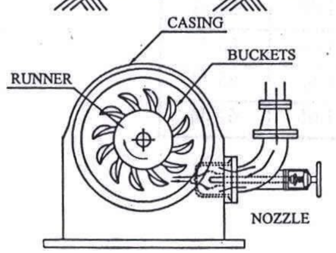
The following graphs are drawn.

1. BHP Vs IHP

2. BHP Vs speed

3. BHP Vs Efficiency





PELTON WHEEL TURBINE

1. Pelton Turbine
2. Flow control valve
3. Orificemeter
4. Brake drum
5. Spring balance
6. Weight hanger
7. Supply pump
8. Pelton runner
9. Transparent front side
10. Sump tank
11. Pressure gauges

PELTON WHEEL TURBINE TEST RIG

Experiment No: 9

Operating Instruction
Manual Of

KAPLAN TURBINE TEST RIG APPARATUS

PRODUCT

EIE INSTRUMENTS PVT. LTD.

(MFR. OF HIGH CLASS LABORATORY EQUIPMENTS)

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Note : Please Read the Instructions before Operation

CONDUCTING EXPERIMENTS AND DRAWING THE CHARACTERISTICS CURVES OF KAPLAN TURBINE TEST RIG

AIM:

To study the characteristics of a Kaplan turbine

APPARATUS REQUIRED:

1. Venturimeter
2. Stopwatch
3. Tachometer
4. Dead weight

FORMULAE:

1. **VENTURIMETER READING:**

$h = (P1 \sim P2) \times 10$ (m of water)

Where,

P1, P2 - Venturimeter reading in Kg /cm^2

2. **DISCHARGE:**

$Q = 0.0055 \times \sqrt{h}$ (m^3 / s)

3. **BRAKE HORSE POWER:**

$BHP = (\pi \times D \times N \times T) / (60 \times 75)$ (hp)

Where,

N = Speed of the turbine in (rpm)

D = Effective diameter of brake drum = 0.315 m T

= Torsion in To + T1 – T2 (Kg)

4. **INDICATED HORSE POWER:**

$IHP = (1000 \times Q \times H) / 75$ (hp)

Where,

H = Total head (m)

5. **PERCENTAGE EFFICIENCY:**

$\%\eta = (B.H.P / I.H.P \times 100)$ (%)

S.No	Pressure Gauge Reading [Hp] $Kg\backslash cm^2$	Total Head [H] m of water	Venturimeter reading Kg/cm^2		H = (P1-P2) x 10 m of water	Weight of hanger To Kg	Speed of turbine N Rpm	Weigh of hanger [T1] kg	Spring Balance T2 Kg	Tension [T] Kg	Discharge Q $x10^{-3}$ m^3/sec	B.H.P hp	I.H.P hp	□ %
			P1	P2										
											Mean =			

DESCRIPTION:

Kaplan turbine is an axial flow reaction turbine used in dams and reservoirs of low height to convert hydraulic energy into mechanical and electrical energy. They are best suited for low heads say from 10m to 5 m. the specific speed ranges from 200 to 1000

The flow through the pipelines into the turbine is measured with the office meter fitted in the pipeline. A mercury manometer is used to measure the pressure difference across the orifice meter. The net pressure difference across the turbine output torque is measured with a pressure gauge and vacuum gauge. The turbine output torque is determined with the rope brake drum. A tachometer is used to measure the rpm.

EXPERIMENTAL PROCEDURE:

1. Keep the runner vane at require opening
2. Keep the guide vanes at required opening
3. Prime the pump if necessary
4. Close the main sluice valve and they start the pump.
5. Open the sluice valve for the required discharge when the pump motor switches from star to delta mode.
6. Load the turbine by adding weights in the weight hanger. Open the brake drum cooling water gate valve for cooling the brake drum.
7. Measure the turbine rpm with tachometer
8. Note the pressure gauge and vacuum gauge readings
9. Note the orifice meter pressure readings.

Repeat the experiments for other loads

GRAPHS:

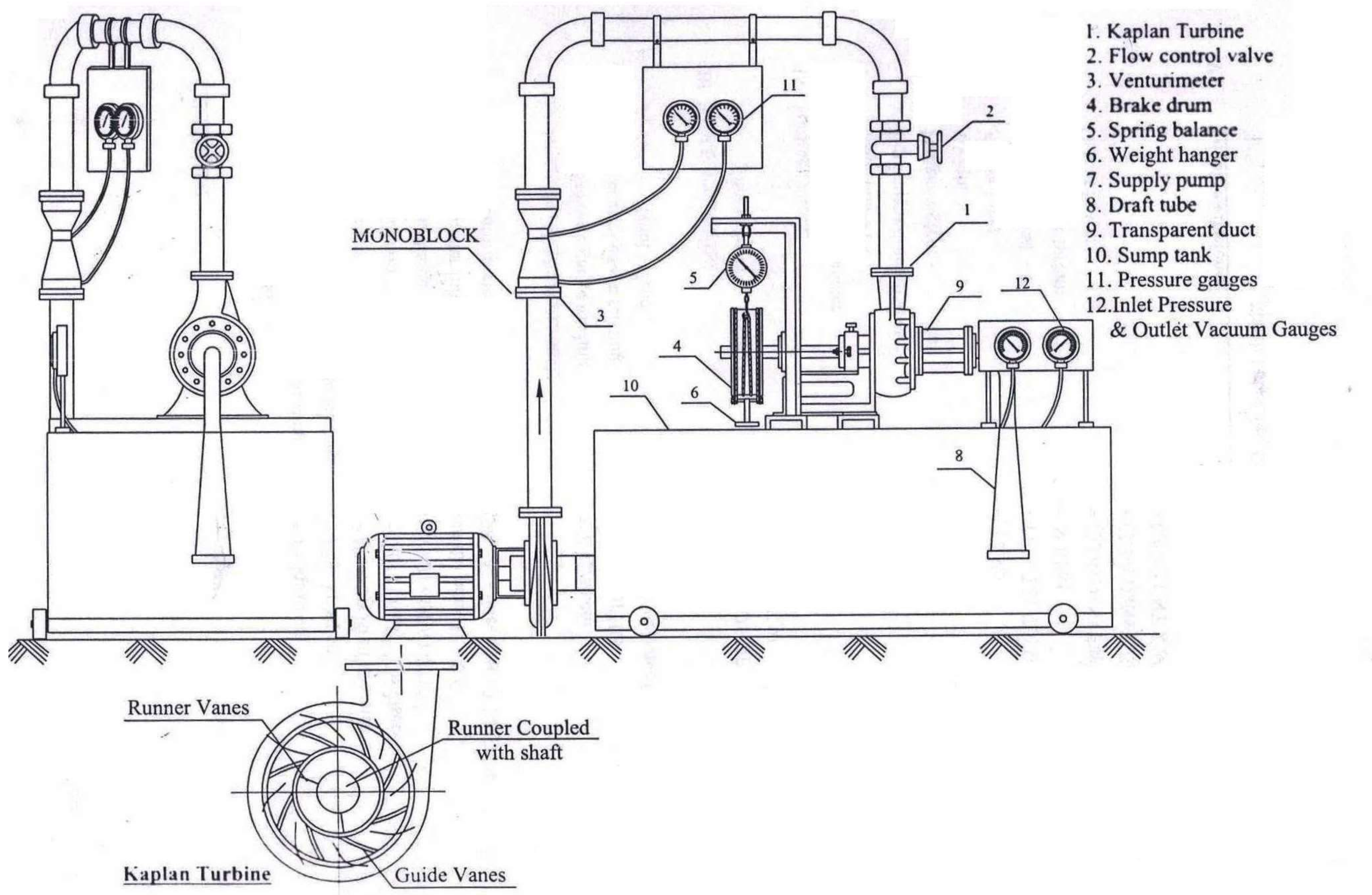
The following graphs are drawn.

1. BHP Vs IHP
2. BHP Vs speed
3. BHP Vs Efficiency

MODEL CALCULATION:

RESULT:

Thus the performance characteristic of the Kaplan Turbine is done and the maximum efficiency of the turbine is.................................... %



KAPLAN TURBINE TEST RIG

Experiment No: 10

Operating Instruction

Manual Of

FRANCIS TURBINE TEST RIG APPARATUS

EIE INSTRUMENTS PVT. LTD.

(MFR. OF HIGH CLASS LABORATORY EQUIPMENTS)

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Note : Please Read the Instructions before Operation

OBJECTIVE: AIM:

- To study the operation of Francis turbine.

- To determine the output power of Francis turbine.
- To determine the efficiency of the Francis turbine.
- To plot the performance characteristics curve for Francis Turbine.

THEORY:

The Francis turbine is an inward flow reaction turbine which was designed and developed by the American engineer James B. Francis. Francis turbine has a purely radial flow runner; the flow passing through the runner had velocity component only in a plane of the normal to the axis of the runner. Reaction hydraulic turbines of relatively medium speed with radial flow of water in the component of turbine are runner.

CONSTRUCTION DETAILS OF FRANCIS TURBINE:

Components of the Francis turbine:-

- Pen stoke: – It is a large sized shaped; where the water is provided to the turbine runner from the dam.
- Scroll casing: – Penstocks connected to and feeds water directly into an annular channel surrounding the turbine runner. The channel is spiral in its layout.
- Guide vanes: – A series of airfoil shaped vanes called the guide vanes are arranged inside the casing to form a number of flow passages between the casing and the runner blades. Guide vanes are fixed in position (they do not rotate with rotating runner).
- Guide wheel and governing mechanism: – It changes the position of guide blades to affect variation in the water flow rate in the wake of changing load conditions on the turbine. When the load changes, the governing mechanism rotates all the guide blades about their axis through the same angle so that the water flow rate to the runner.
- Runner and runner blades: – Runner of the Francis turbine is a rotor which has passages formed between the drat tube and scroll casing.
- Draft tube: – After passing through the runner, the water is discharged to the tail race through a gradually expanding tube.

WORKING OF FRANCIS TURBINE:

The amount of water falls on the vanes (buckets) of the runner. The turbine rotor is called runner. Runner revolves at constant with the help of governing mechanism. The runner shaft is connected with the generator; thus the electricity is produce with the help of generator. And the water is discharge from the tail race.

THEORY OF OPERATION:

The Francis turbine is a reaction turbine, which means that the working fluid changes pressure as it moves through the turbine, giving up its energy. A casement is needed to contain the water flow. The turbine is located between the high pressure water source and the low pressure water exit, usually at the base of a dam.

The inlet is spiral shaped. Guide vanes direct the water tangentially to the runner. This radial flow acts on the runner vanes, causing the runner to spin. The guide vanes (or wicket gate) may be adjustable to allow efficient turbine operation for a range of water flow conditions.

As the water moves through the runner its spinning radius decreases, further acting on the runner. Imagine swinging a ball on a string around in a circle. If the string is pulled short, the ball spins faster. This property, in addition to the water's pressure, helps inward flow turbines harness water energy.

At the exit, water acts on cup shaped runner features, leaving with no swirl and very little kinetic or potential energy. The turbine's exit tube is specially shaped to help decelerate the water flow and recover kinetic energy.

APPLICATION:

Francis Inlet Scroll, Grand Coulee Dam Large Francis turbines are individually designed for each site to operate at the highest possible efficiency, typically over 90%. They are best suited for sites with high flows and low to medium head. Francis Turbines are very expensive to design, manufacture and install, but operate for decades.

In addition to electrical production, they may also be used for pumped storage; where a reservoir is filled by the turbine (acting as a pump) during low power demand, and then reversed and used to generate power during peak demand.

Francis turbines may be designed for a wide range of heads and flows. This, along with their high efficiency, has made them the most widely used turbine in the world.

POWER GENERATION

For power generation using Francis Turbine the turbine is supplied with high pressure water which enters the turbine with radial inflow and leaves the turbine axially through the draft tube. The energy from water flow is transferred to the shaft of the turbine in form of torque and rotation. The turbine shaft is coupled with dynamos or alternators for power generation. For quality power generation speed of turbine should be maintained constant despite the changing loads. To maintain the runner speed constant even in reduced load condition the water flow rate is reduced by changing the guide vanes angle.

DESCRIPTION:

The Francis Turbine Consists of Spiral Casing, an outer bearing pedestal and rotor assembly with runner shaft and brake drum, all mounted on a suitable sturdy iron base plate. A straight conical draft tube is provided for the purpose of regaining the kinetic energy from the exit water and also facilitating easy assembly of the turbine due to it's locating at higher level than tailrace. A transparent hollow perplex cylinder is provided in between the draught bend and the casing for the purpose of observation of the flow at the exit runner. A rope brake arrangement is provided to load the turbine. The Output of the turbine can be controlled by adjusting the guide vanes for which a hand wheel and suitable link mechanism are provided. The net Supply head on the turbine is measured by the pressure & vacuum gauge.

SPECIFICATIONS:

- Pump : Centrifugal type high speed
- Power Required : AC, 5Hp, 3 Phase, and 440 Volt
- Head : 10-35 meter
- Discharge : 39-18 LPs
- Speed : 2880 RPM
- Spring Balance: 5 Kg
- Runner Dia : 162 mm
- No. of Guide Vanes : 10
- Rated Speed : 1000 RPM
- Power Output : 1 Kilowatt
- Flow measurement : Pitot tube

UTILITIES REQUIRED:

- Water supply : 400 liters (aprox.)
- 3 Phase supply, 440 volt AC
- Drain
- Space required 2.5 m x 1.5m x 3.0 m

EXPERIMENTAL PROCEDURE:-

1. Clean the apparatus and make it free from dust
2. Close the drain valve provided
3. Fill sump tank ¾ with clean water and ensure that no foreign particles are there
4. Fill manometer fluid i.e. Hg in manometer
5. Now switch on the power supply (440 VAC, 50 Hz)
6. Switch on the pump with the help of starter
7. Open the air releasing valve provided on the manometer, slowly release the air from manometer
8. When there is no air in the manometer, close the air releasing valves
9. Now regulate the Guide Vanes position with the help of hand wheel provided.
10. Now turbine is in operation.
11. Regulate the discharge by regulating the Guide vane position
12. Load the turbine by applying weight on plat form.
13. Note the manometer reading
14. Note the pressure gauge reading

15. Note the RPM of the turbine
16. Note the spring balance reading
17. Repeat the same procedure for different load and different discharge
18. When the experiment is over, first remove load on dynamometer
19. Close the ball valves provided on manometer
20. Switch off pump with the help of starter.
21. Switch off main power supply.
22. Drain the water from turbine with the help of ball valve provided on turbine.

STANDARD DATA:

Diameter of the pipe	:	80 mm
Acceleration due to gravity (g)	:	9.8 m/sec^2
Density of water (ρ_w)	:	1000 Kg/m^3
Density of manometric liquid (ρ_m)	:	13600 Kg/m^3
Dia of Brake Drum (D_b)	:	0.2m
Dia of Rope (D_R)	:	0.019 m
Coefficient of Discharge (C_d)	:	0.98
Weight of the Hanger (W_3)	:	0.298 kg

FORMULAE:

Total Head

$$H = 10.325 \times P_d \quad "m" \text{ of water}$$

Discharge

$$Q = A \times C_d \sqrt{2 \times g \times h \left(\frac{\rho_m}{\rho_w} - 1 \right)} \quad m^3/\text{sec}$$

Where h = Manometric Difference in "m"

Turbine Output

$$\frac{2 \times 9.81 \times \pi \times N \times W \times R_e}{60000} \quad Kwatt$$

Where,

Net load W = (T_1+W_3)-T_2 Kg

Equivalent radius $R_e = \frac{(D_b + 2D_R)}{2}$

Turbine Input

$$\frac{\rho_w \times g \times Q \times H}{1000} \text{ Kw}$$

Turbine Efficiency

$$\eta_{turbine} = \frac{Output\ power}{Input\ power} \times 100$$

OBSERVATION TABLE:-

S.No	RPM(N)	Pressure gauge reading P_d(Kg/cm^2)	Differential pressure h(m)	Load on turbine(Kg)	
				T_1(Applied Load)	T_2(Spring Balance Load)

Calculation Table:-

S.No	RPM	Total Head H (m of water)	Discharge Q(m^3/sec)	Output (watt)	Input (watt)	Turbine efficiency (%)

NOMENCLATURE:-

P_d = Pressure gauge reading (Kgf/cm^2)
ρ_w = density of water
ρ_m = density of mercury
h = manometric difference (m)
C_d = Coefficient of discharge
T_1 & T_2 = spring balance reading
N = RPM of runner shaft
g = Acceleration due to gravity

PRECAUTIONS & MAINTAINANCE INSTRUCTIONS:-

- Do not run the pump at low voltage i.e. less than 390 volts.
- Never fully closed the delivery line and bypass line valves simultaneously
- Always keep the apparatus free from dust.
- To prevent clogging of moving parts, always run the pump once in a week.

- Frequently grease/oil the rotating parts, once in three months.
- Always use clean water
- If the apparatus will not be in use for more than one month, drain the apparatus completely.

TROUBLE SHOOTING:-

- If the pump is not lifting any water, the revolution of motor may be reversed. Change the electric connection of the motor to change revolution.
- If the panel is not showing input, check the main supply.