DEPARTMENT OF CHEMICAL ENGINEERING

SRM INSTITUTE OF SCIENCE & TECHNOLOGY, KATTANKULATHUR

CHENGALPATTU DISTRICT, TAMILNADU – 603203

CHEMICAL ENGINEERING LABORATORY – I

SRM INSTITUTE OF SCIENCE & TECHNOLOGY

(Under Section 3 of UGC Act,1956)

SRM Nagar,KATTANKULATHUR – 603203

CHENGALPATTU DISTRICT

BONAFIDE CERTIFICATE

Reg.No.															

Certified to be the bonafide record of work done by______________________________ of ____________________________________ B.Tech Degree course in the practical ____ in **SRM Institute of Science and Technology, Kattankulathur** during the academic year ______________________

Lab Incharge

Date: **Head of the Department**

Submitted for University examination held in ___________________________________ **SRM Institute of Science and Technology, Kattankulathur.**

Date	Examiner I	Examiner II

Name: **Branch:**

Class: **Reg.No:**

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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

80% passing size =

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										

This screen scale has as its base an opening of 0.0029 in., which is the open
200-mesh 0.0021-in. wire, the standard sieve, as adopted by the National Bur
Standards.

Mesh	Clear opening, in.	Clear opening, mm	Approximate opening, in.	Wire diamet
	1.050	26.67	1	0.148
†	0.883	22.43	$\frac{7}{8}$	0.135
	0.742	18.85	$\frac{3}{4}$	0.135
†	0.624	15.85	$\frac{5}{8}$	0.120
	0.525	13.33	$\frac{1}{2}$	0.105
†	0.441	11.20	$\frac{7}{16}$	0.105
	0.371	9.423	$\frac{3}{8}$	0.092
$2\frac{1}{2}$†	0.312	7.925	$\frac{5}{16}$	0.088
3	0.263	6.680	$\frac{1}{4}$	0.070
$3\frac{1}{2}$†	0.221	5.613	$\frac{7}{32}$	0.065
4	0.185	4.699	$\frac{3}{16}$	0.065
5†	0.156	3.962	$\frac{5}{32}$	0.044
6	0.131	3.327	$\frac{1}{8}$	0.036
7†	0.110	2.794	$\frac{7}{64}$	0.0328
8	0.093	2.362	$\frac{3}{32}$	0.032
9†	0.078	1.981	$\frac{5}{64}$	0.033
10	0.065	1.651	$\frac{1}{16}$	0.035
12†	0.055	1.397		0.028

Mesh	Clear opening, in.	Clear opening, mm	Approximate opening, in.	Wire diameter, in.
14	0.046	1.168	$\frac{3}{64}$	0.025
16†	0.0390	0.991		0.0235
20	0.0328	0.833	$\frac{1}{32}$	0.0172
24†	0.0276	0.701		0.0141
28	0.0232	0.589		0.0125
32†	0.0195	0.495		0.0118
35	0.0164	0.417	$\frac{1}{64}$	0.0122
42†	0.0138	0.351		0.0100
48	0.0116	0.295		0.0092
60†	0.0097	0.246		0.0070
65	0.0082	0.208		0.0072
80†	0.0069	0.175		0.0056
100	0.0058	0.147		0.0042
115†	0.0049	0.124		0.0038
150	0.0041	0.104		0.0026
170†	0.0035	0.088		0.0024
200	0.0029	0.074		0.0021

RESULT:

By Differential analysis

Volume surface mean diameter = ...mm

Mass mean diameter = ...mm

Volume mean diameter =...................................... mm

By cumulative analysis:

80% passing size =.. mm

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Ex.No. Date:

SIZE REDUCTION BY USING JAW CRUSHER

AIM:

To determine the size reduction ratio of particles by conducting an experiment in a jaw crusher.

THEORY:

Crushers are slow speed machines for coarse reduction of large quantities of solids. The main types are jaw crushers, gyratory crushers, smooth-roll crushers and toothed-roll crushers. There are two distinct types of jaw crushers, the Blake crushers and the dodge crusher. The Blake Jaw crusher is the commonly used crusher.

In Blake Jaw crusher feed is admitted between the two jaws, set to form a V open at the top. One jaw, the fixed or anvil jaw is nearly vertical and does not move; the other, the swinging jaw reciprocates in a horizontal plane. It makes an angle of 20º to 30º with the anvil jaw. It is driven by an eccentric so that it applies great compressive force to lumps caught between the jaws. The jaw faces are flat or slightly bulged; they may carry shallow horizontal grooves. Large lumps caught between the upper pacts of the jaws are broken, drop into the narrower space below, and are recrushed the next time the jaws close. After sufficient reduction they drop out the bottom of the machine.

In the dodge crusher the moving jaw is pivoted at the bottom. The minimum movement is thus at the bottom and a more uniform product is obtained, but the tendency to choke is high, so it is not mostly used.

PROCEDURE:

- 500 grams of the sample was taken.
- The Average size of the feed was determined by volume displacement method.
- The sample was put into the crusher where it was crushed.
- The product from the crusher was sieved using set of sieves to find the average product size.
- The product present in each sieve was weighed.
- The results were tabulated.
- 1 / D_{pi} Vs ϕ graph was plotted.
- The size reduction ratio was calculated.

OBSERVATIONS:

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 :

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

FORMULAE:

1. Volume displacement method:

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

   r = ...mm

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

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

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

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

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

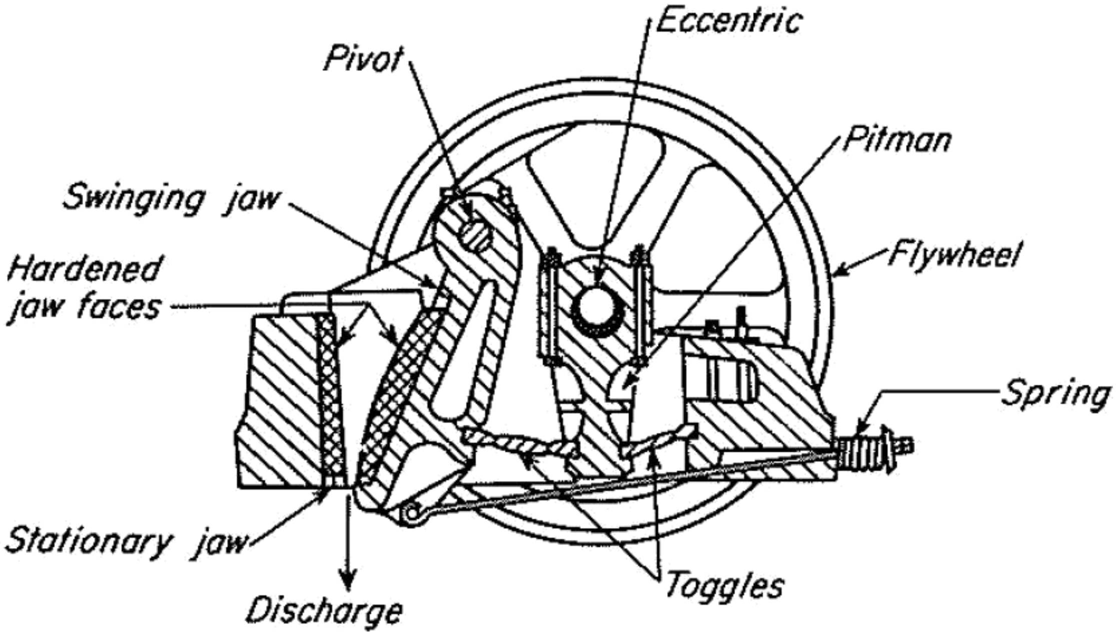
   Size reduction ratio =Average feed size /average product size

   (ii) By cumulative analysis:

   Plot the graph of $1 / \overline{D}_{pi}$ Vs ϕ

   Area under the curve from the graph ---------

   Size reduction ratio =Average feed size /average product size



BLAKE JAW CRUSHER

RESULT:

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

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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, $\bar{D}_{pi}$ (mm)	Mass retained (g)	Mass fraction, x_i	Cumulative Mass fraction, ϕ	$x_i / \bar{D}_{pi}$ mm^{-1}
1							
2							
3							
4							
5							
6							
7							
8							
9							
					$\sum Xi =$		$\sum(Xi/\bar{D}_{pi}$ =

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 ith increment

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

   Size reduction ratio =Average feed size /average product size

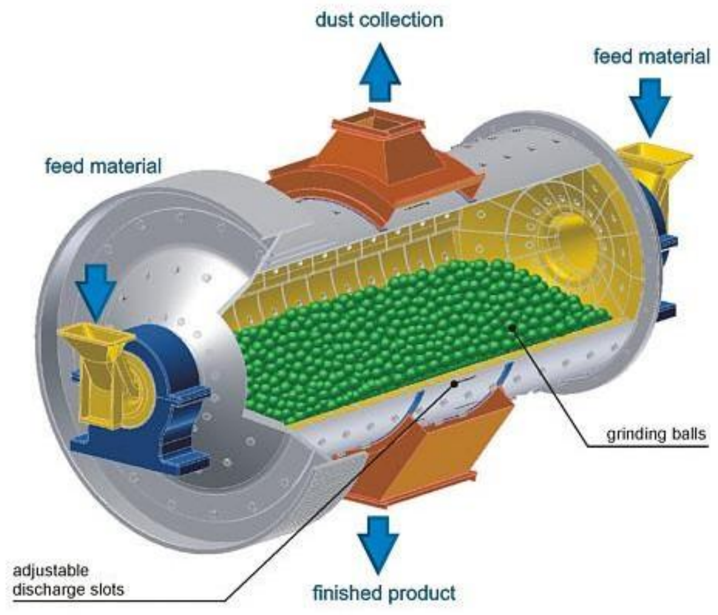
3. Critical speed of a ball mill , $n_c = \frac{1}{2\pi}\, x \sqrt{\frac{g}{R-r}}$

Where

g = Acceleration due to gravity

R= mill radius

r = ball radius


dust collection
feed material
feed material
grinding balls
adjustable
discharge slots
finished product

BALL MILL

RESULT:

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

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

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Ex.No. Date:

BATCH SEDIMENTATION

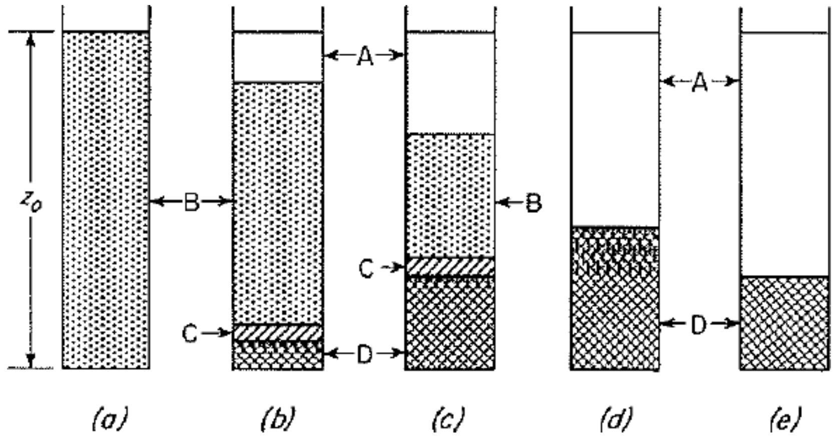
AIM:

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.

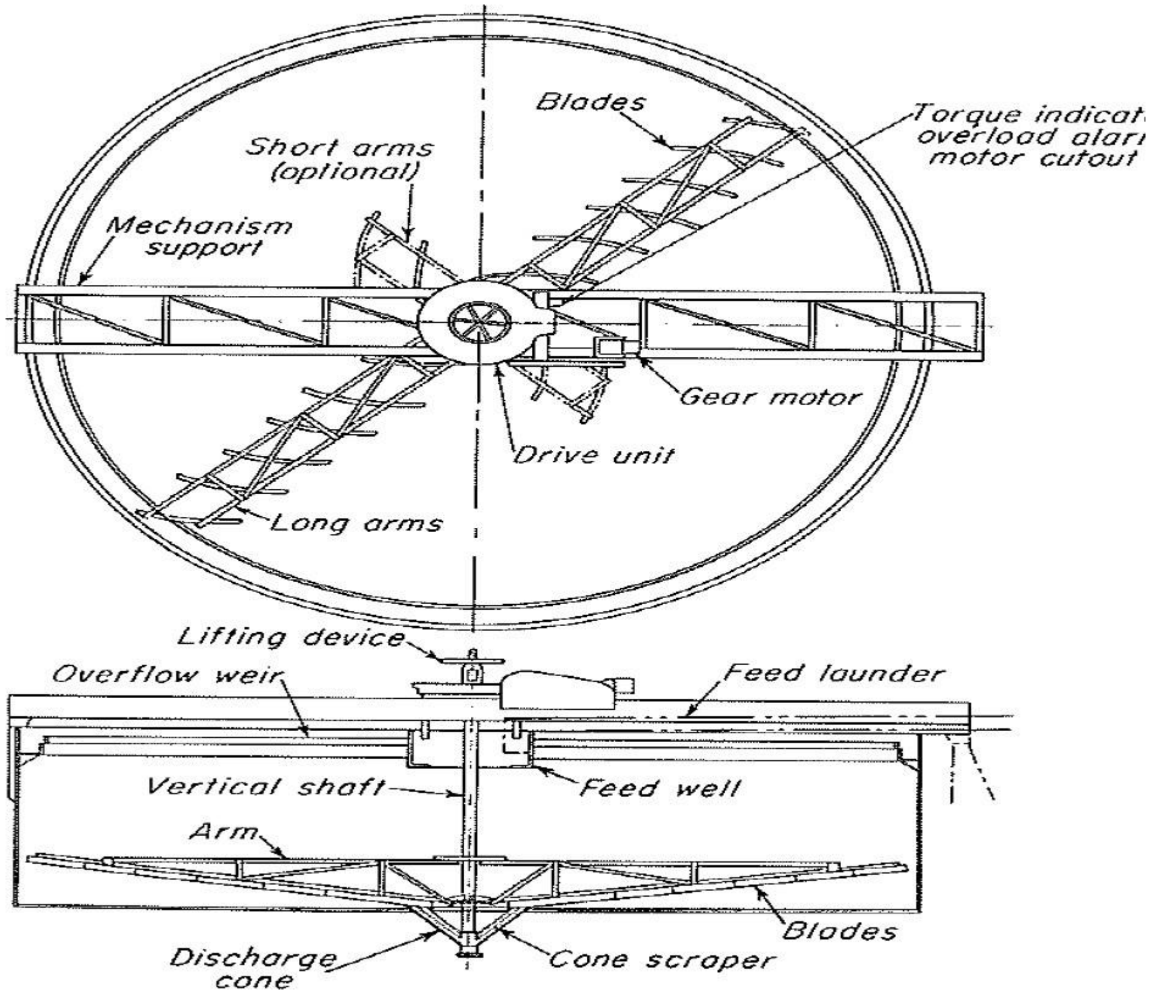
THEORY:

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

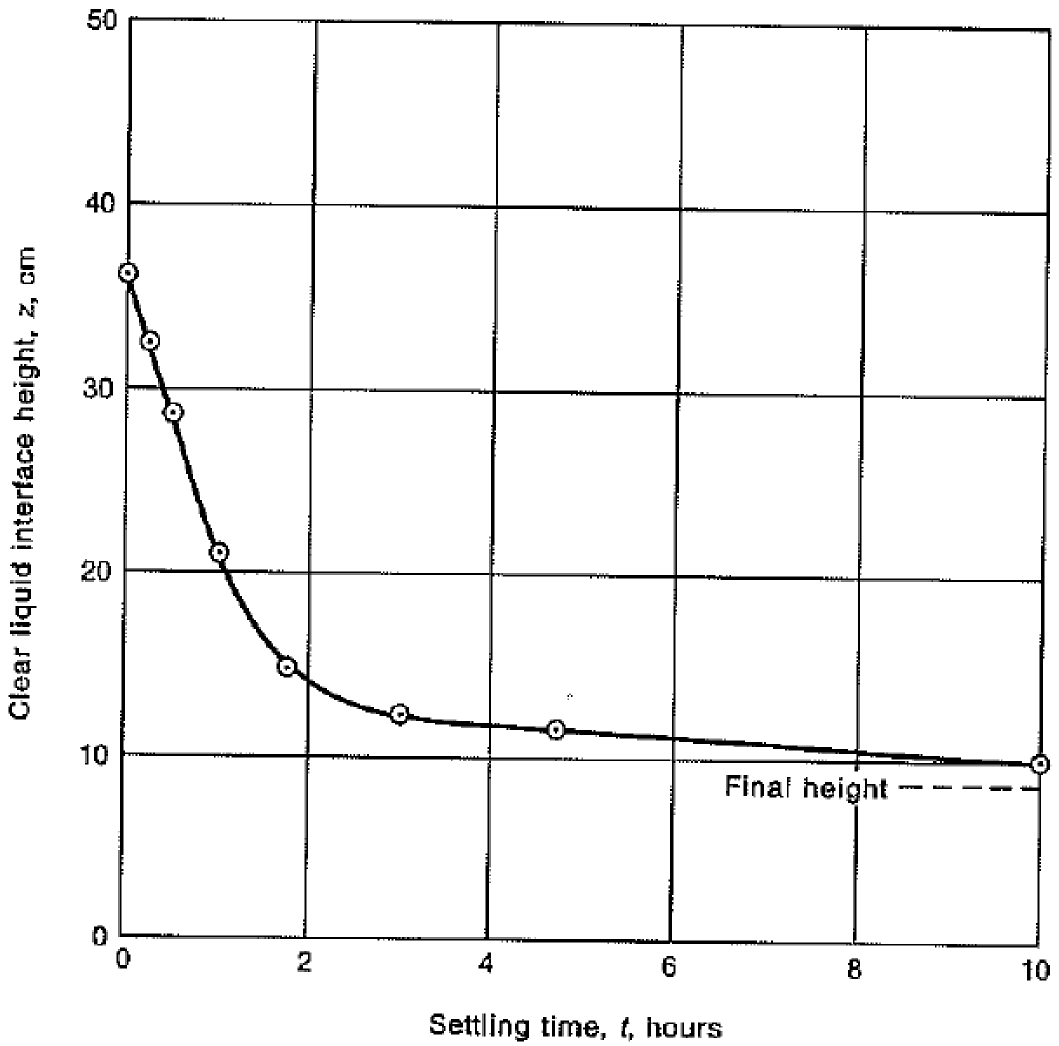


GRAVITY THICKENER

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						

<u>FORMULAE:</u>

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.

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Ex.No. **Date:**

PLATE AND FRAME FILTER PRESS

AIM:

To determine the specific cake resistance and filter medium resistance for the filtration of $CaCO_3$ slurry in a Plate and Frame Filter press.

DESCRIPTION:

The setup consists of 7 plates and 6 frames. Frames are covered with filter cloth. Feed is fed by gear pump at the top in slurry tank, and the filtrate is collected from the outlet valve. After removing cake, washing and cleaning can be done by water provided from water tank. Inlet and outlet pressure are measured by pressure gauge. Rate of filtrate collection can be measured by using the measuring tank provided.

THEROY:

Filter press is a discontinuous press consists of a set of plates designed to provide a series of compartments in which solids may collect. The plates are covered with a filter medium. Slurry is admitted into each compartment under pressure. Liquor passes through the septum and out through a discharge pipe leaving a cake of wet solids behind. Filtration is continued until liquor no longer flows out or the filtration pressure suddenly rises. This occurs when the frame is full of solid and nor more slurry can enter. The press is then said to be jammed. Wash liquid is then admitted to remove soluble impurities from the solids after which the cake is blown with steam or air to displace as much residual liquid as possible. The press is then opened and the cake of solids removed from the septum. Thorough washing in a filter press may take several hours.

PROCEDURE:

- The plates and frames were fixed properly by applying pressure through the lead screw.
- All the valves were closed.
- 10 liter of water was taken in the slurry tank and the agitator was switched on.
- The feed solution was prepared by mixing 500g of $CaCO_3$ in 10 liter of water in the slurry tank.
- The valve V_1 was opened and the pump was switched on.
- The feed solution was allowed to enter the filter press by opening the valves V_2 and bypass valve V_3.
- The inlet and outlet pressure were noted and kept constant.
- Filtrate was collected in the collection tank by opening the valve V_4.
- The height of filtrate collection in a given time was measured.
- The experiment was stopped when no more filtrate is collected.
- A sample of wet cake was taken and transferred to a weighed watch glass.

- The weight of the wet cake was noted.
- The watch glass with the cake was kept in the oven and dried and weighed again to get the weight of the dry cake.

DATA:

Area of filtrate collection tank = 0.0398 m^2
Area of frame = 0.04 m^2

FORMULAE:

1. Concentration of solid in the slurry,

$$C_s = \frac{mass\ of\ CaCO_3\ taken}{Volume\ of\ H_2O\ added}, \text{ kg/m}^3$$

2. Corrected Concentration of solid in the slurry,

$$C = \frac{C_s}{\left[1 - \left(\frac{m_f}{m_c} - 1\right)\left(\frac{C_s}{\rho}\right)\right]}, \text{ kg/m}^3$$

Where C_s = slurry concentration, kg/m^3
m_f = mass of wet cake, kg
m_c = mass of dry cake, kg
ρ = Density of filtrate, kg/m^3

3. Specific cake resistance, $\alpha = \frac{K_c \Delta P A^2}{\mu C}$, m/kg

Where K_c = slope form the graph of $\Delta t/\Delta V$ vs $\bar{V}$

ΔP = pressure, N/m^2

A = filtration area, m^2

μ = filtrate viscosity, kg/m s

C = Corrected Concentration of solid in the slurry, kg/m^3

4. Filter medium resistance, $R_m = \frac{A\Delta P\left(1/q_0\right)}{\mu}$, m^{-1}

Where $1/q_0$ = intercept from graph $\Delta t/\Delta V$ vs $\bar{V}$

TABLE 1:

S.No	Filtrate volume, V (m³)	Time, t (sec)	Δt (sec)	ΔV (m³)	$\bar{V}$ =(V1+V2)/2 (m³)	Δt/ΔV (sec/m³)

MODEL GRAPH

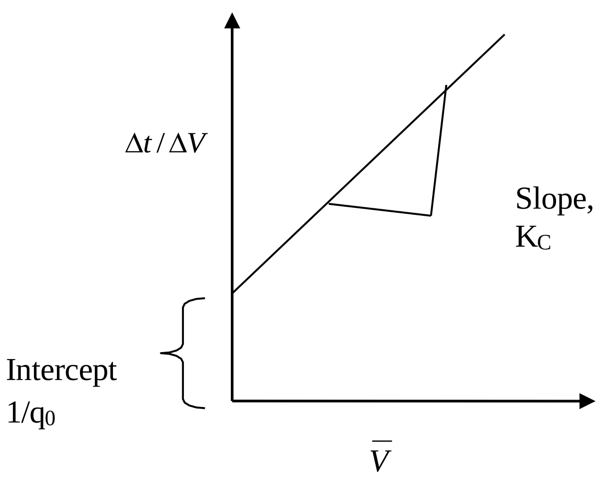


PLATE AND FRAME FILTER PRESS

RESULT:

Specific cake resistance (α) was found out to be.................................... m/kg

Filter medium resistance (R_m) was found out to be …………………….m^{-1}

Ex No. **Date:**

FLOW MEASUREMENT USING VENTURIMETER

AIM

To determine the coefficient of discharge of venturimeter.

THEORY

The venturimeter is a flow measuring device very widely used in industry. It operates on the same principle as that of the orifice meter. It differs from the orifice meter by the fact that there is a gradual variation in the cross-section so as to reduce losses due to turbulence. The head loss in the orificemeter at the same conditions as the venturimeter is many times greater. The power loss is proportionally greater and when an orifice is inserted in a line that is carrying fluid continuously for a long period of time, the cost of this power loss is more than the saving in the first cost. The venturimeter are however used only for permanent installations. The venturimeter consists of tapering sections inserted in the pipeline with the taper smooth and gradual. At a point in the line and at the throat of the venturimeter, tapings are provided which has to be connected with a manometer. The venturimeter itself is connected across the pipes for which the fluid flow is to be determined.

PROCEDURE

- The following dimensions were noted:
  - i) Length and breadth of the collection tank
  - ii) Diameter of the pipe at the entrance
  - iii) Diameter of the pipe at the throat
- The motor of the supply pump was switched on.
- The delivery valve of the pipe was opened.
- The manometer reading was noted.
- The outlet valve of the collection tank was closed.
- The time taken for 10cm rise of water in the collection tank was noted.
- The same procedure was repeated for 5 different flow rates.

Specifications:

Length of the collection tank, L = 0.3 m

Breadth of the collection tank, B = 0.3 m

Diameter of pipe, d_1 = 0.025 m

Diameter of venturi throat, d_2 = 0.01879 m

FORMULAE :

The coefficient of discharge is then calculated using the following formulae.

1. Pressure head difference, h = $\Delta H_m \left(\frac{S_m}{S_w} - 1 \right)$

2. Theoretical discharge, $Q_{theo} = \frac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$

3. Actual discharge, $Q_{act} = \frac{LBH}{t}$

4. Coefficient of discharge, $C_d = \frac{Q_{act}}{Q_{theo}}$

5. Reynold's number, $N_{Re} = d_2 V_2 \rho / \mu$

6. Velocity of fluid, $V_2 = Q_{act} / a_2$

Where

ΔH_m = Height difference in manometer in , m

S_m = Specific gravity of manometric fluid, 13.6

S_w = Specific gravity of working fluid, 1

a_1 = area at section 1 shown in the venturi meter diagram, $a_1 = \frac{\pi}{4} d_1^2$, m²

a_2 = area at section 2 shown in the venturi meter diagram, $a_2 = \frac{\pi}{4} d_2^2$, m^2

g = Acceleration due to gravity, 9.81 m/s^2

L - length of collection tank, m

B - breadth of collection tank, m

H - Height of liquid rise, m

t - Time taken for a rise through 'H', s

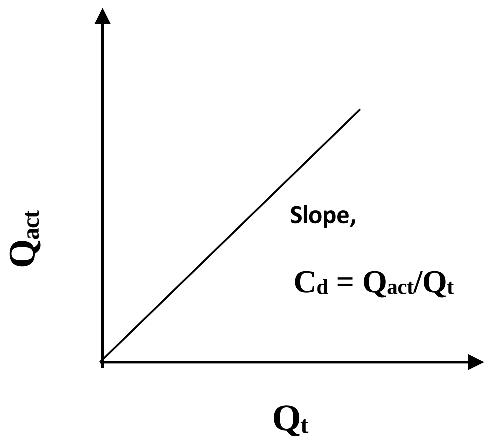
d_1 = diameter of pipe, m

d_2 = diameter of venturi throat, m

ρ = density of fluid, kg/ m^3

μ = viscosity of fluid used, kg/m.s

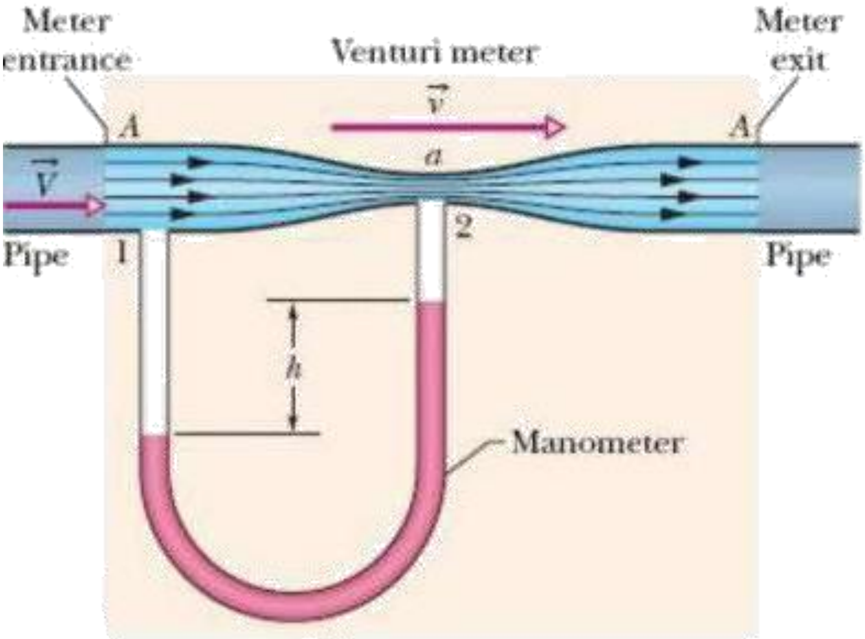
Model Graph:



OBSEREVATION

TABLE

S. No.	Manometer Reading(m)			Time for 10cm rise of water (sec)	Pressure head difference, m of H_2O	Theoretical discharge, Q_{theo} m^3/s	Actual discharge, Q_{act} m^3/s	Coefficient of discharge, C_d	N_{Re}
	Left	**Right**	**Difference,** ΔH_m						
								C_d mean =	



VENTURIMETER

RESULT

The venturi coefficient was calculated and required graphs were plotted. The venturi coefficient was found to be (i) Analytically ____________. (ii) graphically ___________________.

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Ex. No. **Date:**

FLOW MEASUREMENT USING ORIFICEMETER

AIM

To determine the coefficient of discharge of orifice meter.

THEORY:

The orifice meter is an extremely simple device used to measure the flow rate of fluids and hence widely used in practice. It normally consists of a plate with a centrally drilled hole. The drilled plate is inserted perpendicular to the direction of flow. Pressure taps are provided before and after the orifice plate and are connected to a manometer. Whenever a constriction is introduced into the fluid stream, there is a reduction in the pressure of the fluid coming through the constriction and an increase in the velocity. A manometer is used to measure the reduction in pressure due to the constriction between the tapings. Bernoulli's equation provides a basis for correlating the increase in the velocity head with a decrease in the pressure head. The equation governing the flow in an orifice meter is :

$$V_0 = \frac{Q}{A_o} = C_d \sqrt{\frac{2g(\rho_m - \rho_f)}{\rho_f (1-\beta^4)} \Delta H_m}$$

where

Q = Volumetric flow rate in m^3/s

A_o = area of orifice in m^2

V_o = velocity of fluid at the orifice in m/s

C_d = coefficient of discharge

β = Ratio of diameter of orifice to diameter of pipe.

ρ_m = density of manometer fluid in kg/m^3

ρ_f = density of fluid in pipe in kg/m^3

ΔH_m = height difference in manometer in m.

PROCEDURE :

- The following dimensions were noted:
  - iv) Length and breadth of the collection tank
  - v) Diameter of the pipe at the entrance
  - vi) Diameter of the pipe at the throat
- The motor of the supply pump was switched on.
- The delivery valve of the pipe was opened.
- The manometer reading was noted.
- The outlet valve of the collection tank was closed.
- The time taken for 10cm rise of water in the collection tank was noted.
- The same procedure was repeated for 5 different flow rates.

Specifications:

Length of the collection tank, L = 0.3 m

Breadth of the collection tank, B = 0.3 m

Diameter of pipe, d_1 = 0.025 m

Diameter of orifice, d_o = 0.01877 m

FORMULAE:

The coefficient of discharge is then calculated using the following formulae.

1. Pressure head difference, h = $\Delta H_m \left(\frac{S_m}{S_w} - 1 \right)$

2. Theoretical discharge, $Q_{theo} = \frac{a_o \sqrt{2gh}}{\sqrt{1 - \left(\frac{a_o}{a_1} \right)^2}}$

3. Actual discharge, $Q_{act} = \frac{LBH}{t}$

4. Coefficient of discharge, $C_d = \frac{Q_{act}}{Q_{theo}}$

5. Velocity of fluid at orifice $(V_o) = Q_{act}/a_o$

6. Reynold's number, $N_{Re} = d_o V_o \rho / \mu$

Where

ΔH_m = Height difference in manometer in , m

S_m = Specific gravity of manometric fluid, 13.6

S_w = Specific gravity of working fluid, 1

a_1 = area at section 1 shown in the orificemeter diagram, $a_1 = \frac{\pi}{4} d_1^2$, m^2

a_o = area of orifice as shown in the orificemeter diagram, $a_o = \frac{\pi}{4} d_o^2$, m^2

g = Acceleration due to gravity, 9.81 m/s^2

L - length of collecting tank, m

B - breadth of collecting tank, m

H - Height of liquid rise, m

t - Time taken for a rise through 'H', s

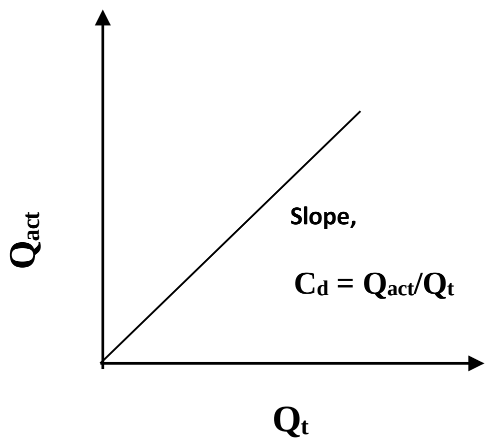
d_1 = diameter of pipe, m

d_o = diameter of orifice, m

ρ = density of fluid, kg/ m^3

μ = viscosity of fluid, kg/m.s

Model Graph:

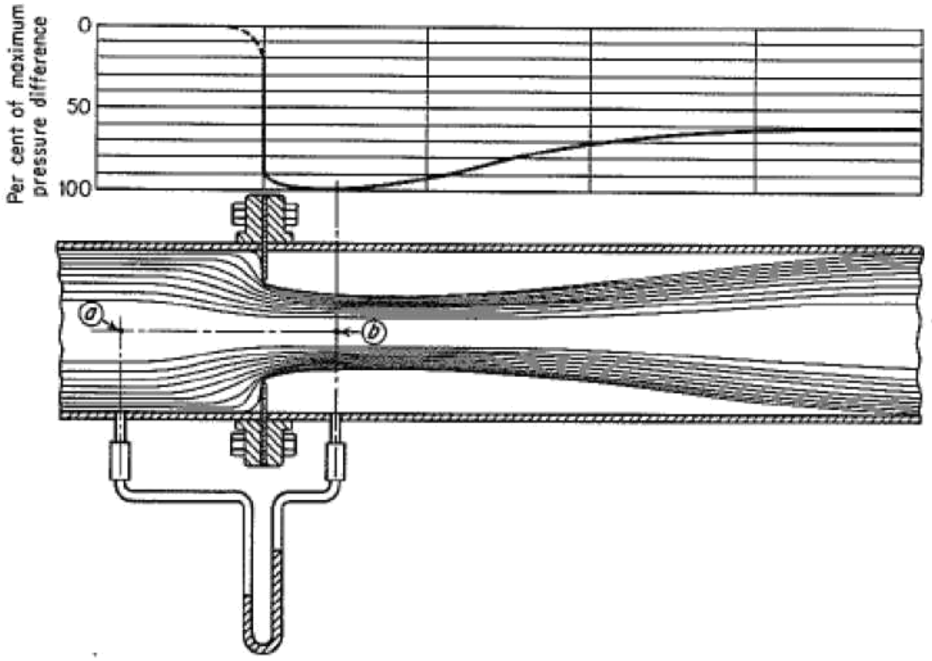


OBSERVATIONS

Table

S. No.	**Manometer Reading(m)**			**Time for 10cm rise of water (s)**	**Pressure head difference, m of H_2O**	**Actual discharge Q_{act} m^3/s**	**Coefficient of discharge, C_d**	**N_{Re}**
	Left	**Right**	**Difference, ΔH_m**					
							C_d mean =	

ORIFICE METER



RESULT :

The orifice coefficient was calculated and required graphs were plotted. The orifice coefficient was found to be (i) Analytically ____________. (ii) graphically ____________________.

****

Ex No. **Date:**

PIPE FRICTION

AIM

To verify Reynold's number vs friction relation in a straight circular pipe

THEORY

The flow of fluid is important in many unit operations in chemical engineering. The handling of liquid is much simpler, much cheaper and less troubles some than handling of solids. Consequently the chemical engineering handles everything in the form of liquid solution or suspensions wherever possible. One of the most widely used methods for transporting fluids are pipes and the losses which arise due to friction etc. are important to us. Any fluid flowing in contact with a solid surface suffers loss due to friction. For fluid that flows through pipes, manometer is used for the measurement of pressure drop. A globe valve is provided on the pipe line by means of which the flow rates of water into the pipe can be controlled. Water, after flowing in the pipelines, can be collected for known time interval and the flow rate calculated.

PROCEDURE

N.B.: Keep the delivery valve open while start and stop of the pump power supply.

1. Switch on the pump and choose any one of the pipe and open its corresponding inlet and exit valves to the manometer.
2. Adjust the delivery control valve to a desired flow rate. (i.e. fully opened delivery valve position initially)
3. Take manometer readings and time taken for 10 cm rise of water in the collecting tank
4. Repeat the readings for various flow rates by adjusting the delivery valve. (i.e. gradually closing the delivery valve from complete opening)
5. Switch of the power supply after opening the valve completely at the end.

Readings are tabulated and the fanning's friction factor is determined using fanning's equation as shown below:

$$\Delta H_f = \frac{\rho_m - \rho_f}{\rho_f} . \Delta H_m = 4f \frac{L}{D} \frac{V^2}{2g}$$

Where ΔH_f = Pressure drop

f = fanning's friction factor

L = Length of the pipe under observation

$\overline{V}$ = Average velocity of water in pipe

D = Diameter of the pipe used

FORMULAE

Length between Pressure tapping, L = 3 m

Pipe Diameter, d = 0.015 m

Measuring tank area, A= 0.6 x 0.3 x $0.1m^3$

(i) $\Delta H_f = \frac{(\rho_m - \rho_f)}{\rho_f} \Delta H_m$

ΔH_f – pressure drop,(in meter of water)

ΔH_m - manometer difference

ρ_f - Density of water

(ii) $Q = \frac{LBH}{t}$

L - lenght of the collection tank

B - Breath of the collection tank

H - Rise in water level

(iii) $\overline{V} = Q/A$

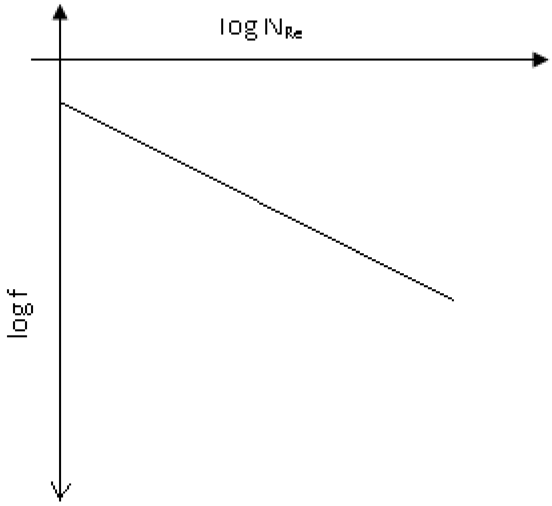
(iv) $N_{Re} = \frac{D\overline{V}\rho_f}{\mu}$

(v) Friction factor

$$f = \frac{\Delta H_f \times 2g \times D}{4L\overline{V}^2}$$

(iv) Blasius equation $f_{th} = \frac{0.079}{R_e^{0.25}}$

MODEL GRAPH

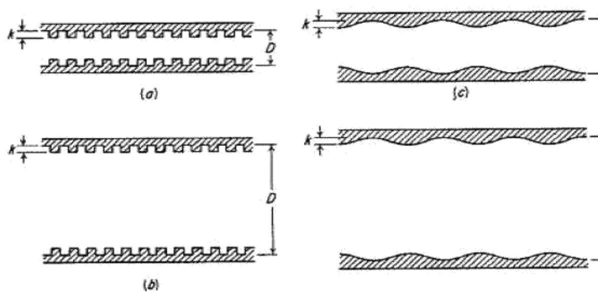


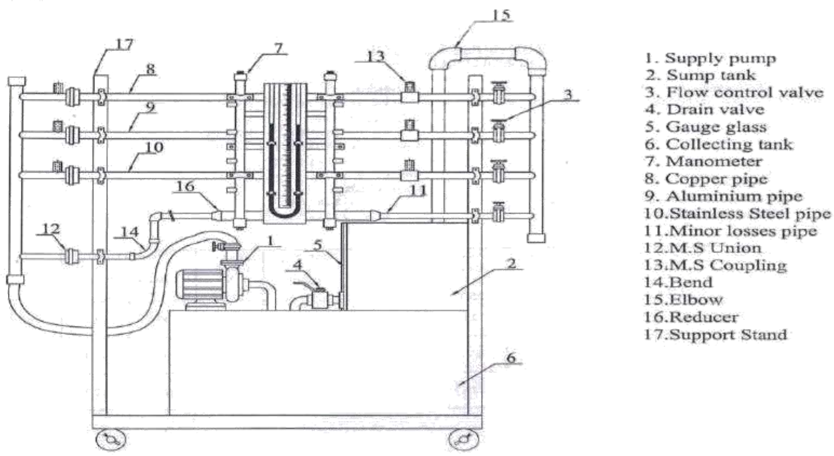
OBSERVATIONS

Table

S.No.	Manometer Reading(m)			Time for 10cm rise of water (s)	ΔH_f (m)	Q (m^3/s)	V (m/s)	N_{Re}	f	f_{th}
	Left	Right	Difference							

Types of Roughness





FRICTION LOSSES TEST RIG

RESULT

The graph between log f vs log N_{Re} was drawn. The relation between Reynolds number and friction factor was verified.

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Ex. No. **Date:**

DETERMINATION OF MINOR LOSSES DUE TO PIPE FITTINGS

AIM

To study the various losses due to the pipe fittings

THEORY

Fluids are usually transported in pipe or tubing,which is circular in cross section and available in widely varying sizes, wall thickness and materials of construction. The methods used to join the pieces of pipe depend in part on the properties of the material but primarily on the thickness of the wall. Thick walled tubular products are usually connected by screwed fittings, by flanges or by welding. Pieces of thin walled tubing are joined by soldering or by compression or flare fittings.

A typical processing plant contains thousands of valves of many different sizes and shapes. Despite the variety in their design, however, all valves have a common primary purpose; to slow down or stop the flow of a fluid.

Whenever the velocity of fluid is changed, either in direction or magnitude, by a change in the direction or the size of conduit, friction is generated in addition to the skin friction. Such friction includes form friction resulting from vortices that develop when the normal stream lines are disturbed and when boundary layer separation occurs.

The various pipe fittings used in the piping applications are joints, bends, elbows, entry, exit and sudden flow area changes (enlargement and contraction) etc. The energy losses associated with these types of pipe fittings are termed as the minor losses due its lesser values compared to the major loss (pipe friction) in the pipe. The loss of head is indicated by the manometer connected across the respective pipe fitting.

PROCEDURE

N.B.: Keep the delivery valve open while start and stop of the pump power supply.

1. Switch on the pump. Adjust the delivery valve to a desired steady flow rate.
2. Note down the time taken for 10 cm rise of water level in the collecting tank.
3. Choose any one of the pipe fittings (2 bends, one enlargement and one contraction). e.g. Bend-1
4. Open the levers (cocks) of respective pipe fitting to the manometer. Ensure other fitting levers should be closed. e.g. Open the entry and exit levers of Bend-1(left & right side cocks at the top of the panel)
5. Note down the manometer head levels (e.g. h_1& h2 for bend-1)

6. Now open the other two entries and exit levers of next pipe fitting. Then close the levers of first chosen pipe fitting. (e.g. Open the 2nd left & right levers for Bend-2 and close the top levers of Bend-1)
7. Note down the manometer for the second pipe fitting. (e.g. h_1& h2 for bend-2)
8. Repeat this procedure by opening the respective levers of sudden enlargement fitting after closing other levers(i.e. for sudden enlargement by opening the next down left & right cocks of sudden enlargement and then close the previous left & right cocks of Bend-2).
9. Repeat this procedure by opening the respective levers of sudden contraction fitting after closing other levers(i.e. for sudden contraction by opening the next down left & right cocks of sudden contraction and then close the previous left & right cocks of sudden enlargement).
10. Ensure the readings taken for all pipe fittings and then switch off the pump.

FORMULAE

(i) Discharge, Q = (A x h) / t (m^3/s)

A = Area of tank in m^2

h = Rise water level in collecting tank (m) = 0.10 m

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

(ii) Velocity, V = Discharge / Area of pipe = Q/A… (m/s)

Where A = $\pi d^2/4$ (m^2) , d – Dia of pipe in m

(iii) Actual loss of head

$\mathbf{h_f} = (h_1 - h_2) \times 12.6 \times 10^{-2}$ … (m)

(iv) Theoretical Velocity loss heads for pipe fittings

Velocity head loss for bend and elbow hv = $V_1^2 / (2g)$ (m)

Velocity head loss for sudden enlargement $h_v = (V1 - V_2)^2 / (2g)$ (m)

Velocity head loss for sudden contraction $h_v = 0.5 (V_1)^2 / (2g)$ (m)

Where V_1= velocity of smaller pipe (m/s)

(v) Loss co-efficient

K = Actual loss of head /Theoretical Velocity head = $hf_/ h_v$

TABULATION

Collecting Tank area, A = 0.6 m x 0.3 x 0.1m^3, Pipe Diameter, d = 0.015 m or d = 0.020 m

Pipe fittings	**Manometer Reading (cm)**			**Time for 10 cm rise (sec)**	**Discharge (m^3/s)**	**Velocity (m/s)**	**Actual Loss of head, (m)**	**Theoretical Loss of head (m)**	**Loss co-efficient K**
	h_1	**h_2**	**h_m**	**t**	**Q**	**V**	**h_f**	**h_v**	**h_f / h_v**
Bend-1									
Bend-2									
Sudden Enlarge (20-40 mm)									
Sudden Contraction (40-20 mm)									

RESULT

The Loss coefficient in pipe fittings for

Bend - 1 = -----------------

Bend – 2 = ------------------

Sudden Enlarge = ------------------

Sudden Contraction = ------------------

Ex. No. **Date:**

PERFORMANCE CHARACTERISTICS STUDY IN CENTRIFUGAL PUMP

AIM

To study the characteristics of centrifugal pump at constant speed.

THEORY

In a centrifugal pump, the mechanical energy of the liquid is increased by centrifugal action. The liquid enters through a suction connection concentric with the axis of an impeller which carries radial vanes integrally cast in it. The liquid flows outward in the spaces between the vanes and leaves the impeller at a considerably greater velocity. In a properly functioning pump the space between the vanes is completely filled with liquid flowing without cavitation. The liquid leaving the outer periphery of the impeller is collected in a spiral casing called the volute and leaves the pump through a tangential discharge connection. In the volute the velocity head of the liquid from the impeller is converted into pressure head. The pump efficiency is the ratio of fluid power to the total power consumed. The efficiency rises rapidly with flow rate at low rates, reaches a maximum at or near the rated capacity, and then falls as the flow rate approaches the zero-head value.

PROCEDURE

1. Ensure the complete opened position of delivery valve.
2. Start the pump power supply.
3. Vary the flow rate (discharge) by closing the delivery valve.
4. Note down pressure gauge reading for 0.5 kg/cm2 and vacuum gauges readings.
5. Measure height of the pressure gauge above the vacuum gauge. (Z)
6. Note down time taken (t) for ‘h’ cm rise of water (10 cm) in collecting tank.
7. Note down the time taken (T) for ‘n’ revolutions for energy meter (3 rev) disc.
8. Repeat the procedure for 0.5, 1.0, 1.5, 2.0, 2.5 kg/cm2 in the pressure gauge reading by gradual closing of delivery valve.
9. Switch off the power supply after opening the delivery valve completely.

FORMULAE

1. $H_s = \frac{P_s S_m}{1000}$

H_s = suction head, m of H_2O

Ps = suction pressure (mm of Hg)
S_m = Specific gravity of mercury = 13.6

2. $H_d = \frac{P_d x 10^4}{1000}$

H_d = delivery head,m of H_2O

P_d = delivery pressure (kg/cm^2)

3. $H = H_d + H_s + H_c$
H_c = correction head = 0.5 m

4. Actualdischarge, $Q_{act} = \frac{\text{volume of water collected}}{\text{time taken}} = \frac{LBH}{t}$

L = Length of the collection tank = 0.5m
B = breadth of the collection tank = 0.5m
H = Rise of water in the collection tank = 0.1m
t = Time taken for the rise of water, s

5. Output power, $O_p = \frac{\gamma Q H}{1000}$

$\gamma = \rho g$

Q = Discharge, m^3 / s

H = total head,m of H_2O

g = Gravitational acceleration = 9.81 m^2/s

ρ = Density of fluid (water) = 1000 kg/m^3

6. Input power, $I_p = \frac{3600 \times N \times \eta_m}{E_c \times t_2}$

N = no.of rotations
E_c = energy meter reading = 200 rev / kWh
t_2 = Time required to complete ‘n’ revolution in sec
η_m = Efficiency of motor = 0.8

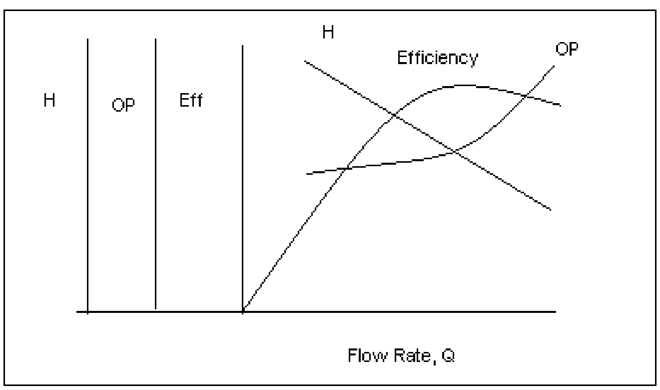
7. Overall efficiency, $\eta_o = \frac{O_P}{I_P} \times 100\ \%$

8. $Ns = \frac{N\sqrt{Q}}{\left(H/n\right)^{3/4}}$

Ns = speed,rpm
N = speed of impeller,rpm
n = no.of stages

Characteristic curves of Centrifugal pump:
Discharge Vs Head, Output, Efficiency

(a) Head Capacity (b) Power (c) Efficiency



RESULT:

1. Maximum overall efficiency, η_{max}= ________________
2. Maximum discharge Q $_{max}$ = ______________________
3. Total Head at η_{max} = ____________________________
4. Input power at η_{max} = ___________________________
5. Critical speed,N_s = _____________________________

TABULATION

Suction pressure, Ps (mm Hg)	**Discharge pressure, Pd (kg_f / cm^2)**	**Time for 10cm rise, t (s)**	**Time for 3 revolution (s)**	**Suction head, Hs (m of H_2O)**	**Discharge head, Hd (m of H_2O)**	**Total head, H (m of H_2O)**	**Discharge, (m^3/s)**	**Output power, (kW)**	**Input power, (kW)**	**Overall efficiency**