BERNOULLI EXPERIMENT

1. Objective

The aim of this experiment is to verify Bernoulli Equation by using a venturi meter to observe fluid elevation through the tube with different flow rates and research the reasons of different between theory and practice.

2. Theory

The Bernoulli equation is an approximate relation between pressure, velocity, and elevation, and is valid in regions of steady, incompressible flow where net frictional forces are negligible (Fig. 1). Despite its simplicity, it has proven to be a very powerful tool in fluid mechanics. In this section, we derive the Bernoulli equation by applying the conservation of linear momentum principle, and we demonstrate both its usefulness and its limitations.

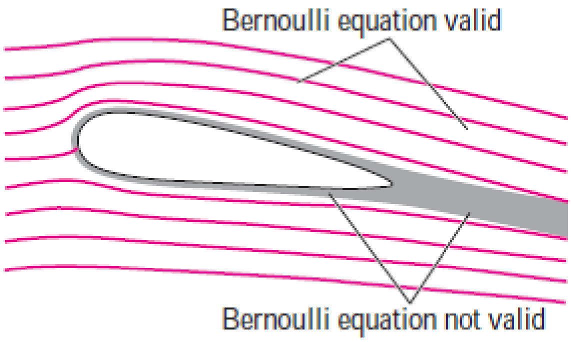

Figure 1. Practicable regions of Bernoulli equation

To derive the Bernoulli equation Consider the motion of a fluid particle in a flow field in steady flow.

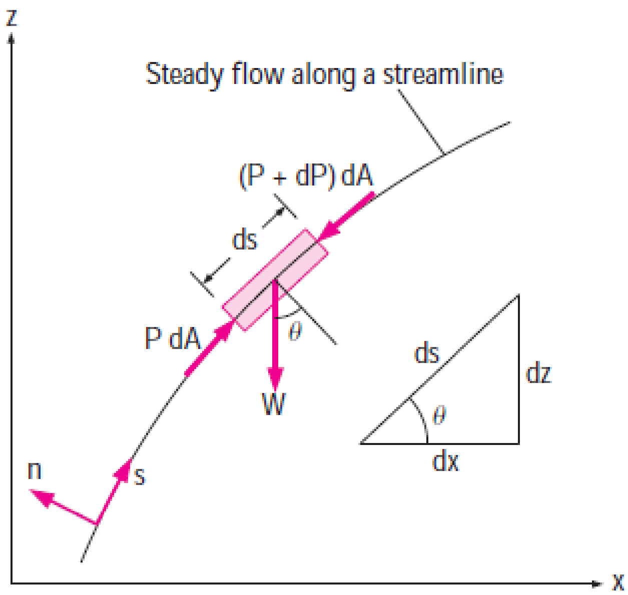

Figure 2. The forces acting on a fluid particle along a streamline

Applying Newton's second law (which is referred to as the conservation of linear momentum relation in fluid mechanics) in the s-direction on a particle moving along a streamline gives:

$$\sum F_S = ma_S \tag{1}$$

In regions of flow where net frictional forces are negligible, the significant forces acting in the s-direction are the pressure (acting on both sides) and the component of the weight of the particle in the s-direction (Fig. 2). Therefore, Eq. 1 becomes:

$$PdA - (P + dP)dA - Wsin\theta = mV\frac{dV}{ds} \tag{2}$$

where θ is the angle between the normal of the streamline and the vertical z-axis at that point, m = ρV = ρ.dA.ds is the mass, W = mg = ρ.g.dA.ds is the weight of the fluid particle, and sinθ = dz /ds. Substituting;

$$-dP\ dA - \rho g\ dA\ ds\frac{dz}{ds} = \rho\ dA\ ds\ V\frac{dV}{ds} \tag{3}$$

Canceling dA from each term and simplifying,

$$-dP - \rho g\ dz = \rho\ V\ dV \tag{4}$$

Noting that V dV =1/2 d(V^2) and dividing each term by ρ gives;

$$\frac{dP}{\rho} + \frac{1}{2}\ d(V^2) + gdz = 0 \tag{5}$$

For steady flow along a streamline equation becomes;

$$\int\frac{dP}{\rho} + \frac{V^2}{2} + gz = constant$$

since the last two terms are exact differentials. In the case of incompressible flow, the first term also becomes an exact differential, and its integration gives;

$$\frac{P}{\rho} + \frac{V^2}{2} + gz = constant \tag{6}$$

The value of the constant can be evaluated at any point on the streamline where the pressure, density, velocity, and elevation are known. The Bernoulli equation can also be written between any two points on the same streamline as;

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + gz_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + gz_2 \tag{7}$$

3. Static, Dynamic and Stagnation Pressures

The Bernoulli equation states that the sum of the flow, kinetic, and potential energies of a fluid particle along a streamline is constant. Therefore, the kinetic and potential energies of the fluid can be converted to flow energy (and vice versa) during flow, causing the pressure to change. This phenomenon can be made more visible by multiplying the Bernoulli equation by the density ρ;

$$P + \rho\frac{V^2}{2} + \rho gz = constant \tag{8}$$

Each term in this equation has pressure units, and thus each term represents some kind of pressure:

- P is the static pressure (it does not incorporate any dynamic effects); it represents the actual thermodynamic pressure of the fluid. This is the same as the pressure used in thermodynamics and property tables.
- $\rho V^2/2$ is the dynamic pressure; it represents the pressure rise when the fluid in motion is brought to a stop isentropically.
- ρgz is the hydrostatic pressure, which is not pressure in a real sense since its value depends on the reference level selected; it accounts for the elevation effects, i.e., of fluid weight on pressure.

The sum of the static, dynamic, and hydrostatic pressures is called the total pressure. Therefore, the Bernoulli equation states that the total pressure along a streamline is constant.

The sum of the static and dynamic pressures is called the stagnation pressure, and it is expressed as:

$$P_{stag} = P + \rho \frac{V^2}{2} \quad (9)$$

The stagnation pressure represents the pressure at a point where the fluid is brought to a complete stop isentropically. The static, dynamic, and stagnation pressures are shown in Fig. 5–27. When static and stagnation pressures are measured at a specified location, the fluid velocity at that location can be calculated from:

$$V = \sqrt{\frac{2(P_{stag} - P)}{\rho}} \quad (10)$$

4. EXPERIMENTS

As seen from Fig. 3 that there are 11 water columns from inlet to outlet through the main tube in the setup. Diameter and cross section area are not constant (Fig. 4) and diameter values are given in Table 1. Also a comprehensive informing will be performed on the experiment day.

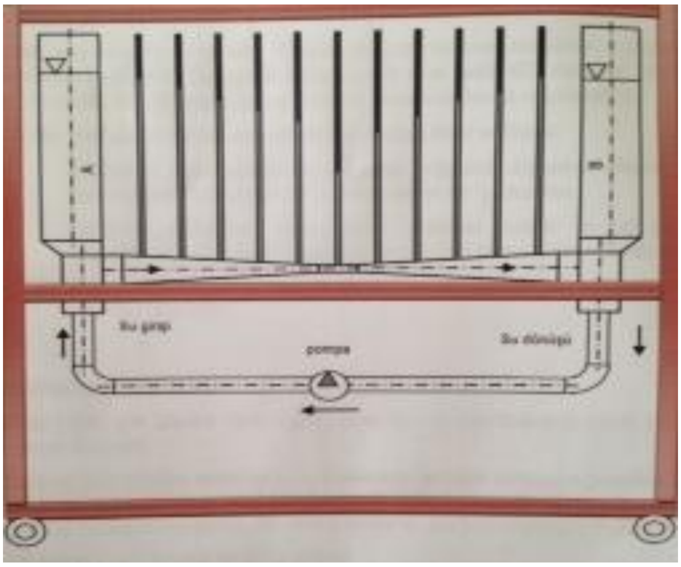

Figure 3. Experimental setup

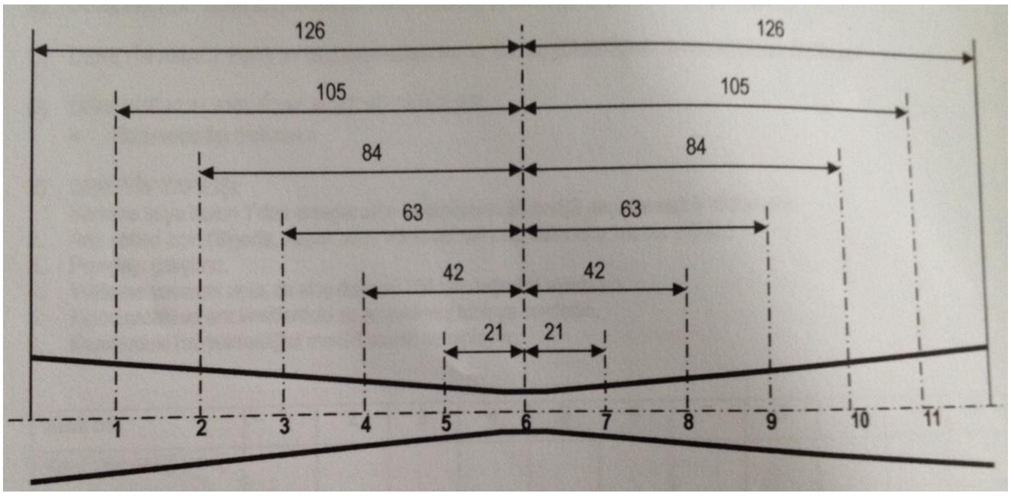

Figure 4. Front view of main tube

Table 1. Diameter and cross section areas through the tube

No	1	2	3	4	5	6	7	8	9	10	11
Diameter (mm)	26	24,66	22,49	20,33	18,16	16	18,16	20,33	22,49	24,66	26

Table 2. Data table

No	1	2	3	4	5	6	7	8	9	10	11
Height (mm)											
Height at Column A (mm)											
Velocity (m/s)											
Dynamic Pressure (kPa)											
Total Pressure (kPa)											

Actions to be taken:

- **a)** Do necessary calculations and fill the data sheet.
- **b)** Draw water height distribution through the tube.
- **c)** Draw velocity distribution through the tube.
- **d)** Draw total pressure through the tube.