Old Dominion University
Mechanical Engineering Technology

MET 335 – Fluid Mechanics Laboratory

Title: Venturi Discharge Coefficient (Rev. February 2024, NJL)

Purpose: To determine the venturi discharge coefficient

Apparatus Description

The apparatus is the TecQuipment Venturi meter. This clear venturi has eleven pitot static tubes attached along its length which measure the pressure head at each location. See figures 2 and 3 for details.

The venturi is located on a flow measuring tank assembly. The assembly has a pump which takes water from a sump, pushes it through an upstream control value, through the venturi meter, and through a downstream control valve into a volume measuring tank, which then discharges to the sump.

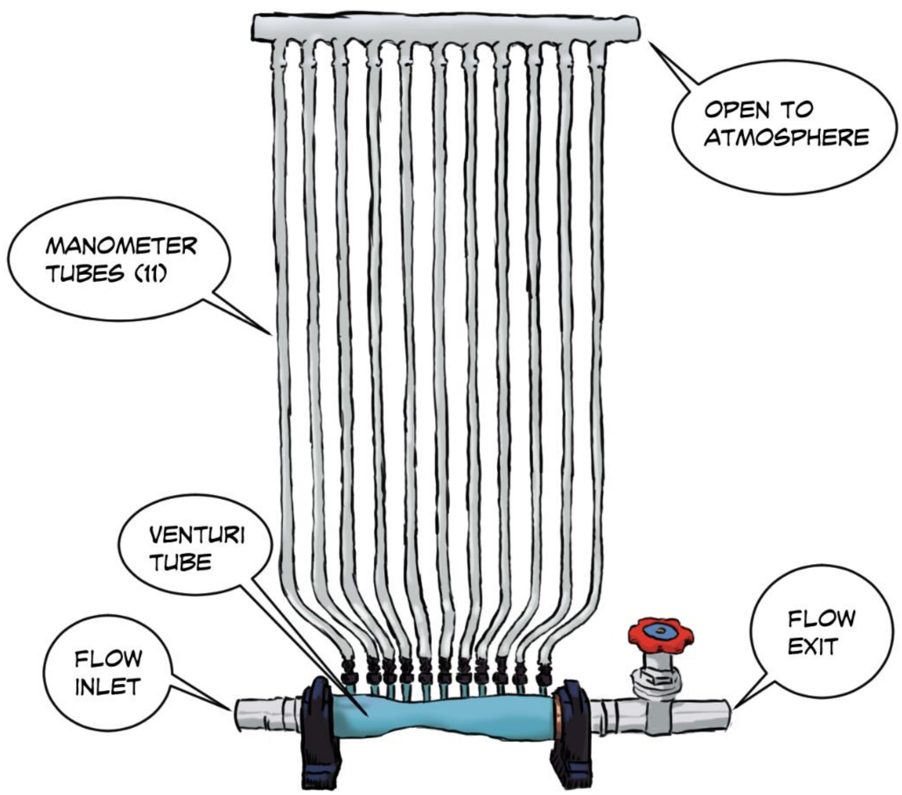

Figure 1 Venturi Meter Experimental Setup

Nomenclature

Symbol	Definition
A	Area
C_V	Discharge Coefficient
D	Diameter
g	Gravity
N_R	Reynolds Number
$\frac{P}{\gamma}$	Pressure Head
Q	Actual Volumetric Flow Rate
$Q_{\max}$	Theoretical Volumetric Flow Rate
t	Time
Symbol	**Definition**
V	Velocity
$\forall$	Volume
ρ	Density
μ	Dynamic Viscosity

Subscript	Definition
A	Inlet pitot static tube location
D	Throat pitot static tube location

Theory

The discharge coefficient is a crucial parameter used to measure the flow rate of fluids in a Venturi meter. It is a dimensionless factor that relates the actual flow rate of a fluid to the theoretical flow rate.

A venturi meter is a differential flowmeter that measures the fluid flow rate in a pipe. Compared to other differential flowmeters, it causes very low head losses, making it ideal for applications that cannot allow large pressure drops and require high accuracy. Examples of such applications include oil and gas pipelines, chemical processing plants, and water treatment plants.

A venturi meter consists of a converging section, a throat, and a diverging section, as shown in Figure 2 below.

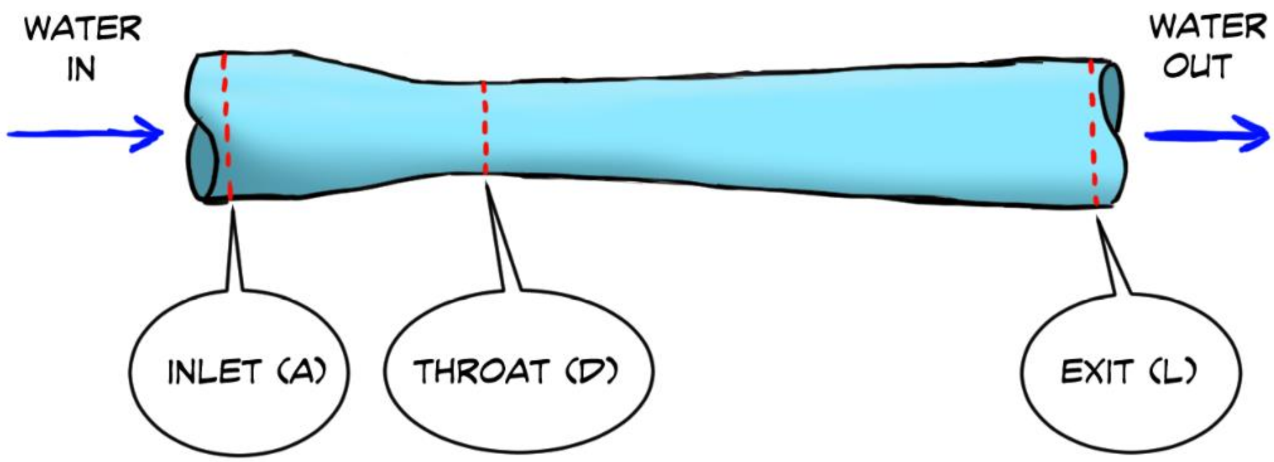

Figure 2 Venturi Meter

In the convergent section, fluid velocity increases as it narrows down. Upon reaching the throat, the fluid achieves its maximum velocity, and the pressure becomes minimal.

Moving on to the divergent section, the fluid restores its pressure energy by slowing down in velocity. The recompression leads to an increase in fluid pressure. Between the inlet and throat, there is a significant pressure drop. This pressure drop can be used to calculate the flow rate.

The key principle behind the venturi meter is Bernoulli's equation, which relates the pressure, velocity, and elevation in a steady, incompressible fluid flow. The Bernoulli equation calculates the theoretical (maximum) flow rate based on these parameters:

$$Q_{\max} = A_D \sqrt{\frac{2g\left(\frac{P_A}{\gamma} - \frac{P_D}{\gamma}\right)}{1-\left(\frac{D_D}{D_A}\right)^4}}$$

Because Bernoulli’s equation does not account for energy losses in the venturi, the actual flow rate will be less than the theoretical flow rate, and this is where the discharge coefficient comes into play. By multiplying the theoretical flow rate by the discharge coefficient, you can obtain a more accurate estimate of the actual flow rate. The formula for the actual volumetric flow rate across a venturi meter then becomes:

$$Q = C_V Q_{\max}$$

The discharge coefficient is a dimensionless parameter that represents the ratio of the actual flow rate through a venturi meter to the theoretical flow rate:

$$C_V = \frac{Q}{Q_{\max}}$$

Its value accounts for the losses due to friction, wall roughness, pipe geometry, and other factors that affect the flow. Its value ranges between 0 and 1, with 1 indicating a perfect match between theoretical (maximum) and actual flow rates.

The theoretical (maximum) flow rate is calculated using bernoullis equaion, while the actual flow rate is determined using a flow-measuring tank assembly and the following equation:

$$Q = \frac{\forall}{\Delta t} = \frac{Volume\ of\ Water\ Collected}{Recorded\ Flow\ Time}$$

The value of a venturi meter’s discharge coefficient is primarily dependent on two factors: the Reynolds number and the ratio between the throat diameter and inlet diameter. Reynolds number is a dimensionless quantity that helps predict flow patterns in different situations by measuring the ratio between inertial and viscous forces:

$$N_R = \frac{\rho V D}{\mu}$$

In general, the higher the Reynolds number the higher the discharge coefficient.

	DIAMETER (MM)
A	26.0
B	23.20
C	18.40
D	16.00
E	16.80
F	18.47
G	20.16
H	21.84
J	23.53
K	25.24
L	26.00

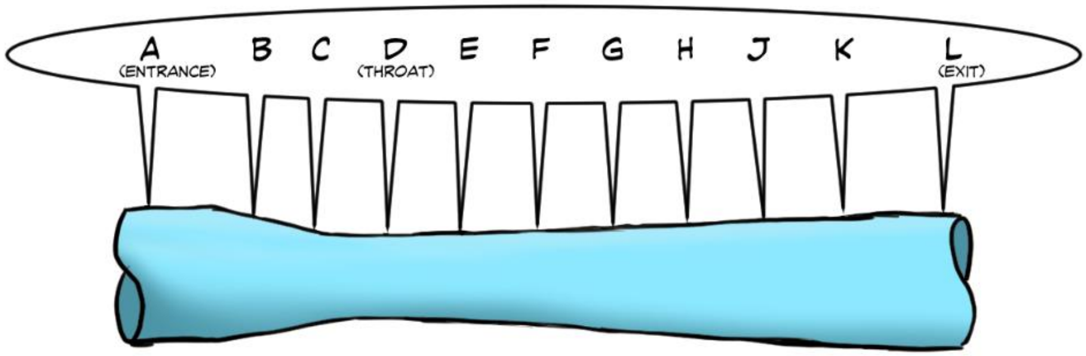

Figure 3 Venturi Meter Dimensions

Experimental Procedure:

1. Set the flow through the venturi at the maximum allowed by the pitot static tube scales, $\frac{P_A}{\gamma} \cong 250mm$ $\frac{P_D}{\gamma} \cong 0mm$ This will require adjusting the upstream and downstream valves

2. Record the pressure head at inlet $\left(\frac{P_A}{\gamma}\right)$ and the throat $\left(\frac{P_D}{\gamma}\right)$.

3. Measure and record the flow rate by timing a specified volume as instructed.

4. Set the flow through the venturi for the next flow setting: Reduce $\frac{P_A}{\gamma}$ by 10% and $\frac{P_D}{\gamma} \cong 0mm$

5. Record the pressure head at inlet and the throat.

6. Measure and record the flow rate by timing a specified volume as instructed.

7. Repeat steps 4 – 6 for a total of 10 flow settings.

Raw Data Sheet

Volume of Water Collected ______

Flow setting	Recorded Flow Time	Pressure Head at Inlet $\left(\frac{P_A}{\gamma}\right)$	Pressure Head at Throat $\left(\frac{P_D}{\gamma}\right)$
1 (maximum)			
2			
3			
4			
5			
6			
7			
8			
9			
10 (minimum)			

Report Requirements

Submit a complete and professional looking laboratory report. Refer to module 1 for report writing tips.

1. Calculate the theoretical (maximum) volumetric flow rate of water for each flow setting.

2. Calculate the actual volumetric flow rate of water for each flow setting.

3. Calculate the discharge coefficient and inlet Reynolds number for each flow rate.

4. Tabulate the discharge coefficient and inlet Reynolds number versus actual flow rate.

5. Plot the discharge coefficient (ordinate) versus inlet Reynold's number (abscissa).

6. Thoroughly discuss your results.