



BERNOULLI EQUATION

Chemical Science

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ABSTRACT

This study explores the practical application of Bernoulli's equation, a cornerstone of fluid dynamics that describes the conservation of energy in a flowing, incompressible fluid. The experiment utilized a venturi apparatus equipped with a series of manometers and a hypodermic probe, enabling precise measurement of pressure and velocity variations across sections of a duct with variable cross-sectional areas. By applying Bernoulli's equation, we analyzed the inverse relationship between velocity and pressure within a streamline, confirming that as the fluid velocity increased due to constrictions in the duct, there was a corresponding drop in pressure, consistent with theoretical predictions of energy conservation. **However**, the accuracy of the results was influenced by experimental factors, including the presence of air bubbles within the manometer tubes, which introduced potential sources of error in pressure readings. Despite these limitations, the experiment underscores the relevance of Bernoulli's principle in engineering applications, such as fluid transport systems and aerodynamic design, providing valuable insights into the behavior of incompressible fluids under varying flow conditions.

KEYWORDS

INTRODUCTION

The **Bernoulli equation** is a fundamental principle in fluid dynamics that relates the pressure, velocity, and elevation of a fluid flowing in a streamline. It is named after the Swiss mathematician and physicist Daniel Bernoulli, who derived this equation in the 18th century.

The **Bernoulli equation** is based on the principle of conservation of energy. It states that along a streamline, the total energy per unit mass of a fluid remains constant. This total energy consists of three components: **potential energy** (due to elevation), **kinetic energy** (due to motion), and **pressure energy** (due to fluid pressure).

This equation implies that as one component of energy increases, another component must decrease to maintain a constant total energy per unit mass. For example, if the velocity of a fluid increases along a streamline, then either its pressure or elevation must decrease.

The **Bernoulli equation** finds applications in various fields such as **aerodynamics**, **hydrodynamics**, and engineering. It helps explain phenomena like lift in aircraft wings, flow through pipes and nozzles, and even blood flow in arteries.

However, it is important to note that certain assumptions are made when using the Bernoulli equation. These assumptions include steady flow (**no changes with time**), incompressible fluids (**constant density**), negligible viscosity effects, and no external work being done on or by the fluid.

Objective

The objective of the **Bernoulli equation** is to describe the conservation of energy in a fluid flow system. It relates the pressure, velocity, and elevation of a fluid at any given point along a streamline. By understanding and applying the Bernoulli equation, engineers and scientists can analyze and predict the behavior of fluids in various applications such as **fluid dynamics**, **aerodynamics**, **hydraulics**, and **more**.

Theory of Bernoulli's Theorem Experiment

Bernoulli's theorem assumes that the flow is frictionless, steady, and incompressible. These assumptions are also based on the laws of conservation of mass and energy. Thus, the input mass and energy for a given control volume are equal to the output mass and energy:

$$Q_{in} = Q_{out} \quad (1a)$$

$$E_{in} = E_{out} \quad (1b)$$

These two laws and the definition of work and pressure are the basis for Bernoulli's theorem and can be expressed as follows for any two points located on the same streamline in the flow:

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 \quad (2)$$

where:

P: pressure,

g: acceleration due to gravity,

v: fluid velocity, and

z: vertical elevation of the fluid.

In this experiment, since the duct is horizontal, the difference in height can be disregarded, i.e., $z_1 = z_2$.

The **hydrostatic pressure** (P) along the flow is measured by manometers tapped into the duct. The pressure head (h), thus, is calculated as:

$$h = \frac{P}{\rho g} \quad (3)$$

Therefore, Bernoulli's equation for the test section can be written as:

$$h_1 + \frac{v_1^2}{2g} = h_2 + \frac{v_2^2}{2g} \quad (4)$$

in which is called the velocity head (h_v).

The **total head** (h_t) may be measured by the traversing hypodermic probe. This probe is inserted into the duct with its end-hole facing the flow so that the flow becomes stagnant locally at this end; thus:

$$h_t = h + \frac{v^2}{2g} \quad (5)$$

The conservation of energy or the Bernoulli's equation can be expressed as:

$$h_{t1} = h_{t2} \quad (6)$$

The flow velocity is measured by collecting a volume of the fluid (V) over a time period (t). The flow rate is calculated as:

$$Q = \frac{V}{t} \quad (7)$$

The velocity of flow at any section of the duct with a cross-sectional area of is determined as:

$$v = \frac{Q}{A} \quad (8)$$

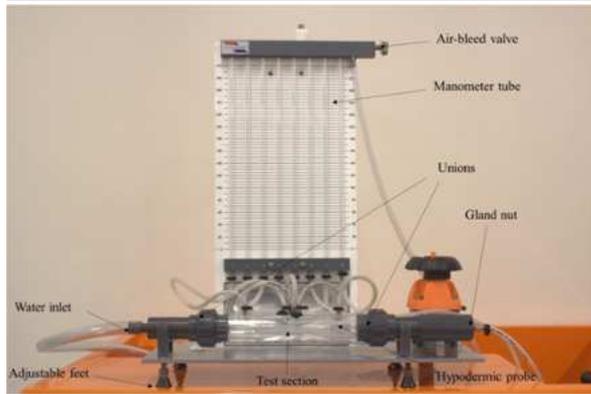
For an incompressible fluid, conservation of mass through the test section should be also satisfied (Equation 1a), i.e.:

$$A_1 v_1 = A_2 v_2 \quad (9)$$

Equipment Description:

The Bernoulli test apparatus consists of a tapered duct (venture), a series of manometers tapped into the venture to measure the pressure head, and a hypodermic probe that can be traversed along the center of the test section to measure the total head. The test section is a circular duct of varying diameter with a 14° inclined angle on one side and a 21° inclined angle on other side. Series of side hole pressure tapings are provided to connect manometers to the test section (**Figure 1**).

Figure 1: Artfield F1-15 Bernoulli's apparatus test equipment



Tapping number	1	2	3	4	5	6	7	8	9	10	11
Flow area	102.5	90.1	77.6	65.2	52.7	40.3	52.7	65.2	77.6	90.1	102.5
	6	1	6	2	7	2	7	2	6	1	6

Figure 2: Bernoulli's device and the different county area are back

Tools:

There are several tools that can be used to solve or analyze the Bernoulli equation, which describes the conservation of energy in fluid flow.

Some of these tools include:

1. Bernoulli's equation itself: The equation relates the pressure, velocity, and elevation of a fluid along a streamline. It is written as :

$$P + 0.5\rho v^2 + \rho * g * h = \text{constant}$$

where P is the pressure, ρ is the density of the fluid, v is the velocity, g is the acceleration due to gravity, and h is the height above a reference point.

2. Pitot tube: A Pitot tube is a device used to measure fluid velocity by measuring the difference between total pressure (static pressure plus dynamic pressure) and static pressure alone. It can be used to verify Bernoulli's equation.

3. Ventur meter: A Ventur meter is a device that measures fluid flow rate by creating a constriction in a pipe and measuring the pressure difference across it. It relies on Bernoulli's equation to determine flow rate.

4. Flow visualization techniques: Techniques such as smoke or dye injection can be used to visualize fluid flow patterns and verify Bernoulli's equation.

5. Computational Fluid Dynamics (CFD) software: CFD software uses numerical methods to solve complex fluid flow problems, including those involving Bernoulli's equation. These tools allow for detailed analysis and simulation of fluid behavior.

6. Fluid mechanics textbooks and reference materials: Various textbooks and reference materials provide detailed explanations and examples of applying Bernoulli's equation in different scenarios.

It is important to note that while these tools can aid in solving or analyzing problems related to Bernoulli's equation, they should be used in conjunction with an understanding of fluid mechanics principles and assumptions underlying the equation for accurate results.

Steps to make the experiment:

The Bernoulli equation is a fundamental principle in fluid dynamics that relates the pressure, velocity, and elevation of a fluid flowing in a streamline. The action steps for applying the Bernoulli equation are as follows:

1. Turn on the pump and stabilize the water flow into the inlet tank.
2. Adjust the drain pipe to have a variable pressure head height of 50cm.
3. Calculate the height of the water level in each manometer tube and record the data in the table
4. Take a certain volume of water ranging from 5 to 10 liters of water

and calculate its collection time.

5. Calculate the flow rate from the relationship $Q = v/t$ whereas t is the collection time of the water and V is the volume of water, $v = \text{number of liter} / 1000$

6. Calculate the velocity from the following relationship $V = Q / A$ at each monomeric tube, where A is area Test tube clip.

7. Make a graph between the height of the pressure head (Y) taken across the manometer tubes with the distance (X).

8. Make a graph between $h + (v^2 / 2g)$ with distance.

Calculations

Dg (1)

$$V = 600\text{ml}, v = 0.0006 \text{ m}^3/\text{s}$$

$$Q = 0.0006/9.2 = 0.0000652 \text{ m}^3/\text{sec}$$

$$g = 9.81 \text{ m}^2/\text{sec}$$

A (m ²)	h (m)	V (m/s)	(v ²)/2g	h+(v ²)/2g
0.00010256	0.438	0.6357	0.0206	0.458599
0.00009011	0.428	0.7236	0.0267	0.454684
0.00007766	0.415	0.8396	0.0359	0.450925
0.00006522	0.39	0.9997	0.0509	0.440937
0.00005277	0.346	1.2356	0.0778	0.423808
0.00004032	0.272	1.6171	0.1333	0.405277
0.00005277	0.305	1.2356	0.0778	0.382808
0.00006522	0.344	0.9997	0.0509	0.394937
0.00007766	0.358	0.8396	0.0359	0.393925
0.00009011	0.367	0.7236	0.0267	0.393684
0.00010256	0.373	0.6357	0.0206	0.393599

Dg (2)

$$V = 760\text{ml}, v = 0.00076 \text{ m}^3/\text{s}, t = 12.5\text{sec}$$

$$Q = 0.00076/12.5 = 0.0000608 \text{ m}^3/\text{sec}$$

$$g = 9.81 \text{ m}^2/\text{sec}$$

A (m ²)	h (m)	V (m/s)	(v ²)/2g	h+(v ²)/2g
0.00010256	0.438	0.5928	0.0179	0.455912
0.00009011	0.425	0.6747	0.0232	0.448204
0.00007766	0.406	0.7829	0.0312	0.43724
0.00006522	0.38	0.9322	0.0443	0.424294
0.00005277	0.33	1.1522	0.0677	0.39766
0.00004032	0.245	1.5079	0.1159	0.360896
0.00005277	0.289	1.1522	0.0677	0.35666
0.00006522	0.328	0.9322	0.0443	0.372294
0.00007766	0.343	0.7829	0.0312	0.37424
0.00009011	0.343	0.6747	0.0232	0.366204
0.00010256	0.359	0.5928	0.0179	0.376912

Dg (3)

$$V = 1180\text{ml}, v = 0.00118 \text{ m}^3/\text{s}, t = 16\text{sec}$$

$$Q = 0.00118/16 = 0.00007375 \text{ m}^3/\text{sec}$$

$$g = 9.81 \text{ m}^2/\text{sec}$$

A (m ²)	h (m)	V (m/s)	(v ²)/2g	h+(v ²)/2g
0.00010256	0.427	0.7191	0.0264	0.453355
0.00009011	0.415	0.8184	0.0341	0.449141
0.00007766	0.395	0.9497	0.046	0.440965
0.00006522	0.362	1.1308	0.0652	0.427172
0.00005277	0.304	1.3976	0.0996	0.403552
0.00004032	0.204	1.8291	0.1705	0.374523
0.00005277	0.26	1.3976	0.0996	0.359552
0.00006522	0.303	1.1308	0.0652	0.368172
0.00007766	0.322	0.9497	0.046	0.367965
0.00009011	0.334	0.8184	0.0341	0.368141
0.00010256	0.342	0.7191	0.0264	0.368355

Dg (4)

$$V = 820\text{ml}, v = 0.000820, t = 10.15\text{sec}$$

$$Q = 0.000820/10.15 = 0.00008079 \text{ m}^3/\text{sec}$$

$$g = 9.81 \text{ m}^2/\text{sec}$$

A (m ²)	h (m)	V (m/s)	(v ²)/2g	h+(v ²)/2g
0.00010256	0.422	0.7877	0.0316	0.453627
0.00009011	0.406	0.8966	0.041	0.44697
0.00007766	0.383	1.0403	0.0552	0.43816
0.00006522	0.346	1.2387	0.0782	0.424209
0.00005277	0.279	1.531	0.1195	0.398465
0.00004032	0.163	2.0037	0.2046	0.367633
0.00005277	0.231	1.531	0.1195	0.350465
0.00006522	0.28	1.2387	0.0782	0.358209
0.00007766	0.301	1.0403	0.0552	0.35616

0.00009011	0.315	0.8966	0.041	0.35597
0.00010256	0.325	0.7877	0.0316	0.356627

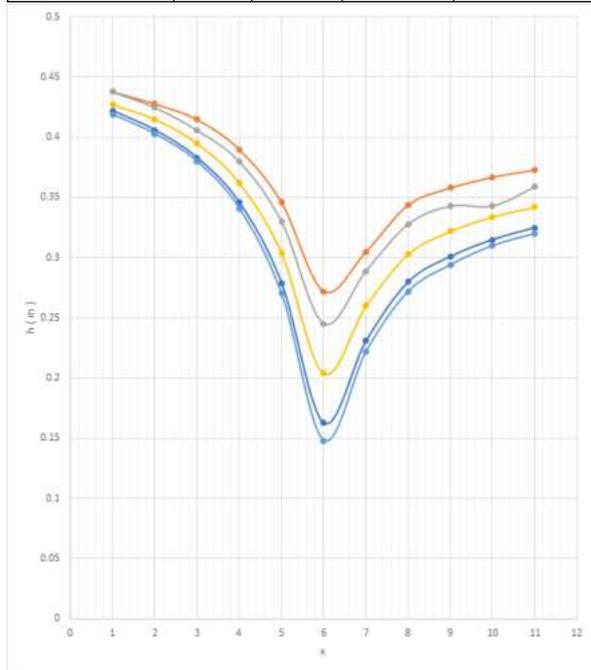
Dg (5)

V=1020ml, v=0.001020 m³, t=12.5 sec

Q=0.001020/12.5=0.0000816 m³/sec

g=9.81 m²/sec

A (m ²)	h (m)	V (m/s)	(v ²)/2g	h+(v ²)/2g
0.00010256	0.419	0.7956	0.0323	0.451265
0.00009011	0.403	0.9056	0.0418	0.444796
0.00007766	0.38	1.0507	0.0563	0.436271
0.00006522	0.341	1.2511	0.0798	0.420785
0.00005277	0.27	1.5463	0.1219	0.391873
0.00004032	0.148	2.0238	0.2088	0.356757
0.00005277	0.222	1.5463	0.1219	0.343873
0.00006522	0.272	1.2511	0.0798	0.351785
0.00007766	0.294	1.0507	0.0563	0.350271
0.00009011	0.31	0.9056	0.0418	0.351796
0.00010256	0.32	0.7956	0.0323	0.352265



SHAPE (1)

Dg (6)

V=1620ml, v=0.00162 m³, t=18.8 sec

Q=0.00162/18.8=0.00008617 m³/sec

g=9.81 m²/sec

A (m ²)	h (m)	V (m/s)	(v ²)/2g	h+(v ²)/2g
0.00010256	0.415	0.8402	0.036	0.45098
0.00009011	0.396	0.9563	0.0466	0.442609
0.00007766	0.37	1.1096	0.0628	0.432751
0.00006522	0.326	1.3212	0.089	0.414972
0.00005277	0.247	1.6329	0.1359	0.382906
0.00004032	0.113	2.1372	0.2328	0.345794
0.00005277	0.195	1.6329	0.1359	0.330906
0.00006522	0.25	1.3212	0.089	0.338972
0.00007766	0.275	1.1096	0.0628	0.337751
0.00009011	0.292	0.9563	0.0466	0.338609
0.00010256	0.303	0.8402	0.036	0.33898

Dg (7)

V=1480ml, v=0.00148 m³, t=16.5sec

Q=0.00148/16.5=0.0000897 m³/sec

g=9.81 m²/sec

A (m ²)	h (m)	V (m/s)	(v ²)/2g	h+(v ²)/2g
0.00010256	0.41	0.8746	0.039	0.448988
0.00009011	0.39	0.9955	0.0505	0.440506
0.00007766	0.36	1.155	0.068	0.427997
0.00006522	0.311	1.3753	0.0964	0.40741
0.00005277	0.322	1.6998	0.1473	0.469269

0.00004032	0.073	2.2247	0.2523	0.325258
0.00005277	0.166	1.6998	0.1473	0.313269
0.00006522	0.226	1.3753	0.0964	0.32241
0.00007766	0.255	1.155	0.068	0.322997
0.00009011	0.274	0.9955	0.0505	0.324506
0.00010256	0.286	0.8746	0.039	0.324988

Dg (8)

V=1070ml, v=0.001070 m³, t=11.1 sec

Q=0.001070/11.1=0.0000964 m³/sec

g=9.81 m²/sec

A (m ²)	h (m)	V (m/s)	(v ²)/2g	h+(v ²)/2g
0.00010256	0.402	0.9399	0.045	0.44703
0.00009011	0.38	1.0698	0.0583	0.438332
0.00007766	0.347	1.2413	0.0785	0.425534
0.00006522	0.293	1.4781	0.1114	0.404351
0.00005277	0.197	1.8268	0.1701	0.367091
0.00004032	0.003	2.3909	0.2913	0.294349
0.00005277	0.136	1.8268	0.1701	0.306091
0.00006522	0.202	1.4781	0.1114	0.313351
0.00007766	0.233	1.2413	0.0785	0.311534
0.00009011	0.253	1.0698	0.0583	0.311332
0.00010256	0.267	0.9399	0.045	0.31203

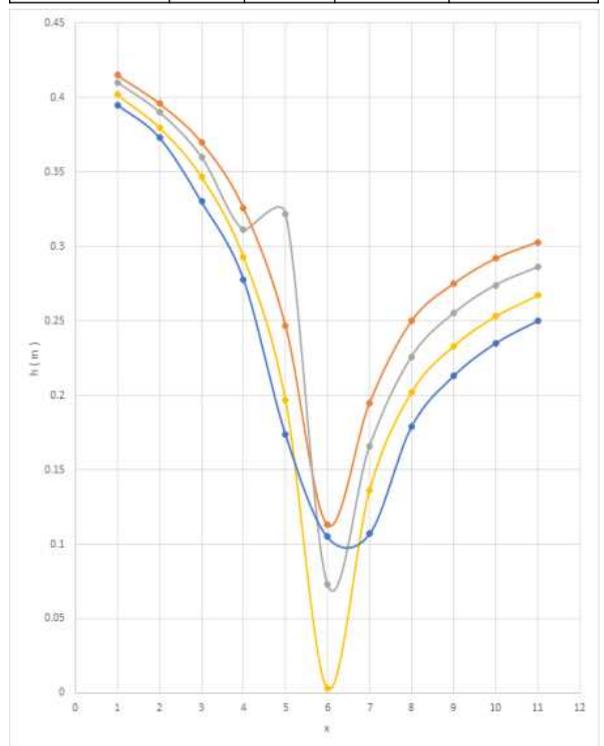
Dg (9)

V=960ml, v=0.00096 m³, t=9.7 sec

Q=0.00096/9.7=0.00009897 m³/sec

g=9.81 m²/sec

A (m ²)	h (m)	V (m/s)	(v ²)/2g	h+(v ²)/2g
0.00010256	0.395	0.965	0.0475	0.442463
0.00009011	0.373	1.0983	0.0615	0.434484
0.00007766	0.33	1.2744	0.0828	0.412778
0.00006522	0.278	1.5175	0.1174	0.395367
0.00005277	0.174	1.8755	0.1793	0.353281
0.00004032	0.105	2.4546	0.3071	0.412091
0.00005277	0.107	1.8755	0.1793	0.286281
0.00006522	0.179	1.5175	0.1174	0.296367
0.00007766	0.213	1.2744	0.0828	0.295778
0.00009011	0.235	1.0983	0.0615	0.296484
0.00010256	0.25	0.965	0.0475	0.297463



SHAPE (2)

DISCUSSION:

This experience has important practical applications in multiple fields such as engineering, meteorology, and aviation. It helps engineers

understand and predict the behavior of fluids in pipes and ducts, while meteorologists use it to study airflow patterns. In aviation, Bernoulli's principle is crucial to understanding the generation of lift on aircraft wings.

Overall, Bernoulli's experiment is a fundamental illustration of the relationship between fluid velocity and pressure and has wide-ranging implications for many scientific and engineering disciplines.

CONCLUSION:

The Bernoulli equation experiment is a great way of teaching students about the relationship between velocity and pressure. This experiment shows that as velocity increases, pressure decreases. This is an important concept to understand in fluid dynamics and is something that students should be familiar with. From the calculation, it is very clear that with decrease in area of the flow velocity increase and pressure.

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- (6) Note of class
- (7) ChatGPT
- (8) أساسيات قدرة الموانع- عملي (المؤسسة العامة للتدريب التقني والمهني الإدارة العامة لتصميم وتطوير المناهج)