STUDY OF BERNOULLI’S THEOREM, CONSTRUCTION OF AN APPARATUS AND VERIFY THE THEOREM

A PROJECT SUBMITTED TO THE DEPARTMENT OF “MECHANICAL ENGINEERING “IN PARTIAL FULLFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF SCIENCE.

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DECEMBER 2012-12-03

DECLARATION

We hereby declare that the project titled "**DESIGN AND CONSTRUCTION OF BERNOULLIS APPARATUS "**is submitted to the Department of Mechanical Engineering for the partial fulfilment of the requirements for Bachelor of Science Degree on Mechanical Engineering (course no 400).This is our original work and was not submitted elsewhere for the award of any other degree or diploma or any other publication.

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SUPERVISOR CERTIFICATION

This is to certify that,SyedEnamulHasan Kamal, Student ID:200818001; MD.NajmusSakib,Student ID:200818002, Sk.RezanurIslam,Student ID:200818003,have completed their undergraduate project and thesis entitled ***"DESIGN AND CONSTRUCTION OF A BERNOULLI'S APPARATUS"***.This paper embodies original work done under my supervision.

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ACKNOWLEDGEMENT

This project is one of the greatest additions to our knowledge and experience.We acknowledge the help of the individuals who contributed to the successful construction of the different parts of this apparatus .We would specially like to express our most sincere gratitude to our Supervisor Captain MMunir Hassan (BN), Head of The Department, Department of Mechanical Engineering, Military Institute of Science & Technology. His heartfelt assistance and innovative ideas for working out for the project has helped us a lot to complete the project to this far within the given time.

We gratefully acknowledge our deepest gratitude to Captain MMunir Hassan (BN), Head of The Department,Department of Mechanical Engineering,Military Institute of Science &Technology(MIST) who has the whole contribution to this project by allowing us to use the lab facility.

We are extremely grateful to Machine Tools Lab for their technical support and machining facility.

Last but not the least; we would like to show our thanks to the Lab Assistance of Fluid Mechanics Lab.Special Thanks to Dibakarda and Ashraf. Also we are grateful to the "JAMAL METAL WORKS", and Welder Ismail of 16 ECB. They did their best to help with this accomplishment. Without being helped from all personalities mentioned above ,it would not be possible to successfully construct the different parts of the apparatus and the project would not be completed to this far.

ABSTRACT

Bernoulli's apparatus is one of the simple but fundamental experimental devices of fluid mechanics. With this set up anyone could be able to verify physically verify the Bernoulli's equation which is the foundation of Fluid Mechanics and base of fluid flow problem. It will help the undergraduate students to understand the basic concepts of fluid friction, pressure head, velocity head and many others related terminology about the static and dynamic fluid flow. Designing, characterizing and constructing such a device is surely a challenging job which is definitely a result of combination of merits and hard work. In most of the cases this devices are imported from outside the country for experimental purpose and basic lab works. But by using our engineering knowledge and true effort we can construct such device rather than importing them. On the other hand by constructing such complex structure,students will be able to be oriented with many important aspects about construction of engineering apparatus. Subsequent further modification and improvement of this project is always welcome.

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NOMENCLATURE

NOTATION	DEFINITION
g=	Gravitationalacceleration,$9.81m/s^2$
p =	Pressure of fluid, Pa
u=	Velocity offluid,m/s
Z =	Height abovedatum,m
ρ=	Density of fluid,kg/m^3
P=	static pressure of the fluid,
γ=	Specific Weight of the flowing fluid,
v=	velocity of flow,
g=	gravitational acceleration,
Z=	datum head

$\frac{p}{\gamma}$	is the static pressure head
$\frac{v^2}{2g}$	is the dynamic pressure head
C_d	coefficient of discharge
Q	Discharge Volume
X	pitot tube water height
$p_1 + \frac{1}{2}\rho u_1^2$	Stagnation Pressure
$\frac{1}{2}\rho u_1^2$	Dynamic Pressure

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

1.1.1 Background:

Daniel Bernoulli was the son of Johann Bernoulli. He was born in Groningen, Switzerland while his father held the chair of mathematics there. By this In early stage, Daniel Bernoulli’s fatherJohann Bernoulli was prepared to teach his son more mathematics while he studied medicine and Daniel studied his father's theories of kinetic energy. What he learned on the conservation of energy from his father he applied to his medical studies and Daniel wrote his doctoral dissertation on the mechanics of breathing.

A second important work which Daniel produced while in St Petersburg was one on probability and political economy. Undoubtedly the most important work which Daniel Bernoulli did while in St Petersburg was his work on hydrodynamics. Daniel Bernoulli was much honoured in his own lifetime. He was elected to most of the leading scientific societies of his day including those in Bologna, St Petersburg, Berlin, Paris, London, Bern, Turin, Zurich and Mannheim

1.1.3 OBJECTIVES:

1. To visualize the Bernoulli's equation and the conditions for which it applies.
2. To verify Bernoulli's equation by demonstrating the relationship between pressure head and kinetic head.
3. To get the definitions of the energy grade line and the hydraulic grade line and also visualize how it changes.
4. To measure the flow rate and throat area and review how it is used to measure velocity.
5. Demonstrate the use of manometer for measuring manometric head in the "Bernoulli apparatus" that consists of a horizontal flow in a contracting section, a constant cross-sectional area throat, and an expanding section.
6. In the contracting part of the Bernoulli apparatus, demonstrate Bernoulli's equation with decreasing manometric head as the velocity increases and vice versa in the expanding part.
7. To observe the various losses of flow through conduits of rectangular section.

CHAPTER TWO

LITERATURE REVIEW

2.1 APPLICATIONS OF THE BERNOULLI EQUATION :

The Bernoulli equation can be applied to a great many situations not just the pipe flow we have been considering up to now. In the following sections we will see some examples of its application to flow measurement from tanks, within pipes as well as in open channels.

2.1.1Pitot Tube

If a stream of uniform velocity flows into a blunt body, the stream lines take a pattern similar to this:

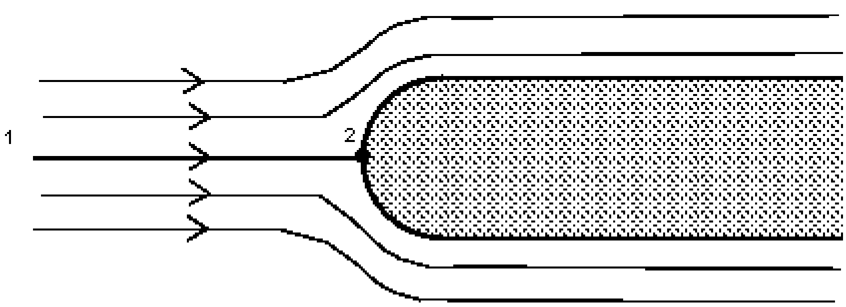


Fig 2.1.1 :Streamlines around a blunt body

Note how some move to the left and some to the right. But one, in the centre, goes to the tip of the blunt body and stops. It stops because at this point the velocity is zero - the fluid does not move at this one point. This point is known as the *stagnation point*.

From the Bernoulli equation we can calculate the pressure at this point. Apply Bernoulli along the central streamline from a point upstream where the velocity is u_1 and the pressure p_1 to the stagnation point of the blunt body where the velocity is zero, $u_2 = 0$. Also $z_1 = z_2$.

$$\frac{p_1}{\rho g}+\frac{u_1^2}{2g}+z_1=\frac{p_2}{\rho g}+\frac{u_2^2}{2g}+z_2$$

$$\frac{p_1}{\rho}+\frac{u_1^2}{2}=\frac{p_2}{\rho}$$

$$p_2=p_1+\frac{1}{2}\rho u_1^2$$

This increase in pressure which bring the fluid to rest is called the *dynamic pressure*.

Dynamic pressure = $\frac{1}{2}\rho u_1^2$

or converting this to head (using $h=\frac{p}{\rho g}$)

Dynamic head = $\frac{1}{2g}u_1^2$

The total pressure is know as the *stagnation pressure* (or *total pressure*)

Stagnation pressure = $p_1+\frac{1}{2}\rho u_1^2$

or in terms of head

Stagnation head = $\frac{p_1}{\rho g} + \frac{1}{2g}u_1^2$

The blunt body stopping the fluid does not have to be a solid. I could be a static column of fluid. Two piezometers, one as normal and one as a Pitot tube within the pipe can be used in an arrangement shown below to measure velocity of flow.

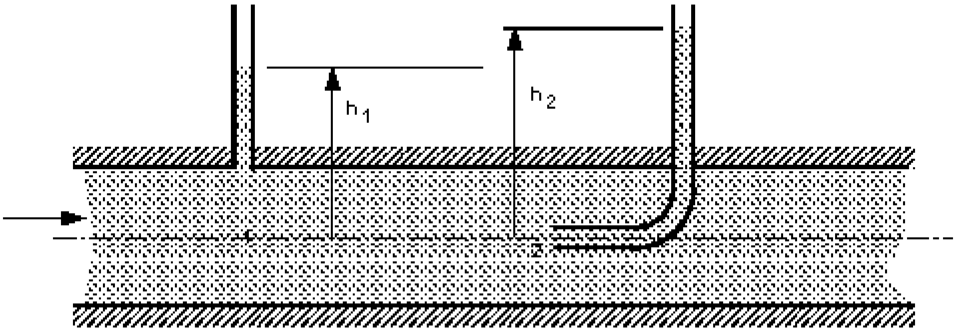


Fig 2.1.2 A Piezometer and a Pitot tube

Using the above theory, we have the equation for p_2 ,

$$\begin{aligned} p_2 &= p_1 + \frac{1}{2}\rho u_1^2 \\ \rho g h_2 &= \rho g h_1 + \frac{1}{2}\rho u_1^2 \\ u &= \sqrt{2g(h_2 - h_1)} \end{aligned}$$

We now have an expression for velocity obtained from two pressure measurements and the application of the Bernoulli equation.

2.1.2 Pitot Static Tube

The necessity of two piezometers and thus two readings make this arrangement a little awkward. Connecting the piezometers to a manometer would simplify things but there are still two tubes. The *Pitot static* tube combines the tubes and they can then be easily connected to a manometer. A Pitot static tube is shown below. The holes on the side of the tube connect to one side of a manometer and register the *static head, (h_1)*, while the central hole is connected to the other side of the manometer to register, as before, the *stagnation head (h_2)*.

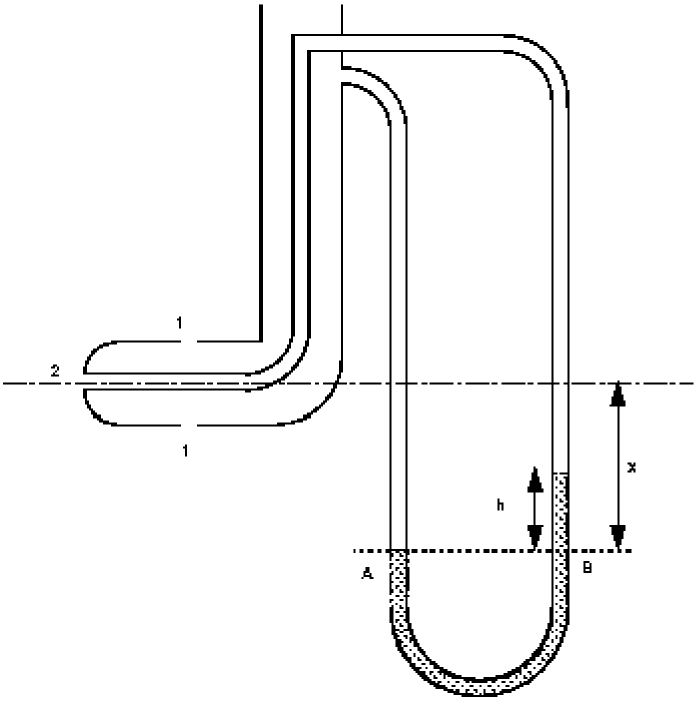


Fig 2.1.3 APitot-static tube

Consider the pressures on the level of the centre line of the Pitot tube and using the theory of the manometer,

$$p_A = p_2 + \rho g X$$
$$p_B = p_1 + \rho g(X - h) + \rho_{man} g h$$
$$p_A = p_B$$
$$p_2 + \rho g X = p_1 + \rho g(X - h) + \rho_{man} g h$$

We know that $p_2 = p_{static} = p_1 + \frac{1}{2}\rho u_1^2$, substituting this in to the above gives

$$p_1 + hg(\rho_{man} - \rho) = p_1 + \frac{\rho u_1^2}{2}$$
$$u_1 = \sqrt{\frac{2gh(\rho_m - \rho)}{\rho}}$$

The Pitot/Pitot-static tubes give velocities at points in the flow. It does not give the overall discharge of the stream, which is often what is wanted. It also has the drawback that it is liable to block easily, particularly if there is significant debris in the flow.

2.1.3Venturi Meter

The Venturi meter is a device for measuring discharge in a pipe. It consists of a rapidly converging section which increases the velocity of flow and hence reduces the pressure. It then returns to the original dimensions of the pipe by a gently diverging 'diffuser' section. By measuring the pressure differences the discharge can be calculated. This is a particularly accurate method of flow measurement as energy loss are very small.

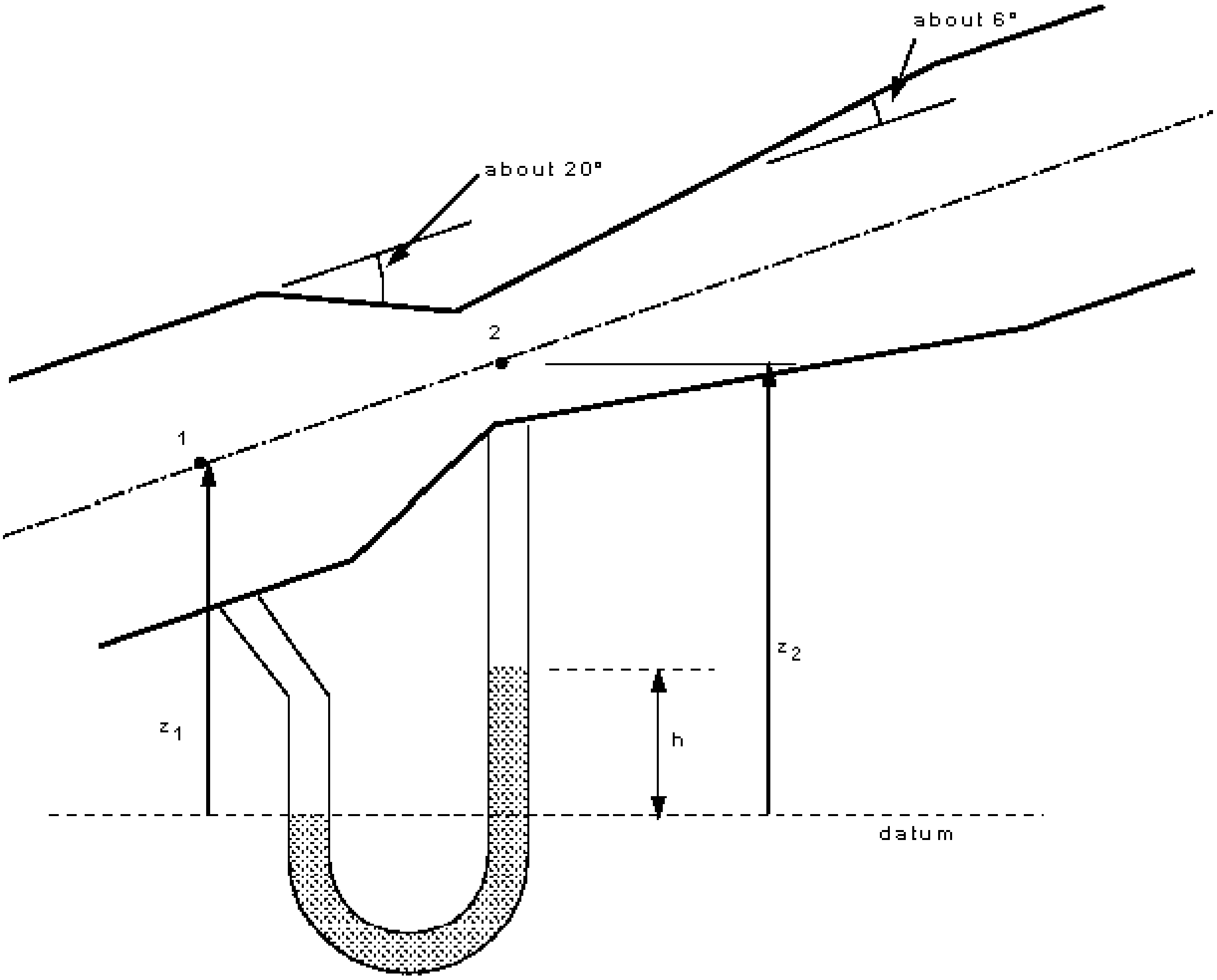


Fig 2.1.4 A Venturi meter

Applying Bernoulli along the streamline from point 1 to point 2 in the narrow *throat* of the Venturi meter we have

$$\frac{p_1}{\rho g}+\frac{u_1^2}{2g}+z_1=\frac{p_2}{\rho g}+\frac{u_2^2}{2g}+z_2$$

By the using the continuity equation we can eliminate the velocity u_2,

$$Q = u_1 A_1 = u_2 A_2$$
$$u_2 = \frac{u_1 A_1}{A_2}$$

Substituting this into and rearranging the Bernoulli equation we get

$$\frac{p_1 - p_2}{\rho g} + z_1 - z_2 = \frac{u_1^2}{2g}\left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]$$
$$u_1 = \sqrt{\frac{2g\left[\frac{p_1 - p_2}{\rho g} + z_1 - z_2\right]}{\left(\frac{A_1}{A_2}\right)^2 - 1}}$$

To get the theoretical discharge this is multiplied by the area. To get the actual discharge taking in to account the losses due to friction, we include a coefficient of discharge

$$Q_{ideal} = u_1 A_1$$
$$Q_{actual} = C_d Q_{ideal} = C_d u_1 A_1$$
$$Q_{actual} = C_d A_1 A_2 \sqrt{\frac{2g\left[\frac{p_1 - p_2}{\rho g} + z_1 - z_2\right]}{A_1^2 - A_2^2}}$$

This can also be expressed in terms of the manometer readings

$$p_1 + \rho g z_1 = p_2 + \rho_{man} g h + \rho g (z_2 - h)$$
$$\frac{p_1 - p_2}{\rho g} + z_1 - z_2 = h\left(\frac{\rho_{man}}{\rho} - 1\right)$$

Thus the discharge can be expressed in terms of the manometer reading::

$$Q_{actual} = C_d A_1 A_2 \sqrt{\frac{2gh\left(\frac{\rho_{man}}{\rho} - 1\right)}{A_1^2 - A_2^2}}$$

Notice how this expression does not include any terms for the elevation or orientation (z_1 or z_2)of the Venturimeter. This means that the meter can be at any convenient angle to function.

The purpose of the diffuser in a Venturi meter is to assure gradual and steady deceleration after the throat. This is designed to ensure that the pressure rises again to something near to the original value before the Venturi meter. The angle of the diffuser is usually between 6 and 8 degrees. Wider than this and the flow might separate from the walls resulting in increased friction and energy and pressure loss. If the angle is less than this the meter becomes very long and pressure losses again become significant. The efficiency of the diffuser of increasing pressure back to the original is rarely greater than 80%.

2.1.4 Real life application

2.1.4.1 Flying machines are applying this theorem.

2.1.4.2 Drawing fluids upward : atomizers and chimneys are using this theorem.

2.1.4.3 Spin , curve , and pull : the counterintuitive principle also uses this principle.

2.2 FUNDAMENTAL CONCEPT OF BERNOULLI’S PRINCIPLE:

There are so many basic assumptions involved in the derivation of Bernoulli's equation, it is important to remember them all when applying it. They are:

1. It assumes viscous (friction) effects are negligible;
2. It assumes the flow is steady;

3. The equation applies along a streamline;
4. It assumes the fluid to be incompressible; and
5. It assumes no energy is added to or removed from the fluid along the streamline.

If we do not comply with any of these restrictions, serious errors can result. However, we do sometimes apply the Bernoulli equation to ***real*** fluids with good results in situations where the frictional effects and head losses are very small. The mathematical representation of Bernoulli's principle is,

$$\frac{p}{\gamma}+\frac{v^2}{2g}+Z=constant$$

Here,

P= static pressure of the fluid,

γ= Specific Weight of the flowing fluid,

v=velocity of flow,

g=gravitational acceleration,

Z=datum head.

In this equation $\frac{p}{\gamma}$ is the static pressure head, $\frac{v^2}{2g}$ is the dynamic pressure head also known as kinetic head and Z is the datum head.

2.3 SIGNIFICANCE OF EACH TERM OF BERNOULLI'S EQUATION:

Bernoulli's equation states that the sum of the three quantities**,** i.e. $\frac{v^2}{2g}$,$\frac{p}{\gamma}$and $\boldsymbol{Z}$ is a constant. From the principle of dimensional homogeneity it implies that each term of equation must have the same dimensions and, therefore, the nature of quantities must be same. In order to have a clear picture of each term and to understand its significance let examine what each term of equation stands for. The first term $\frac{v^2}{2g}$, represents kinetic energy of flow per unit weight (per kg or per N) of fluid.

Kinetic energy = $\frac{1}{2}$ x mass **x** V^2, and kinetic energy divided by the weight of the fluid

$$= \frac{\frac{1}{2}(\text{mass})V^2}{\text{weight}} = \frac{\frac{1}{2}(\text{mass})V^2}{(\text{mass})g} = \frac{V^2}{2g}$$

The second term $\frac{p}{\gamma}$ represents ability of unit weight of fluid to do work by virtue of its pressure. Let a net pressure *p* act over a fluid element of cross-sectional area ***dA***resulting in a pressure force ***pdA***acting in the direction of flow. When the fluid element moves a distance ds**,** work is done on the element by the pressure force which is equal to ***pdAds.*** The work done by the pressure force per unit weight of fluid element is $\frac{pdAds}{\gamma dAds} = \frac{p}{\gamma}$. The term $\frac{p}{\gamma}$ is, therefore, the work done by the pressure force per unit weight of fluid and it known as ***flow work*** **or** ***flow energy.*** It is sometimes misleadingly termed as pressure energy. When a pressure is applied to a fluid, it gets compressed to some extent and the elastic energy is imparted to the fluid. The flow energy $\frac{p}{\gamma}$ has nothing to do with the elastic energy. The third term Z **IS** the potential energy per unit weight of fluid and represents the energy given to a unit weight of fluid in raising it from datum level to a height **Z above it**The potential energy of weight **W**of fluid in raising it to a height **Z**above the datum level is **WZ,** and, therefore, potential energy per unit weight of fluid is **WZ/W=Z.** The potential energy is also sometimes known as the gravitational energy.

Each term of the Bernoulli'**S** equation, therefore, represents some form of energy per unit of weight of fluid and has the dimension

$$= \frac{Energy}{Weight} = \frac{[\mathbf{ML^2T^{-2}}]}{[\mathbf{MLT^{2}}]} = \mathbf{[L]}$$

Since each term has alength dimension, it can be represented graphically with reference to an arbitrarily chosen datum plane. The quantities $\frac{V^2}{2g}, \frac{p}{\gamma}$ and **Z**are, therefore, known as ***velocity head, pressure head and elevation or datum head*** and their sum is called the ***total head.***

2.4 DEFINITION AND EXPLANATION OF HYDRAULIC GRADIENT LINE AND ENERGY GRADIENT LINE:

Hydraulic Gradient and Total Energy Lines

The concept of hydraulic gradient line and total energy line is quite useful in the study of flow of fluid in pipes. These lines may be obtained as indicated below.

Total Energy Line (T.E.L. or E.G.L.)

It is known that the *total head* (which is also total energy per unit weight) with respect to anyarbitrary datum, is the sum of the elevation (potential) head, pressure head and velocity head, i.e.,

Total head = $\frac{p}{\gamma} + \frac{v^2}{2g} + Z$

When the fluid flows along the pipe, there is loss of head (energy) and the total energy decreases in the direction of flow. If the total energy at various points along the axis of the pipe is plotted joined by a line, the line so obtained is called the *Energy gradient line (E.G.L.).*

In literature, energy gradient line (E.G.L.) is also known as *'Total energy line' (T.E.L).*

2.4.1 Hydraulic Gradient Line (H.G.L)

The sum of potential (or elevation) head and the pressure head ($\frac{p}{\gamma}$+Z) at any point is called the *piezometric head.* If a line is drawn joining the piezometric levels at various points, the line so obtained is called the *'Hydraulic Grade Line'*.

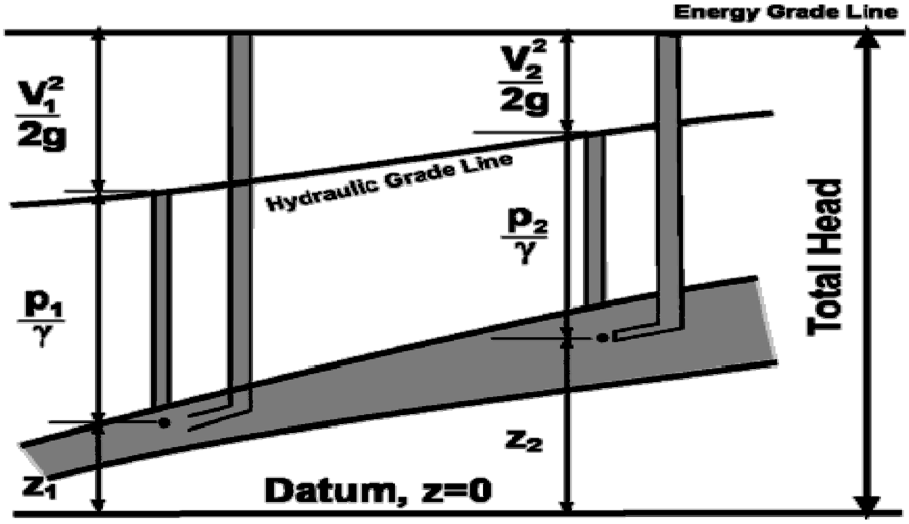


Figure 2.4.1 : Energy gradient line and hydraulic gradient line.

2.4.1.1 The following points are worth knowing about E.G.L. and H.G.L.

1. Energy gradient line (E.G.L.) always drops in the drops in the direction of flow because of loss of head.

2. Hydraulic gradient line (H.G.L.) may rise or fall depending on the pressure changes.
3. Hydraulic gradient line (H.G.L.) is always below the energy gradient line (E.G.L.) and the vertical distance between the two is equal to the velocity head $(\frac{v^2}{2g})$.
4. For a pipe of uniform cross section the slope of the hydraulic gradient line is equal to the slope of energy gradient line.
5. There is no relation whatsoever between the slope of energy gradient line and the slope of thee axis of the pipe.

HGL and EGL are shown in the following figure

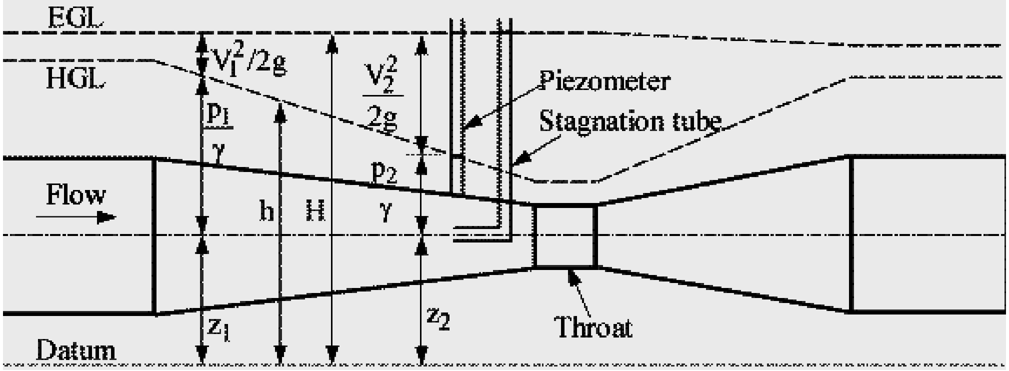
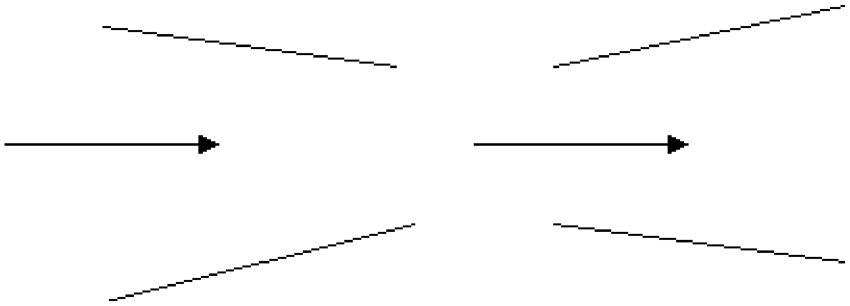


Figure2.4.2 : HGL and EGL in converging diverging section.

2.5 THE BASIC IDEA ABOUT A CONVERGING-DIVERGING SECTION:

A converging and a diverging section of a rectanglar duct act as follows.The converging sectioan of the duct is a nozzle and the diverging section of the duct act as a diffuser.



A decreases	A increases
V increases	V decreases
P decreases	P increases
This is a NOZZLE	This is a DIFFUSER

Figure 2.5.1: Nozzles and Diffuser

So in a converging-diverging section of a rectangular duct the H.G.L. and E.G.L. changes for the change of pressure and the velocity of flow.

A most common example of converging and diverging section is a venture nozzle and for visualizing the changes of H.G.L. and E.G.L. Bernoulli's apparatus is the most efficient way and these are shown .

Loss of head inside duct is a common phenomenon in fluid mechanics as well as minor losses like loss due to sudden contraction, loss due to sudden enlargement, fitting loss, elbow loss etc. Bernoulli's apparatus can show the major loss and two other minor losses of expansion and contraction termed also as "Eddy Loss". These are the main purpose of designing and constructing the *Bernoulli's Apparatus*.

CHAPTER THREE

Construction of Bernoulli's Apparatus

3.1GENERAL DESCRIPTION:

This is a bench top unit for studying Bernoulli's theorem, airflow measurement and air flow in various devices.The set uses an industrial type centrifugal blower with inlet and outlet ducts, flow straighteners, a damper,various flow measuring devices using manometers for the study of air flow measurement. Various measuring devices for the study of air flow are provided as an option. The bench is onwheels.

Technical Data

Blower

Origin: Belgium

Model: BJ2008

Hz: 30

Type : Industrial, centrifugal.

Rating : 0.37 kW, 3360 rpm.

Pressure: 2016 Pa

Max operating Temperature: 40 'C

Air Flow Rate: 0.284 m^3/sec

3.3 DESCRIPTION OF APPARATUS:

This basic air flow bench is designed for testing fans to determine the fan characteristics generally in accordance with BS 848 as well as for providing air supply as basic service unit to conduct other air flow experimental studies. This testing unit is equipped with an industrial centrifugal fan and suitable inlet and outlet ducting system and measuring equipment conforming to British Standard BS 848. The air supply unit is conveniently mounted on the top of the bench. The bench has ample storage space in the lower deck to store the various experimental apparatus when it is not in use. The inlet and outlet sections are so designed to accommodate add-on apparatus that can be readily attached to the air supply unit by means of wing bolts. Hence the versatility of this unit is ensured and the scope of work that can be dealt with is possible to be extended in the future. The main components of this unit are as follows:

3.2. Tube Water Manometer& Bernoulli's Apparatus

The manometer is 400 mm high x 1 mm graduation with anadjustable height water reservoir. Manometer tube are clear acrylic.Pressure ports are at the top. It is to be used with Bernoulli's Experiment Apparatus or Flow Around aBend Apparatus or Air Flow in Pipes Apparatus.

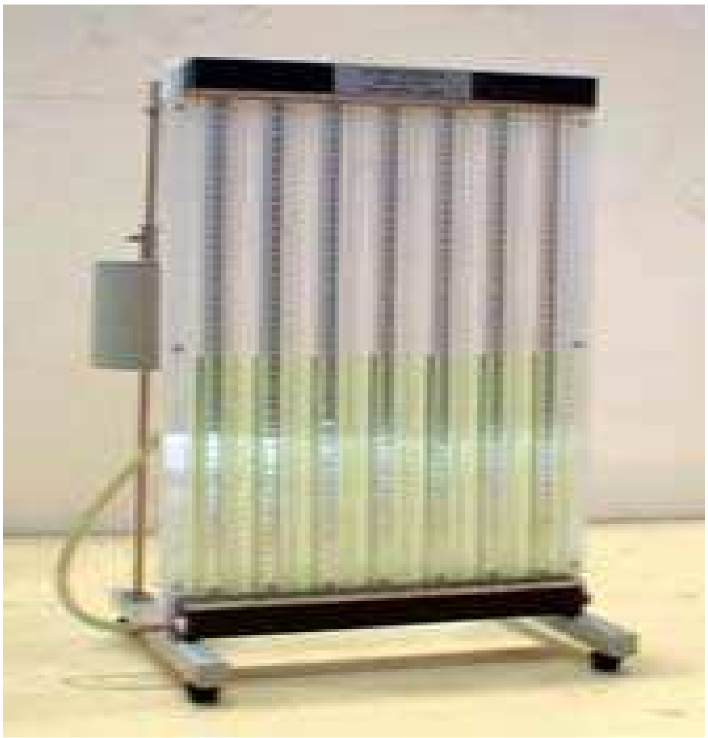


Fig 3.2.1 Tube Water Manometer

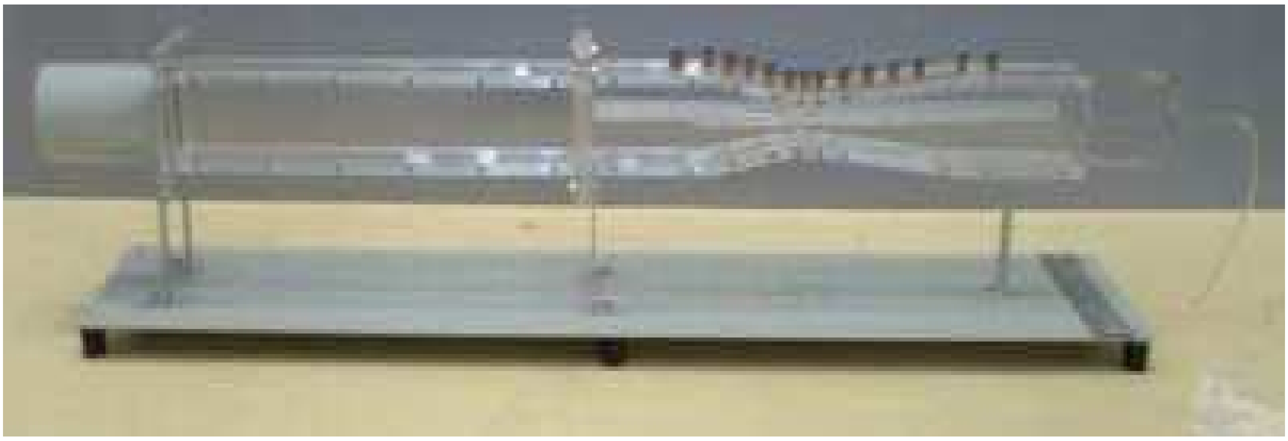


Fig 3.2.2 **Bernoulli's Experiment Apparatus**

This apparatus demonstrates Bernoulli's theorem for air flow. Theapparatus is a rectangular Venturi duct 60x50 mm converging to20x50 mm throat. The front and rear walls are transparent withscales. Pressure taps are fitted along the upper wall with a total headprobe along the axis of the duct. The pressure taps are connected tothe 18 tube manometer (optional item) The duct is connected to theblower outlet by a hose.

3.4. RELEVANT THEORY:

General Features

A fan is a dynamic type of machine. In the operation of a fan there is a dynamic or kinetic actionbetween a mechanical element and air or other compressible fluids creating a velocity change and acorresponding acting force. Hence kinetic energy is converted into static pressure. The term fan is usuallyused when the machine develops a relatively low pressure difference in the order of a few inches of water toless than one pound per square inch, in contrast with the terms used for blower or compressor. Sometimes afan may be called a "blower" when piping is connected to the fan and the fan inlet is open directly to theatmosphere. Essential components of the centrifugal fan are its rotating members with blades so-called"impellers" and a scroll case surrounding it as shown in Figbelow.

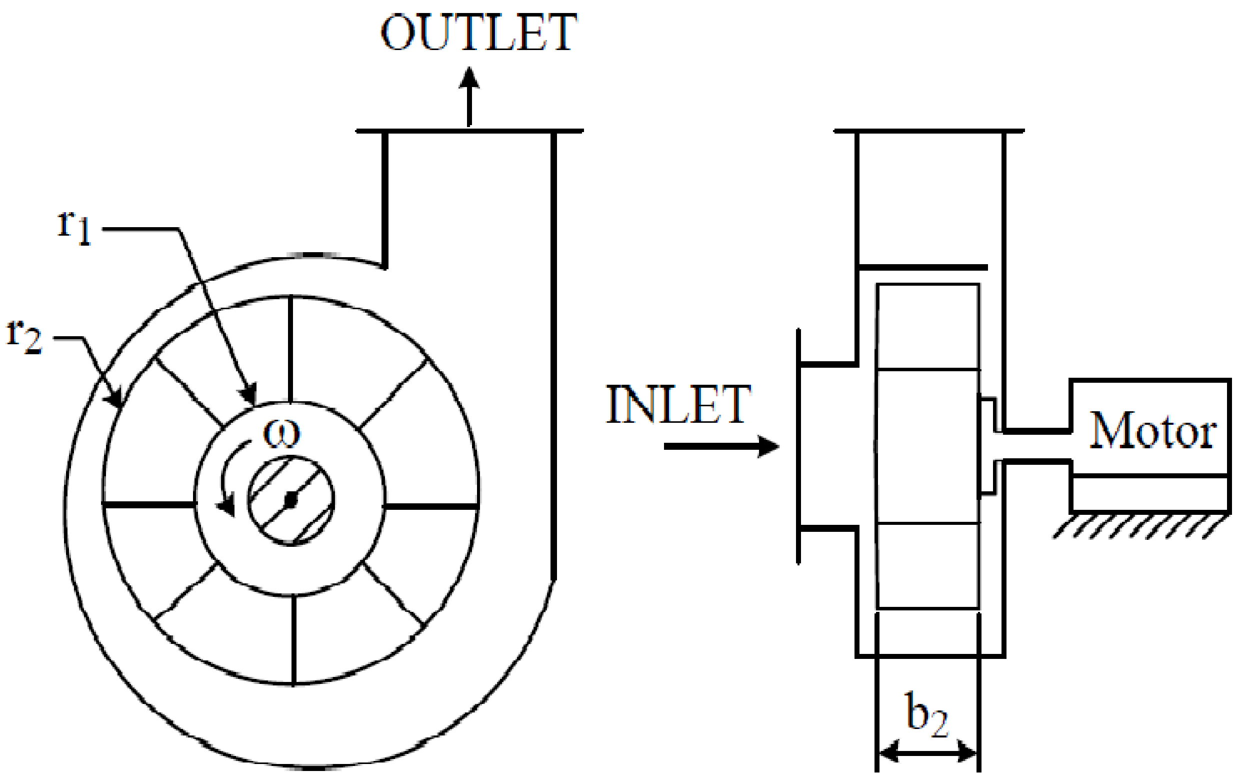


Fig3.4.1 :Velocity Triangle Diagrams

They are three basic types of impeller blades namely radial blade, backward blade, and forward blade.Fig 3.4.1 shows the velocity triangle diagrams at the exit of the impeller blade and the terminologyused.

CHAPTER FOUR

PROCEDURE

4.1. EXPERIMENTAL PROCEDURE:

4.1.1 Start the pump and initiate a flow of water through the test section.

4.1.2 Regulate the flow to the inlet head tank so that there is a small but steady overflow from inlet tank.

4.1.3 Adjust the level of the outlet tank to obtain a differential head of 20mm.

4.1.4 Observe the manometric deflection of different manometer of the Bernoulli's apparatus.

4.1..5 Measure the time using stop watch and collect the discharged water simultaneously to measure the flow rate.

4.1.6 Steadily increase the flow rate by increasing the total differential head, while carefully observing the condition of the fluid in the channel and measure the corresponding value of the flow rate.

4.1.7 Note each manometric deflection for each rate of flow.

4.1.8 Continuous manipulation of the flow rate while observing the flow conditions may be conducted as a useful visual aid to the appreciation of laminar and turbulent flow conditions and head losses.

4.1.9 Switch off the pump and allow the apparatus to drain back to the main reservoir.

4.2 BERNOULLI'S EXPERIMENT APPARATUS

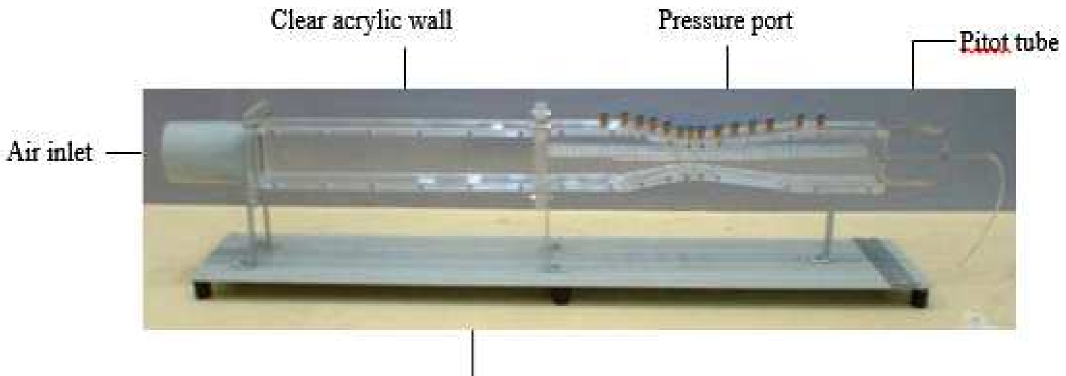


Fig4.2.1

4.3

Note:

1. Mount unit on top shelf of a
2. Connected one end of the co

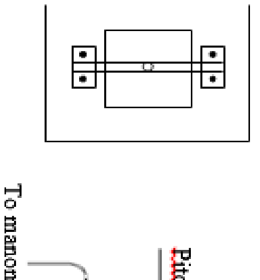


Fig 4.3.1 Bernoulli's apparatus setup

4.4 RELEVANTTHEORY

For a singlestreamline condition under steady flow conditions

thefollowingrelationshipholds:-

$$\frac{p}{\gamma} + \frac{u^2}{2g} + Z = \text{constant}$$

The above equation isknownas Bernoulli’sequation.

Thefirsttermisknownasthepressurehead,thesecondtermasthevelocityheadthethirdtermas elevationheadandthesum ofthethreeisthetotalhead.TheimplicationofBernoulli’sequationisthatthetotal energyofafluid,understeadyflowconditionsismade upofvariouscomponentswhichareinterchangeable,e.g. for agas suchas air,velocityenergy canchangeinto pressure energyandvice-versa.

In the caseofhorizontalduct,*Z*becomes constant and the above equation issimplified to:

$$\frac{p}{\gamma} + \frac{u^2}{2g} = \text{constant}$$

The form of the equation usually employed for flow of a gas is:

$$p + \frac{\rho u^2}{2} = \text{constant}$$

4.5 EXPERIMENTALPROCEDURES

4.5.1 Beforethe Test

4.5.1 SetuptheBernoulli'sExperimentApparatushorizontallyasshowninFig.3-2,onanappropriate location ontop ofthebench.

4.5.2 Openthefan outlet opening portprovidedfor supplyingairflow toanyadd-onequipment.

4.5.3 ConnecttheabovefanoutletporttotheinletsectionoftheBernoulli'sExperimentApparatuswith a flexible hose.

4.5.4 Connect the Pitot tube totalheadprobe to oneof the14 manometers.

4.5..5Connect thestatic head measurement sockets to theothermanometers.

4.5.2 Test Run

4.5.1 Set thedamper to abouthalf of the fullyopen position.

4.5.2 Start thefan motorby pressing the"ON"switchon the controlpanel.

4.5.3 Adjust the air flow valve sothat the totalpressure reading isabout50 mmofwater.

4.5.4 Set the Pitottube totalhead probe inthefirst forwarding position (converging entrance).

Adjustthemanometerreservoirbyascrewdriveruntilthereservoirwaterlevelisattheindicated water level and all readings are within the manometer range. Record pressurelevel.

4.5.5 Movethetotalheadprobetobeinlinewiththesuccessivestaticheadportsandrecordpressure level respectively.

Thetotalheadshouldbeapproximatelyconstantatvariousmeasuringpointsorveryslightly decreases as the Pitot tubeprobe tip movesalong thedirection ofairflow.

4.5.3 Afterthe Test Run

3.3.1 Turnoff thefanby pressing the "OFF"switch.

3.3.2 Disconnect themanometers.

3.3.3 Disconnect theflexible hose.

3.3.4 DisassembletheBernoulli'sExperimentApparatusandstoreproperlyinthebencheslower Storage area.

3.3.5 Close thefan outlet duct opening portofadd-onequipment.

4.5.4 Results and Calculations

4.5.1 Subtract the static head from the total head at each point to obtain velocity head.

4.5.2 Plot the following graphs:

- Total head vs. Distance of measuring position.
- Velocity head vs. Distance of measuring position.
- Static head vs. Distance of measuring position.

4.6. CALCULATIONS:

DATA SHEET

MP100 AIR FLOW BENCH

Bernoulli's ExperimentAPPARATUS

RoomTemp: 30 ^oC Testedby: Gp 1 Date: 07.12.2012

Probe Position mm	Total head or pressure		Static head or pressure		Velocity head or pressure	
	mm.H_2O	Pa	mm.H_2O	Pa	mm.H_2O	Pa
0	45	439.55	21	205.43	24	234.42
30	45	439.55	31	302.80	14	136.74
50	45	439.55	04	39.06	41	400.48
70	45	439.55	-11	-107.44	65	546.99
90	45	439.55	-65	-634	110	1074.46
110	45	439.55	-115	-1123.29	160	1562.24
125	45	439.55	-85	-830.26	130	1269.81
140	45	439.55	-85	-830.26	130	1269.81
165	45	439.55	-75	-732.58	120	1172.13
190	45	439.55	-65	-634.90	110	1074.45
215	45	439.55	-15	-146.51	60	586.06
240	45	439.55	-5	-48.53	50	488.97
280	45	439.55	1	-9.76	44	429.45
310	45	439.55	2	19.53	43	420.05

4.7. SAMPLECALCULATIONS

FromData sheet & Result sheet, probeposition =0 mm.give the followingdata:

Total head= 45mm.H_2O

Static pressurehead= 21mm.H_2O

Roomtemperature = $30^{\circ}C$(∴ density of water =995.7kg/m^3

Fromthe experimental data, give the followingresults

$$\text{Totalpressure} = \rho g(\text{totalhead})$$

$$= 995.7\frac{kg}{m^3}\times 9.81\frac{m}{s^2}\left(45mm\times\frac{1m}{1{,}000mm}\right)$$

$$= 439.55\frac{N}{m^2}\ \text{(orPa)}$$

$$\text{Staticpressure} = \rho g(\text{Staticpressurehead})$$

$$= 995.7\frac{kg}{m^3}\times 9{,}81\frac{m}{s^2}\left(21mm\times\frac{1m}{1{,}000mm}\right)$$

$$= 205.12\frac{N}{m^2}\ \text{(orPa)}$$

$$\text{Velocityhead} = \text{Totalhead} - \text{Staticpressurehead}$$

$$= 45mm,H_2O - 21mm,H_2O$$

$$= 24mm,H_2O$$

$$\text{Velocitypressure} = \rho g(\text{Velocityhead})$$

$$= 995.7\frac{kg}{m^3}\times 9.81\frac{m}{s^2}\left(24mm\times\frac{1m}{1{,}000mm}\right)$$

$$= 234.42\frac{N}{m^2}\ \text{(orPa)}$$

Thevelocitypressurecanalsobecalculatedfromthedifferenceof*Totalpressure*and*Staticpressure* asshown below:

$$\text{Velocity pressure} = \text{Total pressure} - \text{Static pressure}$$

$$= 439.55\,\frac{N}{m^2} - 205.12\,\frac{N}{m^2}$$

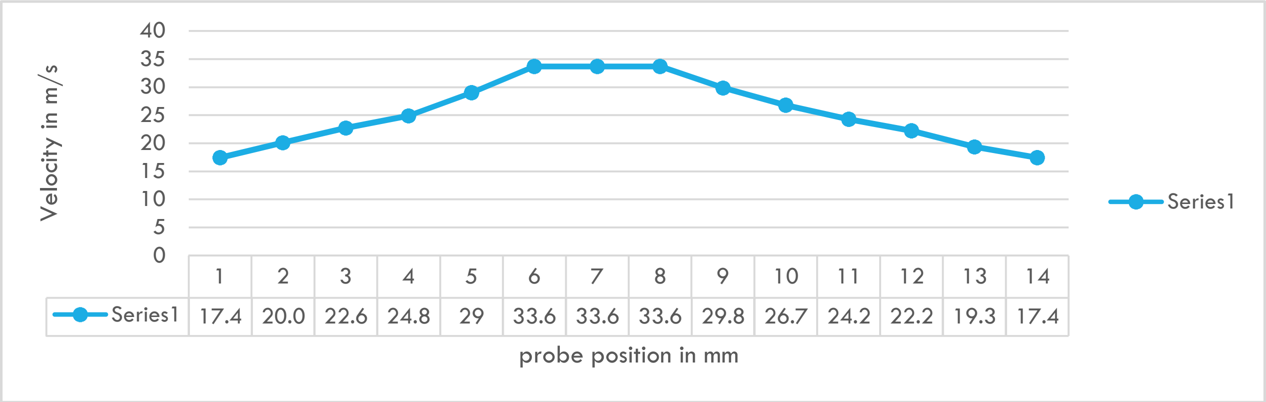
$$= 234.42\,\frac{N}{m^2}$$

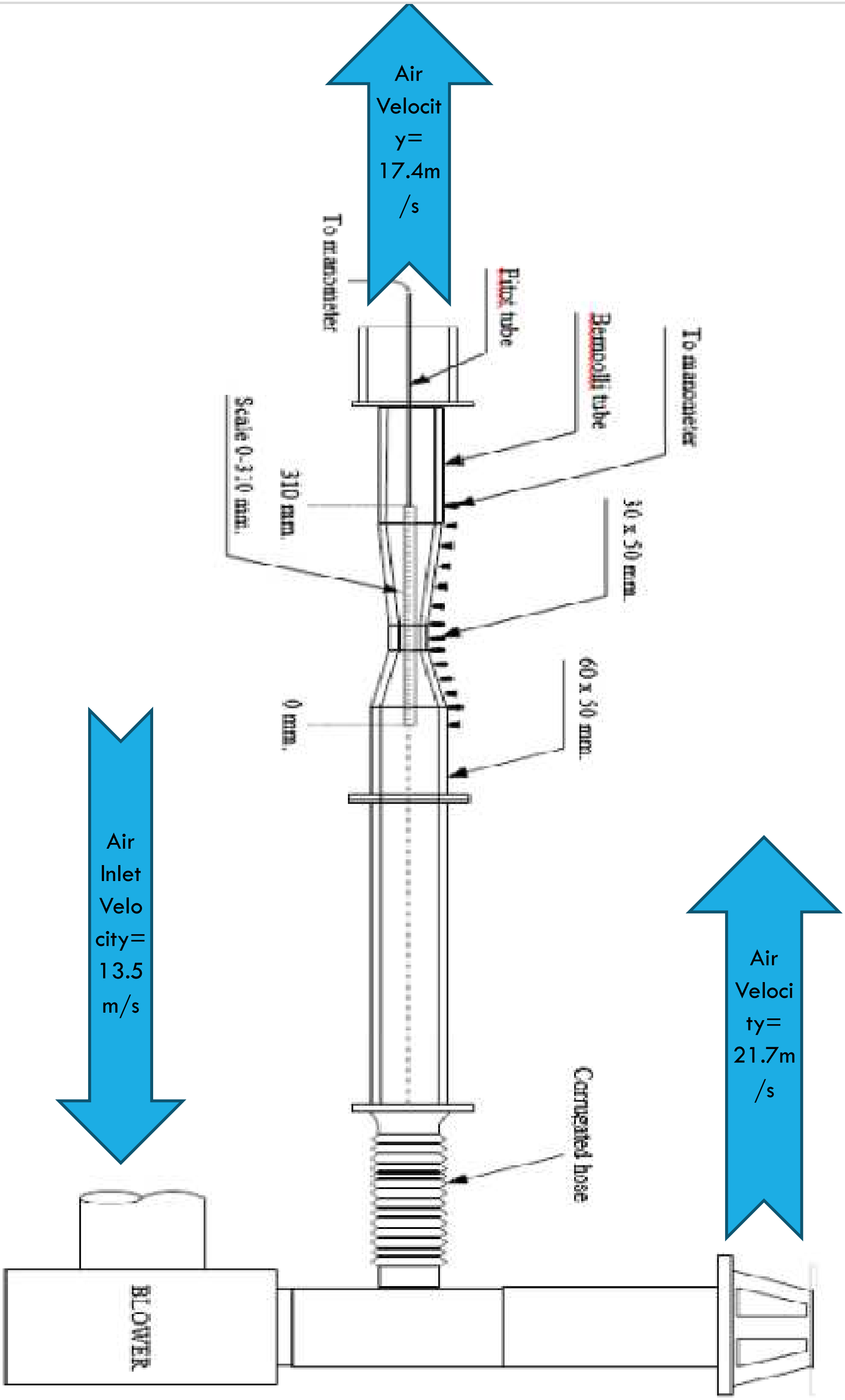
Data Sheet

Total Air Flow at Different Probe Position of Bernoulli's Apparatus

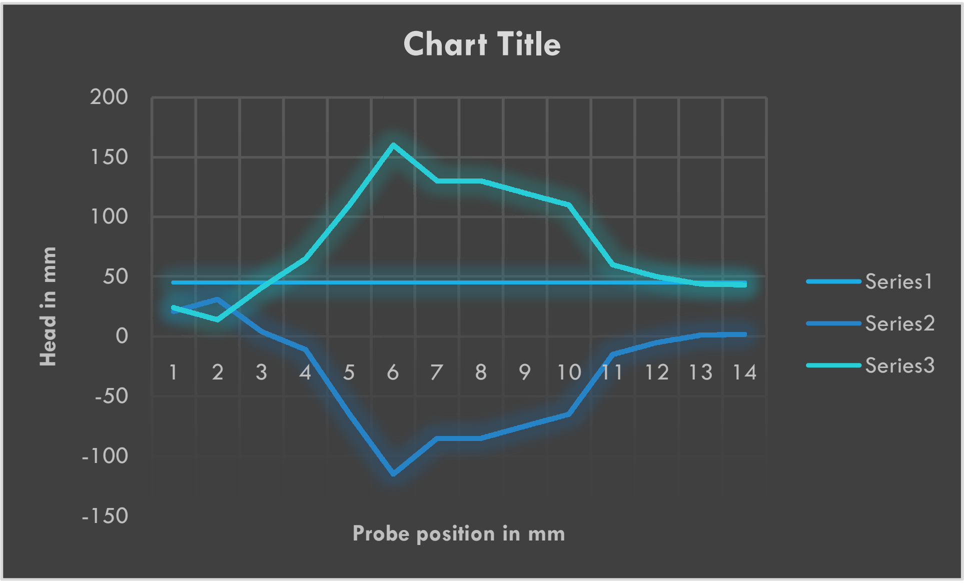
PROBE POSITION mm	CROSS SECTIONAL AREA $A_{X=1,2,3,4,....}$ M^2	Air velocity $V_{X=1,2,3,4,....}$ m/s	Air Flow Volume at Probe position $Q_{X=1,2,3,....}$ M^3	Total Air Flow Q_T M^3
0	50 x 60 x 10^{-6} = 0.003	17.4	.0522	50 x 60 x 17.4 x 10^{-6} = 0.0522
30	50 x 52 x 10^{-6} =0.0026	20.07	.05212	0.0522
50	50 x 46 x 10^{-6} =0.0023	22.69	.05218	0.0522
70	50 x 42 x 10^{-6} =0.0021	24.85	.052185	0.0522
90	50 x 36 x 10^{-6} =0.0018	29	.0522	0.0522
110	50 x 31 x 10^{-6} =0.00155	33.67	.0521885	0.0522
125	50 x 31 x 10^{-6} =0.00155	33.67	.0521885	0.0522
140	50 x 31 x 10^{-6} =0.00155	33.67	.0521885	0.0522
165	50 x 35 x 10^{-6} =0.00175	29.82	.052185	0.0522
190	50 x 39 x 10^{-6} =0.00195	26.76	.052182	0.0522
215	50 x 43 x 10^{-6} = 0.00215	24.27	.0521805	0.0522
240	50 x 47 x 10^{-6} =0.00235	22.21	.0521935	0.0522
280	50 x 54 x 10^{-6} =0.0027	19.33	.05212	0.0522
310	50 x 60 x 10^{-6} = 0.003	17.4	0.0522	0.0522

Graph: Probe position Vs Air Velocity

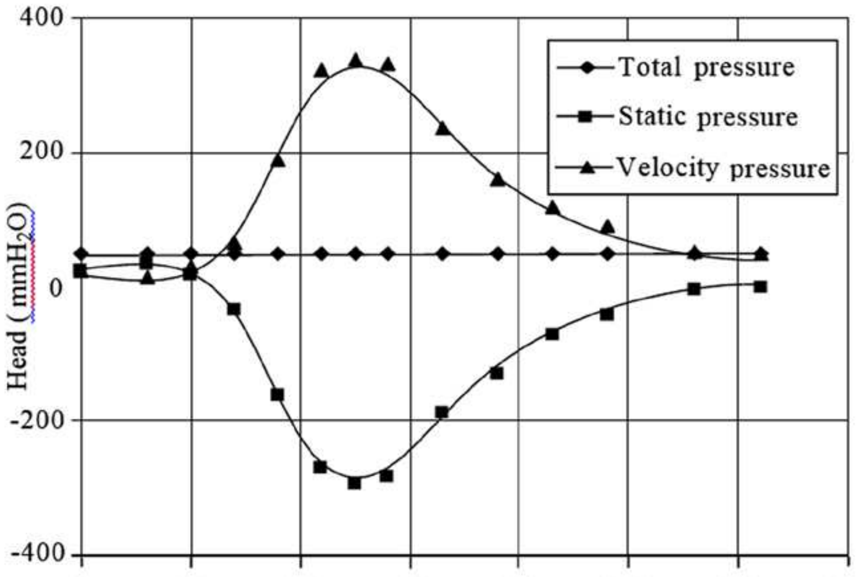

Velocity in m/s
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Series1 17.4 20.0 22.6 24.8 29 33.6 33.6 33.6 29.8 26.7 24.2 22.2 19.3 17.4
probe position in mm
Series1


Air Velocity= 17.4m/s
To manometer
Pitot tube
Bernoulli tube
To manometer
Scale 0-310 mm
310 mm
30 x 50 mm
60 x 30 mm
0 mm
Air Inlet Velocity= 13.5 m/s
Air Velocity= 21.7m/s
Corrugated hose
BLOWER

4.8 **Graph:**



SAMPLE GRAPHS



CHAPTER FIVE

RESULT & DISCUSSION

5.1 RESULTS ANALYSIS:

5.1.1 We have recorded the results on a copied of the result sheet provided.

5.1.2 We calculated the flow rate for each set of results.

5.1.3 Plotted a graph of head against distance and also $H + V^2 / 2g$ against distance.

5.1.4 We compared the graph with the sample graph provided by the Essom Company Limited, Thailand.

5.1.5 We found the pattern of the graph is similar with the inclusion of some errors.

5.2 DISCUSSION:

5..2.1 From This Experimental Setup The Following Observation Can Be Made

5.2.1.1 Change of velocity head with the varying cross sectional area.

5.2.1.2 Loss of energy of air due to friction or major loss.

5.2.1.3 Change of hydraulic gradient line and energy gradient line of flowing fluid.

5.2.1.4 Different losses i.e. eddy loss or separation loss, and other minor losses like loss due to sudden contraction and expansion.

5.2.1.5 Change of energy heads for different flow rate.

Chapter SIX

CONCLUSION & RECOMMENDATION

6.1 CONCLUSION:

Bernoulli's principle is one of the most renowned theories of fluid mechanics. Bernoulli's equation states that the sum of the three quantities, such as velocity head, datum head & pressure headis a constant.When the fluid flows through the closed conduits, there is a loss of head (energy) and the total energy decreases in the direction of flow.***Loss of head inside the duct is a common phenomenon in fluid mechanics. To understand and visualize these basic ideas of fluid mechanics Bernoulli's apparatus is an useful scientific tool.***

6.2 RECOMMENDATION:

All the parts off these apparatus were not constructed within the due time of the project so this project needs further work for its completion. To fully run the experimental setup the following should be constructed,

6.2.1 For flow regulation an inlet and an outlet should be constructed as per the design mentioned in design section.

6.2.2. For measuring the flow rate a measuring pot of convenient size should be used along with a stop watch to measure the time.

6.2.3 With the making of some parts like bendapparatus, Air flow in pipe apparatus, Dispersionofjetapparatus, Drag apparatus, Boundarylayer apparatus, Flow visualizationapparatus etc. can make this project more dynamic.

6.2.4 Now, anyone can perform more six(6) experiments with the same apparatus attached.

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