ME301 FLUID MECHANICS I

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EXPERIMENT II: BERNOULLI'S THEOREM

A. Objective: To investigate the validity of Bernoulli's Theorem as applied to the flow of water in a tapering circular duct.

B. Theory: Considering flow at two sections in a pipe. Bernoulli's equation may be written as

$$\frac{V_1^2}{2g} + \frac{P_1}{\rho g} + z_1 = \frac{V_2^2}{2g} + \frac{P_2}{\rho g} + z_2$$

For this apparatus $z_1=z_2$ and $P = \rho g h$ so, one can write

$$\frac{V_1^2}{2g} + h_1 = \frac{V_2^2}{2g} + h_2$$

$\frac{V_1^2}{2g}$ is the velocity head

h_1 is the static head. H is the total head and can be defined as

$$H = \frac{V^2}{2g} + h$$

Hence, if Bernoulli's Theorem is obeyed, the total head is constant at all sections along the duct.

C. Equipment:

This experiment can be performed by using the service module and the Bernoulli apparatus in our laboratory

a) Hydraulic Bench Service Module

The Hydraulic Bench Service Module is shown in Figure 1. Parts of the Bench are numbered in this figure. Operation of the Hydraulic Bench is explained below; A self-priming centrifugal pump. 1N, draws water from sump tank, 1G, and delivers into a vertical transparent pipe, 1M. A panel mounted control valve, 1C, is used to regulate the flow in the pipe which terminates in a quick release pipe connector, 1 o, allows for rapid substitution of accessories which are supplied with a flexible supply tube terminating a mating connector. Special purpose terminations may be connected to the pump supply by unscrewing connector, lo.

Water discharging from the accessory on test is collected in a volumetric measuring tank, 1U. This tank is stepped to accommodate low or high flow rates and incorporates a stilling baffle, 1S, to reduce turbulence. A remote sight tube and scale, 1A, connected to a tapping, 1T, in the base of the volumetric tank and gives an instantaneous indication of water level,

A dump valve, 1V, in the base of the volumetric tank is operated by a remote actuator, 1E. Lifting the actuator opens the dump valve allowing the entrained water to return to the sump, 1G, for recycling.

b) <u>Bernoulli’s Theorem Demonstration Apparatus</u>

Bernoulli's Theorem Demonstration Apparatus is shown in Figure 2. Parts of the Apparatus are numbered in this figure. Operation of the Apparatus is explained below; The test section, 6A, is an accurately machined perspex duct of varying circular cross section provided with pressure tapings hereby the static pressures may be measured simultaneously at each of 6 sections. The test section in corporates unions,6C, at either end to facilitate reversal for convergent or divergent testing.

A hypodermic probe, 6F, is provided which may be positioned to read the total head at any section of the duct. The probe may be moved after slackening the gland nut, 6G; this nut should be re-tightened by hand. To prevent damage, the probe should be fully inserted during transport/storage. An additional tapping, 6L, is provided to facilitate setting up. All eight pressure tapings are connected to a bank of pressurized manometer tubes. Pressurization of the manometers is facilitated by removing the hand pump, 6M, from its storage location at the rear of the manometer board and connecting its flexible coupling to the inlet valve, 6E, on the manometer manifold.

In use, the apparatus, mounted on base board, 6I, is stood on the work surface of the bench and feet, 6H, adjusted to level the apparatus.

Inlet pipe, 6B, terminates in a female coupling which may be connected directly to the bench supply, lo. A flexible hose attached to the outlet pipe, 6J, is directed to the volumetric measuring tank, 1U.

A flow control valve, 6K, is incorporated downstream of the test section. Flow rate and pressure in the apparatus may be varied independently by adjustment of the flow control valve, 6K, and the bench supply control valve, 1C.

D. <u>Procedure:</u>

a) Connect the apparatus to the bench, having injected a small quantity of wetting agent into the test section. Ensure that the test section is oriented with the duct converging in the direction of flow. If it is necessary to reverse the test section, total head probe 6F should be withdrawn before releasing couplings 6C. The apparatus should be levelled by adjusting feet 6H.

b) Close control valve, 1C, and switch on the pump by operating the starter, ID. Open valve 6K slightly and then carefully open valve 1C to fill the apparatus manometer tubes with water. The manometer tubes should be allowed to fill to discharge all pockets of air from the system. Ensure that all connecting pipes are free from air. Manometer bank 6D is fitted with a Schrader valve, 6E, to enable levels to be raised or lowered as required. In the latter case, hand pump 6M is connected to the valve to raise the air pressure above the liquid columns.

c) Carefully open the two valves and adjust them to provide that combination of flow rate and system pressure which will give the largest convenient difference between the highest and lowest manometer levels. Note the scale reading of each manometer level. Take at least three sets of readings of volume and time to find the flow rate using volumetric tank, 1V.

d)Insert the total head probe as far as the end of the parallel portion of the duct and then advance it into the tapered portion 1cm at a time. For each position of the probe tip, note the distance from the end of the parallel portion and record the scale reading of its manometer level.

e)Repeat c and d for different combinations of valve openings to give high and low flow rates at both high and low static pressures.

f) Close the valve, 1C, allow the apparatus to drain, and withdraw the total head probe, 6F, to the end of its travel. Undo the couplings, 6C, reverse the test section, 6A, and replace the couplings.

Repeat b, c, d and e.

E. Pre-lab:

After reviewing the laboratory description and procedure, develop a data sheet on which record the required data. Bring this data table to the lab when you perform this experiment.

F. Data Analysis and Reporting Requirements:

Set out, in tabular form where appropriate, all the readings from the above procedures.
Calculations: For each of the valve settings, determine the fluid velocity at each tapping position from the volume flow rate and duct cross section.

Hence, determine the theoretical velocity head at each tapping position.
Add the theoretical velocity head to the measured static head to determine a theoretical total head.
Do these computed heads agree with the readings from the total head probe? If they differ, what reasons are there for this difference?

Comment on the validity of Bernoulli's equation for the system tested for

a) Convergent flow
b) Divergent flow

G. Pre-lab Questions:

1. What's Bernoulli's equation?
2. How can you measure and calculate the head loss?
3. How does the pitot tube work?

Reference

Fox, R.W. and McDonald, A.T., Introduction to Fluid Mechanics, Fourth Edition, John Wiley and Sons, 1994.

	a	b	c	d	e	f	Measured Total Head
Diameter (mm)	10.0	10.6	11.3	12.4	14.6	25	
Static head (mmSS)							
Area (mm^2)							
Velocity (mm/s)							
Velocity head (mmSS)							
Theoretical Total Head (mmSS)							

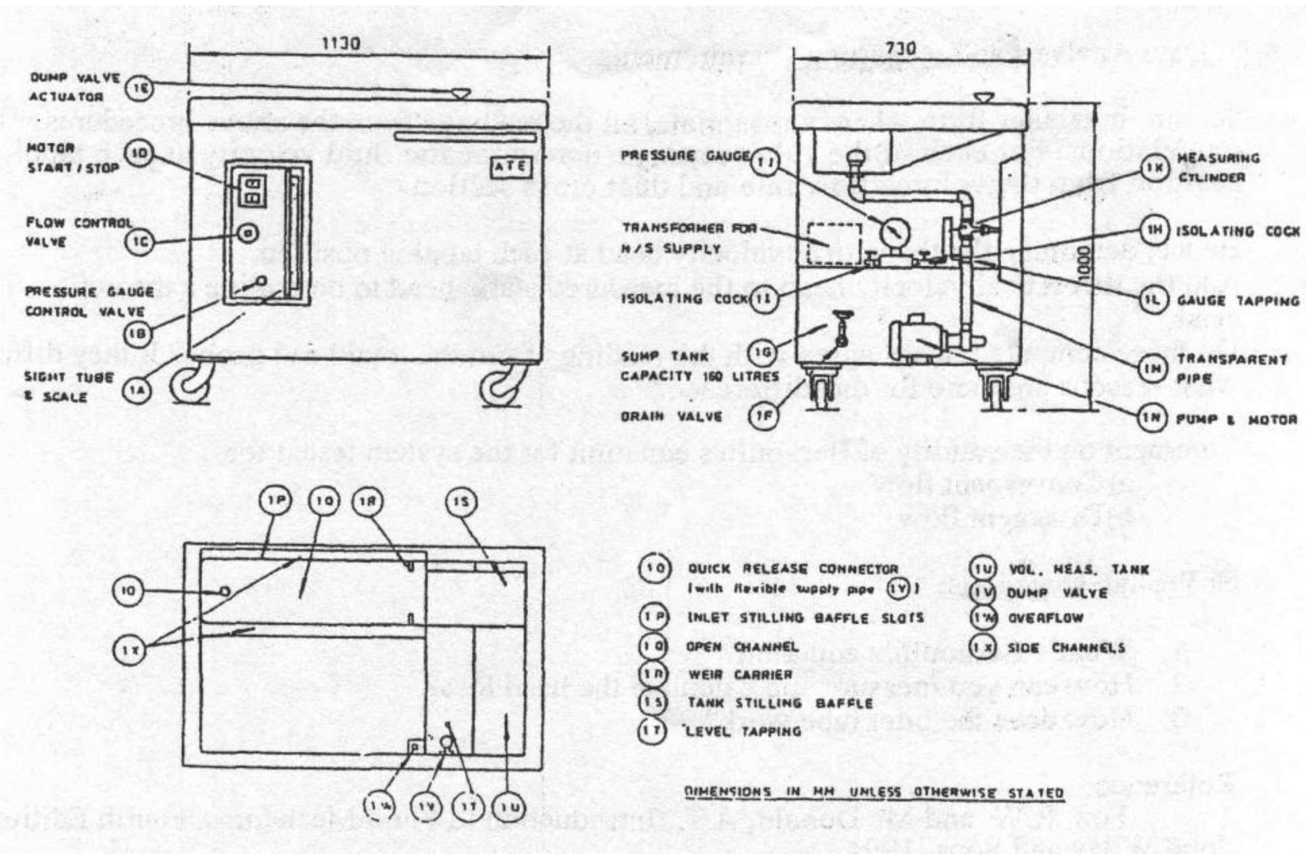

Fig. 1. Installation drawing for hydraulics bench service module.

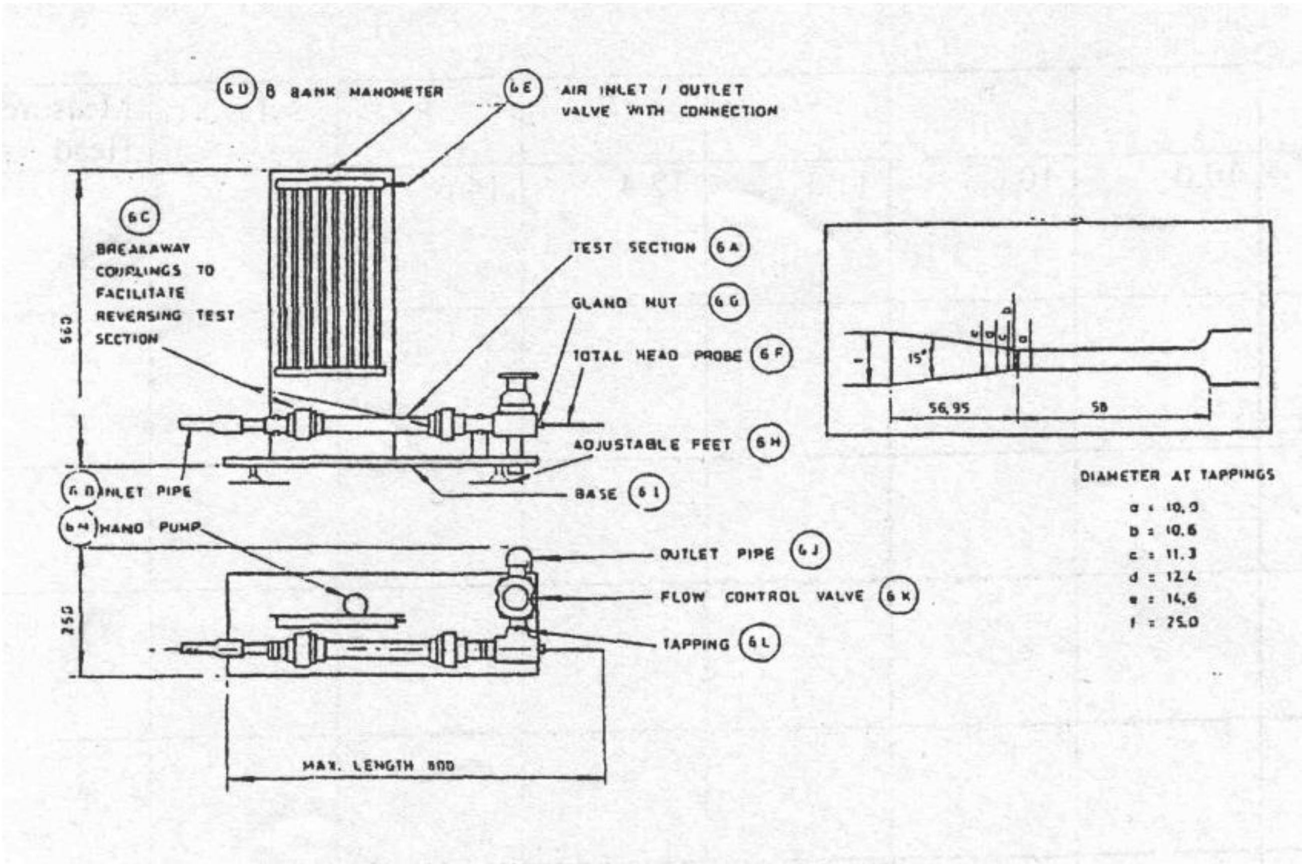

Fig. 2. Installation drawing for Bernoulli apparatus
Instruction: Insert probe 6F fully when not in use to prevent damage.