EXPERIMENT No.1

FLOW MEASUREMENT BY VENTURIMETER

1.1 AIM: To determine the co-efficient of discharge of the Venturimeter

1.2 EQUIPMENTS REQUIRED: Venturimeter test rig, Stopwatch

1.3 PREPARATION

1.3.1 THEORY

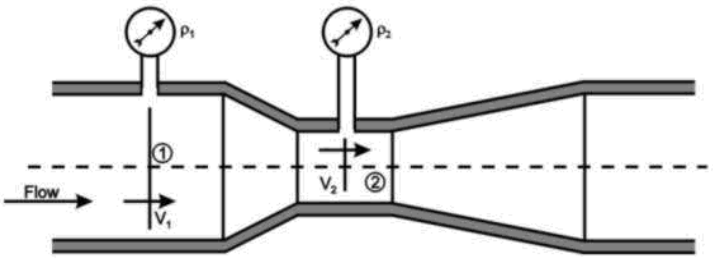


Fig.1. Venturimeter

In a Venturimeter there is first a converging section in which the cross sectional area for flow is reduced. Then there is a short section at the reduced diameter, known as the throat of the meter. Then there is a diverging section in which the cross sectional area for flow is gradually increased to the original diameter. The velocity entering the converging section is where the pressure is P1. In the converging section the velocity increases and the pressure decreases. The maximum velocity is at the throat of the meter where the minimum pressure P2 is reached. The velocity decreases and the pressure increases in the diverging section. There is a considerable recovery of pressure in the diverging section. However, because of frictional effects in the fluid, the pressure leaving the diverging section is always less than P1, the pressure entering the meter.

1.3.2 PRE-LAB QUESTIONS

1.3.2.1 Differentiate mass and volume flow rate?

1.3.2.2Which property is remains same in the incompressible flow?

1.3.2.3 What is meant by discharge?

1.3.2.4 What is the use of Venturimeter?

1.4 PROCEDURE:

1.4.1. Switch on the power supply to the pump

1.4.2. Adjust the delivery flow control valve and note down manometer heads (h1, h2) and time taken for collecting 10 cm rise of water in collecting tank (t). (i.e. Initially the delivery side flow control valve to be kept fully open and then gradually closing.)

1.4.3. Repeat it for different flow rates.

1.4.4. Switch off the pump after completely opening the delivery valve.

1.5 OBSERVATIONS

1.5.1 FORMULAE / CALCULATIONS

1.5.1.1 The actual rate of flow, $Q_a = A \times h / t$ (m^3/sec)

Where A = Area of the collecting tank = length x breadth (m^2)

h = Height of water (10 cm) in collecting tank (m),

t = Time taken for 10 cm rise of water (sec)

1.5.1.2 The Theoretical discharge through Venturimeter,

$\mathbf{Q_t} = (a_1\, a_2 \sqrt{2gH}) / \sqrt{(a_1^2 - a_2^2)}$ m^3/sec

Where, H = Differential head of manometer in m of water

$= 12.6 \times h_m \times 10^{-2}$ (m)

g = Acceleration due to gravity (9.81m/sec^2)

Inlet Area of Venturimeter in m^2, $a_1 = \pi\, d_1^2 / 4$,

Area of the throat in m^2, $a_2 = \pi\, d_2^2 / 4$

1.5.1.3 The co-efficient of discharge,

$\mathbf{C_d}$ = Actual discharge / Theoretical discharge = Q_a / Q_t

1.5.2 TABULATION:

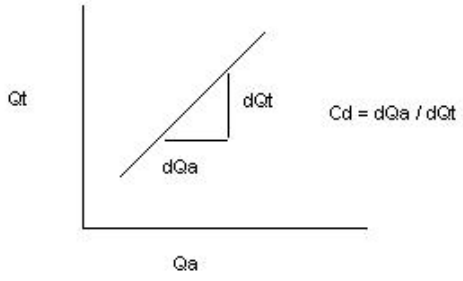
Inlet Diameter of Venturimeter (or) Diameter of Pipe d_1 = 20 or 25 mm

Throat diameter of Venturimeter d_2 = 11.83 or 14.79 mm

Area of collecting tank, A = Length x Breadth = 0.5 x 0.3 m^2

Sl. No.	Manometer Reading (cm)			Mano-meter Head H	Time for 10 cm rise T	Actual Discharge Q_a	Theoretical Discharge Q_t	Co-efficient of discharge C_d
	h_1	h_2	$h_m = h_1 \sim h_2$	m	sec	m^3/sec	m^3/sec	
1.								
2.								
3.								
4.								
5.								
Average C_d value								

1.5.3 GRAPH:



Draw Q_a Vs Q_t.

Find C_d value from the graph and compare it with calculated C_d value from table.

1.6 POST-LAB QUESTIONS

1.6.1 How do you find actual and theoretical discharge?

1.6.2 What do you meant by throat of the Venturimeter?

1.6.3 List out the practical applications of Bernoulli's equation?

1.6.4 What is the use of U-tube manometer?

1.7 INFERENCES

1.8 RESULT

The co-efficient of discharge of Venturimeter = ……. From Calculation

The co-efficient of discharge of Venturimeter = ……. From Graph

EXPERIMENT No.2

FLOW MEASUREMENT BY ORIFICEMETER

2.1 AIM: To determine the co-efficient of discharge of the orifice meter

2.2 EQUIPMENTS REQUIRED: Orifice meter test rig, Stopwatch

2.3 PREPARATION

2.3.1 THEORY

An orifice plate is a device used for measuring the volumetric flow rate. It uses the same principle as a Venturi nozzle, namely Bernoulli's principle which states that there is a relationship between the pressure of the fluid and the velocity of the fluid. When the velocity increases, the pressure decreases and vice versa. An orifice plate is a thin plate with a hole in the middle. It is usually placed in a pipe in which fluid flows. When the fluid reaches the orifice plate, with the hole in the middle, the fluid is forced to converge to go through the small hole; the point of maximum convergence actually occurs shortly downstream of the physical orifice, at the so-called *vena contracta* point. As it does so, the velocity and the pressure changes. Beyond the *vena contracta*, the fluid expands and the velocity and pressure change once again. By measuring the difference in fluid pressure between the normal pipe section and at the *vena contracta*, the volumetric and mass flow rates can be obtained from Bernoulli's equation. Orifice plates are most commonly used for continuous measurement of fluid flow in pipes. This experiment is process of calibration of the given orifice meter.

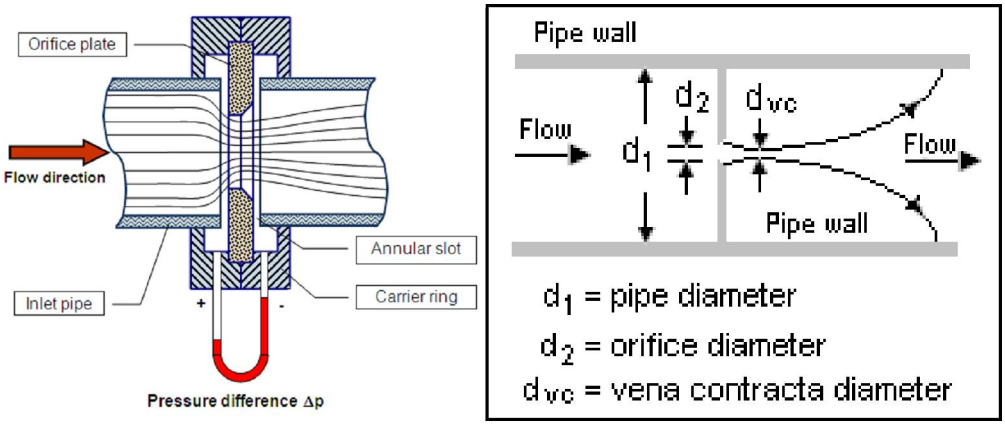


Fig.2. Orifice Plate

2.3.2 PRE-LAB QUESTIONS

2.3.2.1 Write continuity equation for incompressible flow?

2.3.2.2 What is meant by flow rate?

2.3.2.3 What is the use of orifice meter?

2.3.2.4 What is the energy equation used in orifice meter?

2.3.2.5 List out the various energy involved in pipe flow.

2.4 PROCEDURE

2.4.1 Switch on the power supply to the pump

2.4.2 Adjust the delivery flow control valve and note down manometer heads (h1, h2) and time taken for collecting 10 cm rise of water in collecting tank (t). (i.e. Initially the delivery side flow control valve to be kept fully open and then gradually closing.)

2.4.3 Repeat it for different flow rates.

2.4.4. Switch off the pump after completely opening the delivery valve.

2.5 OBSERVATIONS

2.5.1 FORMULAE / CALCULATIONS

2.5.1.1 The actual rate of flow, $Q_a = A \times h / t$ (m^3/sec)

Where A = Area of the collecting tank = length x breadth (m^2)

h = Height of water (10 cm) in collecting tank (m),

t = Time taken for 10 cm rise of water (sec)

2.5.1.2 The Theoretical discharge through orifice meter,

$\mathbf{Q_t} = (a_1\, a_2\sqrt{2gH}) / \sqrt{(a_1^2 - a_2^2)}$ m^3/sec

Where, H = Differential head of manometer in m of water

$= 12.6 \times h_m \times 10^{-2}$ (m)

g = Acceleration due to gravity (9.81m/sec^2)

Inlet Area of orifice meter in m^2, $a_1 = \pi\, d_1^2 / 4$,

Area of the throat or orifice in m^2, $a_2 = \pi\, d_2^2 / 4$

2.5.1.3 The co-efficient of discharge,

$\mathbf{C_d}$ = Actual discharge / Theoretical discharge = Q_a/Q_t

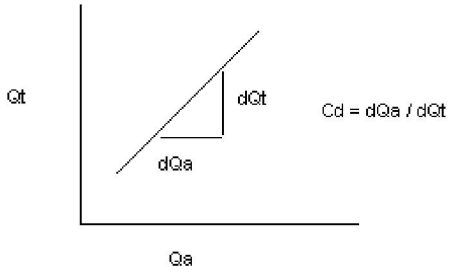
2.5.2 TABULATION

Size of Orifice meter:

Inlet Diameter d_1 = 20 or 25 mm,
Orifice Diameter d_2 = 13.41 or 16.77 mm,
Measuring area in collecting tank A = 0.5 x 0.3 m^2

Sl. No.	Manometer Reading (cm)			Manometer Head H	Time for 10 cm rise T	Actual Discharge Q_a	Theoretical Discharge Q_t	Co-efficient of discharge C_d
	h_1	h_2	$h_m = h_1 \sim h_2$	m	sec	m^3/sec	m^3/sec	
1.								
2.								
3.								
4.								
5.								
							Average C_d value	

2.5.3 GRAPH:



Draw Q_a Vs Q_t.

Find C_d value from the graph and compare it with calculated C_d value from table.

2.6 POST-LAB QUESTIONS

2.6.1 How do you find actual discharge?

2.6.2 How do you find theoretical discharge?

2.6.3 What do you meant by co-efficient of discharge?

2.6.4 Define vena-contracta?

2.6.5 List out the Bernoulli's applications.

2.7 INFERENCES

2.8 RESULT

The co-efficient of discharge of orifice meter = ……. From Calculation

The co-efficient of discharge of orifice meter = ……. From Graph

EXPERIMENT No.3

VERIFICATION OF BERNOULLIS THEOREM

3.1 AIM: To verify the Bernoulli's theorem

3.2 EQUIPMENTS REQUIRED: Bernoulli's Theorem test set-up, Stopwatch

3.3 PREPARATION

3.3.1 THEORY

Bernoulli's Theorem

According to Bernoulli's Theorem, in a continuous fluid flow, the total head at any point along the flow is the same. $Z_1 + P_1/\rho g + V_1^2/2g = Z_2 + P_2/\rho g + V_2^2/2g$, Since Z1 –Z2 = 0 for Horizontal flow, $h_1 + V_1^2/2g = h_2 + V_2^2/2g$ (Pressure head, $h = P_1/\rho g$). Z is ignored for adding in both sides of the equations due to same datum for all the positions.

3.3.2 PRE-LAB QUESTIONS

3.3.2.1 State Bernoulli's theorem?

3.3.2.2 What is continuity equation?

3.3.2.3 What do you meant by potential head?

3.3.2.4 What do you meant by pressure head?

3.3.2.5 What do you meant by kinetic head?

3.4 PROCEDURE

3.4.1 Switch on the pump power supply.

3.4.2 Fix a steady flow rate by operating the appropriate delivery valve and drain valve

3.4.3. Note down the pressure heads ($h_1 – h_7$) in meters

3.4.4. Note down the time taken for 10 cm rise of water in measuring (collecting) tank.

3.4.5. Switch off the power supply.

3.5 OBSERVATIONS

3.5.1 FORMULAE / CALCULATIONS

3.5.1.1 Rate of flow $Q = Ah/t$.

Where A: Area of measuring tank = Length x Breadth (m^2)

h: Rise of water in collecting tank (m) .. (i.e. h = 10 cm)

t: Time taken for 10 cm rise of water in collecting tank (sec)

3.5.1.2 Velocity of flow, V = Q/a,

Where a – Cross section area of the duct at respective piezometer positions ($a_1 – a_7$)

3.5.1.3 Hydraulic Gradient Line (HGL): It is the sum of datum and pressure at any point

HGL = Z + h

3.5.1.4 Total Energy Line (TEL): It is the sum of Pressure head and velocity head

TEL = Z + h +$V^2/2g$

3.5.2 TABULATIONS

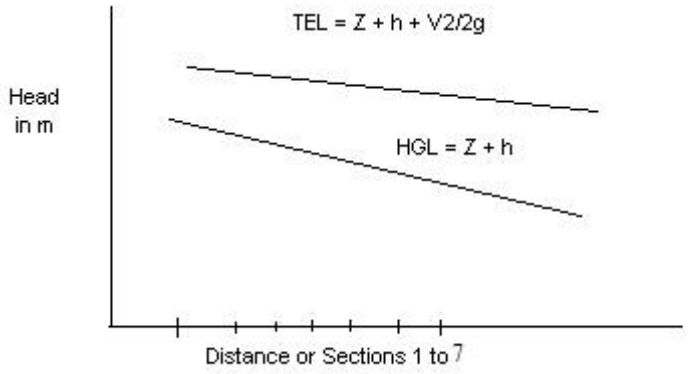
Area of measuring tank = 0.3 x 0.3 m^2

Assume Datum head Z = 0

Dimension at the section of the channel		***Cross - sectional Area a = h x b***	***Time for 10 cm rise t***	***Discharge Q=Ah/t***	***Velocity V=Q/a***	***Velocity Head $V^2/2g$***	***Piezometer Reading i.e. Pr. Head (H=P/ρg)***	***Total Head Z +H+ $V^2/2g$***
(h) $x10^{-3}$ m	(b) $x10^{-3}$ m	$x10^{-6}$ m^2	sec	m^3/sec	m/sec	m	$x10^{-2}$m	M
35	20							
32.5	20							
30	20							
25	20							
22.5	20							
18.5	20							
14	20							

3.5.3 GRAPH

Draw the graph: Distance of channel (Locations 1-7) Vs HGL, TEL



3.6 POST-LAB QUESTIONS

3.6.1 What do you meant by velocity head?

3.6.2 What do you meant by HGL?

3.6.3 What do you meant by datum head?

3.6.4 What is the use of piezometer?

3.6.5 Define TEL?

3.6.6 What is the reason for the slight decrease in the total energy head between the successive locations in the duct?

3.7 INFERENCES

3.8 RESULT

The Bernoulli's theorem is verified.

Ex.No: **Date:**

FLOW MEASUREMENT USING ROTAMETER

AIM

To determine the coefficient of discharge of rotameter.

THEORY

The most important area meter is rotameter. It consists of a gradually tapered glass tube mounted vertically in a frame with the large end up. The fluid flows upward through the tapered tube and suspends freely a float. The float is the indicating element, and the greater the flow rate, the higher the float rides in the tube. The entire fluid stream must flow through the annular space between the float and the tube wall. The tube is marked in divisions, and the meter is read from the scale reading at the edge of the float. Rotameters are used for both liquid and gas flow measurements.

PROCEDURE

- The motor is switched on.
- The water is allowed to flow through the inlet valve.
- The flow rate of water is fixed using the float present in the rotameter.
- Collect the outlet water in the collection tank and note the time taken for 10cm rise of water level in the collection tank.
- Repeat the same procedure for different flow rates.

FORMULAE

1.Actual discharge, $Q_{act} = \frac{\text{volume of water collected}}{\text{time taken}} = \frac{LBH}{t}$

L = Length of the collection tank,m

B = breadth of the collection tank,m

H = Rise of water in the collection tank,m

t = Time taken for the rise of water,s

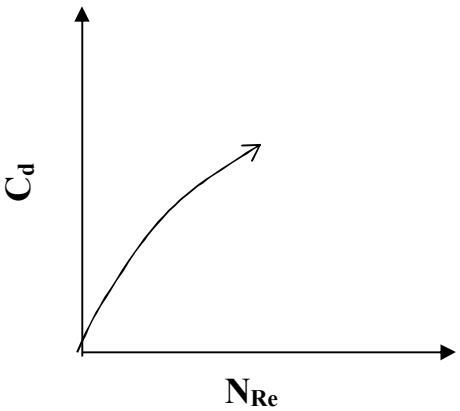
2. Theoretical discharge, Q_{th} = Rotameter reading

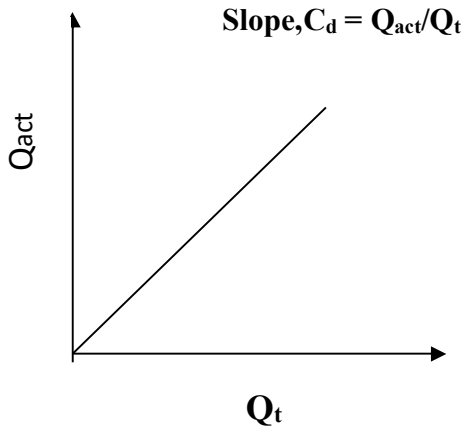
3. Coefficient of discharge, $C_d = \frac{Q_{act}}{Q_{th}}$

TABLE

S.No	Rotameter reading, (m)	Time taken for 10cm rise of water level,s (s)	Volume of water collected, (m^3)	Theoretical discharge, Q_{th}, (m^3/s)	Actual discharge, Q_{act}, (m^3/s)	Coefficient of discharge, C_d

MODEL GRAPH





RESULT

The discharge coefficient of rotameter was calculated and required graphs were plotted. The discharge coefficient, C_d was found to be (graphically) _____

Viscosity

Aim:

To verify Stoke's law and hence to determine the coefficient of viscosity of a highly viscous liquid.

Apparatus and Accessories:

A glass cylinder of about 5 cm (or more) in diameter and about 100 cm in length**,** few spherical metal balls of diameters ranging from 1 to 3 mm, stop watch, screw gauge, meter scale, experimental liquid.

Formula Used :

Coeffficent of viscosity of experimental liquid (glycerine) is given by

$$\eta = \frac{2}{9}\frac{(\rho - \sigma)gr^2}{v}$$

σ = density of glycerine.
ρ = density of material of ball.
r = radius of spherical ball.
g = acceleration to gravity.
ν = terminal velocity.

Where, η is the coefficient of viscosity of fluid, ρ and σ represent respectively the density of the material of the ball and that of the fluid, and g is the acceleration due to gravity and is the radius of the ball falling in the experimental liquid.

Theory:

When a spherical ball of (radius r) is dropped in a viscous field it moves in it with certain velocity 'ν' (say) it experiences an opposing force(viscous force F_d). According to Stoke's law this viscous force is given by

$$F_d = 6\pi\eta r v$$

Simultaneously it experiences an upthrust (or buoyant force) F_b and gravitational force F_g. F_g tries to increase the velocity of ball whereas F_d decreases the velocity. After some time the ball will move with a steady velocity, called the terminal velocity. Under the steady condition.

$$F_g = F_b + F_d$$

Or

$$F_d = F_g - F_b$$

$$6\pi\eta r v = \frac{4}{3}\pi r^3(\rho - \sigma)g$$

Or,

$$\eta = \frac{2}{9}\frac{(\rho - \sigma)gr^2}{v}, \qquad (1)$$

where ρ and σ represent respectively the density of the material of the ball and that of the fluid, and g is the acceleration due to gravity.

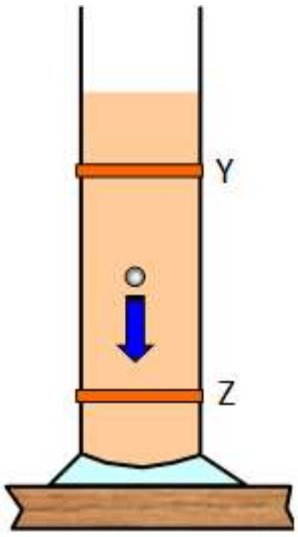
In actual practice the experiment is performed in a liquid column of finite depth H contained in a cylinder of inner radius R. To take into account the effect of the finite depth and radius of the liquid column two corrections, known as Ladenburg corrections, are introduced as multipliers of the observed velocity 'v'. Thus the terminal velocity v is given by

$$v = v'(1 + \frac{2.4r}{R})(1 + 3.3\frac{r}{H}) \ , \qquad (2)$$

where the first correction term accounts for the finite radius of the liquid column and the second correction term is used for the finite depth of the liquid column. The relations (1) and (2) are the working formulae of the experiment.

In SI units, the radii r and R are expressed in m, H in m, v' in m/s, the densities ρ and σ in kg/m^3. And g in m/s^s. Then h is obtained in N.s/m^2 or Poiseulle (PI).

The relation (1) is deduced from Stoke's law and indicates that for a given liquid at a given temperature the ratio r^2/v should be a constant. Thus, the verification of Stoke's law requires that a graph of r^2 along the x-axis and 'v' along the y-axis should be a straight line. By using a value of r^2/v from this graph and measuring all other physical parameters appearing on the right-hand side of Eq.(1), the coefficient of viscosity η of the liquid can be determined.



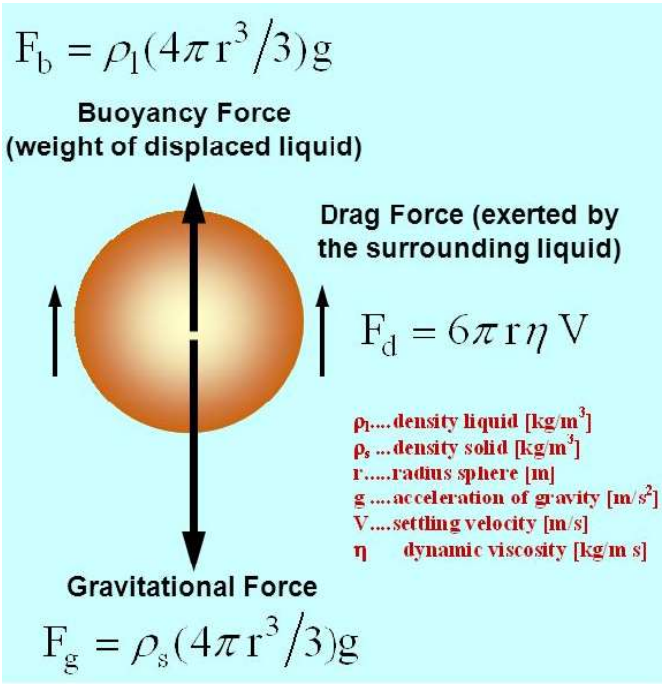


Fig. 1 The glass cylinder with the liquid

Procedure:

1. Measure the inner diameter of the cylinder at various places by slide calipers. Fin the mean diameter (2R) and hence the radius (R) of the cylinder.

2. Select three sets of balls; measure the diameter (2r) and hence the radius (r) of each ball by screw gauge. If the balls are very small, use a microscope for the measurement of the radius.

3. Set the cylinder vertically on a stand and pour the experimental liquid slowly. Measure the height H of the liquid column by a meter scale. Put horizontal marks Y and Z on the outer surface of the cylinder.

4. Wet the balls thoroughly in the experimental liquid and then drop one ball from each set gently one by one starting from the largest size with the help of a spatula into the liquid in the cylinder so that they fall centrally. For each ball, note the times of crossing of the distances Y and Z by a stop watch. Note the reading in Table 2.

5. After adjusting the positions of the markings Y and Z, drop the balls of one set gently again one by one and note by a stop watch the time taken by each ball in crossing the marks Y and Z. Measure the distance YZ by a meter scale and obtain the terminal velocity (v') by dividing the distance by the mean time for a set of balls. Repeat this procedure for the other sets.

6. Calculate v from v', r, R and H. Find the value of r^2/v for each set of balls. The constancy of this value for all the sets proves the validity of Stoke's law.
7. Also draw a graph by putting r^2(in m^2) along the x-axis and v (in m/s) along the y-axis. This will be a straight line passing through the origin. This nature of the graph also proves the validity of Stoke's law.
8. Find the value of r^2/v corresponding to a point on the graph sufficiently removed from the origin and calculate the viscosity η of the liquid using Eq. (1).

Observations:

Inner radius of Cylinder (R) = 1.44 cm
Distance between Y and Z (H) = 60 cm
Density of material of balls (ρ) = 7.8 gm/cm^3
Density of liquid (σ) = 1.26 gm/ cm^3

Table 1: For radii 'r' of the balls

Least count of screw gauge ……..

No. of sets	Diameter (2r) of the ball (cm)					Mean r (cm)
	Ball numbers	m.s. (cm)	Vernier scale (v.d. × v.c.)	Total (cm)	Mean (cm)	
1	1 2 3	… … …	… … …	… … …	…	…

	etc.					
2					…	…
etc.					…	…

Table 2: Measurement of v' and determination of v

Length of the middle portion of the liquid column (YZ), l = … cm

No. of sets	Ball numbers	Mean radius, r (cm) from Table 1	Time of fall (sec.)	Mean time, t (sec.)	Observed velocity v' (= l/t) (cm/sec.)	Corrected $v = v'(1+2.4\frac{r}{R})\times(1+3.3\frac{r}{H})(cm/\sec.)$
1	1 2 3 etc.	…	… … … etc.	…	…	….
2	1 2 3 etc.	…	… … … etc.	…	…	….
etc.	1 2 3 etc.	…	… … … etc.	…	…	….

Table 3:

Verification of Stoke's law and determination of η

g= …m/s^2

No. of sets	Mean radius r (cm)	Value of r^2 (m^2)	Value of v from Table 2 (m/s)	r^2/v (m.s)	r^2/v from graph (m.s)	$\eta = \frac{2}{9}(\rho-\sigma)g(r^2/v)(N.s/m^2)$
1	…	…	…	…	…	….
2	…	…	…	…		
3	…	…	…	…		

Result:

1. The graph of r^2 along the x-axis and v along the y-axis is found to be a straight line hence Stoke's law is verified.
2. Viscosity of experimental liquid (glycerine) is …..

Computation and percentage error:

We have from eqs. (1) and (2)

$$\eta = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{v'K},$$

Where $K = (1+2.4\frac{r}{R})(1+3.3\frac{r}{H})$

Or, $$\eta = \frac{1}{18}.\frac{D^2}{l}.\frac{(\rho-\sigma)gt}{K},$$

Since $v' = \frac{l}{t}$ and $r=\frac{D}{2}$, where D is the diameter of a ball.

Hence the proportional error in η is

$$\frac{\delta\eta}{\eta} = \frac{2\delta D}{D'} + \frac{\delta(\rho-\sigma)}{\rho-\sigma} + \frac{\delta t}{t} + \frac{\delta l}{l} + \frac{\delta K}{K}.$$

Since the values of l, R and H are fairly large and the values of ρ and σ can be determined fairly accurately, the contributions of $\frac{\delta(\rho-\sigma)}{\rho-\sigma}, \frac{\delta l}{l}$ and $\frac{\delta K}{K}$ to the total proportional error in η are very small and can be neglected. Therefore the percentage error in η is given by

$$\frac{\delta\eta}{\eta}\times 100 = 2\frac{\delta D}{D'}\times 100 + \frac{\delta t}{t}\times 100.$$

This indicates that maximum care should be taken to measure D, i.e., 2r and t in the measurement of η. Use the least count of the screw gauge and the value of the smallest division of the stop watch to calculate $\frac{\delta\eta}{\eta}\times 100$.

Precautions:

1. The radii of the spheres must be measured very accurately since r occurs in the expression of η in the second power. When the balls are very small, a microscope should be used to measure their radii.

2. Before the balls are dropped into the liquid of the cylinder ensure that they are wetted thoroughly in the experimental liquid; otherwise a layer of air surrounding each ball will affect the result.

3. Since the viscosity changes rapidly with the temperature of the liquid, care should be taken to maintain the temperature of the liquid constant during the experiment.

4. As an error in the measurement of t contributes much to the proportional error in η, care should be taken to measure it as accurately as possible.

5. When the size and the number of the balls are small, determine ρ by dividing mass by volume of the balls; otherwise, a large error in the measurement of ρ by the specific gravity bottle will occur.

Ex.No. **Date:**

PARTICLE SIZE ANALYSIS BY SIEVE ANALYSIS

AIM:

To determine the average particle size of a given mixture by different methods.

THEORY:

Sieve analysis is one of the most important methods for accessing the size of the mineral particles. The test sieves used in the sieve analysis are made of bronze or steel wire drawn to a very close tolerances and are woven into a screen cloth with standardized square aperture or openings of various size. One of the standard screen series is Tyler standard screen series. This set of screens is based on the opening of the 200mesh screen, which is established at 0.074mm. The area of the openings in any one screen in the series is exactly twice that of the openings in the next smaller screen is $\sqrt{2}$. There are different methods of plotting the sieve analysis data. The most widely used are given below.

PROCEDURE:

- 200 grams of the sample was taken after proper sampling.
- Set of sieves were arranged
- Sieves were placed in a sieve shaker.
- Sieve shaker was operated for 20 minutes by setting the time switch.
- After shaking process the particles present in each sieve were weighed.
- The results were tabulated.

FORMULAE:

Differential analysis:

1. Volume surface mean diameter , $\overline{D_s} = \dfrac{1}{\sum_{i=1}^{x} \left(X_i / \overline{D_{pi}} \right)}$

2. Mass mean diameter , $\overline{D_w} = \sum_{i=1}^{x} x_i \overline{D_{pi}}$

3. Volume mean diameter, $\overline{D_V} = \left[\dfrac{1}{\sum_{i=1}^{x} \left(X_i / \overline{D_{pi}}^3 \right)} \right]^{\frac{1}{3}}$

Cumulative analysis:

Plot a graph of 1/Dpi vs ϕ

TABLE

S. no	**Mesh No.**	**Size of screen opening Dpi (mm)**	**Average diameter, $\overline{D}_{pi}$ (mm)**	**Mass retained (g)**	**Mass fraction, Xi**	**Cumulative Mass fraction ϕ**	$\frac{x_i}{\overline{Dp_i}}$ **mm^{-1}**	$x_i.\overline{D_{Pi}}$ **mm**	$\frac{x_i}{\overline{Dp_i^3}}$ **mm^{-3}**	$\frac{1}{Dp_i}$ **mm^{-1}**
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

RESULT:

By Differential analysis

Volume surface mean diameter = …….mm

Mass mean diameter = …….mm

Volume mean diameter = …….mm

By cumulative analysis:

Average Particle size =……...mm

Ex.No. Date:

SIZE REDUCTION BY USING BALL MILL

AIM:

To determine the size reduction ratio and critical speed by conducting an experiment in a ball mill.

THEORY:

Ball mill is a tumbling mill (grinder) type size reduction equipment. It has a cylindrical Shell slowly rotating about a horizontal axis and filled to about half of its volume with balls which act as a grinding medium. It can be operated batch-wise or continuously.

In ball mill most of the size reduction is done by impact as the balls drop from near the top of the Shell. When the mill is rotated, the balls are picked up by the mill wall and carried nearly to the top, where they break contact with the wall and fall to the bottom to be picked up again. Centrifugal force keeps the balls in contact with the wall and with each other during upper movement. While in contact with the wall the balls do some grinding by slipping and rolling over each other, but most of the grinding occurs at the zone of impact.

If the speed of the mill is too high the balls are carried over and the mill is said to be centrifuging. The minimum speed at which centrifuging occurs is called the critical speed. Little or no grinding is done when a mill is centrifuging and operating speed must be less than the critical speed.

PROCEDURE:

- About 500g of feed was weighed.
- The Average size of the feed was determined by volume displacement method.
- The sample was put into the ball mill.
- The ball mill was then set into rotation.
- After 15 min, motor was stopped and the product was removed from the mill.
- The product from the mill was sieved using set of sieves to find the average product size.
- The product present in each sieve was weighed.
- The results were tabulated.
- The size reduction ratio was calculated.
- After noting the radius of the mill and the ball, critical speed of the ball mill was calculated.

OBSERVATION:

Weight of sample =…… …….gm

No.of stones, n = …….

Initial volume of water =……cm^3

Volume of water after adding stones =……cm^3

Increase in volume of water =…… ……cm^3

TABLE 1.

S. No	Mesh No.	Size of screen opening D_{pi} (mm)	Average diameter, $\overline{D}_{pi}$ (mm)	Mass retained (g)	Mass fraction, x_i	Cumulative Mass fraction, ϕ	$x_i / \overline{D}_{pi}$ mm^{-1}
1							
2							
3							
4							
5							
6							
7							
8							
9							
					ΣXi =		$\Sigma(Xi/\overline{D}_{pi}$ =

FORMLAE:

1. **Volume displacement method:**

   Increase in volume of water = $n\,x\left(\frac{4}{3}\right)x\,\pi\,x\,r^3$ =…… ……cm^3

   r = …….. mm

   Average size of the feed, D_{sa} = …….. mm

2. **(i) By Differential analysis :**

   Product size, $D_{sb} = 1 / \sum(xi / \overline{D}_{pi})$, mm

   Where, xi = mass fraction retained on the i^{th} increment

   $\overline{D}_{pi}$ = average size of particle retained on the i^{th} increment

   Size reduction ratio =Average feed size /average product size

3. Critical speed of a ball mill , $n_c = \frac{1}{2\pi}x\sqrt{\frac{g}{R-r}}$

   Where

   g = Acceleration due to gravity

   R= mill radius

   r = ball radius

RESULT:

	Product size, (mm)	Size reduction ratio
By Differential analysis		

Critical speed of the ball mill = …….. rpm

Ex.No. Date:

BATCH SEDIMENTATION

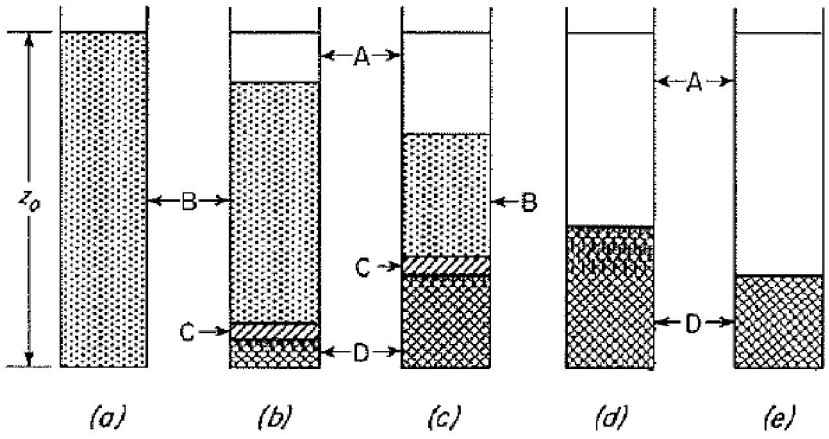
AIM:

To study the settling characteristics of slurry and to determine the area of the continuous thickener required to concentrate the slurry from a concentration of ----g/l at the rate of 10,000m^3/day using kynch theory.

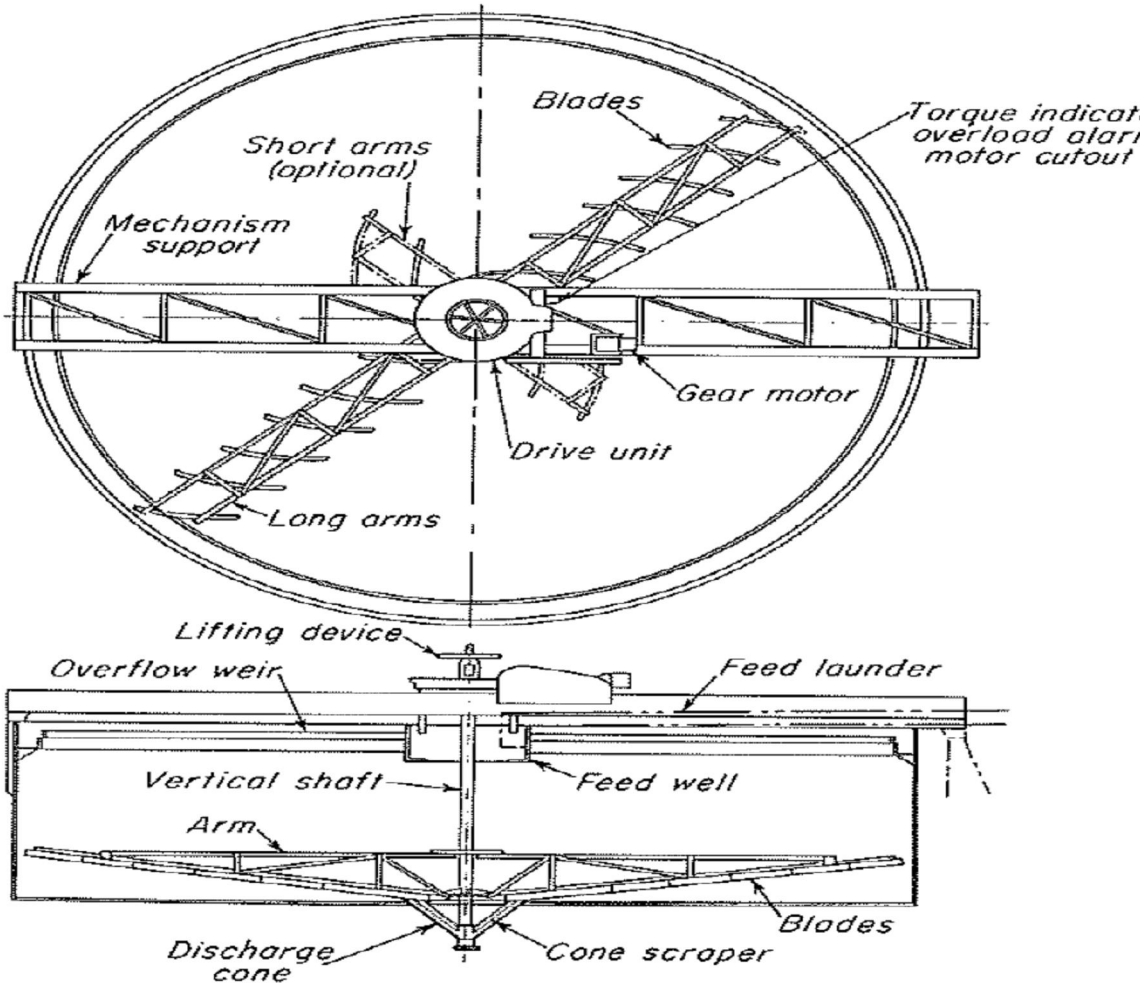
THEORY:

The separation of slurry by gravity settling into a clear fluid and slurry of higher solids content is called sedimentation. The mechanism of sedimentation may be best described by observation of what occurs during a batch settling test as solids settle from slurry in a glass cylinder. Gravity settling under hindered settling conditions is often used to convert dilute slurry of fine particles into a clarified liquid and a concentrated suspension. This process is carried out in large open tanks called thickeners or clarifiers. The thickener design is generally based on measurements of the settling rates obtained from batch tests in the laboratory.

There are several stages in the settling of a flocculates suspension and different zones are formed as the sedimentation proceeds. Usually, the concentration of solids is high enough that the sedimentation of individual particles or flocs is hindered by other solids to such an extent that all the solids at a given level settle at common velocity. At first, the solid is uniformly distributed in the liquid. After sometime, the solids have settled to give a zone of clear liquid, zone A and a zone D of settled solids. Above zone D is a transition layer, zone C, in which the solids content varies from that in the original pulp to that in zone D. In zone B, the concentration is uniform and equal to the original concentration, since the settling rate is the same throughout this zone. The boundaries between zones D and C and between C and B may not be distinct, but the boundary between zones A and B is usually sharp. As settling continues, the depths of zones D and A increase. The depth of zone C remains nearly constant, and that of zone B decreases. Eventually zone B disappears and all the solids are in zones C and D. Meanwhile, the gradual accumulation of solids put stress on the material at the bottom, which compresses solids in layer D. Compression breaks down the structure of the flocs or aggregates, and liquid is expelled into the upper zones. Sometimes liquid in the flocs spurts out of zone D. Finally, when the weight of the solid is balanced by the compressive strength of the flocs, the settling process stops. The entire process is called sedimentation.



BATCH SEDIMENTATION

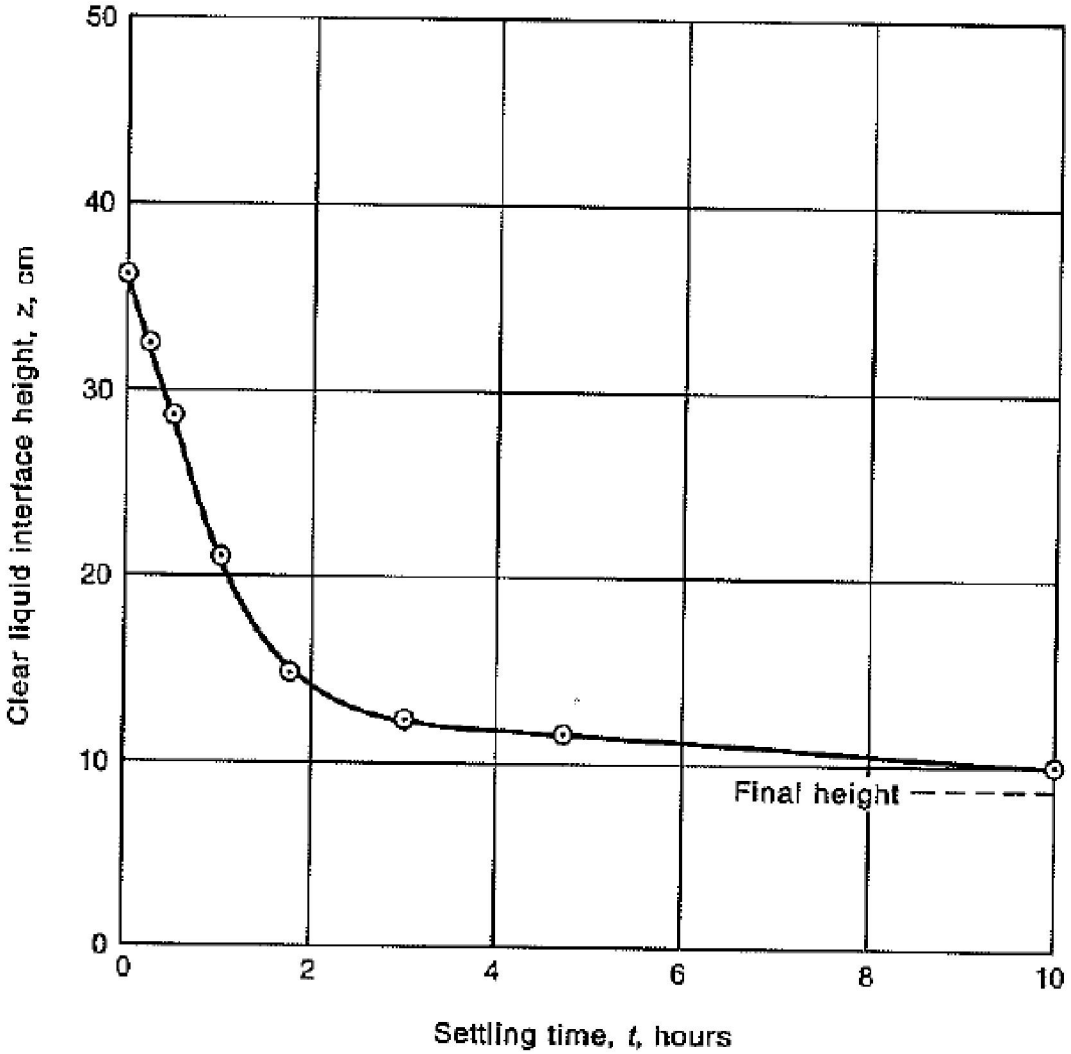


GRAVITY THICKENER

PROCEDURE:

- Required concentration of $CaCO_3$ slurry was prepared and kept in a measuring cylinder which is graduated in cm.
- The slurry was stirred well.
- Stirring was stopped and the height of interface was noted, for every 2 min time interval.
- The readings of height and time were tabulated.
- A plot of height Vs time was drawn.

MODEL GRAPH:



TABLE

S.No	Height of interface, cm	Time, min	S.No	Height of interface, cm	Time, Min
1			21		
2			22		
3			23		
4			24		
5			25		
6			26		
7			27		
8			28		
9			29		
10			30		
11			31		
12			32		
13			33		
14			34		
15			35		
16			36		
17			37		
18			38		
19			39		
20			40		

Plot the graph of height of interface vs time

TABLE:2

S.No	Z_i (m)	Z_L (m)	θ_L (Sec)	$C_L = \frac{C_0 Z_0}{Z_i}$ (kg/m^3)	$V_L = \frac{Z_i - Z_L}{\theta_L}$ (m/s)	$\frac{V_L}{\left(\left(\frac{1}{C_L}\right)-\left(\frac{1}{C_U}\right)\right)}$ (kg/m^2 s)
1						
2						
3						
4						
5						

FORMULAE:

1. Slurry concentration, $C_L = \frac{C_0 Z_0}{Z_i}$, kg/m^3

2. Under flow concentration, $C_U = \frac{C_0 Z_0}{Z_U}$, kg/m^3

3. Settling velocity, $V_L = \frac{Z_i - Z_L}{\theta_L}$ L, m/Sec

4. Thickener area, $A = \frac{FC_0}{\frac{V_L}{\left(\frac{1}{C_L} - \frac{1}{C_U}\right)}}$, m^2

Where,

F = Rate of feed, m^3/s

C_0= Initial concentration, kg/m^3

C_U = under flow concentration, kg/m^3

Z_0= Initial height, m

Z_U= final height, m

V_L= Settling velocity, m/s

Plot $\frac{V_L}{\left(\frac{1}{C_L}-\frac{1}{C_U}\right)}$ vs C_L

RESULT:

The area of the continuous thickener required to concentrate the slurry from the concentration ----------g/lit at 10,000m^3/day is ---------- m^2.