LABORATORY MANUAL

Fluid Mechanics - I

(ME181413)

Department of Mechanical Engineering

Jorhat Engineering College
Jorhat – 785007 (Assam)

COLLEGE VISION AND MISSION

Vision:

To develop human resources for sustainable industrial and societal growth through excellence in technical education and research.

Mission:

1. To impart quality technical education at UG, PG and PhD levels through good academic support facilities.

2. To provide an environment conducive to innovation and creativity, group work and entrepreneurial leadership.

3. To develop a system for effective interactions among industries, academia, alumni and other stakeholders.

4. To provide a platform for need-based research with special focus on regional development.

DEPARTMENT VISION AND MISSION

Vision:

To emerge as a centre of excellence in mechanical engineering and maintain it through continuous effective teaching-learning process and need-based research.

Mission:

M1: To adopt effective teaching-learning processes to build students capacity and enhance their skills.

M2: To nurture the students to adapt to the changing needs in academic and industrial aspirations.

M3: To develop professionals to meet industrial and societal challenges.

M4: To motivate students for entrepreneurial ventures for nation-building.

Program Outcomes (POs)

Engineering graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Programme Educational Objectives (PEOs)

The Programme Educational Objectives of Department of Mechanical Engineering are given below:

PEO1: Gain basic domain knowledge, expertise and self-confidence for employment, advanced studies, R&D, entrepreneurial ventures activities, and facing challenges in professional life.

PEO2: Develop, improve and maintain effective domain based systems, tools and techniques that socioeconomically feasible and acceptable and transfer those technologies/developments for improving quality of life.

PEO3: Demonstrate professionalism through effective communication skill, ethical and societal commitment, team spirit, leadership quality and get involved in life-long learning to realize career and organisational goal and participate in nation building.

Program Specific Outcomes (PSOs)

The programme specific outcomes of Department of Mechanical Engineering are given below:

PSO1: Capable to establish a career in Mechanical and interdisciplinary areas with the commitment to the society and the nation.

PSO2: Graduates will be armed with engineering principles, analysing tools and techniques and creative ideas to analyse, interpret and improve mechanical engineering systems.

Course Outcomes (COs)

At the end of the course, the student will be able to:

CO215.1	Measure the dynamic and kinematic viscosity of liquids.
CO215.2	Determine the friction factor both for Laminar Flow and Turbulent Flow.
CO215.3	Determine the coefficient of discharge of Venturimeter and Orificemeter.
CO215.4	Verify the Bernoulli's Theorem.
CO215.5	Identify the type of Flow through Reynolds Number.

Mapping of COs with POs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO215.1	2	1	-	-	-	-	-	1		1	-	1	-	1
CO215.2	2	1	-	-	-	-	-	1		1	-	1	-	1
CO215.3	2	1	-	-	-	-	-	1		1	-	1	-	1
CO215.4	2	1	-	-	-	-	-	1		1	-	1	-	1
CO215.5	2	1	-	-	-	-	-	1		1	-	1	-	1
C215	**2.00**	**1.00**	-	-	-	-	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**

STUDENT PROFILE	
NAME :	
ROLL NUMBER :	
SECTION :	
SEMESTER :	4th Semester
YEAR :	

PERFORMANCE RECORD		
EXP. NO.	**TITLE OF EXPERIMENT**	**REMARKS / GRADE**
1	Measurement of kinematic and dynamic viscosity of oil.	
2	Bernoulli's Apparatus.	
3	Minor losses in pipe fittings.	
4	Reynolds Apparatus.	
5	Flow through Venturimeter and Orificemeter.	

OFFICE USE	
Checked By :	
Overall Grade / Marks :	
Signature of Teacher :	

Experiment No. 1

TITLE:Measurement of Kinematic and Dynamic Viscosity of Oil.

OBJECTIVE:

To measure the dynamic and kinematic viscosity of mineral oil, liquid fuel and other similar liquids using Redwood Viscometer.

APPARATUS:

REDWOOD VISCOMETER 1 ---- Bore Diameter = 1.62 mm, Length = 10 mm

REDWOOD VISCOMETER 2 ---- Bore Diameter = 3.80 mm, Length = 15 mm

THEORY:

Viscosity is the property of a liquid or fluid by virtue of which it offers resistance to its own flow. A liquid in a state of steady flow on a surface may be supposed to consist of a series of parallel layers moving one above the other. Any two layers will move with different velocities: top layer moves faster than the next lower layer due to viscous drag

The kinematic viscosity in centistokes is calculated by using the equation:

$$\boldsymbol{v = Ct - B/t}$$

Where $\boldsymbol{t}$ is time in Redwood sec of flow and B & C are constant of viscometer.

Value of t	**Value of B**	**Value of C**	For 50 ml of oil
34 — 100 sec	1.78	0.00260	
Above 100 sec	0.50	0.00247	

PROCEDURE:

1. The level oil cup is cleaned and ball of valve rod is placed on the jet to close it.

2. Oil under test free from any suspension etc. is filled in the cup up to the pointer levels,

3. An empty Kohlrausch Flask is kept just below the jet.
4. Water is filled in the bath and side tube is heated slowly with constant stirring of the bath. When the oil is at the desired temperature the ball valve is lifted and suspended from the thermometer bracket.
5. The time taken for 50 ml of oil to collect in the flask is noted and then valve is closed.

OBSERVATION:

Redwood Viscometer 1 **Fluid used =**

Sl. No.	Temp (^{o}C)	Time (Redwood No. 1) sec	Kinematic Viscosity (v) in (centistokes)	Dynamic Viscosity (μ) in (centipoise)
1				
2				
3				

Redwood Viscometer 2 **Fluid used =**

Sl. No.	Temp (^{o}C)	Time (Redwood No. 2) sec	Kinematic Viscosity (v) in (centistokes)	Dynamic Viscosity (μ) in (centipoise)
1				
2				
3				

Exp. No. 1	**Title:** Measurement of Kinematic and Dynamic Viscosity of Oil
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher with Date of Check **SEAL**

Experiment No. 2

TITLE: Bernoulli's Apparatus

OBJECTIVE:

To verify the Bernoulli Theorem.

INTRODUCTION:

The flow of a fluid has to conform with a number of scientific principles in particular the conservation of mass and the conservation of energy. The first of these when applied to a liquid flowing through a conduit requires that for steady flow the velocity will be inversely proportional to the flow area. The second requires that if the velocity increases then the pressure must decrease.

Bernoulli's Apparatus demonstrates both of these principles and can also be used to examine the onset of turbulence in an accelerating fluid stream.

Both Bernoulli's equation and the Continuity equation are essential analytical tools required for the analysis of most problems in the subject of Mechanics of Fluids.

DESCRIPTION OF APPARATUS:

Bernoulli's Apparatus consists essentially of a two dimensional rectangular section convergent divergent duct designed to fit between Head Inlet Tank Variable Head Outlet Tank. An eleven tube static pressure manometer bank is attached to the convergent divergent duct. The differential head across the test section can be varied from zero up to a maximum of 250mm. The test section, which is manufactured from acrylic sheet, is illustrated in figure 1 below.

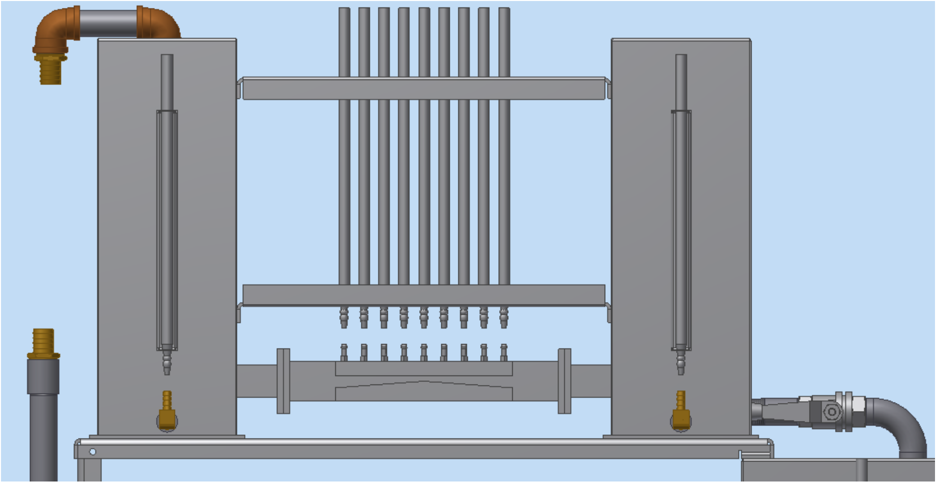
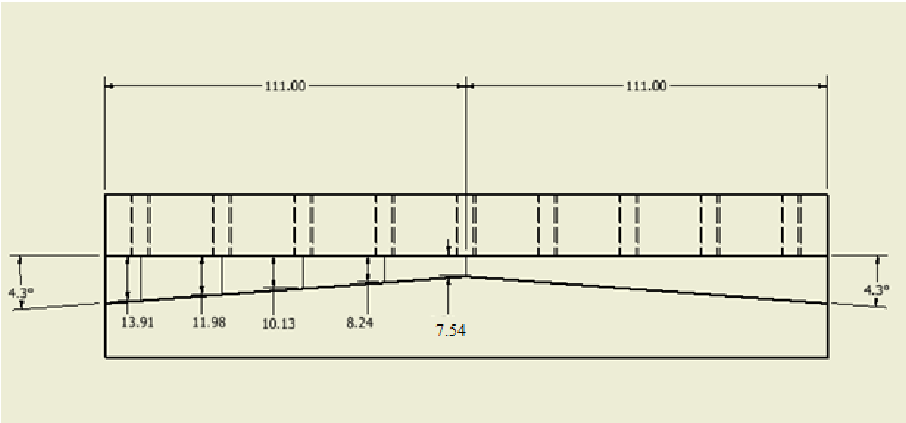
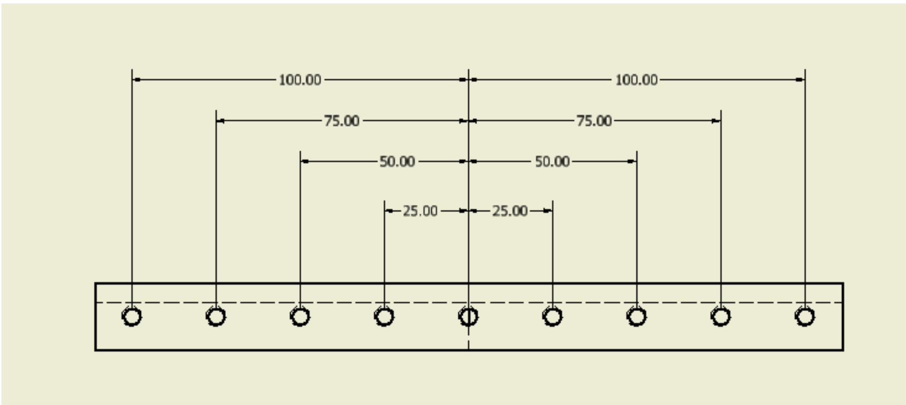


Figure 2.1: Bernoulli's Apparatus

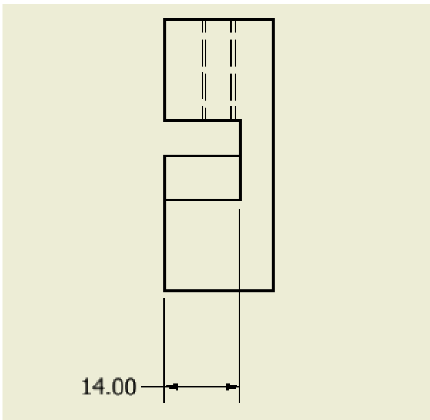
The convergent divergent duct is symmetrical about the centre line with a flat horizontal upper surface into which the nine static pressure tapings are drilled. The lower surface is at an angle of 4º 29'. The width of the channel is 6·35 mm. The height of the channel at entry and exit is 14.76 mm and the height at the throat is 6·34 mm. The static tapings are at a pitch of 25 mm distributed about the centre and therefore about the throat. The flow area at each tapping is tabulated below the dimensions which are shown in figure 2.



Front View (all dimensions in mm)



Top View (all dimensions in mm)



Side View (all dimensions in mm)

Figure 2.2

Tapping Number	1	2	3	4	5	6	7	8	9
Flow Area in mm^2	194.74	167.72	141.82	115.36	88.76	115.36	141.82	167.72	194.74

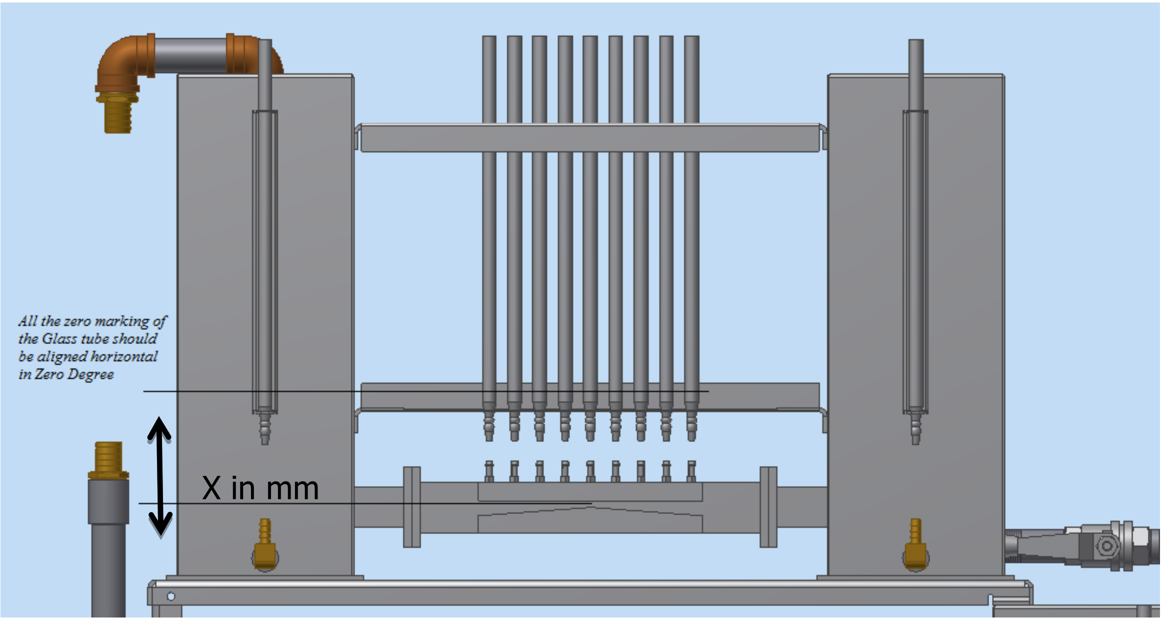


Figure 2.3

Please note: Measure the distance between the centre section to the zero marking of the Glass Tube and add the value to the relevant head reading (Example if H_1 is 100 mm and x is 50 mm, total H_1 is 100+50 = 150 mm)

THEORY:

The Bernoulli theorem is an approximate relation between pressure, velocity, and elevation, and is valid in regions of steady, incompressible flow where net frictional forces are negligible. The equation is obtained when the Euler's equation is integrated along the streamline for a constant density (incompressible) fluid. The constant of integration (called the Bernoulli's constant) varies from one streamline to another but remains constant along a streamline in steady, frictionless, incompressible flow. Despite its simplicity, it has been proven to be a very powerful tool for fluid mechanics.

Bernoulli's equation states that the "sum of the kinetic energy (velocity head), the pressure energy (static head) and Potential energy (elevation head) per unit weight of the fluid at any point remains constant" provided the flow is steady, irrotational, and frictionless and the fluid used is incompressible. This is however, on the assumption that energy is neither added to nor taken away by some external agency. The key approximation in the derivation of Bernoulli's equation is that viscous effects are negligibly small compared to inertial, gravitational, and pressure effects. We can write the theorem as

$$\boldsymbol{Pressure\ head\ (P)\ +\ Velocity\ head\ (V)\ +\ Elevation\ (Z)\ =\ constant}$$

Where,

P =the pressure. (N/m^2)

ρ =density of the fluid, kg/m^3

V =velocity of flow, (m/s)

g =acceleration due to gravity, rn/s^2

Z =elevation from datum line, (m)

Pressure head increases with decrease in velocity head.

$$\frac{P_1}{w}+\frac{{V_1}^2}{2g}+Z_1=\frac{P_2}{w}+\frac{{V_2}^2}{2g}+Z_2=constant$$

Where,

P/w =is the pressure head

$V/2g$ =is the velocity head

Z =is the potential head

The Bernoulli's equation forms the basis for solving a wide variety of fluid flow problems such as jets issuing from an orifice, jet trajectory, flow under a gate and over a weir, flow metering by obstruction meters, flow around submerged objects, flows associated with pumps and turbines etc.

The Bernoulli's equation forms the basis for solving a wide variety of fluid flow problems such as jets issuing from an orifice, jet trajectory, flow under a gate and over a weir, flow metering by obstruction meters, flow around submerged objects, flows associated with pumps and turbines etc.

The equipment is designed as a self-sufficient unit it has a sump tank, measuring tank and a pump for water circulation as shown in figure1. The apparatus consists of a supply tank, which is connected to flow channel. The channel gradually contracts for a length and then gradually enlarges for the remaining length.

In this equipment the **Z** is constant and is not taken for calculation.

PROCEDURE:

1. Keep the bypass valve open and start the pump and slowly start closing valve.

2. The water shall start flowing through the flow channel. The level in the Piezometer tubes shall start rising.

3. Open the valve on the delivery tank side and adjust the head in the Piezometer tubes to steady position.

4. Measure the heads at all the points and also discharge with help of stop watch and measuring tank.

5. Varying the discharge and repeat the procedure.

OBSERVATIONS:

Distance between each piezometer = 2.5 cm

Density of water = 1000 kg/m^3

1. Note down the SI. No's of Pitot tubes and their cross sectional areas.

2. Height difference in given time, Df = ………… m

3. Time taken for collection of water, t = ………… sec

FORMULAE:

(a) Discharge

$$Q = \frac{(AT * Df)}{t}$$

(b) Bernoulli's Equation

$$V_{ib} = \sqrt{2 * g * (H - H_i)}$$

(c) Continuity Equation

$$V_{ic} = \frac{Q}{A_i}$$

(d) Velocity Head

$$V_H = \frac{{V_{ic}}^2}{(2 * g)}$$

ABBREVIATION AND SYMBOLS USED:

Sl. No.	Description	Symbol	Value	Unit
1	Density of Water	ρ	0.001	kg/cm3
2	Width of Collecting Tank	W	38	cm
3	Length of Collecting Tank	LC	38	cm
4	Area of Collecting Tank	AT	1444	cm^2
5	Width of the test section	we	1.4	cm
6	Area Flow Point (Al)	Al	1.9474	cm^2
7	Area Flow Point (A2)	A2	1.6772	cm^2
8	Area Flow Point (A3)	A3	1.4182	cm^2
9	Area Flow Point (A4)	A4	1.1536	cm^2
10	Area Flow Point (A5)	AS	1.0556	cm^2
11	Area Flow Point (A6)	A6	1.1536	cm^2
12	Area Flow Point (A7)	A7	1.4182	cm^2
13	Area Flow Point (A8)	A8	1.6772	cm^2
14	Area Flow Point (A9)	A9	1.9474	cm^2
15	Distance between the centre section to the zero marking of the Glass Tube	x	0	cm

SAMPLE OBSERVATIONS:

Sl. No.	Initial Reading of Collection Tank (cm)	Final Reading of Collection Tank (cm)	Difference in Reading (D*f*) in cm	Time Taken (t) in sec	Head Intake Tank in cm
1	11	21	10	100	24

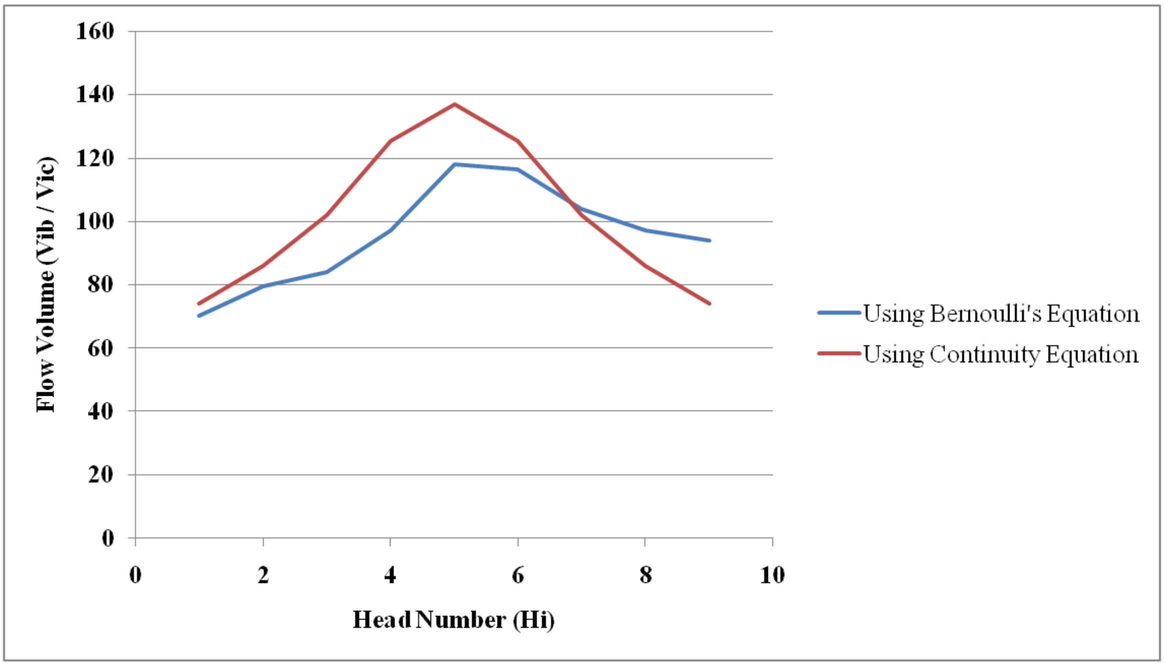
Sl. No.	H1 in cm	H2 in cm	H3 in cm	H4 in cm	H5 in cm	H6 in cm	H7 in cm	H8 in cm	H9 in cm
1	21.5	20.8	20.4	19.2	16.9	17.1	18.5	19.2	19.5

SAMPLE RESULTS:

Sl. No.	Cross Section Area of Flow (A_i) in cm^2	Using Continuity equation $V_{ic} = \frac{Q}{A_i}$	Head at H_i in cm	Pressure Head $(H_i + x)$ in cm	Velocity Head $(V^2/2g)$ in cm/sec	Total Head (Pressure head + Velocity Head) in cm	Discharge (Q) in cm^3/sec
1	1.95	74.15	21.50	21.5	2.8	24.3	144.4
2	1.68	86.1	20.8	20.8	3.78	24.58	
3	1.42	101.82	20.4	20.4	5.28	25.68	
4	1.15	125.17	19.2	19.2	7.99	27.19	
5	1.06	136.79	16.9	16.9	9.54	26.44	
6	1.15	125.17	17.1	17.1	7.99	25.09	
7	1.42	101.82	18.5	18.5	5.28	23.78	
8	1.68	86.1	19.2	19.2	3.78	22.98	
9	1.95	74.15	19.5	19.5	2.8	22.3	

Sl. No.	Head Intake Tank (H) in cm	Head at(H_i)in cm	Cross Sectional Area of Flow (A_i) in cm	Using Bernoulli's Equation (V_{ib}) in cm^3	Using Continuity equation $V_{ic} = Q/A_i$ in cm^3	Discharge (Q) in cm^3/sec
1	24	21.5	1.95	70.04	74.15	144.4
2	24	20.8	1.68	79.24	86.1	
3	24	20.4	1.42	84.04	101.82	
4	24	19.2	1.15	97.04	125.17	
5	24	16.9	1.06	118.03	136.79	
6	24	17.1	1.15	116.35	125.17	
7	24	18.5	1.42	103.88	101.82	
8	24	19.2	1.68	97.04	86.1	
9	24	19.5	1.95	93.96	74.15	

SAMPLE GRAPH:



OBSERVATIONS:

Sl. No.	Initial Reading of Collection Tank (cm)	Final Reading of Collection Tank (cm)	Difference in Reading (Df) in cm	Time Taken (t) in sec	Head Intake Tank in cm
1					

Sl. No.	H1 in cm	H2 in cm	H3 in cm	H4 in cm	H5 in cm	H6 in cm	H7 in cm	H8 in cm	H9 in cm
1									

CALCULATION:

Sl. No.	Cross Section Area of Flow (A_i) in cm^2	Using Continuity equation $V_{ic} = \frac{Q}{A_i}$	Head at H_i in cm	Pressure Head $(H_i + x)$ in cm	Velocity Head $(V^2/2g)$ in cm/sec	Total Head (Pressure head + Velocity Head) in cm	Discharge (Q) in cm^3/sec
1							
2							
3							
4							
5							
6							
7							
8							
9							

Sl. No.	Head Intake Tank (H) in cm	Head at(H_i)in cm	Cross Sectional Area of Flow (A_i) in cm	Using Bernoulli's Equation (V_{ib}) in cm^3	Using Continuity equation $V_{ic} = Q/A_i$ in cm^3	Discharge (Q) in cm^3/sec
1						
2						
3						
4						
5						
6						
7						
8						
9						

Graph: Comparison between the velocities obtained by continuity equation and Bernoulli's equation

Exp. No. 2	**Title:** Bernoulli's Apparatus
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher with Date of Check

SEAL

Experiment No. 3

TITLE: Minor losses in pipe fittings

OBJECTIVE:

To determine the loss of head in the pipe fitting at various water flow rates.

REQUIREMENTS:

Pipe flow test rig, power supply (single phase, 240 volts, 50 Hz), water supply drain.

One of the most common problems in fluid mechanics is the estimation of pressure loss. Calculating pressure losses is necessary for determining the appropriate size pump. Knowledge of the magnitude of frictional losses is of great importance because it determines the power requirements of the pump forcing the fluid through the pipe. For example, in refining and petrochemical industries, these losses have to be calculated accurately to determine where booster pumps have to be placed when pumping crude oil or other fluids in pipes to distances thousands of kilometers away.

Pipe losses in a piping system result from a number of system characteristics, which include among others; pipe friction, changes in direction of flow, obstructions in flow path, and sudden or gradual changes in the cross-section and shape of flow path.

Whenever the velocity of a fluid is changed, either in direction or magnitude, by a change in the direction or size of the conduit, friction additional to the skin friction from flow through the straight pipe is generated. Such friction includes form friction resulting from vortices which develop when the normal streamlines are disturbed and when boundary-layer separation occurs. The form friction is due to the obstructions present in the line of flow, it may be due to a bend or a control valve or anything which changes the course of motion of the flowing fluid.

Fittings and valves also disturb the normal flow lines and cause friction. In short lines with many fittings, the friction loss from the fittings may be greater than that from the straight pipe.

As in straight pipe, velocity increases through valves and fittings at the expense of head loss. This can be expressed by equation similar to Equation1:

$$h_{fe} = K_e \frac{v^2}{2g} \quad \dots\dots\dots \quad Eq.(1)$$

Where V is the average velocity of the pipe leading to fitting

$K_e$is called the resistance coefficient and is defined as the number of velocity heads lost due to the valve or fitting. It is a measure of the following pressure losses in a valve or fitting:

- Pipefrictionintheinletandoutletstraightportionsofthevalveorfitting
- Changes in direction of flow path
- Obstructions in the flow path

Sudden or gradual changes in the cross-section and shape of the flow path

Pipe friction in the inlet and outlet straight portions of the valve or fitting is very small when compared to the other three. Since friction factor and Reynolds Number are mainly related to pipe friction, K_e can be considered to be independent of both friction factor and Reynolds Number. Therefore, K_e is treated as a constant for any given valve or fitting under all flow conditions, including laminar flow. Indeed, experiments showed1that for a given valve or fitting type, the tendency is for K_e to vary only with valve or fitting size.

Pressure losses in fittings is usually represented by equivalent length$\left(L_{eq}\right)$. It is the length of a straight pipe that offers same resistance to flow as that offered by the fitting.

The ratio L_{eq}/D is equivalent length in pipe diameters of straight pipe that will cause the same pressure drop or head loss as the valve or fitting under the same flow.

Friction loss from different fittings in a pipeline must be accounted for when calculating friction losses for each section of pipe. Add the equivalent length of pipe for each fitting or valve that occurs in each section of the pipe line.

INTRODUCTION:

Basic equations of fluid dynamics are

1. Mass Balance Equation (continuity)

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2 \xrightarrow{for\ constant\ \rho} A_1 v_1 = A_2 v_2$$

2. Energy Balance Equation (Bernoulli)

$$\frac{P_1}{\rho} + \frac{{v_1}^2}{2\alpha} + gz_1 = \frac{P_2}{\rho} + \frac{{v_2}^2}{2\alpha} + gz_2 \ , \qquad J/kg$$

3. Momentum Transfer Balance (2nd law of mechanics by Newton)

$$Rate\ of\ change\ of\ momentum\ of\ the\ system\ = \sum forces\ of\ the\ system$$

$$\frac{d(mv)}{dt} = \sum Forces$$

In our course we are concerned with the first two equations. The Bernoulli's equation is modified to include other terms:

$$\frac{P_1}{\rho} + \frac{{v_1}^2}{2\alpha} + gz_1 + W_P = \frac{P_2}{\rho} + \frac{{v_2}^2}{2\alpha} + gz_2 + \sum F \quad , \qquad J/kg$$

$\sum F$is the total frictional losses in the mechanical energy balance equation.

It consists of

Major Losses

$$h_f = \frac{4fLv^2}{2gD}$$

Minor Losses

1. Sudden expansion
2. Sudden contraction
3. Fittings and Valves

WHAT ARE THE MINOR LOSSES?

- Those losses occur in pipelines due to bends, elbows, joints, valves, etc.
- Minor losses are neglected for L/D > 1000
- Minor losses are not neglected for L/D <1000

Note: In many situations Minor losses are more important than the losses due topipe friction, but it is conventional name.

TYPES OF MINOR LOSSES:

1. Sudden Expansion Losses

For sudden change additional losses are formed due to eddies in the expanding jet in the enlarged section. Refer Fig. 3.1.

$$h_{ex} = \frac{(v_1 - v_2)^2}{2\alpha g} = \left(1 - \frac{A_1}{A_2}\right)^2 \frac{{v_1}^2}{2\alpha g}$$

$$h_{ex} = K_{ex} \frac{{v_1}^2}{2\alpha g}\ , m \qquad or \qquad h_{ex} = K_{ex} \frac{{v_1}^2}{2\alpha}\ , J/kg$$

$\alpha$is a correction factor for kinetic energy term. $\alpha = 1$for turbulent flow, and $\alpha = {}^1/_2$ for laminar flow.

For a special case of sudden expansion from pipe to tank → $A_1 \sim 0$ w.r.t.A_2

or$A_1 \ll A_2 \rightarrow h_{ex} = {v_1}^2/2\alpha g$; $K_{ex} = 1$

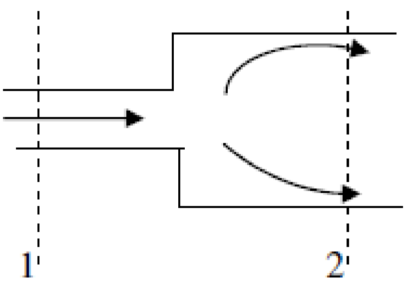


Figure 3.1

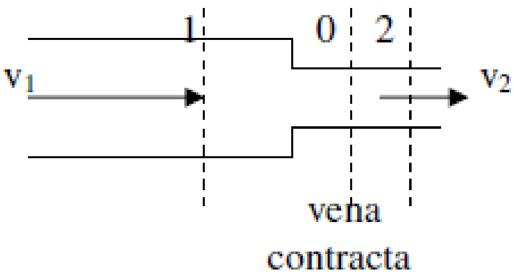


Figure 3.2

2. Sudden Contraction

The process consists of two steps, sudden contraction from A_1 to A_0 then sudden expansion from $A_0$to A_2 . Refer Fig. 3.2.

The step of converting pressure head into velocity is very efficient, i.e., head loss from section 1 to vena-contracta (the section of greatest contraction of the jet) is small compared with the loss from section 0 to section 2 (sudden expansion) i.e., velocity head / pressure head.

$$h_c = 0.55\left(1 - \frac{A_2}{A_1}\right)\frac{{v_2}^2}{2\alpha g} = K_c \frac{{v_2}^2}{2\alpha g}\ , m$$

$$K_c = 0.55\left(1 - \frac{A_2}{A_1}\right)$$

The value 0.55 differs according to D_1/D_2 but as an average value it is taken 0.55.

For the special case of sudden contraction from reservoir to pipe $(A_1 \gg A_2)$.

$$h_c = 0.55 \frac{{v_2}^2}{2\alpha g}$$

3. Losses in Fittings and Valves

Fittings and valves disturb the normal flow line, in a pipe and cause additional friction losses. For a short pipe with many fittings the friction loss from these fittings could be greater than in the straight pipe (friction losses) i.e., minor losses >major losses.

$$h_{fitting} = K_f \frac{{v_1}^2}{2g} \;\; ; \;\; v_1\ is\ the\ velocity\ leading\ to\ the\ fitting$$

Note-1: K_f values in Table 3.1 for turbulent flow and Table 3.2 for laminar flow (Transport Processes & Unit Operations, Geankoplis)

Note-2: The correction factor α in included in K_f , so it is not considered in $h_{fitting}$.

The correction factor α is used in
- Sudden expansion
- Sudden contraction
- Kinetic energy terms

PROCEDURE:

1. The pipe is selected for doing experiments.
2. The motor is switched on; as a result water will flow.
3. Open the Italian ball valves of the respective fitting, which needs to be tested (All other ball valve to be kept in closed condition.
4. According to the flow, the mercury level fluctuates in the U-tube manometer.
5. The reading of H1 and H2 are noted.
6. The time taken for 10 cm rise of water in the collecting tank is noted.
7. The experiment is repeated for various other fittings.

S. No	Description	Symbols	Value	Units
1	Sudden Enlargement Pipe Fitting (Entry internal Diameter)	SD1	28	mm
2	Sudden Enlargement Pipe Fitting (Exit internal Diameter)	SD2	38	mm
3	Sudden Contraction Pipe Fitting Diameter(Entry internal Diameter)	CD1	38	mm
4	Sudden Contraction Pipe Fitting Diameter(Exit internal Diameter)	CD2	28	mm
5	Sudden Enlargement Pipe Fitting (Entry Area)	SA1	0.000615752	m^2
6	Sudden Enlargement Pipe Fitting (Exit Area)	SA2	0.001134115	m^2
7	Sudden Contraction Pipe Fitting Diameter(Entry Area)	CA1	0.001134115	m^2
8	Sudden Contraction Pipe Fitting Diameter(Exit Area)	CA2	0.000615752	m^2
9	internal Diameter of the inlet section Elbow & Long Bend	D	25	mm
10	Area of the inlet section of Elbow & Long Bend	A	0.000490874	m^2
11	Width of Collecting Tank	W	0.378	meter
12	Length of Collecting Tank	LC	0.378	meter
13	Area of Collecting Tank	AT	0.142884	m^2
14	Acceleration due to gravity	g	9.81	m/sec^2

OBSERVATIONS:

Sl. No	Initial Tank Reading in cm	Final Tank Reading in cm	Difference in Tank Reading in Meters (Df)	Time Taken in Sec t	Manometer reading ΔH in mm	Type of Pipe fitting
1						Long Bend
2						Elbow
3						Sudden Enlargement
4						Sudden Contraction

FORMULAE

1. Long Bend & Elbows

$$h_f = \frac{13.6 * \Delta H}{1000} \ \ m$$

$$Q_a = \frac{AT * Df}{t} m^3/sec$$

$$v = \frac{Q_a}{A} m/sec$$

$$K = \frac{h_f}{\left(\frac{v^2}{2*g}\right)}$$

2. Sudden Enlargement

$$v_1 = \frac{Q_a}{SA_1} m/sec$$

$$v_2 = \frac{Q_a}{SA_2} m/sec$$

$$Q_a = \frac{AT * Df}{t} m^3/sec$$

$$h_{ex} = \frac{(v_1 - v_2)^2}{2g} \ \ m$$

3. Sudden Contraction

$$Q_a = \frac{AT * Df}{t} m^3/sec$$

$$v_2 = \frac{Q_a}{CA_2} m/sec$$

$$h_c = 0.55 \frac{{v_2}^2}{2g} \ \ m$$

RESULTS:

Sl. No.	Loss of Head due to Fitting h_f	Actual Discharge Q_a in m^3/sec	Velocity Head v	Loss of coefficient K	Type of Fittings
1					Long Bend
2					Elbow

Sl. No.	Loss of Head due to Fitting h_{ex}	Actual Discharge Q_a in m^3/sec	Velocity at Entry v_1	Velocity at Entry v_2	Type of Fitting
1					Sudden Enlargement

Sl. No	Loss of Head due to Fitting h_c	Actual Discharge Q_a in m^3/sec	Velocity at Entry v_2	Type of Fitting
1				Sudden Contraction

VIVA VOCE:

1. What is theoretical discharge? Give formula
2. What is actual discharge? Give formula
3. What is $\boldsymbol{C_d}$?
4. What is the industrial application of coefficient of discharge?
5. What is the relation between C_v, C_c and C_d?

Exp. No. 3	**Title:** Minor losses in pipe fittings.
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher with Date of Check

SEAL

EXPERIMENT No. 4

TITLE: Reynolds Apparatus

OBJECTIVE:

To find the critical Reynolds Number for pipe flow.

APPARATUS REQUIRED:

Critical Reynolds Number Determination Apparatus, power supply 240 volt 50 Hz

INTRODUCTION

The Reynolds number is the most important dimensionless number in fluid mechanics. Reynolds number, in fluid mechanics, a criterion of whether fluid (liquid or gas) flow is absolutely steady (streamlined, or laminar) or on the average steady with small unsteady fluctuations (turbulent). Whenever the Reynolds number is less than about 2,000, flow in a pipe is generally laminar, whereas, at values greater than 2,000, flow is usually turbulent which is shown in Fig.4.1 (a) & (c). Actually, the transition between laminar and turbulent flow occurs not at a specific value of the Reynolds number but in a range usually beginning between 1,000 to 2,000 and extending upward to between 3,000 and 5,000 which is shown in Fig. 4.1 (b).

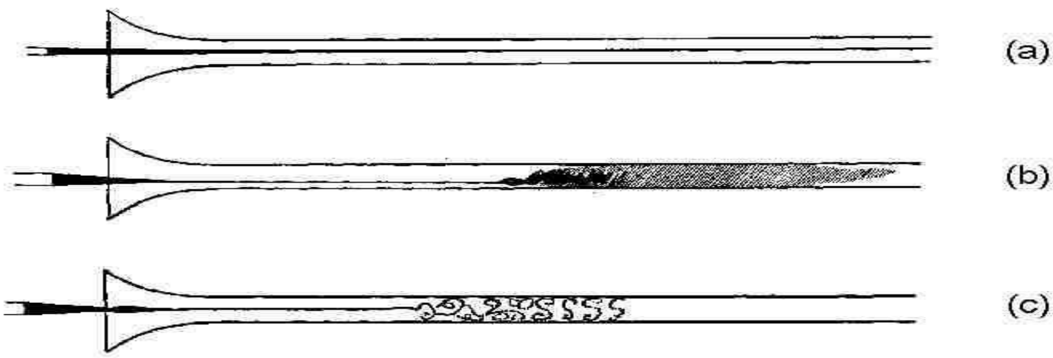


Figure 4.1: (a) Laminar flow (b) Transition flow (c) Turbulent flow

In laminar flow the fluid particles move along well-defined paths or streamlines, such that the paths of the individual fluid particles do not cross those of neighboring particles. Laminar flow is possible only at low velocities and when the fluid is highly viscous. But when the velocity is increased or fluid is less viscous, the fluid particles do not move in straight paths. The fluid particles move in a random manner resulting in mixing of the particles. This type of flow is called as Turbulent flow. The most important characteristic of turbulent motion is the fact that velocity and pressure at a point fluctuate with time in a random manner. This phenomenon is clearlydemonstrated in Figure below.

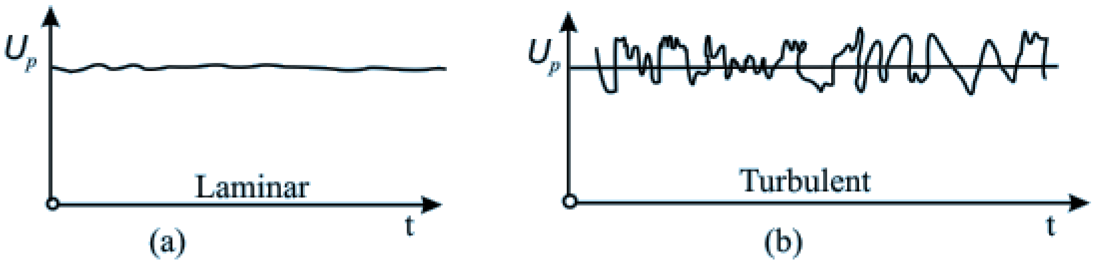


Figure 4.2: Variation of horizontal components of velocity for laminar and turbulent flows at a point P

The turbulent motion is an irregular motion. Turbulent fluid motion can be considered as an irregular condition of flow in which various quantities (such as velocity components and pressure) show a random variation with time and space in such a way that the statistical average of those quantities can be quantitatively expressed.

At a Reynolds number less than the critical, the kinetic energy of flow is not enough to sustain the random fluctuations against the viscous damping and in such cases laminar flow continues to exist. At somewhat higher Reynolds number than the critical Reynolds number, the kinetic energy of flow supports the growth of fluctuations and transition to turbulence takes place. The mixing in turbulent flow is more due to these fluctuations. As a result we can see more uniform velocity distributions in turbulent pipe flows as compared to the laminar flow shows below figure.

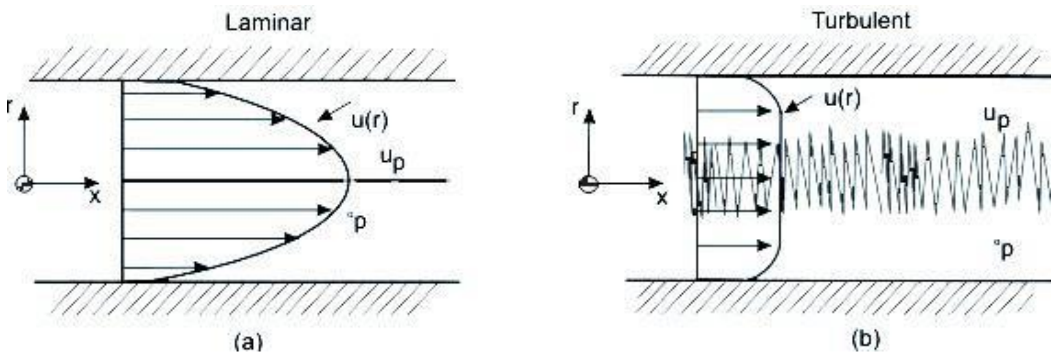


Figure4.3: Comparison of velocity profiles in a pipe for (a) laminar and (b) turbulent flows

DEFINITION:

In fluid mechanics, the Reynolds number Re is a dimension less number that gives a measure of the ratio of inertial forces $\rho V^2/L$ to viscous forces $\mu V/L^2$ and consequently quantifies the relative importance of these two types of forces for given flow conditions. The concept was introduced by George Gabriel Stokesin (1851), but the Reynolds number is named after Osborne Reynolds (1842-1912), who popularized its use in l883.

Reynolds number generally includes the fluid properties of density and viscosity, plus velocity and a characteristic length or characteristic dimension. This dimension is a matter of convention-for example a radius or diameter is equally valid for spheres or circles. For aircraft or ships, the length or width can be used. For flow in a pipe or a sphere moving in a fluid the internal diameter is generally used today.

$$Re = \frac{\rho v L}{\mu} = \frac{\rho v D_H}{\mu} = \frac{v D_H}{\nu} \quad \dots\dots\dots \; Eq. (4.1)$$

Where,

$v$is the mean velocity of the object relative to the fluid in (m/s),

$L$is a characteristic length (m)

$D_H$is the hydraulic diameter of the pipe flow (m)

$\mu$is the dynamic viscosity of the fluid [$Pa.s$ or $N.s/m^2$ or $kg/(m.s)$]

$\nu$is the kinematic viscosity ($\nu = \mu/\rho$) (m^2/s)

$\rho$is the density of the fluid (kg/m^3)

IMPORTANCE OF REYNOLDS NUMBER:

If an airplane wing needs testing, one can make a scaled down model of the wing and test it in a wind tunnel using the same Reynolds number that the actual airplane is subjected to. If for example the scale model has linear dimensions one quarter of full size, the flow velocity of the model would have to be multiplied by a factor of to obtain similar flow behavior. Alternatively, tests could be conducted in a water tank instead of in air (provided the compressibility effects of air are not significant) .As the kinematic viscosity of water is around13 times less than thatofairat15°C, in this case the scale model would need to be about one thirteenth the sizes in all dimensions to maintain the same Reynolds number, assuming the full-scale flow velocity was used. The results of the laboratory model will be similar to those of the actual plane wing results. Thus there is no need to bring a full scale plane in to the lab and actually test it.

This is an example of "dynamic similarity". Reynolds number is important in the calculation of a body's drag characteristics. A notable example is that of the flow around a cylinder. Above roughly 3×106 Re the drag coefficient drops considerably. This is important when calculating the optimal cruise speeds for low drag (and the long range) profiles for airplanes.

Poiseuille blood circulation in the body is dependent on laminar flow. In turbulent flow the flow rate is proportional to the square root of the pressure gradient, as opposed to its direct proportionality to pressure gradient in laminar flow. Using the definition of the Reynolds number we can see that a large diameter with rapid flow, where the density of the blood is high, tends towards turbulence. Rapid changes in vessel diameter may lead to turbulent flow, for instance when a vessel widens to a larger one.

Where the viscosity is naturally high, such as polymer solutions and polymer melts, flow is normally laminar. The Reynolds number is very small and Stokes' Law can be used to measure the viscosity of the fluid. Spheres are allowed to fall through the fluid and they reach the terminal velocity quickly, from which the viscosity can be determined. The laminar flow of polymer solutions is exploited by animals such as fish and dolphins, which exude viscous solutions from their skin to aid flow over their bodies whiles winning. It has been used in yacht racing by owners who want to gain a speed advantage by pumping a polymer solution such as low molecular weight poly oxy ethylene in water, over the wetted surface ft he hull. It is however, a problem for mixing of polymers, because turbulence is needed to distribute fine filler (for example) through the material. Inventions such as the cavity transfer mixer "have been developed to produce multiple folds into a moving melt so as to improve mixing efficiency. The device can be fitted onto extruders to aid mixing.

PROCEDURE:

(a) Start the experiment and allow the water to flow in to the tank of the apparatus. Water level inthe pyrometer is slightly rising along with rise in tank. Control valve of the glass tube should be slightly opened for removing air bubbles.

(b) After the tank is filled outlet valve of the glass tube and inlet valve of the tank should beclosed, so that water should be at rest.

ABBREVIATION:

Sl. No.	Description	Symbol	Value	Unit
1	Internal Diameter of the acrylic Pipe	D	0.025	meter
2	Cross Section area of The Pipe	A	0.000490874	m^2
3	Dynamic viscosity of the fluid	μ	0.000891	Kg/(m.s)
4	Kinematic Viscosity of Water	ν (nu)	8.93565E-07	$(\nu = \mu/\rho)$ (m^2/s)
5	Length of Acrylic Pipe	L	0.8	meter
6	Density of Water	ρ	997.13	Kg/m^3
7	Ambient Temperature	T	25	^0C
8	Width of Collecting Tank	W	0.38	meter
9	Length of Collecting Tank	LC	0.38	meter
10	Area of Collecting Tank	AT	0.1444	m^2

FORMULAE USED:

$$Q = \frac{(AT \times Df)}{t}$$

$$v = \frac{Q}{A}$$

$$Re = \frac{(v \times D)}{\nu}$$

OBSERVATIONS:

Sl. No.	Initial Tank Reading in cm	Final Tank Reading in cm	Difference in Tank Reading (D*f*) in meters	Time Taken (t) in sec	Type of flow Observed
1					
2					
3					

RESULT:

Sl. No.	Discharge (Q) in m^3/sec	Mean Velocity (v) in m/sec	Reynolds Number	Type of Flow Theoretical
1				
2				
3				

VIVA VOCE:

1. Define Reynolds Number
2. give the range of Reynolds number in the flow is laminar and turbulent
3. Can a similar procedure be followed for gases?
4. Is the Reynolds number obtained at transition dependent on tube size or shape?
5. Can this method work for opaque liquids?
6. What is laminar or turbulent flow?
7. Give the formula for hydraulic diameter.

Temperature	Pressure	Saturation vapour pressure	Density	Specific enthalpy of liquid water		Specific heat		Volume heat capacity	Dynamic viscosity
℃	Pa	Pa	kg/m^3	kJ/kg	$kcal/kg$	kJ/kg	$kcal/kg$	kJ/m^3	$kg/m.s$
0.00	101325	611	999.82	0.06	0.01	4.217	1.007	4216.10	0.001792
1.00	101325	657	999.89	4.28	1.02	4.213	1.006	4213.03	0.007731
2.00	101325	705	999.94	8.49	2.03	4.210	1.006	4210.12	0.001674
3.00	101325	757	999.98	12.70	3.03	4.207	1.005	4207.36	0.001620
4.00	101325	813	1000.00	18.90	4.04	4.205	1.004	4204.74	0.001569
5.00	101325	872	1000.00	21.11	5.04	4.202	1.004	4202.26	0.001520
6.00	101325	935	999.99	25.31	6.04	4.200	1.003	4199.89	0.001473
7.00	101325	1001	999.96	29.51	7.05	4.198	1.003	4197.63	0.001429
8.00	101325	1072	999.91	33.70	8.05	4.196	1.002	4795.47	0.001386
9.00	101325	1147	999.85	37.90	9.05	4.194	1.002	4793.40	0.001346
10.00	101325	1227	999.77	42.09	10.05	4.192	1.001	4791.42	0.001308
11.00	101325	1312	999.68	46.28	11.05	4.191	1.001	4189.61	0.001271
12.00	101325	1402	999.58	50.47	12.06	4.189	1.001	4187.67	0.001236
13.00	101325	1497	999.46	54.66	13.06	4.188	1.000	4185.89	0.001202
14.00	101325	1597	999.33	58.85	14.06	4.187	1.000	4184.16	0.001170
15.00	101325	1704	999.19	63.04	15.06	4.186	1.000	4182.49	0.001139
16.00	101325	1817	999.03	67.22	16.06	4.185	1.000	4180.86	0.001109
17.00	101325	1936	998.86	71.41	17.06	4.184	0.999	4779.27	0.001081
18.00	101325	2063	998.68	75.59	18.05	4.183	0.999	4177.72	0.001054
19.00	101325	2196	998.49	79.77	19.05	4.182	0.999	4176.20	0.001028
20.00	101325	2337	998.29	83.95	20.05	4.182	0.999	4174.70	0.001003
21.00	101325	2486	998.08	88.14	21.05	4.181	0.999	4173.23	0.000979
22.00	101325	2642	997.86	92.32	22.05	4.181	0.999	4171.78	0.000955
23.00	101325	2808	997.62	96.50	23.05	4.180	0.998	4170.34	0.000933
24.00	101325	2982	997.38	100.68	24.05	4.180	0.998	4166.92	0.000911
24.00	101325	2982	997.38	100.68	24.05	4.180	0.998	4168.92	0.000911
25.00	101325	3166	997.13	104.86	25.04	4.180	0.998	4167.51	0.000891
26.00	101325	3360	996.86	109.04	26.04	4.179	0.998	4166.11	0.000871
27.00	101325	3564	996.59	113.22	27.04	4.179	0.996	4164.71	0.000852
28.00	101325	3779	996.31	117.39	28.04	4.179	0.998	4163.31	0.000833
29.00	101325	4004	996.02	121.57	29.04	4.179	0.998	4161.92	0.000815
30.00	101325	4242	995.71	125.75	30.04	4.178	0.998	4160.53	0.000798
31.00	101325	4491	995.41	129.93	31.03	4.178	0.998	4159.13	0.000781
32.00	101325	4754	995.09	134.11	32.03	4.178	0.998	4157.73	0.000765
33.00	101325	5029	994.76	138.29	33.03	4.178	0.998	4156.33	0.000749
34.00	101325	5318	994.43	142.47	34.03	4.178	0.998	4154.92	0.000734
35.00	101325	5622	994.08	146.64	35.03	4.178	0.998	4153.51	0.000720
36.00	101325	5940	993.73	150.82	38.02	4.178	0.998	4152.08	0.000705
37.00	101325	6274	993.37	155.00	37.02	4.176	0.998	4150.65	0.000692
38.00	101325	6624	993.00	159.18	38.02	4.178	0.998	4149.20	0.000678
39.00	101325	6991	992.63	163.36	39.02	4.179	0.998	4147.74	0.000666
40.00	101325	7375	992.25	167.54	40.02	4.179	0.998	4146.28	0.000653
41.00	101325	7777	991.86	171.71	41.01	4.179	0.998	4144.80	0.000641
42.00	101325	8198	991.46	175.89	42.01	4.779	0.998	4143.30	0.000629
43.00	101325	8639	991.05	180.07	43.01	4.179	0.998	4141.80	0.000618
44.00	101325	9100	990.64	184.25	44.01	4.179	0.998	4140.28	0.000607
45.00	101325	9582	990.22	188.43	45.01	4.180	0.998	4138.7$	0.000596
46.00	101325	10085	989.80	192.61	46.00	4.180	0.998	4137.20	0.000586
47.00	101325	10612	989.36	196.79	47.00	4.180	0.998	4135.64	0.000576
0.00	101325	611	999.82	0.06	0.01	4.217	1.007	4216.10	0.001792
1.00	101325	657	999.89	4.28	1.02	4.213	1.006	4213.03	0.007731

Exp. No. 4	**Title:**Reynolds Apparatus
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher with Date of Check **SEAL**

Experiment No. 5

TITLE: Flow through Venturimeter and Orificemeter

OBJECTIVE:

To determine the coefficient of discharge of a Venturimeter and Orifice meter.

APPARATUS REQUIRED:

1. Venturimeter
2. Stop watch
3. Collecting-tank
4. Differential U- tube
5. Manometer

DESCRIPTION:

Venturimeter has two sections. One divergent area and the other throat area. The former is represented as a 1 and the later is a 2 water or any other liquid flows through the Venturimeter and it passes to the throat area the value of discharge is same at a 1 and a 2.

PROCEDURE:

1. The pipe is selected for doing experiments
2. The motor is switched on, as a result water will flow
3. According to the flow, the mercury level fluctuates in the U-tube manometer
4. The reading of H1 and H2 are noted
5. The time taken for 10 cm rise of water in the collecting tank is noted
6. The experiment is repeated for various flow in the same pipe
7. The co-efficient of discharge is calculated

VENTURIMETER DATA INPUT SHEET:

Sl. No.	Description	Symbols	Value	Units
1	Inlet Diameter of the venturimeter	D	0.025	meter
2	Outlet Diameter of the venturimeter	d	0.012	meter
3	Cross section Area of Inlet	A	0.000490874	m^2
4	Cross section Area of outlet	a	0.000113097	m^2
5	Width of Collecting Tank	W	0.375	meter
6	Length of Collecting Tank	LC	0.375	meter
7	Area of Collecting Tank	AT	0.140625	m^2
8	Acceleration due to gravity	g	9.81	m/see^2

FORMULAE:

$$Q_{th} = \frac{A * a * \sqrt{2 * g * 13.6 * \Delta H}}{\sqrt{A^2 - a^2}} m^3/sec$$

$$Q_a = \frac{AT * Df}{t} m^3/sec \; C_d = \frac{Q_a}{Q_{th}}$$

THEORY:

Flow meters are used in the industry to measure the volumetric flow rate of fluids. Differential pressure type flow meters (Head flow meters) measure flow rate by introducing a constriction in the flow. The pressure difference caused by the constriction is correlated to the flow rate using Bernoulli's theorem.

If a constriction is placed in a pipe carrying a stream of fluid, there will be an increase in velocity, and hence an increase in kinetic energy, at the point of constriction. From energy balance as given by Bernoulli’s theorem, there must be a corresponding reduction in pressure. Rate of discharge from the constriction can be calculated by knowing this pressure reduction, the area available for flow at the constriction, the density of the fluid and the coefficient of discharge C_d. Coefficient of discharge is the ratio of actual flow to the theoretical flow and makes allowances for stream contraction and frictional effects. Venturimeter, orifice meter, and Pitot tube are widely used head flow meters in the industry. The Pitot-static is often used for measuring the local velocity in pipes or ducts. For measuring flow in enclosed ducts or channels, the Venturimeter and orifice meters are more convenient and more frequently used. The Venturi is widely used particularly for large volume liquid and gas flows since it exhibits little pressure loss. However, for smaller pipes orificemeter is a suitable choice. In order to use any of these devices for measurement it is necessary to empirically calibrate them.

ORIFICE METER:

An orificemeter is a differential pressure flow meter which reduces the flow area using an orifice plate.

An orifice is a flat plate with a centrally drilled hole machined to a sharp edge. The orifice plate is inserted between two flanges perpendicularly to the flow, so that the flow passes through the hole with the sharp edge of the orifice pointing to the upstream. The relationship between flow rate and pressure drop can be determined using Bernoulli's equation as:

$$Q = C_d A_0 \sqrt{\frac{2(p_1 - p_2)}{\rho(1-\beta^4)}} \; \dots\dots\dots \; Eq. (5.1)$$

Where, Q is the volumetric flow rate, A_0 is the orifice cross sectional area, p_1 and p_2 are the pressure measured at the upstream and downstream and C_d is the discharge coefficient for the orifice.

$\beta$is the ratio of orifice diameter to the pipe diameter $= \frac{d_0}{d_p}$ where d_0 is the diameter of the orifice and d_p is the pipe diameter.

The fluid contracts and then expands as it moves through the orifice and this result in a pressure drop across the orifice, which can be measured. The magnitude of the pressure drop can be related to the volumetric flow rate.

An orifice in a pipeline is shown in figure 1 with a manometer for measuring the drop in pressure (differential) as the fluid passes through the orifice. The minimum cross sectional area of the jet is known as the "vena contracta".

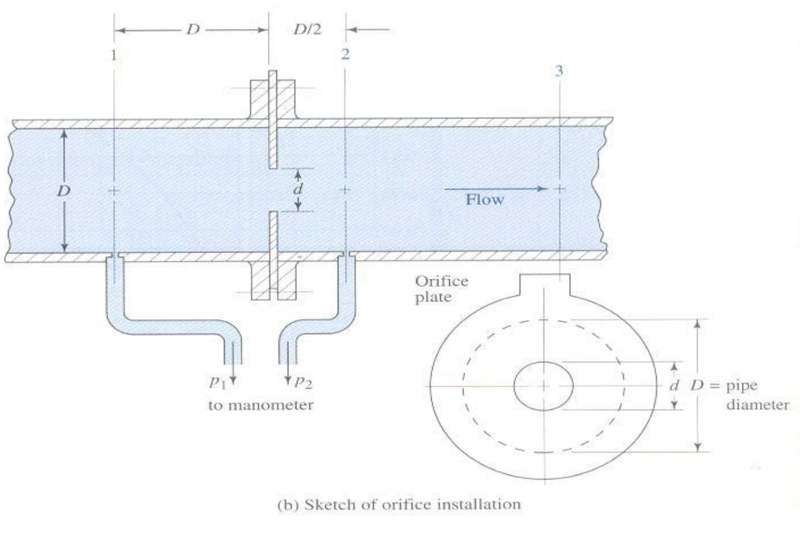


Figure 5.1

HOW DOES IT WORK?

As the fluid flows through the orifice plate the velocity increases, at the expense of pressure head. The pressure drops suddenly as the orifice is passed. It continues to drop until the "vena contracta" is reached and then gradually increases until at approximately 5 to 8 diameters downstream a maximum pressure point is reached that will be lower than the pressure upstream of the orifice. The decrease in pressure as the fluid passes through orifice is a result of the increased velocity of the fluid passing through the reduced area of the orifice. When the velocity decreases as the fluid leaves the orifice the pressure increases and tends to return to its original level. All of the pressure loss is not recovered because of friction and turbulence losses in the stream. The pressure drop across the orifice increases when the rate of flow increases. When there is no flow there is no differential. The differential pressure is proportional to the square of the velocity, it therefore follows that I fall other factors remain constant, then the differential pressure is proportional to the square of the rate of flow.

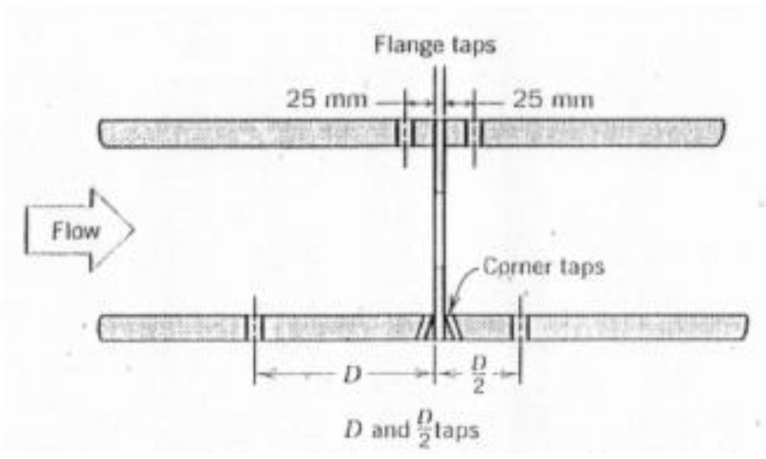


Figure 5.2

The analysis of the flow through a restriction (Figure2) begins with assuming straight, parallel streamlines at cross sections 1 and 2, and the absence of energy losses along the streamline from point 1 to point 2.

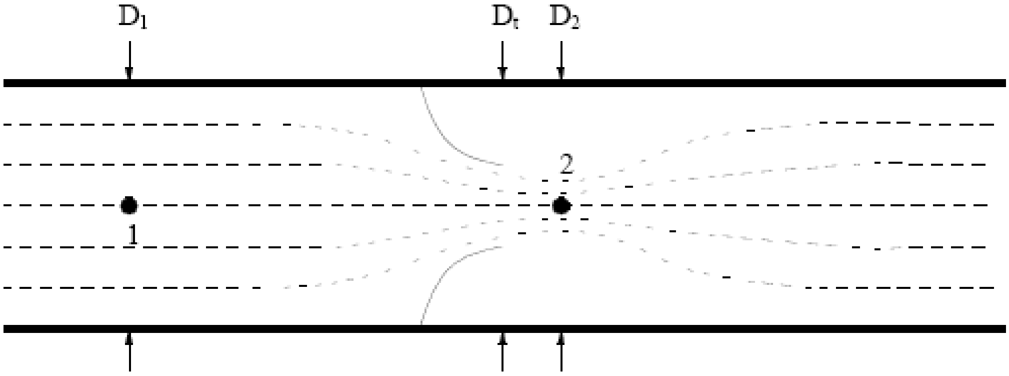


Figure 5.3

The objective is to measure the mass flow rate (m).By continuity

$$m = \rho V_1 A_1 = \rho V_2 A_2 \quad \dots\dots\dots \; Eq.(5.2)$$

Bernoulli's equation may now be applied to a streamline down the centre of the pipe from a point 1 well upstream of the restriction to point 2 in the vena contracta of the jet immediately downstream of the restriction where the streamlines are parallel and the pressure across the duct may therefore be taken to be uniform:

$$\frac{{V_1}^2}{2g} + \frac{P_1}{\rho g} = \frac{{V_2}^2}{2g} + \frac{P_2}{\rho g} \quad \dots\dots\dots \; Eq.(5.3)$$

Assuming that the duct is horizontal. Combining Eq. (5.3) with (5.2) gives,

$$m = \frac{A_2}{\sqrt{1 - \frac{{A_2}^2}{{A_1}^2}}} \sqrt{2\rho(p_1 - p_2)}$$

For a real flow through a restriction, the assumptions above do not hold completely. Further, we cannot easily measure the cross-sectional area of the jet at the vena contracta at cross-section 2 where the streamlines arc parallel. These errors in the idealized analysis arc accounted for by introducing a single, cover all correction factor, the discharge coefficient, C_d , such that,

$$m = \frac{C_d A_2}{\sqrt{1 - \beta^4}} \sqrt{2\rho(p_1 - p_2)}$$

Coefficient of discharge for a given orifice type is a function of the Reynolds number $\left(N_{R_{eo}}\right)$ based on orifice diameter and velocity, and diameter ratio β. At Reynolds number greater than about 30000, the coefficients are substantially constant and independent of β. For square edged or sharp edged concentric circular orifices, the value will fall between 0.595 and 0.62 for vena contracta or radius taps for β up to 0.8 and for flange taps for 13 up to 0.5.

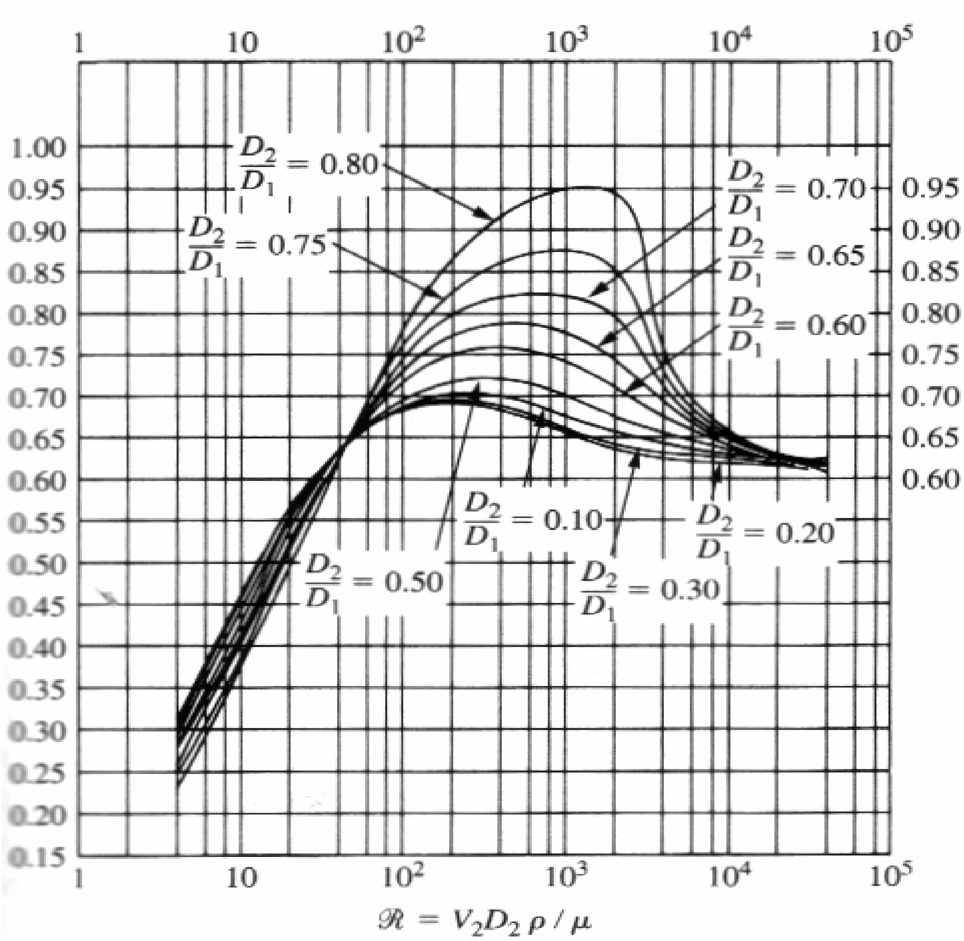


Figure 5.4

$$R = \frac{V_2 D_2 \rho}{\mu}$$

Coefficient of discharge for square edged circular orifices with corner taps [Tuve and Sprenle Instruments (1933)]

In summary, the principal advantages of the orifice plate arc

- it is simple and robust
- standards are well established and comprehensive
- plates are cheap
- may be used on gases, liquids and wet mixtures (e.g. steam)

Its principal drawbacks are:

- low dynamic range: maximum to minimum mass flow rates only 4:1 at best

ORIFICE METER:

Orifice meter has two sections. First one is of area a_1, and second one of area a_2 , it does not have throat like venturimeter but a small holes on a plate fixed along the diameter of pipe. The mercury level should not fluctuate because it would come out of manometer.

PROCEDURE:

1. The pipe is selected for doing experiments
2. The motor is switched on, as a result water will flow
3. According to the flow, the mercury level fluctuates in the U-tube manometer
4. The reading of H_1 and H_2 are noted
5. The time taken for 10 cm rise of water in the collecting tank is noted
6. The experiment is repeated for various flow in the same pipe
7. The co-efficient of discharge is calculated

ORIFICE METER DATA INPUT SHEET

Sl. No.	Description	Symbols	Value	Units
1	Inlet diameter of the Orifice	D	0.027	meter
2	Outlet diameter of the Orifice	D	0.013	meter
3	Cross-section Area of Inlet	A	0.000572555	m^2
4	Cross-section Area of Outlet	A	0.000132732	m^2
5	Width of Collecting Tank	W	0.375	meter
6	Length of Collecting Tank	LC	0.375	meter
7	Area of Collecting Tank	AT	0.140625	m^2
8	Acceleration sue to Gravity	g	9.81	m/sec^2
9	Difference in Tank Reading	Df		meter

FORMULAE:

$$Q_{th} = \frac{A * a * \sqrt{2 * g * 13.6 * \Delta H}}{\sqrt{A^2 - a^2}} m^3/sec$$

$$Q_a = \frac{At * Df}{t} m^3/sec$$

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

OBSERVATIONS:

Sl. No.	Initial Tank Reading in cm	Final Tank Reading in cm	Difference in Tank Reading (Df) in Meters	Time taken (t) in Sec	Manometer reading (ΔH) in mm
1					
2					
3					

RESULT:

Sl. No.	Theoretical Discharge (Q_{th}) in m^3/sec	Actual Discharge (Q_a) in m^3/sec	Co-efficient of Discharge (C_d)	Average (C_d)
1				
2				
3				

Exp. No. 5	**Title:** Flow through Venturimeter and Orificemeter
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	
Signature of Teacher with Date of Check	**SEAL**