DEPARTMENT OF ENVIRONMENTAL, WATER RESOURCES, AND COASTAL ENGINEERING

MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY

FLUID MECHANICS SESSIONAL

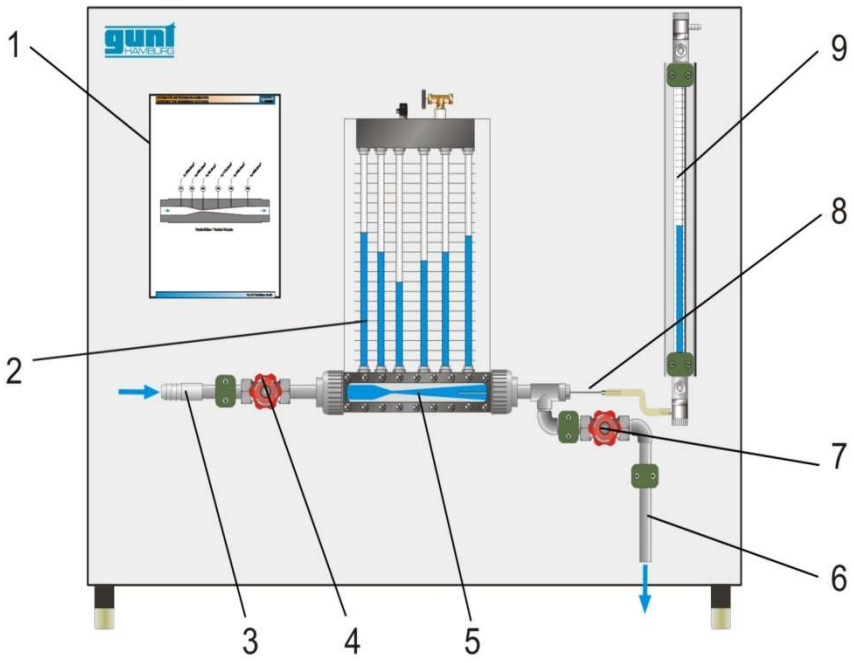
EWCE 262

Experiment No. 1

PROOF OF BERNOULLI'S EQUATION

1.1 General

Energy is the ability to do work. It manifests in various forms and can change from one form to another. The various forms of energy present in fluid flow are elevation, kinetic, pressure and internal energies. Internal energies due to molecular agitation and manifested by temperature. Heat energy may be added to or subtracted from a flowing fluid through the walls of the tube, or mechanical energy may be added to or subtracted from the fluid by a pump or turbine. Daniel Bernoulli in the year 1938 stated that in a steady flow system of frictionless (or non-viscous) incompressible fluid, the sum of pressure, elevation and velocity heads remains constant at every section, provided no energy is added to or taken out by an external source.



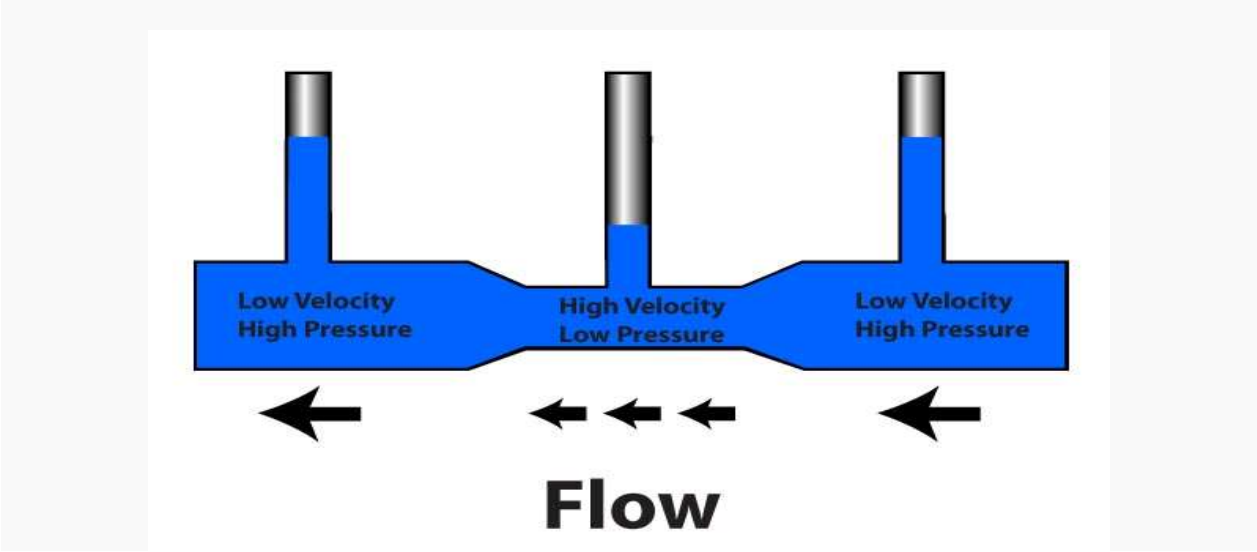
2 tube manometers (static pressures), 3 water supply, 4 valve, 5 Venturi nozzle, 6 water outlet, 7 valve for water outlet, 8 pitot tube, 9 single tube manometer (total pressure)

1.2 Applications

Bernoulli's Energy Equation can be applied in practice for the construction of flow measuring devices such as Venturimeter, flow nozzle, orifice meter and Pitot tube, Furthermore, it can be applied to the problems of flow under a sluice gate, free liquid jet, radial flow and free vortex motion. It can also be applied to real incompressible fluids with good results in situations where frictional effects are very small.

The relationship between the velocity and pressure exerted by a moving liquid is described by the Bernoulli's Principle: as the velocity of a fluid increases, the pressure exerted by that fluid decreases.

Airplanes get a part of their lift by taking advantage of Bernoulli's principle. Race cars employ Bernoulli's principle to keep their rear wheels on the ground while traveling at high speeds.



1.3 Theory

Assuming frictionless flow, Bernoulli's Theorem states that, for a horizontal conduit

$$\frac{P_1}{\gamma}+\frac{V_1^2}{2g}=\frac{P_2}{\gamma}+\frac{V_2^2}{2g}=\frac{P_3}{\gamma}+\frac{V_3^2}{2g}=\ldots\ldots\ldots \quad (1)$$

Where, P_1,P_2 = pressure of flowing fluid at sections 1 and 2

γ = unit weight of fluid

V_1, V_2	=	mean velocity of flow at sections 1 and 2
g	=	acceleration due to gravity.

The equipment can be used to demonstrate the validity of this theory after an appropriate allowance has been made for friction losses.
For actual condition there must be some head loss in the direction of flow. So if the head loss between section 1 and 2 is h_L, Bernoulli's theorem is modified to

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

1.4Objectives

1. 1 To plot the static head, velocity head and total head against the length of the passage in one plain graph paper.
2. To plot the total head loss, h_L against the inlet kinematic head, $V^2/2g$, for different inflow conditions in plain graph paper.

1.5 Procedure

-Arrange the experimentation set-up on the **HM150** such that the discharge routes the water into the channel

- Make hose connection between **HM150** and unit

- Open discharge of **HM150** - Set cap nut [1] of probe compression gland such that slight resistance is felt on moving probe

- Open inlet and outlet ball cock

- Close drain valve [2] at bottom of single wa-

ter pressure gauge

- Switch on pump and slowly open main cock

of **HM150** - Open vent valves [3] on water pressure gau-

ges

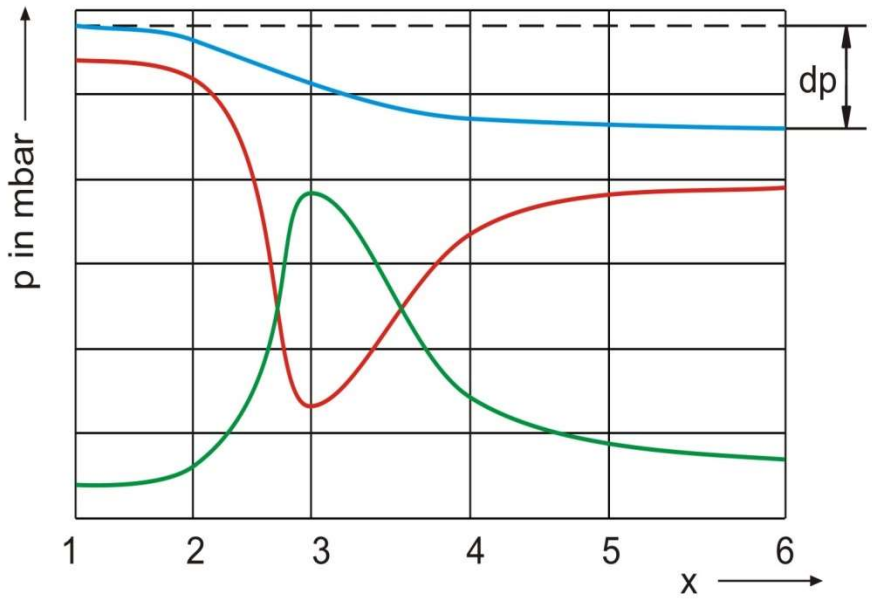
- Carefully close outlet cock until pressure gau-

ges are flushed

- By simultaneously setting inlet and outlet cock, regulate water level in pressure gauges such that neither upper nor lower range limit [4,5] is overshot or undershot

- Record pressures at all measurement points. Then move overall pressure probe to corresponding measurement level and note down overall pressure

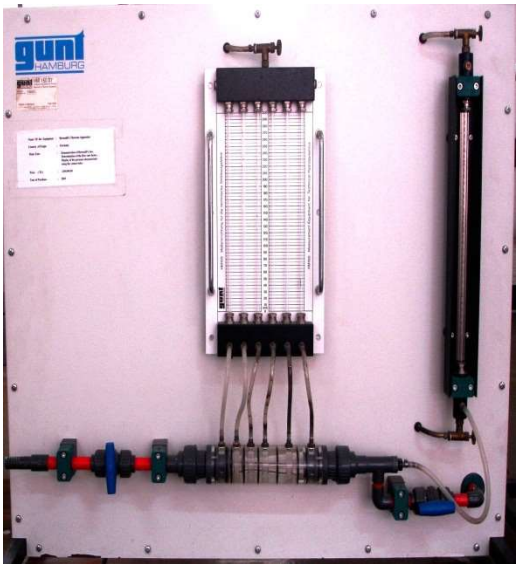
- Determine volumetric flow rate. To do so, use stopwatch to establish time t required for raising the level in the volumetric tank of the **HM150** from 20 to 30 litres



Pressure curve in the Venturi nozzle: blue: total pressure, red: static pressure, green: dynamic pressure; x pressure measuring points, p pressure

1.6. Apparatus

Bernoulli's apparatus, hydraulic bench, stop watch etc.



Bernoulli's Apparatus



Stop Watch



Hydraulic Bench

1.7

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PROOF OF BERNOULLI'S EQUATION

Experimental Data Sheet

Collection time = _____

Volume of water = _____

Discharge Q = _____

.

Piezometer tube no.	**1**	**2**	**3**	**4**	**5**	**6**
d						
A						
H $_{stat,}$ P/γ						
H $_{total}$						
H $_{detum,}$ Z	.08 m	.08 m	.08 m	.08 m	.08 m	.08 m
H $_{dyn}$ = H $_{total}$ **-** $(P/\gamma + z)$						
V $_{mes}$ = Q/A						
V$_{calc}$ **=** $\sqrt{(2gH_{dyn})}$						

Level / Term : **Dept. :**

Reg No. : **Section:**

Group No. : **Date :**

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Signature of the Teacher

1.8 CALCULATION:

1.9 DISCUSSION:

What are the possible experimental errors?

Why are the total energy values at 1st and last sections not same?

Explain the nature of velocity, head pressure head and total head curves.

1.10 ASSIGNMENT:

1. What are the assumptions underlying the Bernoulli's energy equation?

2. Do you need any modification(s) of Eqn (1) when (a) the frictional head loss is to be considered, and (b) the conduit is not horizontal?

3. What is the difference between energy line and energy grade line?



Daniel Bernoulli

His discovery was the first time that an analysis of water flowing from a hole in a container was correct. His discovery was that, as iterated above, that a rise in pressure would cause a decrease in speed and a decrease in pressure would cause an increase in speed. Bernoulli largely created his principal based on the theory of conservation of energy. (The law of conservation of energy states that energy can be neither created nor destroyed, and therefore the sum of all the forms of energy in the system is constant.) He used the conservation of energy as well as pumps and other machines that are used to raise water to come up with this principle.Daniel Bernoulli (1700-82), son of Johann I, was born on Groningen, Netherlands. Of all the Bernoullis, he was perhaps the greatest mathematician. Daniel also had the widest interests which includes medicine, biology, physics, mechanics, and astronomy. Daniel originally planned a career business and medicine. Like other family members, however, he was drawn to the field of mathematics. Between 1725 and 1732, he taught mathematics at the Academy of Science in St. Petersburg, Russia. He then went to the University of Basel, where he taught anatomy, botany and then physics. Daniel's most important work was in mechanics. He was the founder of the science of hydrodynamics, the study of moving fluids. One of his main contributions in this area is Bernoulli's Principle, which states that the pressure in a fluid decreases as its velocity, or speed, increases. Daniel is also noted for his work in calculus and probability theory, especially as it applies to games. He's also considered one of the founders of the kinetic theory of gases, which helps explain the property and behavior of gases. Between 1725 and 1749, Daniel won many prizes for his work on astronomy, gravity, tides, magnetism, and ocean currents.

Common Applications of Bernoulli's Principle

Bernoulli's Principle has common several various modern day applications in the world around us. The following section discusses where, and in what applications can you see this principle take place.

Airflight

One of the most common everyday applications of Bernoulli's principle is in airflight. The main way that Bernoulli's principle works in air flight has to do with the architecture of the wings of the plane. In an airplane wing, the top of the wing is soomewhat curved, while the bottom of the wing is totally flat. While in the sky, air travels across both the top and the bottom concurrently. Because both the top part and the bottom part of the plane are designed differently, this allows for the air on the bottom to move slower, which creates more pressure on the bottom, and allows for the air on the top to move faster, which creates less pressure. This is what creates lift, which allows planes to fly. An airplane is also acted upon by a pull of gravity in which opposes the lift, drag and thrust. Thrust is the force that enables the airplane to move forward while drag is air resistance that opposes the thrust force.

Lift

One of the most common trends that occurs in the modern day physics world is that of lift. Lift can be seen in many different ways, shapes, and forms in our world. Lift is seen in airflight, as in my example above, as well as in several of my forthcoming examples. But , what is lift exactly? Most people define lift in terms of Bernoulli's principle which has some validity to it, but the main way for one to define lift is through Newton's three laws. While most accept that Bernoulli's principle is what creates lift, some say that it leaves many unanswered questions. For one, it says that upside down flight cannot happen. Also, many people say that by using Bernoulli's principle to explain lift, it doesn't take into account the fact that no where in the commonly accepted defenition of lift, is there any mention of work, and lift can only take place if there is a certain type of unit of work that we are all familiar with, called power. The next most widely accepted definition of lift involves Newton's three laws, specifically his first and third. (The first is the law of intertia and the third is that for every acton there is an equal and opposite reaction.) As we have all seen on an airplane, the wing moves up and down a little bit as it flies through the air, but under the common defintion of lift, this cannot happen; the wing just stays still. Many physics scholars believe that there must be some form of movement on the object that is being lifted. Some believe that according to Newton's law "the wing must change something of the air to get lift.

Baseball

Baseball Baseball is an example of where Bernoulli's principle is very visible in everyday life, but rarely do most people actually take note of it. One example in baseball is in the case of the curve ball. The entire pitch works because of Bernoulli's principle. Since the stitches of the ball actually form a curve, it is necessary for the pitcher to grip the seams of the baseball. The reason as to why this is a necessity is that by gripping the baseball this way, the pitcher can make the ball spin. This allows for friction to cause a thin layer of air to engilf the misunderstanding of the baseball as it is spinning, but since the ball is

spinning in a certain manner, this allows for more air pressure on the top of the ball and less air pressure on the bottom of the ball. Therefore, according to Bernoulli's principle there should be less speed on the top of the ball than there is on the bottom of the ball. What transpires is that the bottom part of the ball accelearates downwards faster than the top part, and this phenomenon allows for the ball to curve downward, which causes the batter to miscalculate the ball's position.

Draft

And furthermore, another example of Bernoulli's principle in our everyday lives is in the case of someone feeling a draft. We all at at least one time or another, have experienced feeling a draft, and it is because of Bernoulli's principle that we feel this draft. Let's say that in your room, you are really hot, but you know that it is nice and cool both outside your window and outside your door. If you open up your window, to try and let fresh air in, there won't be much of a temperature change, unless the door to your room is open to air out the hot air. The reason why it works this way is that if the front door is closed the door will become an area of high pressure built up from the hot air, and right outside the door there is little pressure, meaning that the rate at which the air enters will be in an incredibly high speed. When you open the door, the pressure is relieved from the door on the inside and the hot air exits quickly. When the hot air exits there is a lot more pressure outside meaning that it will take awhile for the cool air to come in. Once the hot air has flown out, the cool air will come in at a fast speed, thus causing a draft.

Sailing

In addition to the three items above, Bernoulli's principle is also the governing theory that is behind sailing. Most people believe that sailing is just having a big sail and that when you put it up, the wind just takes your boat and drag it along the sea. This is not 100% correct. This is true only in the cases when the boat is moving with the wind, otherwise it is not true. When the boat does not travel with the wind, it usually moves perpendicular to the wind, and the boat moves not because the wind drags it along, but because of the concept of lift, which as mentioned above and in the case of airplanes, is what happens when either a liquid or a gas act on an object. The same way that Bernoulli's principle works for creating lift in airplanes, it works for creating lift in sails. All sail boats have two parts to it: a sail which points north and a keel which points on the opposite direction. If the speed of the air increases on the sail, there is less pressure on the sail, and conversely there is less pressure on the keel but a higher speed. Just like with an airplane this produces lift and propels the sail to move in the water.