Lab#4: Bernoulli's Theorem Demonstration

CE 336

Department of CECEM

Group Report

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Purpose of Study

The purpose of this experiment is to make use of the venturi meter to verify Bernoulli's theorem. This will be done by obtaining the static head for the different flow rates and using that to find the kinetic head which then will allow us to obtain the total energy through the venture pipe.

Introduction

During this experiment, measurements were taken and data was collected involving the presence of fluid flow in a system dealing with water flowing through a venturi meter with varying cross-sectional areas and determining the pressure through the first six manometers at the differing diameters of the venturi pipe system. Both static and kinetic heads were found using different flow rates through the system and the velocity, pressure, and respective cross-sectional areas were used to validate Bernoulli's theorem in practice. For practical purposes, the system met the three necessary qualifications for Bernoulli's theorem to be applied; the fluid was "ideal", had a steady flow, and along its streamline there were only slight changes in energy. For this reason, it is coherent that within any point of the fluid, there was somewhat constant total energy per unit weight, considering that the real fluid is viscous and not perfectly ideal. Knowing that the real fluid would have some resistance through the pipe, friction losses through the pipe walls, the Hydraulic Grade Line (HGL) and Energy Grade Line (EGL) were calculated to find the location of static along the flow direction and total energy along the flow direction, respectively.

Theory

Bernoulli's theorem is the law of conservation of energy for a fluid flow system. The theorem finds that for ideal fluids with steady flow the total energy is constant along the streamline. An ideal fluid is one that has three identifiers: inviscid, incompressible, and irrotational. The theorem is expressed in the following equation:

$$\frac{P}{\gamma}+z+\frac{V^2}{2g}= \text{Constant (1)}$$

P and V are the pressure and velocity at a point in the streamline of flow and z is the level of elevation of the point relative. $\frac{P}{\gamma}$ is the pressure head and $\frac{V^2}{2g}$ is the kinetic head and z refers to the elevation head. The three can be thought of as pressure energy per unit weight, kinetic energy per unit weight, and potential energy per unit weight respectively.

Bernoulli's equation is only valid if the following assumptions are made:

- Inviscid flow
- Incompressible fluid
- Steady flow
- Flow along streamline

When applied to two points along the stream for an ideal fluid, Bernoulli's equation can be written as:

$$\frac{P_1}{\gamma}+z_1+\frac{V_1^2}{2g}=\frac{P_2}{\gamma}+z_2+\frac{V_2^2}{2g} \text{ (2)}$$

Subscript 1 and 2 refer to the image below:

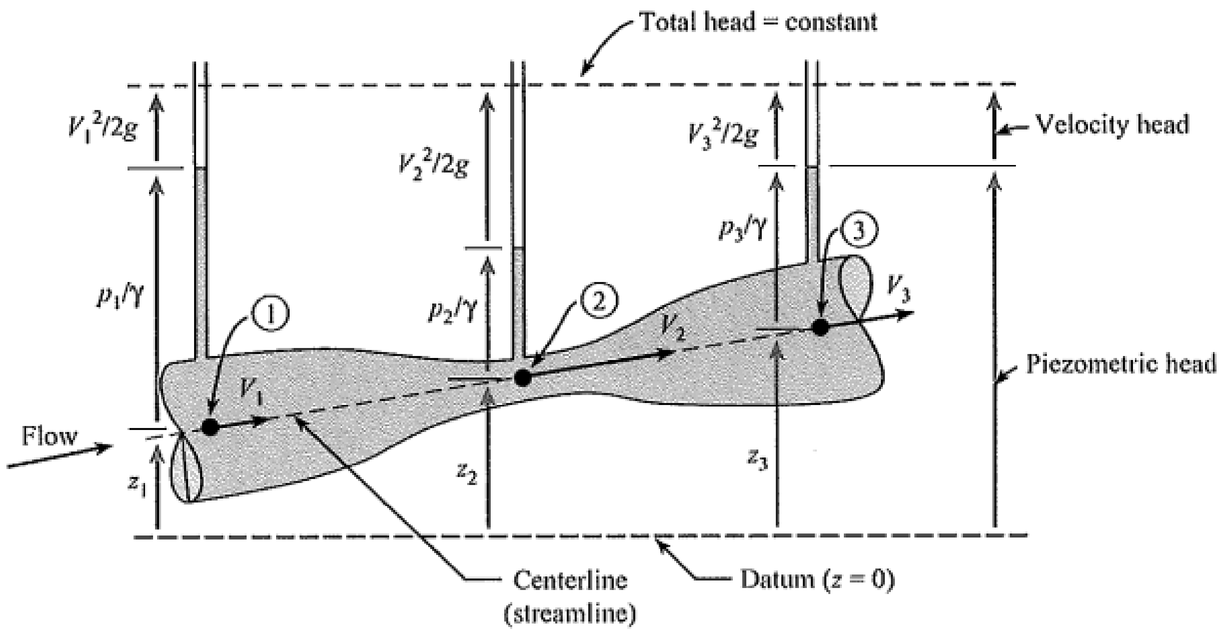

Figure 1. Graphical representation of Bernoulli's equation

Equipment

1.Venturi meter for measurements of head

2.Hydraulic bench for fluid flow

3. Stopwatch for time calculations

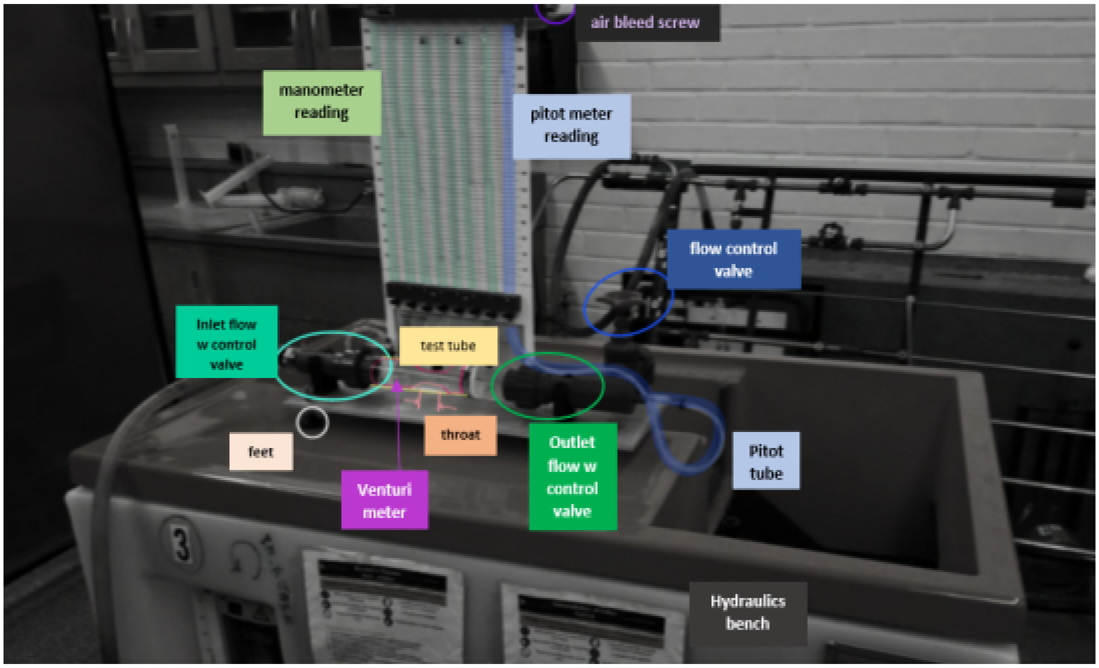

Figure 2. Lab set-up

Experimental Set-Up and Procedures

We first located the apparatus on the flat top of the bench with the outlet pipe over the molded channel of the hydraulic bench. Then using the spirit level attached to the baseplate, located the apparatus on the flat top of the bench with the outlet pipe over the molded channel of the hydraulic bench. We then connected the flexible inlet tube at the left hand end to the quick release fitting in the bed of the channel. Next we placed the free end of the flexible outlet tube in the volumetric tank of the bench. From here we fully opened the outlet flow control valve at the right hand end of the apparatus. After doing so, we closed the bench flow control valve and started the service pump. We gradually opened the bench flow control valve and allowed the pipework to fill with water until all air had been expelled from the pipework. In order to bleed air from pressure tappings points and the manometers, we closed both the bench flow control valve and the outlet flow control valve and opened the air bleed screw. Next removing the cap from the adjacent air inlet/outlet connection. Then connecting a length of small bore tubing from the air valve to the volumetric tank. We then opened the bench flow control valve and allowed flow through the manometers to purge all air from them, then tightened the air bleed screw and partly opened both the bench valve and the outlet flow control valve. Next we opened the air bleed screw slightly to allow air to enter the top of the manometers, then retightening the screw when the manometer levels reached mid height. After doing so, we gradually increase the volume flow rate by opening the outlet flow control valve or the bench flow control valve as required until the maximum flow rate is achieved. In the case that the pattern is too low on the manometer, open the bench flow control valve to increase the static pressure. If the pattern is too high, open the outlet flow control valve to lower the static pressure. By controlling the bench flow control valve, we can regulate the flow rate through the duct. At this flow rate, we measured the piezometric head, water level in each tube with respect to a fixed datum. We then determined the flowrate through the venturi pipe by recording the time to collect a known volume of water in the tank. The hydraulic bench has two tanks. For low flow we used the scale for low flow tank and for high flow we used the scale for high flow. We repeated steps 2 to 4 for at least 3 values of the inlet head. Finally measuring the distance of each piezometric tube location (x), from the first tube at the entrance of the duct and the duct area (A) at each of these points.

Discussion

Table 1. Measured and Observed Data

Flow Rate Q (m^3/sec)		Distance into Duct (m)	Area of Duct A (m^2)	Static Head h (mm)
5.65E-04	h1	0	5.31E-04	374
5.65E-04	h2	0.020	4.23E-04	354
5.65E-04	h3	0.032	2.66E-04	226
5.65E-04	h4	0.046	2.01E-04	30
5.65E-04	h5	0.062	2.21E-04	82

5.65E-04	h6	0.077	2.68E-04	180
4.79E-04	h1	0	5.31E-04	372
4.79E-04	h2	0.020	4.23E-04	358
4.79E-04	h3	0.032	2.66E-04	266
4.79E-04	h4	0.046	2.01E-04	122
4.79E-04	h5	0.062	2.21E-04	158
4.79E-04	h6	0.077	2.68E-04	232
3.95E-04	h1	0	5.31E-04	380
3.95E-04	h2	0.020	4.23E-04	370
3.95E-04	h3	0.032	2.66E-04	308
3.95E-04	h4	0.046	2.01E-04	210
3.95E-04	h5	0.062	2.21E-04	232
3.95E-04	h6	0.077	2.68E-04	284

Table 2. Calculations Based off Table 1 Results

Static Head h (m)		Velocity V (m/s)	Dynamic Head $V^2/2g$ (m)	Total Head H (m)
0.374	h1	1.06E+00	0.05772612985	0.4317261298
0.354	h2	1.34E+00	0.09106120583	0.4450612058
0.226	h3	2.12E+00	0.230123631	0.456123631
0.030	h4	2.81E+00	0.4023219721	0.4323219721
0.082	h5	2.55E+00	0.3319270602	0.4139270602
0.180	h6	2.11E+00	0.2267004934	0.4067004934
0.372	h1	9.02E-01	0.04149029981	0.4134902998
0.358	h2	1.13E+00	0.06544968009	0.4234496801
0.226	h3	1.80E+00	0.1653999406	0.3913999406
0.122	h4	2.38E+00	0.2891664362	0.4111664362

0.158	h5	2.16E+00	0.2385705274	0.3965705274
0.232	h6	1.79E+00	0.1629395815	0.3949395815
0.380	h1	7.44E-01	0.02821432973	0.4082143297
0.370	h2	9.34E-01	0.04450724298	0.414507243
0.308	h3	1.49E+00	0.1124756505	0.4204756505
0.210	h4	1.96E+00	0.1966396294	0.4066396294
0.232	h5	1.78E+00	0.1622332824	0.3942332824
0.284	h6	1.47E+00	0.1108025514	0.3948025514

Table 2. HGL and EGL

HGL	EGL
3.74E-01	4.32E-01
3.54E-01	4.45E-01
2.26E-01	4.56E-01
3.00E-02	4.33E-01
8.20E-02	4.15E-01
1.80E-01	4.07E-01
3.72E-01	4.13E-01
3.58E-01	4.23E-01
2.26E-01	3.91E-01
1.22E-01	4.11E-01
1.58E-01	3.97E-01
2.32E-01	3.95E-01
3.80E-01	4.08E-01
3.70E-01	4.14E-01
3.08E-01	4.20E-01
2.10E-01	4.07E-01
2.32E-01	3.95E-01
2.84E-01	3.95E-01

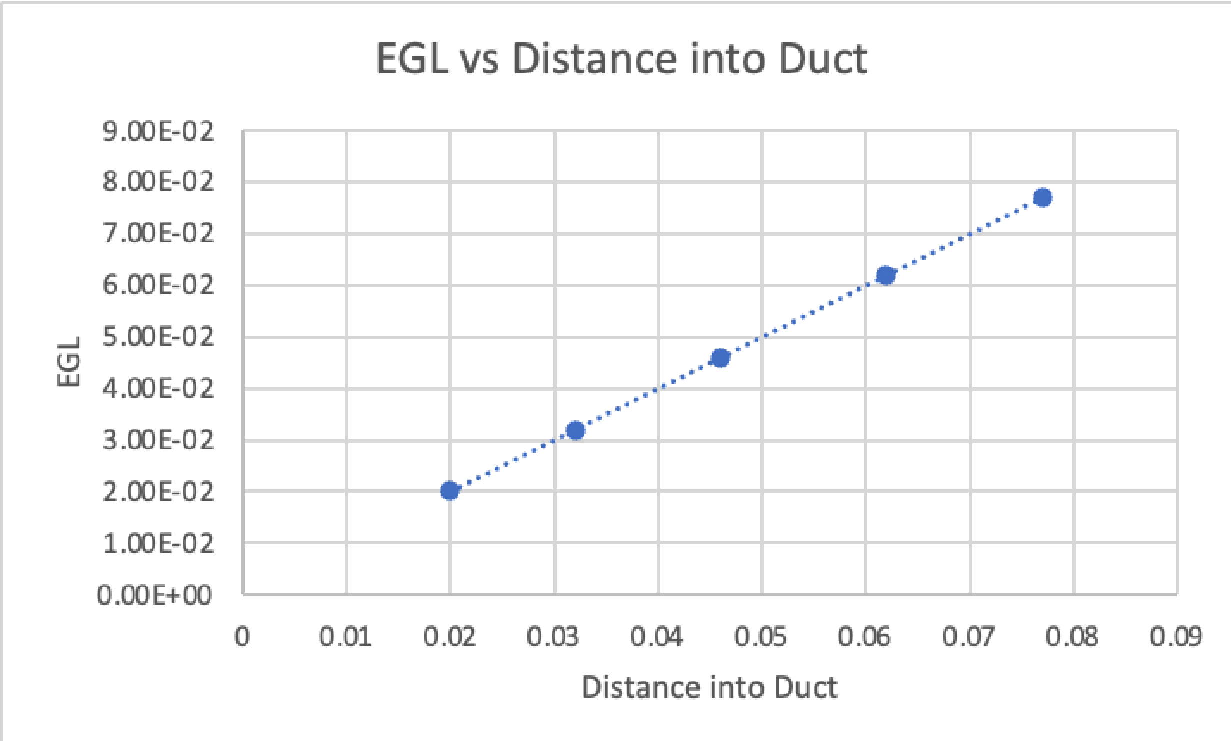

Figure 3. EGL vs Distance into Duct Graph

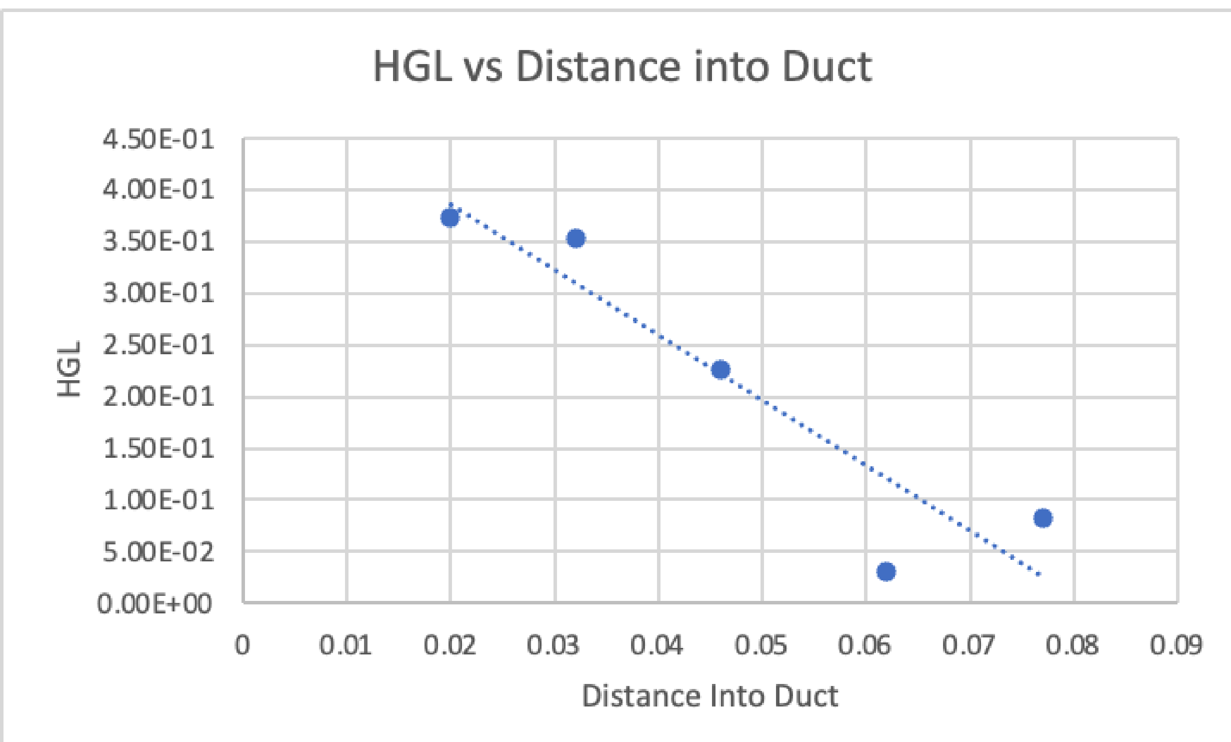

Figure 4. HGL vs Distance into Duct Graph

Conclusion

By performing this experiment, we were able to determine the validity of Bernoulli's equation with steady flow of water and finding the total energies. When flow goes from a bigger to smaller area the flow is steady and one of the assumptions for Bernoulli's is met and therefore the equation is able to be used.

1. *What is venturi meter? What is the advantage of using venturi meter over weir or orifice to measure discharge?*

   A venturi meter is a device that is used to measure flow through a pipe and it consists of a pipe that has five different areas to test different flows. The venturi meter has an advantage because the main cause of head loss is due to the friction of the walls rather than loss due to separated flows and inefficient mixing motions.
2. *What are the assumptions of Bernoulli's equation?*

   The assumptions that are made in Bernoulli's equation are that energy stays constant along the streamline, that it is an ideal fluid, the ideal fluid is inviscid, and that it is an incompressible fluid. With the following assumptions the following equation can be used:

   $$\frac{P}{\gamma} + z + \frac{V^2}{2g} = \text{Constant}$$

3. *How HGL and EGL changed along the length of the duct?*

   The HGL follows the path correctly and follows with pressure drops and increases in the duct.
4. *Discuss on the validity of the Bernoulli's equation for convergent and divergent flow.*

Divergent flow does not have a steady flow along the streamline and this violates one of the assumptions that need to be met in order to utilize Bernoulli's equation. When flow goes from a bigger to smaller area the flow is steady and one of the assumptions for Bernoulli's is met and therefore the equation is able to be used.

References

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