CONTENTS

V = Fluid velocity.

γ =Specific weight of fluid.

Z= Datum head.

A piezometer tube records the pressure head $\frac{p}{\gamma}$ at the channel centre line. If the datum head is Z, the Piezometer tubes record $(\frac{P}{\gamma}+Z)$ above the datum base line. A curve joining the piezometer levels constitutes the hydraulic gradient line. Addition of velocity head $\frac{V^2}{2g}$ to the piezometer level readings result in the total energy for the incompressible flow.

PROCEDURE:

1. The cross sectional areas of the channel below the piezometer tubes are measured.
2. A sheet of paper is placed at the backside of piezometer tubes.
3. Setup the apparatus to give differential head between inlet and outlet.
4. The-flow steadiness is obtained by adjusting the valves. When steady flow occurs the water heads in the piezometer tubes remain constant.
5. The height of the water level in the piezometer tubes is recorded on the paper sheet and in the data sheet.
6. Now water is collected in a bucket for a particular time. Then the weight of water and bucket is noted from platform scale.
7. Take a number of observations by varying the rate of discharge of water.

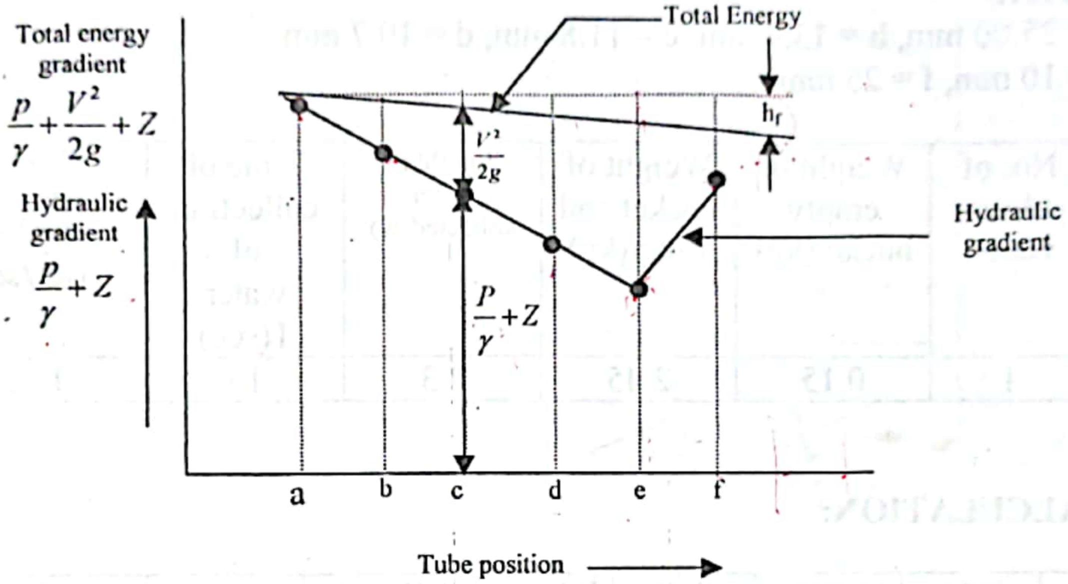
DATA:

No. of Observation	Weight of Empty Bucket(kg)	Weight of Bucket and water(kg)	Weight of Water Collected(w)	Time of Collection of Water T(sec)	Flow rates Q=W/T (m^3/sec) kg/sec.
1				8·65	
2				9·87	
3				11·08	

CALCULATION:

No of Observation	Tube Position (mm)	Diameter in (m)	Cross sectional Area A(m^2)	Velocity $V = \frac{Q}{A}$ (m/sec)	Velocity head $\frac{V^2}{2g}(m)$	Piezometer Head $\frac{p}{\gamma}$+Z (m)	Total Head $H = \frac{P}{\gamma} + \frac{V^2}{2g} + z$ (m)
1	a 240	25,0	2				
	b 224	14,6					
	c 205	12,4					
	d 170	11,3					
	e 173	10,6					
	f 166	10, 0					
2	a 175						
	b 162						
	c 138						
	d 135						
	e 121						
	f 115						
3	a 112						
	b 100						
	c 53						
	d 77						
	e 66						

PERFORMANCE CURVE:



DISCUSSION:

The following points may be discussed.

1. Variation of the total energy line along the flow
2. Effect of friction.
3. . Source and effect of the errors in measurements should be included.

PERFORMANCE TEST:

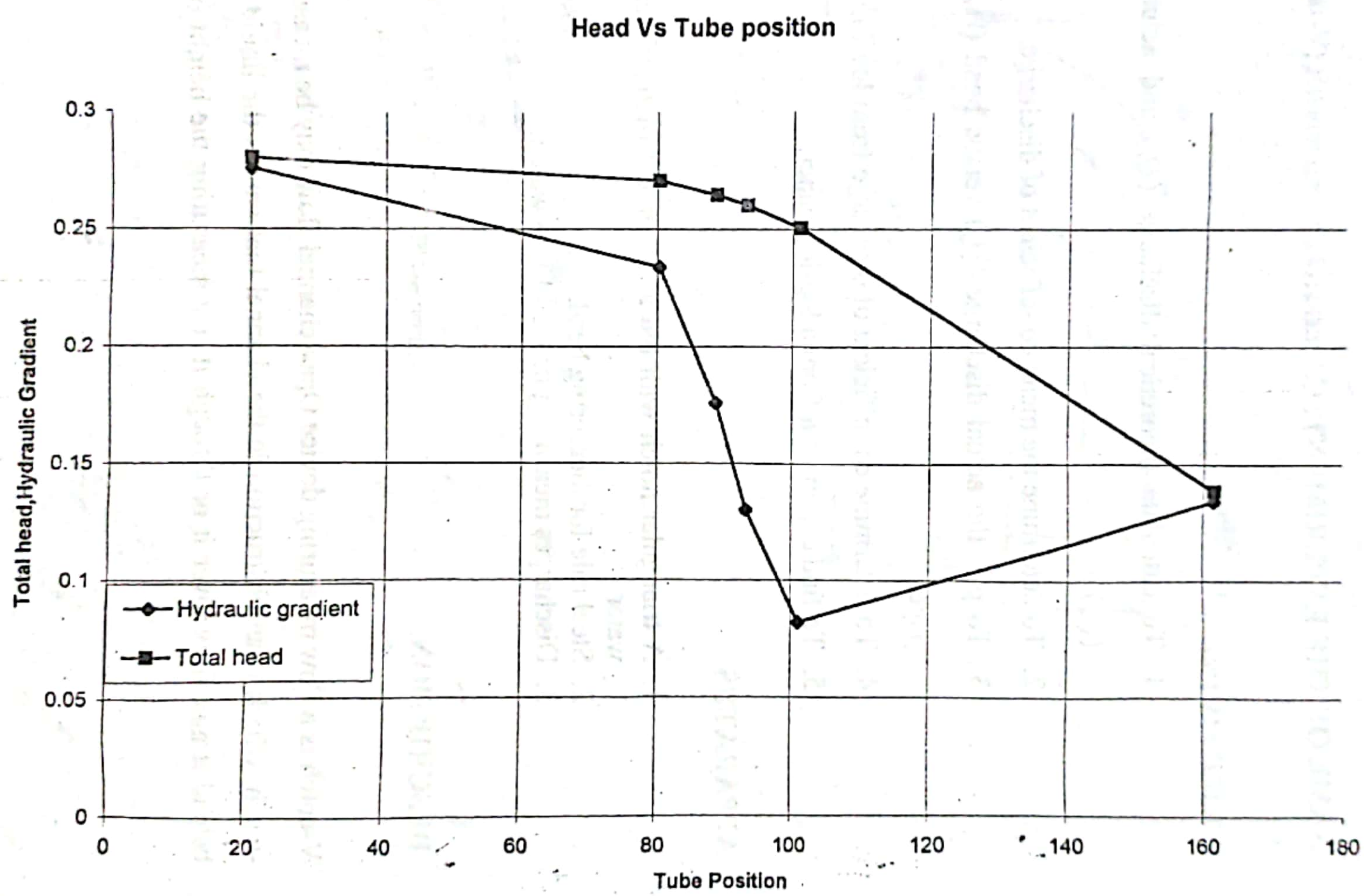
DATA:

a = 25.00 mm, b = 13.9 mm, c = 11.8 mm, d = 10.7 mm
e = 10 mm, f = 25 mm

No. of observation	Weight of empty bucket(kg)	Weight of bucket and water(kg)	Weight of water collected(w)	Time of collection of water T(sec)	Flow rates (W/T) Q $\times 10^{-4}$ (m^3/sec)
1	0.15	2.45	2.3	16	1.437

CALCULATION:

No of Observation	Tube Position (mm)	Diameter $d \times 10^{-3}$ (m)	Cross sectional area $A \times 10^{-3}$ (m^2)	Velocity $V = \frac{Q}{A}$ (m/sec)	Velocity head $\frac{V^2}{2g} \times 10^{-3}$ (m)	Piezometer Head $\frac{p}{\gamma}+Z$ (m)	Total Head $H = \frac{P}{\gamma}+\frac{V^2}{2g}+Z$ (m)
1	a	25	0.491	0.293	4.375	0.276	0.2804
	b	13.9	0.152	0.9453	45.544	0.2340	0.27054
	c	11.8	0.109	1.318	88.538	0.176	0.2645
	d	10.7	0.0899	1.598	130.15	0.13	0.260
	e	10	0.079	1.818	168.45	0.082	0.25045
	f	25	0.491	0.293	4.375	0.134	0.1384


Head Vs Tube position
Total head,Hydraulic Gradient
Tube Position
Hydraulic gradient
Total head
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
120
140
160
180

EXPERIMENT NO: 2

NAME OF THE EXPERIMENT: Calibration of a triangular notch, (V-notch).

OBJECTIVES:

1. To calculate theoretical discharge (Q_t) and actual discharge (Q_a).
2. To determine the mean co -efficient of discharge.
3. To plot the actual discharge (Q_a) versus head (H) on log-log paper.
4. To determine co- efficient of discharge from log-log graph.
5. To find exponent n from a log-log paper.

APPARATUS:

1. A triangular notch with the arrangement of regulated supply of water.
2. Steel rule for measuring head.
3. Discharges measuring tank and stop watch.

DESCRIPTION:

V-notch is a flow measuring device Open channel flow may be measured by a V -notch, which is an obstruction in the channel that causes the liquid to back up behind it and flow Over it or through it. By measuring the height of upstream liquid surface, the rate of flow is determined. A typical experimental setup for calibration of a V- notch is shown in fig.

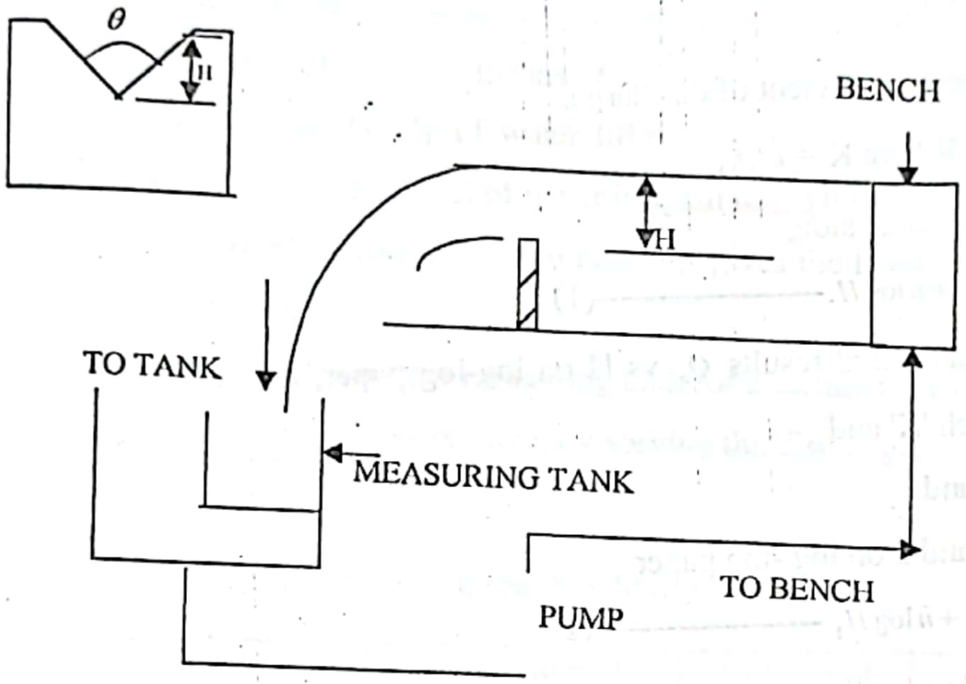


Figure: Open flow channel

THEORY:

We know that the theoretical discharge through a V-notch,

$$Q_t = \frac{8}{15}\sqrt{2g}\tan\frac{\theta}{2}H^{5/2}$$

Where H = height of water surface.

θ = Notch angle.

For a given V -notch,

$$K_1 = \frac{8}{15}\sqrt{2g}\tan\frac{\theta}{2}$$

Actual flow rate $Q_a = C_d Q_t$

$$\text{Or, } C_d = \frac{Q_a}{Q_t}$$

$$Q_a = C_d K_1 H^{5/2}$$

C_d is Known as the co- efficient of discharge.

$Q_a = KH^{5/2}$, Where K = $C_d K_1$

Taking logarithm of each side,

$$\log Q_a = \log K + n \log H \text{------------------(1)}$$

Plotting from experimental results Q_a vs H on log-log paper, a straight line is obtained from which 'K' and

'n' can be found.

Choosing points 1 and 2 on log -log paper

$$\log Q_{a1} = \log K + n \log H_1 \text{------------------(2)}$$

$$\log Q_{a2} = \log K + n \log H_2 \text{------------------(3)}$$

From (3)-(2) we get,

$$\log Q_{a2} - \log Q_{a1} = n(\log H_1 - \log H_1)$$

$$\text{Or, } n = \frac{\log(\frac{Q_{a2}}{Q_{a1}})}{\log(\frac{H_2}{H_1})} \text{---------------------------------(4)}$$

Putting the value of n in equation (2) and (3) we get the value of K and then we get C_d.

PROCEDURE:

1. Allow the water to flow into the tank till it just starts passing over the notch.
2. Now stop the supply of water and then no water passes over the notch, note the level of water by means of steel rule. This is the initial reading.
3. Next adjust the supply of water till the head over the sill of the notch remains constant the level of water is again noted by means of steel rule.
4. The difference between the two readings gives the head of water causing flow over notch.
5. Note the flow from flow measuring tank for a certain time interval.
6. Take a number of observations by varying the discharge.

DATA:

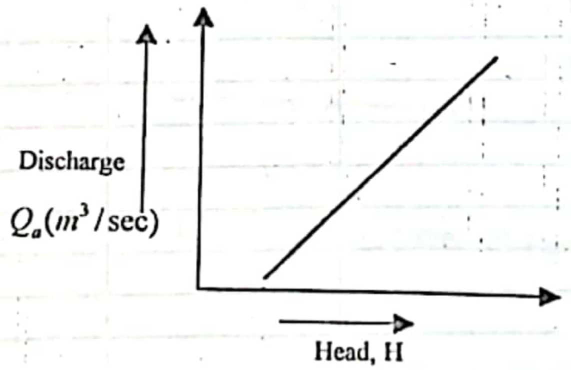
θ =Angle of notch 45°. Initial height of water =

No. of Observation	Head reading H (meter)	Time of Collection t(sec)	Volume of Water Q (m^3)	Actual flow rate $Q_a = \frac{Q}{t}(m^3)$
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

CALCULATION:

No. of Obs.	Actual Flow Rate $Q_a(m^3)$	Head H (m)	TheoretiCal Flow Rate $Q_t(m^3)$	$C_d = \frac{Q_a}{Q_t}$	Mean C_d	C_d from log-log graph	Value 'n' from log-log graph	Value Of K From Log-Log graph
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

PERFORMANCE CURVE:



DISCUSSION:

The following points may be discussed,

1. Comment on the mean co- efficient of discharge. The usual range of co-efficient of discharge for a V-notch is from 0.6 to0.65.
2. The value of n is to be close to 2.5.
3. Advantages of V-notch.

PERFORMANCE TEST:

DATA & CALCULATION:

No of obs	Actual flow rate $Q_a \times 10^{-3}$ (m^3/sec)	Head, H (m)	Theoretical flow rate $Q_T \times 10^{-3}$ (m^3/sec)	$C_d = \frac{Q_a}{Q_T}$	Mean C_d	Cd from Log-log graph	Value of n from log-log graph	Value of k from log-log graph
1	3.03	0.1051	3.501	.86	0.819	0.954	2.53	0.934
2	3.11	0.1085	3.794	.82				
3	5.8	0.139	7.048	.822				
4	8.58	0.1637	10.6	.809				
5	9..91	0.1731	12.19	.812				
6	11.33	0.1811	13.65	.8309				
7	12.32	0.1887	15.24	.8137				
8	13.03	0.1935	16.12	.8083				
9	13.88	0.1993	17.35	.8				
10	14.72	0.2027	18.1	.8132				

We know that theoretical discharge, $Q_T = \frac{8}{15}\sqrt{2g}\tan\frac{\theta}{2}H^{\frac{5}{2}}$

Here we use observation as a sample.
For V-Notch $\theta = 45^0$

$$Q_{T_1} = \frac{8}{15}\sqrt{2\times 9.81}\times \tan 22.5(.1051)^{\frac{5}{2}} = 3.501\times 10^{-3}$$

$$C_{d_1} = \frac{Q_a}{Q_T}$$

So co -efficient of discharge is, $C_d = \frac{3.03\times 10^{-3}}{3.504\times 10^{-3}}$

$$\therefore C_d = .86$$

We know,

$Q = K\ H^n$

Taking log on both sides,

Log Q = log K+ n log H

Choosing point A (0.139,5.8 $\times 10^{-3}$) and B (0.181,0.01133)

From graph considering point A and B we get,

Log0.0058 = log K + n log 0.139

Or, -2.237 = log K + n (-0.857)---------------(1)

Taking the value of B point

Log 0.01133 = log K + n log 0.1811

Or -1.946 = log K + n (- 0.7421) ---------------(2)

Subtracting equation (1) from (2)

n =2.53

putting the value of n in equation (1)

-2.237 = log K +2.53 (- 0.857)

K = 0.934   - 0.06879

A (0.027 , 0.12)

B (0.049, 0.55)

Again for a V-notch ,we know

$$K = \frac{8}{15}\sqrt{2g}\tan\frac{\theta}{2}\times C_d$$

$$\Rightarrow 0.934 = \frac{8}{15}\sqrt{2\times 9.81}\tan 22.5\times C_d$$

$$\therefore C_d = 0.954$$

A (0.039, 0.318) B (0.053, 0.435)

log - 3.498 = logk + n (-1.409)

- 3.197 = logk + n (-1.276)

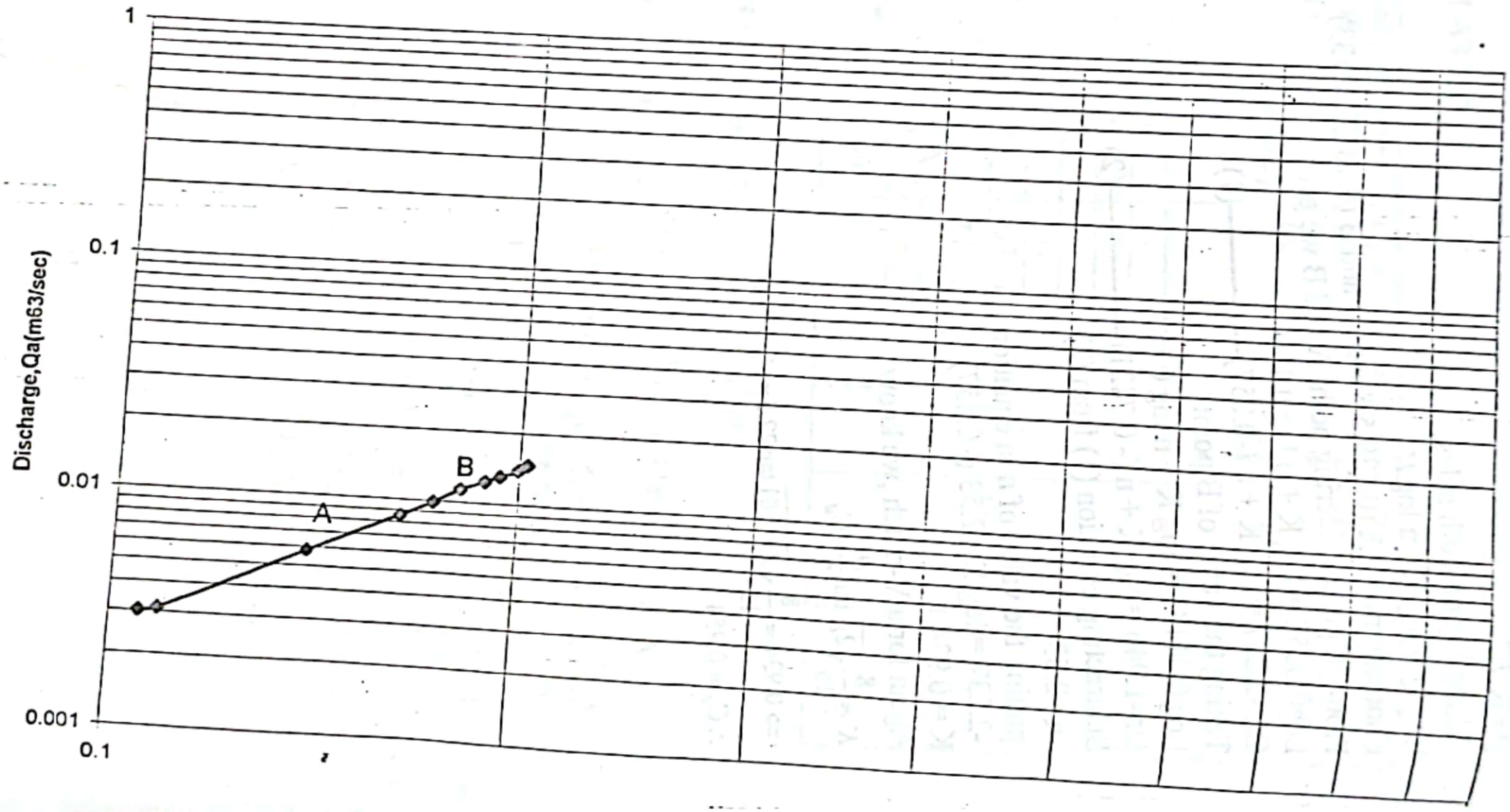
(+) (-) (-)

- 0.301 = n (-0.133)

$\therefore$ n = 2.263

$\therefore$ K = $\log^{-1}$ ~~(0.06879)~~ (-0.309433)

Actual discharge Vs Head



EXPERIMENT NO: 3

NAME OF THE EXPERIMENT: Study of flow through an orificemeter.

OBJECTIVES:

1. To calculate the co-efficient of discharge.
2. To plot head (H) versus actual flow rate (Q_a) in a log-log paper.
3. To find the value of mean co- efficient of discharge from log-log paper.
4. To find the value of 'n' from log-log paper.

APPARATUS:

An Orificemeter fitted in a long pipeline with flow measuring device, multitube manometer and flow control valve.

DESCRIPTION:

Orificemeter is a flow-measuring device. It is used to measure flow through pipeline, A typical experimental setup is shown in fig o3 to study orifice meter.

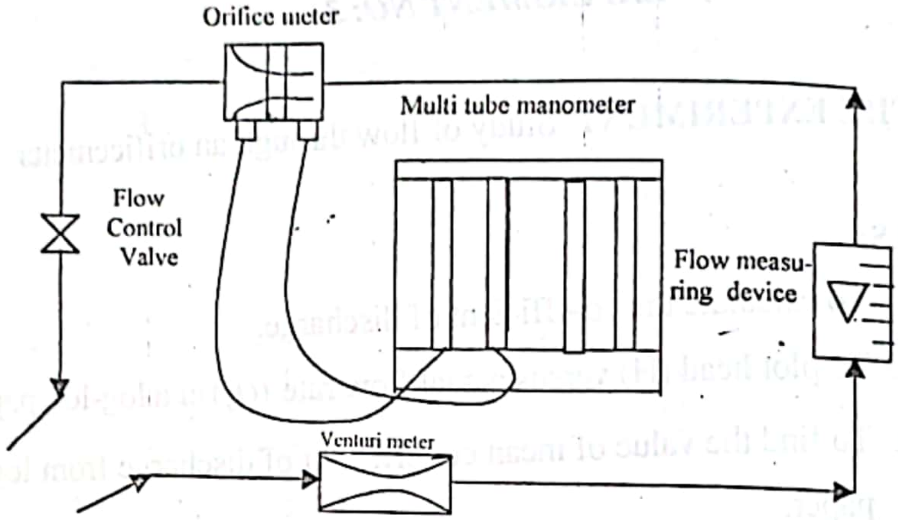


Figure : Orifice meter test-rig

THEORY:

Actual flow rate

$$Q_a = \frac{C_d A_0 \sqrt{2gH_m(S_m/S-1)}}{\sqrt{1-C_c^2\left(\frac{D_o}{D_1}\right)^4}}$$

Where $C_d = co-efficient$ of discharge.

A_O =Orifice area.

H_m =Deflection in the manometer.

S_m =Specific gravity of manometric fluid.

S= Specific gravity of flowing fluid.

C_c = Co- efficient of concentration.

D_0 = Orifice diameter.

D_1 = Pipe diameter.

$$Q_a = C_d K_1 \sqrt{H_m}\text{ , Where } K_1 = \frac{A_0\sqrt{2g(S_m/S-1)}}{\sqrt{1-C_c^2(D_0/D)^4}}$$

For a given meter and a given fluid,

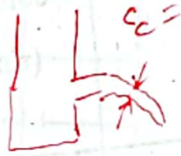
$$Q_a = KH_m^n \text{ , } \quad \text{Where } K = K_1 C_d \text{ .}$$

Taking logarithm of each side

$$\log Q_a = \log K + n \log H_m,$$

Which is the equation of straight line.

Choosing two points on log-log graph we get



$$\log Q_{a_1} = \log K + n \log H_{m1} \text{ --------(1)}$$
$$and \log Q_{a2} = \log K + n \log H_{m2} \text{ --------(2)}$$

= .64

$$n = \frac{\log \frac{Q_{a2}}{Q_{a1}}}{\log \frac{H_{m2}}{H_{m1}}}$$

Putting the value of n in equation (1) or (2) we get K and then C_d.

PROCEDURE:

1. Knowing the pipe diameter and orifice diameter, the areas of cross section at these two sections can be found out.
2. Now water is allowed to flow through the Orifice meter
3. When the flow becomes steady, the deflection in the manometer is noted, and notes actual flow rate from flow measuring device
4. By varying the flow rate with the help of down stream control valve more observation are taken

5. The discharge should be varied uniformly to get a good set of observations.

DATA:

Pipe dia, D_1 =------ orifice dia, D_0 =..........

Specific gravity of fluid's =..........................

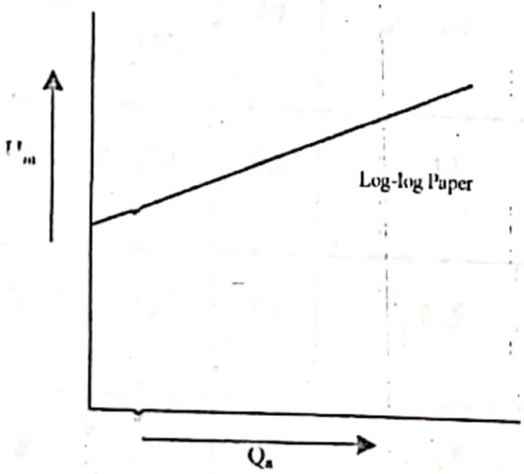
Specific gravity of manometric fluid, S_m =....................

No.of Obs.	Left column (mm)	Right column (mm)	Net Deflection (mm)	Actual Flow rate $Q_a(L/min)$	Net Deflection in (mm)Hg
1					
2					
3					
4					
5					

CALCULATION:

No of observation	Actual flow rate $Q_a (L/\min)$	Mano Metric Deflection, H_m (cm of Hg) $\times 10^{-3}$	$\sqrt{H_m}$	Co-efficent of discharge C_d	$mean C_d$	C_d, from log-log graph	Value of n From log-log graph
1	17.5	2.43	0.049	0.512			
2	11.5	2.72	0.052	0.411			
3	10.2	2.47	0.049	0.387	0.411		
4	8.2	1.69	0.041	0.372			
5	7	1.25	0.035	0.372			

PERFORMANCE CURVE:



$$C_d = \frac{Q_a}{K_1 \sqrt{H_m}}$$

DISCUSSION:

The following points may be discussed.

1. Discuss the factors affecting the value of C_d, C_v and C_c

2. Comment on the mean co- efficient of discharge, the usual range of co-efficient of discharge for an Orifice meter is from o.6 to 0.65

3. The value of n is to be close to 0.5.

PERFORMANCE TEST:

DATA:

Pipe diameter D_i=31.75 mm, orifice diameter D_0=20 mm, specific gravity of flowing fluid =1, specific gravity of manometric fluid =13.6.

No. of obs	Manometric reading			Actual Flow $Q_a \times 10^{-3}$ (m^3/s)	Manometric deflection (m-Hg) $\times 10^{-3}$
	Left Column (mm)	Right Column (mm)	Net deflection (mm)		
1	300	212	88	20	6.47
2	370	214	156	16	11.47
3	300	253	47	14	3.46
4	376	358	18	11	1.32
5	373	363	15	8.5	1.103
6	291	283	8	5.5	.588

CALCULATION:

No Of obs	Actual flow rate $Q_a \times 10^{-3}$ (m^3/s)	Manometric deflection (m-Hg) $H \times 10^{-3}$ (H_m)	$\sqrt{H_m}$	Coefficient of Discharge C_d	Mean C_d	C_d, from log-log graph	Value of n From log log graph
1	20	6.47	0.0804	0.462			
2	16	11.47	0.107	0.278			
3	14	3.46	0.0588	0.442	0.4405	0.543	0.253
4	11	1.32	0.0630	0.563			
5	8.5	1.103	0.0332	0.476			
6	5.5	.588	0.0242	0.422			

$$K_1 = \frac{A_0\sqrt{2g(S_m/S-1)}}{\sqrt{1-C^2c(\frac{D_0}{D_1})^4}} = \frac{\frac{\pi}{4}(.2)^2\sqrt{2\times 9.81\times 12.6}}{\sqrt{1-1^2(0.2/0.3175)^4}} = 0.538$$

$$C_{d_1} = \frac{Q_1}{K_1\sqrt{H_m}} = \frac{0.016}{0.538\times\sqrt{11.47\times 10^{-3}}} = 0.278$$

We know ,

$$Q = KH^n{}_m$$

Taking log on both sides,

Log Q = log K + n log H_m

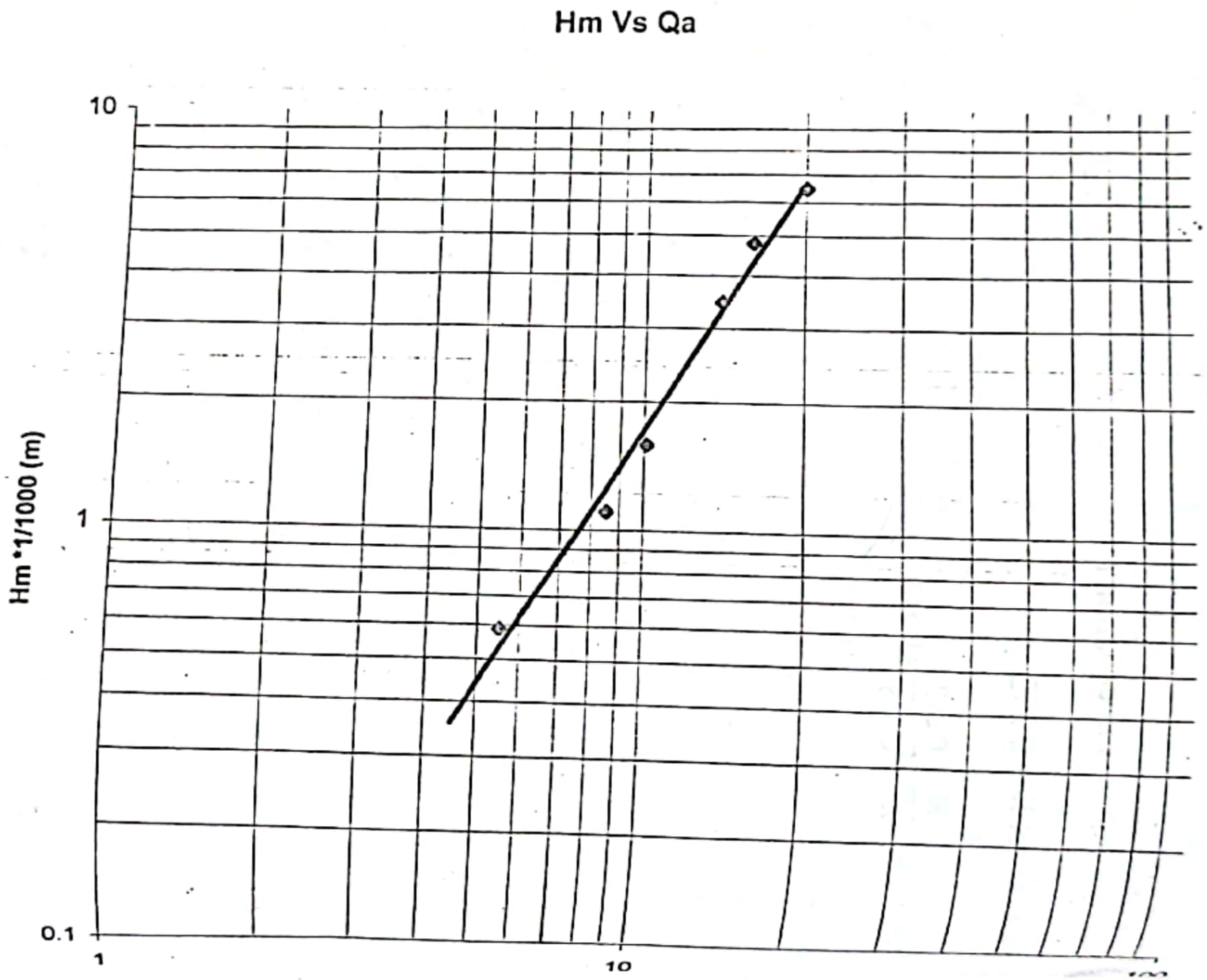
Considering poin (3) and (4)
Log 14×10^{-3} = log K + n log 3.46×10^{-3} -----------------(1)

And log 11×10^{-3} = log K + n log 1.32×10^{-3}------------(2)
Substracting equation (1) from equation (2)

N = 0.253
Putting value of n in equation (1)

Then we get K = 0.292

Again $C_d = \frac{K}{K_1} = \frac{0.292}{0.538} = 0.543$



Hm Vs Qa
Hm *1/1000 (m)
10
1
0.1
1
10

EXPERIMENT NO:6

NAME OF THE EXPERIMENT: Determination of the location of the center pressure for a submerged plane surface.

OBJECTIVES:

1. To find the magnitude of resultant force exerted on a vertical plane surface immersed partially or completely in water.
2. To find the line of action of the resultant force and locate the center of pressure

APPARATUS:

1. Measuring weight.
2. Hydraulic pressure apparatus.

DESCRIPTION:

The apparatus consists of a quadrant mounted on a balance arm. The balance arm is pivoted on knife-edge. The line of contact of the knife-edge coincides with the axis of the quadrant. The hydrostatic force acting on the quadrant will be equal to the force on rectangular end face which gives rise to a moment about the knife edge axis. At one end of the balance arm there is an adjustable weight and the other end is provided with a balance pan. Water is admitted to the top of the tank and the water level is indicated on a scale that is attached on the side face of the quadrant. There is a beam level indicator in one side of the tank. The experimental setup is shown in figure.

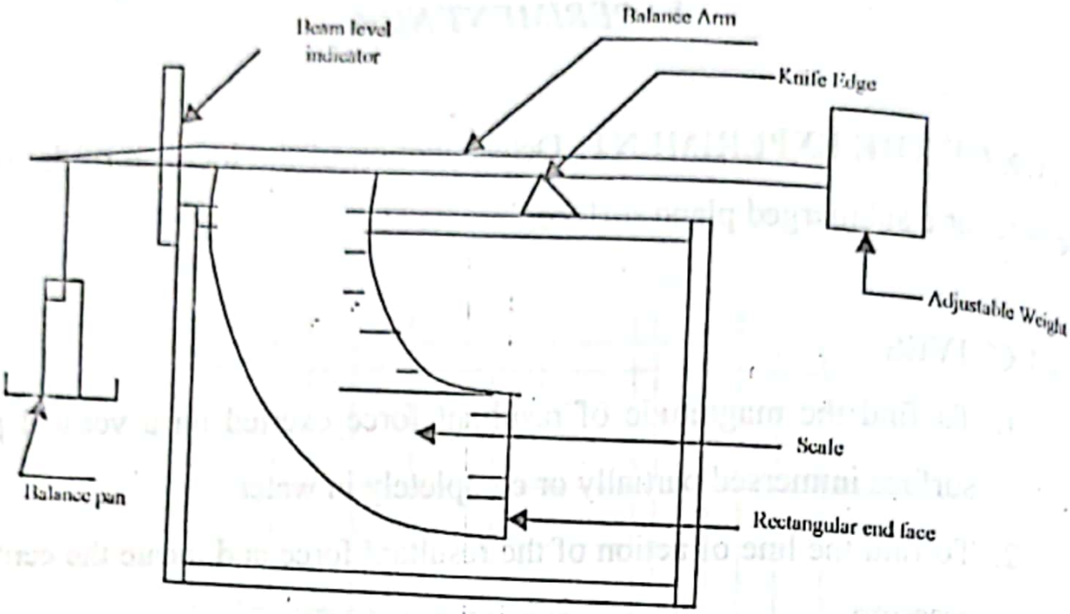


Figure: Submerged plane surface

THEORY:

The magnitude of the resultant force on a submerged plane surface is given by

$$F = \rho g \bar{h} A$$

$$= \rho g \frac{Y}{2} bY$$

$$= \rho g \frac{Y^2}{2} b \text{ ------------- (1)}$$

Where ρ = density of water.

g = acceleration due to gravity

$\bar{h}$ = Vertical distance of the centroid from liquid surface =Y/2

b =Width of plane surface (cm).

A = Area of plane surface.

Now theoretical value of centre pressure is

$$Y_p = \frac{I_G}{\bar{Y}A} + \bar{Y}$$

$$= \frac{b\frac{Y^3}{12}}{\frac{Y}{2}bY} + Y = \frac{2}{3}Y \text{ from free surface of water} \text{------------------(2)}$$

Now moment 'M' of force F about knife-edge is given by

$$M = \frac{1}{2}\rho g b Y^2 (a + d - \frac{Y}{3}) \text{--------------(3)}$$

$$= F\,(a+d-Y+Y_p^1)$$

Again, M = mg×L

Where m = mass added to balance pan

L = distance from knife edge axis to balance pan suspension rod axis.

Therefore, $mgL = F\,(a+d-Y+Y_p^1)$

Hence , $Y^1{}_P = \frac{mgL}{F} - (a + d - Y)$

For completely submerged plane surface (Y >d)

Let , $\bar{Y}$ = Y-d/2

Total force, F = $\rho g \bar{Y} bd = \rho g (Y - d/2)(bd)$

Theoretical $Y_p = \frac{I_G}{\bar{Y}A} + \bar{Y}$

$$= \frac{bd^3/12}{bd\bar{Y}} + \bar{Y}$$

$$= \frac{d^2}{12\bar{Y}} + \bar{Y} = \frac{d^2}{12(Y - d/2)} + (Y - d/2)$$

Moment M of force F about knife edge axis is given by

$M = F\,(a+d-Y+Y_p^1)$

Therefore, $mgL = F\,(a+d-Y+Y_p^1)$

$$\text{Or, } Y_p^1 = \frac{mgL}{F} - (a+d-Y)$$

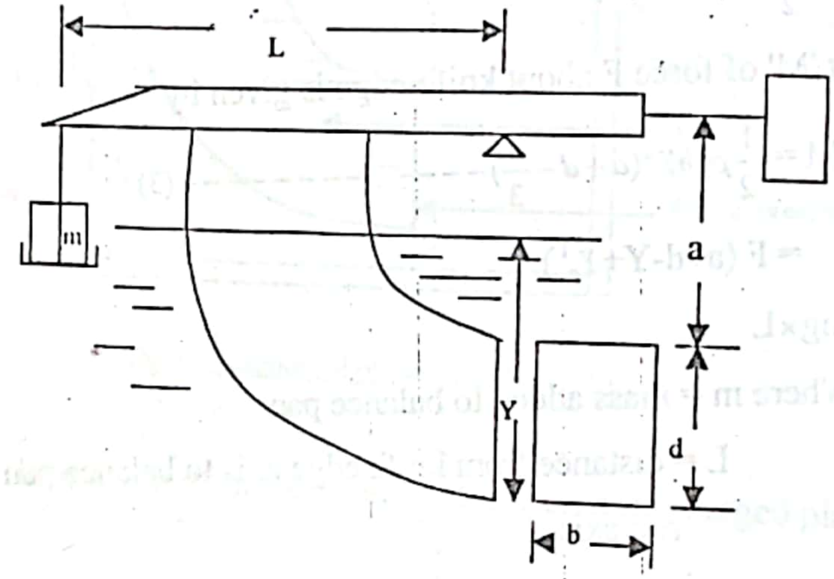


Figure: Completely submerged plane surface

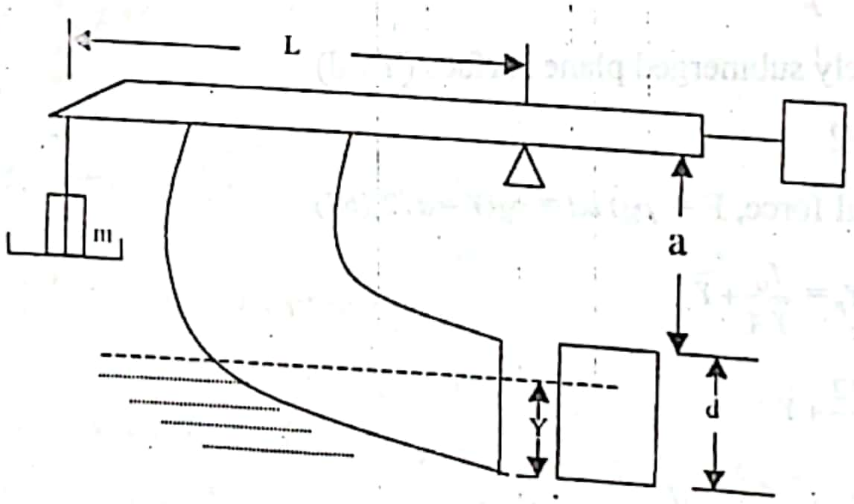


Figure: Partially submerged plane

PROCEDURE:

1. Attached the quadrant to the balance arm by the central screw.
2. Measure the dimension 'a' and the width 'b' and height 'd' of the plane rectangular vertical face. The distance 'L' from the knife-edge to the balance pan axis is also to be noted.
3. Move the adjustable weight until the balance arm is horizontal. This is indicated on the beam level indicator.
4. Place a mass on the balance pan. Admit water into the tank until the balance arm is horizontal. Note the water level on the scale.
5. Repeat the procedure by placing different masses on balance pan and note the corresponding water levels.
6. Repeat the reading by reducing masses on the balance pan.

DATA:

(For Partial submerged or completely immersion)

No. of obser-vation	Balancing mass m (gm)	Distance Y (cm)	Total force F (N)	Theoretical Y_P (m)	Measured Y_P^1 (m)
1					
2					
3					
4					
5					
6					

PERFORMANCE CURVE:

Plot Y_p versus Y_p^1

DISCUSSION:

The following points may be discussed.

1. Give reason for discrepancies between the theoretical and measured values of the result.
2. Sources of error.

PERFORMANCE TEST:

DATA:

Observation:

a = 10 cm; b = 7.6 cm; d = 10 cm; L = 27.5 cm

Completely submerged:

No of observation.	Balancing mass, m (Kg)	Distance Y (m)	Total force, F (N)	Theoretical Y_P (m)	Measured Y_P^1 (m)
1	0.425	0.148	7.306	0.1065	0.1049
2	0.40	0.140	6.710	0.099	0.1008
3	0.375	0.135	6.337	0.095	0.0946
4	0.350	0.129	5.889	0.0895	0.0893
5	0.300	0.116	4.921	0.0786	0.08046
6	0.250	0.105	4.101	0.0702	0.0695

CALCULATION:

For observation no: 1

We know, $F = \rho g \bar{Y} bd = \rho g\,(Y\text{-}d/2)\,bd$

$=1000 \times 9.81(0.148 - 0.1/2)\times 0.076\times 0.1$

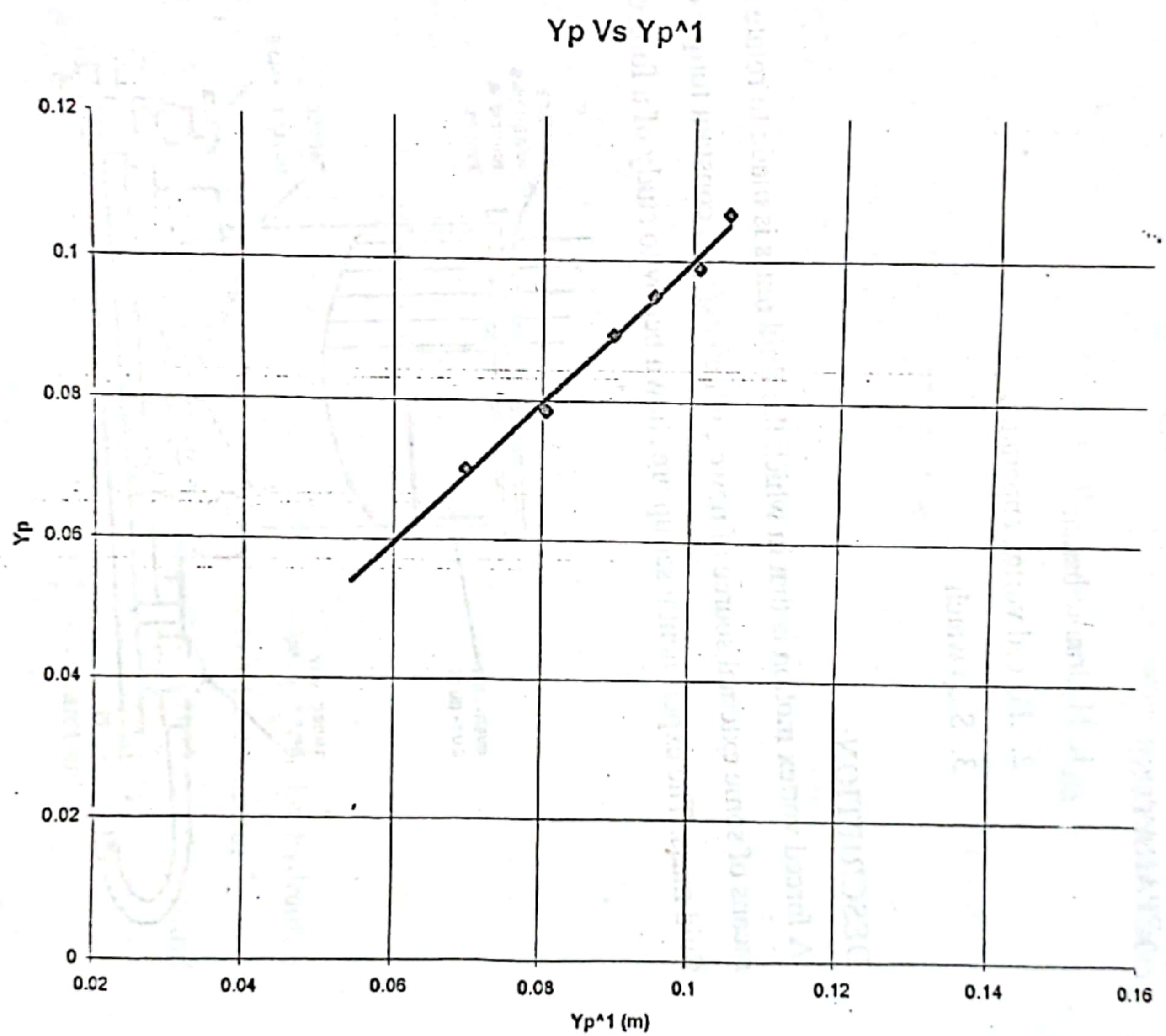
$= 7.306$ N

$$Y_p = \frac{d^2}{12(Y-d/2)} + (Y-d/2)$$

$$= \frac{(0.1)^2}{12(0.148-0.1/2)} + (0.148-0.1/2) = 0.1065 \text{ m}$$

We know, $Y_p^{\,1} = \frac{mgL}{F} - (a+d-Y)$

$$= \frac{0.425\times 9.81\times 0.275}{7.306} - (0.1+0.1-0.148) = 0.1049 \text{ m}$$


Yp Vs Yp^1
Yp
0.12
0.1
0.08
0.06
0.04
0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Yp^1 (m)

EXPERIMENT NO:7

NAME OF THE EXPERIMENT: Study of forced vortex

OBJECTIVE:

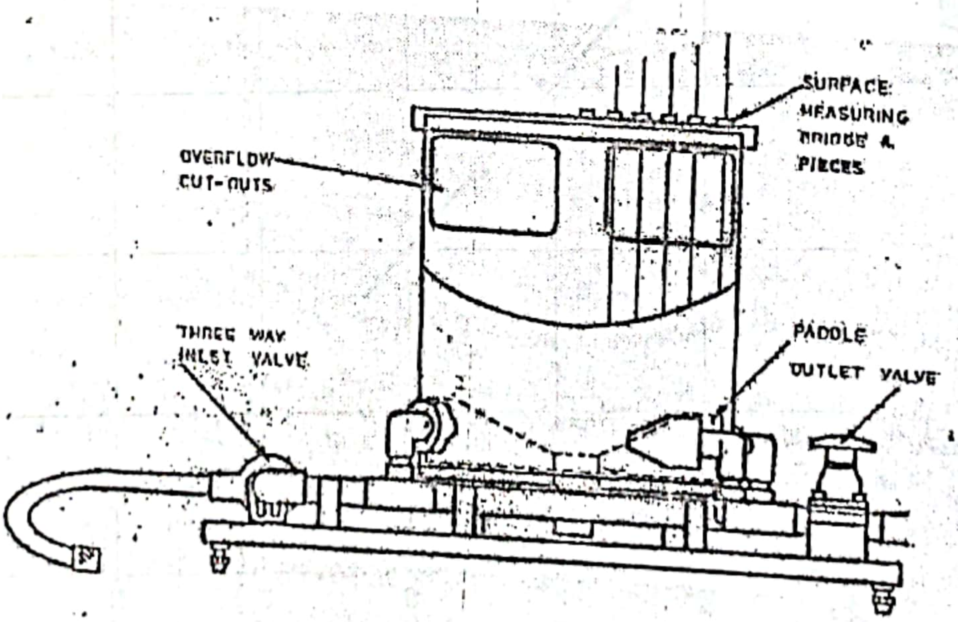
To determine the surface profile of a forced vortex.

APPARATUS:

1. Hydraulic bench.
2. .Forced vortex apparatus.
3. Stop watch

DESCRIPTION:

A forced vortex motion is that in which the fluid mass is made to rotate by means of some external source of power, which exerts a constant torque on the fluid mass. The experimental set-up are shown below to study of a forced vortex



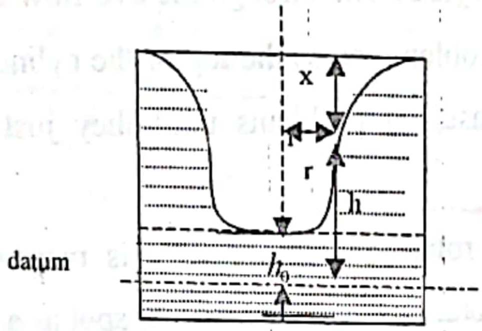
THEORY:

For a constant speed of rotation ω

$v = \omega r$, where r = radius .

v = velocity of flow at radius r

If the horizontal plane passing through the radir of vortex is taken as datum, theory shows that $h = h_0 + \dfrac{\omega^2 r^2}{2g}$, which is the equation of a parabola.



PROCEDURE:

1. Position the apparatus into the working channel of the hydraulics bench and connect to the bench via the quick release connector.
2. Place the blanking plug incorporating the locating stud into the central hole in the base of the cylinder. Press paddle on to stud.
3. Connect a flexible hose to the outlet pipe. Close outlet valve.

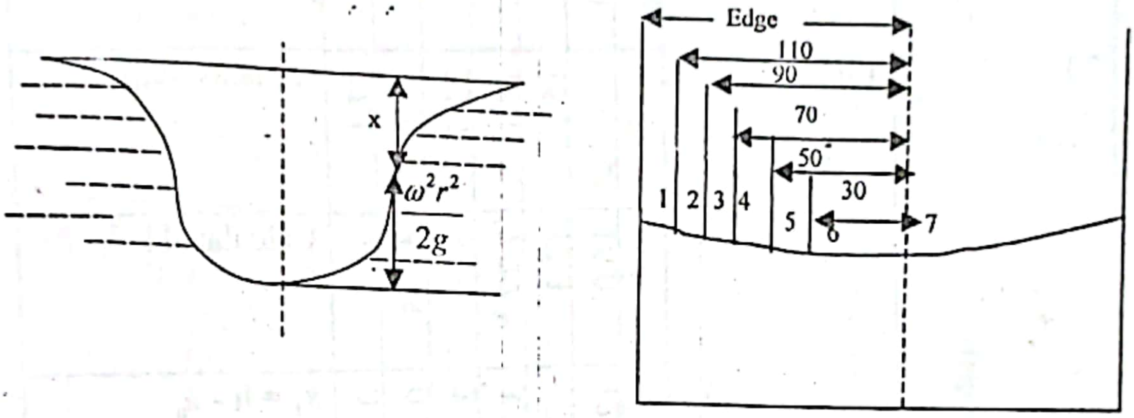
4. Switch on bench pump, open bench control valve, open three way inlet valve so that water enters the cylinder from the 9 mm tangential inlet ports set at 60^0, and leaves through the larger ports, discharging into the volumetric tank.
5. Raise outlet pipe and allow it to fill with water, when it is full, lower it into volumetric tank, this includes a symphonic effect hence increasing discharge rate. For each value of flow rate, the outlet valve should be adjusted until water just flows through the overflow cut outs.
6. Place measuring problem across the top of the cylinder. The profile of the surface is measuring problems until they just touch the water surface.
7. The speed of the rotation of the paddle is measured by timing a number of paddle rotations using the marker spot as a reference.
8. Remove measuring bridge, record the length of the each probe.

DATA:

Rps n	Time for revs/sec	Measuring position							
		Edge	110	90	70	50	30	0	
									x (measured)
									Calculated h
									$x_1 = h - h_0$

Calculation of h :

$$h = h_0 + \frac{\omega^2 r^2}{2g}$$



Measuring points

PERFORMANCE CURVE:

1. Plot the co-ordinate points experimentally obtained for the vortices at various speed of rotation.

Plot and compare the theoretically obtained curves of vortex surface profile with the experimentally determined forced vortices.

PERFORMANCE TEST:
DATA

Rps n	Time for revs/sec	Measuring position	x (measured)	Calculated h	$x_1 = h - h_0$
30	1.96	Edge			
		110		16.07	12.05
		90	15	13.3	9.3
		70	18.1	7.79	3.79
		50	23.5	6	2
		30	26.6	4.695	0.695
		0	27.1	4	0

CALCULATION:

$h_0 = 4cm$

The largest height $= 16.1$ cm

Now, $h_1 = h_0 + \dfrac{\omega^2 r^2{}_1}{2g}$

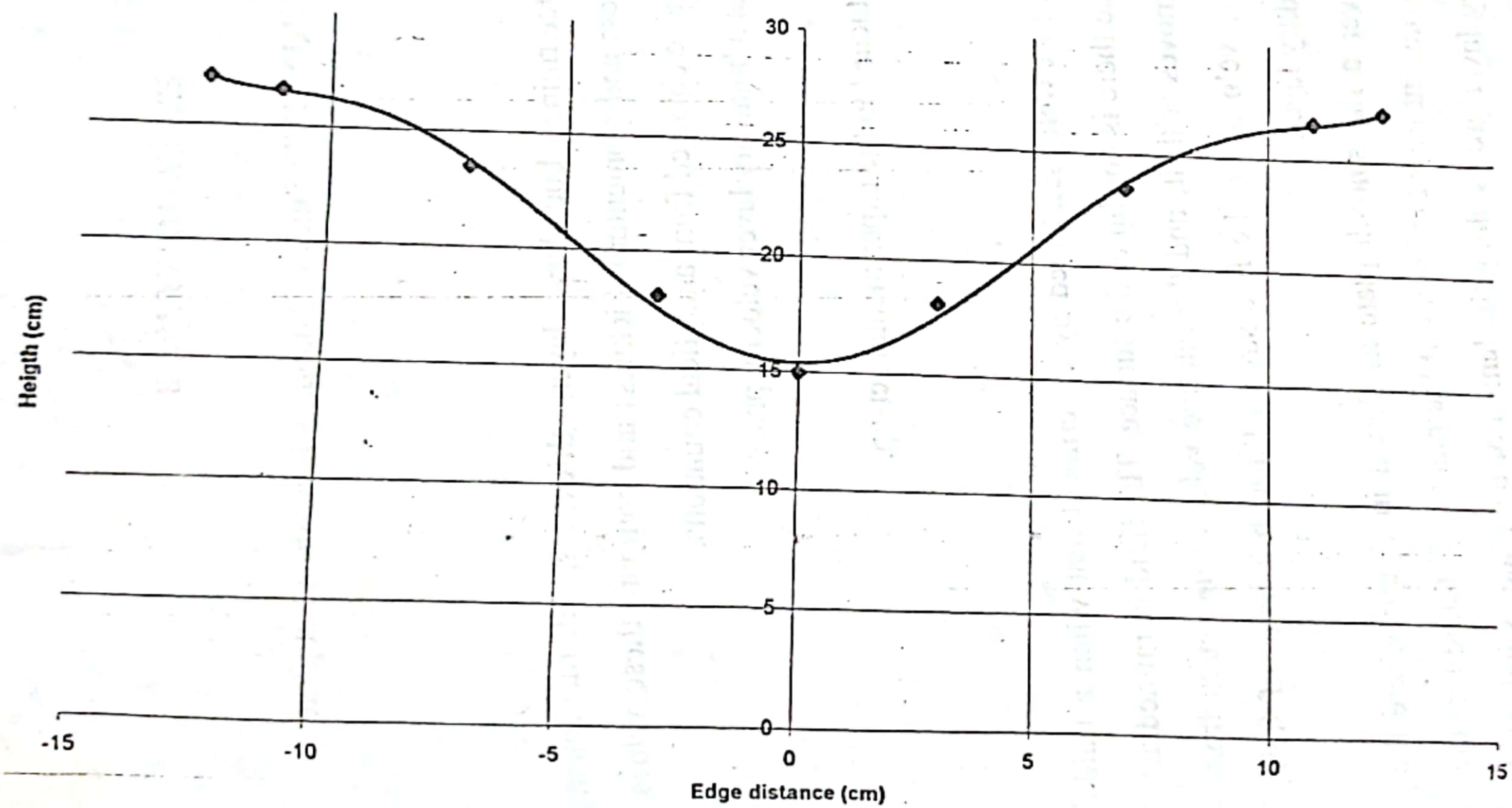
Here $r_1 = 0\,, h_0 = 4$ cm,

$\omega = 2\pi n$

$= 2\pi \times 1.96 = 12.315$

$\therefore h_1 = 4 + \dfrac{(12.315)^2 \times 0}{2 \times 9.81 \times 100} = 4cm$

Height Vs Edge distance



EXPERIMENT NO: 8

NAME OF THE EXPERIMENT: Study of boundary layer on a flat plate.

OBJECTIVES:

1. To determine boundary layer thickness, displacement thickness and momentum thickness and compare these values with those obtained from analytical equations.
2. To plot a boundary layer velocity profile

APPRATUS: All are attached to the experimental set-up.

INTRODUCTION:

It is a fact well established by experiment that when a fluid flows over a solid surface there is no slip at the surface. The fluid in immediate contact with a surface moves with it, and the relative velocity increases from zero at the surface to the velocity in the free stream through a layer of fluid which is called the boundary layer.

Consider steady flow over a flat smooth plate as shown in figure where the streaming velocity U is constant over the length of the plate. It is found that the thickness of the boundary layer grows along the length of the plate as indicated on the figure. The motion in the boundary layer is laminar at the start, but if the plate is sufficiently long, a transition to turbulence is observed. This transition is produced by small disturbances which, beyond a contained distance, grow rapidly and merges to produce the apparently random fluctuation of velocity which are characteristics of turbulent motions. The parameter which characterises the position of the transition is the Reynolds number R_{ex} based on distance x from the leading edge, $R_{ex} = \frac{Ux}{\nu}$

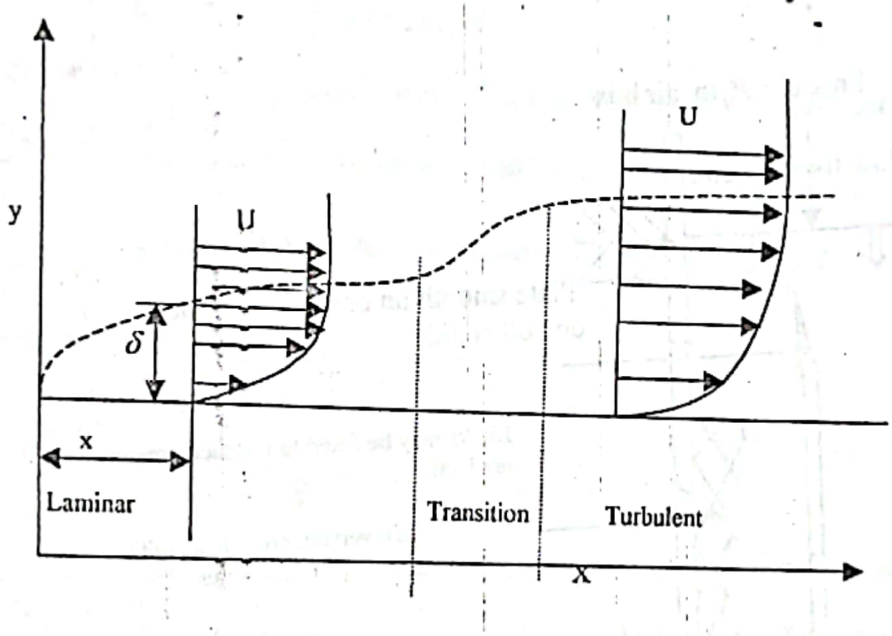


Figure: General characteristics of boundary layer over a flat plat

DESCRIPTION:

A flat plate is placed at mid height in the section, with a sharpened edge facing the oncoming flow. One side of the plate is smooth and the other is rough so that by turning the plate over, results may be obtained on both types of surface. Liners may be placed on the walls of the working section so that either a generally accelerating or generally decelerating free stream may be produced along the length of the plate, depending on which way round they are fitted with the liners removed, uniform free stream flow conditions obtain over the plate length.

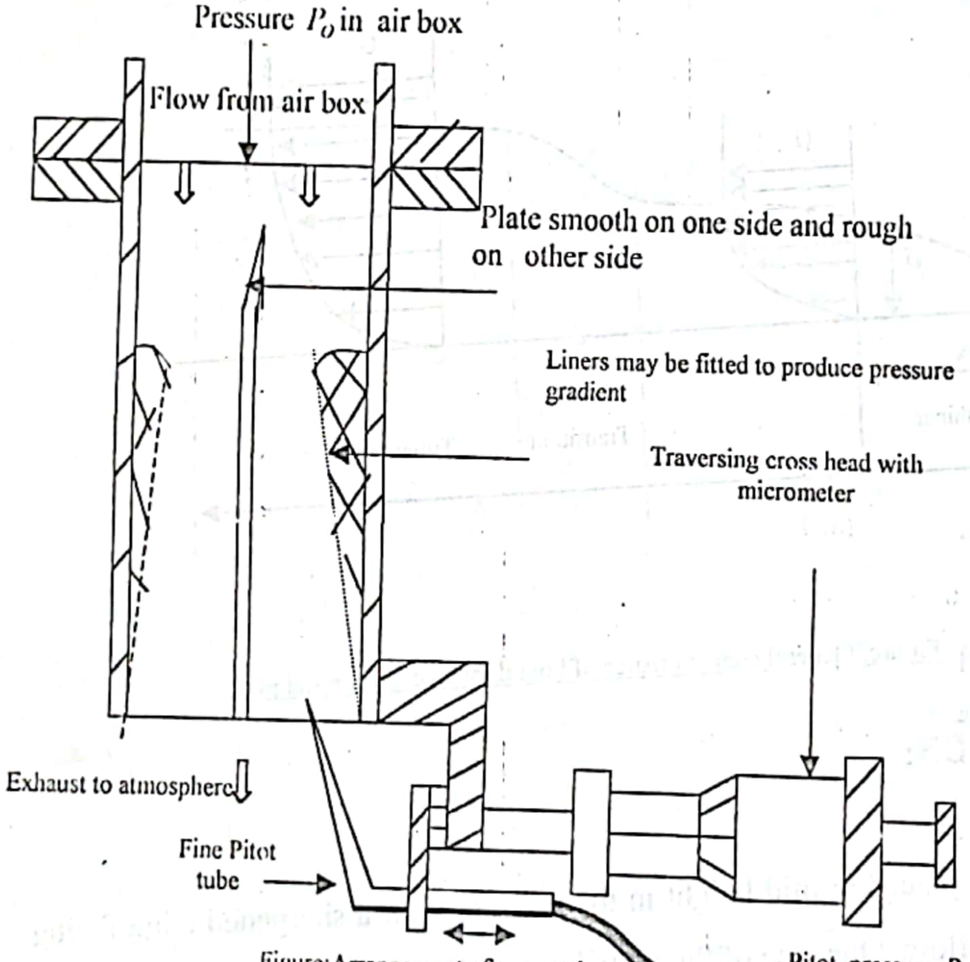


Figure: Arrangement of test section

THEORY:

1. Boundary layer thickness = δ
2. Displacement thickness = δ_1

   It indicates the distance from the solid surface by which the external streamlines are shifted owing to the formation of boundary layer and is defined as $\delta_1 = \int_0^a (1-\frac{u}{U})dy$
3. Momentum thickness, δ_2

   The momentum thickness 'δ_2' is defined as the distance from the actual boundary surface such that the momentum flux corresponding to the main stream velocity, i;e $\delta_2 = \int_0^a \frac{u}{U}(1-\frac{u}{U})dy$

   value of $\frac{u}{U}$ are found from

   $$\frac{u}{U} = \sqrt{\frac{P}{P_0}} \text{----(1)}$$

   where P_0 is the pitot tube reading in the free stream and P is the pitot tube reading in the boundary layer. Analytical solution for velocity,

	Boundary layer	Turbulent boundary layer
Boundary layer thickness	$\delta = 5\sqrt{\frac{ux}{U}}$	$\delta = 0.37(R_{ex})^{-0.2}$
Displacement thickness	$\delta_1 = 1.73\sqrt{\frac{ux}{U}}$	$\delta_1 = 0.01738(R_{ex})^{0.861\frac{u}{U}}$
Momentum thickness	$\delta_2 = 0.664\sqrt{\frac{ux}{U}}$	$\delta_2 = 0.036(R_{ex})^{-0.2}$

PROCEDURE:

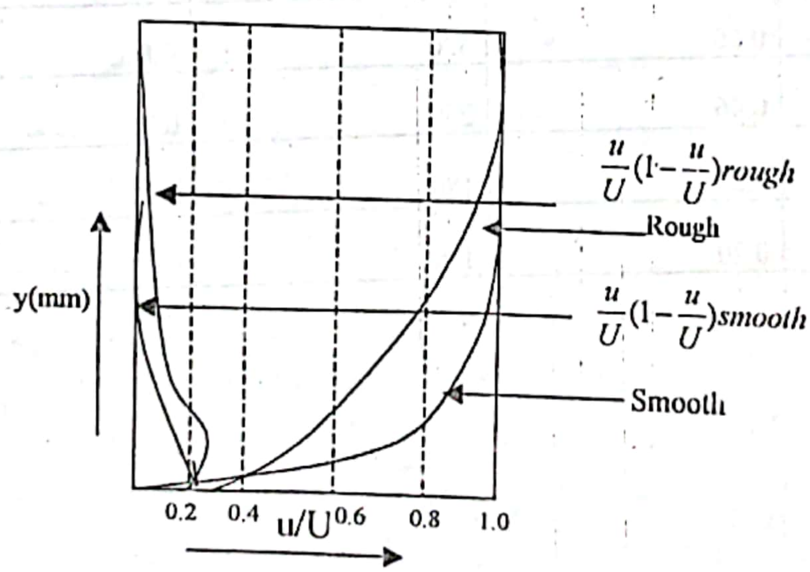
1. Open the delivery valve.
2. Start the motor.
3. The pitot tube is set at about 10 mm distance from the surface and the desired wind speed is established by bringing the pressure P in the air box to the required value. Reading of total pressure P measured by the pitot tube are then recorded over a range of settings of the micrometer as the tube is traversed towards the plate. At first the readings should be substantially constant, indications that the traverse has been started in the free stream; if this is not the case, go back and start with an initial setting further from the plate. As the Pitot tube reading beings to fall, the step length of the traverse should be reduced so that at least 10 reading are obtained over the range of reducing readings. The reading does not fall to zero as the tube touches the wall because of its finite thickness, so the traverse is stopped as soon as contact is indicated either by the electrical circuit or by the readings becoming constant as the micrometer is advanced towards the surface.

Readings obtained in turbulent boundary layers are subject to unsteadiness which leads to difficulty in obtaining average readings on the manometer. Damping may be provided by squeezing the connecting plastic tube, but care should be taken that the restriction is not too severe, which can lead to false readings.

DATA:

No of Observation	Micrometer reading (mm)	y(mm)	Manometric Reading, h_1 (mb)	Manometric reading h_2,(mb)	ΔP (mb)	P (N/m^2)	u/U
1							
2							
3							
4							
5							

PERFORMANCE CURVE:



PERFORMANCE TEST:

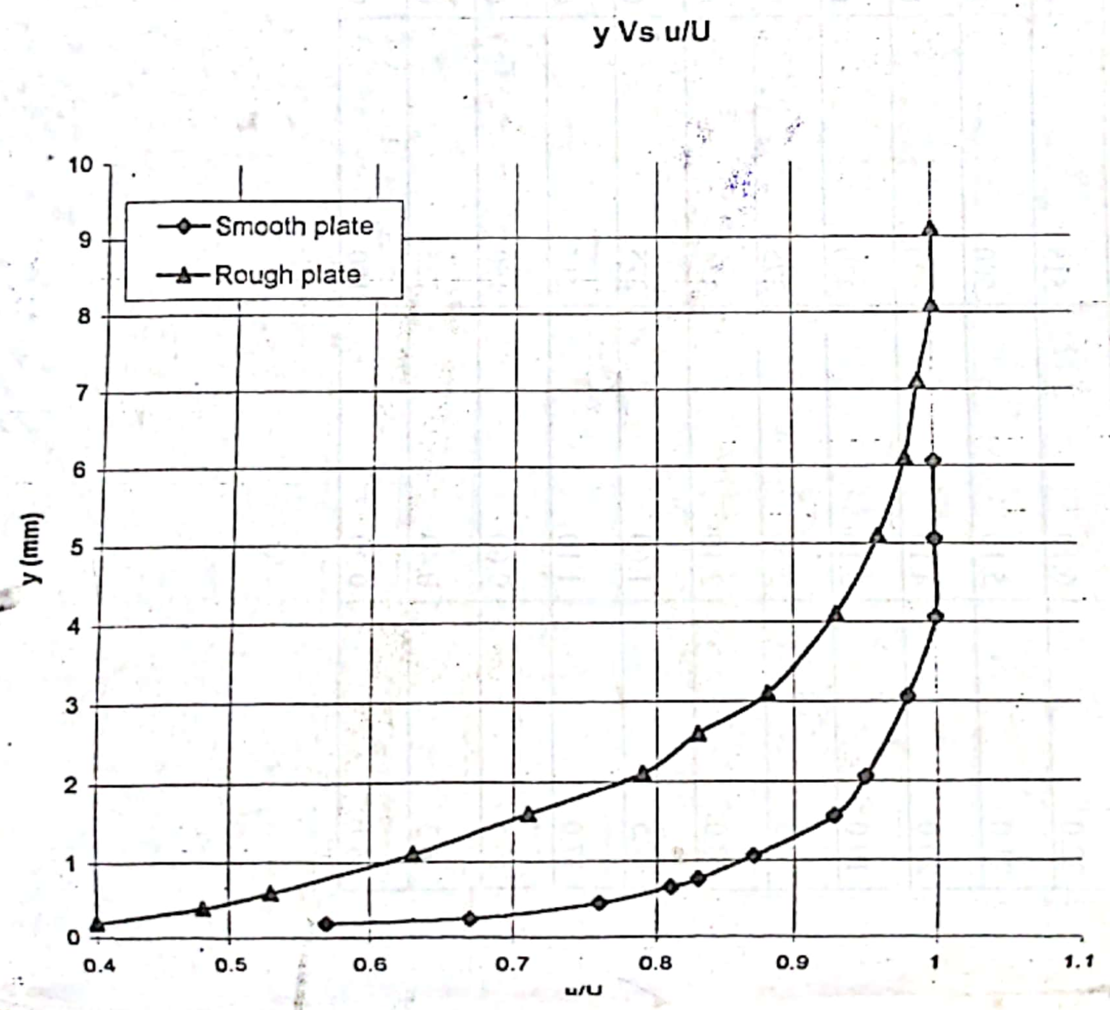
DATA:

(1)Velocity distribution in boundary layer on smooth flat plate :

Micrometer reading	y (mm)	P ($\frac{N}{m^2}$)	u/U
21.0	6.06	550	1.00
20.0	5.06	555	1.00
19.0	4.06	530	1.00
18.0	3.06	495	0.98
17.0	2.06	460	0.95
16.5	1.56	415	0.97
16.0	1.06	380	0.87
15.8	0.86	360	0.83
15.6	0.66	320	0.81
15.4	0.46	250	0.76
15.2	0.26	180	0.67
15.14	0.20	120	0.57

(2) Velocity distribution in boundary layer on rough plate:

Micrometer reading	y (mm)	P ($\frac{N}{m^2}$)	u/U
25.0	9.10	540	1.00
24.0	8.10	540	1.00
23.0	7.10	525	0.99
22.0	6.10	515	0.98
21.0	5.10	500	0.96
20.0	4.10	470	0.93
19.0	3.10	420	0.88
18.5	2.60	375	0.83
18.0	2.10	335	0.79
17.5	1.60	275	0.71
17.0	1.10	215	0.63
16.5	0.60	150	0.53
16.3	0.40	125	0.48
16.10	0.20	100	0.4



y Vs u/U
Smooth plate
Rough plate
y (mm)
u/U
0
1
2
3
4
5
6
7
8
9
10
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1

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INSTRUCTION MANUAL
FOR
FLUID MACHANICS & MACHINERY LAB
COURSE NO. ME-506

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