TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS

LABORATORY MANUAL ON FLUID MECHANICS
(SECOND YEAR/ SECOND PART)

FOR
BACHELOR’S DEGREE IN MECHANICAL ENGINEERING

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PREFFACE

The lab manual is specially designed for the Mechanical student of Tribhuvan University Institute of Engineering Pulchowk Campus. I would like to thank Mechanical Department Head Mr. Ram Chandra Sapkota for giving opportunity for producing this LABORATORY MANUAL ON FLUID MECHANICS.

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Table of Contents

EXPERIMENT AND REPORTING WRITING

1. Individual observation sheet must be completed and checked on the date of performance of the corresponding experiments.

2. There must be a signature of teacher on each individual observation sheets.

3. Individual lab report must be submitted on the following day of the performance of the corresponding experiments.

4. The lab report should contain: Cover page, Objective, Theory and Equations, Observation Table, Result Table, Sample Calculation, Graphs, Conclusions.

5. Internal marking system (Full marks – 25, Pass marks - 10): Lab performance- 5, Lab Report-8, Final Quiz- 6, Pre and post viva-6

EXPERIMENT NO. 1a
PROPERTIES OF FLUID

I. OBJECTIVE OF THE EXPERIMENT

To study the properties of fluid and theories of measuring the properties.

1. To determine the density of liquid and solid provided using different methods and compare the result obtained with the standard value.
2. To determine the viscosity of the liquid provided and compare the experiment result with the standard value.
3. To determine the specific gravity of liquid provided using hydrometer and compare with the standard value.

II. THEORY AND EQUATION

The term "fluid" relates to both gases and liquids (for example, air and water) and, although there are differences between them, they both have the same essential property that when acted upon by any unbalanced external force an infinite change of shape will occur if the force acts for a long enough time. Alternatively one may say that if acted on by a force, a fluid will move continuously whilst a solid will distort only a fixed amount. If a shear force is applied to one surface of a volume of fluid, the layers of fluid will move over one another thus producing a velocity gradient in the fluid. For a given shear stress, a property called the viscosity determines the velocity gradient and hence the velocity of the fluid in the plane of the applied stress. The viscosity is a measure of fluid resistance to motion. Viscosity is a very important property in fluid mechanics since it determines the behavior of fluids whenever they move relative to solid surfaces.

Liquids and gases both share the property of “fluidity” described above, but they differ in other respects. A quantity of liquid has a definite volume and if in contact with a gas it has a definite boundary or “free surface”. Gases, on the other hand, expand to fill the space available and cannot be considered as having a definite volume unless constrained on all sides by fixed boundaries (e.g. a totally enclosed vessel). The volume of a liquid changes slightly with pressure and temperature, but for a gas these changes can be very large. For most engineering purposes liquids can be regarded as incompressible, by which we mean that volume and density do not change significantly with pressure, whereas gas usually have to be treated as compressible. Similarly the effects of varying temperature can often be ignored for liquids (except in certain special cases), but must be taken into account with gases.

The engineer is often concerned with determining the forces produced by static or moving fluids and when doing this the above differences between liquids and gases can be very important. Generally it is much easier to deal with liquids because, for most purposes, it can be assumed that their volume and density do not change with pressure and temperature. In the study of hydrostatics we are primarily concerned with the forces due to static liquids. The forces result from the pressure acting in the liquid and at a given point this depend on the depth below the free surface. Density, or mass per unit volume, is a basic property which must be known before any calculations of forces can be made.

When considering the interfaces between liquids, solids and gases there is a further property which can produce forces and this is called the surface tension. When a liquid/gas interface is in contact with a solid boundary the edge of the liquid will be distorted upwards or downwards depending on whether the solid attracts or repels the liquid. If the liquid is attracted to, or “wets” the solid, it will move upwards at the edge and the surface tension will cause a small upwards force on the body of the liquid. If the liquid is in a tube the force will act all round the periphery and the liquid may be drawn up the tube by a mall amount. This is sometimes called the “capillarity” effect or “capillary” action. The forces involved are small and the effect need only be considered in a limited number of special cases.

III. DESCRIPTION OF EQUIPMENT SET-UP

1.Measuring beaker – 800 ml	12. Stop clock	23.Cycle pump	34. Left hand sink cover
2.Measuring beaker – 100 ml	13. Pascal tubes	24.Barometer	35. Side moulding
3.Beam balance	14. Archimedes	25.Valve (V1)	36. Schrader valve (V4)
4.Eureka can	15. Pontoon	26.Depth gauge	37. User guide
5.Density bottle	16. Toroidal segment	27. Hydrometer	38. Mercury manometer trap
6.Header tank	17. Weights (brass)	28. Ball guide	39. Water manometer trap
7.Capillary tubes	18. Bourdon gauge	29. Pipette tube	40. Top moulding
8.Capillary plate	19. Calibration cylinder	30. Rubber bung	41. Main unit
9.Shims	20. Weights (iron)	31. 50g weight hanger (brass)	42. Sump tank
10.Spheres	21. Mercury manometer	32. Drain cover	43. Vertical scale
11.Graduated jars	22. Water manometer	33. Right hand sink cover	44. Bilge pump

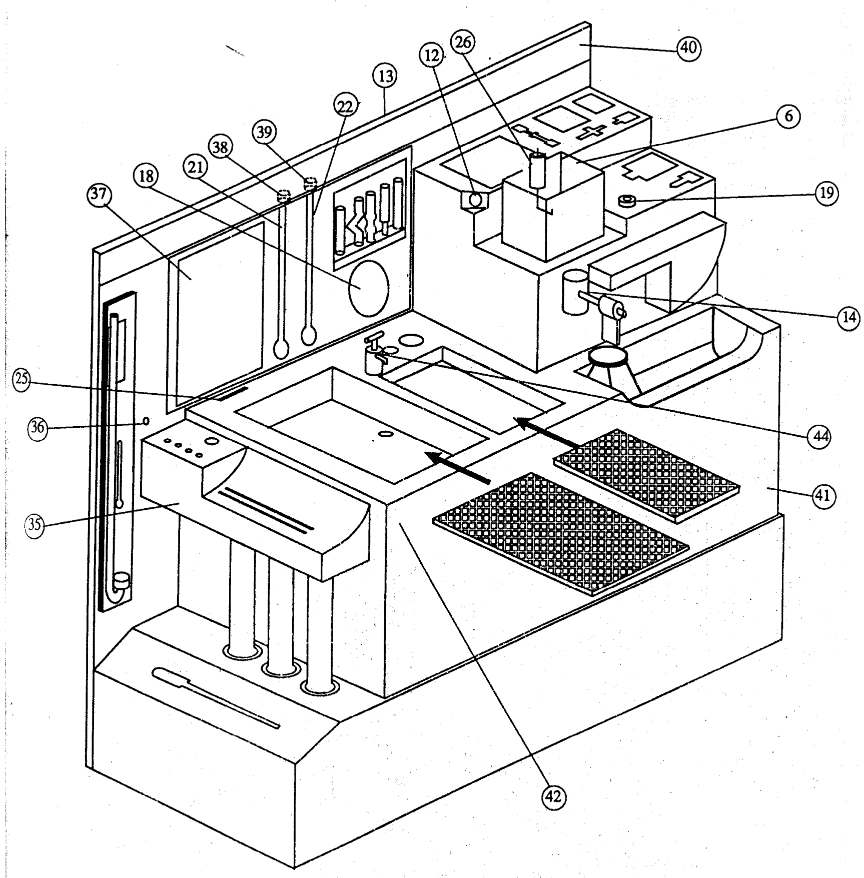


Fig. 1.1 A Installation Drawing for Properties of Fluids Apparatus

Hydrostatics and Properties of Fluids Apparatus provides a comprehensive range of experiments and demonstrations which are designed to give the student a thorough understanding of the basic principles of fluid mechanics and properties of fluids. Properties such as densities, viscosity and surface tension can be determined and basic principles such as Pascal's Law and Archimedes' Law demonstrated.

From these the student can progress to a wide range of practical applications of hydrostatic principles including buoyancy, center of pressure, flotation and stability of floating bodies, measurement of barometric pressure, operation and calibration of a Bourdon pressure gauge, and the very important subject of manometer. In addition to these topics a demonstration of static head due to friction along a pipe can be given.

The apparatus is shown above. The basic unit consists of a single integral plastic moulding mounted on lockable castors. Water is drawn from a sump tank via a lift pump to the experiments. A large drainable working surface is provided for small experiments.

The right hand side of the unit has moulded features to locate a number of experiments (e.g. center of pressure, Archimedes, etc) together with storage for loose items. The back panel supports manometers (pressurized by an air pump), a pressure gauge, and Pascals tubes. This is covered in an easy to clean plastic sheet. The left hand side provides covered storage for viscosity jars and small items.

A portion of the working surface can be removed to access a reservoir which stores a stability pontoon and can be filled to float the pontoon for experiments.

IV. PROCEDURE

4.1 DETERMINATION OF DENSITY

4.1.1 DETERMINATION OF DENSITY OF LIQUID PROVIDED

To determine the density of a liquid it is necessary to measure the mass of a known volume of liquid. The volume is more difficult quantity to determine, and three methods are outlined below. Any liquid may be used but for demonstration purposes water is the most convenient.

(A) <u>MEASURING BEAKER</u>

1. Weigh the empty measuring beaker (1) using the triple beam balance (3) and record the mass.

2. Fill the beaker with water and read the volume as accurately as possible.
3. Weigh the beaker plus water and record the mass. The mass of water can then be determined by subtraction and the density ρ obtained as :

$$\rho = \frac{mass.in.grammes}{volume.in.ml} x \frac{10^6}{10^3} \quad (kg/m^3) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

The density of pure water at 20^o C is 998,2 kg/m^3 and this is often rounded up to 1000 kg/m^3 for engineering purposes. The experimental result should be within 1% of this value. The measurement of volume is not very precise and depends on the accuracy of the graduations on the beaker and this cannot be checked.

(B) <u>EUREKA CAN</u>

The Eureka can (4) is a container with a fixed spout. If filled until liquid overflows will always be the same provided the can is level and the liquid is not contaminated. If the can is initially full and a solid object is placed in it, a volume of liquid will be displaced equal to the volume of the object. This gives us a basic method of obtaining a known volume of liquid.

1. Take a solid object which will fit in the can (for example a cylinder or cube) and accurately measure its dimensions and calculate its volume.
2. Place the Eureka can at the edge on the working surface and fill it with liquid until it overflows.
3. Weigh an empty beaker (2), then place this under the spout.
4. Gently lower the object into the can until fully immersed and collect the liquid in the beaker. Then re-weigh the beaker plus liquid.

The mass of liquid displaced can be obtained by subtraction and the density calculated as before. The result may be less accurate than with the measuring beaker but it demonstrates a more fundamental way of determining the volume of liquid. The errors might be reduced if the can and the solid object were much larger. A good question for discussion might be whether the best accuracy would be obtained with a narrow, deep can, or wide, shallow can.

(C) <u>DENSITY BOTTLE</u>

The problem of accurately measuring a volume of liquid can be overcome by using a special vessel with a known volume such as a density bottle (5). This is accurately made and has a glass stopper with a hole in it through which excess liquid is expelled. When the liquid is level with the top of the stopper, the volume of liquid is 50 cm^3 (ml).

1. Dry and weigh the bottle and stopper.
2. Fill the bottle with liquid and replace the stopper.
3. Carefully dry the outside of the bottle with a cloth or tissue paper and remove any excess liquid from the stopper such that the liquid in the hole is level with the top of the stopper.
4. Re-weigh the bottle plus liquid and determine the mass of liquid and hence the density.

This method should give an accurate result and is limited more by the accuracy of the balance than by the volume of liquid.

4.1.2 DETERMINATION OF DENSITY OF SOLID PROVIDED

Having determined the density of a liquid such as water is interesting to note that methods used can be adapted to measure the density of regular and irregular solids, for example stone. If a measured weight of solid is put into the Eureka can, we can determine the volume of solid from the mass of water displaced (since we know the density of water). The density of the solid is then its mass divided by the volume of water displaced. The density bottle could also be used to determine the density of grain solid (eg. sand) and the student could be asked to work out how to do this as a further exercise.

4.2 SPECIFIC GRAVITY

Specific gravity or relatively density as it is sometimes called, is the ration of the density of a fluid to the density of water. Typical values are 0,8 for paraffin, 1,6 for carbon tetrachloride and 13,6 for mercury. Specific gravity should not be confused with density even though in some units (eg the C.G.S. system) it has the same numerical values.

Similarly specific weight should not be confused with density or specific gravity. Specific weight is used in some text books in place of density and is the weight force per unit volume of a fluid. It only has a fixed value when the gravitational acceleration is constant. In determining density we have used a beam balance to “weigh” quantities of liquid and this is calibrated in grams (i.e. units of mass). The quantity to be weighed is balanced by sliding weights along the lever arms. A useful question for discussion could be “would the density of water be the same on the Moon where gravity is one sixth that on the Earth, and would you obtain the same result for density if you used the methods of section “determination of density” on the Moon?”

Specific gravity can be determined directly from the density of a liquid as measured, for example, by using a density bottle. The value is simply divided by the density of water to obtain the specific gravity. A convenient alternative method os to use a specially calibrated instrument called a hydrometer (27). This takes the form of a hollow glass float which is weighted to float upright in liquids of various densities. The depth to which the stem links in the liquid is a measure of the density of the liquid and a scale is provided which is calibrated to read specific gravity. The sensitivity of the hydrometer depends on the diameter of the stem. A very sensitive hydrometer would have a large bulb and a thin stem (see Fig 2). To determine the specific gravity of any liquid, place one of the tall glass cylinders (11) on the measuring surface and fill with a liquid and allow air to rise to the top. Carefully insert the hydrometer and allow it to settle in the center of the cylinder. Take care not to let it touch the sides otherwise surface tension effects may cause errors. When the hydrometer has settled, read the scale at the level of the free water surface (i.e. at the bottom of the meniscus, see F.8).

4.3 VISCOSITY

As explained in the introduction to this section, viscosity is one of the most important properties of fluids since it determines the behavior whenever relative movement between fluids and solids occurs. In a simple case in which a section of fluid is acted on by a shear sress τ it can be shown that a velocity gradient is produced which is proportional to be applied shear stress. The constant of proportionality is the coefficient of viscosity μ and the equation is usually written :

$$\tau = \mu \frac{du}{dy} \qquad \text{.....6}$$

where du/dy is the velocity gradient normal to the plane of the applied stress.

The above equation is derived in most text books and represents a model of a situation in which layers of fluid move smoothly over one another. This is termed “viscous” or “laminar” flow. For such conditions, experiments show that equation 6 is valid and that μ is constant for any given fluid at a given temperature. For other conditions at higher velocities, when turbulent eddies are formed and mixing takes place between the layers, the behavior cannot be represented so simply and we will not consider these cases here.

Equation 6 shows that if fluid flows over an object there will be a velocity gradient in the flow adjacent to the surface and a shear force transmitted to the fluid which tends to resist its motion. Similarly if an abject moves through a fluid, velocity gradients will also be set up and a force generated on the object which tends to resist its motion. In all such cases a knowledge of μ is required to calculate the forces involved. It should be noted that μ varies with temperature, therefore values for a given fluid are usually tabulated for various temperatures. In the SI system μ has units of Ns/m^2.

In fluid mechanics the term μ/ρ often appears and this is called the Kinematic Viscosity and denoted by :

$$\nu = \frac{Coefficient.of.Viscosity.\mu}{Density.\rho} \text{ ………………………………………………………7}$$

Kinematic Viscosity is very often more convenient to use and has units of m^2/s which are often easier to work with.

There are many experimental methods which can be used to determinate μ and these are generally less direct than measuring the parameters in equation 6. One common method is to consider the rate at which a smooth sphere will fall through a liquid for which it is required to determine the viscosity. Under equilibrium conditions the shear or "friction" forces on the sphere will equal its weight and the sphere will fall at a constant velocity μ called the terminal velocity. An equation due to Stokes defines the terminal velocity and this is called Stokes Law.

The equation can be written,

$$u = \frac{gd^2}{18\nu}\left(\frac{\sigma}{\rho} - 1\right) \text{ ……………………………………………………………………8}$$

where d is the diameter of the sphere

σ is the density of the sphere

ρ is the density of the fluid

ν is the kinematic viscosity of the fluid

This equation is only applicable for viscous flow for which a variable called Reynolds Number is below a certain value where,

$$\text{Reynolds Number, } Re = \frac{\rho ud}{\mu} = \frac{ud}{\nu} \text{ ……………………………………………...9}$$

The limiting value of Re is often taken as 0,2 and above this value the errors in applying equation 8 becomes significant.

Considering equation 8 it is clear that the velocity decreases as ν increases and this can be demonstrated for a range of different liquids. It is also possible to determine ν (or μ) from equation 8 and this can be done using the falling sphere viscometer supplied with the apparatus.

(A) DEMONSTRATION OF VARYING VISCOSITY OF LIQUIDS

For this simple demonstration the three graduated jars can be used together with the set of steel balls supplied. The cylinders should be filled with three different liquids, for example, water, oil, and glycerin. Insert ball guide (28) into the top of each cylinder in turn. Comparisons can be made by dropping balls (10) of the same size into each cylinder and observing the time taken to reach the bottom. By comparing different sized balls it can be shown that the velocity depends on diameter as shown in equation 8.

(B) DETERMINATION OF VISCOSITY

The viscosity of relatively high viscosity fluids can be determined (e.g. oil, glycerin, castor oil, etc). Fill each of the three graduated jars with different fluids. Test each fluid in turn by

a. Inserting the ball guide.
b. Set the upper timing band marker approximately 20 mm below the level of th base of the ball guide.
c. Set the lower timing band marker to approximately 200 mm below the first.
d. Drop the ball into the fluid and time the descent between the markers using the stop clock (12).
e. Measure the distance between the markers.
f. Measure the temperature of the liquid.

Note :

(i) Moveable timing band markers are used to allow practical timings for very viscous fluid where less than 200 mm fall is required.

(ii) A vertical reference for the timing band markers is provided by the volume scale on the jar.

Liquid	Specific Gravity at 20°C	Kinematic Viscosity (ν x 10^5) m^2/s at 20°C	Typical time to fall 200 mm (s)	
			1,6 mm ball	3,2 mm ball
Water	1.0	0.1	0.02	0.005
Medium oil	0.89	12	2.8	0.7
Thick oil	0.90	30	6.8	1.7
Glycerin	1.26	65	10	2.5
Castor oil	0.96	100	20	5

TABLE 1 : Viscosity Data for Typical Liquids

It can be seen that thick oils, Glycerin and Castor oil are the most suitable and that the best accuracy (i.e. longest times) are obtained with the smallest balls.

A typical result obtained with fairly thick lubricating oil using a 1.6 mm ball was as follows:

Actual ball diameter = 1.59 mm

Temperature oil = 18°C

Time to fall 200 mm = 4.2 sec

V. QUESTION AND ANSWER

1. Causes of errors in the experiment
2. Which is the best method of measuring density of water?
3. State different parameters that affect the density of fluids.
4. What will be the effect of taking larger size of sphere for measurement of viscosity?

VI. OBSERVATION AND RESULT TABLE

Date of performance: Teacher's Signature:

Students' Name:

Roll No:

OBSERVATION SHEET: Expt.:– Determination of Density of water and irregular and regular solids.

1. **Density of Water:***(Use beaker)*

Wt. of empty beaker (kg)	Wt of beaker with water (kg)	Wt. of water (m) Kg	Vol. of water (V) m3	Density of water (ρ_o) = m/V kg/m3	Standard density of water (ρs)	% error = $\frac{\rho_0 - \rho_s}{\rho_s} * 100$

2. **Density of Water:** *(Use Density bottle)*

Wt. of empty density bottle (kg)	Wt of density bottle with water (kg)	Wt. of water (m) Kg	Vol. of water (V) m3	Density of water (ρ_o) = m/V kg/m3	Standard density of water (ρs)	% error = $\frac{\rho_0 - \rho_s}{\rho_s} * 100$

3. **Density of irregular Solid***(Use Eureka can method)*

Wt. of solid (m) (kg)	Vol. Of displaced water (V) (m3)	Density of solid (ρ_o) = m/V (kg/m3)	Standard density of solid (ρs)	% error = $\frac{\rho_0 - \rho_s}{\rho_s} * 100$

4. **Density of regular Solid***(Use Eureka can method)*

Wt. of solid (m)	Vol. of displaced water	Density of solid (ρ_o) = m/V	Standard density of	% error = $\frac{\rho_0 - \rho_s}{\rho_s} * 100$

(kg)	(V) (m3)	(kg/m3)	solid (ρs) (kg/m3)	

5. Measuring side of the solid:

Wt. of solid (m) (kg)	Vol. of solid (V) = l * b* h (m3)	Density of solid (ρ_o) = m/V (kg/m3)	Standard density of solid (ρs) (kg/m3)	% error = $\frac{\rho_0 - \rho_s}{\rho_s} * 100$

6. Experiment: Determination of sp. Gravity of fluids

Direct measurement with hydrometer:

Sp. Gravity or relative density of Glycerin $\mathbf{S_{go}}$ =

Sp. Gravity or relative density of Castor oil $\mathbf{S_{co}}$ =

Standard Sp. Gravity or relative density of Glycerin $\mathbf{S_{gs}}$ =

Standard Sp. Gravity or relative density of Castor oil $\mathbf{S_{cs}}$ =

% Error = $\mathbf{(S_{go} - S_{gs}) \times 100 / S_{gs}}$

% Error = $\mathbf{(S_{co} - S_{cs}) \times 100 / S_{cs}}$

7. Experiment: Determination of Viscosity of Liquids:

Distance Between two marking (D)	Diameter of sphere(d)	Time taken by sphere to fall (t) (sec)	Density of sphere kg/m3	Terminal Velocity (u)= D/t	$v_0 = \frac{gd^2}{18u}(\frac{\sigma}{\rho} - 1)$	Standard viscosity υ_s	% error = $(\upsilon_o - \upsilon_s) \times 100 / \upsilon_s$
Glycerin	1/8’’						
	1/16’’						
Castor oil	1/8’’						
	1/16’’						

EXPERIMENT NO. 2
HYDROSTATIC PRESSURE

I OBJECTIVE OF THE EXPERIMENT

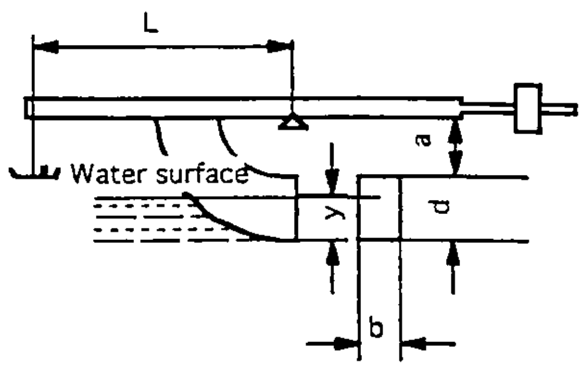
To determine the center of pressure on a partially submerged plane surface.
To determine the position of the center of pressure of plane surface immersed in water and to compare the experimental position with the theoretical position.

II THEORY AND EQUATION

2.1 *Experiment A :*

$$mgL = \frac{\rho g}{2} by^2\left[(a+d) - \frac{y}{3}\right]$$

$$\therefore \frac{m}{y^2} = \frac{\rho b}{2L}[a+d] - \frac{\rho b}{2L}\left(\frac{y}{3}\right)$$



The force F on any flat submerged surface is the pressure at the center of area multiplied by the area A of the submerged surface.

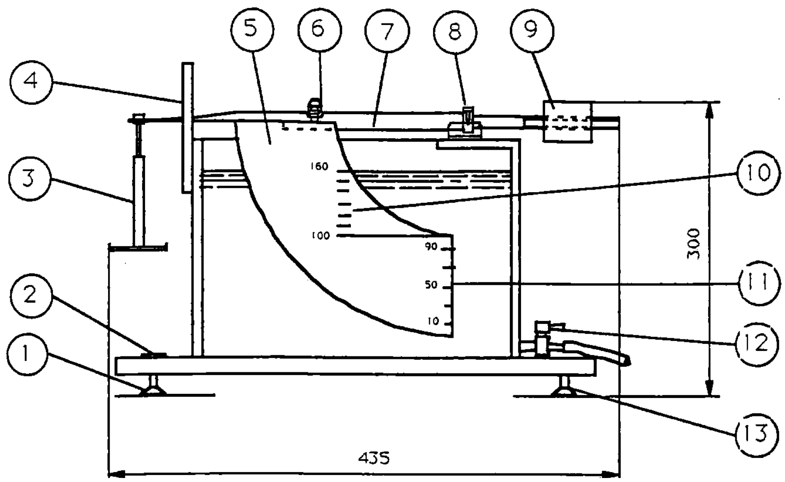
$$F = \rho.g.\overline{X}.A$$

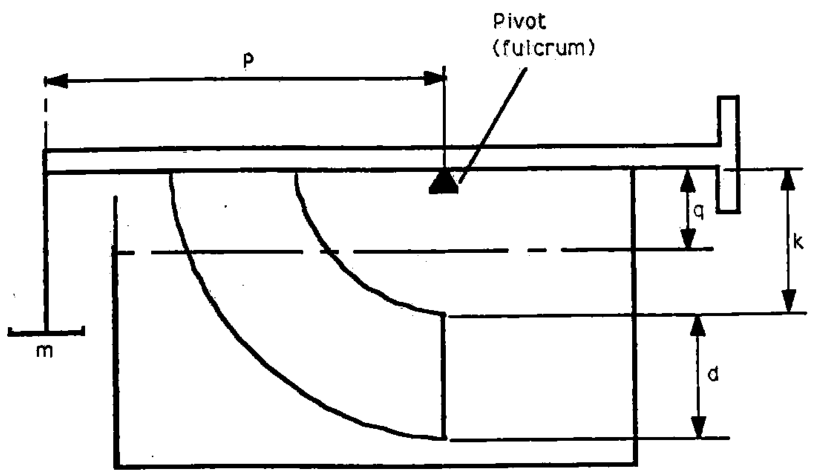
We know the magnitude of the distributed force F, which may be considered as a series of small forces spread over the submerged surface. The sum of the moments of all these small forces about any point must be equivalent to the moment about the same point of the resultant force F acting through its point of application (known as the **CENTRE OF PRESSURE**).

III DESCRIPTION OF EQUIPMENT SET-UP

Hydraulics Bench and

Hydrostatic Pressure Apparatus





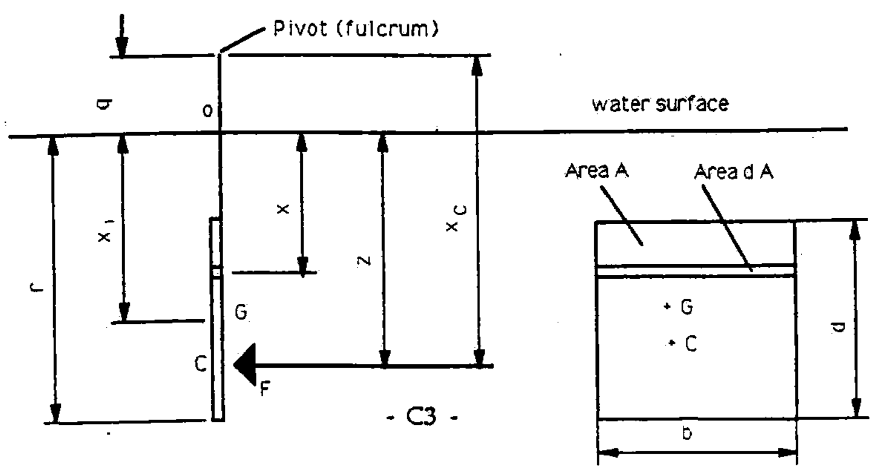


Fig.2.1 Installation Drawing for Hydrostatic Pressure Apparatus

A fabricated quadrant, (5) is mounted on a balance arm, (7) which pivots on knife edges (8). The line of contact of the knife edges coincides with the axis of the quadrant. Thus the hydrostatic forces acting on the quadrant when immersed, only the force on the rectangular end face, (11) gives rise to a moment about the knife edge axis.

In addition to quadrant clamping screw (6), the balance arm incorporates a balance pan, (3) and adjustable counterbalance (9).

The Perspex tank, (1) may be leveled by adjusting the screwed feet (13). Correct alignment is indicated on a circular spirit level (2) mounted on the base of the tank.

An indicator, (4) attached to the side of the tank shows when the balance arm (7) is horizontal.

Water is admitted to the top of the tank by flexible tube and may be drained through the cock (12) to which a length of half inch flexible tube may be attached. The water level is indicated on a scale (10). The water supply may be obtained from the outlet of the hydraulic bench. Alternatively, this accessory may be used independent of the bench.

IV PROCEDURE

Place the quadrant on the two dowel pins and using the clamping screw, fasten to the balance arm. Measure a, L, depth d and width b, of the quadrant end face. With the Perspex tank on the bench, position the balance arm on the knife edges (pivot). Hang the balance pan from the end of the balance arm. Connect a length of hose from the drain cock to the sump and a length from the bench feed to the triangular aperture on the top of the Perspex tank. Level the tank using the adjustable feet and spirit level. Move the counter balance weight until the balance arm is horizontal.

Close the drain cock and admit water until the level reaches the bottom edge of the quadrant. Place a weight on the balance pa, slowly adding water into the tank until the balance arm is horizontal. Record the water level on the quadrant and the weight on the balance pan.

Fine adjustment of the water level can be achieved by overfilling and slowly draining, using the stop cock.

Repeat the above for each increment of weight until the water level reaches the top of the quadrant end face. Then remove each increment of weight noting weights and water levels until the weights have been removed.

V QUESTION AND ANSWER

1. Plot m/y^2 against y
2. Find the value of slope of the graph ($-\frac{\rho b}{6L}$) and the value of intercept $\frac{\rho b}{6L}(a+d)$
3. Give reasons for the discrepancies, if any, between the measured and predicted values of the above expressions for the graph parameters.
4. Find the % error if there is any and give reasons for the errors occurred.

VI OBSERVATION AND RESULT TABLE

Date of performance: Teacher's Signature:

Students' Name:

Roll No:

OBSERVATION SHEET:

Filling Tank		Draining Tank		Average			
Weight (m1) grams	Height of water (y) cm	Weight (m2) grams	Height of water (y)	m grams	y cm	y^2 cm^2	m/y^2 g/m^2
50							
100							
150							
200							
250							
300							
350							

L = cm b = cm

a = cm d = cm

EXPERIMENT NO. 3
BERNOULLI'S THEOREM

I OBJECTIVE OF THE EXPERIMENT

To investigate the validity of Bernoulli's Theorem as applied to the flow of water in a tapering circular duct.

II THEORY AND EQUATION

Considering flow at two sections in a pipe, Bernoulli's equation may be written as:

$$\frac{U_1^2}{2g} + \frac{p_1}{\rho g} + Z_1 = \frac{U_2^2}{2g} + \frac{p_2}{\rho g} + Z_2$$ for this apparatus $Z_1 = Z_2$ = elevation

Hence if Bernoulli's Theorem is obeyed :

III DESCRIPTION OF EQUIPMENT SET-UP

Hydraulics Bench, Bernoulli's Theorem Demonstration Apparatus, Stop watch

Figure: Installation drawing for Bernoulli's Theorem Demonstration Apparatus

The test section (5), is an accurately machined Perspex duct of varying circular cross section provided with pressure tapers whereby the static pressure may be measured simultaneously at each 6 sections. The test section incorporates unions (2, at either end to facilitate reversal for convergent or divergent testing.

A hypodermic (7), is provided which may be positioned to read the total head at any section of the duct. The probe may be moved after slackening the gland nut (6); this nut should be water-tightened by hand. To prevent damage, the probe should be fully inserted during

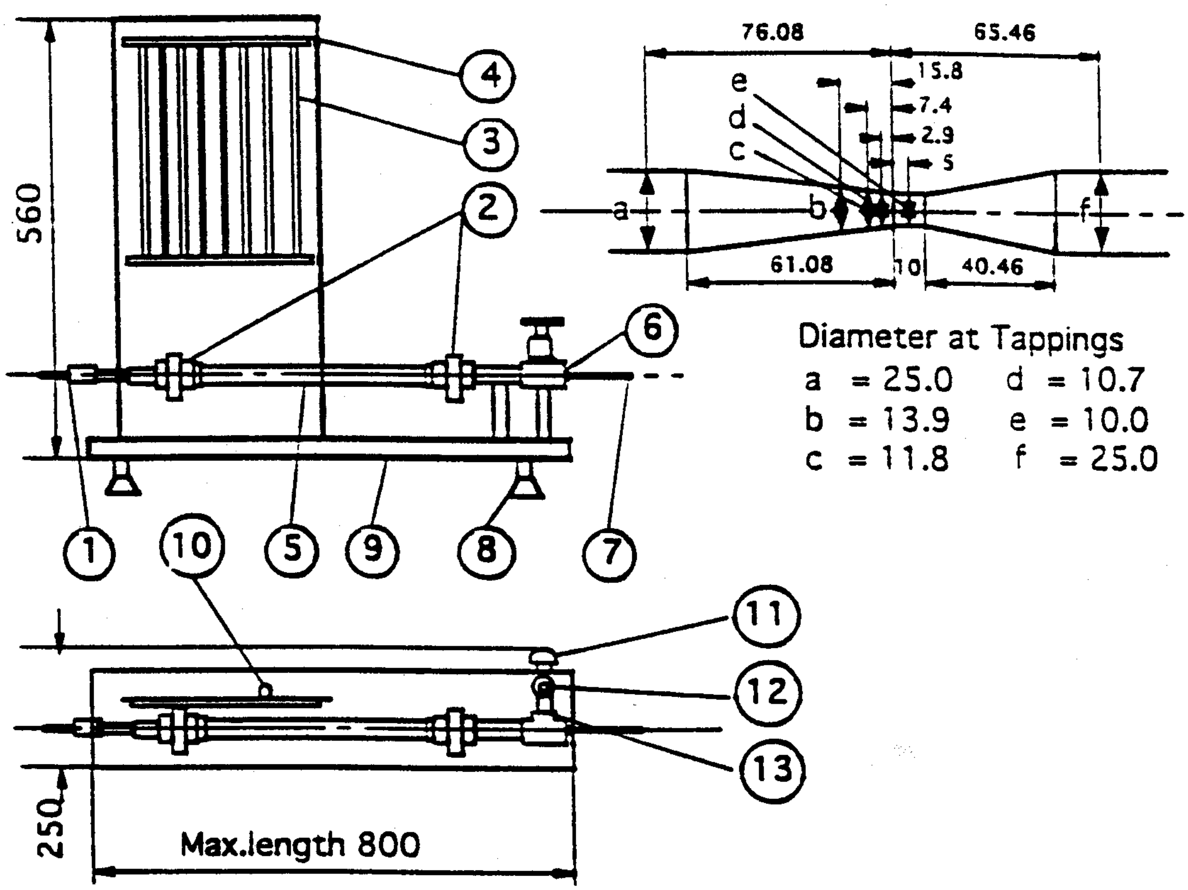


Fig.3.1. Installation Drawing for Bernoulli Apparatus

transport/storage. An additional tapping (13), is provided to facilitate setting up. All eight pressure taper are connected to a bank of pressurized manometer tubes (3). Pressurisation of the manometers is facilitated by removing the hand pump, (10) from its storage location at the rear of the manometer board and connecting its flexible coupling to the inlet valve (4) on the manometer manifold.

IV PROCEDURE

By using the adjustable feet, the apparatus is leveled on the Hydraulics Bench. After injecting a small amount of wetting agent into the test section, the apparatus is connected to the bench, ensuring that the test section has the 14^{o} tapered duct converging in the direction of flow. To reverse the test section, the total head probe must be withdrawn before releasing the couplings.

Carefully fill the apparatus manometer tubes with water to discharge all pockets of air from the system and ensure all connecting pipes are free from air. By adjusment of feed water and the flow control valve, the levels can be raised or lowered as required. For finite lowering of the levels, the hand pump is used at the air inlet to raise the air pressure above the liquid columns. Carefully adjust the inlet feed and the flow control valves to provide the combination of flow rate and system pressure which will give the largest convenient difference between the highest and lowest manometer levels. Note the scale reading of each manometer level. Take at least three sets of readings of volume and time to find the flow rate using the volumetric tank.

Insert the probe to the end of the parallel position of the duct, then move it into the tapered portions ***a ~f***. For each position, record the scale reading of its manometer level.

Repeat this to give high and low flow rates at both high and low static pressure for different combinations of valve openings.

Stop the inlet feed, drain off the apparatus, withdraw the probe (full length), undo the couplings, reverse the test sections and replace the couplings.
Repeat the above procedure.

V QUESTION AND ANSWER

1. List out the limitations of Bernoulli Equation.
2. Compare theoretical BE with the current experiment results.
3. Why do you level the experiment section (tube)?
4. Draw graph for the positions of manometer Vs. EGL and HGL for three different flow rates.
5. Describe the different slope obtained in the graph.
6. Discuss the result obtained by the manometer tube no. 6 and 7 & 1 and 8.
7. What is dynamic pressure and static pressure?
8. Write your comments if any in the experiment.

VI OBSERVATION AND RESULT TABLE

Date of performance: Teacher's Signature:

Students' Name:

Roll No:

Flow Rate (Q_1) m^3/sec = Elevation energy Head (Z) m =

Tube No.	Dia. Of the tube (D) m	Cross section area of the tube ($\frac{\Pi D^2}{4}$) m^2	Manometer reading of the tube from position 1 to 8 m	Velocity of water in the tube in position 1 to (v) m/s	Pressure energy Head (p/ρg) m	Velocity energy Head ($v^2/2g$) m	EGL (p/ρg+ $v^2/2g$+z) m	HGL (p/ρg+ z) m
1								
2								
3								
4								
5								
6								
7								
8								

Flow Rate (Q_2) m^3/sec = Elevation energy Head (Z) m =

Tube No.	Dia. Of the tube (D) m	Cross section area of the tube $(\frac{\Pi D^2}{4})$ m^2	Manometer reading of the tube from position 1 to 8 m	Velocity of water in the tube in position 1 to (v) m/s	Pressure energy Head (p/ρg) m	Velocity energy Head ($v^2/2g$) m	EGL ($p/\rho g + v^2/2g + z$) m	HGL ($p/\rho g + z$) m
1								
2								
3								
4								
5								
6								
7								
8								

Flow Rate (Q_3) m^3/sec = Elevation energy Head (Z) m =

Tube No.	Dia. Of the tube (D) m	Cross section area of the tube $(\frac{\Pi D^2}{4})$ m^2	Manometer reading of the tube from position 1 to 8 m	Velocity of water in the tube in position 1 to (v) m/s	Pressure energy Head (p/ρg) m	Velocity energy Head ($v^2/2g$) m	EGL ($p/\rho g + v^2/2g + z$) m	HGL ($p/\rho g + z$) m
1								
2								
3								
4								
5								
6								
7								
8								

EXPERIMENT NO. 4
LOSSES IN PIPE

I OBJECTIVE OF THE EXPERIMENT

Demonstration of the losses and characteristic associated with flow through bends and fittings.

II THEORY AND EQUATION

It is usual to express the energy head loss h in terms of the velocity head in the case of bends values and fittings in a pipe network i.e.

$$h_2 = K\frac{v^2}{2g}$$

where K = loss coefficient, v= velocity of flow

III DESCRIPTION OF EQUIPMENT SET-UP

Hydraulics Bench, Losses in Bends Apparatus, Stop watch, Tapping clamp

The apparatus should be placed on the Hydraulics Bench.

Inlet pipe (11) should be connected to the bench outlet and the outlet pipe from flow control valve (12) positioned in the volumetric tank.

The long bend (1), area enlargement (2), area contraction (3), elbow bend (4), short bend (6), valve fitting (9) and mitre bend (10) are installed in a series configuration to permit direct comparison. Flow rate through the circuit is controlled by the flow control valve (12).

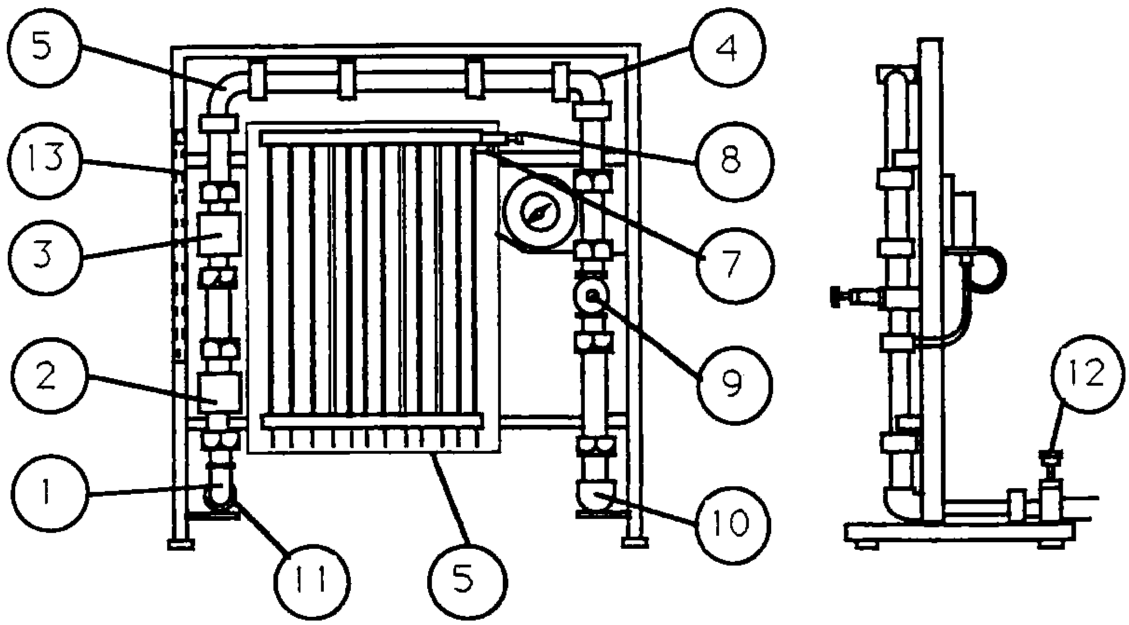


Fig.4.1 Installation Drawing for Losses in Bends Apparatus

Pressure tapings in the circuit are connected to a twelve bank manometer (5), which incorporates an air inlet/outlet valve (7) with an air bleed screw (8) in the top manofold with facilities for connection of a hand pump (13).

This enables the levels to be adjusted in the manometer bank, to a convenient level to suit the system static pressure.

A clamp which closes off the tapings to the mitre bend is introduced when experiments on the valve fitting (9) are required. A differential pressure gauge (14) gives a direct reading of losses through the gate valve (9).

IV PROCEDURE

Set up the apparatus on the bench with the bench feed connected to the inlet pipe, and the outlet pipe running into the volumetric tank. Open the bench feed valve, the gate valve and the flow control valve to admit water into the apparatus, also to disperse any air pockets. When the pipe work has filled with water, connect a short length of flexible tubing to the air connector, close the flow control valve and carefully open the air bleed screw until all tapings and manometer tubes are full of water. In operation, the levels in the manometer tubes can be adjusted by using the hand pump attached to the air connector for raising, and the air bleed screw for lowering. The air bleed screw opens and closes the air flow through the air valve, so when using the hand pump, the bleed screw must be opened. To retain the hand pump pressure in the system the screw must be closed after pumping.

Open the flow control valve slightly, take readings of each manometer tube and measure the flow of water. Note all these readings. Adjust the control valve in stages, noting all readings as above for each stage, until the valve is closed.

Now close the two tapings to the mitre bend by means of a clamp. Open the flow control valve fully and close the gate valve fitting. Note the reading on the pressure gauge. Open the gate valves in regular stages, notng the pressure gauge reading for each stage and measuring the flow. Repeat this until the valve is fully closed. Repeat the sequence in regular stages until the valve is fully open.

V QUESTION AND ANSWER

1. Do the results confirm that h varies with the square of the velocity?

2. How do the values obtained for K compare at different flow rates? Is K constant?

3. Plot h against velocity.
4. The gradient of this graph at any point should be equal to $\frac{Kv}{2g}$
5. A straight line graph can also be obtained by plotting h against V^2.
6. The gradient of this graph at any point is $\frac{K}{2g}$

VI OBSERVATION AND RESULT TABLE

Teacher's Signature

Date of performance/ Students' Name/ Roll No:

Observation no. 1

Fitting	H_1 mm	H_2 mm	Head loss, h= $(H_1 - H_2)$ mm	Area of the pipe A,m^2	Time sec	Flow rate Q Liter/sec	Velocity v m/sec	$v^2/2g$	K
Mitre									
Elbow									
Short Bend									
Enlargement									
Contraction									

Observation no. 2

Fitting	H_1 mm	H_2 mm	Head loss, h= $(H_1 - H_2)$ mm	Area of the pipe A,m^2	Time sec	Flow rate Q Liter/sec	Velocity v m/sec	$v^2/2g$	K
Mitre									
Elbow									
Short Bend									
Enlargement									
Contraction									

Observation no. 3

Fitting	H_1 mm	H_2 mm	Head loss, h= $(H_1 - H_2)$ mm	Area of the pipe A,m^2	Time sec	Flow rate Q Liter/sec	Velocity v m/sec	$v^2/2g$	K
Mitre									
Elbow									
Short Bend									
Enlargement									
Contraction									

Observation no. 4

Fitting	H_1 mm	H_2 mm	Head loss, h= $(H_1 - H_2)$ mm	Area of the pipe A,m^2	Time sec	Flow rate Q Liter/sec	Velocity v m/sec	$v^2/2g$	K
Mitre									
Elbow									
Short Bend									
Enlargement									
Contraction									

Observation no. 5

Fitting	H_1 mm	H_2 mm	Head loss, h= $(H_1 - H_2)$ mm	Area of the pipe A,m^2	Time sec	Flow rate Q Liter/sec	Velocity v m/sec	$v^2/2g$	K
Mitre									
Elbow									
Short Bend									
Enlargement									
Contraction									

EXPERIMENT NO. 5

CHARACTERISTIC OF DIFFERENT TYPES OF FLOWMETERS

I OBJECTIVE OF THE EXPERIMENT

Demonstration of the operation and characteristic of three different basic types of flowmeter.

II THEORY AND EQUATION

For the venturi meter and orifice plate, the basic Bernoulli equation reduces to :

$$Q = C_d A_2 \left(1 - \frac{A_2}{A_1}\right)^2 . \tfrac{1}{2} \left[2g \left(\frac{p_1 - p_2}{\rho} \right) \right]^{\frac{1}{2}}$$

C_d values assumed to be : C_d = 0.98 for the venturi meter

C_d = 0.63 for the orifice plate.

III DESCRIPTION OF EQUIPMENT SET-UP

Hydraulics Bench, Flowmeter Demonstration Apparatus, Stop Watch

The apparatus should be positioned on the side channels of the bench top channel. Inlet pipe (9) should be connected to the bench outlet and outlet pipe (1), positioned in the volumetric tank. The venturi meter (7), variable area meter (5) and orifice plate (3) are installed in a series configuration to permit direct comparison. Flow control valve (2), permits variation of the flow rate through the circuit and adjustment in conjunction with bench control valve allows system static pressure to be varied. Pressure tappings, (8) in the circuit are connected to an eight-bank manometer (6), which incorporates an air inlet/outlet valve (4) in the top manifold with facilities for connection of a hand pump (10). This

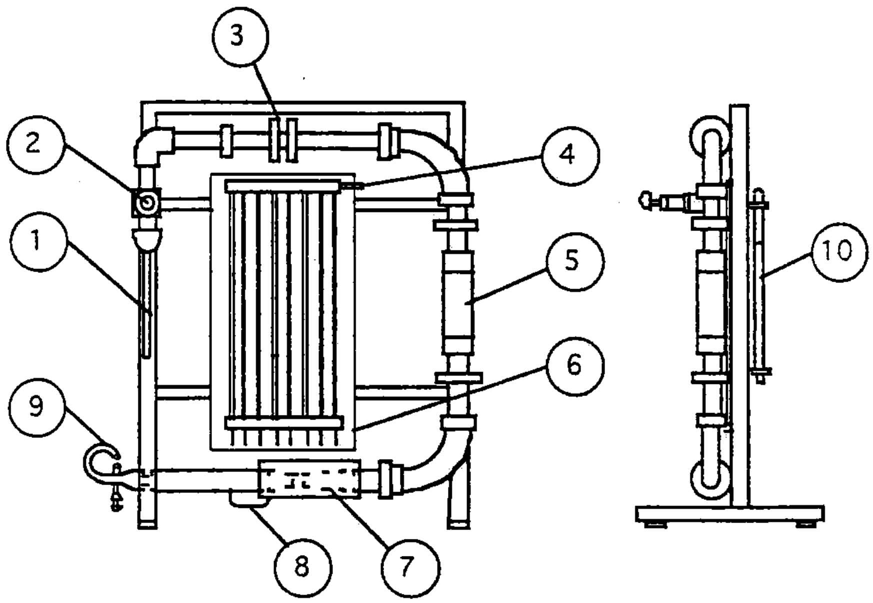


Fig.5.1. Installation Drawing for Flowmeter Demonstration Apparatus

enables the levels in the manometer bank to be adjusted to a convenient level to suit the system static pressure.

IV PROCEDURE

Place apparatus on bench, connect inlet pipe to bench supply and outlet pipe into volumetric tank. Open bench valve fully, open flow control valve. To disperse air from orifice plate, open and close flow control valve, close flow control valve, open air bleed screw and prime manometer and tapping. Close air bleed screw.

The manometer levels can be raised or lowered accordingly by the air bleed screw or hand pump. Open flow control valve fully whilst retaining maximum readings on manometers. Note readings on manometers, variable area meter and measured flow rates. Repeat at different valve positions. To demonstrate similar flow rates at different system static pressure, adjust bench and flow control valve together, adjusting manometer levels as required.

V OBSERVATION AND RESULT TABLE

Date of performance: Teacher's Signature:

Students' Name:

Roll No:

Observation sheet:

Manometer Readings								Variable Area Meter(l/s)	Volume (Bench meter) Liter /Sec	Flow rate Liter/sec (calculated)
1	2	3	4	5	6	7	8			
								20		
								15		
								10		
								5		
								3		

VI QUESTION AND ANSWER

From the manometer, obtain the following:

Venturi reading Man. 1 – Man. 2; Loss in venturi Man. 1 – Man. 3; Loss in variable area meter Man. 4 – Man. 5; Orifice plate reading Man. 6 – Man. 7; Loss in orifice Man. 7 – Man. 8. These quantities are shown diagrammatically above.

Form the readings obtained on the venturi and orifice plate calculate the volume flow rate using the basic equation with relevant C_d factor.

Compare these calculated values with the reading on the variable area meter and the volume flow rate determined, using the Hydraulics Bench facility.

Compare the losses in each of the meters in relation to the volume flow rate. (Note that the loss in the venturi and orifice plate may be related to the velocity head $\frac{U^2}{2g}$).

VII TECHNICAL DATA :

For the venturi :

Upstream pipe dia.	= 31.75 mm
hence A_1	= 7.92×10^{-4} m^2
Throat dia.	= 15 mm
hence A_2	= 1.77×10^{-4} m^2
Upstream taper	= 21^o inclusive
Downstream taper	= 14^o inclusive

For the orifice plate :

Upstream pipe dia.	= 31.75 mm
hence A_1	= 7.92×10^{-4} m^2
Orifice diameter	= 20 mm
hence A_2	= 3.14×10^{-4} m^2

EXPERIMENT 6
FLOW VISUALISATION

I. OBJECT OF EXPERIMENT-

Visualisation of flow patterns over or around immersed objects.

II. SUMMARY OF THEORY

The primary purpose of this piece of apparatus is to demonstrate visually a wide range of hydraulic effects associated with flow in open channels. The intention is to complement lecturers associated with the subject and not to form the basis for theoretical analysis. No theoretical analyses or detailed procedures are included. However, any of the effects may be studied independently in detail, reference being made to a relevant text book.

III. EQUIPMENT SET-UP:

Hydraulics Bench, Flow Visualisation Channel , Vegetable Dye

The inlet pipe (1) is connected direct to the Hydraulics Bench outlet by a quick release connector. The model is positioned on the side channels of the bench top, with the overshot weir adjacent to the volumetric tank. Adjustable feet (13) are provided for leveling the apparatus. Water is fed to the streamlined channel entry via a stilling tank which incorporates marbles (2) to reduce turbulence. The channel (8) consists of a Perspex working section of large depth to width ratio incorporating an undershot weir (7), and an overshot weir (10) at the inlet and discharge ends respectively.

Water discharging from the channel is collected in the volumetric tank of the Hydraulics Bench and returned to the sump for recirculation. A dye injection system, consisting of a reservoir (5), flow control valve (4), manifold (3) and hypodermic tubes (6), is incorporated at the inlet to the channel and permits flow visualisation in conjunction with a graticule on the rear face of the channel. The overshot weir (10) is fully raised for low visualization experiments, this is achieved by releasing thumb screw (11) and weir support (12), moving the weir to the desired position and locking the screws.

Before use the packet dye supplied must be diluted with 1 liter of deionized/distilled water: Open the 3gm packet of Blue Dye and pour the contents along with 1 liter of distilled water into the 1 liter bottle (supplied), "shake well". The 1 liter bottle can be used to store the unused blue dye.

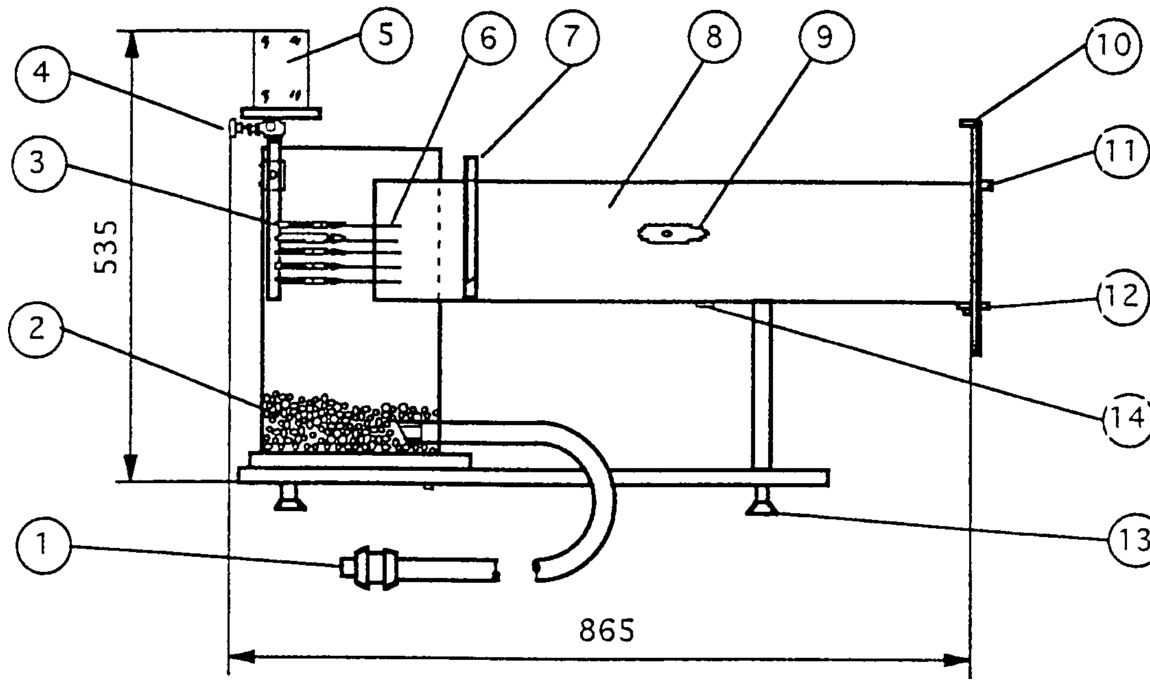


Fig.6.1 Installation Drawing for Flow Visualisation Channel

IV. OBSERVATIONS:

The apparatus should be installed over the bench top open channel. It is important that the apparatus is sited as far as possible from the volumetric tank, along the channels, to ensure that water discharging from the apparatus is contained within the volumetric tank.

Models used in the channel should be positioned using the tongs provided and installed by the appropriate retaining screw. A blanking plug is provided for each of the holes in the wall and floor when not in use.

- The flow visualisation technique involves the use of dye injected at the hypodermic tubes. In operation, the overshot weir should be raised fully and the undershot weir should be removed. The model under investigation should be installed on its retaining screw and the dye injection system installed in its retaining clip. The dye reservoir should be filled with vegetable dye.

- Flow rate through the channel should be adjusted at bench control valve. Density of the dye streams may be adjusted using the control valve at the base of the reservoir.

- With the overshot weir in the raised position, the channel will run full of water enabling flow patterns around and over submerged objects to be demonstrated.
- Demonstrations include flow around small or large cylinders and symmetrical or asymmetrical aero-foils. Patterns of flow over submerged broad and narrow crested weirs may also be demonstrated. '

Note: A vegetable dye having a density similar to water is suggested for use in the apparatus. Heavier or lighter dyes will result in dye streams sinking or floating, resulting in artificial flow patterns. If concentrated dyes are used, rapid colouration of the water in the sump will occur resulting in loss of definition.

VI. QUESTION AND ANSWER

1. Draw the visualisation of flow patterns over or around immersed objects. Repeat the same for two more different flow rates.

2. Describe the conditions for the laminar and turbulent flow for the conditions used in above conditions.

3. How flow rates effect the flow pattern?

4. What is stream line?

5. How stream lines of different objects differs?

6. Write the field of applications of this experiment.

7. Write your comments if any in the experiment.

REFERENCES

1. Hydraulic Bench and accessories, F1-00, Armfield Ltd. England, April 1996

2. Hydrostatics and Properties of Fluid Apparatus, H314 MKII, Tecquipment Limited, London, 1995

3. Victor L. Steeter and E. Benjamin Wylie, 1993, Fluid Mechanics, McGraw Hill Book Company

4. Dr. Jagadish Lal, *Hydraulics Machines*, Metropoliton Co.

5. R.K Rajput, A text book of Hydraulic Machine, S. Chandand Company Ltd. India

THE END

(THANK YOU)