Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

3rd Year, 1st Semester

Student Name :

Student ID :

Experiment No. 1

STUDY OF BERNOULLI'S THEOREM

General

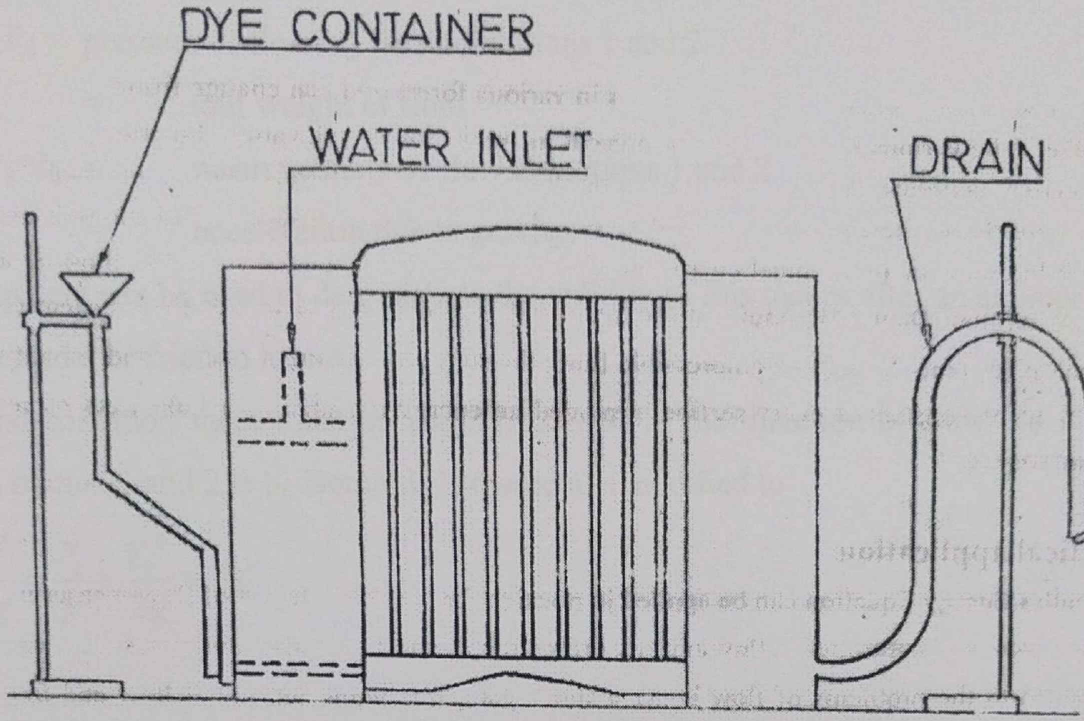
Energy is the ability to do work. It manifests in various forms and can change from one form to another. This various forms of energy present in fluid flow are elevation, kinetic, pressure and internal energies. Internal energies are due to molecular agitation and manifested by temperature. Heat energy may be added to or subtracted from a flowing fluid through the walls of the tube or mechanical energy may be added to or subtracted from the fluid by a pump or turbine. Daniel Bernoulli in the year 1738 stated that in a steady flow system of frictionless (or non-viscous) incompressible fluid, the sum of pressure, elevation and velocity heads remains constant at every section, provided no energy is added to or taken out by an external source.

Practical application

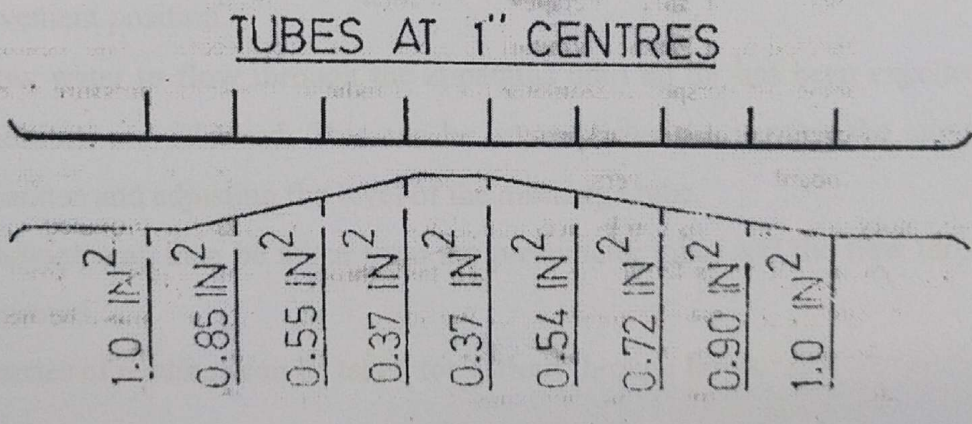
Bernoulli's Energy Equation can be applied in practice for the construction of flow measuring devices such as venturimeter, flow nozzle, orifice meter and Pitot tube. Furthermore, it can be applied to the problems of flow under a sluice gate, free liquid jet, radial flow and free vortex motion. It can also be applied to real incompressible fluids with good results in situations where frictional check is very small.

Description of apparatus

The unit is constructed as a single Perspex fabrication. It consists of two cylindrical reservoirs inter-connected by a Perspex Venturi of rectangular cross-section. The Venturi is provided with a number of Perspex piezometer tubes to indicate the static pressure at each cross-section. An engraved plastic backboard is fitted which is calibrated in British and Metric units. This board can be reversed and mounted on either side of the unit so that various laboratory configurations can be accommodated. The inlet vessel is provided with a dye injection system. Water is fed to the upstream tank through a radial diffuser from the laboratory main supply. For satisfactory results, the main water pressure must be nearly constant. After flowing through the venture, water is discharged through a flow-regulating device. The rate of flow through the unit may be detrimental either volumetrically or gravimetrically. The equipment for this purpose is excluded from the manufacturer's supply. The apparatus has been made so that the direction of flow through the venture can be reversed for demonstration purpose. To do this the positions of the dye injector and discharge fitting have to be interchanged.



SKETCH OF APPARATUS



VENTURI DETAILS

Governing Equation

Assuming frictionless flow, Bernoulli's Theorem states that, for a horizontal conduit

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} = \ldots\ldots\ldots\ldots$$

where, P_1P_2 = pressure of flowing fluid at sections 1 and 2

γ = unit weight of fluid

$V_{1,}V_2$ = mean velocity of flow at sections 1 and 2

g = acceleration due to gravity.

The equipment can be used to demonstrate the validity of this theory after an appropriate allowance has been made for friction losses.

For actual condition there must be some head loss in the direction of flow. So if the head loss between section 1 and 2 is h_L Bernoulli's theorem is modified to

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

Procedure

1. The apparatus should be recurrently leveled by means of screws provided at the base.
2. Connect the water supply to the radial diffuser in the upstream tank.
3. Adjust the level of the discharge pipe by means of the stand and clamp provided to a convenient position.
4. Allow water to flow through the apparatus until all air has been expelled and steady flow conditions are achieved. This can be accomplished by varying the rate of inflow into the apparatus and adjusting the level of the discharge tube.
5. Readings may then be taken from the piezometer tubes and the flow through the apparatus measured.
6. A series of readings can be taken for various through flows.

Objective

1. To calculate the total head loss $h_L = h_1 - h_{11}$
2. To plot the static head, velocity head and total head against the length of the passage in one plain graph paper.
3. Verification of total head loss by plotting head loss in each passage or segment.
4. To plot the total head loss h_L, against the inlet kinematics head, $V^2/2g$, for different in- flow conditions in plain graph paper.

Practice Question

1. What are the assumptions underlying the Bernoulli's energy equation?
2. Do you need any modification (s) of Eqn (1) when (a) the frictional head loss is to be considered, and (b) the conduit is not horizontal?

Experiment No. 1

STUDY OF BERNOULLI'S THEOREM

Experimental Data Sheet

Course no.: **Student ID no.:**

Group no.: **Date:**

Cross-sectional area of the measuring tank = ____________________

Initial point gage reading = ____________________

Final point gage reading = ____________________

Collection time = ____________________

Volume of water = ____________________

Discharge Q = ____________________

Piezometer tube no.	1	2	3	4	5	6	7	8	9	10	11
A											
V=Q/A											
$V^2/(2g)$											
p/γ											
$h=p/\gamma+v^2/(2g)$											

Head loss in each segment	0	$h_{1-2} = h_2 - h_1$	h_{2-3}	h_{3-4}	h_{4-5}	h_{5-6}	h_{6-7}	h_{7-8}	h_{8-9}	h_{9-10}	h_{10-11}
h_L	0										

Gr. NO	1	2	3	3	5
$V_1^2/2g$					
h_L					

____

Signature of the teacher

Experiment No. 2

FLOW THROUGH VENTURIMETER

General

The converging tube is an efficient device for converting pressure head to velocity head, while the diverging tube converts velocity head to pressure head. The two many be combined to form venture tube. As there is a definite relation between the pressure differential and the rate of flow. The tube may be made to serve as metering device.

Venturi meter consists of a tube with a constricted throat that produces an increased velocity accompanied by a reduction in pressure followed by a gradual diverging portion in which velocity is transformed back info pressure with slight frictions loss.

Practical application

The venturimeter is used for measuring the rate of flow of both compressible and incompressible fluids.

The venturimeter provides an accurate means for measuring flow in pipelines. Aside from the installation cost, the only disadvantage of the venturi meter is that in introduces a permanent frictional resistance in the pipelines.

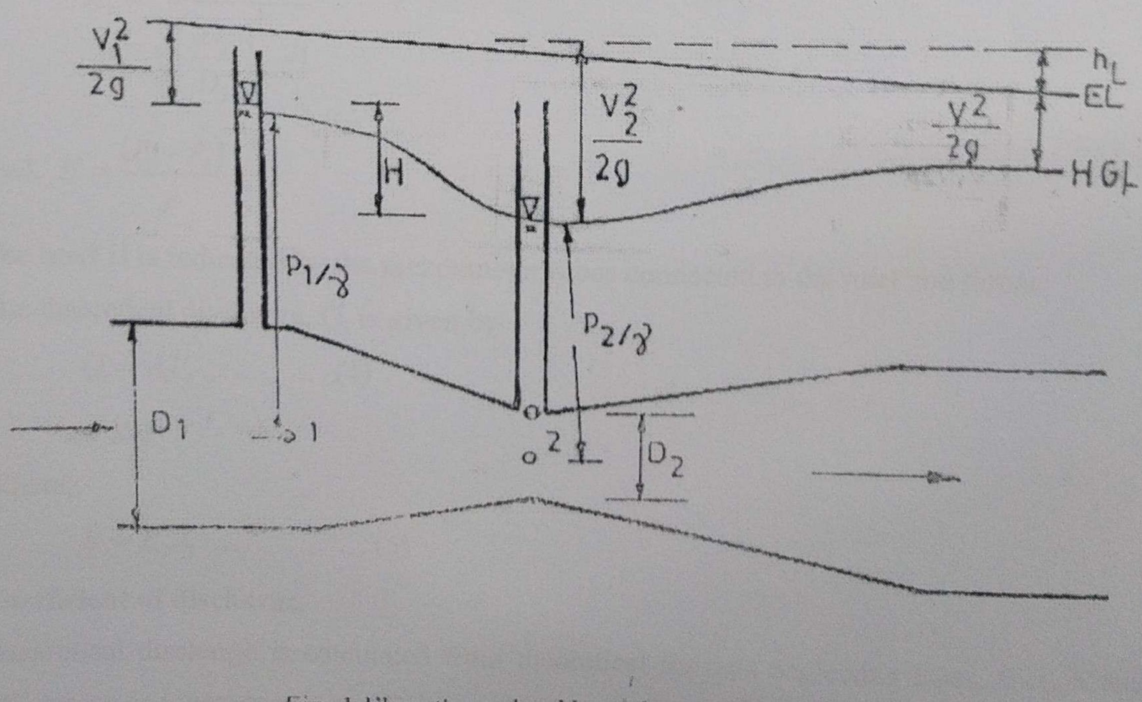


Fig. 1 Flow through a Venturimeter

Theory

Consider the Venturimeter shown in the above figure. Applying the Bernoulli's equation between Point 1 at the inlet and point 2 at the throat, we obtain.

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

Where P_1 and V_1 are the pressure and velocity at point 1, P_2 and V_2 are the corresponding quantities at point 2, γ is the specific weight of the fluid and g is the acceleration due to gravity from continuity equation, we have.

$$A_1V_1 = A_2V_2\text{...........(2)}$$

Where, A_1 and A_1 re the cross sectional areas of the inlet and throat respectively since

$$A_1=\frac{\pi}{4}D_1^2, A_2=\frac{\pi}{4}D_2^2$$

From Equations (1) and (2), we have

$$V_1=\sqrt{\frac{2g}{\left(\frac{D_1}{D_2}\right)^4-1}\frac{(P_1-P_2)}{\gamma}}$$

$$= K_1H^{1/2}\text{.............(3)}$$

Where,

$$K_1=\sqrt{\frac{2g}{\left(\frac{D_1}{D_2}\right)^4-1}}$$

And, $H=\frac{(P_1-P_2)}{\gamma}$

The head H is indicated by the piezonmeter tubes connected to the inlet and throat.

The theoretical discharge, Q_t is given by

$$Q_t = A_1V_1\text{........... (4)}$$

$$= KH^{1/2}$$

Where,

$$K = K_1A_1\text{................ (5)}$$

Coefficient of discharge

Theoretical discharge is calculated from theoretical formula neglecting loses, friction losses. For this season we introduce a coefficient named coefficient of discharge which is the ration of actual discharge to theoretical discharge.

Now, if C_d is the coefficient of discharge (also known as the meter coefficient) and Q_a is the actual discharge then,

$$C_d = \frac{Q_a}{Q_t}$$

$$Q_a = C_d Q_t$$

$$= C_d K H^{1/2}$$

$$= C H^n \text{ .... (6)}$$

The value of Cd may be assumed to be about 0.99 for large meter and about 0.97 or 0.98 for small ones provided the flow is such as to give reasonably high Reynolds number.

Calibration

One of the objectives of the experiment is to find the values of C and n for a particular meter so that in future we can measure actual discharge only by measuring H. Here C and n are called calibration parameters.
For five sets of actual discharge and H data we plot Q_a vs. H in log-log paper and draw a best –fit straight line.

The Equation of line

$\log Q_a = \log CH^n$

$\log Q_a = \log C + n \log H$

Now from the plotting we take two points on the straight line say (H_1, Q_{a1}) and (H_2, Q_{a2})
So from the equation (3) we get

$\log Q_{a1} = \log C + n \log H_1$
$\log Q_{a2} = \log C + n \log H_2$

$$Solving, n = \frac{\log \frac{Q_{a1}}{Q_{a2}}}{\log \frac{H_1}{H_2}}$$

C= antilog [anti log Q_{a1}-n $\log H_1$]
So the calibration equation is $Q_a = CH^n$
Now $C = C_d K$
$C_d = C/K$

Now from the calibration equation we can calculate actual discharge for different H and plot on a plain graph paper. In practice we can use the plot to find actual discharge for any H. Thus the venturi meter is calibrated.

Objective

1. To find C_d for the Venturimenter
2. To plot Qa against H in log-log paper and to find (a) exponent of H and(b) C_d-
3. To calibrate the Venturimeter.

Practice Questions

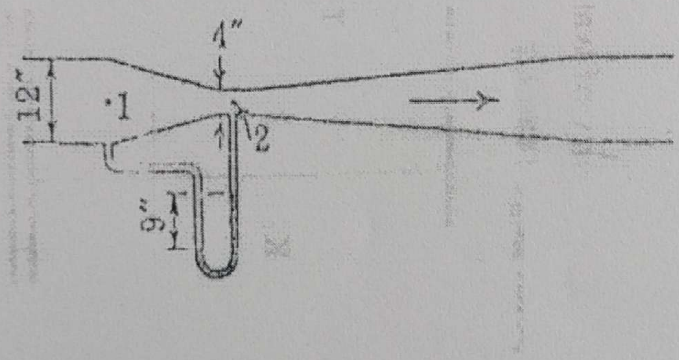
1. Why is the diverging angle smaller than the converging angle for a venturimeter?

2. How can the accuracy of venturimeter be increased in use?

3. On what factors does the meter co-efficient depend?

4. What is cavitations? Discuss its effect on flow through a venturimeter. How can you avoid cavitation in a venturimcter?

5. A Venturi meter having a throat 4 in. in diameter is installed in a horizontal 12 in pipe line carrying light oil (sp gr 0.82). A mercury U tube as shown in fig 1. shows a difference in height of mercury columns of 9 in, the remainder of the tube being filled with oil. Find the rate of discharge, Q in cubic meter per second, if C_d=0.975.



Experiment No.2

FLOW THROUGH A VENTURIMETER

Experimental Data and Calculation Sheet

Course no.: **Student ID no.:** **Group no.:** **Date:**

Cross sectional area of the measuring tank, A= ____________

Pipe diameter, D_1= ____________ Area of the pipe, A_1= ____________

Throat diameter D_2= ____________ Area of the throat, A_2= ____________

Temperature of water, t= ____________ Kinematic viscosity of water v= ____________

Initial point gage reading= ____________ Final point gage reading = ____________

No of obs	Volume of water v	Collection time T	Actual Dis-charge Q_a	Piezometer reading			k_1	k	Theoretical discharge Q_t	$C_d = \frac{Q_a}{Q_t}$	$V_2 = \frac{Q_a}{A_2}$	Reynolds number R_e
				Left h_1	Right h_2	Diff. H						

roup No					
Actual discharge Qa					
Head difference H					
Coefficient of discharge					
Reynolds number					

Signature of the Teacher

Experiment No. 6
FLOW THROUGH AN ORIFICE

General

An orifice is an opening in the wall of a tank or in a plate normal to the axis of a pipe, the plate being either at the end of pipe or in some intermediate location. An orifice is characterized by the fact that the thickness of the wall or plate is very small relative to the size of the opening. For a standard orifice there is only a line contact with fluid.

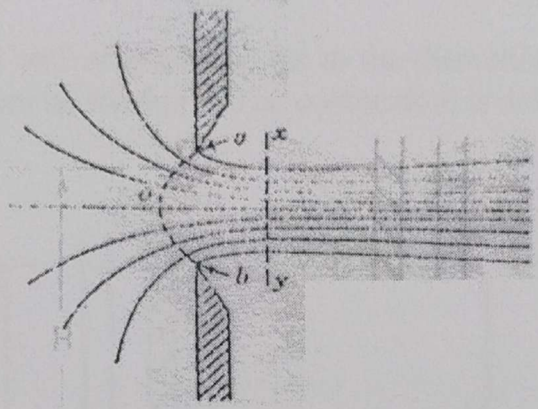


Fig 1 Jet contraction

Where the streamlines converge in approaching an orifice, they continue to converge beyond the upstream section of the orifice until they reach the section xy where they become parallel. Commonly this section is about $0.5D_0$ from the upstream edge of the opening, where D_o is diameter of the orifice. The section xy is then a section of minimum area and is called the vena contracta. Beyond the vena contracta the streamlines commonly diverge because of frictional effects.

Practical application

The usual purpose of an orifice is the measurement or control of flow from a reservoir. The orifice is frequently encountered in engineering practice operating under a static head where it is usually not used for metering but rather as a special feature in a hydraulic design. Another problem of orifice flow, which frequently arises in engineering practice, is that of discharge from an orifice under falling head, a problem of unsteady flow.

Theory

Coefficient of contraction:

The ratio of the area of a jet at the vena contracta to the area of the orifice is called the coefficient of contraction.

Coefficient of velocity:

The velocity that would be attained in the jet if the friction did not exist may be termed the theoretical velocity. The ratio of actual to the theoretical velocity is called coefficient of velocity.

Coefficient of discharge:

The ratio of the actual rate of discharge Qa to the theoretical rate of discharge Q (the flow that would occur if there were no friction and no contraction) is defined as the coefficient of discharge.

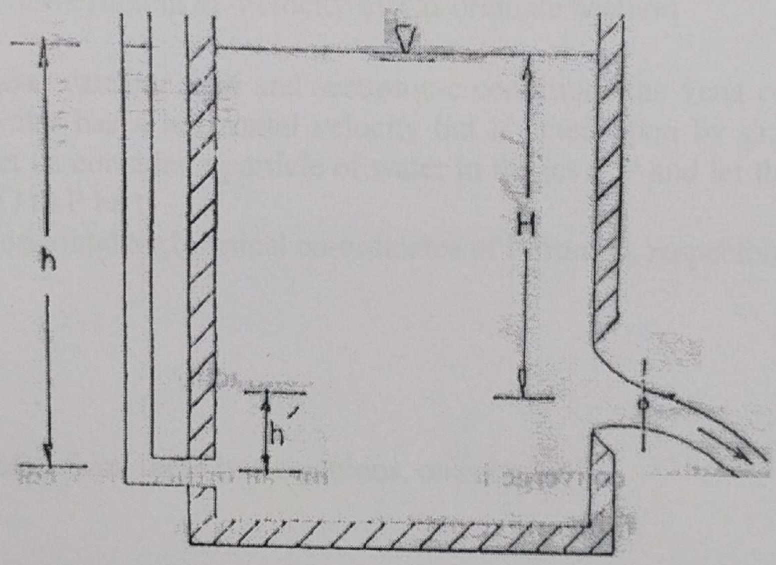


Fig. 2 Flow Through an orifice

Consider a small orifice having a cross–sectional area A and discharging water under a constant head H as shown in the above figure. Applying Bernoulli's theorem between the water surface

$$H = 0 + v^2/2g$$

so, $V_t = \sqrt{2gH}$

where g is the acceleration due to gravity. Let Q_a be the actual discharge.

So theoretical discharge Qt is given by

$Q_t = A\sqrt{2gH}$

Then the coefficient of discharge, C_d is given by

$$C_d = \frac{Q_a}{Q_t}$$

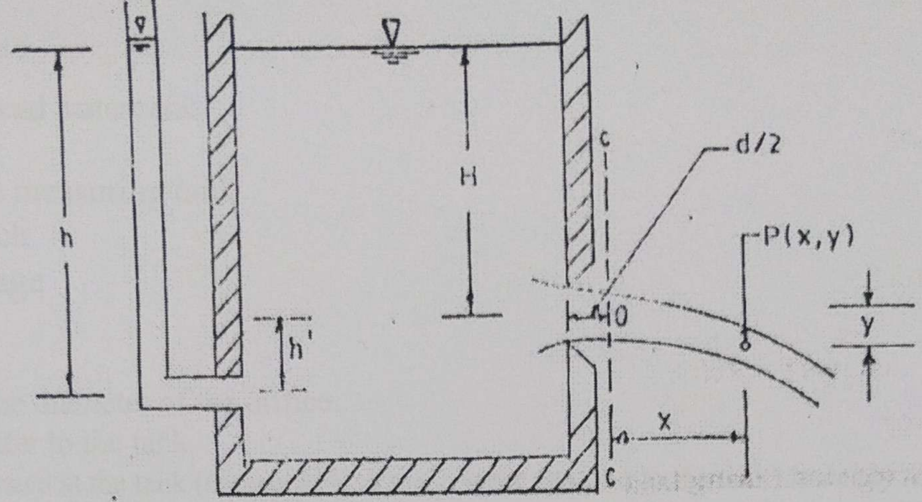


Fig 3: Co-efficient of Velocity by Co-ordinate Method

Let H be the total head causing flow and section-c-c conditions the vena contract as shown in the figure. The jet of water has a horizontal velocity but is acted upon by gravity with a downward acceleration of g. Let us consider a particle of water in the jet at P and let the time taken for this to move particle from O to P be t.

Let x and y be the horizontal and vertical co-ordinates of P from O, respectively. Them,

$x = V_a t$

and

$y = \frac{1}{2} g t^2$

Equating the value of t^2 from these two equations, one obtains

$\frac{x^2}{V_a^2} = \frac{2y}{g}$

$V_a = \sqrt{\frac{gx^2}{2y}}$

But, the theoretical velocity, $V_t = \sqrt{2gH}$

Hence, the coefficient of velocity, C_v is given by

$C_v = \frac{v_a}{v_t} = \sqrt{\frac{x^2}{4yH}}$

And the head loss is given by

$H_l = (1 - C_v^2) H$

$C_v = \frac{v_a}{v_t} = \frac{v_a}{\sqrt{2gH}}$

Coefficient of contraction, C_c is defined as the area of jet at vena contracta to the area of orifice, thus,

$C_c = \frac{A_a}{A}$

It follows that

$$C_d = C_c x C_v$$

Apparatus

1. Constant head water tank
2. Orifice
3. Discharge measuring tank
4. Stop watch
5. Point gauge

Procedure

1. Measure the diameter of the orifice.
2. Supply water to the tank.
3. When the head at the tank (measured by a manometer attached to the tank) is steady record the reading of the manometer.
4. Measure the x and y co-ordinate of the jet from the vena contracta.
5. Measure the flow rate.
6. Repeat the procedure for different combinations of discharge.

Objective

1. To find the value of C_d for the orifice.
2. 3.To plot Q_a vs. H in log-log paper and to find the value of (a) the exponent of H an (b) C_d.
3. To find C_v for the orifice.
4. To find the head loss, H_L.
5. To plot V_a vs. H in log-log paper and to find (a) C_v and (b) the exponent of H.

Practice Questions

1. What are the coefficient of velocity, coefficient of contraction and coefficient of discharge for an orifice? On what factors do these coefficients depend? What are average values of these coefficients for a sharp-crested orifice?
2. What is a submerged orifice? What are the average values of the coefficient of velocity, coefficient of contraction and coefficient of' discharge for a submerged orifice?
3. Why is the actual discharge through an orifice less than the theoretical discharge?
4. Define vena contracta. Why does it form?
5. Will the value of C_v be different for sharp-edged and rounded orifices? Why?

Experiment No. 6

FLOW THROUGH AN ORIFICE

Observation and Calculation Sheet

Course no.: **Student ID no.:**

Group no.: **Date:**

Cross-sectional area of the measuring tank= ____________________

Diameter of the orifice, D = ____________________

Area of the orifice= ____________________

Head correction, h= ____________________

No of obs	Observed Head			Point gage reading			Collection time T	Vol. of Water V	Actual Head H=h-h'	Actual discharge Q_a	Theoretical Discharge Q_t	Coeff. of discharge C_d
	Initial	Find	Mean	Initial	Final	Diff						

No Of Obs.	Horizontal Coordinate x	vertical Coordinate y	Actual velocity V_a	Coeff. of velocity C_v	Head loss H_L

No of observation					
Actual discharge, Q_a					
Theoretical Discharge Q_t					
Actual Velocity V_a					
Theoretical velocity V_t					
Actual head H					

Practice Questions

1. Explain why the discharge through an orifice is increased by fitting a standard short tube to it?
2. What will happen to the coefficient of discharge if the tube is shorter than the standard length or the head causing the flow is relatively high?
3. What is the effect of rounding the entrance of the mouthpiece?
4. What is a submerged tube? Does the coefficient of the tube change due to submergence?

Experiment No. 4
FLOW OVER A V-NOTCH

General

The most common types of sharp-crested weir are the rectangular weir and the triangular weirs. The triangular or V-notch weir is preferable to the rectangular weir for the measurement of widely variable flows. In the case of a rectangular weir, the total weighted perimeter does not vary directly with the head, as the length of the base is the same for all heads. Therefore, the coefficient of contraction, which depends on the wetted perimeter, is not constant for all heads. But in case of a V-notch there is no base to cause contraction which will be due to the sides only. The coefficient of contraction will therefore, be a constant for all heads. For this reason, the V-Notch is the most satisfactory type for flow measurement in canals.

Practical application

The V-notch weir is preferred when small discharges are involved, because the triangular cross-section of the flow 'nappe' leads to a relatively greater variation in head. V-notch Weir has the advantage that it can function for a very small flows and also measure reasonably larger flows as well.

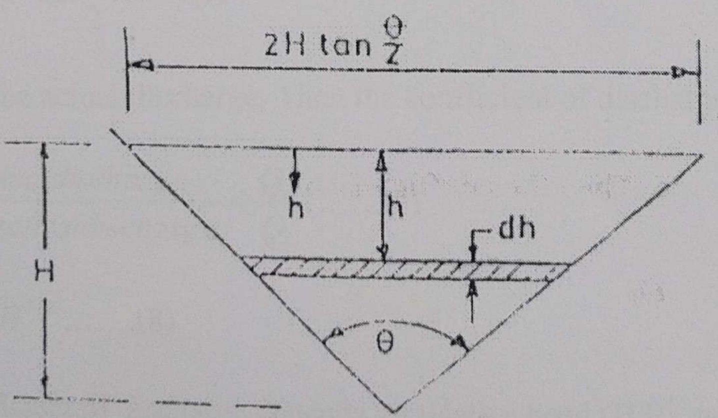


Fig. 1 Flow over a V-Notch

Theory

Consider the V-notch shown in the figure. Let H be the height of water surface and θ be the angle of notch. Then width of the notch at the water surface.

$$L = 2H \tan\frac{\theta}{2} \quad ....(1)$$

Consider a horizontal strip of the notch of thickness dh under a head h. Then, width of the strip,

$$W = 2(H - h)\tan\frac{\theta}{2} \quad ....(2)$$

Hence, the theoretical discharge through the strip

dQ_t = area of the strip x velocity =2(H-h) tan $\frac{\theta}{2} dh\sqrt{2gh}$ ....(3)

Integrating between the limits 0 and H and simplifying, the total theoretical discharge over the notch is given by

$$Q_t = \frac{8}{15}\sqrt{2g}\ \tan\frac{\theta}{2} H^{5/2} \quad ....(4)$$

$$= KH^{5/2} \quad ....(5)$$

Where,

$$K = \frac{8}{15}\sqrt{2g}\ \tan\frac{\theta}{2} \quad ....(6)$$

Let Q_a be the actual discharge, Then the confficient of discharge, Cd is given by

$$C_d = \frac{actual discharge}{theoretical discharge} = \frac{Q_a}{Q_t} \quad ....(7)$$

$$Q_a = KC_d H^{5/2} \quad ....(8)$$

The co-efficient of discharge depends on relative head (H/P), relative height (P/B) and angle of the notch (θ)

From hydraulic point of view a weir may be fully contracted at low heads while at increasing head it becomes partially contracted. The flow regime in a weir is said to be partially contracted when the contractions along the sides of the V-notch are not fully developed due to proximity of the walls and bed of approach channel. Whereas a weir which has an approach channel and whose bed and sides of the notch arc sufficiently remote from the edges of the V-notch to allow for a sufficiently great approach velocity component parallel to the weir face so that the contraction is fully developed is a fully contracted weir. In case of a fully contracted weir C_d is fairly constant for a particular angle of notch.

At lower heads, frictional effects reduce coefficients. For the most common angle of notch 90 degree, the discharge coefficient, C_d is about 0.6.

Apparatus

1. A constant steady water supply with a means of varying the flow rate.
2. An approach channel
3. A V-notch weir plate
4. A flow rate measuring facility
5. A point gauge for measuring H.

Procedure

1. Position the weir plate at the end of approach channel, in a vertical plane, with the sharp edge on the upstream side.
2. Admit water to channel until the water discharges over the weir plate.
3. Close the flow control valve and allow water to stop flowing over weir.
4. Set the point gauge to a datum reading.
5. Position the gauge about half way between the notch plate and stilling baffle.
6. Admit water to the channel and adjust flow control valve to obtain heads, H, increasing in steps of 1 cm.
7. For each flow rate, stabilize conditions, measure and record H.
8. Take readings of volume and time using the volumetric tank to determine the flow rate.

Objective

1. To find C_d for the V-notch.
2. To plot Q_t vs. Q_a in a plain graph paper.
3. To plot Q_a vs. H in a log-log paper and to find (a) the exponent of H and (b) C_d

Practice Questions

1. Why does the V-notch give more accurate flow measurement than any other weirs and orifices when the flow is slightly fluctuating?
2. What is the average value of C_d for a 90° V-notch? Does it depend on flow condition (partially or fully contracted)?
3. Determine the discharge of water over a 60° triangular weir if the measured head is 0.623 ft.

Experiment No. 4

FLOW OVER A V-NOTCH

Observation and Calculation Sheet

Course no.:

Group no.:

Student ID no.:

Date:

Angle of the notch, θ = ____________________

K= ____________________

Cross-sectional area of the measuring tank= ____________________

Initial point gauge reading = ____________________

Final point gauge reading= ____________________

Difference in reading = ____________________

Datum water level reading = ____________________

Water level above vertex= ____________________

Final water level reading= ____________________

No of obs	Vol. of water	Collection time T	Actual discharge Q_a	Effective head H	Theoretical discharge Q_t	Co-eff. of discharge

No of observation					
Actual discharge Q_a					
Effective head H					
Theoretical discharge					

Signature of the Teacher

Head losses in pipes and fittings

Objective

- To find the head losses in pipe, elbow, expansion and contraction in pipe, globe valve and overall system.
- To plot the Head losses vs. Velocity graph and to analyze the losses characteristics in flow.
- To calculate the friction factor of pipe.
- To calculate the minor loss coefficients of elbow, expansion and contraction in pipe, and globe valve.

Theory

Friction loss is the loss of energy or "head" that occurs in pipe flow due to viscous effects generated by the surface of the pipe. Friction Loss is considered as a "major loss" and it is not to be confused with "minor loss", which includes energy lost due to obstructions.

This energy drop is dependent on the wall shear stress between the fluid and pipe surface. The shear stress of a flow is also dependent on whether the flow is turbulent or laminar. For turbulent flow, the pressure drop is dependent on the roughness of the surface. In laminar flow, the roughness effects of the wall are negligible because, in turbulent flow, a thin viscous layer is formed near the pipe surface that causes a loss in energy, while in laminar flow, this viscous layer is non-existent.

One of the accepted methods to calculate friction losses resulting from fluid motion in pipes is by using the Darcy–Weisbach equation. For a circular pipe:

$$h_f = \frac{f\,Lv^2}{2gd}$$

Where:

h_f = Head loss due to friction, given in units of length

f = Darcy friction factor

L = Pipe length

d = Pipe diameter

v = Flow velocity

g = Gravitational acceleration

The minor losses of energy are those which are caused on account of the change in velocity of flowing fluid. In case of long pipes these losses are usually quite small as compared with the loss of energy due to friction and hence these are termed 'minor losses' which may even be neglected without serious error. However, in short pipes, these losses may sometimes outweigh the friction loss. Some of the losses of energy which may be caused due to the change of velocity are indicated below:

(a) Loss of energy in bends and various pipe fittings

(b) Loss of energy due to sudden expansion and contraction

(c) Loss of energy due to gradual expansion and contraction

(d) Loss of energy at the entrance and exit of pipe

With pipe bends, valves etc., it is usually to account for head losses through these devices, in addition to the losses sustained by the pipes. This must almost always be done by resorting to experimental results. Such minor loss is given in the form

$$h_l = K\frac{v^2}{2g}$$

Where,

h_l = Minor loss

K = Minor loss coefficient

v = Flow velocity

g = Gravitational acceleration

As there are two different velocities in expansion and contraction, the largest velocity of the smaller diameter pipe is considered to calculate minor losses.

Setup components

Piping arrangement with the wall-

i. GI pipes
ii. Pressure gauges
iii. Water meter
iv. Ball valve
v. Globe valve
vi. Pipe fittings
vii. Couplers
viii. Flexible pipes

Manometer-

i. Coupler
ii. Acrylic tube
iii. Mercury
iv. Flexible rubber tube
v. Ring clips
vi. Measuring scale
vii. Hardboard

Working procedures

1. Water meter is connected in the path of flow to evaluate the volumetric flow-rate.
2. Calculating the time period of certain flow by stopwatch the volumetric flow-rate can be measured.
3. Thus from the known diameter of the pipes, the velocity of the flow can be computed.
4. Female ports of the couplers are connected with the male ports at certain points covering 1.94m of the pipe, elbow, globe valve, and expansion and contraction sockets; in order to find the pressure difference of those points in mercury column in manometer.
5. Pressure losses are converted to SI unit by essential calculations and are further assigned to calculate the friction factor of pipe and minor loss coefficients of the fittings, valves, and expansion and contraction in pipe.

Experimental Data

Specifications:

Pipe length, L = 1.94m

Thin pipe dia. = ¾ inch = 0.01905m; Thick pipe dia. = 1½ inch

Cross-sectional area of smaller pipe, $A = \frac{1}{4}\pi d^2 = \frac{1}{4} \times 3.1416 \times (0.01905)^2 = 2.85 \times 10^{-4}\ m^2$

Density of Mercury, $\rho_{hg} = 13550\ kg/m^3$; Specific weight of Water, $\gamma_w = 9810$

Table: Flow Rate, Velocity and Losses in Pipes and Fittings

No. of Observations	Flow rate, Q (m^3/s)	Velocity, v = Q/A (m/s)	Head loss, h_{hg} (mm mercury column)					
			Loss in pipe	Loss in elbow	Loss for expansion	Loss for contraction	Loss in globe valve	Overall loss
1								
2								
3								
4								
5								

Calculation Data

Table: Friction Factor of Pipe and Minor Loss Coefficients of Fittings

No. of obs.	Pipe friction factor F	Elbow loss coefficient, K	Expansion loss coefficient, K	Contraction loss coefficient, K	Globe valve loss coefficient, K	Overall loss from manometer (m of water)
1						
2						
3						
4						
5						
Avg.						

Sample calculation

- Pressure drop due to pipe friction, $p = \gamma_{hg} h_{hg}$

$$= \rho_{hg} g h_{hg}$$

$$=$$

Head loss of water due to friction, $h_f = \frac{p}{\gamma_w}$

$$=$$

$\therefore$ Friction factor, $f = \frac{2gdh_f}{Lv^2}$

$$=$$

- Pressure drop in elbow, $p = \gamma_{hg} h_{hg}$

$$=$$

Head loss of water, $h_l = \frac{p}{\gamma_w}$

$$=$$

$\therefore$ Elbow loss coefficient, $K = \frac{2gh_l}{v^2}$

$$=$$

- Pressure drop for expansion, $p = \gamma_{hg} h_{hg}$

$$=$$

Head loss of water, $h_l = \frac{p}{\gamma_w}$

$$=$$

$\therefore$ Expansion loss coefficient, $K = \frac{2gh_l}{v^2}$

=

- Pressure drop for contraction, $p = \gamma_{hg} h_{hg}$

=

Head loss of water, $h_l = \frac{p}{\gamma_w}$

=

$\therefore$ Contraction loss coefficient, $K = \frac{2gh_l}{v^2}$

=

- Pressure drop in globe valve, $p = \gamma_{hg} h_{hg}$

=

Head loss of water, $h_l = \frac{p}{\gamma_w}$

=

$\therefore$ Globe valve loss coefficient, $K = \frac{2gh_l}{v^2}$

=

- Overall Pressure drop, $p = \gamma_{hg} h_{hg}$

=

$\therefore$ Overall head loss of water, $h_l = \frac{p}{\gamma_w}$

=

Experiment Name:Study of A Centrifugal Pump and Pump Characteristics.

Theory:

A centrifugal pump is a machine which converts mechanical energy into kinetic and pressure energy through centrifugal force.

A centrifugal pump consists of two main parts:

- A rotating element, including an impeller and a shaft.
- A stationary element made up of a casing, stuffing box and bearings.

The shaft of the pump is driven by power from an external source by which means the impeller along with the vanes inside is rotated. The fluid receives energy from the vanes during flow through the rotating impeller resulting in an increase in both velocity and pressure. Fluid flows from the suction pipe due to the formation of partial vacuum in the center of impeller. A large part of the total energy of the fluid leaving the impeller is kinetic energy. It is necessary to reduce the absolute velocity and transform the large portion of the velocity head into pressure head. In overcoming the delivery head of the pump the high pressure head of the leaving fluid is utilized.

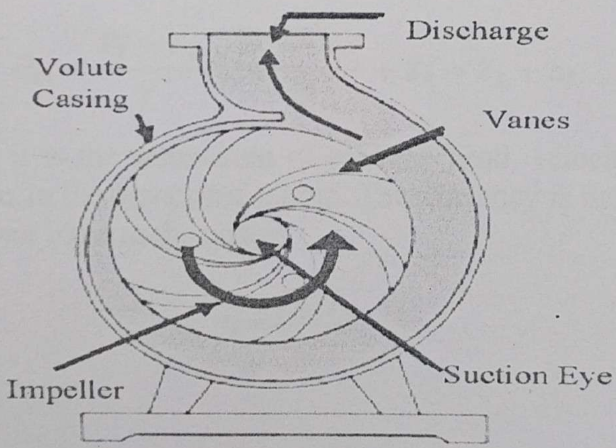


Figure 1: Liquid flow paths of a centrifugal pump

The actual head rise (H) produced by acentrifugal pump is a function of the flow rate (Q). It is possible to determine the head-flow relationship by appropriate selection of the geometry of the impeller blades. Normally, pumps are designed so that the head decreases with increasing flow since such a design results in a stable flow rate when the pump is connected to a piping system. A typical head flow curve for a pump is shown in Figure 2.

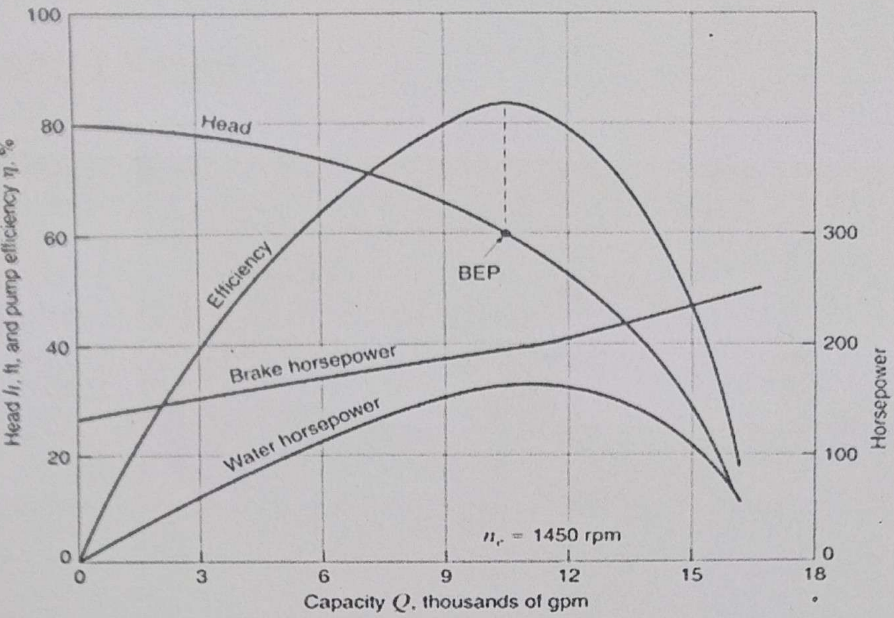


Figure 2: Characteristics curve of Centrifugal Pump.

If the mechanical energy equation is applied, section 1 is located as the pump inlet and section 2 asthe pump outletbetween two points in a piping system onopposite sides of the pump, then

$$\frac{P_1}{\gamma}+\frac{{V_1}^2}{2g}+Z_1+H_m=\frac{P_2}{\gamma}+\frac{{V_2}^2}{2g}+Z_2+h_f$$

$$H_m=\frac{P_2-P_1}{\gamma}+\frac{{V_2}^2-{V_1}^2}{2g}+Z_2-Z_1+h_f$$

H_m is the pump head and it is the summation of pressure head, velocity head, elevation head and h_f is the total head loss in the associated piping. Theefficiency is defined as the ratio of the fluid work to the shaft power input to the pump:

$$\eta=\frac{\gamma Q H_m}{P}$$

Experimental Setup

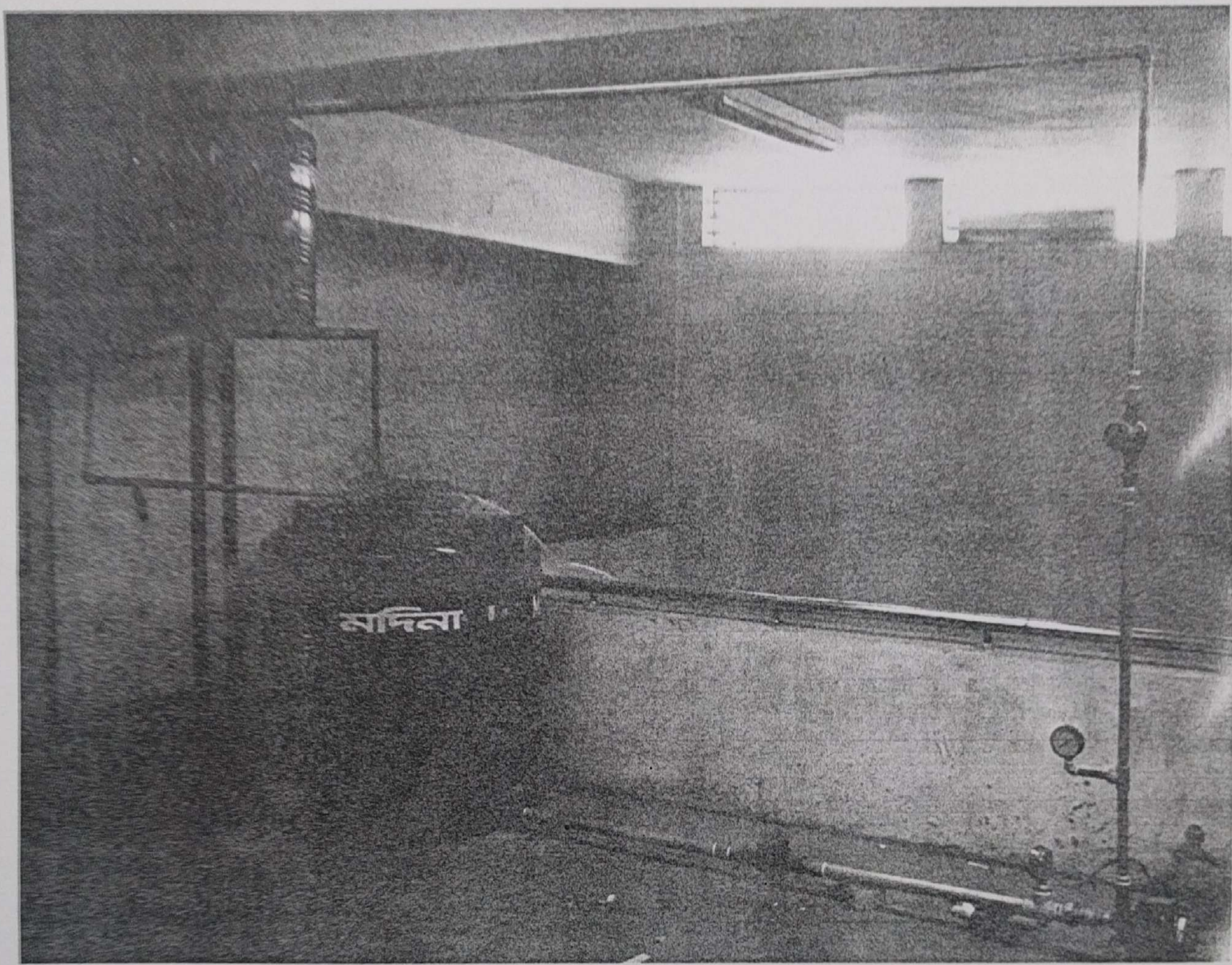


Figure 3: Centrifugal Pump Test Rig

Objective:

The objective of this experiment is to

- ✓ To do the performance test of different centrifugal pumps by varying their flow rates.
- ✓ To check the performance of centrifugal pump with different head and rpm.
- ✓ To plot the characteristics curve for different centrifugal pumps.

Apparatus:

Stopwatch, Wattmeter, Tachometer, Measuring Tape

Experimental Procedure

- ➢ Set up the centrifugal pump to the test rig.
- ➢ Wire connection to the pump.
- ➢ Measure power, voltage and current with Wattmeter.
- ➢ Measure RPM of the pump with non-contact Tachometer.
- ➢ Do this for all the pumps 0.5hp, 1hp, 1.5hp, 2hp & 3hp respectively.
- ➢ Open the gate valve at suction side of sump tank.
- ➢ Open the gate valve at delivery side of measuring tank.
- ➢ Turn on the pump.
- ➢ Take the value of flow rate at suction side and delivery side with flow meter and stopwatch.
- ➢ Take the value of pressure with pressure gauge at both sides.
- ➢ Reduce the flow of the water by controlling gate valve at delivery side step by step. Keep the flow rate of water at suction side constant.
- ➢ Now reduce the flow of the water by controlling gate valve at suction side step by step. Keep the flow rate of water at delivery side constant.
- ➢ Record all the values.
- ➢ Calculate friction in the delivery and suction side.
- ➢ Calculate the velocity head and total head.
- ➢ Calculate the pump efficiency.

Data Table:

Pipe Diameter (Suction) = 1.5 inch

Pipe Diameter (Delivery) = 1 inch

Pipe Length (Suction) = 96 inch

Pipe Length (Delivery) = 273 inch

Elevation Head, H = 2.7432 m

Height of Base = 72 cm

Width of Base = 38 cm

Pump Speed, N [r.p.m]	No Of Ob s	Inlet Pressure, P_{in} [KPa]	Outlet Pressure, P_{out} [KPa]	Flow Rate, Q [m^3/s]	Inlet Velocit y, V_{in} [m/s]	Outlet Velocit y, V_{out} [m/s]	friction in Suction H_s [m]	friction in Delivery H_v [m]	Elevatio n Head,H [m]	Pressure Head [m]	Velocit y Head [m]	Total Head, H_t [m]	Output Power [w]	Hyd rauli c Pow er [w]	Pump Efficiency [%]

Calculation:

Flow rate, Q = AV

Reynolds Number, $Re = \frac{\rho V D}{\mu}$

Friction, $H_f = \frac{flV^2}{2gd}$

Total Head,

$$H_m = \frac{P_2 - P_1}{\gamma} + \frac{{V_2}^2 - {V_1}^2}{2g} + Z_2 - Z_1 + H_f$$

Efficiency, $\eta = \frac{\gamma Q H_m}{P}$