Aerodynamics Lab – I

(AE29202)

Verification of Bernoulli's Theorem

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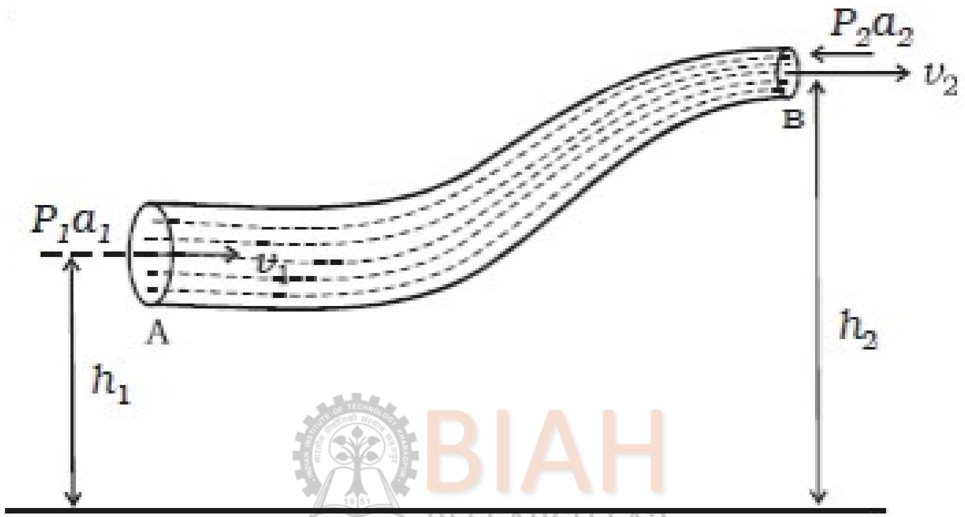
What is Bernoulli's Theorem?

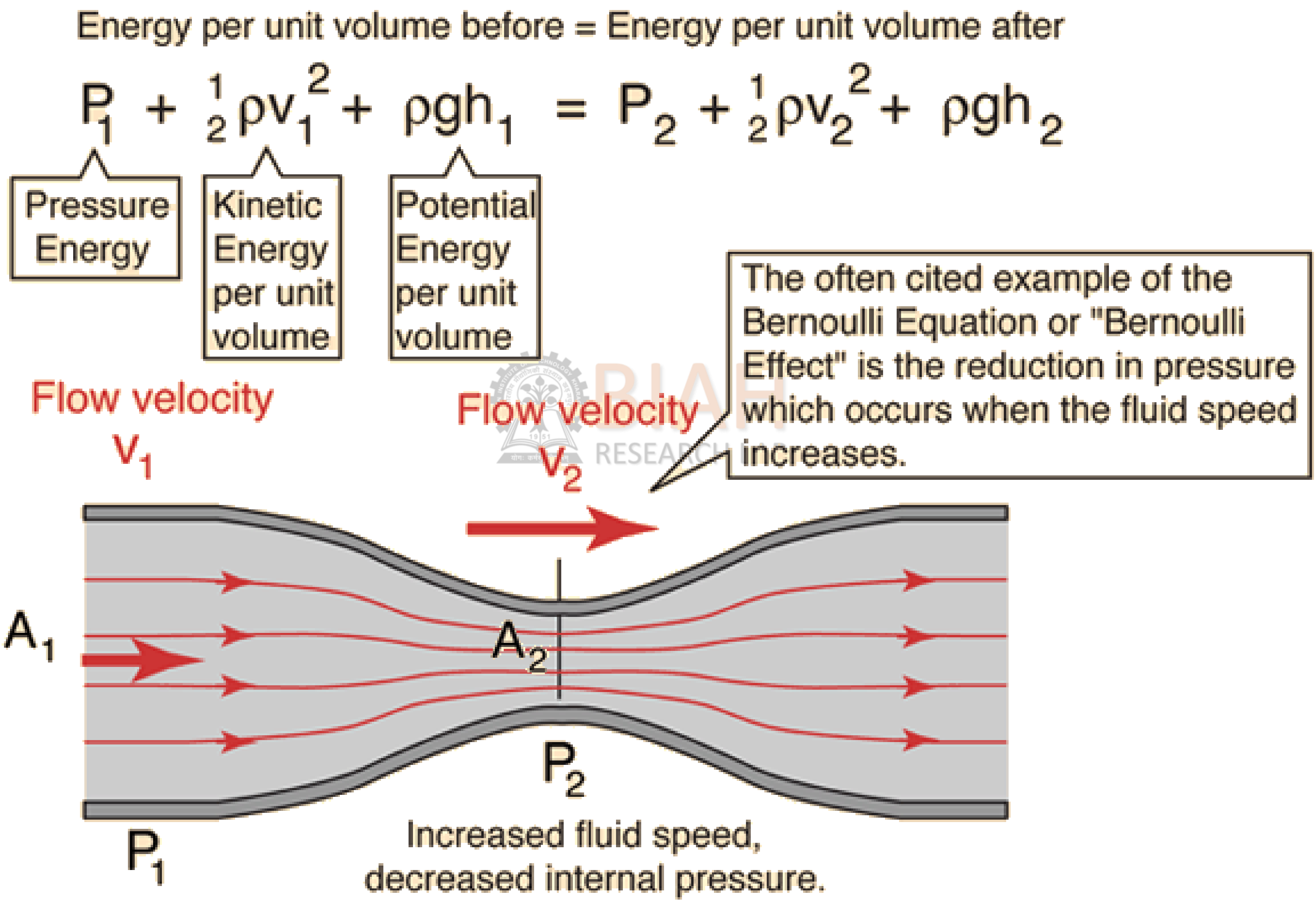


This theorem states that an increase in the speed of the moving fluid is accompanied by a decrease in the fluids static pressure.

In other words, sum of the kinetic (velocity head), pressure (static head) and potential energy at any point in the flow remains constant provided that the flow is incompressible, steady, irrotational and frictionless.

* Images are taken from various web sources

What is Bernoulli's Theorem?



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What are Different Types of Pressure in a Fluid Flow?

➢ Static Pressure:

- Static pressure is the pressure felt at a point by virtue of the state of the fluid.
- In case of stationary fluid it is called hydrostatic pressure. In case of a flow, the static pressure measurement is taken perpendicular to the fluid flow direction or by moving with the fluid.

➢ Total or Stagnation Pressure

- If the fluid at a point is brought to rest with an isentropic and adiabatic process, the pressure rises until a maximum that is called the total pressure.

➢ Dynamic Pressure

- The dynamic pressure is the difference between the total and the static pressure.

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Pressure Measurement

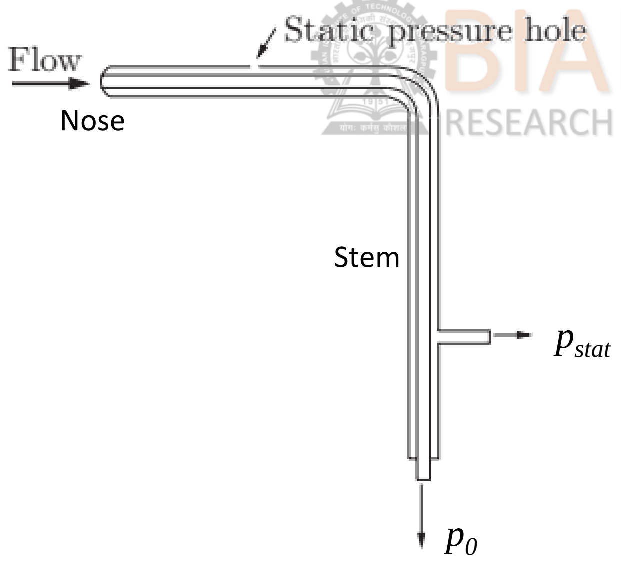
Pitot-Static Tube

- A pitot-static tube is used for measuring the total and static pressures simultaneously.

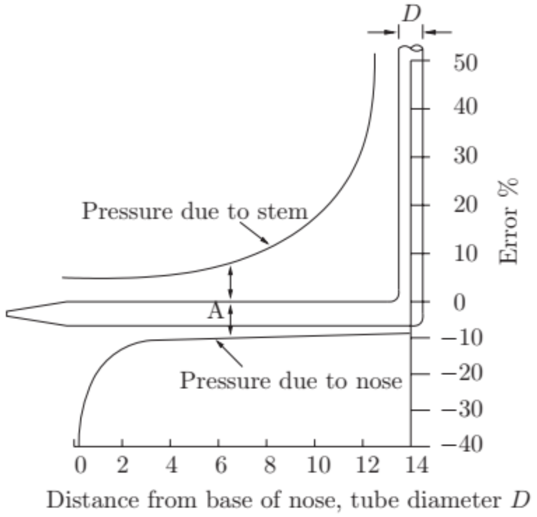
- It is usually a blunt-nosed tube with an opening at its nose to sense the total pressure and a set of holes on the surface of the tube to sense the static pressure.

- The accuracy in static pressure measurement using static tubes depends mainly on the position of the sensing holes with respect to the nose of a tube and its supporting stem.

- If the static pressure ports are close to nose or stem, acceleration effects caused by the nose tend to lower the static pressure; stagnation effects caused by the stem tend to raise the tap pressure. In a properly compensated tube, these two effects will just cancel at the plane of the pressure holes. Refer the figure.



Pitot-static probe



Pressures due to nose and stem of a static probe

* Images are taken from various web sources

Pressure Measurement

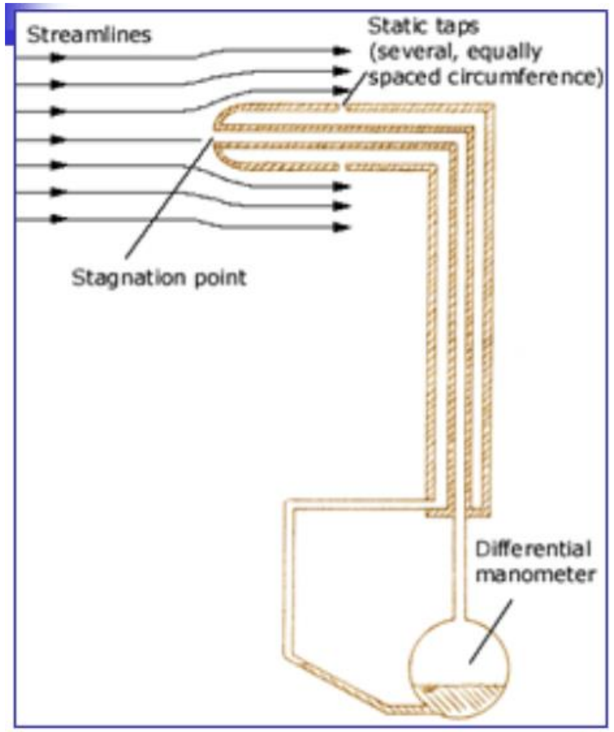
Pitot-Static Tube

Working Principle (Incompressible Flow)

- Pressure taps sensing static pressure (also the reference pressure for this measurement) are placed radially on the probe stem and then combined into one tube leading to the differential manometer (p_{stat}).

- The pressure tap located at the probe tip senses the stagnation pressure (p_0).

- Use of the two measured pressures in the Bernoulli equation allows to determine one component of the flow velocity at the probe location.



$$p_0 = p_{stat} + \frac{1}{2}\rho V^2, (Bernoulli)$$

$$V = \sqrt{2(p_0 - p_{stat})/\rho}$$

$$V = \sqrt{2(p_0 - p_{stat})/\rho}$$

P_0 = stagnation pressure
P_{stat} = static pressure

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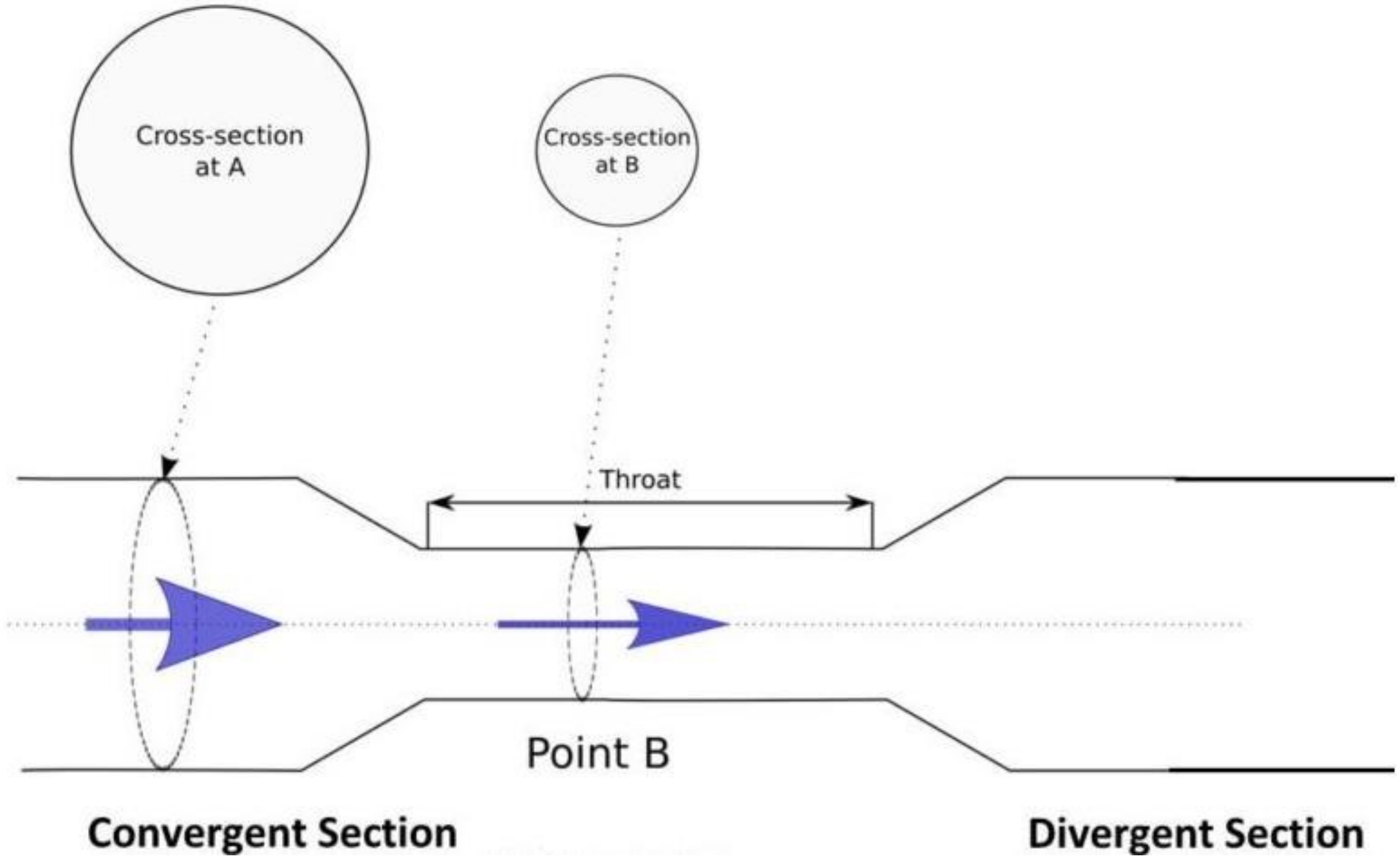
Verification of the Bernoulli's Theorem

Can we get velocity information without Bernoulli's Theorem?



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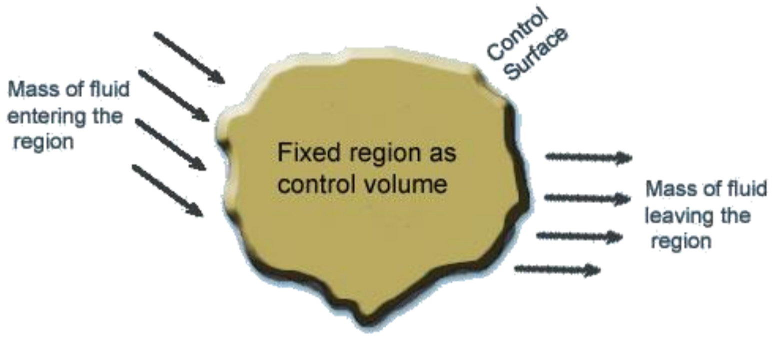
What is Continuity Equation?

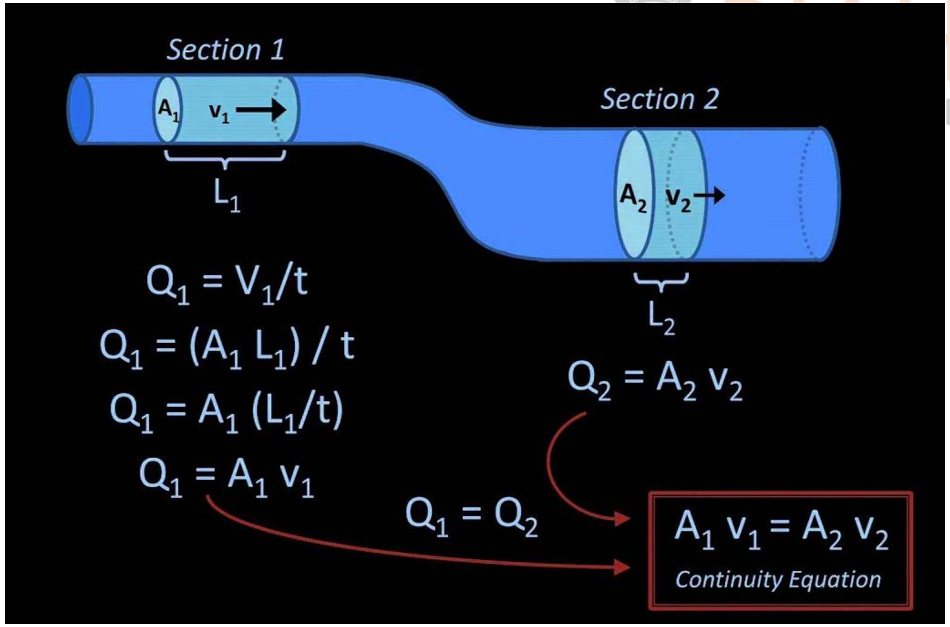
The continuity equation states the conservation mass in a fluid flow domain.

For a control volume, the principle of conservation of mass is stated as
Rate at which mass enters CV = Rate at which mass leaves the CV + Rate of accumulation of mass in the CV



A Control Volume in a Flow Field

For a steady and incompressible flow



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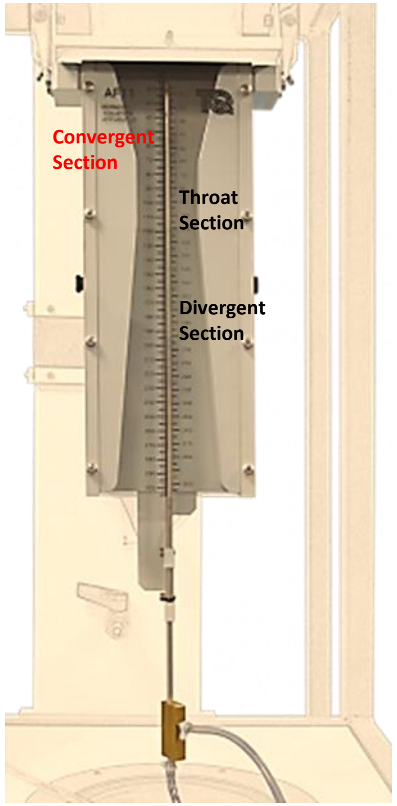
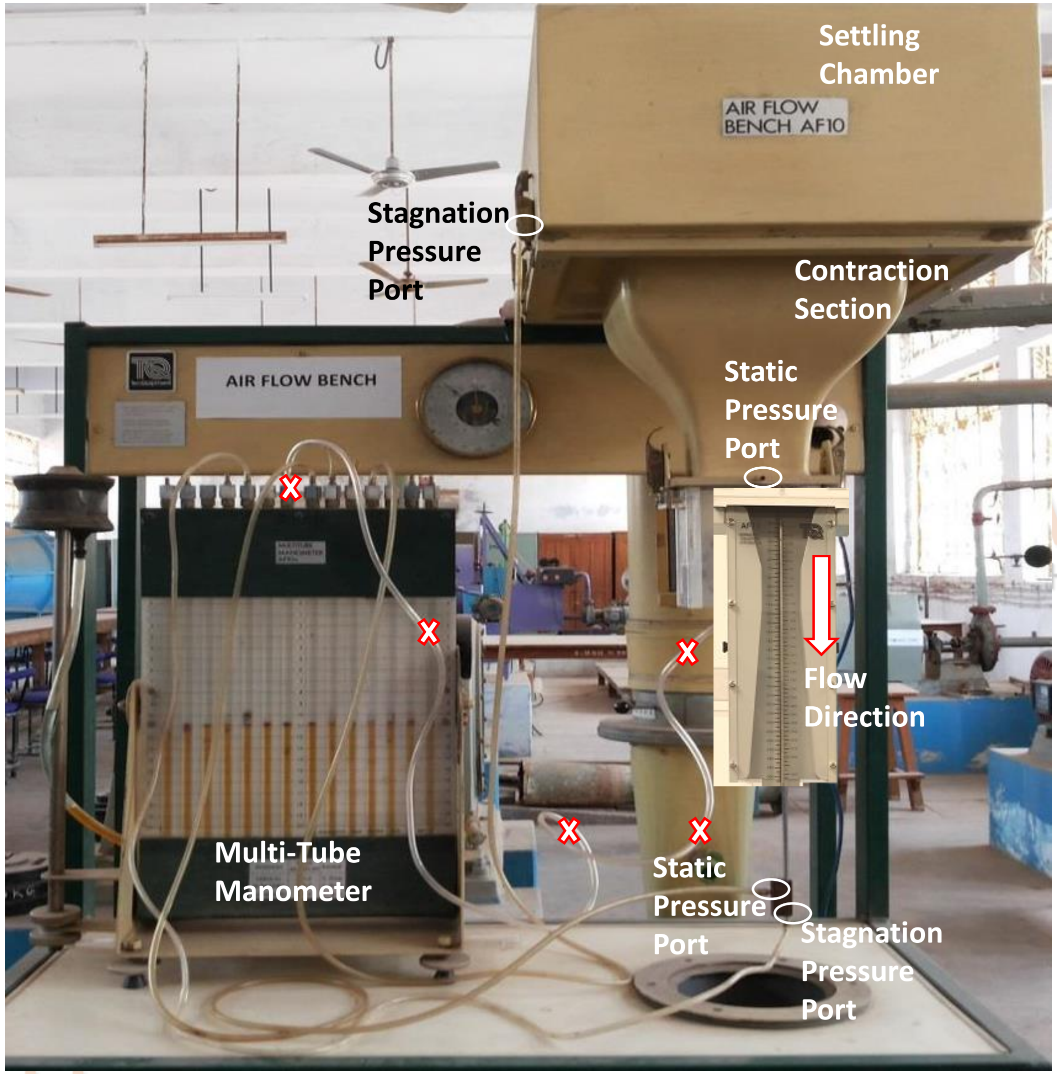
Report Format

1. Aim of the Experiments
2. Objectives
3. Experimental Procedure
4. Observations
5. Results and Discussion
6. Conclusions
7. Questionnaires
8. Ansys Fluent Simulations (optional)



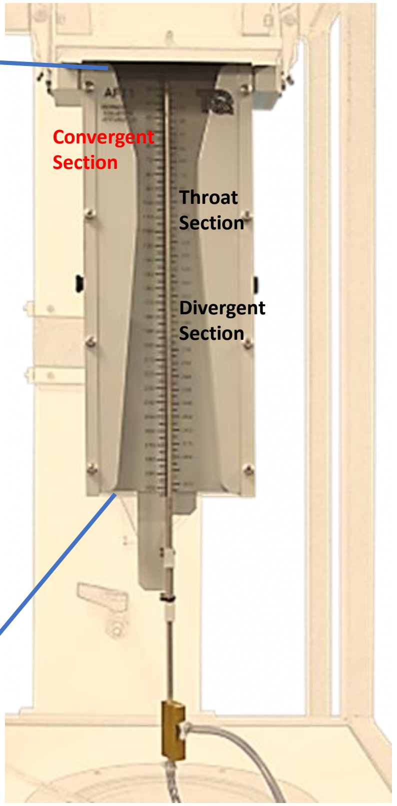
Venturi Test Section

Experimental Setup and Procedure



Airflow Bench

A (in cm^2) (cross sectional area)	Length (in cm)
37.25	0
35.00	1
33.00	2
31.00	3
28.00	4
26.00	5
24.00	6
21.00	7
21.00	8
21.00	9
21.00	10
21.00	11
21.00	12
22.00	13
23.00	14
24.00	15
25.00	16
26.00	17
27.00	18
27.50	19
28.00	20
29.00	21
30.00	22
31.00	23
32.00	24
32.50	25
33.00	26
34.00	27
35.00	28
36.00	29
37.00	30



Venturi Test Section

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Observation Table

Group - 1						
Global static pressure = 269 mm H_2O						
Global total pressure = 306 mm H_2O						
Global velocity = 24.9646 m/s						
Length (in cm)	**Total pressure (mm of water)**	**Static pressure (mm of water)**	**V_b (in m/s) From Bernoulli's equation**	**A (in cm^2) (cross sectional area)**	**V_c (in m/s) From the continuity equation**	**Error of V_c (in %)**
0	306	269		37.25		
1	306	260		35.00		
2	306	252		33.00		
3	306	242		31.00		
4	306	234		28.00		
5	306	220		26.00		
6	306	202		24.00		
7	306	190		21.00		
8	306	184		21.00		
9	306	182		21.00		
10	306	181		21.00		
11	306	180		21.00		
12	306	182		21.00		
13	306	186		22.00		
14	306	191		23.00		
15	306	198		24.00		
16	306	203		25.00		
17	306	208		26.00		
18	306	212		27.00		
19	306	216		27.50		
20	306	220		28.00		
21	306	224		29.00		
22	306	227		30.00		
23	306	230		31.00		
24	306	231		32.00		
25	306	233		32.50		
26	306	238		33.00		
27	306	240		34.00		
28	306	242		35.00		
29	306	243		36.00		
30	306	244		37.00		

Sample Calculation

Total pressure (P_T) = 306 mm of water = 0.306 m of water = $0.306 \times 9.81 \times 1000$ Pa = 3001.86 Pa

Static pressure (P_S) = 234 mm of water = 0.234 m of water = $0.234 \times 9.81 \times 1000$ Pa = 2295.54 Pa

Density of air (ρ) = 1.23 Kg/m^3

From Bernoulli's equation, $V_b^2 = 2 \times (P_T - P_S) / \rho$

$V_b^2 = 2 \times (3001.86 - 2295.54) / 1.23$

$V_b^2 = 1148.48$

Thus, $V_b = 33.89$ m/s.

From Continuity equation, $V_c = (A_0 \times V_0) / A_{4,cm}$

$V_c = (37.25 \times 24.29453) / 28$

So, $V_c = 32.32$ m/s.

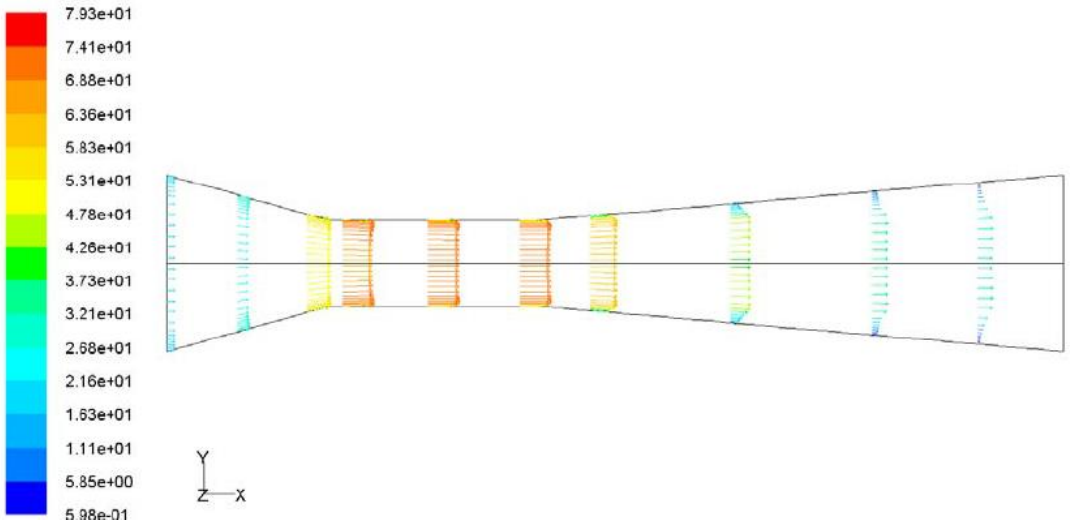
Error of V_b (in %) = $(V_b - V_c) \times 100 / V_c$

$= (33.89 - 32.32) \times 100 / 32.32$

$= 4.85.$

Plots to Include in the Report

1. Velocity vs Length (Both Bernoulli's and Continuity Equation)
2. Static Pressure vs Length
3. Total Pressure vs Length
4. Error vs Length
5. Comparison of experimental results with ANSYS Fluent Simulation (Optional)



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Questionnaire

1. Name four fluid flow types that do not follow Bernoulli's theorem?
2. Why the velocities obtained from continuity and Bernoulli's equation do not match on the venturi section in your experiment?
3. Is the flow incompressible in your experiment? How do you confirm this?

Thank you