Flow Measurements

Objectives

1. The students can measure flow rates of the fluids by Orifice measurement, Venturi measurement, Pitot tube measurement, Rotameter and Hydraulic bench.
2. The students can determine the values of Discharge Coefficient of Orifice Measurement, Venturi Measurement, Pitot-Static Measurement and Rotameter.

Introduction

Flow measurements become a significant subject of fluid mechanic in engineering for two main reasons. The first reason is that fluid measurement is utilized in many daily life applications. Some applications are daily and practically used. Sufficient understanding of the principles can help to use the instruments properly. The second reason is providing the student skill of measuring fluid velocity. The fluid velocity is very dominant variables in fluid mechanics and applied thermodynamic. These subjects are the main courses in mechanical engineering.

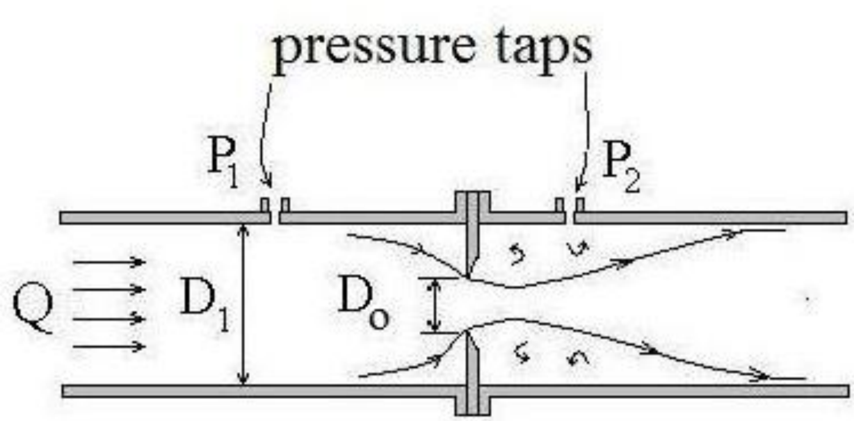
Flow measurements are easily found in daily life. When people go to Oil Station, they find fuel dispenser with some instruments for measuring the fuel that people buy. People can also find the flow measurement on their water tap meter that counts how much water that they consume. Such instrument also can be easily found in chemical industries, power plants, food - beverage industries, and any others. Some measurement principles are applied in analytical instruments. It sounds that flow measurement is very important in current life.

Currently, there are some basic principles of flow measurement. They are weir-notch measurement, direct measuring flow meter, pressure difference flow meters, positive displacement flow meter, variable area flow meters, electromagnetic flow meter, ultrasonic flow meter, and Coriolis flow meter. Every method has its own advantage and disadvantage. It also appropriates for specific application that should consider type of flow, range of flow, accuracy, and some other aspects. Apart of the first method that is suitable for open channel flow measurement, the other methods are applicable for in pipe flows. It means that understanding of the pros and contras of every instrument is important.

Figure 1. Some flow measurement instruments that we daily find (oil dispenser, water meter, pitot of the aircraft, single direction digital turbine flow-meter)

Orifice Meter

Orifice measurement is based on Bernoulli's equation. It is based on pressure difference of the flow before the orifice and the flow after the orifice (especially on vena contracta). Due to friction effect, the actual velocity of the fluid flow doesn't exactly equal to theory that is derived from Bernoulli's equation. There is a coefficient that is called discharge coefficient. The discharge coefficient tells about the friction correction of the measurement to the Bernoulli's ideal condition.



(http://www.engineeringexcelspreadsheets.com/wp-content/uploads/2011/09/Orifice-Meter-Parameters.jpg)

Figure 2. Orifice meter diagram. Measurement should be done in fully developed flow.

The velocity of the fluid flow on the vena contracta is defined by Eq. (1).

$$V_2 = \frac{1}{\sqrt{1-\left(\frac{D_2}{D_1}\right)^4}}\sqrt{2g\Delta h} \tag{1}$$

The actual flow rate is determined by Eg. (2).

$$Q_{act} = \frac{C_O A_O}{\sqrt{1-\left(\frac{D_O}{D_1}\right)^4}}\sqrt{2g\Delta h} \tag{2}$$

where :

Q_{act} = actual flow rate

C_O = coefficient of discharge for orifice

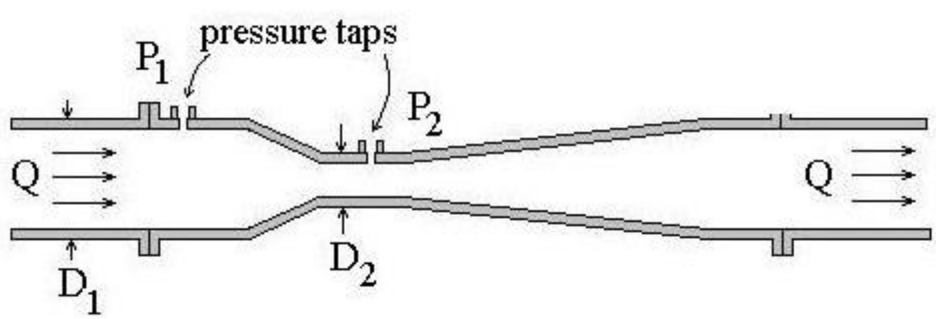
A_O = cross section area of the orifice

D_1 = pipe diameter, (29 mm)

D_O = orifice diameter, (20 mm)

Δh = difference in pressure head

Venturi Meter



(http://img.bhs4.com/a0/d/a0d93423fff524d13dd4bc1c20adf37327b0de95_large.jpg)

Figure 3. Venturi meter diagram

The venturi meter also exploits pressure difference between flow at inlet and flow at throat by applying the Bernoulli's equation. In this equipment, the flow rate is defined by Eq. (3).

$$Q_{act} = \frac{C_V A_2}{\sqrt{1-\left(\frac{D_2}{D_1}\right)^4}} \sqrt{2g\Delta h} \qquad (3)$$

where :

Q_{act} = actual flow rate

C_V = coefficient of discharge for venturi

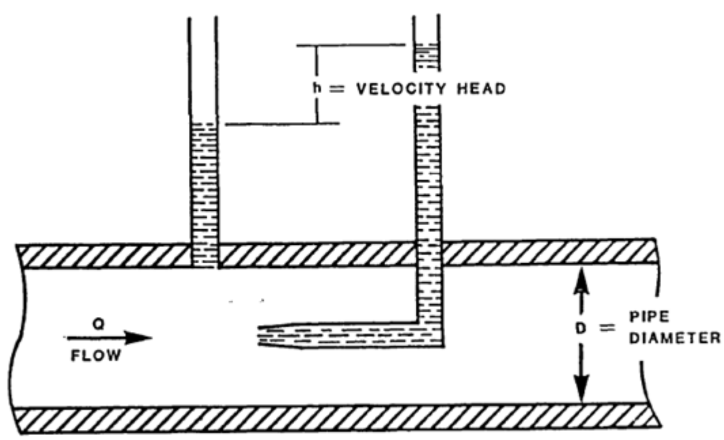
A_2 = cross section area of the throat

D_1 = pipe diameter, (29 mm)

D_2 = throat diameter, (17 mm)

Δh = difference in pressure head

Pitot Tube



(protorit.blogspot.com)

Figure 4. Pitot tube diagram. The stagnation point is on the tip of the tube.

Pitot Tube is a kind of flow meter instrument that applies the pressure difference of the stagnation point and another place on fluid flow. In this case, the velocity of fluid flowing on the stagnation point is assumed as zero. The equation to calculate the actual flow rate of flowing liquid is

$$Q_{act} = C_P A_1 \sqrt{2g\Delta h} \tag{4}$$

where :

Q_{act} = actual flow rate

C_P = coefficient of discharge for pitot tube

A_1 = cross section area of the pipe (D1=19 mm)

Δh = difference in pressure head

Rotameter

This kind of flowing instrument is applying the force balance on the floater for measuring the flow rate. The equation for determining the velocity of the fluid is provided at Eq. (5).

$$V_f = \frac{\sqrt{2V_{floater}g(\rho_{floater}-\rho_f)}}{C_D A_{floater}\rho_{floater}} \tag{5}$$

where :

V_f = velocity of the fluid flow

$V_{floater}$ = volume of the floater

C_D = coefficient of the discharge

$A_{floater}$ = Cross section area of the floater

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

Experiment Design

To achieve the objectives, the experiment is designed to have 2 main parts. These parts are calibration process and measurement using orifice, venturi and pitot tube. The tables that student has to complete represent this approach. At the calibration, the students learn how to use Hydraulic Bench for calibrating orifice, venturi and pitot tube. The student will use rotameter as the instrument for approximating the specific flow rates. Then the student will use HB for measuring the 'referenced flow rate'. They should do this experiment many times and average the results. Meanwhile, they have to record the pressure difference of each instrument. Comparison of the referenced flow rate and their pressured difference records are utilized for determining the coefficient of discharges. The result of this process is coefficient of discharge for every instrument. The second part asks the students to use the coefficient of discharges that they get for measuring the volumetric flow rate. They just need to apply the coefficient of discharge into the pressure difference that they have. A complete experiment design is provided in the flowchart of Fig. 5.

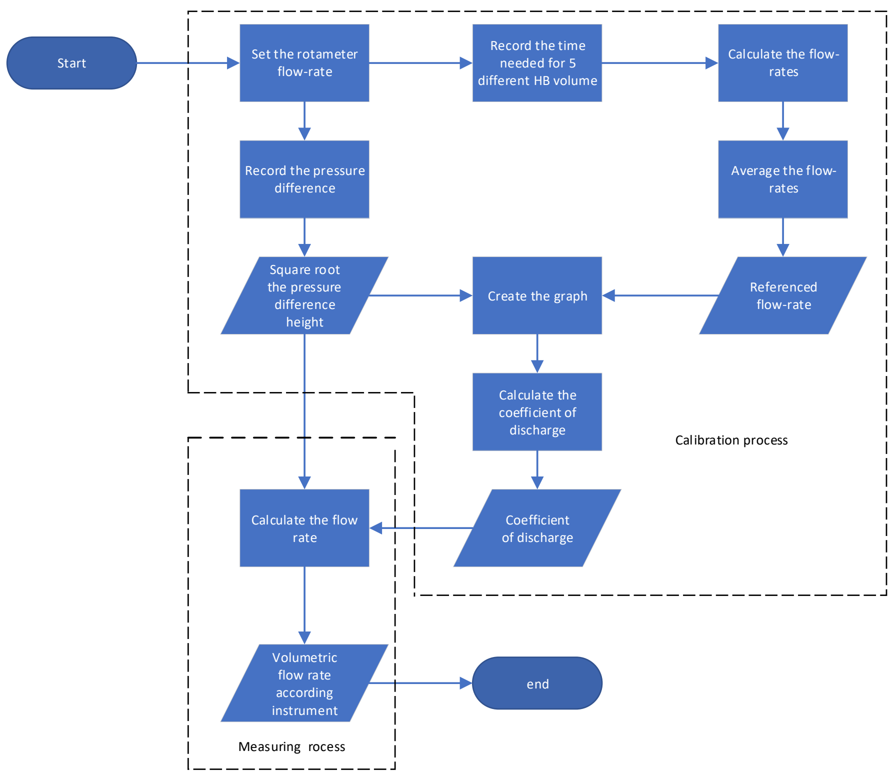


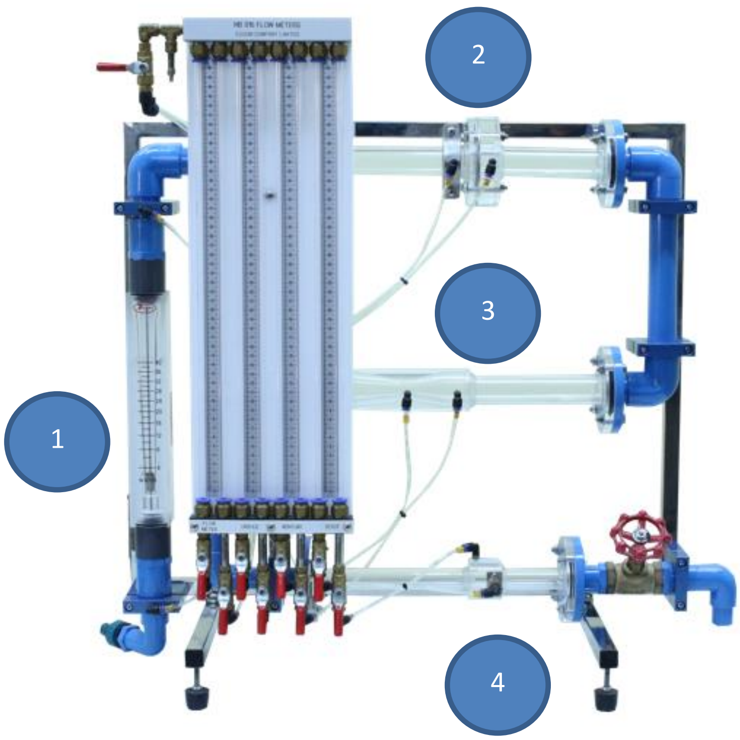
Figure 5. Complete experiment design. The experiment consists of calibration process and measuring process.

Experiment Procedure

Equipments

The experiment will be done on HB 106 flow meters that consist of

1. Rotameter
2. Orifice Meter
3. Venturi Meter
4. Pitot Tube
5. Hydrolic Bench
6. Stopwatch



(http://essom.com/product/details/13/29)

Figure 6. The equipment for experiment (HB 016 flow measurement set) and the position of flow measurement instruments.

Steps of experiment

1. Start the pump and open the bench flow control valve until air bubbles are completely removed from the test set. Then reduce the flow rate to about 10 lpm or required flow rate. (As rotameter shows)
2. Observe water levels in the manometer and ensure that all levels can be observed. If they are too high, pump air into the manometer head manifold. If they are too low, slightly close the test equipment discharge valve or bleed air out from the manometer head manifold by vent valve.
3. Record manometer levels for each flow measuring device.
4. Record the measuring tank volume and time. (Hint : You should proceed at least 5 consecutive times and plot them into graph)
5. Repeat the steps for another flow rate (as you are aked).

Tabel of data

Measuring Device			Approximate flow rate on Rotameter (liter per minute)									
Hydraulics Bench	**Hydraulics Bench Measuring Tank**	Vol (liter)	time (s)	Q_i	time (s)	Q_i	time (s)	Q_i	time (s)	Q_i	time (s)	Q_i
	Average flow rate, (liter per second)											
	Average flow rate, (liter per minute)											
	Average flow rate, (m^3/s)											
Orifice	Water manometer level, high (mm)											
	Water manometer level, low (mm)											
	Level difference, Δh (mm)											
	Flow rate, Q (liter/minute)											
Venturi	Water manometer level, high (mm)											
	Water manometer level, low (mm)											
	Level difference, Δh (mm)											
	Flow rate, Q (liter/minute)											
Pitot Tube	Water manometer level, high (mm)											
	Water manometer level, low (mm)											
	Level difference, Δh, (mm)											
	Flow rate, Q (liter/minute)											

Calculation Tables

Orifice Meter

Q_{act} (m^3/s)	Δh (m)	$\sqrt{\Delta h}$(m$^{1/2}$)	C_O	

Venturi Meter

Q_{act} (m^3/s)	Δh (m)	$\sqrt{\Delta h}$(m$^{1/2}$)	C_v	

Pitot Tube

Q_{act} (m^3/s)	Δh (m)	$\sqrt{\Delta h}$(m$^{1/2}$)	C_P	

Comparison of Measurement

Hydraulic Bench	Rotameter	Orifice	Venturi	Pitot Tube
Q (liter/min)	Q (liter/min)	Q (liter/min)	Q (liter/min)	Q (liter/min)

Comparison of the Flow Meters

Measurement Necessity	Rotameter	Venturi Meter	Orifice Meter	Pitot Tube	Hydraulics Bench	Notes
Unsteady flow						
Turbid Fluids						
Different direction of flow						
Different type of fluid (different ρ)						
High Accuracy						
Low velocity flow						
High velocity flow						
High temperature						

Some Miscellaneous Flow Measurements Apparatus

Type	Description

Basic In-Line Flow Meter

Hedland offers a complete line of over 15,000 variable area flow meters to measure oil, phosphate esters, water and water-based fluids, as well as air and other compressed gases. In addition to the basic in-line model, these variable area flow meters are available in high temperature models and test kits with pressure gauge.

- Rugged, durable construction featuring aluminum, brass and stainless steel bodies
- Most models available in sizes from 1/4" to 3"
- Accuracy of ±2% of full scale
- Temperatures to 240 °F (116 °C); 400 °F (204 °C) for
- high temperature models
- Pressures up to 6000 psi (414 bar)
- Operates in any position
- No flow straighteners or special piping required
- 360° rotatable scales
- Custom scales available

HTTF Transit Time Ultrasonic Flow Meters

The HTTF Series utilizes a non-intrusive, clamp-on design for liquid measurement in pipe sizes from 1/2" to 100". Compact, integral models are available for pipe sizes from 1/2" to 2". Remote mount models provide flow measurement for the full range of pipe sizes.

- Easy, low cost installation
- Offered with or without a local display
- Provides rate and total (forward, reverse and net)
- 4-20 mA and pulse outputs for direct interface to data collection systems
- Designed for maintenance free operation
- Software utility allows in-field calibration and configuration
- Class I, Division 2 hazardous area certification

HB Turbine Flow Meters

Designed to withstand the demands of the most rigorous flow measurement applications of water and other liquids, the HB Series turbine flow meters feature rugged stainless steel and tungsten carbide construction. For a complete system, the HB2800 flow monitor provides a local indication of both flow rate and total flow. To
integrate with other instruments, PLCs and computers, Hedland also offers additional electronic accessories.

- Flow ranges from 0.6-3 to 500-5,000 GPM (2.27-11.36 to
- 1893-18,927 LPM)
- NPT, BSP, Victaulic®, or flange end connections from 1/2" to 10"
- Accuracy of ±1% of reading
- Temperatures to 350 °F (177 °C)
- Pressures up to 5000 psi (345 bar)
- CE compliant
- CSA Class I, Division 1, (intrinsically safe) certification

http://www.royalhydraulics.com/index.php?option=com_content&view=article&id=78&Itemid=80