International Journal of Applied Engineering and Technology ISSN: 2277-212X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jet.htm
2014 Vol. 4 (2) April-June, pp.75-90/Sujatha and Prethiviraj
Research Article

DEVELOPMENT OF CALIBRATION TEST RIG FOR FLOW MEASUREMENT OF LIQUIDS IN FOOD INDUSTRY

***G. Sujatha[1] and R. Prethiviraj[2]**
[1]*Department of Food Engineering, College of Food and Dairy Technology, Koduvalli, Chenn 600 052*
[2]*College of Food and Dairy Technology, Koduvalli, Chennai 600 052.*
**Author for Correspondence*

ABSTRACT
This paper deals with the assessment of flow rate of fluids with different types of flow meters. Almost all the Food processing industry in the world involves processing of food in the form of fluids. These fluids have to be transported and processed in the factory. Food technologists must be familiar with the principles that govern the flow of fluids and with the machinery and equipment that is used to handle fluids. In this view an equipment is designed to assess the flow rate of fluids, calibrate the flow meters and compare different kinds of meters. The flow meters used here are venturimeter, orifice meter and pitot tube. All these flow meters belong to the group of differential flow meters. They measure fluid flow indirectly by creating and measuring a differential pressure by means of an obstruction to the fluid flow. Using well-established conversion coefficients differential pressure may be translated into a volume rate. All types of fluids can be used and the flow rate can be measured. Hence the designed equipment can be used to compare the three flow meters, regulate and assess the flow rate, determine the time taken for fluid to pass from one container to another and study the factors affecting the flow rate.

Keywords: *Venturimeter, Orifice Meter, Pitot tube, Manometer, Collecting Tank*

INTRODUCTION
Many food processing industries involve processing of food in the form of fluid such as milk, fruit pulp, juices, and carbonated beverages. In order to control the above industrial process, it is essential to know the amount of material entering and leaving the process. This can be measured by flow meters. Thus an apparatus is designed in order to assess the volumetric flow rate of various fluid using venturimeter, orifice meter and pitot tube. This equipment consists of a sump in which the fluid can be stored. The fluid is sucked by means of pump and allowed to flow through three pipes consisting of different flow meters. A hand operated valve is provided next to the pump to regulate the flow of fluid. Shutdown valves are provided at each pipe after the flow meter in order to measure the flow in a flow meter at once (i.e., fluid is made to pass through the single flow meter by shutting down the other two valves). Then the water is collected in a tank which is measurable. The flow meters used are orifice, venturi and pitot tube. The differential pressure is measured by means of a differential manometer. These flow meters works on the principle of Bernoulli's equation. Hence this equipment is used to compare the three flow meters, regulate and assess the flow rate and to some extend can determine the processing time.

MATERIALS AND METHODS
The apparatus consists of venturimeter, orifice meter and pitot tube separately on a pipeline with flow control valve. Pressure tapping from venturimeter, orifice meter and pitot tube are connected to a multiport manifold and to a manometer. The whole unit is mounted on a sturdy iron stand. A collecting tank with gauge glass, scale fitting and a drain valve. A sump tank with a mono block pumping unit is provided.

Description of Flow Meters
Venturimeter, orifice meter and pitot tube belongs to the group of differential pressure flow meters. These flow meters works on the principle of Bernoulli's equation.These flow meters are arranged parallely in horizontal position.

Venturimeter

A venturimeter is a device used for measuring the rate of a flow of a fluid flowing through a pipe. Venturi tubes exhibit a very low pressure loss compared to other differential pressure head meters, but they are also the largest and most costly.



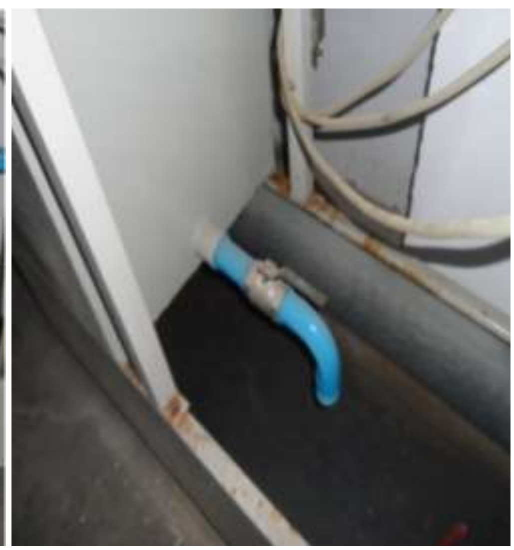
Orifice Meter

It is a device used for measuring the rate of flow of fluid through a pipe. It is a cheaper device as compared to venturimeter. It also works on the same principle as that of venturimeter.

Pitot Tube

Pitot tube is a device used for measuring the velocity of flow at any point in a pipe or a channel. It is based on the principle that if the velocity of flow at a point becomes zero, the pressure there is increased due to the conversion of the kinetic energy into pressure energy.





Manometer

An u-tube manometer is used to measure the difference of pressures between two points in a pipe. It consists of an u-tube, containing a heavy liquids (Hg), whose two ends are connected to the points.

Design of Calibration Test Rig

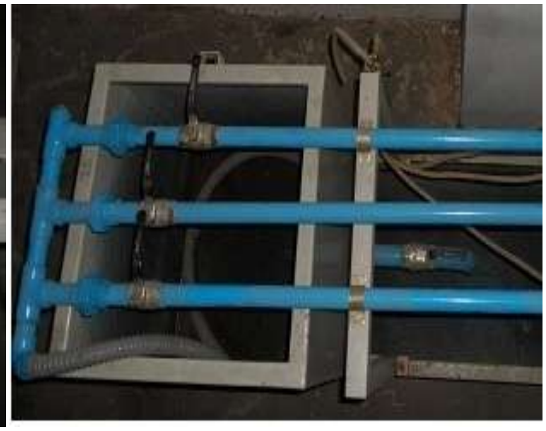
SUMP

It is a rectangular tank made up of iron. It has a length of 0.3m and breadth of 0.5m and height of 1.9m.It can hold a volume of 250 ltrs and it can be operated with the volumeof 150 ltrs. The fluid whose flowrate to be assessed is kept in this tank.

Motor Pump

International Journal of Applied Engineering and Technology ISSN: 2277-212X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jet.htm
2014 Vol. 4 (2) April-June, pp.75-90/Sujatha and Prethiviraj
Research Article

The motor pump is used to pump the water from the sump into different flow meters and to the collecting tank.It is a monoblock type and has a capacity of 0.5horse power. It is kirloskar make.

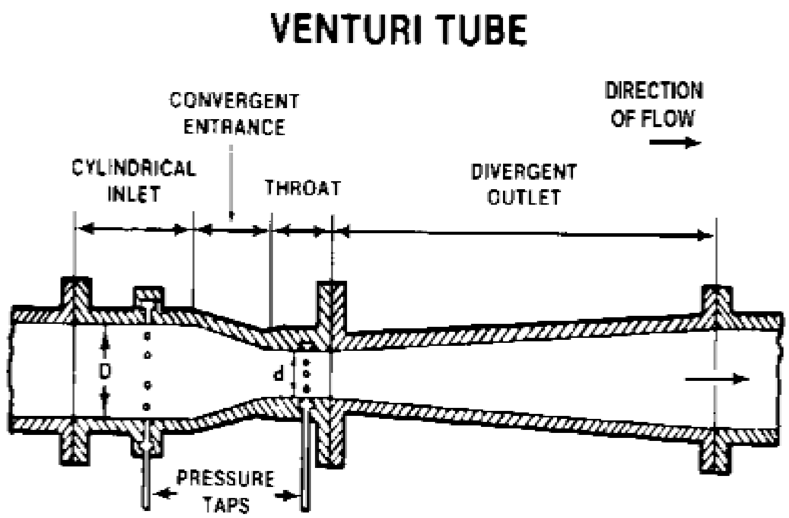


Collecting Tank
The fluid after flowing through the pipe is collected in the collecting tank. It is a square shaped tank which has a side of 0.4m and height of 5m.It consists of glass tube which indicates the level of water present in the tank and the time taken for 10cm rise in water level is measured from this tank.
Flow Regulating Valve
It is a hand operated valve which is used to provide a regulated flow. The readings h1 and h2 (i.e., pressure difference in the limbs of manometer) are taken with the regulating valve fully opened and half opened conditions.



Shut Down Valve
It is provided to facilitate the flow measure in a single flowmeter at a time. The experiment is usually done by keeping only one valve opened and other two valve closed.
Multiport Manifold
The pressure tappings from each flow meters are connected to the multiport manifold from which the pressure difference is transferred to the manometer limbs. It consists of valve for each flow meter
Venturimeter
It consists of three parts: (i) A short converging part, (ii) Throat, and (iii) diverging part.
Inlet diameter of venturimeter $d1=25mm$
Throat diameter of venturimeter $d2=15mm$
Inlet area of venturimeter $=a1=0.000490874m^2$

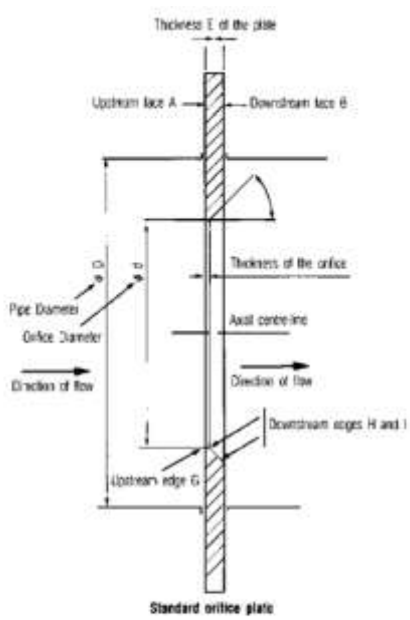
Throat area of venturimeter =a2=0.00017671m²

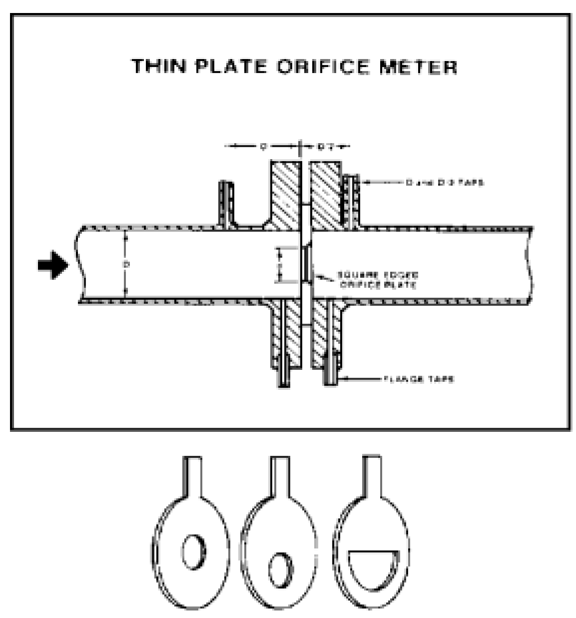


Orifice Meter

It consists of a flat circular plate which has a circular sharp edged hole called orifice, which is concentric with the pipe [2]. The orifice diameter is kept generally 0.5 times the diameter of the pipe, though it may vary from 0.4 to 0.8 times the pipe diameter.

Inlet diameter of orificemeter d1=25mm
Orifice bore diameter d2=15mm
Area of the pipe=0.000490874m²
Area of the orifice=0.000176715m²

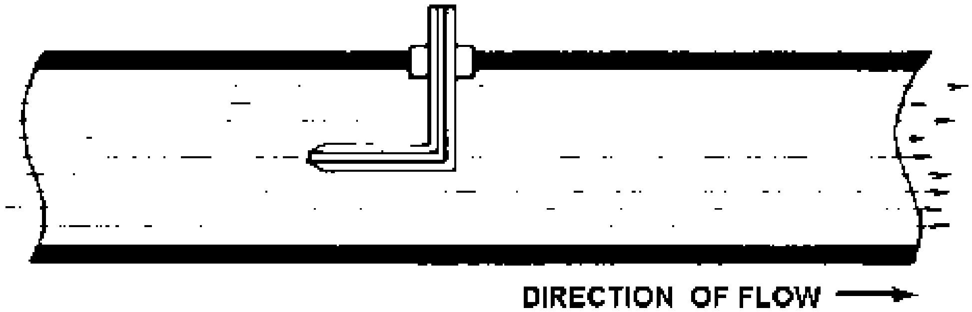




Pitot Tube

These tubes can be mounted separately in the pipe or installed together in one casing as a single device. One tube measures the stagnation or impact pressure (velocity head plus potential head) at a point in the flow [3]. The other tube measures only the static pressure (potential head), usually at the wall of the pipe. The differential pressure sensed through the pitot tube is proportional to the square of the velocity.

International Journal of Applied Engineering and Technology ISSN: 2277-212X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jet.htm
2014 Vol. 4 (2) April-June, pp.75-90/Sujatha and Prethiviraj
Research Article



PITOT TUBE

Calibration of Flow Meters

The flow rate of fluid to be measured is taken in the sump and the flow regulating valve should be opened fully at the initial stage. The shutdown valves should be closed except one in which the flow is allowed and measured by the respective flow meter. The collecting tank has a drain valve which should be opened initially. The pressure tappings from each flow meter are connected to the multiport manifold and then to the manometer. Hence the valve in the multiport manifold corresponding to its flow meter should be opened and closed. At this setup the pump is switched on and the pressure difference in the manometer is noted. Now the drain valve in the collecting tank should be closed and the time taken for 10cm raise of water level in the collecting tank. Now the flow regulating valve should be half opened and repeat the same. Hence this is repeated for the other two flow meters.

Flow Rate Measurement of Salt Water

The salt water having density of 1098Kg/m^3 is prepared by adding 10% NaCl and is fed into the sump. The length and breadth of the collecting tank is measured and area is calculated as 0.16m^2. First the valve for venturimeter is opened and the remaining two valves are closed completely. Flow regulating valve is opened fully and the pump is switched on Note the left limb reading (h_1)m and right limb reading (h_2)m of the manometer. Close the drain valve of the collecting tank. The time taken t for 0.1m (R) rise of water level in the collecting tank is noted using a stopwatch. After taking the reading for venturimeter, the valve for orificemeter is opened and the venturimeter is closed. The valve present in the multiport manifold should also be changed correspondingly. Now note the left limb reading (h_1)m and right limb reading (h_2)m of the manometer for orifice meter and the time taken is also noted. Simillarly for the pitot tube the h_1 and h_2, time taken readings are taken. The experiment is repeated for all the flow meters with flow regulating valve halfly opened and corresponding readings are noted as direct measures in table 1.

Direct Measures

Table 1

Regulating valve: fully opened			
Flowmeters	h_1(cm)	h_2(cm)	Time taken for 10cm rise(seconds)
Venturimeter	22.4	30.3	30.38
Orificemeter	17.5	35	33.19
Pitot-tube	25.7	27	32.06
Regulating Valve: Half Opened			
Flowmeters	h_1(cm)	h_2(cm)	Time taken for 10cm rise(seconds)
Venturimeter	22.5	30	31.82
Orificemeter	18.2	34	33.31
Pitot-tube	25.8	26.8	33.19

Based on the above readings the theoretical discharge for venturimeter and orificemeter is calculated by a formula $Q_t = K\sqrt{h}m^3$ Where $k = a_1 \times a_2\sqrt{2g}/\sqrt{(a_1^2 - a_2^2)}$, g=9.81m/sec^{2,} $h = h_1 - h_2(S_1/S_2 - 1)$m of water column where S_1 and S_2 are densities of manometric fluid and salt water respectively. The manometric fluid used here is mercury whose density is 13500 Kg/m^3 and the density of salt water used is 1098 Kg/m^3. The actual discharge for venturimeter and orifice meter can be calculated by the formula Q_a=AR/t m^3/sec [4], where A is the area of collecting tank and R is the rise in water level and t is the time taken for the 10cm rise in water level. The theoretical discharge for pitot tube is calculated by Q_t=V×a where V is the velocity of water flowing in the pipe line V=$\sqrt{2gh}$ and a is the area of the pipe 0.000491m² The actual discharge for pitot tube can be calculated by the formula Q_a=AR/t m^3/sec where A is the area of collecting tank and R is the rise in water level and t is the time taken for the 10cm rise in water level. The C.O.P for each flow meter can be determined by the formula $\mathbf{C_d = Q_a/Q_t}$. and tabulated as indirect measures for the three flow meters under regulating valve fully opened and half opened.

Indirect Measures

Table 1.1

Regulating valve: fully opened

Flowmeters	Theoretical Discharge (Q_t)m^3/sec	Actual discharge (Q_a)m^3/sec	Coefficient of performance $C_d=Q_a/Q_t$
Venturimeter	7.9253×10^{-4}	5.2666×10^{-4}	0.66
Orificemeter	11.7956×10^{-4}	4.8207×10^{-4}	0.41
Pitot tube	1.41457×10^{-4}	4.9906×10^{-4}	0.35

Based on the indirect measures a bar diagram is drawn for the regulating valve fully opened condition. The coefficient of performance of venturi meter, orifice meter and pitot tube is drawn by taking C.O.P in Y-axis. From the chart it is clear that venturi meter shows higher performance (i.e.,0.66) when compared to orifice meter which shows C.O.P of 0.41 and pitot tube (0.35).

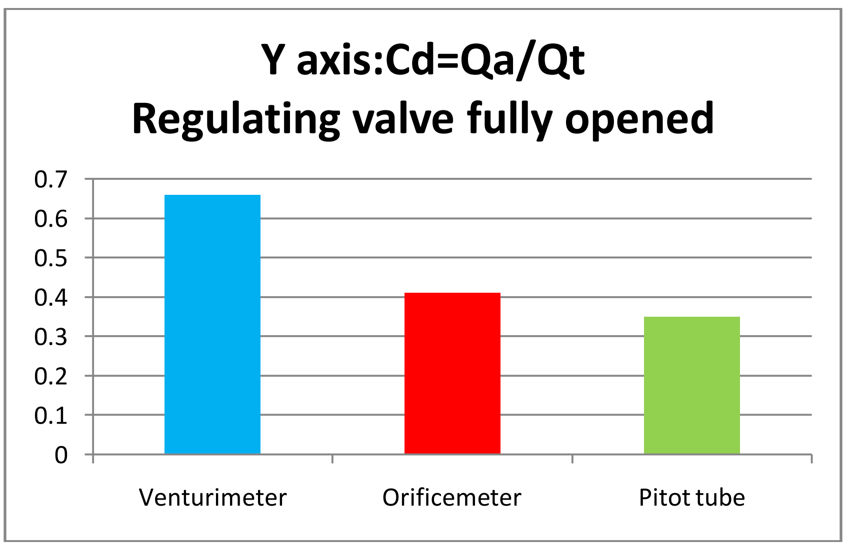
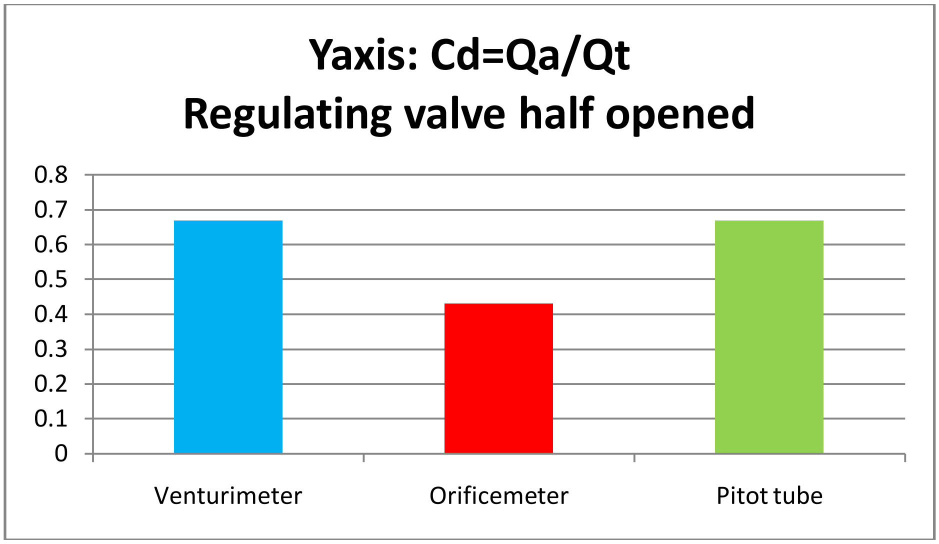


Table 1.2

Regulating Valve: Half Opened

Flowmeters	Theoretical Discharge (Q_t)m^3/sec	Actual discharge (Q_a)m^3/sec	Coefficient of performance $C_d=Q_a/Q_t$
Venturimeter	8.05422×10^{-4}	5.028284098×10^{-4}	0.62
Orificemeter	11.6902×10^{-4}	4.803362354×10^{-4}	0.41
Pitot tube	7.62364×10^{-4}	4.820729135×10^{-4}	0.63

Based on the indirect measures a bar diagram is drawn for the regulating valve half opened condition. The coefficient of performance of venturi meter, orifice meter and pitot tube is drawn by taking C.O.P in Y-axis.From the chart it is clear that venturi meter and pitot tube shows higher performance(i.e.,0.62) when compared to orifice meter whose C.O.P is 0.41



Flow Rate Measurement of Salt Water

The salt water having density of 1131Kg/m^3 is prepared by adding 20% NaCl and is fed into the sump. The length and breadth of the collecting tank is measured and area is calculated as 0.16m^2. First the valve for venturimeter is opened and the remaining two valves are closed completely. Flow regulating valve is opened fully and the pump is switched on Note the left limb reading (h_1) m and right limb reading (h_2) m of the manometer. Close the drain valve of the collecting tank. The time taken t for 0.1m (R) rise of water level in the collecting tank is noted using a stopwatch. After taking the reading for venturimeter, the valve for orificemeter is opened and the venturimeter is closed. The valve present in the multiport manifold should also be changed correspondingly. Now note the left limb reading (h_1) m and right limb reading (h_2) m of the manometer for orifice meter and the time taken is also noted. Similarly for the pitot tube the h_1 and h_2, time taken readings are taken. The experiment is repeated for all the flow meters with flow regulating valve half opened and corresponding readings are noted as direct measures in table 2

Direct Measures

Table 2

Regulating Valve: Fully Opened			
Flowmeters	h_1(cm)	h_2(cm)	Time taken for 10cm rise(seconds)
Venturimeter	22.6	29.8	33.85
Orificemeter	18.8	33.8	35.55
Pitot-tube	25.8	26.8	33.75
Regulating Valve: Half Opened			
Flowmeters	h_1(cm)	h_2(cm)	Time taken for 10cm rise(seconds)
Venturimeter	23	29.5	34.05
Orificemeter	19.5	33.1	36.85
Pitot-tube	25.8	26.8	35.02

Based on the above readings the theoretical discharge for venturimeter and orificemeter is calculated by a formula Q_t= $K\sqrt{h}m^3$ Where $k = a_1 \times a_2\sqrt{2g}/\sqrt{(a_1^2\text{-}a_2^2)}$, g=9.81m/$sec^2$, $h = h_1\text{-}h_2(S_1/S_2\text{-}1)$m of water column where S_1 and S_2 are densities of manometric fluid and salt water respectively[1].The manometric fluid used here is mercury whose density is 13500 Kg/m^3 and the density of salt water used is 1131 Kg/m^3.The actual discharge for venturimeter and orifice meter can be calculated by the formula Q_a=AR/t m^3/sec where A is the area of collecting tank and R is the rise in water level and t is the time taken for the 10cm rise in water level. The theoretical discharge for pitot tube is calculated by $Q_t=V\times a$ where V is the velocity of water flowing in the pipe line $V=\sqrt{2gh}$ and a is the area of the pipe 0.000491m² The actual discharge for pitot tube can be calculated by the formula $Q_a=AR/t$ m^3/sec where A is the area of collecting tank and R is the rise in water level and t is the time taken for the 10cm rise in water level. The C.O.P for each flow meter can be determined by the formula $\mathbf{C_d = Q_a/Q_t}$. and tabulated as indirect measures for the three flow meters under regulating valve fully opened and half opened.

Indirect Measures

Table 2.1

Regulating Valve: Fully Opened

Flowmeters	Theoretical Discharge (Q_t)m^3/sec	Actual discharge (Q_a)m^3/sec	Coefficient of performance $C_d=Q_a/Q_t$
Venturimeter	7.4449×10^{-4}	4.72676×10^{-4}	0.64
Orificemeter	10.7459×10^{-4}	4.50070×10^{-4}	0.42
Pitot tube	7.19227×10^{-4}	4.5688×10^{-4}	0.63

Based on the indirect measures a bar diagram is drawn for the regulating valve fully opened condition. The coefficient of performance of venturi meter, orifice meter and pitot tube is drawn by taking C.O.P in Y-axis. From the chart it is seen that venturi meter shows higher performance (i.e.,0.64) then comes the pitot tube (0.63) and then the orifice meter atlast with c.o.p of 0.42

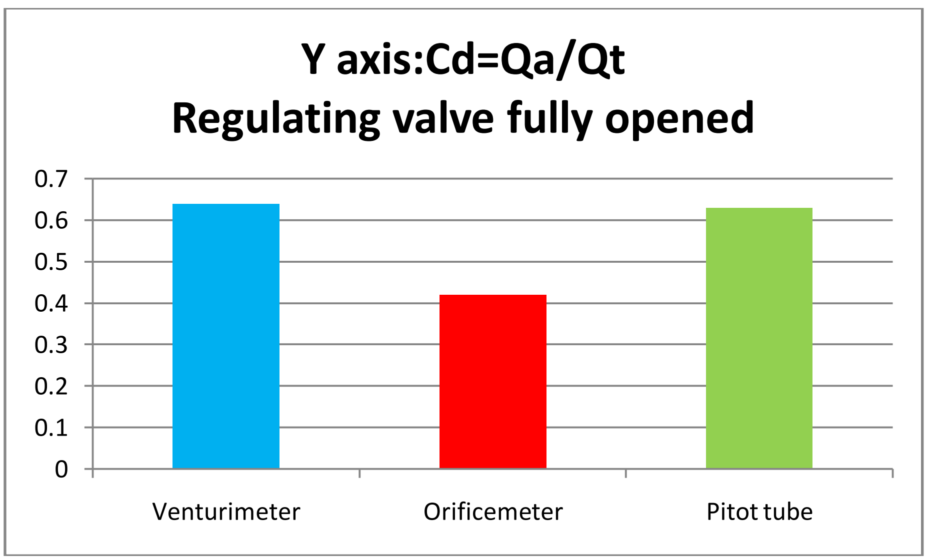
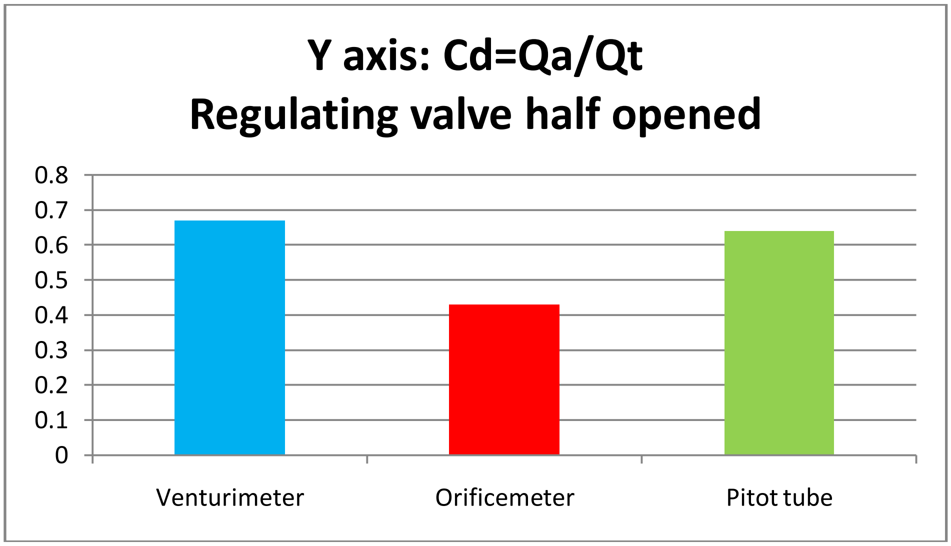


Table 2.2

Regulating Valve: Half Opened

Flowmeters	Theoretical Discharge (Q_t)m^3/sec	Actual discharge (Q_a)m^3/sec	Coefficient of performance $C_d=Q_a/Q_t$
Venturimeter	7.07004×10^{-4}	4.6989721×10^{-4}	0.67
Orificemeter	10.2269×10^{-4}	4.3419267×10^{-4}	0.43
Pitot tube	7.19227×10^{-4}	4.568817818×10^{-4}	0.64

Based on the indirect measures a bar diagram is drawn for the regulating valve half opened condition. The coefficient of performance of venturi meter, orifice meter and pitot tube is drawn by taking C.O.P in Y-axis. From the chart it is clear that venturi meter shows higher performance (i.e.,0.67) when compared to pitot tube (0.64) and orifice meter which shows C.O.P of 0.43



Flow Rate Measurement of Lime Water

The lime water having density of 1045Kg/m^3 is prepared by squeezing lime into the water and is fed into the sump. The length and breadth of the collecting tank is measured and area is calculated as 0.16m^2. First the valve for venturimeter is opened and the remaining two valves are closed completely. Flow regulating valve is opened fully and the pump is switched on Note the left limb reading (h1)m and right limb reading (h2)m of the manometer. Close the drain valve of the collecting tank. The time taken t for 0.1m (R) rise of water level in the collecting tank is noted using a stopwatch. After taking the reading for venturimeter, the valve for orificemeter is opened and the venturimeter is closed. The valve present in the multiport manifold should also be changed correspondingly. Now note the left limb reading (h1)m and right limb reading (h2)m of the manometer for orifice meter and the time taken is also noted. Simillarly for the pitot tube the h1 and h2, time taken readings are taken. The experiment is repeated for all the flow meters with flow regulating valve halfly opened and corresponding readings are noted as direct measures in table 3

Direct Measures

Table 3

Regulating Valve: Fully Opened			
Flowmeters	**h1(cm)**	**h2(cm)**	**Time taken for 10cm rise (seconds)**
Venturimeter	22.6	30.1	30
Orificemeter	18	33	33
Pitot-tube	26	27	31
Regulating Valve: Half Opened			
Flowmeters	**h1(cm)**	**h2(cm)**	**Time taken for 10cm rise (seconds)**
Venturimeter	22.9	30	31
Orificemeter	18.5	32.6	34
Pitot-tube	26	27	32

Based on the above readings the theoretical discharge for venturimeter and orificemeter is calculated by a formula Q_t= K$\sqrt{h}m^3$ Where k = $a_1 \times a_2\sqrt{2g}/\sqrt{(a_1^2\text{-}a_2^2)}$, g=9.81m/$sec^{2,}$ h = h_1-h_2(S_1/S_2-1)m of water column where S_1 and S_2 are densities of manometric fluid and salt water respectively.The manometric fluid used here is mercury whose density is 13500 Kg/m^3 and the density of salt water used is 1098 Kg/m^3.The actual discharge for venturimeter and orifice meter can be calculated by the formula Q_a=AR/t m^3/sec where A is the area of collecting tank and R is the rise in water level and t is the time taken for the 10cm rise in water level. The theoretical discharge for pitot tube is calculated by $Q_t=V\times a$ where V is the velocity of water flowing in the pipe line $V=\sqrt{2gh}$ and a is the area of the pipe 0.000491m² The actual discharge for pitot tube can be calculated by the formula $Q_a=AR/t$ m^3/sec where A is the area of collecting tank and R is the rise in water level and t is the time taken for the 10cm rise in water level. The C.O.P for each flow meter can be determined by the formula $\mathbf{C_d = Q_a/Q_t}$. and tabulated as indirect measures for the three flow meters under regulating valve fully opened and half opened.

Indirect Measures

Table 3.1

Regulating Valve: Fully Opened

Flowmeters	**Theoretical Discharge (Q_t)m^3/sec**	**Actual discharge (Q_a)m^3/sec**	**Coefficient of performance $C_d=Q_a/Q_t$**
Venturimeter	7.932461×10^{-4}	5.3333×10^{-4}	0.67
Orificemeter	11.21247×10^{-4}	4.8485×10^{-4}	0.43
Pitot tube	7.508353×10^{-4}	4.5688×10^{-4}	0.68

Based on the indirect measures a bar diagram is drawn for the regulating valve fully opened condition. The coefficient of performance of venturi meter, orifice meter and pitot tube is drawn by taking C.O.P in Y-axis. From the chart it is seen that venturi meter shows higher performance (i.e.,0.67) then the pitot tube (0.68) and then the orifice meter at last with c.o.p of 0.43

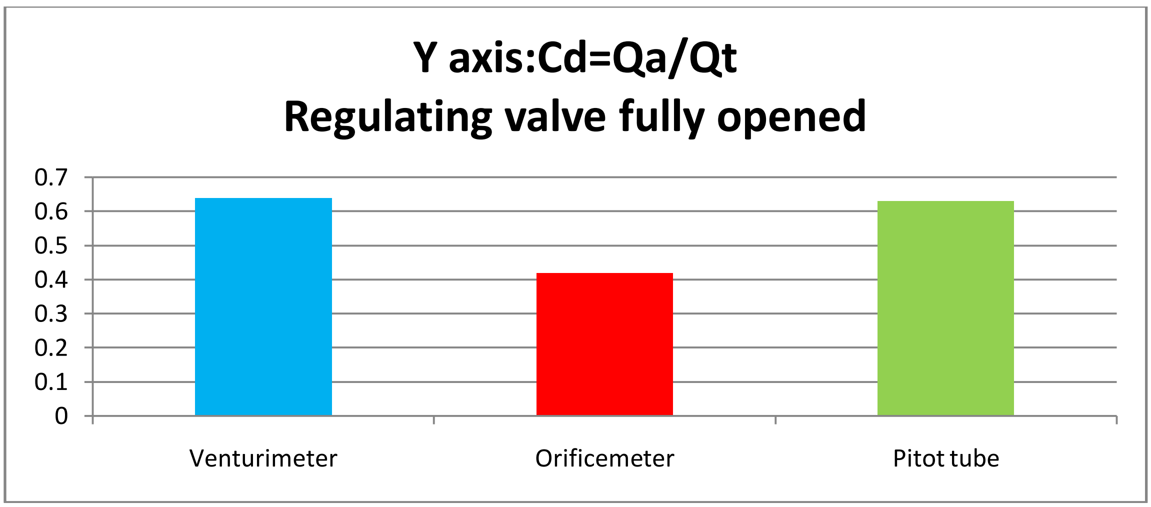
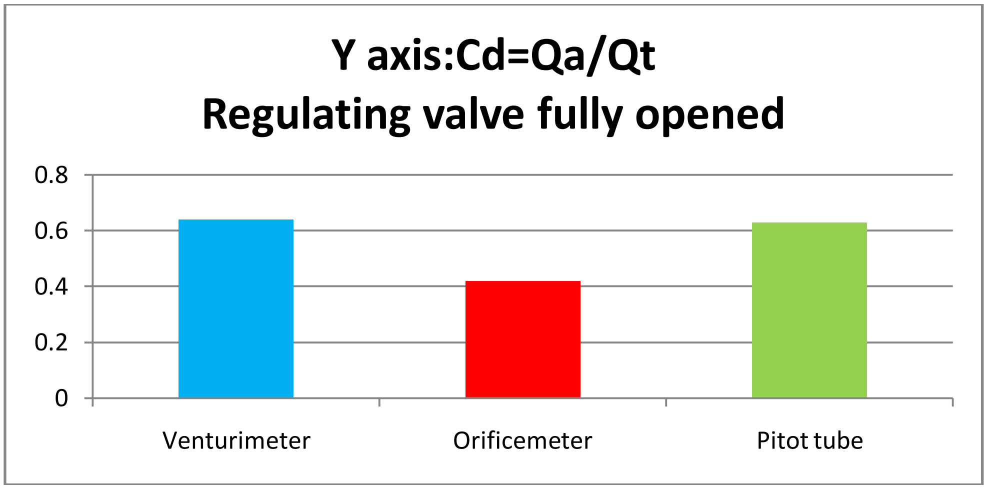


Table 3.2

Regulating Valve: Half Opened

Flowmeters	**Theoretical Discharge (Q_t)m^3/sec**	**Actual discharge (Q_a)m^3/sec**	**Coefficient of performance $C_d=Q_a/Q_t$**
Venturimeter	7.903982×10^{-4}	5.1612903×10^{-4}	0.65
Orificemeter	10.87644×10^{-4}	4.7058824×10^{-4}	0.43
Pitot tube	7.19227×10^{-4}	4.5688178×10^{-4}	0.65

Based on the indirect measures a bar diagram is drawn for the regulating valve half opened condition. The coefficient of performance of venturi meter, orifice meter and pitot tube is drawn by taking C.O.P in Y-axis.From the chart it is clear that venturi meter and pitot tube shows higher performance(i.e.,0.65) when compared to orifice meter whose C.O.P is 0.43



D. Flow rate measurement of oil

The oil having density of 924Kg/m^3 is prepared by mixing oil into the water and is fed into the sump. The length and breadth of the collecting tank is measured and area is calculated as 0.16m^2. First the valve for venturimeter is opened and the remaining two valves are closed completely. Flow regulating valve is opened fully and the pump is switched on Note the left limb reading (h1)m and right limb reading (h2)m of the manometer. Close the drain valve of the collecting tank. The time taken t for 0.1m (R) rise of water level in the collecting tank is noted using a stopwatch. After taking the reading for venturimeter, the valve for orificemeter is opened and the venturimeter is closed. The valve present in the multiport manifold should also be changed correspondingly. Now note the left limb reading (h1)m and right limb reading (h2)m of the manometer for orifice meter and the time taken is also noted.Simillarly for the pitot tube the h1 and h2, time taken readings are taken.The experiment is repeated for all the flow meters with flow regulating valve halfly opened and corresponding readings are noted as direct measures in table 4

Direct Measures

Table 4

Regulating Valve: fully opened

Flowmeters	h1(cm)	h2(cm)	Time taken for 10cm rise(seconds)
Venturimeter	20	28	30
Orificemeter	19	34	35
Pitot-tube	26	27	31

Regulating Valve: Half Opened

Flowmeters	h1(cm)	h2(cm)	Time taken for 10cm rise(seconds)
Venturimeter	21	28	30.5
Orificemeter	18	33	36
Pitot-tube	26	27	34

Based on the above readings the theoretical discharge for venturimeter and orificemeter is calculated by a formula Q_t= K$\sqrt{h}$m^3 Where k = $a_1 \times a_2\sqrt{2g}/\sqrt{(a_1^2\text{-}a_2^2)}$, g=9.81m/sec^{2,} h = h_1-h_2(S_1/S_2-1)m of water column where S_1 and S_2 are densities of manometric fluid and salt water respectively. The manometric fluid used here is mercury whose density is 13500 Kg/m^3 and the density of salt water used is 1098 Kg/m^3.The actual discharge for venturimeter and orifice meter can be calculated by the formula Q_a=AR/t m^3/sec where A is the area of collecting tank and R is the rise in water level and t is the time taken for the 10cm rise in water level. The theoretical discharge for pitot tube is calculated by $Q_t=V\times a$ where V is the velocity of water flowing in the pipe line $V=\sqrt{2gh}$ and a is the area of the pipe 0.000491m² The actual discharge for pitot tube can be calculated by the formula $Q_a=AR/t$ m^3/sec where A is the area of collecting tank and R is the rise in water level and t is the time taken for the 10cm rise in water level.The C.O.P for each flow meter can be determined by the formula $\mathbf{C_d = Q_a/Q_t}$. and tabulated as indirect measures for the three flow meters under regulating valve fully opened and half opened.

Indirect Measures

Table 4.1

Regulating Valve: Fully Opened

Flowmeters	**Theoretical Discharge (Q_t)m^3/sec**	**Actual discharge (Q_a)m^3/sec**	**Coefficientof performance $C_d=Q_a/Q_t$**
Venturimeter	8.750289×10^{-4}	5.33333×10^{-4}	0.61
Orificemeter	11.98789×10^{-4}	4.57143×10^{-4}	0.38
Pitot tube	8.023544×10^{-4}	5.16129×10^{-4}	0.64

Based on the indirect measures a bar diagram is drawn for the regulating valve fully opened condition. The coefficient of performance of venturi meter, orifice meter and pitot tube is drawn by taking C.O.P in Y-axis.From the chart it is seen that venturi meter shows higher performance(i.e.,0.61) then the pitot tube(0.64) and then the orifice meter atlast with c.o.p of (0.38).

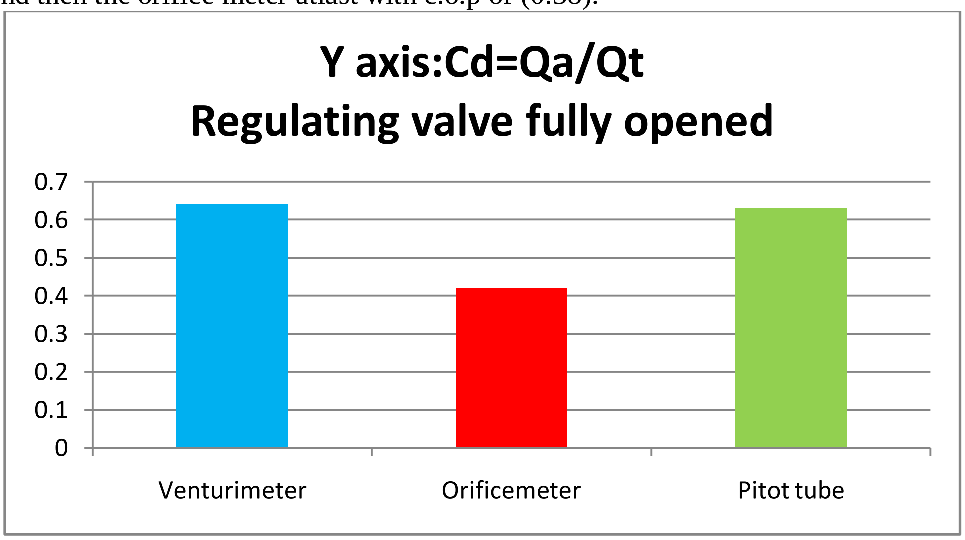


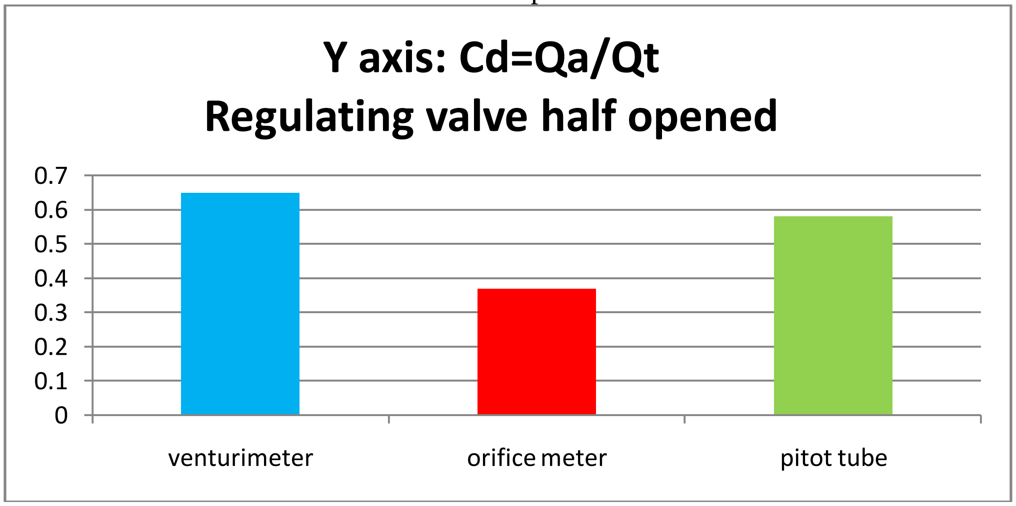
Table 4.2

Regulating Valve: Half Opened

Flowmeters	**Theoretical Discharge (Q_t)m^3/sec**	**Actual discharge (Q_a)m^3/sec**	**Coefficient of performance $C_d=Q_a/Q_t$**
Venturimeter	8.189321×10^{-4}	5.24590×10^{-4}	0.65
Orificemeter	11.98789×10^{-4}	4.44444×10^{-4}	0.37
Pitot tube	8.023544×10^{-4}	4.70588×10^{-4}	0.58

International Journal of Applied Engineering and Technology ISSN: 2277-212X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jet.htm
2014 Vol. 4 (2) April-June, pp.75-90/Sujatha and Prethiviraj
Research Article

Based on the indirect measures a bar diagram is drawn for the regulating valve half opened condition. The coefficient of performance of venturi meter, orifice meter and pitot tube is drawn by taking C.O.P in Y-axis.From the chart it is clear that venturi meter shows higher performance(i.e.,0.65) when compared to orifice meter which shows C.O.P of 0.37 and C.O.P of pitot tube is 0.58



E. Flow rate measurement of water

The water having density of 1000Kg/m^3 is fed into the sump. The length and breadth of the collecting tank is measured and area is calculated as 0.16m^2. First the valve for venturimeter is opened and the remaining two valves are closed completely. Flow regulating valve is opened fully and the pump is switched on Note the left limb reading (h1)m and right limb reading (h2)m of the manometer. Close the drain valve of the collecting tank. The time taken t for 0.1m (R) rise of water level in the collecting tank is noted using a stopwatch. After taking the reading for venturimeter, the valve for orificemeter is opened and the venturimeter is closed. The valve present in the multiport manifold should also be changed correspondingly. Now note the left limb reading (h1)m and right limb reading (h2)m of the manometer for orifice meter and the time taken is also noted.Simillarly for the pitot tube the h1 and h2, time taken readings are taken.The experiment is repeated for all the flow meters with flow regulating valve halfly opened and corresponding readings are noted as direct measures in table 4

Direct Measures

Table 5

Regulating valve: fully opened			
Flowmeters	**h1(cm)**	**h2(cm)**	**Time taken for 10cm rise(seconds)**
Venturimeter	22.9	30	31
Orificemeter	19	33.7	34
Pitot-tube	26	27	30
Regulating Valve: Half Opened			
Flowmeters	h1(cm)	h2(cm)	Time taken for 10cm rise(seconds)
Venturimeter	23	29.8	31
Orificemeter	19.5	33.3	34
Pitot-tube	26	27	31

Based on the above readings the theoretical discharge for venturimeter and orificemeter is calculated by a formula Q_t= $K\sqrt{h}m^3$ Where k = $a_1 \times a_2\sqrt{2g}/\sqrt{(a_1^2\text{-}a_2^2)}$, g=9.81m/sec^2, h = h_1-h_2(S_1/S_2-1)m of water column where S_1 and S_2 are densities of manometric fluid and salt water respectively.The manometric fluid used here is mercury whose density is 13500 Kg/m^3 and the density of water used is 1000 Kg/m^3.The actual discharge for venturimeter and orifice meter can be calculated by the formula Q_a=AR/t m^3/sec where A is the area of collecting tank and R is the rise in water level and t is the time taken for the 10cm rise in water level. The theoretical discharge for pitot tube is calculated by Q_t=V×a where V is the velocity of water flowing in the pipe line V=$\sqrt{2gh}$ and a is the area of the pipe 0.000491m² [5]. The actual discharge for pitot tube can be calculated by the formula Q_a=AR/t m^3/sec where A is the area of collecting tank and R is the rise in water level and t is the time taken for the 10cm rise in water level.The C.O.P for each flow meter can be determined by the formula $\mathbf{C_d = Q_a/Q_t}$.and tabulated as indirect measures for the three flow meters under regulating valve fully opened and half opened.

Indirect Measures

Table 5.1

REGULATING VALVE:FULLY OPENED

Flowmeters	**Theoretical Discharge (Q_t) m^3/sec**	**Actual discharge (Q_a) m^3/sec**	**Coefficient of performance $C_d=Q_a/Q_t$**
Venturimeter	7.903982×10^{-4}	5.161290323×10^{-4}	0.65
Orificemeter	11.373×10^{-4}	4.705882353×10^{-4}	0.41
Pitot tube	7.68928×10^{-4}	5.333×10^{-4}	0.69

Based on the indirect measures a bar diagram is drawn for the regulating valve fully opened condition. The coefficient of performance of venturi meter, orifice meter and pitot tube is drawn by taking C.O.P in Y-axis.From the chart it is seen that venturi meter shows higher performance (i.e.,0.65) then the pitot tube(0.69) and then the orifice meter t with c.o.p of 0.41

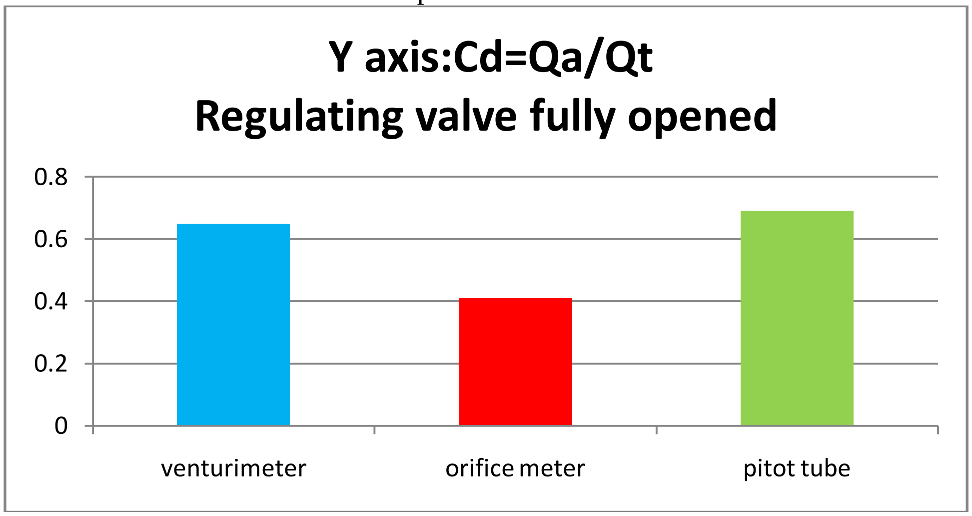
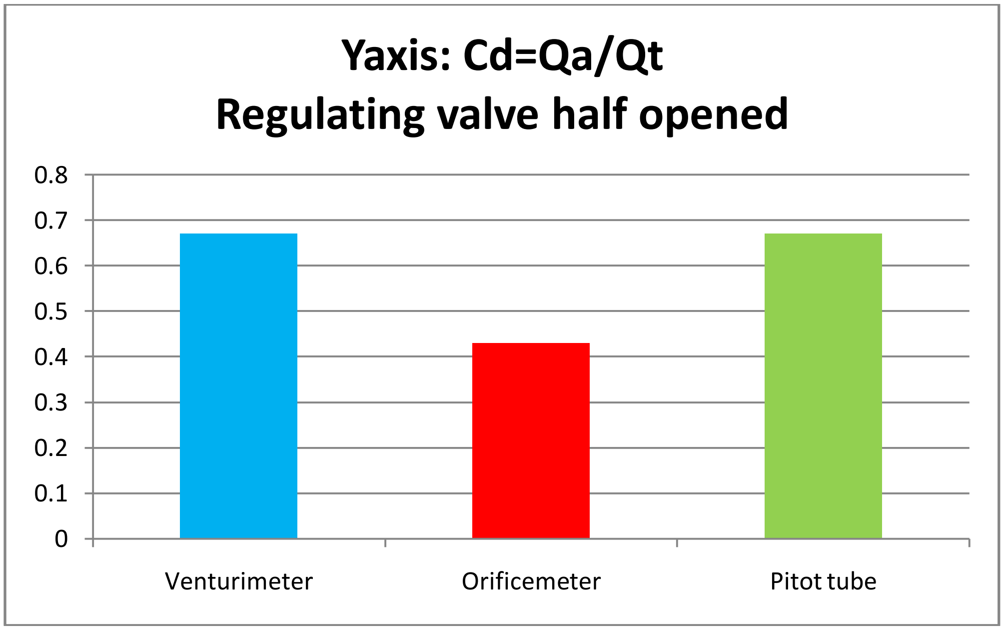


Table 5.2

Regulating Valve: Half Opened

Flowmeters	Theoretical Discharge (Q_t)m^3/sec	Actual discharge (Q_a)m^3/sec	Coefficient of performance $C_d=Q_a/Q_t$
Venturimeter	7.7313×10^{-4}	5.161290323×10^{-4}	0.67
Orificemeter	11.01935×10^{-4}	4.705882353×10^{-4}	0.43
Pitot tube	7.685365×10^{-4}	5.161290323×10^{-4}	0.67

Based on the indirect measures a bar diagram is drawn for the regulating valve half opened condition. The coefficient of performance of venturi meter, orifice meter and pitot tube is drawn by taking C.O.P in Y-axis. From the chart it is clear that venturi meter shows higher performance(i.e.,0.67) when compared to orifice meter which shows C.O.P of 0.43 and C.O.P of pitot tube is 0.67



RESULTS AND DISCUSSION

The coefficient of performance remains almost the same for all the three flow meters even if the density of fluid varies. The flow rate of fluid slightly decreases with decrease in the density of fluid. The c.o.p for venturimeter and pitot tube are higher when compared to orifice meter because orifice plate produces overall pressure loss. The c.o.p of pitot tube decreases drastically when salt water of high density is used.This error often occurs in the pitot tube when the fluid consists of very small particles and this error never occurs in the venturimeter.

Conclusion

Of all the three flowmeters the venturimeter whose c.o.p is not affected at whatever the properties of fluids. The venturimeter is used to measure the volumetric flow rate of effluent water from the industry because it allows the solid particles to flow easily throught its converging and diverging throat. Orifice meter is better when compared to cost wise whereas venturimeter is costly. The C.O.P of orifice meter decreases when the flow rate of fluid is reduced. This is because the accuracy will be higher only if the flow of fluid is maximum. Pitot tube can be used only for the fluids without viscous medium.

REFERENCES

Bansal RK (No Date). *Fluid Mechanics and Hydraulic Machines.*

Chao Sun Lijun Sun, Xiang Qiu, Tao Zhang (2011). Experimental research of averaging Pitot tube with rotameter. *International Conference on Electrical and Control Engineering* 4502 – 4505.

Earle RL and Earle MD (No Date). *Unit Operations in Food Processing*.

Lijun Xu, Wanlu Zhou, Xiaomin Li, Shaliang Tang (2011). Wet Gas Metering Using a Revised Venturi Meter and Soft-Computing Approximation Techniques. *IEEE Transactions on Instrumentation and Measurement* **60**(3) 947 – 956.

Robicsek, Francis (2009). Orifice-Plate Flowmeter for Extracorporeal Circuit. *IRE Transactions on Medical Electronics* **6**(4) 249.