MNIT JAIPUR

DEPARTMENT OF CHEMICAL ENGINEERING

FLUID MECHANICS LAB MANUAL

Contents

EXPERIMENT - 1

LOSSES DUE TO PIPE FRICTION

LOSSES DUE TO PIPE FRICTION

AIM:

1. To determine the head loss due to friction in GI ½", GI 1", and SS ½" pipes, and to calculate the corresponding friction factors using the Darcy–Weisbach equation.

2. To analyse the effect of pipe material, diameter, surface roughness, and flow rate on frictional losses, and to study the behaviour of laminar and turbulent flow regimes with respect to the friction factor.

INTRODUCTION AND THEORY:

Pipelines are used to transport fluids from one place to another. In the case of long pipelines, (e.g. those transporting oil and natural gas from offshore platforms to process plants on land) the frictional loss in the pipes constitutes a major energy loss. To design such pipelines and the pumping power required for them it is essential to have an understanding of frictional losses in laminar and turbulent pipe flow. The frictional loss arises due to viscous drag between adjacent fluid layers and the pipe surface. Unlike minor losses caused by fittings or bends, frictional losses in long, straight pipe sections are typically much larger and are thus termed major losses.

The primary cause of this friction is the no-slip condition, where fluid particles in contact with the pipe wall remain stationary, while layers farther from the wall move faster. This velocity gradient generates shear stress and leads to energy dissipation through molecular interactions between fluid layers and the pipe wall. Several factors influence the magnitude of frictional loss:

- Wetted Surface Area – Larger internal surface areas increase contact and friction.
- Fluid Density – Affects the magnitude of inertial forces in motion.
- Surface Roughness – Rougher surfaces cause more turbulence and energy loss.
- Pressure Independence – Friction loss does not directly depend on fluid pressure.
- Velocity of Flow – Frictional loss increases proportionally with the square of velocity.
- Viscosity of the Fluid – Higher viscosity leads to more internal resistance and increased frictional loss, especially in laminar flow.
- Reynolds Number (Re) – Determines the flow regime (laminar or turbulent), which significantly affects frictional loss behaviour.

Understanding these factors is essential for predicting head loss and for designing efficient piping systems using models like the **Darcy–Weisbach** equation.

Head Loss Due to Pipe Friction (Darcy–Weisbach Equation)

The loss of head in the pipe due to friction is calculated using the Darcy–Weisbach equation:

$$\boldsymbol{H}_{\mathrm{f}} = \boldsymbol{f}\left(\frac{\boldsymbol{L}}{\boldsymbol{D}}\right)\frac{\boldsymbol{V}^2}{2\boldsymbol{g}} \tag{1}$$

Where:

$\boldsymbol{H}_{\mathrm{f}}$	=	Head loss due to friction (m)
$\boldsymbol{f}$	=	Darcy friction factor (dimensionless)
$\boldsymbol{L}$	=	Length of pipe between pressure points (m)
$\boldsymbol{V}$	=	Mean velocity of fluid (m/s)
$\boldsymbol{D}$	=	Diameter of pipe (m)
$\boldsymbol{g}$	=	Acceleration due to gravity (9.81 m/s²)

Variation of Friction Factor (*f*):

a. Laminar Flow

In Laminar flow, the **friction factor (f)** is a function of the **Reynolds number (Re)**

$$\boldsymbol{f} = \frac{\mathbf{64}}{\mathbf{Re}} \tag{2}$$

b. Turbulent Flow

Friction Factor for Rough Pipes

For turbulent flow in rough pipes, the friction factor (*f*) is a function of the Reynolds number (Re) and the relative roughness $\boldsymbol{k = \varepsilon/D}$, where $\boldsymbol{\varepsilon}$ is roughness height of the pipe and $\boldsymbol{D}$ is diameter of the pipe. Depending on the relative roughness, the internal surface of the pipe may be considered hydraulically smooth or rough. The friction factor varies accordingly and cannot be determined directly by a simple equation; instead, it is typically obtained from the Moody chart or by solving the Colebrook equation.

Implicit form of Colebrook equation:

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re*\sqrt{f}}\right) \tag{3}$$

Explicit form:

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon}{D}\right) + 1.74 \tag{4}$$

Friction Factor for Smooth Pipes

For Reynolds Number (Re) between 4000 and 100000, the friction factor *f* is given by the **Blasius** relation:

$$f = \frac{0.316}{\mathrm{Re}^{0.25}} \tag{5}$$

For Reynolds Number Re >10^5, the friction factor f is given by empirical correlation:

$$f = 0.0032 + \frac{0.221}{\mathrm{Re}^{0.237}} \tag{6}$$

DESCRIPTION:

The apparatus consists of multiple pipes, typically three, made from different materials and sizes. These pipes are connected to a common inlet, which is equipped with a control valve to regulate the flow of water near the downstream end of the pipe. Pressure tapping is performed at appropriate intervals along the pipes, and a manometer is used to measure the pressure loss caused by friction. The discharge through the pipes is determined using a measuring tank and a stopwatch. The setup includes two GI (Galvanized Iron) pipes of different diameters and one stainless steel (SS) pipe with a diameter similar to that of the GI pipes. This allows for the study of how different materials and pipe sizes affect the flow and pressure losses in the system.

EXPERIMENTAL PROCEDURE

Starting Procedure

1. Clean the apparatus and ensure all tanks are free from dust.
2. Close the drain valve.
3. Fill the sump tank with ¾ clean water, ensuring no foreign particles are present.
4. Close all flow control valves on the water line and open the By-Pass Valve.
5. Check the level of the manometric fluid in the tube.
6. Close all pressure taps connected to the manometer.
7. Ensure that the on/off switch on the panel is in the off position.
8. Turn on the main power supply (220V AC, 50Hz) and Switch on the pump.
9. Operate the flow control valve to regulate the flow of water to the desired test section.

10. Open the pressure taps of the manometer related to the test section very slowly to avoid a sudden blow of water on the manometer fluid.
11. Open the air release valve on the manometer to release air in the manometer.
12. Once there is no air in the manometer, close the air release valve.
13. Adjust the water flow rate in the desired test section with the help of flow control valve.
14. Record the manometer reading.
15. Measure the flow of water discharged through the desired test section using a stopwatch and measuring tank.
16. Repeat the procedure for different flow rates by operating the control valve and By-Pass Valve.
17. When the experiment is over for a test section, close the flow control valve of the current test section and open the control valve for the next section.
18. Repeat the procedure for different test sections to compare results for different pipe diameters and materials.

Closing the Experiment

19. Close all manometer pressure taps.
20. Switch off the pump.
21. Switch off the power supply of the panel.

DATA, FORMULEA, ONSERVATIONS & CALCULATIONS:

T(s)	:	Time taken for the liquid level to rise by 10 cm in the measuring tank
Q	:	Volumetric Flow Rate (m^3/s)
h_1	:	Height of mercury column in the left limb
h_2	:	Height of mercury column in the right limb
$h = h_1 - h_2$		Difference in height of mercury columns, used to calculate pressure difference
H_f	:	Head loss (in meters of water)
f	:	Darcy Friction Factor

A (Area of collecting tank)	=	0.1 m^2
R (Rise of liquid level in the collecting tank)	=	10 cm
ρ_m (Density of manometric fluid, e.g., mercury)	=	13600 kg/m^3
ρ_w (Density of working fluid, e.g., water)	=	1000 kg/m^3
g (Acceleration due to gravity)	=	9.81 m/s^2

Inside Diameter of different pipes

Inside Diameter of GI Pipe (1”) = 25 mm
Inside Diameter of GI Pipe (½”) = 15 mm
Inside Diameter of SS Pipe (½”) = 15 mm

Cross-sectional area of different pipes (a_p) –

Cross-sectional area of GI Pipe (1”) Pipe = …… m^2 (calculate)
Cross-sectional area of GI Pipe (½”) = …….m^2
Cross-sectional area of SS Pipe (½”) = ……….m^2

OBSERVATION TABLE:

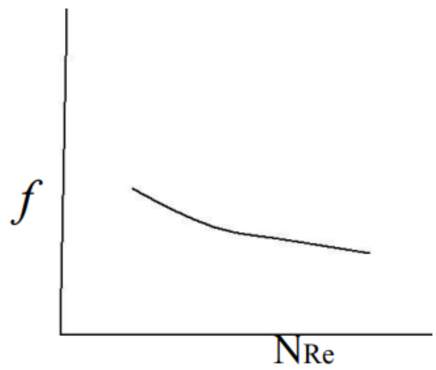
PIPE	Valve position	Manometer Reading			R (cm)	T (s)
		h_1 (cm)	h_2 (cm)	$h = h_1 - h_2$ (cm)		
For GI pipe (½")	**Full open**				10	
	¾ th open				10	
	½ open				10	
For GI pipe (1")	**Full open**				10	
	¾ th open				10	
	½ open				10	
For SS pipe (½")	**Full open**				10	
	¾ th open				10	
	½ open				10	

CALCULATION TABLE:

PIPE	Valve position	$H_f = h((\rho_m/\rho_w) - 1)$ (m)	Q =(A*R)/T (m^3/s)	$V = Q/a_p$	$f = (2gDH_f)/(LV^2)$	Re
For GI pipe (½")	**Full open**					
	¾ th open					
	½ open					
For GI pipe (1")	**Full open**					
	¾ th open					
	½ open					
For SS pipe (½")	**Full open**					
	¾ th open					
	½ open					

RESULTS:

Friction factor chart to be plotted as shown (f vs Re on log-log graph).

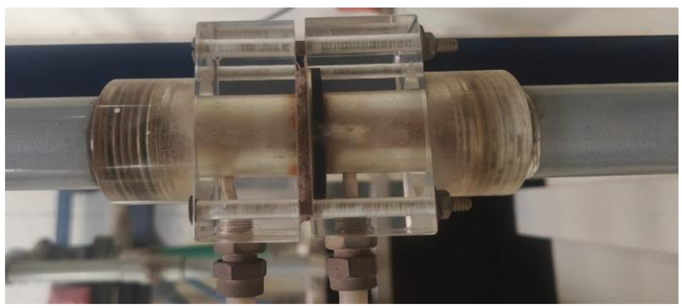


PRECAUTIONS & MAINTENANCE INSTRUCTIONS:

1. Always keep the apparatus free from dust to avoid any interference with measurements and to ensure the proper functioning of the apparatus.
2. Always use clean water. Ensure that the water used in the experiment is free from impurities and particles to avoid clogging or affecting the readings.
3. Drain the apparatus completely after the experiment is over. Proper drainage prevents water from stagnating in the system, which could lead to corrosion or contamination.

EXPERIMENT - 2

VENTURI METER AND ORIFICE METER



VENTURI METER AND ORIFICE METER

AIM:

To calculate the theoretical and actual flow rate of water and determine the coefficient of discharge (C_d) using a Venturi meter and an Orifice meter

INTRODUCTION AND THEORY:

Venturi meter

A Venturi meter is a flow-measuring device used to determine the discharge (flow rate) of a fluid flowing through a pipe. It works on the principle of Bernoulli's theorem, which states that for an incompressible, steady flow, the sum of pressure energy, kinetic energy, and potential energy per unit weight of fluid remains constant along a streamline.

A Venturi meter consists of three main parts:

1. Converging section – where the pipe diameter gradually decreases.
2. Throat – the section with minimum cross-sectional area.
3. Diverging section – where the pipe diameter gradually increases.

The inlet section of the Venturi meter is of the same diameter as that of the pipe, which is followed by a convergent cone. The convergent cone is a short pipe that tapers from the original size of the pipe to that of the throat of the Venturi meter. The throat of the Venturi meter is a short, parallel-sided tube having a cross-sectional area smaller than that of the pipe. The divergent cone of the Venturi meter is a gradually diverging pipe, with its cross-sectional area increasing from that of the throat to the original size of the pipe. At the inlet section and throat of the Venturi meter, pressure taps are provided. As the fluid enters the converging section, its velocity increases and pressure decreases. The velocity reaches a maximum and pressure reaches a minimum at the throat. The pressure difference between the inlet and the throat is measured using a manometer. This pressure difference is used to calculate the discharge through the pipe. The theoretical discharge through a Venturi meter is given by:

$$Q_t = \frac{a_1 a_2 \sqrt{(2g\,H)}}{\sqrt{(a_1^2 - a_2^2)}}$$

Due to frictional and other losses, the actual discharge Q_a is less than the theoretical discharge. Therefore, a coefficient of discharge (**C_d**) is introduced, which is typically 0.95 to 0.99 for Venturi meters.

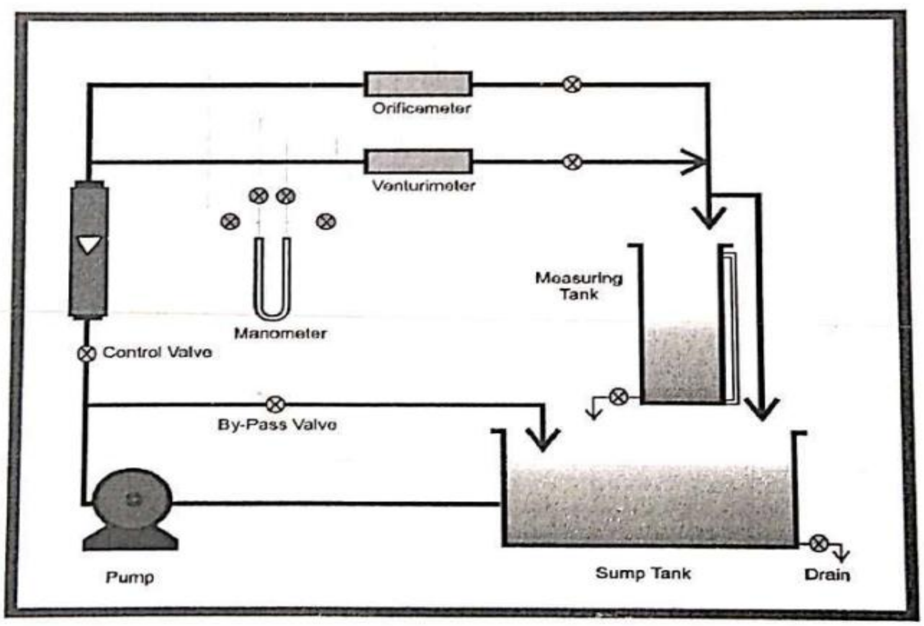
$$C_d = Q_a / Q_t$$

Orifice meter

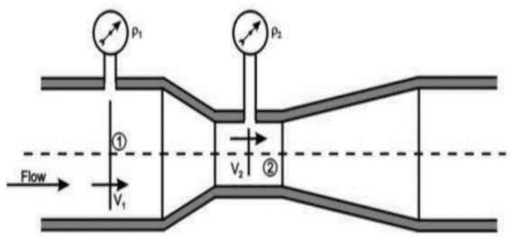
An orifice meter consists of a thin circular plate with a sharp-edged hole (orifice) at its center. The plate is fixed between two flanges in a pipeline. Pressure tapping points are provided upstream and downstream of the orifice plate and are connected to a manometer to measure the pressure difference. When fluid flows through the pipe and passes through the orifice, the cross-sectional area suddenly reduces, fluid velocity increases and pressure decreases at the orifice. The minimum cross-section of the jet formed after the orifice is called the vena contracta**.** The pressure difference between the upstream section and vena contracta is used to calculate the discharge using Bernoulli's principle. The theoretical discharge through an orifice meter is given by:

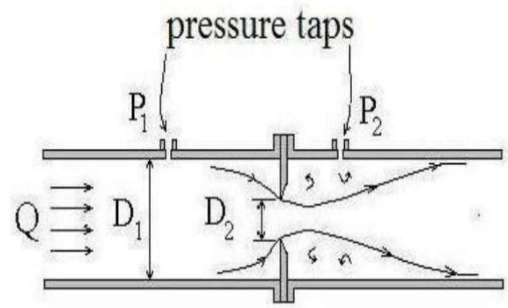
$$Q_t = \frac{\mathbf{a_1 a_2}\sqrt{(\mathbf{2g\ H})}}{\sqrt{(\mathbf{a_1}^2 - \mathbf{a_2}^2)}}$$

The coefficient of discharge (**C_d**) varies from 0.60 – 0.70 for orifice meters.



Schematic Diagram for Venturi meter & Orifice meter Apparatus





VENTURIMETER ORIFICEMETER

EXPERIMRNTAL PROCEDURE:

Starting Procedure

1. Clean the apparatus and make all tanks free from dust.
2. Close the drain valves provided.
3. Fill sump tank ¾ with clean water and ensure that no foreign particles are present.
4. Close all flow control valves on the water line and open the by-pass valve.
5. Close all pressure taps of the manometer connected to the Venturi meter & Orifice meter.
6. Ensure that the On/Off switch on the panel is in the OFF position.
7. Switch on the main power supply (220 Volts AC, 50 Hz).
8. Switch on the pump.
9. Operate the flow control valve to regulate water flow in the desired test section.
10. Open the pressure taps of the manometer for the related test section very slowly to avoid disturbance in manometer fluid.
11. Open the air release valve on the manometer slowly to release trapped air.
12. When there is no air in the manometer, close the air release valves.
13. Adjust the water flow rate using the control valve in the desired section.
14. Record the manometer reading.
15. Measure the flow of water discharged through the test section using a stopwatch and measuring tank.
16. Repeat the same procedure for different water flow rates by operating the control valve and by-pass valve.
17. After completing the experiment in one test section, open the by-pass valve fully. Then close the control valve of the current test section and open the control valve of the next desired test section.

Closing Procedure

1. When the experiment is over, close all manometer pressure taps first.
2. Switch off the pump.
3. Switch off the power supply to the panel.

DATA, FORMULEA, ONSERVATIONS & CALCULATIONS:

Data

T (s)	:	Time taken for the liquid level to rise by 10 cm in the measuring tank
Q_a	:	Actual volumetric flow rate (m^3/s)
Q_t	:	Theoretical volumetric flow rate (m^3/s)
C_d	:	Coefficient of discharge
h_1	:	Height of mercury column in the left limb
h_2	:	Height of mercury column in the right limb
$h = h_1 - h_2$	:	Difference in height of mercury columns

H = Head loss (in meters of water)

A (Area of collecting tank)	=	0.1 m^2
R (Rise of liquid level in the collecting tank)	=	10 cm
ρ_m (Density of manometric fluid, e.g., mercury)	=	13600 kg/m^3
ρ_w (Density of working fluid, e.g., water)	=	1000 kg/m^3
g (Acceleration due to gravity)	=	9.81 m/s^2

For Venturi meter

d_1 (Diameter at inlet)	=	28 mm
d_2 (Diameter at throat)	=	14 mm
a_1 (Area at inlet)	=	……….m^2
a_2 (Area at throat)	=	……….m^2

For Orifice Meter

d_1 (Diameter at inlet)	=	28 mm
d_2 (Diameter at throat)	=	14 mm
a_1 (Area at inlet of orifice meter)	=	……….m^2
a_2 (Area of orifice plate)	=	……….m^2

OBSERVATION TABLE:

Flow meter	Valve position	Manometer Reading			R (cm)	T (s)
		h_1 (cm)	h_2 (cm)	$h = h_1 - h_2$ (m)		
Venturimeter	FULL OPEN					
	¾ th open					
	½ open					
	¼ open					
Orifice Meter	FULL OPEN					
	¾ th open					
	½ open					
	¼ open					

CALCULATION TABLE:

Flow meter	Valve position	H $=h((\rho m/\rho w)-1)$ (m)	$Q_a=(A*R)/T$ (m^3/s)	$Q_t = \frac{a_1 a_2\sqrt{(2g\,H)}}{\sqrt{(a_1^2 - a_2^2)}}$	$V_a = Q_a/a_1$	$C_d = Q_a/Q_t$	$Re = \frac{\rho\, d_1\, V_a}{\mu}$
Venturi meter	Full open						
	¾ th open						
	½ open						
	¼ open						
Orifice Meter	Full open						
	¾ th open						
	½ open						
	¼ open						

RESULT:

1. Calibration plot, Q_a vs h.
2. The variation of C_d with Re is to be plotted in log-log graph.

PRECAUTIONS & MAINTENANCE INSTRUCTIONS:

1. Do not run the pump at low voltage, i.e., less than 180 Volts.
2. Never fully close the Delivery line and By-Pass line valves simultaneously.
3. Always keep the apparatus free from dust.
4. To prevent clogging of moving parts, run the pump at least once in a fortnight.
5. Frequently grease/oil the rotating parts, once in three months.
6. Always use clean water.
7. If the apparatus will not be in use for more than one month, drain the apparatus completely and fill the pump with cutting oil.

EXPERIMENT - 3

BERNOULLI’S THEOREM

VERIFICATION OF BERNOULLI'S THEOREM

AIM

To verify Bernoulli's equation experimentally using a horizontal test section with varying cross-section. To plot the Total Energy Line (TEL) vs. distance along the flow path and observe the constancy of total energy in ideal flow conditions.

INTRODUCTION AND THEORY:

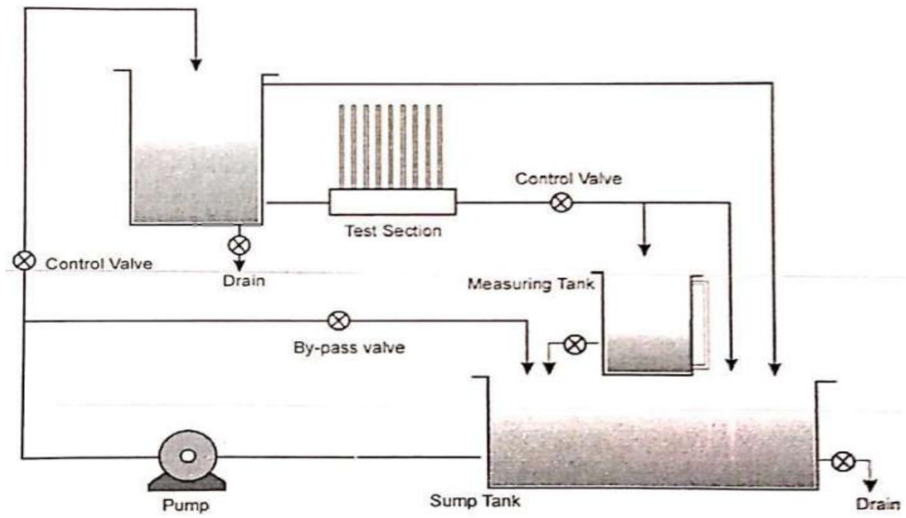
Bernoulli's Theorem is a fundamental principle in fluid mechanics that describes the behaviour of a flowing incompressible and frictionless fluid. It relates the **pressure energy, kinetic energy,** and **potential energy** of the fluid at different points along a streamline. Bernoulli's equation states 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. 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

$$\frac{P}{\rho g} + \frac{V^2}{2g} + Z = H = constant$$

pressure head **velocity head** **static head** **total head**

DESCRPTION:

The present experimental set-up for Bernoulli's Theorem is a self-contained, re-circulating unit. The set-up includes the sump tank, constant head tank, centrifugal pump for water lifting, measuring tank, and other components. A control valve and by-pass valve are provided to regulate the flow of water in the constant head tank. A conduit, made of Perspex and having varying cross-sections (converging and diverging), is provided. Piezometer tubes are fitted on this test section at regular intervals. The inlet of the conduit is connected to the constant head tank. At the outlet of the conduit, a valve is provided to regulate the flow of water through the test section. After achieving steady-state flow, the discharge through the test section can be measured using the measuring tank and a stopwatch.



Schematic Diagram for Bernoulli's Apparatus

EXPERIMENTAL PROCEDURE:

Starting Procedure:

1. Clean the apparatus and ensure that all tanks are free from dust and debris.
2. Close all the drain valves provided in the system.
3. Fill the sump tank up to ¾ of its capacity with clean water, ensuring no foreign particles are present.
4. Close the Flow Control Valve located at the end of the test section.
5. Open the Flow Control Valve and By-Pass Valve on the water supply line to the Overhead Tank.
6. Ensure all ON/OFF switches on the control panel are in the OFF position.
7. Switch ON the main power supply (220 V AC, 50 Hz).
8. Start the pump to initiate water flow.
9. Regulate the water flow through the test section using the Gate Valve provided at the outlet end.
10. Measure the flow rate by collecting water in the Measuring Tank and recording the time using a Stopwatch.

Closing Procedure:

1. After completing the experiment, switch OFF the pump.
2. Turn off the power supply to the control panel.
3. Drain the water from all tanks using the provided drain valves.

DATA, FORMULEA, ONSERVATIONS & CALCULATIONS:

Data

T(s) : Time taken for the liquid level to rise by 10 cm in the measuring tank
Q : Volumetric Flow Rate (m^3/s)
h_1 : Height of mercury column in the left limb
h_2 : Height of mercury column in the right limb
$h = h_1 - h_2$ Difference in height of mercury columns, used to calculate pressure difference
f_F : Fanning Friction Factor
a : Section Area (m^2)
$P/\rho g$: Pressure head (m)
$V^2/2g$: Velocity Head (m)
A (Area of collecting tank) = 0.1 m^2
R (Rise of liquid level in the collecting tank) = 10 cm
ρ_m (Density of manometric fluid, e.g., mercury) = 13600 kg/m^3
ρ_w (Density of working fluid, e.g., water) = 1000 kg/m^3
g (Acceleration due to gravity) = 9.81 m/s^2

OBSERVATION TABLE:

S.No	**calculating Q**			**Section**	**Distance from Reference Point (S) (m)**	**Section Area (a) (m^2)**	**Piezometer Height ($P/\rho g$) (cm)**	
	Rise (R) (cm)	**Time (T) (s)**	**Flowrate (Q) (m^3/s)**					
1.	10			1.	0.03	6.1707×10^{-4}		
				2.	0.07	5.0074×10^{-4}		
				3.	0.11	4.1620×10^{-4}		
				4.	0.15	3.3329×10^{-4}		
				5.	0.19	2.7172×10^{-4}		
				6.	0.23	3.3006×10^{-4}		
				7.	0.27	4.2273×10^{-4}		
				8.	0.31	5.1794×10^{-4}		
				9.	0.35	6.4063×10^{-4}		

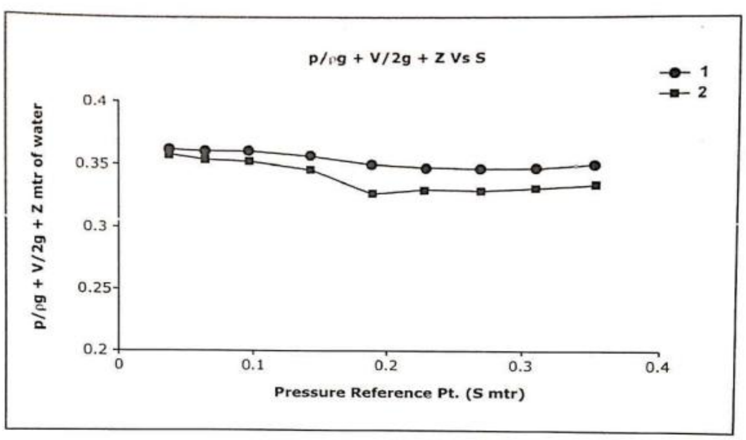
CALCULATION TABLE:

S.No	Flow rate Q = A*R/T (m^3/s)	Section	Section Area (a) (m^2)	Distance (S) (m)	Pressure Head ($P/\rho g$) (cm)	Calculating V & $V^2/2g$		Total Head ($P/\rho g + V^2/2g$) (cm)
						Velocity (V=Q/a) (cm/s)	Velocity Head ($V^2/2g$) (cm)	
1.		1.	6.1707×10^{-4}	0.03				
		2.	5.0074×10^{-4}	0.07				
		3.	4.1620×10^{-4}	0.11				
		4.	3.3329×10^{-4}	0.15				
		5.	2.7172×10^{-4}	0.19				
		6.	3.3006×10^{-4}	0.23				
		7.	4.2273×10^{-4}	0.27				
		8.	5.1794×10^{-4}	0.31				
		9.	6.4063×10^{-4}	0.35				

RESULTS:

Plot the graph between total head and distance for three different flow rates.

Sample Plot-Total Energy Line (TEL) vs. distance along the flow path:



Total Energy Line (TEL) vs. distance along the flow path

PRECAUTIONS & MAINTENANCE INSTRUCTIONS:

1. Do not run the pump at low voltage, i.e., less than 180 Volts.
2. Never fully close the delivery line valve and the by-pass line valve simultaneously.
3. Always keep the apparatus clean and free from dust.
4. To prevent clogging of moving parts, run the pump at least once every fortnight.
5. Grease or oil the rotating parts once every three months.
6. Always use clean water in the system.
7. If the apparatus is not going to be used for more than one month, drain the water completely and fill the pump with cutting oil to prevent rusting.

EXPERIMENT - 4

LOSSES DUE TO PIPE FITTINGS

LOSSES DUE TO PIPE FITTINGS

AIM:

The objective of this experiment is to measure the head loss caused by different pipe fittings—such as bends, valves, expansions, and contractions—and to calculate the associated loss coefficients (K-values) using observed flow parameters.

INTRODUCTION AND THEORY:

When fluid flows through changes in cross-section, elbows, valves, or fittings, minor losses occur. In long pipelines, major (frictional) losses dominate and minor losses are often negligible. However, in short pipelines, minor losses become significant and must be considered for accurate analysis.

In fluid systems, pipe fittings and valves play a critical role in influencing the overall flow dynamics, and their contribution to minor losses due to changes in flow direction, cross-sectional area, and flow obstructions must be carefully considered. The type and configuration of these fittings significantly impact the energy dissipation in the form of head loss. A smooth bend, for example, allows for a gradual change in the flow direction, which minimizes the occurrence of turbulence and results in relatively low head loss. This type of bend facilitates a more stable transition for the fluid, reducing the likelihood of flow separation and energy dissipation. On the other hand, a 90° bend causes a sharp redirection of the fluid flow, which leads to significant flow separation, increased turbulence, and consequently, a higher energy loss. The abrupt change in direction creates swirling vortices and eddies, which contribute to additional pressure drop and head loss. Comparatively, a 45° elbow provides a gentler change in direction than a 90° bend, which results in lower turbulence and, therefore, a reduction in the associated head loss. This makes 45° elbows a preferable option when minimizing friction losses is a priority.

Additionally, the configuration of pipe fittings like T-joints and changes in pipe diameter also influences head loss. A T-joint, where flow splits or merges at a right angle, creates substantial turbulence as the flow abruptly changes direction and volume. This turbulence leads to significant pressure loss and a corresponding increase in head loss. Similarly, when there is a sudden expansion in the pipe diameter, the flow decelerates and separates, resulting in the formation of eddies or vortex structures that increase energy dissipation and cause a rise in head loss. Sudden contractions in the pipe diameter, on the other hand, force the flow to contract into a smaller cross-section, creating a phenomenon known as "vena contracta," where the velocity of the fluid increases, but at the cost of generating localized turbulence and energy loss. In both cases of sudden expansion and contraction, the overall efficiency of the system is reduced, and energy is lost due to these disturbances in flow. A union fitting, used to connect two pipes, can introduce slight misalignment in the flow path, creating localized resistance that leads to minor but still significant head loss.

Valves, as key components in controlling and regulating flow, also contribute significantly to minor losses in fluid systems. A gate valve, when fully open, allows near full-bore flow, causing minimal resistance to the fluid and resulting in only a small head loss. However, when partially closed, the gate valve creates turbulence in the flow as the water is forced to pass through a smaller opening. This disruption of the flow leads to significant pressure drop and an increase in head loss. In contrast, a globe valve, which is designed specifically for throttling or regulating flow, forces the fluid to navigate a tortuous and complex path through the valve. Even when fully open, this convoluted path generates high levels of turbulence and pressure loss, making globe valves a significant source of head loss in a fluid system. Unlike gate valves, which cause head loss primarily when throttled, globe valves consistently contribute to pressure drop due to their restrictive internal geometry. Understanding the impact of these fittings and valves is crucial for accurate flow and pressure drop calculations, especially in complex piping systems where efficient energy use is essential for optimal performance.

Head loss due to various fittings follows the order from least to greatest as

Smooth Bend < Union < Gate Valve (Open) < 45° Elbow < Contraction < Expansion < T-Joint < 90° Bend < Gate Valve (Partially Closed) < Globe Valve

DESCRIPTION:

The experimental setup consists of a ½-inch bend and elbow, a sudden expansion from ½" to 1", and a sudden contraction from 1" to ½", along with a ½" ball valve and a gate valve. Pressure tapings are provided at appropriate locations at the inlet and outlet of these fittings to measure the pressure difference. A differential manometer is used to determine the head loss caused by each fitting. Water is supplied to the pipeline by a centrifugal pump that draws water from a sump tank. The flow of water through the pipe is regulated using a control valve and a bypass valve. Discharge is measured using a measuring tank and stopwatch, allowing for accurate calculation of flow rate and the associated head losses across various fittings.

EXPERIMENTAL PROCEDURE:

Starting Procedure

1. Clean the apparatus and ensure all tanks are free from dust.
2. Close the provided drain valve.
3. Fill the sump tank up to ¾ level with clean water, ensuring no foreign particles are present.
4. Close all flow control valves on the water line and open the bypass valve.

5. Check the level of the manometric fluid in the tube.
6. Close all pressure taps of the manometer connected to the pipes.
7. Ensure the panel's on/off switch is in the "OFF" position.
8. Switch on the main power supply (220 Volts AC, 50 Hz).
9. Switch on the pump.
10. Operate the flow control valve to regulate the flow of water in the desired test section.
11. Slowly open the pressure taps of the manometer/test section to avoid sudden fluid surge.
12. Open the air release valve on the manometer to release trapped air.
13. Once all air is removed, close the air release valves.
14. Adjust the water flow rate using the control valve.
15. Record the manometer reading.
16. Measure the flow of discharged water using a stopwatch and measuring tank.
17. Repeat the procedure for different flow rates by operating the control valve and bypass valve.
18. After completing tests on one section, open the bypass valve, close the tested section's valve, and open the valve for the next section.
19. Repeat the same procedure for the new test section.

Closing Procedure

1. Close all manometer pressure taps after completing the experiment.
2. Switch off the pump.
3. Switch off the power supply.

DATA:

T(s)	:	Time taken for the liquid level to rise by 10 cm in the measuring tank
Q	:	Volumetric Flow Rate (m^3/s)
h_1	:	Height of mercury column in the left limb
h_2	:	Height of mercury column in the right limb
$h = h_1 - h_2$	:	Difference in height of mercury columns
H_L	:	Head loss (in meters of water)
K_L	:	Loss Coefficient
V	:	Velocity of fluid in the pipe (m/s)
a	:	Cross-sectional area of the pipe (m^2)

A (Area of collecting tank)	=	0.1 m^2
R (Rise of liquid level in the collecting tank)	=	10 cm
ρ_m (Density of manometric fluid, e.g., mercury)	=	13600 kg/m^3
ρ_w (Density of working fluid, e.g., water)	=	1000 kg/m^3
g (Acceleration due to gravity)	=	9.81 m/s^2

OBSERVATION TABLE:

Type of fitting	Valve position	Manometer Reading			R (cm)	T (s)
		h_1 cm	h_2 cm	h= h_1-h_2 (cm)		
Smooth bend	Full open				10	
	½ open				10	
t-joint	Full open				10	
	½ open				10	
45^0 elbow	Full open				10	
	½ open				10	
Expansion	Full open				10	
	½ open				10	
Contraction	Full open				10	
	½ open				10	
union	Full open				10	
	½ open				10	
Gate valve	Full open				10	
	½ open				10	
90^0 bend	Full open				10	
	½ open				10	
Globe valve	Full open				10	
	½ open				10	

CALCULATION TABLE:

Type of fitting	Valve position	$H_L =$ h $((\rho_m/\rho_w) - 1)$ (m)	Q= (A*R)/T (m^3/s)	V= Q/a_p	Loss Coefficient (K_L) Formula	Calculate K_L
Smooth bend	Full open				$K_L = \frac{H_L}{V^2/2g}$	
	½ open					
t-joint	Full open				$K_L = \frac{H_L}{V^2/2g}$	
	½ open					
45^0 elbow	Full open				$K_L = \frac{H_L}{V^2/2g}$	
	½ open					
Expansion	Full open				$K_L = \frac{H_L}{(V_1 - V_2)^2/2g}$	
	½ open					
Contraction	Full open				$K_L = \frac{H_L}{\frac{V^2}{2g} * (\frac{1}{C_c} - 1)^2}$	
	½ open					
union	Full open				$K_L = \frac{H_L}{V^2/2g}$	
	½ open					
Gate valve	Full open				$K_L = \frac{H_L}{V^2/2g}$	
	½ open					
90^0 bend	Full open				$K_L = \frac{H_L}{V^2/2g}$	
	½ open					
Globe valve	Full open				$K_L = \frac{H_L}{V^2/2g}$	
	½ open					

PRECAUTIONS & MAINTENANCE INSTRUCTIONS:

1. Do not run the pump at low voltage (i.e., below 180 Volts).
2. Never fully close both the delivery line valve and the bypass line valve at the same time.
3. Keep the apparatus clean and free from dust at all times.
4. To prevent clogging of moving parts, run the pump at least once every fortnight.
5. Grease or oil all rotating parts regularly, at least once every three months.
6. Always use clean water in the system.
7. If the apparatus is not in use for more than one month, drain it completely and fill the pump with cutting oil for preservation.

EXPERIMENT - 5

FLOW THROUGH PACKED BED

FLOW THROUGH PACKED BED

AIM:

1) To calculate the pressure drop per unit length of bed.
2) To plot modified friction factor vs modified Reynolds number on a log-log plot.
3) To verify Ergun's equation.

INTRODUCTION AND 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 passes through the 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.

Ergun's equation is used to estimate the pressure drop for flow of fluid through a packed bed.

$$\frac{\Delta P}{L} = \frac{150 * \mu * (1-\varepsilon)^2 * V}{\varepsilon^3 * {D_P}^2 * {\varphi_s}^2} + \frac{1.75 * \rho * (1-\varepsilon) * V^2}{\varepsilon^3 * D_P * \varphi_s}$$

Kozeny-Carman equation + Burke-Plummer equation

(Laminar flow) (Turbulent flow)

where,

$\Delta h = h_2 - h_1$, m is manometer reading.
ε = porosity, volume of voids / total volume of the bed
$V =$ the superficial velocity of fluid through packed bed calculated as Q/A,
A = cross-sectional area of column unit
Q = volumetric flow rate
D_P = equivalent diameter of the particle (packing)
φ_s = sphericity of the particle, defined as $\varphi_s = \frac{6V_P}{S_P D_P}$

V_P = volume of a single particle
S_P = surface area of a single particle

The friction factor in the bed is given by Kozeny-Carman equation:

$$f_P = \frac{\Delta P}{L}\frac{\varepsilon^3}{(1-\varepsilon)}\frac{(\varphi_s\, D_P)}{\rho V^2}$$

The modified Reynolds number is defined as:

$$N_{Re} = \frac{(\varphi_s\, D_P) * V * \rho}{\mu}\frac{1}{(1-\varepsilon)}$$

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 rotameter. 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. Note down the manometer reading and volumetric flow rate.
7. Calculate friction factor, modified Reynolds number and pressure drop per unit length.
8. Draw the graph.

DATA:

Diameter of the Packed column (D)	=	0.05 m
Length of the Packed column (L)	=	0.75 m
Particle (packing) diameter D_p	=	12.5 mm
Sphericity, φs for Raching ring	=	1
Density of Manometer fluid ρ_m	=	13,600 kg/m^3 (Mercury)
Density of flowing fluid ρ	=	1000 kg/m^3 (Water)

OBSERVATION TABLE:

S. No.	Manometer Reading			Volumetric flow rate, Q (Rotameter reading LPM)
	h_1 (cm)	h_2 (cm)	$h = h_1 - h_2$ (cm)	
1.				
2.				
3.				
…..				
10.				

CALCULATION TABLE:

S. No	Experimental $\frac{\Delta P}{L} = h * g * (\rho_m - \rho)/L$	Calculated (Ergun equation) $\frac{\Delta P}{L}$	flow rate, Q (m^3/s)	Superficial velocity, V = Q/A (m/s)	Modified Reynolds number N_{Re}	Friction factor, f_P
1						
2						
3.						
…						
10						

RESULTS:

1. Ergun's equation is verified.
2. Relation for friction factor and modified Reynolds number (plot).

PRECAUTIONS & MAINTENANCE INSTRUCTIONS:

1. Never run the apparatus if power supply is less than 200 volts & more than230 volts.
2. Never close completely the control valve V1 and by pass valve V2 simultaneously.
3. To prevent clogging of moving parts, run pump atleast once in a fortnight. Always keep apparatus free from dust.

EXPERIMENT - 6

CHARACTERISTICS OF FLUIDISED BED

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.

INTRODUCTION AND THEORY:

Fluidized beds are used extensively in the chemical process industries, particularly for the cracking of high-molecular-weight petroleum fractions. Such beds inherently possess excellent heat transfer and mixing characteristics. These are devices in which a large surface area of contact between a liquid and a gas, or a solid and a gas or liquid is obtained for achieving rapid mass and heat transfer and for chemical reactions.

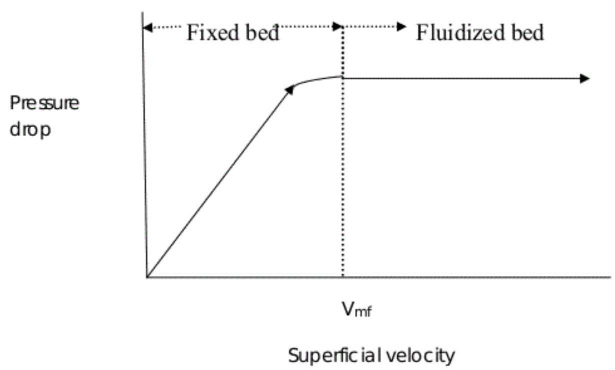


Figure: 6.1

When a fluid is admitted at the bottom of a packed bed of solids at a low flow rate, it passes upward through bed without causing any particle motion. If the particles are quite small, flow in the channels between the particles will be laminar and the pressure drop across the bed will be proportional to the superficial velocity and for turbulent situations, pressure drop across the bed increase nonlinearly with the increase in the superficial velocity. As the velocity is gradually increased, the pressure drop increases, but particles do not move and the bed height remains the same. At a certain velocity, the pressure drop across the bed counterbalances the force of gravity on the particles or the weight of the bed, and any other further increase in velocity causes the particles to move and the true fluidization begins. For a high enough fluid velocity, the friction force is large enough to lift the particles. This represents the onset of fluidization. Once the bed is fluidized pressure drop across the bed remains constant, but the bed height continues to increase with increasing flow.

Minimum fluidization velocity: It is necessary to determine a minimum flow rate allowing the particles to become fluidized, the minimum fluidization velocity (V_m). This is the minimum superficial fluid velocity required for the fluidization to occur. It can be obtained by setting the pressure drop across the bed equal to the weight of the bed per unit area of cross section.

Ergun's equation is used to estimate the pressure drop for flow of fluid through a packed bed.

$$\frac{\Delta P}{L} = \frac{150 * \mu * (1-\varepsilon)^2 * V}{\varepsilon^3 * {D_P}^2 * {\varphi_s}^2} + \frac{1.75 * \rho * (1-\varepsilon) * V^2}{\varepsilon^3 * D_P * \varphi_s}$$

For very small particles ($Re_P < 1$), only laminar flow term of the Ergun's equation is significant. At the onset of fluidization, the pressure drop across the bed equals the weight of bed per unit area of cross section.

$$\frac{\Delta P}{L_m} = g * (\rho_s - \rho) * (1 - \varepsilon_m)$$

The minimum fluidization velocity is defined as:

$$\frac{150 * \mu * (1-\varepsilon_m) * V_m}{{\varepsilon_m}^3 * {D_P}^2 * {\varphi_s}^2} = g * (\rho_m - \rho)$$

The minimum fluidization velocity becomes:

$$V_m = \frac{g(\rho_s - \rho){D_P}^2 \, {\varphi_s}^2}{150 * \mu} \frac{{\varepsilon_m}^3}{(1-\varepsilon_m)}$$

ε = porosity, volume of voids / total volume of the bed

ε_m = Bed-void fraction at minimum fluidization

$V =$ the superficial velocity of fluid through packed bed calculated as Q/A,

$V_m =$ minimum fluidization velocity

$L =$ bed height,

A = cross-sectional area of column

Q = volumetric flow rate

D_P = equivalent diameter of the particle (packing)

φ_s = sphericity of the particle, defined as $\varphi_s = \frac{6V_P}{S_P D_P}$

V_P = volume of a single particle

S_P = surface area of a single particle

EXPERIMENTAL 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 V_m and draw the graph of $\Delta P/L$ versus V and ε versus V.

DATA:

Diameter of the Packed column (D)	=	0.05 m
Packing diameter D_p	=	4 mm
Shape factor, φ_s	=	1
Density of Manometer fluid, ρ_m	=	1500 kg/m^3 (CCl_4)
Density of flowing fluid, ρ	=	1000 kg/m^3 (water)
Viscosity of water, μ	=	1×10^{-3} N-sec/m^2

OBSERVATION TABLE:

Observe V_m and L_m from experiments, when the fluidization starts.

S. No.	Manometer Reading			Volumetric flow rate, Q (Rotameter reading LPM)	Bed height (cm)
	h_1 (cm)	h_2 (cm)	$h = h_1 - h_2$ (cm)		
1.					
2.					
3.					
…..					
10.					

CALCULATION TABLE:

Calculate ΔP and L_m from experiments, when the fluidization starts, and calculate minimum void fraction using-

$$\frac{\Delta P}{L_m} = g * (\rho_s - \rho) * (1 - \varepsilon_m)$$

S. No	Experimental $\Delta P = h * g * (\rho_m - \rho)$	Bed height, L (cm)	porosity $\varepsilon = 1 - \frac{L_m}{L} * (1 - \varepsilon_m)$	Superficial velocity, V = Q/A (m/s)	V_m
1					
2					
3					
…					
10					

RESULT:

1. Plot pressure drop, porosity and bed height vs Superficial velocity.
2. The theoretical and actual minimum fluidized velocities are compared.
3. Ergun's equation is to be verified.

PRECAUTIONS & MAINTENANCE INSTRUCTIONS:

- Ensure clean and uniform particle size.
- Avoid sudden changes in air/water flow.
- Ensure no air leakage in connections.
- Do not exceed the maximum flow rate**.**
- Take readings at steady state.

EXPERIMENT – 7

RECIPROCATING PUMP TEST RIG

RECIPROCATING PUMP TEST RIG

AIM:

To study the performance characteristics of a reciprocating pump and to determine the characteristic with maximum efficiency.

INTRODUCTION AND THEORY:

In general, a pump may be defined as mechanical device when connected in a pipe line, can convert the mechanical energy into hydraulic energy, thus resulting in the flow of liquid from lower potential to higher potential. The types of pumps vary in principle and design. The selection of the pump for any particular application is to be done by understanding their characteristics. The most commonly used pumps for domestic, agricultural and industrial are Centrifugal, reciprocating, axial flow (stage pumps), air jet, diaphragm and turbine pumps. Most of these pumps fall mainly into a class namely rotodynamic, reciprocating (positive displacement) and fluid operated pumps.

Reciprocating pump is a positive displacement pump. It mainly consists of a piston reciprocating inside a cylinder thus performing suction and delivery strokes. The cylinder is alternately filled and emptied by forcing and drawing the liquid by mechanical motion. This type is called positive type.

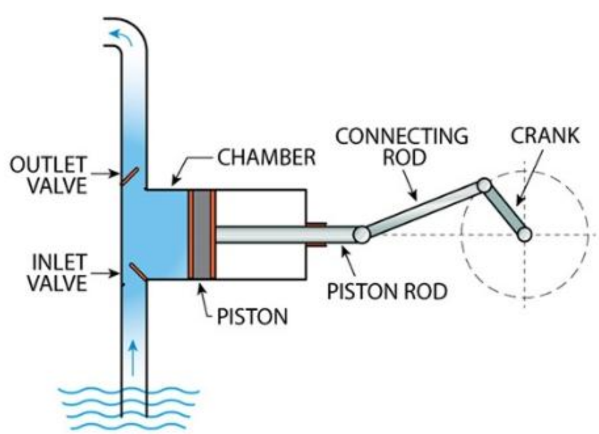


Figure: Schematic of reciprocating pump

Delivery and suction pipes are connected to a cylinder. Each of the two pipes is provided with a non-return valve. The function of which is to ensure unidirectional flow of liquid. It generally operates at low speed and is therefore to be coupled to a motor with V-belt. Reciprocating pumps are used in applications requiring high pressure and precise flow, such as in the oil and gas industry for drilling and pumping, industrial water treatment, and high-pressure cleaning like water blasting and sewer line cleaning.

DISCRIPTION:

The Reciprocating pump test rig mainly consists of:

a) Reciprocating pump
b) AC Drive motor of suitable capacity coupled
c) SS sump tank, SS measuring tank with a piezometer
d) G.I. Pipe connections with necessary control valve
e) The panel board is equipped with an energy meter for measurement of power input to the motor, a digital RPM indicator to indicate the speed of the pump, a Vacuum gauge to measure suction head, a pressure gauges for measurement of delivery head. a three-phase starter of suitable capacity, main indicating lamps and fuses.

EXPERIMENTAL PROCEDURE:

1. Prime the pump close the delivery valve and switch on the unit
2. Open the delivery valve and maintain the required delivery head.
3. Note down the reading and note the corresponding suction head reading
4. Close the drain valve and note down the time taken for 10 cm rise of water level in collecting tank
5. Measure the area of collecting tank
6. For different delivery tubes, repeat the experiment
7. For every set reading note down the time taken for 5 revolutions of energy meter disc.

DATA AND SYMBOLS:

A = area of collecting tank = 0.125 m^2

H_D = Delivery Head

H_S = Suction Head

EMC = Energy meter constant 750 rev/kWh

N = Speed of pump in RPM

H = Total Head

Q = Discharge rate

R = Rise of height in collecting tank =10 cm
t = time taken to achieve the rise R, sec
k = No of Energy meter revolutions in time, t_r sec.

OBSERVATION TABLE:

S. No.	Voltage V	Current I	Speed of Pump N (rpm)	Pressure gauge reading (Delivery pressure, P_D) (kg/cm^2)	Vacuum gauge reading (Suction pressure, P_S) (mm Hg)	R (cm)	T (s)
1.							
2.							
3.							
…							
10.							

CALCULATION TABLE:

S. No	Delivery head H_D (m of water)	Suction head Hs (m of water)	Total head H= $H_D + H_S$ (m of water)	Q = A*R/t (m^3/s)	Input power IP = V*I (kW)	Output power OP = ρ*g*Q*H (kW)	Efficiency η = OP/IP
1.							
2.							
3.							
…							
10							

Note: 1 kg/cm^2 =760 mm Hg = 10 m of Water

Total head " H " in m of wáter is:

=10*(Delivery pressure + Vacuum)

$=10^* (P_D + P_S) = H_D + H_S$

where P_D is in kg / cm^2 and P_S is in mm of Hg.

P_D =(1.032 + pressure reading)

Ps=(1.032 - (suction pressure reading * 1.33 x 10^{-3})

H (m of water) = H_D + H_S

Input power:

$$IP = \frac{\mathrm{k} * 3600}{\mathrm{EMC} * t_r} = \mathrm{V} * \mathrm{I} \qquad kW$$

Output power

$$OP = \rho * \mathrm{g} * \mathrm{Q} * \mathrm{H} \qquad kW$$

$$\text{Efficiency} = \frac{\text{output power}}{\text{input power}}$$

RESULT:

Graphs to be plotted between:

1. Discharge Vs Head
2. OP Vs Head
3. Efficiency Vs Head

PRECAUTIONS:

1. Do not operate the pump without proper priming.
2. Ensure suction line is airtight.
3. Keep delivery valve partially open before starting.
4. Prevent pump from running dry.
5. Take readings only after steady operation.
6. Ensure uniform water level in measuring tank.

EXPERIMENT- 8

CENTRIFUGAL PUMP

CENTRIFUGAL PUMP

AIM:

To conduct performance test on a Single stage Centrifugal pump test rig.

INTRODUCTION AND THEORY:

In general, a pump may be defined as mechanical device when connected in a pipe line, can convert the mechanical energy into hydraulic energy, thus resulting in the flow of liquid from lower potential to higher potential. The types of pumps vary in principle and design. The selection of the pump for any particular application is to be done by understanding their characteristics. The most commonly used pumps for domestic, agricultural and industrial are Centrifugal, reciprocating, axial flow (stage pumps), air jet, diaphragm and turbine pumps. Most of these pumps fall mainly into a class namely rotodynamic, reciprocating (positive displacement) and fluid operated pumps.

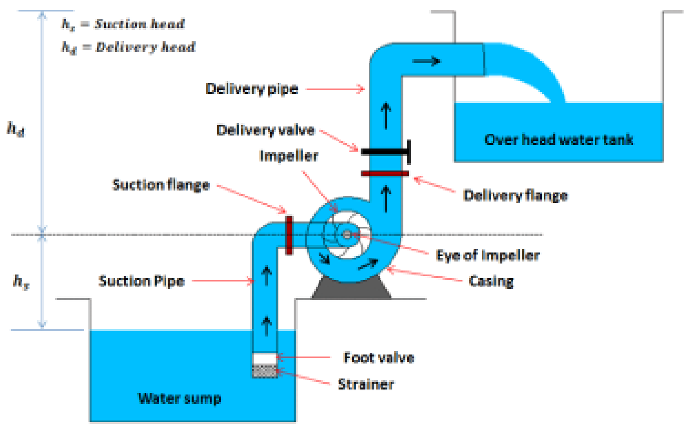


Figure: Schematic of centrifugal pump

The principle of operation of a single stage centrifugal pump is covered under Rotodynamic pump category. In this pump, the liquid is made to rotate in a closed volute chamber. Thus creating the centrifugal action, which gradually builds the pressure gradient towards outlet resulting in a continuous flow. These pumps are of simple construction can be directly coupled to electric motor and more suitable for handling clear, semi viscous, as well as turbid liquids.

The hydraulic head per stage at low flow rates is limited and hence not suitable for high heads, in case of single stage centrifugal pumps. But as the pump in this case in a multi stage construction the pressure gradually builds up in successive stages almost equally in each stage. Thus, achieving considerably higher heads. The multi stage centrifugal pump test rig allows to understand and study the various characteristics and pressure build up pattern in individual stages. The present test rig allows the students to understand and draw the operating characteristics at various heads, flow rates and speeds.

DISCRIPTION:

The centrifugal pump test rig mainly consists of:

a) Centrifugal pump
b) AC Drive motor of suitable capacity coupled
c) SS sump tank, SS measuring tank with a piezometer
d) G.I. Pipe connections with necessary control valve
e) The panel board is equipped with an energy meter for measurement of power input to the motor, a digital RPM indicator to indicate the speed of the pump, a Vacuum gauge to measure suction head, a pressure gauges for measurement of delivery head.

EXPERIMENTAL PROCEDURE:

1. Clean the apparatus and make all tanks free from dust.
2. Close the drain valve provided.
3. Open flow control valve given on the water discharge.
4. now switch on the main power supply 220 V AC , 50 Hz.
5. Operate the flow control valve to regulate the flow of water.
6. Set the desired RPM of motor/ Pump.
7. Operate the control valve to regulate the suction of pump.
8. Record discharge pressure by means of pressure gauge.
9. Record suction pressure by means of suction gauge.
10. Measure the discharge by measuring tank by using stop watch.
11. Repeat the same procedure for different speed.

DATA AND SYMBOLS:

A = area of collecting tank = 0.125 m^2
H_D = Delivery Head
H_S = Suction Head
EMC = Energy meter constant 750 rev/kWh
N = Speed of pump in RPM

H = Total Head
Q = Discharge rate
R = Rise of height in collecting tank =10 cm
t = time taken to achieve the rise R, sec
k = No of Energy meter revolutions in time, t_r sec.

OBSERVATION TABLE:

S. No.	Voltage V	Current I	Speed of Pump N (rpm)	Pressure gauge reading (Delivery pressure, P_D) (kg/cm^2)	Vacuum gauge reading (Suction pressure, P_S) (mm Hg)	R (cm)	T (s)
1.							
2.							
3.							
…							
10							

CALCULATION TABLE:

S. No	Delivery head H_D (m of water)	Suction head Hs (m of water)	Total head H= $H_D + H_S$ (m of water)	Q = A*R/t (m^3/s)	Input power IP = V*I (kW)	Output power OP = ρ*g*Q*H (kW)	Efficiency η = OP/IP
1.							
2.							
3.							
…							
10							

Note: 1 kg/cm^2 =760 mm Hg = 10 m of Water

Total head " H " in m of wáter is:

=10*(Delivery pressure + Vacuum)

$=10*(P_D + P_S) = H_D + H_S$

where P_D is in kg / cm^2 and P_S is in mm of Hg.

$P_D = (1.032 + \text{pressure reading})$

$P_s = (1.032 - (\text{suction pressure reading} * 1.33 \times 10^{-3})$

H (m of water) = $H_D + H_S$

Input power:

$$IP = \frac{\mathrm{k} * 3600}{\mathrm{EMC} * t_r} = \mathrm{V} * \mathrm{I} \qquad kW$$

Output power

$$OP = \rho * \mathrm{g} * \mathrm{Q} * \mathrm{H} \qquad kW$$

$$\text{Efficiency} = \frac{\text{output power}}{\text{input power}}$$

<u>RESULT:</u>

Graphs to be plotted between:

1. Discharge Vs Head
2. OP Vs Head
3. Efficiency Vs Head

<u>PRECAUTIONS:</u>

1. Do not operate the pump without proper priming.
2. Ensure suction line is airtight.
3. Keep delivery valve partially open before starting.
4. Prevent pump from running dry.
5. Take readings only after steady operation.

REFERENCES

S.No.	Name of Books	Authors	Publisher	Edition
1.	Fluid Mechanics	Frank M. White	McGraw-Hill Education	8th Edition, **2016**
2.	Introduction to Fluid Mechanics	Robert W. Fox, Alan T. McDonald, Philip J. Pritchard	John Wiley & Sons	9th Edition, **2015**
3.	Fluid Mechanics: Fundamentals and Applications	Yunus A. Çengel, John M. Cimbala	McGraw-Hill Education	4th Edition, **2018**
4.	Fluid Mechanics and Hydraulic Machines	R. K. Rajput	S. Chand Publishing	Revised Edition, **2016**
5.	Unit Operations of Chemical Engineering	McCabe, W.L., Smith, J.C., Harriott, P.,	McGraw-Hill	8th Edition, **2021**
6.	Fluid Mechanics and Hydraulic Machines	Raghunath H. Subramanya	Tata McGraw-Hill	4th Edition, **2013**