DEPARTMENT OF CHEMICAL ENGINEERING
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Semester -III

FLUID MECHANICS LABORATORY MANUAL

23CH3PCFML

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NAME OF THE STUDENT : ______________________

USN NO : ______________________

BATCH NO : ______________________

Contents

EXPERIMENT NO: 1 DATE:

VENTURI METER

AIM:

1. To calibrate the given Venturi meter.
2. To find its coefficient of discharge.
3. To determine the variation of C_d with N_{Re}.

APPARATUS:

Venturi meter setup is a closed circuit unit consists of Positive displacement Pump, Water tank, Pumped water collection tank with a measuring scale for volume/flow rate, recirculation/bypass arrangements from one to one. It has a straight pipe with Venturi meter and a manometer etc.

THEORY:

Measurement of the flow rate of a fluid used in process is essential in all industries. One of the commonly used methods of flow measurement is to place a resistance in the pipe carrying the fluid and to measure the pressure drop across the resistance. A Simple methods of introducing a resistance is to restrict the area of cross section of flow by inserting an element in the line.

A Venturi meter consists of a flanged inlet section connected at either end to the pipe line by conical sections. The entrance cone angle is 21 ± 2 degrees and the exit cone angle is 5 to 15 degrees. The two cones are connected by short length of pipe of constant cross section called the throat. The throat length equals one throat diameter.

When the flow rate is constant, the velocity at the throat is greater than that in the pipe. The increase in velocity results in an increase in kinetic energy. As the total energy should be constant, there must be a corresponding reduction in pressure. Thus in the figure shown, the downstream pressure P_2 is always less than P_1, the upstream pressure. The difference in pressure is found by connecting a U-Tube manometer containing carbon – tetrachloride or Mercury used as a manometric fluid to measure the drop in static head across the two tapings.

EXPERIMETAL SET UP:

The experimental set up consists of horizontal pipe. The flow rate of water is controlled by Ball Valve. The Venturi meter is connected to the two sections of the pipe by a flange. The manometer tap located at pipe diameter upstream of the entrance cone. The other manometer tap located at the throat of the Venturi meter. The U- tube manometer containing colored carbon – tetrachloride or Mercury as manometric fluid, measures the drop in static head. The water storage or collection tank is used to measure the flow rate by noting the height and time required to fill the specified height. The schematic diagram is as depicted in Figure 1.

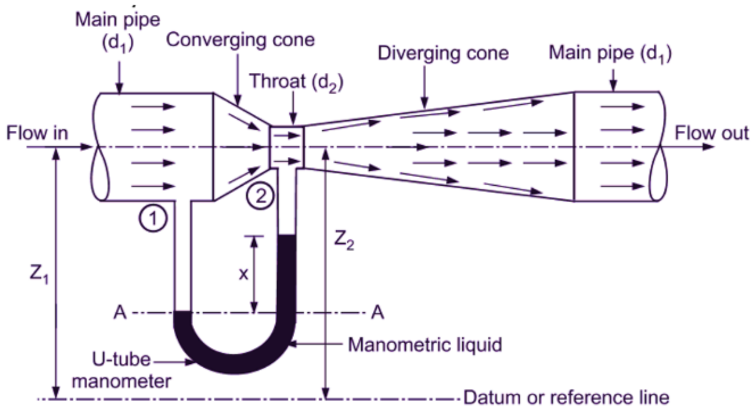


Figure 1: Schematic diagram of the Venturimeter

FORMULAE

Manometer reading= Rm = LHS – RHS, m

Fluid head lost= $H = [(\rho_m - \rho_f) / \rho_f] R_m$, m of water

Theoretical velocity= $V_{throat} = \sqrt{\frac{2gH}{(1-\beta^4)}}$ $, m/s$

Where β = Throat Diameter/Pipe Diameter = D_{throat}/D_{pipe}

Theoretical flow rate, $Q_{th} = V_{throat}$ x Cross sectional (C/S) area of the throat, m^3/s

Actual flow rate, $Q_{act} = (A_{Tank} \times h_{Tank})/time$, m^3/s

Coefficient of discharge (Experimentally) of Venturi, $C_d = \frac{Q_{Act}}{Q_{The}}$

Average Velocity = $V_{Act} = \frac{Q_{Act}}{C/_S\ Area\ of\ the\ pipe}$ $, m/s$

Reynolds Number, $N_{Re} = \frac{D_{Pipe} V_{Act} \rho_f}{\mu}$, Dimensionless.

PROCEDURE:

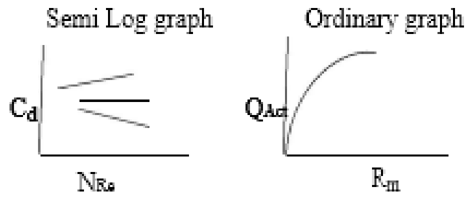
1) Keep the bypass valve fully open and all other valves are fully closed and Start the motor.
2) Allow the water to flow through Venturi and regulate the flow with Ball valve.
3) Remove any entrapped air bubbles from the manometer. After steady state is reached, note down the difference in level of monometer fluid.
4) Note down the time taken for water in collecting tank to rise for a given level.
5) Repeat the experiment for 5-6 readings for different opening of the ball valve and closing the by -pass gate valve.

RESULT:

1) The given Venturi is calibrated and plotted as shown in the graph.
2) The co-efficient of discharge of venturi (C_V or C_O or C_d) is calculated and shown in Table.
3) The variation of C_d with N_{Re} is plotted in the graph

GRAPHS:

1) Calibration chart, Q_{Act} Vs R_m (Ordinary graph).
2) C_d Vs N_{Re} (Semi Log graph).



DATA:

Pipe diameter (D_{Pipe}) = 25.4 mm
Throat diameter (D_{Throat}) = 12.5 mm
Density of Manometer liquid ρ_m = 13600 kg/m^3 (Mercury)
Density of flowing fluid ρ_f = 1000 kg/m^3 (Water)
Area of the Collection Tank (A_{Tank}) = 0.125 m^2
Viscosity of water μ = 0.98x10^{-3} kg/m s

OBSERVATION TABLE:

SL. NO.	Manometer Readings		R_m= (LHS–RHS) $\times 10^{-3}$ m	Actual Flow rate (Q_{act})	
	LHS mm	RHS mm		Height h_{Tank}(m)	Time, Sec.
1.					
2.					
3.					
4.					
5.					

FINAL RESULT TABLE:

Sl. No.	R_m, m	H, m	Q_{Act} m^3/s	Q_{The} m^3/s	V_{The} m/s	V_{Act} m/s	C_d	N_{Re}
1.								
2.								
3.								
4.								
5.								

CONCLUSION AND INFERENCE:

EXPERIMENT NO: 2 DATE:

ORIFICE METER

AIM:

1. To calibrate the given Orifice Meter.
2. To find its coefficient of discharge.
3. To determine the variation of C_o with N_{Re}.

APPARATUS:

Orifice Meter setup is a closed circuit unit consists of Positive displacement Pump, Water tank, Pumped water collection tank with a measuring scale for volume/flow rate, recirculation/bypass arrangements from one to one. It has a straight pipe with Orifice Meter and a manometer etc.

THEORY:

Orifice plate meter are used very commonly in the measurement of flow rates in the chemical industry. It consists of an accurately machined and drilled stainless steel plate mounted between two flanges with the hole concentric with the pipe in which it is mounted. The pressure drops substantially at a point, about one pipe diameter upstream from the orifice, to a minimum at the vena-contracta, located about one-half pipe diameters downstream from the orifice. It increases thereafter to some maximum value at a point, where it is understood that the pressure recovery is completed. The difference in pressure is found by connecting a U–Tube manometer containing mercury as manometric fluid to measure the drop in static head across the two tapings.

EXPERIMETAL SET UP:

The apparatus essentially consists of an accurately machined and drilled stainless steel plate mounted in transparent acrylic between the two flanges with the hole concentric with the pipe in which it is mounted. The unit consists of a sump, pump, water recirculation arrangement with a valves to control the flow rate. The manometer is connected across the orifice. One manometer tap located at one pipe diameter upstream of the entrance pipe. The other manometer tap is located at the center of the Orifice. The U- tube manometer containing colored carbon – tetrachloride or Mercury as manometric fluid, measure the drop in static head. The water storage or collection tank is used to measure the flow rate by noting the height and time required to fill the specified height. The schematic diagram is as depicted in Figure 2.

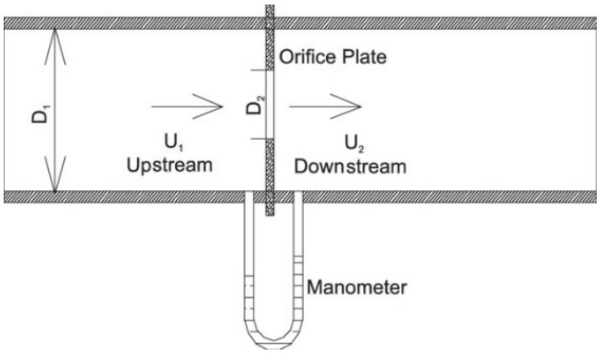


Figure 2: Schematic diagram of the Orifice meter

FORMULAE.

Manometer reading= Rm = LHS – RHS, m

Fluid head lost= H = $[(\rho_m - \rho_f) / \rho_f] R_m$, m of water

Theoretical velocity= $V_{orifice} = \sqrt{\frac{2gH}{(1-\beta^4)}}$ $, m/s$

Where β = Throat Diameter/Pipe Diameter = $D_{orifice}/D_{pipe}$

Theoretical flow rate, $Q_{th} = V_{orifice} \times$ Cross sectional (C/s) area of the orifice, m^3/s

Actual flow rate, $Q_{act} = (A_{Tank} \times h_{Tank})$/time, m^3/s

Coefficient of discharge (Experimentally) of Orifice, $C_d = \frac{Q_{Act}}{Q_{The}}$

Average Velocity = $V_{Act} = \frac{Q_{Act}}{C/_S\ Area\ of\ the\ pipe}$ $, m/s$

Reynolds Number, $N_{Re} = \frac{D_{Pipe} V_{Act} \rho_f}{\mu}$, Dimensionless.

PROCEDURE:

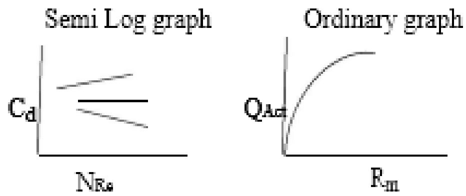
1. Keep the bypass valve fully open and all other valves are fully closed and Start the motor.
2. Allow the water to flow through Orifice and regulate the flow with Ball valve.
3. Remove any entrapped air bubbles from the manometer. After steady state is reached, note down the difference in level of monometer fluid.
4. Note down the time taken for water in collecting tank to rise for a given level.
5. Repeat the experiment for 5-6 readings for different opening of the ball valve and closing the bypass gate valve.

RESULT:

1. The given Orifice is calibrated and plotted as shown in the graph.
2. The co-efficient of discharge of Orifice (C_V or C_o or C_d) is calculated and shown in Table.
3. The variation of C_d with N_{Re} is plotted in the graph

GRAPH:

1) Calibration chart, Q_{Act} Vs R_m (Ordinary graph).
2) C_d Vs N_{Re} (Semi Log graph).



DATA:

Pipe diameter (D_{Pipe})	= 25 mm
Orifice diameter ($D_{Orifice}$)	=12.5 mm
Density of Manometer liquid, ρ_m	= 13600 kg/m^3 (Mercury)
Density of flowing fluid, ρf	= 1000 kg/m^3 (Water)
Area of the Collection Tank (A_{Tank})	= 0.125 m^2
Viscosity of water μ	= 0.98x10^{-3} kg/m s

OBSERVATION TABLE:

SL. NO.	Manometer Readings		R_m = (LHS – RHS) x 10^{-3}, m	Actual Flow rate (Q_{act})	
	LHS mm	RHS mm		Height(H_{Tank}),m	Time, Sec.
1.					
2.					
3.					
4.					
5.					

FINAL RESULT TABLE:

Sl. No.	R_m, m	H, m	Q_{Act} m^3/s	Q_{The} m^3/s	$V_{Orifice}$ m/s	V_{Act} m/s	C_d	N_{Re}
1.								
2.								
3.								
4.								
5.								

CONCLUSION AND INFERENCE:

EXPERIMENT NO: 3 DATE:

CENTRIFUGAL PUMP

AIM: To study the behavior of Centrifugal pump & Plot the operating curve. (To study the performance of pump under varying condition of delivery head and speed. To plot the graph of discharge (Q) V/S I_{HP} (Actual)

APPARATUS:
The centrifugal test grid experiment is a self contained unit operated on closed circuit basis. The pump, electric motor, collecting tank, sump tank, control panel, Pressure gauge, Vacuum gauge etc.

THEORY:
Pumps increase the mechanical energy of the liquid, increasing its velocity, pressure or elevation or all three. The two major classes are positive displacement pumps and centrifugal pumps (negative displacement). Positive-displacement units apply pressure directly to the liquid by a reciprocating piston, or by rotating members which form chambers alternately filled by and emptied of the liquid. Centrifugal pumps generate high rotational velocities, and then convert the resulting kinetic energy of the liquid to pressure energy.

EXPERIMETAL SET UP:
The centrifugal test rid experiment is a self contained unit operated on closed circuit basis. The pump, electric motor, collecting tank, sump tank, control panel, Pressure gauge, Vacuum gauge, Energy meter etc.

1) Conducting the various experiment at various speeds using pulley arrangement.
2) At measuring the input power to the pump by Watt Hour Meter (Whm)
3) For recording rpm using digital rpm indicator.
4) For recording vacuum
5) For changing pressure and vacuum (Suction head by operating the valve)
6) For measuring the discharge by collecting tank level provision.
7) For recirculating of water back into the sump tank by overflow pump.

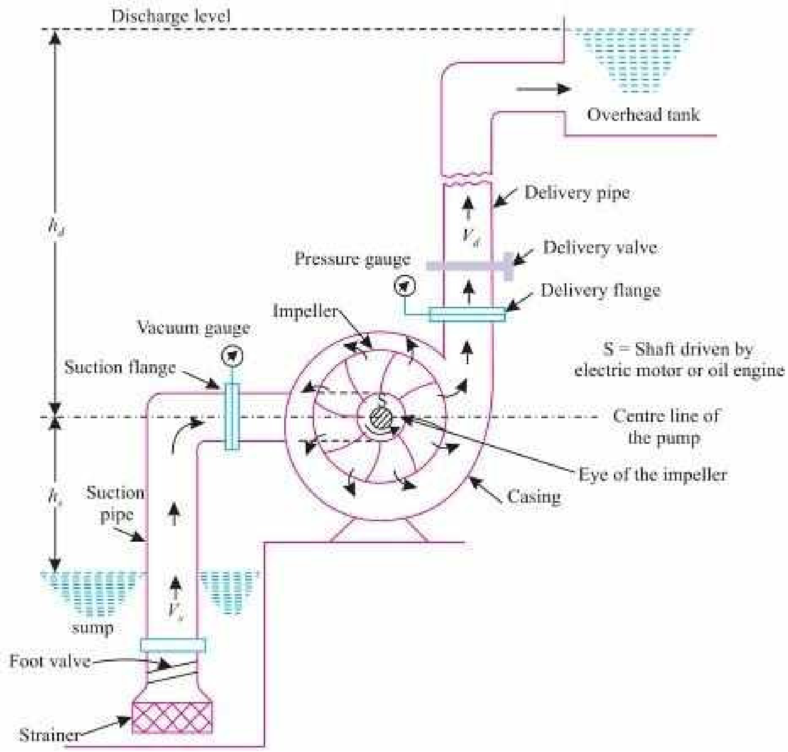


Figure 3: Schematic diagram of the centrifugal pump

FORMULAE:

H_D = Delivery Head, in kg/cm^2

H_S = Suction Head, in mm Hg.

H_T = Total head = H_S + H_D = m of water

Energy Meter Constant (EMC) = 750 rev/kWh,

k = No of Energy meter revolutions in time, t sec .

$I_{hp-Theoretical} = \frac{k\times60\times60\times1000}{EMC\times746\times t}$, hp

$I_{hp-Actual} = (I_{hp-Theoretical}) \times 0.6$, hp

$O_{hp} = \frac{1000\times Q\times H_T}{75}, hp$

Where $H_T = (H_D+H_S)$

Discharge (Q) = ($A_{tank} \times H_{Tank}$)/Time, in m^3/Sec

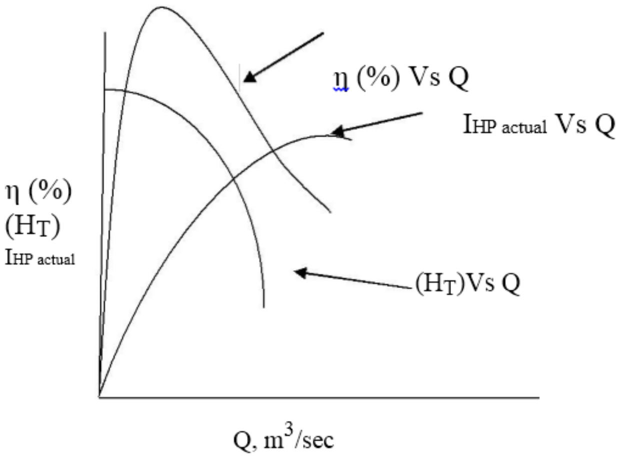
η (%) = (O_{hp} / $I_{hp\text{-}actual}$) × 100

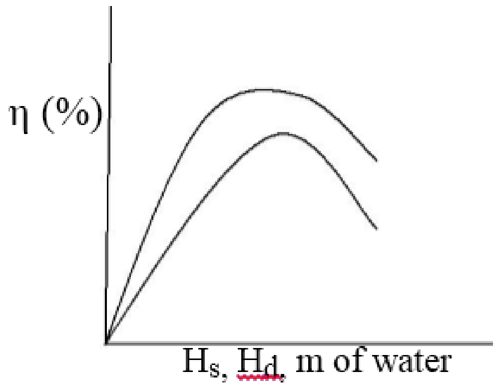
PROCEDURE:

1) Connect the power cable.
2) Keep the delivery and suction valve open fully.
3) Fill the sump with clean water.
4) Air vent the pump by using air vent valve.
5) Select the speed by adjusting the pulley.
6) Switch on the mains and the pump, water starts flowing to the measuring tank.
7) Note down the pressure gauge, vacuum gauge and time for number of revolutions of energy meter disc at full opening of delivery and suction valve.
8) Operate the butterfly valve to note down the collecting tank reading against the known height and time taken in seconds.
9) Repeat the experiments for different closings of the valves either at suction or delivery valve and note down the above readings.

GRAPHS:

1. Draw η (%), $I_{HP\text{-}Actual}$, H_T vs Q
2. Draw η (%) vs H_D & H_S





RESULT:

1) The behavior of the centrifugal pump is studied and operating curve was plotted.
2) The graph was plot for different speeds of Suction and Delivery head verses pump efficiency,η (%)

DATA:

Area of the Collection Tank = $0.125\ m^2$

Energy meter constant (EMC) = 750 rev/kWh

(Note: 760 mm Hg = $(1.0132 \times 10^5)/(9.81 \times 10^3)$ = 10.32 m of water

And 1 $kg/cm^2 = 1\times10^4\ kg/m^2 = (1\times10^4)/n = 1\times10^4/1000$ = 10 m of Water)

OBSERVATION TABLE:

Sl. No.	Speed of the Pump, rpm	Suction Head H_S (mm Hg)	Delivery Head (H_D) kg/cm^2	Time for 5 Revolutions of Energy Meter, sec	Volumetric flow rate (Q)	
					Height in cm	Time in sec
1.						
2.						
3.						

RESULT TABLE:

Sl. No.	H_T (Total head), m	Q, m^3/Sec	I_{hp}- Actual	O_{hp}	η (%)
1.					
2.					
3.					
4.					
5.					
6.					

CONCLUSION AND INFERENCE:

EXPERIMENT NO: 4 **DATE:**

FLOW THROUGH NON CIRCULAR PIPES

AIM: To study the flow characteristics of a fluid through a non –circular pipe and establish the relationship between friction factor and Reynolds number for various flow conditions.

APPARATUS: Experimental setup with square and rectangular pipe, Manometer, Bucket and stop watch arrangement for measuring volumetric flow rate.

THEORY:

A Non-circular pipe is simply a square or a rectangular pipe. The friction in the long straight channels of non-circular cross section can be estimated by using the equation for circular pipes if the diameter in the Reynolds number and the definition of friction factor is taken as the equivalent diameter as explained later. Square and rectangular sections are encountered often in industries and study of the behavior of the fluid flow through such channels is of use

EXPERIMETAL SET UP:

The experiment consists of a Horizontal Non circular pipes of different dimensions such as 1" Square pipe and 1" x ½" pipe , each 1.5 m long. A U-tube manometer is connected across each of these pipes. A half horse power pump is connected to a water pump tank with a bypass pipe to regulate the flow through the Pipes. A measuring tank of known dimensions is used to collect the water and determine the flow rate.

FORMULAE:

Manometer reading R_m = LHS – RHS, m

Equivalent dia. of Square Pipe = D_e = w or b.

Equivalent dia. of Rectangular Pipe = D_e = $D_e = \frac{2\times(w\times b)}{(w+b)}$

Where b=Breadth of the pipe, w=width of the pipe

Pressure Drop $\Delta P = R_m (\rho_m - \rho_f) \times g$, N/m^2

Volumetric Flow rate $Q = \frac{[C/_S\ Area\ of\ the\ tank \times Height\ of\ the\ tank]}{Time},\ m^3/s$

Average Velocity V = Q/A, m/s.

Where are A_{Pipe} = Equivalent C/s of pipe $= A_{pipe} = \frac{\pi(De^2)}{4}$, m^2

Reynolds Number, $N_{Re} = \frac{D_e v\, \rho_f}{\mu}$, Dimensionless.

Fanning's friction factor, $f = \frac{\Delta P \times D_e}{2\rho_f v^2 L}$

Where, L = Length of the pipe

PROCEDURE:

1) Keep the bypass valves fully open and the other valves closed and start the pump.
2) Select the pipe for which the pressure drop is to be determined and connect the manometer across that pipe.
3) Adjust the flow rate at any required value.
4) Measure the flow rate by collecting the water in the tank for a known period of time.
5) Repeat the experiment for different flow rates and different pipes.

RESULT:

Relationship between the friction factor is compared with Reynolds number for the various flow conditions and the results and graph are tabulated.

DATA:

Length of rectangular/square pipe, L Width	=	1.5 m
(w) & Breadth (b) for Square pipe Width (w)	=	1” (1 Inch)
& Breadth (b) for Rectangular pipe Cross	=	1” × 1/4”
sectional Area of collecting tank, A	=	0.125 m^2
Viscosity of water μ	=	0.98×10^{-3} kg/m s

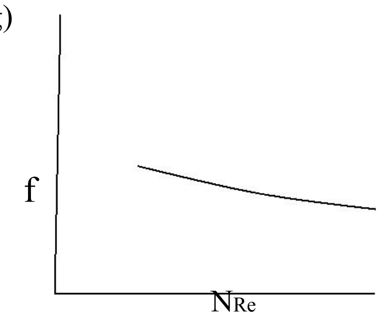
OBSERVATION TABLE:

SL. NO.	Manometer Readings		R_m=(LHS – RHS) × 10^{-3}, m	Discharge/Actual Flow rate (Q_{act})	
	LHS, mm	RHS, mm		Height, m	Time, Sec.
1.					
2.					
3.					

FINAL RESULT TABLE:

Sl. No.	R_m, m	ΔP	Q_{Act} m^3/s	V m/s	f	N_{Re}

Graph : f vs N_{Re} (Log - Log)



CONCLUSION AND INFERENCE:

EXPERIMENT NO: 5 DATE:

FLOW THROUGH CIRCULAR PIPES

AIM:

To plot the friction factor chart (Moody's chart) for flow through circular pipes.

APPARATUS: Circular conduits setup (1", ¾ ", ½ "), stop watch.

THEORY:

When a fluid flows in a steady state through a pipe, energy is dissipated in overcoming friction. The energy dissipated depends on the properties of flowing fluid and the confining pipe and their relative motion. The significant properties of the pipe are their internal diameter, length and roughness ratio (L/D) (Where D is the inside diameter of the pipe and L is the average height of the projections of reference inside the pipe) and of the fluid are its density and viscosity.

Loss due to friction for a fluid flowing through a pipe is given by

$$\Delta H = \frac{\Delta P}{\rho g} = 4f\left[\frac{L}{D}\right] \times \left[\frac{v^2}{2g}\right]$$

This equation is called FANNINGS EQUATION. "f " called the fannings friction factor and it is a function of Reynolds number and the roughness factor.

$$f = \varphi[N_{Re}]\emptyset\left[\frac{\epsilon}{D}\right]$$

The friction factor may be determined by the following or other available equations

f = 16/N_{Re} for Laminar flow (If $N_{Re} < 2100$) and f = 0.046(N_{Re})$^{-0.2}$ for turbulent flow

(NR_e >4000)

EXPERIMETAL SET UP:

The experiment consists of a Horizontal circular pipes of different dimension such as 1" Square and 1" inch by ½" of 1.5 m long connected to across the Manometer. A half horse power pump is connected to a water pump tank with a by pass pipe to regulate the flow throughout the Pipes. A measuring tank of known dimensions are used to collect the water and determine the flow rate. U-tube manometer is connected across the circular pipes.

FORMULAE:

Manometer reading R_m = LHS – RHS, m
Pressure drop $\Delta P = R_m (\rho_m - \rho_f)\, g$ N/m^2
Volumetric flow rate Q = (Cross sectional area of Tank × Height of Tank) / Time, m^3/sec.
Average velocity= $V = \frac{Q}{A_{Pipe}}$, m/s

A_{Pipe} = cross section of the area of the pipe = $\left[\frac{\pi (D_{Pipe})^2}{4}\right]$, m^2

Reynolds Number, $N_{Re} = \frac{D_{Pipe}\, v\, \rho_f}{\mu_f}$, Dimensionless.

Fannings Friction Factor = $f = \left(\frac{\Delta P \times D_{Pipe}}{2 \rho_f L v^2}\right)$

Where L = Length of the pipe.

DATA:

Length of rectangular pipe, L	=	1.5 m
Area of collecting tank, A	=	0.125 m^2
Diameter of pipe, $D_{3/4"}$	=	1.905 cm
Diameter of pipe, $D_{1/2"}$	=	1.27 cm
Diameter of pipe, $D_{1/4"}$	=	0.635 cm
Viscosity of water μ	=	0.98x10^{-3} kg/m s

GRAPHS : f Vs N_{Re} (Log – Log)

OBSERVATION

SL. NO.	Manometer Readings		R_m = (LHS–RHS) $\times 10^{-2}$, m	Discharge/Actual Flow rate (Q_{act})	
	LHS, cm	RHS, cm		Height, m	Time, Sec.
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

PROCEDURE:

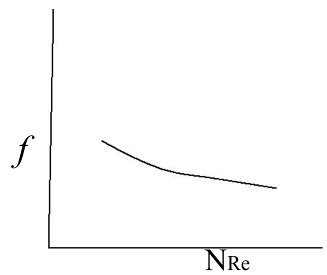
1. Keep the bypass valves fully open and the other valves closed and start the pump.
2. Select the pipe for which the pressure drop is to be determined and connect the manometer across that pipe.
3. Adjust the flow rate at any required value.
4. Measure the flow rate by collecting the water in the tank for a known period of time.
5. Repeat the experiment for different flow rates and different pipes.
6. Calculate f, N_{Re}, and report

RESULT: Friction factor chart is plotted as shown (f Vs N_{Re})

CALCULATIONS

Sl. No.	R_m, m	ΔP	Q_{Act} m^3/s	V m/s	f	N_{Re}
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						

GRAPH : f vs N_{Re} (Log - Log)



CONCLUSION AND INFERENCE:

EXPERIMENT NO: 6 DATE

FLOW THROUGH PACKED BED

AIM:

1) To verify the relationship between the velocity of the fluid and pressure drop per unit length of packing.
2) To verify Ergun's equation.

APPARATUS: Packed bed unit, Stop watch etc.

THEORY:

Packed beds are used extensively in absorption, distillation and liquid extraction process where large surface area is necessary to provide intimate contact between two phases – gas-liquid or solid-liquid.

As the fluid passes through the bed, it does so through empty spaces (Voids) in the bed. The voids form continuous channels through the bed. These channels need not be of same length and diameter. While the flow may be laminar through some channels, it may be turbulent in other channels. The resistance due to friction per unit length of the bed can be the sum of two terms:

1. Viscous drag force which is proportional to the first power of fluid velocity, V.

&

2. Inertial force which is proportional to the square of the fluid velocity, V.

Since V, velocity in the channel is difficult to estimate, V is substituted by V_O, the Velocity through the empty cross section of the column. V_O is related to V by the expression $V_O = \epsilon V$ where ϵ is the bed voidage or porosity. The total surface area of the particles in the bed which come in contact with the fluid is a function of specific surface of the particle and its sphericity and the voids in the bed.

Taking all these facts into considerations ERGUNS EQUATION has been derived to estimate the pressure drop for flow of fluid through a packed bed. { For $\varphi_s = 1$}.

$$\frac{\Delta P}{L_p} \times \left[\frac{\varepsilon^3}{(1-\varepsilon)^2}\right] \times \left[\frac{D_p}{V_0{}^2}\right] = 150 \times \left[\frac{(1-\varepsilon)\mu}{D_p V_0 \rho}\right] + 1.75 = f_p$$

$$f_p = 150\left[\frac{(1-\varepsilon)}{(N_{Re})_P}\right] + 1.75$$

At very low values of $(N_{Re})_P$, the term $150\left[\frac{(1-\varepsilon)}{(N_{Re})_P}\right]$ is very large compared to 1.75. In other words, viscous drag force predominates. As $(N_{Re})_P$ increases, f_P approaches 1.75. For any range of $(N_{Re})_P$, the total friction loss is an additive of resistance due to viscous forces and resistance due to inertial forces.

EXPERIMETAL SET UP

The experimental setup consists of a vertical cylindrical pipe/column of a known diameter and filled with a Raschig Rings. The packing is supported on a stainless screen mesh held between the two bottom flanges. Another wire mesh provided between the top flanges prevents the solids from being carried over. It has an inlet regulating valve, pressure tapings across the bed, a half horsepower pump is connected to a water pump tank with a bypass pipe to regulate the flow throughout the packed bed. A measuring tank of known dimensions are used to collect the water and determine the flow rate. U-tube manometer is connected to the two ends of the column.

FORMULAE

1. Manometer reading, Rm = LHS – RHS, m
2. Fluid head lost, H $= \left[\frac{(\rho_m-\rho_f)}{\rho_f}\right] \times R_m$, m of water
3. Cross sectional area of column, $A = \frac{\pi D^2}{4}$, m^2
4. Superficial Velocity of fluid through packed bed, $V_0 = \frac{Q_v}{A}$, m/sec

   Where, Q_v= Rotameter reading in LPM to be converted to m^3/sec
5. Pressure drop per unit length of packing, $\frac{\Delta P}{L_p} = \left[\frac{R_m g\,(\rho_m-\rho_f)}{L}\right]$
6. Modified Reynold’s Number, $(N_{Re})_P = \frac{D_p V_0 \rho}{\mu}$
7. For Spherical particle (Rasching ring), $D_P = \frac{6V_p}{S_p \varphi_s}$

Where φ_s is sphericity and is defined as the surface – volume ratio of the sphere having the same volume as Rasching ring to the surface volume ration of the sphere of the particle. {surface area of the sphere having the same volume as the particle to the surface area of the particle}

Friction factor for packed bed. (Theoretical)

$$f_{PT} = \frac{\Delta P}{L_p} \times (\frac{1}{\rho_f}) \left[\frac{\varepsilon^3}{(1-\varepsilon)^2}\right] \times \left[\frac{D_p}{{V_0}^2}\right] \varphi_s$$

Friction factor for packed bed. (Experimental)

$f_{PE} == 150 \times \left[\frac{(1-\varepsilon)\mu}{D_p V_0 \rho}\right] + 1.75$ or $f_{PE} == 150 \times \left[\frac{(1-\varepsilon)}{NRe}\right] + 1.75$

Where porosity, ε = Volume of voids /Volume of bed Volume of voids =approximately 2.5 liters or 2.5 x 10^{-3} m^3
Volume of bed = Cross sectional Area of column (A) × Length of Bed

PROCEDURE:

1. Note the dimensions of the packing material and diameter and height of the packed bed.
2. Check for and remove any entrapped air bubbles from the manometer.
3. Keep the bypass valve fully open and inlet valve fully closed. Start the pump and regulate the flow of water through the bypass valve.
4. Open the supply valve slowly and adjust for the required flow rate through the packed bed using the Rota meter. When steady state is reached, record the manometer reading.
5. Repeat the experiment by slowly varying the flow rate starting from the minimum flow rate and going to a maximum value.
6. Calculate f_{PT}, f_{PE} and $(N_{Re})_P$ and report
7. Draw the graph of f_{PT}, f_{PE} V/s $(N_{Re})_P$ on an Ordinary graph sheet.

RESULT:

1) The relationship between the velocity of the fluid and pressure drop per unit length of packing is verified.
2) Ergun's equation is verified.

DATA:

Diameter of the Packed column (D_{Col})	=	0.073 m
Length of the Packed column (L)	=	1 m
Packing diameter D_p	=	12.5 mm or 12.5 x 10^{-3} m
Shape factor, φ_s for rashig ring	=	1
Density of Manometer fluid ρ_m	=	13,600 kg/m^3 (Mercury)
Density of flowing fluid ρ_f	=	1000 kg/m^3 (Water)
Viscosity of water, μ	=	1×10^{-3} N-sec/m^2

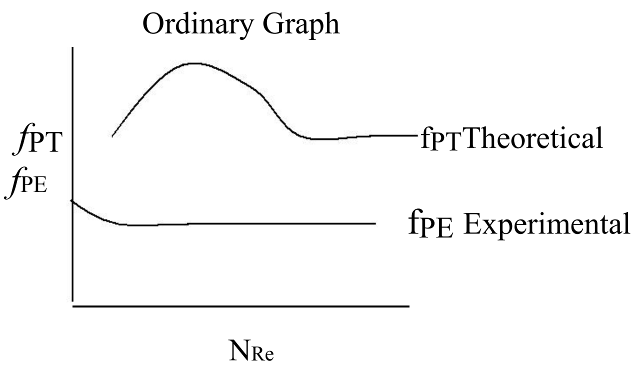
OBSERVATION TABLE:

Sl No	Manometer Readings		R_m= (LHS-RHS) × 10^{-2} m	Volumetric Flow rate (Q_{act})
	LHS	RHS		Rotameter reading LPM
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

FINAL RESULT TABLE:

Sl. No.	**R_m, m**	**ΔP/L, m**	**Q_{Act} m^3/s**	**V_o m/s**	**N_{Re}**	***f*PE Experimental**	***f*PT Theoretical**
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							

NATURE OF THE GRAPH



CONCLUSION AND INFERENCE:

EXPERIMENT NO: 7 DATE:

FLOW THROUGH FLUIDISED BEDS

AIM:

1. To determine the pressure drop per unit bed length as a function of superficial velocity.
2. To compare the theoretical and actual minimum fluidization velocities.

APPARATUS: Fluidised bed unit, Stop watch etc.

THEORY:

Fluidisation is one of the methods available for contacting granular solids with fluids. The fluidization technique was first started by the petroleum refineries to find a better catalytic cracking process than the fixed bed process. The main advantages of the fluidized bed are the greater interfacial, surface area of contact, high rate of heat transfer, avoidance of hot spots and ease of solid handling. Fluidized bed also find application in chemical reaction.

When a fluid passes upwards through a bed of solids there will be certain pressure drop across the bed required to maintain the fluid flow. Depending upon the bed geometry fluid velocity and particle characteristic the following phenomena occur with gradual increase in fluid velocity.

At low fluid velocity there is a pressure drop across the bed but the particle are stationery and the fluid is through a fixed bed.

As the bed velocity is gradually increased a certain velocity is reached when the bed starts expanding. At this point the pressure drop across the bed equals the mass per unit area of the bed. This point is known as Incipient fluidization. With increase in fluid velocity the particles separate still further from one another. The bed continues to expand the porosity increases but the pressure difference does not change. Particulate fluidization occurs when the difference in the density between the particle and fluid is small.

The pressure drop across a fixed bed, is given by Ergun's equation
{ For $\varphi_s = 1$}.

$$\frac{\Delta P}{L_p \rho_f} \times \left[\frac{\varepsilon^3}{(1-\varepsilon)^2}\right] \times \left[\frac{D_p}{{V_0}^2}\right] = 150 \times \left[\frac{(1-\varepsilon)\mu_f}{D_p V_0 \rho_f}\right] + 1.75 = f_p$$

$$f_p = 150\left[\frac{(1-\varepsilon)}{(N_{Re})_P}\right] + 1.75$$

Porosity at any time,

$$\varepsilon = \left[1 - \left(\frac{L_0}{L}\right)[1 - \varepsilon_0]\right]$$

At the onset of fluidization, the pressure drop across the bed equals the weight of the bed per unit area of cross section.

$$\frac{\Delta P}{L} = g\,(\rho_m - \rho_f)(1 - \varepsilon)$$

Minimum fluidization velocity,

$$V_{mf} = D_p^2 g\,\left(\rho_m - \rho_f\right)\frac{\left(\varepsilon_{mf}^3\right)}{\left[150\left(1 - \varepsilon_{mf}\right)\mu_f\right]}$$

EXPERIMETAL SET UP:

The experiment consists of a vertical cylindrical glass pipe/column of a known diameter filled with a packing and the packings are supported on a stainless screen mesh held between the two bottom flanges. Another wire mesh provided between the top flanges prevents the solid being carried over. It has an inlet regulating valve, pressure tapings across the column which are connected to U-tube manometer, a half horse power pump is connected to a water pump tank with a bypass pipe to regulate the flow throughout the packed bed. A measuring tank of known dimensions are used to collect the water and determine the flow rate.

FORMULAE:

Manometer reading Rm = LHS – RHS, m

Cross sectional area of the column $A = \frac{\pi D^2}{4}$, m^2

Superficial Velocity of fluid through packed bed, $V_0 = \frac{Q_v}{A}$, m/sec

Where, Q_v= Rotameter reading in LPM to be converted to m^3/sec

Actual flow rate in LPM = Rota meter reading in LPM x 0.66

Rota meter reading in LPM to be converted to m^3/sec

$\Delta P/L = g\,(\rho_m - \rho_f)(1- \epsilon)$ Where ρ_{p}= Density of manometric fluid

Porosity at any time, $\epsilon = 1-(L_o/L)(1- \epsilon_o)$,

Where,

L_o = Initial height of the bed in m &

L = Varying height of bed in m

ϵ_o = Volume of voids measured/Volume of bed

Volume of voids measured =approximately 125 ml or 125 × 10^{-6} m^3

Volume of bed = C/S Area of column (A) × Length of Bed (L)

Friction factor (f) = $(\Delta P/L) \times (1/\rho_f)\ \{\epsilon^3/(1-\epsilon)^2\}\ (D_{pm}) \times (1/V^2)$

Modified Reynolds Number $(N_{Re})_P = (D_{Particle}\ V_o\ \rho_f)/\ \mu_f$

PROCEDURE:

1) Fill the water in the sump, keep the bypass valve fully open, main valves is fully closed and start the pump.
2) Note down the initial bed height, diameter of the column, particle size, type of particles and their density.
3) Open the main valves slowly and allow a very slow rate of water in the apparatus so as to give a small manometric deflection.
4) Wait for steady state conditions and note down the flow rate of water by reading the rotameter. Note the pressure drop across the bed from the manometric reading. Also note the bed height.
5) Increase the flow rate slowly and repeat the observations keeping the bed in a packed state.
6) At some flow rate the bed begins to expand and this point dote down the bed level and the flow rate.
7) Repeat he experiment for four to five readings in the fluidized bed state.
8) Calculate f, V_{mf} and $(N_{Re})_P$ and report.
9) Draw the graph of $\Delta P/L$ versus V_o and ε versus V_o on ordinary graph sheets.

RESULT:

1. Pressure drop per unit bed length is determined as a function of superficial velocity of fluidization medium(air).
2. The theoretical and actual minimum fluidized velocities are compared.
3. Ergun's equation is verified.

DATA:

Diameter of the Packed column (D_{Col})	=	0.057 m
Height of the Packed column (L)	=	1.27 m
Packing diameter D_p	=	6 mm or 0.006 m
Shape factor, φ_s	=	1
Density of Manometer fluid, ρ_m	=	1600 kg/m^3 (CCl_4)
Density of flowing fluid, ρ_f	=	1000 kg/m^3 (water)
Density of Packing, ρ_p	=	1
Viscosity of water , μ_f	=	1×10^{-3} N-sec/m^2

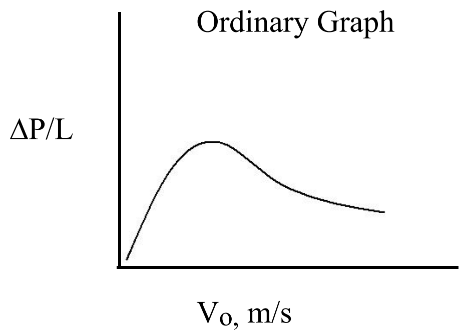
OBSERVATION TABLE:

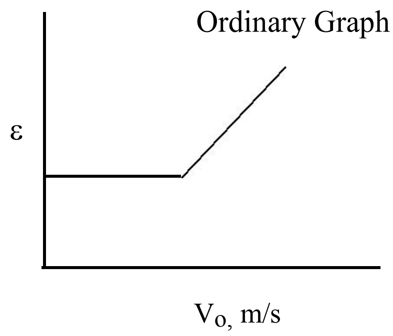
Sl No	Manometer Readings		R_m= (LHS-RHS) × 10^{-2} m	Bed Height m	Volumetric Flow rate (Q_{act})
	LHS	RHS			Rotameter reading LPM
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

FINAL RESULT TABLE:

Sl. No.	R_m, m	ΔP/L, m	Q_{Act} m^3/s	V_o m/s	ε	N_{Re}	f
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							

NATURE OF THE GRAPH





CONCLUSION AND INFERENCE:

EXPERIMENT NO: 8 DATE:

FLOW THROUGH HELICAL COILS

AIM:

1. To determine the critical Reynolds number of a liquid flowing through a helical coil.
2. To compare the pressure drop in a helical coil with that in a straight pipe of same length, inside diameter and surface roughness.
3. To determine the friction factor for flow of a liquid through a Helical coil

APPARATUS: Helical coil setup, stop watch.

THEORY:
The flow through a helical coil is uniquely different from that through a straight pipe due to the secondary flow pattern induced by the imbalance in the radial direction between the outwards-directed centrifugal force and the inwards-directed pressure force acting on the fluid. There is increased pressure drop for flow in curved channels, as compared to the pressure drop for the same rate of flow in the corresponding straight channel of the same length. The fl ow in the straight tube ceases to be laminar beyond N_{Re} 2100, whereas in coiled tubes it persists to be laminar up to much higher Reynolds number. The Fanning friction factor for helical coil tube is found to depend on a dimensionless number obtained by a combination of Reynolds number and geometrical number (d/D), where D is the diameter of the coil and d is the diameter of the pipe. Dean number, De=Re $\sqrt{(d/D)}$.
Due to the advantages of accommodating large heat transfer area within a small space, high heat transfer coefficient and small residence time distribution, tube coils are extensively used in industries as heat exchangers and reactors.

EXPERIMETAL SET UP:
Water will flow through a bank of coils consisting of different coil diameters. A gate valve controls the flow rate of water in the coil. The pressure drop due to friction is measured by a U Tube manometer with water/CCl_4/ mercury.

FORMULAE:

Manometer reading, R_m = LHS – RHS, m

Head loss in coil, $H_C = R_m \{(\rho_m - \rho_f)/\rho_f\}$, m of H_2O

Head loss in straight tube of same length as coil for same flowrate,

$H_S = 4 f_S (L/D_{Pipe}) (V^2/2g)$, m of H_2O

where $f_S = 16/N_{Re}$ (for $N_{Re}<2100$) and $f_S = 0.079/(N_{Re})^{0.25}$ (for $N_{Re}>2100$)

Volumetric flow rate $Q = \frac{\text{C/s Area of Tank (A) x Height of water collected in the tank}}{Time}, \frac{m^3}{s}$

Average velocity $V = Q/A_{Pipe}$

Where A is the cross sectional area of the pipe, $A = \frac{\pi (D_{pipe})^2}{4}$ m^2

Reynolds Number, $N_{Re} = \frac{D_{Pipe} V_{Act} \rho_f}{\mu}$, Dimensionless.

Where, D_{Pipe}= Diameter of Pipe & D_C= Diameter of coil

For coil, Critical Reynolds number, $N_{Rec} = 2100 \left[1 + 12\sqrt{\left(\frac{D_{Pipe}}{D_c}\right)}\right]$

Friction factor in coil,

$$f_c = 0.08\,(NR_e)^{-0.25} + 0.01\,({}^{D_p}/{}_{D_c})^{0.5}$$

$$or$$

$f_c \;=\; f_s\left(1 + 0.09\left(\frac{D_e^{1.5}}{70+D_e}\right)\right)$, for $N_{Re} < N_{Re,c}$

$$= \frac{16}{N_{Re}}\left(1 + 0.09\left(\frac{D_e^{1.5}}{70 + D_e}\right)\right)$$

and

$f_c \;=\; \left(f_s + \frac{0.073}{\sqrt{\frac{D_c}{D_p}}}\left(\frac{D_e^{1.5}}{70+D_e}\right)\right)$, for $N_{Re} > N_{Re,c}$

PROCEDURE:

1) Keep the bypass valves fully open and the other valves closed and start the pump.
2) Allow water to flow through inner helical coil and regulate the with the gate valve.
3) Remove any entrapped air bubbles from the manometer.
4) After the steady state is reached note down the difference level of manometric fluid.
5) Note the time required for the liquid level in the collection tank to increase by 5 cm.
6) Repeat the experiment for at least 5 flow rates starting from minimum flow rate to maximum value.
7) Calculate N_{Re}, H_c, H_s, f_c.

RESULT:

1. Critical Reynolds number of fluid flowing through a coils is determined.
2. The pressure drop in a helical coil is compared with that in a straight pipe of same length, inside diameter and surface roughness.
3. The friction factor for flow through helical coils is determined.

DATA:

Diameter of pipe, D_{Pipe}	=	0.015 m
Length of straight pipe, L	=	5.665 m
Diameter of coil, D_C	=	0.450 m

Viscosity of fluid flowing, μ_f = 1×10^{-3} Ns/m^2
Density of fluid flowing, ρ_f = 1000 kg/m^3

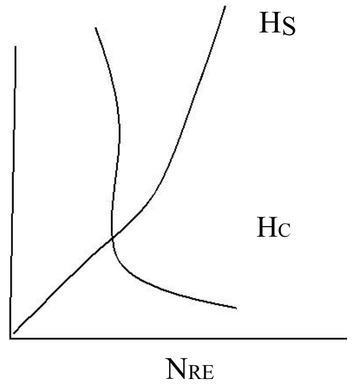
OBSERVATION TABLE:

Sl No	Manometer Readings		R_m= (LHS-RHS) × 10^{-2} m	Volumetric Flow rate (Q_{act})	
	LHS	RHS		Height, m	Time, seconds
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

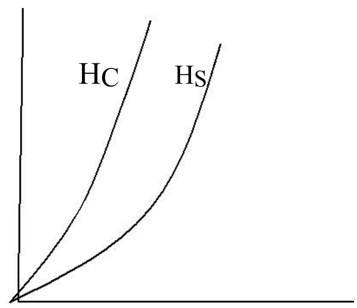
FINAL RESULT TABLE:

Sl. No.	R_m, m	Hc	Q_{Act} m^3/s	V m/s	*fc*	N_{Re}	Hs	N_{ReC}
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								

GRAPH: Hc & Hs Versus N_{Re} (Ordinary Graph)



Or



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CONCLUSION AND INFERENCE:

EXPERIMENT NO 9 **DATE:**

FLOW THROUGH PIPE FITTINGS

AIM: To determine the pressure drop characteristics for the flow of a fluid through different types of Fittings and plot the characteristics curves.

APPARATUS:

Experimental setup with pipe connections and different fittings, manometer, stop watch and collection tank for measuring flow rates.

THEORY:

Pipe fittings are used to introduce directional changes in the flow of fluid. The common fittings that are used are bends, elbows, Tee joints, flanged fittings, valves, reducer, enlarger, collar etc.

EXPERIMETAL SET UP:

The setup consists of a pipe of ¾" diameter with various fittings, U-tube manometer and Rota meter connected across it.

FORMULAE:

Volumetric flow rate,

Volumetric flow rate $Q = \frac{\text{C/s Area of Tank (A) x Height of water collected in the tank}}{Time}, \frac{m^3}{s}$

Average velocity $V = Q/A_P$

where A_p = Cross Sectional area of the pipe/fittings

Manometer reading Rm = (LHS – RHS), m

Fluid head loss, $H = R_m (\rho_m - \rho_f)/\rho_f$, m of water

Reynolds Number, $N_{Re} = \frac{D_{Pipe} V_{Act} \rho_f}{\mu}$, Dimensionless.

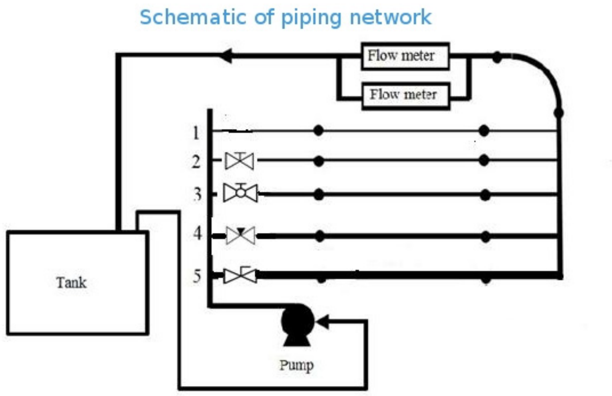
For Laminar flow ($N_{Re} < 2100$) friction factor, $f = 16/N_{Re}$

For Turbulent flow ($4000 < N_{Re} < 10^5$), friction factor, $f = \frac{0.079}{(N_{Re})^{0.25}}$

$$\frac{Le}{D_p} = \frac{gH}{2fv^2}$$

where L_e = Equivalent length of fitting. & D_p = Diameter of pipe.

EXPERIMENTAL SETUP



PROCEDURE:

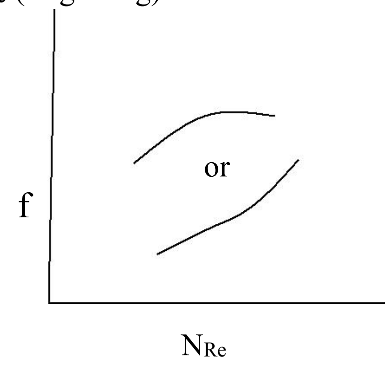
1) A particular fitting is chosen (say Globe Valve) and the manometer is fitted across this fitting.
2) The inlet valve and manometer connections are properly ensured.
3) The inlet valve is slightly opened and water is allowed to flow through the pipe and fitting.
4) After steady state conditions are attained, the manometer reading id noted.
5) Volumetric flow rate is also noted.
6) The above procedure is repeated for various valve openings (flow rates) till eight nuber of readings are obtained.
7) The manometer connection is changed for other Fittings and experiment is to be repeated

GRAPH: Draw the friction factor (f) vs the Reynolds number (N_{Re}) on a log –log graph.

DATA:

Inner diameter of the pipe with fitting, D_p	=	21 mm
Density of Manometer liquid, ρ_m	=	1600 kg/m^3 (Carbon tetrachloride)
Density of flowing fluid, ρ_f	=	1000 kg/m^3
Viscosity of fluid flowing, μ_f	=	1×10^{-3} N-s/m^2
Length of the pipe between fittings	=	22 cm

NATURE OF GRAPH: f vs N_{Re} (Log - Log)



CONCLUSION AND INFERENCE:

OBSERVATION TABLE 1:

Type of Fitting……………………….

Sl No	**Manometer Readings**		**R_m= (LHS-RHS) × 10^{-2} m**	**Volumetric Flow rate (Q_{act})**	
	LHS	**RHS**		**Height, m**	**Time, seconds**
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

RESULT TABLE 1:

Type of Fitting……………………….

Sl. No.	**R_m, m**	**ΔH, m**	**Q_{Act} m^3/s**	**V m/s**	**N_{Re}**	**f**	**$\frac{Le}{D_p}$**
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							

OBSERVATION TABLE 2:

Type of Fitting……………………….

Sl No	Manometer Readings		R_m= (LHS-RHS) × 10^{-2} m	Volumetric Flow rate (Q_{act})	
	LHS	RHS		Height, m	Time, seconds
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

RESULT TABLE 2:

Type of Fitting……………………….

Sl. No.	R_m, m	ΔH, m	Q_{Act} m^3/s	V m/s	N_{Re}	f	$\frac{Le}{D_p}$
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							

OBSERVATION TABLE 3:

Type of Fitting……………………….

Sl No	Manometer Readings		R_m= (LHS-RHS) × 10^{-2} m	Volumetric Flow rate (Q_{act})	
	LHS	RHS		Height, m	Time, seconds
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

RESULT TABLE 3:

Type of Fitting……………………….

Sl. No.	R_m, m	ΔH, m	Q_{Act} m^3/s	V m/s	N_{Re}	f	$\frac{Le}{D_p}$
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							

EXPERIMENT NO 10 DATE:

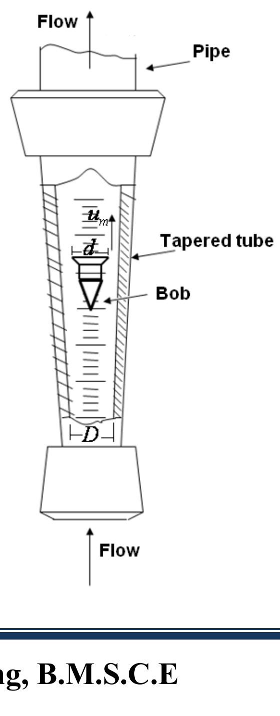
CALIBRATION OF ROTAMETER

AIM:
To calibrate the rotameter and to study the variation between indicated and actual flow rate.

APPARATUS
Rotameter, Pump, Water tank (Source), Discharge tank fitted with level indicator.

THEORY:
A rotameter is a variable area meter which measures the flow rate of liquid in a closed tube. It consists essentially of a gradually tapered glass tube, containing a float, mounted vertically in a frame, with the large end up. The tapered tube has a graduated scale to indicate volumetric flow rate. The fluid flows upward through the tapered tube and suspends the float. An indicator floats at a steady value when the forces on it are equal. The main forces are the weight of the float (downward) and the drag force of the fluid (upward). Other forces are the difference in pressure over the float and the buoyancy force of the displaced fluid, which increases with pressure. The static equilibrium of the float is defined by the weight of the float, the drag, and the buoyancy force on the float. Ideally, a rotameter is designed and calibrated at the same temperature and pressure, and with the same process fluid, for which it will be used. This ensures that the density of the fluid is the same, although it is often too difficult to replicate the exact conditions of use. A rotameter is typically designed for one specific gas density and flow range, so without the rotameter being calibrated to those conditions, accuracy will suffer. Calibrating a rotameter will identify the reference conditions in which the rotameter will be used, thus offering the most precise measurements.

EXPERIMENTAL SET UP:



PROCEDURE:

1. Keep the pump bypass valve fully open.
2. Allow the water to pass through the rotameter.
3. Set a specific value of volumetric flow rate on the rotameter.
4. Once the steady state is attained, note down the time taken for the water to collect for a specific Height in the collecting tank.
5. Repeat the experiment for different values of rotameter reading.
6. Determine Q_{actual} , $Q_{indicated}$, $and\ plot\ a\ graph\ of\ Q_{actual}\ vs\ Q_{indicated}$

CALCULATIONS:

1 LPM= 1 L/min = 1.66×10^{-5} ($^3/s$)

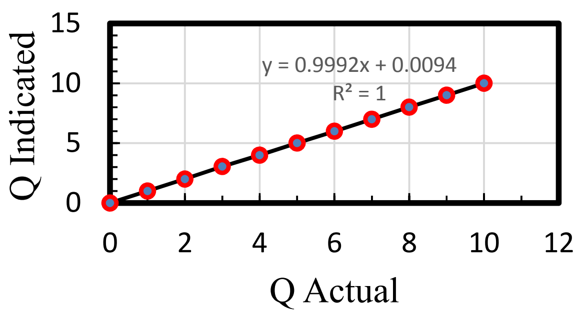
$$Q_{Actual} = \frac{Cross\ Sectional\ Area\ \times Height\ of\ water\ collected}{Time}, m^3/_s$$

$$Q_{Indicated} = Rotameter\ Reading\ \times 1.66 \times 10^{-5}, m^3/_s$$

OBSERVATION & RESULT TABLE

Sl No	Rotameter Reading (LPM)	Height of Water Collected (m)	Time (sec.)	Volumetric Flow rate	
				Q_{Actual}	$Q_{Indicated}$
1.					
2.					
3.					
4.					
5.					
6.					

PLOT GRAPH: $Q_{actual}\ vs\ Q_{indicated}$ (Ordinary Graph)



CONCLUSION AND INFERENCE:

EXPERIMENT NO 11 DATE:

REYNOLDS EXPERIMENT

AIM:

To study different patterns (laminar, transition, and turbulent regimes) of a flow through a pipe and correlate them with the Reynolds number of the flow.

APPARATUS:

Reynolds Apparatus test rig and stop watch

THEORY:

The purpose of this experiment is to illustrate the influence of Reynolds number on pipe flows. Reynolds number is a very useful dimensionless quantity (the ratio of dynamic forces to viscous forces) that aids in classifying certain flows. For incompressible flow in a pipe Reynolds number based on the pipe diameter, N_{Re} = V ave Dρ/μ, serves well. Generally, laminar flows correspond to , $N_{Re} < 2300$, transitional flows occur in the range $2300 < N_{Re} < 4000$, and turbulent flows exist for , $N_{Re} > 4000$. However, disturbances in the flow from various sources may cause the flow to deviate from this pattern. This experiment will illustrate laminar, transitional, and turbulent flows in a pipe.

Reynolds observed that in case of flow through pipe for values of Re<2000 the flow is laminar while offer Re>40000 it is turbulent and for 2000<Re<4000 it is transition flow.

For a particular fluid flow, depending on the velocity, the flow shows the laminar, transition and turbulent patterns. In laminar flow, the fluid flows in a layer without disturbing the other layer, whereas in turbulent flow the fluid does not follow any regular layer and the flow is highly chaotic. The flow shows the randomness of turbulent flow due to elevated dissipation. The flow exhibits intermittent behaviour in the transition regime, sometimes laminar and sometimes turbulent. Compare the essence of the flow with a non-dimensional number called the Reynolds number.

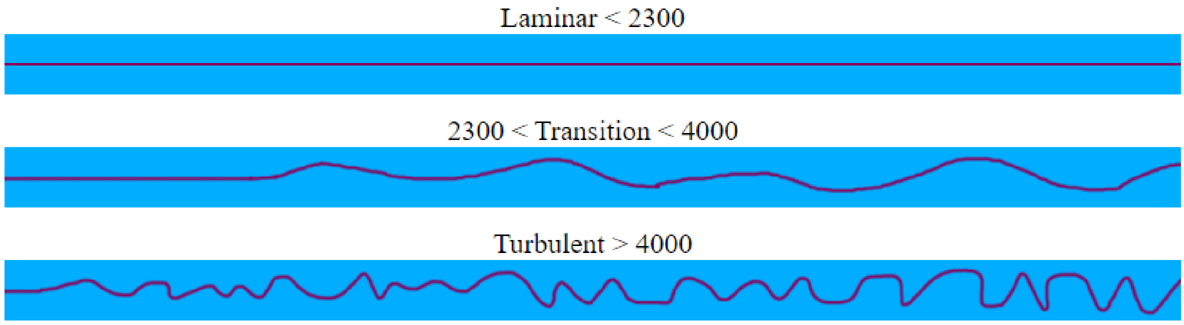
Reynolds number is defined as the ratio of inertia to viscous force in a flow. For a particular fluid i.e. for constant viscosity, the flow transits from laminar to turbulent as the velocity of the flow is increased. The Reynolds number at which the flow starts to transit from laminar is called the critical Reynolds number.

The Reynolds number for a flow in a pipe is obtained using following equation:

$$N_{Re} = \frac{D_{Pipe} V_{Act} \rho_f}{\mu}$$

here, ρ is the density, V is the average flow velocity in the pipe, D is the pipe diameter and μ is the dynamic viscosity.

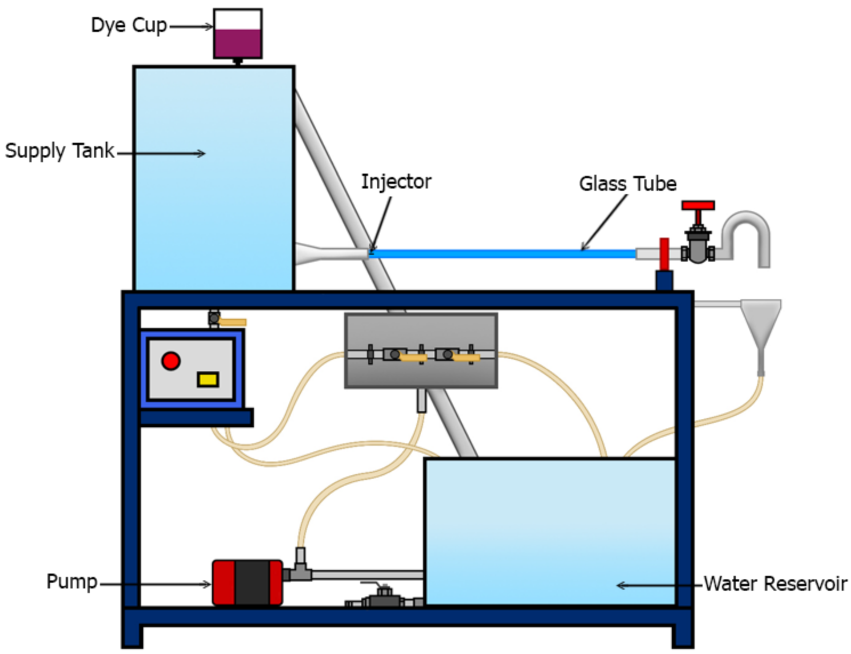
The flow transits from laminar to turbulent for a specific fluid, i.e. for continuous viscosity, as the flow velocity is increased. The critical number of Reynolds is the Reynolds number at which the flow begins to transition from laminar to turbulent. The essential Reynolds number for a flow through a pipe is generally calculated to be 2300. On the basis of the experimental data, Reynolds classified the flow regimes as follows:



EXPERIMETAL SET UP:

The apparatus consists of a glass tube with one end having bell mouth entrance connected to a constant head tank, a centrifugal pump and a sump tank. A needle is introduced centrally in the bell mouth. Dye is injected from the needle to the flow to observe the streamline of the flow. Dye is fed to the needle from a small container, placed at the top of constant head tank, through polythene tubing. A valve is provided at the other end of the glass tube to regulate the flow. Flow rate of the water is measured with the help of a measuring cylinder and stop watch.

Specifications of setup:
Diameter of pipe section(d) = ______
Length of pipe section(L) = ______



DATA:

Inner diameter of the pipe D_p	=	
Density of flowing fluid, ρ_f	=	1000 kg/m^3
Viscosity of fluid flowing, μ_f	=	1×10^{-3} N-s/m^2
Length of the pipe	=	

FORMULAE

Reynolds Number, $N_{Re} = \frac{D_{Pipe}V_{Act}\rho_f}{\mu}$, Dimensionless.

PROCEDURE

1. Close the drainage valve of the constant head tank if it is in open position.
2. Switch ON the main power supply and then switch ON the pump.
3. Open the control valve of water supply to constant head tank and partially close the bypass valve. Wait till overflow occurs.
4. By partially opening the control valve provided at the end of the tube, the minimum flow of water through the glass tube is regulated.
5. Change the flow of dye by the flow adjustment arrangement through the needle such that a fine colored strand is observed.
6. Observer the flow note down the flow pattern observed (laminar, transition or turbulent).
7. Measure the flow rate using measuring cylinder, stop watch and calculate the Reynolds number.
8. Repeat the above 2 steps for different flow rates by adjusting the control valve.
9. Switch OFF the pump and drain the apparatus completely once the experiment is over.

OBSERVATION TABLE

Sl No	Volume (L)	Time (sec)	Observed Flow Regime
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			

CONCLUSION AND INFERENCE:

LAB SAFETY GUIDELINES

1. Always behave in a responsible manner in the laboratory.
2. Always wear laboratory coat (White Color).
3. Ask your teacher before preceding any activity.
4. Keep silence in laboratory.
5. Do not touch any equipment, chemicals, or other materials in the laboratory area until you are instructed to do so.
6. Perform only those experiments authorized by your teacher.
7. Do not eat food, drink beverages, or chew gum in the laboratory. No food or drink of any kind in the laboratory.
8. Dress properly during a laboratory activity. Long hair, dangling jewellery, and loose or baggy clothing are a hazard in the laboratory. Long hair must be tied back, and all loose clothing or dangling jewellery must be secured or removed while in the laboratory.
9. Know location of all exits, evacuation route, first aid kit, eye wash, fire extinguisher, and safety shower.
10. Wear approved eye protection (safety glasses, or goggles) always in the laboratory.
11. Shoes must completely cover the foot. No sandals or crocs are allowed.
12. No equipment may be without proper training or demonstrated competency.
13. All aisles and workspace must be kept clear of clutter. Work areas should be always kept clean and tidy.
14. All exits, fire extinguishers, electrical disconnects, eye washes and safety showers must always remain accessible.
15. All equipment guards must remain in place.
16. All chemical storage rules must be always observed.
17. All chemicals must remain closed until used, and all chemicals must be marked with substance name, hazard information, concentration, date of creation, and person responsible.
18. All waste chemicals must be put in approved and labelled containers. There is to be NO hazardous waste into sinks or garbage cans.
19. Any unsafe or dangerous behaviour must be reported to the faculty.
20. Return the glassware / plastic ware after it is cleaned.
21. Wash your hands with soap after performing all experiments.
22. Obey safety rules.
23. After Completion of Experiments turn off equipment properly.
24. Drain Water and Chemicals after Compilation of Experiments.
25. Before Living the Laboratory turns Off Light/Fan.