



## EXPERIMENT OF FLOW MEASUREMENT METHODS

### 1. OBJECT

The purpose of this experiment is to study some of the famous instruments used in flow measurements. Calculate the coefficient of discharge from experimental data for a venturi meter. Determine the relationship between Reynolds number and the coefficient of discharge.

### 2. INTRODUCTION

The orifice meter, the nozzle meter, and the Venturi meter are the most common devices used to measure the instantaneous flowrate. Each of these meters operates on the similar principle. As the flow area in a pipe decreases, the flow velocity that is accompanied by a decrease in pressure increases in a pipe.

The correlation of pressure difference with the velocity is used to determine for measuring the flow rate in a pipe. Bernoulli equation between points (1) and (2) shown in Fig. 1 is applied by assuming no viscous effects and horizontal flow. The following relation are obtained.

$$Q_{\text{ideal}} = A_2 V_2 = A_2 \sqrt{\frac{2(p_1 - p_2)}{\rho(1 - \beta^4)}} \quad (1)$$

where  $\beta = d/D$ .

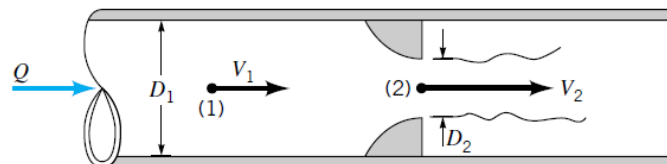


Figure 1: Typical pipe flow meter geometry.

### 3. THEORY

**Venturi meter:** The third and final type of obstruction meter is the venturi, named in honor of Giovanni Venturi (1746–1822), an Italian physicist who first tested conical expansions and contractions. The original, or classical, venturi was invented by a U.S. engineer, Clemens Herschel, in 1898. It consisted of a 21° conical contraction, a straight throat of diameter  $d$  and length  $d$ , then a 7 to 15° conical expansion. The discharge coefficient is near unity, and the nonrecoverable loss is very small. Herschel venturis are seldom used now.

The modern venturi nozzle, Fig. 2, consists of an ISA 1932 nozzle entrance and a conical expansion of half-angle no greater than 15°. It is intended to be operated in a narrow Reynolds-number range of  $1.5 \times 10^5$  to  $2 \times 10^6$ . Its discharge coefficient, shown in Fig. 4, is given by the ISO correlation formula:

$$C_d \approx 0,9858 - 0,196\beta^{4,5} \quad (2)$$

where  $\beta = d/D$ .

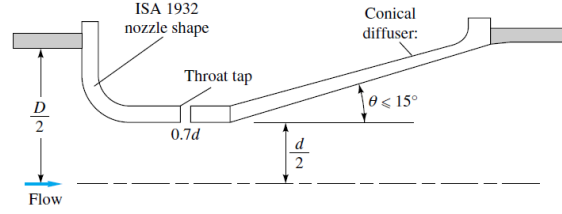


Figure 2: International standard shapes for venturi nozzle

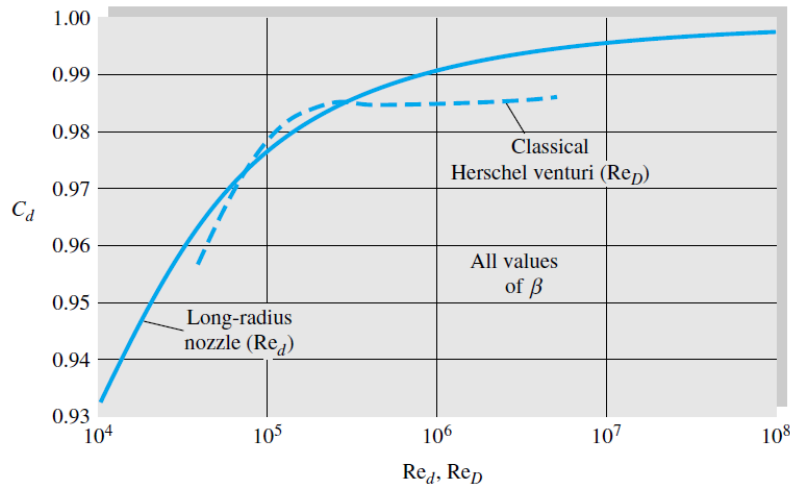


Figure 3: Discharge coefficient for long-radius nozzle and classical Herschel-type venturi

It is independent of  $Re_D$  within the given range. The Herschel venturi discharge varies with  $Re_D$  but not with  $\beta$ , as shown in Fig. 3. Both have very low net losses. The choice of meter depends upon the loss and the cost and can be illustrated by the following table:

| Type of meter | Net head loss | Cost   |
|---------------|---------------|--------|
| Orifice       | Large         | Small  |
| Nozzle        | Medium        | Medium |
| Venturi       | Small         | Large  |

As so often happens, the product of inefficiency and initial cost is approximately constant.

The application of Bernoulli theorem gives the following relation that can be applied to the Venturi meter as well as to the calibrated diaphragm:

$$Q = \frac{C_d A_2}{\sqrt{1-\beta^2}} \sqrt{2g\Delta h} \quad (3)$$

where

$C_d$  = coefficient of discharge  
 $\beta = A_2/A_1$

$A_1$  = pipe section  
 $A_2$  = restriction section  
 $\Delta h$  = head loss in m

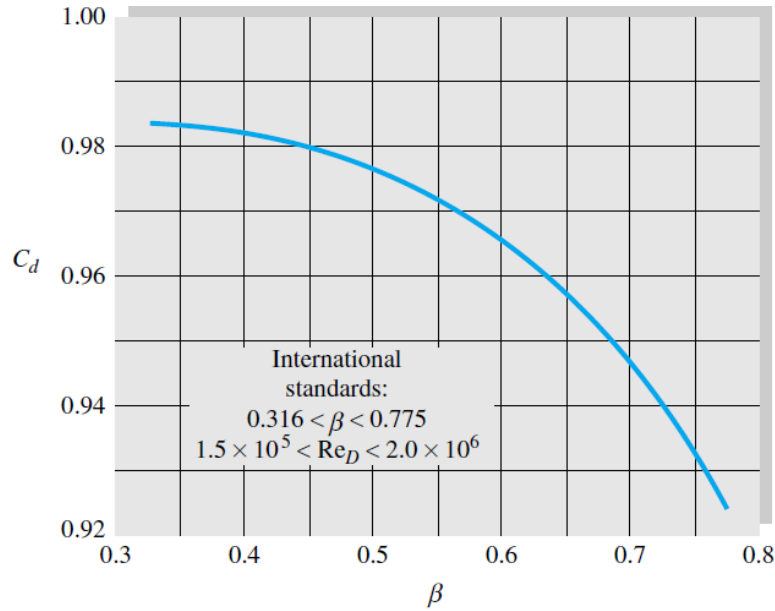


Figure. 4: Discharge coefficient for a venturi nozzle.

The average nonrecoverable head losses for the three types of meters, expressed as a fraction of the throat velocity head  $V_t^2 / (2g)$ , are shown in Fig. 4. The orifice has the greatest loss and the venturi the least.

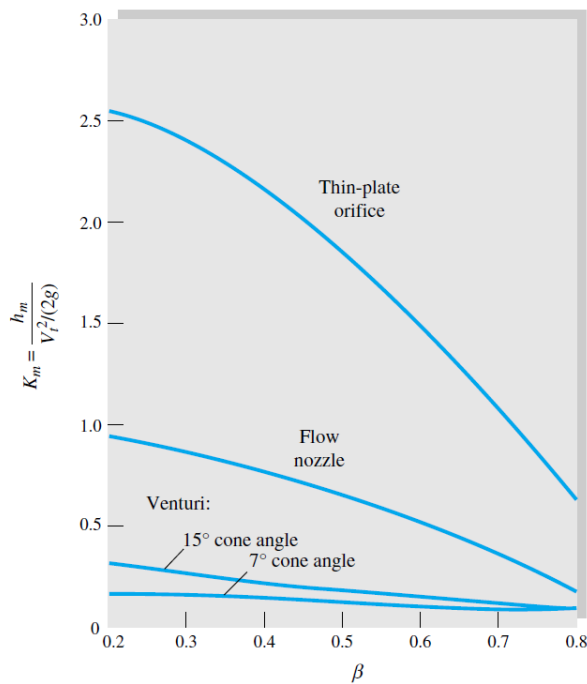


Figure. 4: Nonrecoverable head loss in Bernoulli obstruction meters.



**Rotameter:** The variable-area transparent rotameter of Fig. 5 has a float which, under the action of flow, rises in the vertical tapered tube and takes a certain equilibrium position for any given flow rate. The Rotameter reads the flow rate directly. Capacity may be changed by using different-sized floats. Obviously the tube must be vertical, and the device does not give accurate readings for fluids containing high concentrations of bubbles or particles.

The fluid entering from the lower part, operates a pressure the float depending on the shape and speed of the fluid in the circular crown between the pipe and the same float. The pressure drops when the section of the circular crown remaining free increases and a balance is reached depending on the speed of the fluid, the mass of the float and its shape.

In balance conditions, the flow rate is expressed by the following formula:

$$Q = C_d(A_t - A_f) \sqrt{\frac{2V_f(\rho_f - \rho)}{A_f \rho}} \quad (4)$$

where

$C_d$  = coefficient of efflux

$A_t$  = pipe section

$A_f$  = maximum section of the float

$V_f$  = Volume of the float

$\rho_f$  = density of the float

$\rho$  = density of fluid



Figure. 5: A commercial rotameter



#### 4. EXPERIMENTS TO BE PERFORMED

The test unit will be introduced in the laboratory before the experiment by the relevant assistant.

##### 4.1 Calculation of the coefficient of efflux of the calibrated diaphragm

###### Aim of the Experiment:

- To find out the relationship between the flow rate and the load loss
- To find the coefficient of efflux

The necessary data for calculations will be recorded to the table given below

| $Q_{rot}$ | $Q_{vol}$ | $H_1$ | $H_2$ | $\sqrt{\Delta H_{1,2}}$ | $H_3$ | $H_4$ | $\sqrt{\Delta H_{3,4}}$ | $H_5$ | $H_6$ | $\sqrt{\Delta H_{5,6}}$ |
|-----------|-----------|-------|-------|-------------------------|-------|-------|-------------------------|-------|-------|-------------------------|
|           |           |       |       |                         |       |       |                         |       |       |                         |
|           |           |       |       |                         |       |       |                         |       |       |                         |
|           |           |       |       |                         |       |       |                         |       |       |                         |
|           |           |       |       |                         |       |       |                         |       |       |                         |

**Calculations:** Using the equation given below, calculate the coefficient of efflux.

The flow rate is defined as:

$$Q = \frac{C_d A_2}{\sqrt{1 - \beta^4}} \sqrt{2g\Delta h} = \left[ \frac{C_d A_2}{\sqrt{1 - \beta^4}} \sqrt{2g} \right] \sqrt{\Delta h}$$

Where:

$C_d$  = coefficient of discharge

$\beta$  =  $d/D$

$A_1$  = pipe section

$A_2$  = restriction section

$\Delta h$  = load loss in m

- Draw a relationship between the flow rate in y – axis and the load loss in x – axis
- Carry out a linear interpolation and find the coefficient of efflux from the angular coefficient value of the obtained line.



## 4.2 Calculation of the coefficient of efflux of the venturi meter

### Aim of the Experiment:

- To find out the relationship between the flow rate and the square root of the load loss
- To find the coefficient of efflux

The necessary data for calculations will be recorded to the table given below.

| Q <sub>rot</sub> | Q <sub>vol</sub> | H <sub>1</sub> | H <sub>2</sub> | $\sqrt{\Delta H_{1,2}}$ | H <sub>3</sub> | H <sub>4</sub> | $\sqrt{\Delta H_{3,4}}$ | H <sub>5</sub> | H <sub>6</sub> | $\sqrt{\Delta H_{5,6}}$ |
|------------------|------------------|----------------|----------------|-------------------------|----------------|----------------|-------------------------|----------------|----------------|-------------------------|
|                  |                  |                |                |                         |                |                |                         |                |                |                         |
|                  |                  |                |                |                         |                |                |                         |                |                |                         |
|                  |                  |                |                |                         |                |                |                         |                |                |                         |
|                  |                  |                |                |                         |                |                |                         |                |                |                         |

**Calculations:** Using the equation given below, calculate the coefficient of efflux.

The flow rate is defined as:

$$Q = \frac{C_d A_2}{\sqrt{1 - \beta^4}} \sqrt{2g\Delta h} = \left[ \frac{C_d A_2}{\sqrt{1 - \beta^4}} \sqrt{2g} \right] \sqrt{\Delta h}$$

Where:

$C_d$  = coefficient of discharge

$\beta$  =  $d/D$

$A_1$  = pipe section

$A_2$  = restriction section

$\Delta h$  = load loss in m

- Draw a relationship between the flow rate in y – axis and the square root of the load loss in x – axis
- The slope of the best line is :

$$\text{Slope} = C_d A_2 \sqrt{\frac{2g}{1 - \left(\frac{A_2}{A_1}\right)^2}}$$

- Then , Calculate  $C_d$



### 4.3 Calibration of the variable area flowmeter

- Fill a graph with the measured flowrate with the rotameter against the one obtain using the volumetric tank.
- Carry out a linear interpolation; the obtained straight line represents the calibration line of the flow meter

|                              |  |  |  |  |  |  |  |
|------------------------------|--|--|--|--|--|--|--|
| <b>Q<sub>rot</sub> (l/h)</b> |  |  |  |  |  |  |  |
| <b>V (l)</b>                 |  |  |  |  |  |  |  |
| <b>T (sec)</b>               |  |  |  |  |  |  |  |
| <b>Q<sub>vol</sub> (l/h)</b> |  |  |  |  |  |  |  |

### 4.4 Measurement methods comprosion

- Using the coefficients of efflux determined in the exercises 4.1 and 4.2, carry out a series of measurements and calculate the measuremts error fort he flow meters.

### 4.5 Comparing the load losses

- Using the data obtained, draw a graph with the load loss as fuction of the flow for three flow meters.

| Volume (l) | Time (sec) | Q (l/h) | Q <sub>ROT</sub> (l/h) | H <sub>1</sub> (m) | H <sub>2</sub> (m) | H <sub>3</sub> (m) | H <sub>4</sub> (m) | H <sub>5</sub> (m) | H <sub>6</sub> (m) |
|------------|------------|---------|------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
|            |            |         |                        |                    |                    |                    |                    |                    |                    |
|            |            |         |                        |                    |                    |                    |                    |                    |                    |
|            |            |         |                        |                    |                    |                    |                    |                    |                    |
|            |            |         |                        |                    |                    |                    |                    |                    |                    |



## **5. REPORT**

In your laboratory reports must have the followings;

- a) Cover
- b) A short introduction
- c) All the necessary calculations using measured data.
- d) Discussion of your results and a conclusion.

## **6. REFERENCES**

Frank M. White, “Fluid Mechanics”, McGraw-Hill, New York.

H. S. Bean (ed.), “Fluid Meters: Their Theory and Application, 6th ed.”, American Society of Mechanical Engineers, New York

Philip J. Pritchard, “Fox and McDonald’s introduction to fluid mechanics 8th ed.”, John Wiley & Sons, Inc., United States of America

Bruce R. Munson, “Fundamentals of Fluid Mechanics”, John Wiley & Sons, Inc., the United States of America