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# Fabrication of an Orifice Meter Using Local Material: Means of Enhancing Technological Innovations and Entrepreneurship

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***Abstract-*** **Creative innovation and Entrepreneurship development is gathering enormous momentum in the world. Inadequate laboratory facilities in most tertiary institution have caused a serious setback in demonstrating the required practicals enshrined in curricula. In this paper a locally fabricated orifice meter was tested. Experiments were conducted to calibrate and test its efficiency compared to ISO standardized apparatus. Results showed that the apparatus is viable and gave same value of discharge and coefficient of discharge as the ISO approved equipment. The lines of best fit in the graph of the fabricated and ISO orifice meters are similar. The apparatus is highly recommended for use in our tertiary institutions.**

***Keyword--*** **Orifice meter, Fabricated, Discharge Coefficient, Orifice plate, PVC material, Reynolds number**

## I. INTRODUCTION

Lack of laboratory equipment in our laboratory is a serious problem that has resulted in graduating half-baked engineers. In some cases the apparatuses are available but are malfunctioning in view of the fact that they have been abandoned. They are abandoned because they are either obsolete or operation manual and effective training of technicians and technologist have being ignored. The apparatuses are sometimes bought in dilapidated condition, painted and showcased for the purpose of securing accreditation in institutions. It was this problem that led to the idea of locally fabricating some laboratory equipment to bridge the gap that has been avoidably created.

In this paper a locally fabricated orifice meter is compared with ISO standardized. Fabrication of orifice meter an important apparatus in hydraulic laboratories in tertiary institutions is imperative. Putting into consideration the huge amount of money spent in importing this apparatus for institutions and the unavailability of its resulted in the motivation of this idea. Our thought here is to fabricate the apparatus using local materials to minimize the cost of production and equally enhances technological innovations and entrepreneurship. Technological and infrastructural development can grow to its apex if drives like this can be encouraged, nurtured, and sustained.

The apparatus is reliable and sustainable because the materials used for its construction are readily available and cheap to purchase.

The apparatus is used for measurement of flow in pipes and the results obtained are used to determine the discharge coefficients of such pipes. It is a conduit that has restriction installed to create a pressure drop. A thin sharp edged orifice is used as the flow restriction. It is necessary to empirically calibrate it before using it for measurement. This is done by passing a known volume through the meter and noting the reading in order to provide a standard for measuring other quantities. In view of the fact that it is easy to construct and duplicate, the thin sharp edged orifice was adopted as a standard. Extensive calibration work was done so that it is widely accepted as a standard means of measuring fluids. Provided the standard mechanics of construction were followed therefore no further calibration is required.

## II. LETERATURE REVIEW

[1] discussed extensively on orifice flow rate, plate coefficient of discharge, velocity of approach factor, expansive factor, and Reynolds number. Flange taps are a pair of tap holes positioned as in Plate 1 and 2. The upstream tap centre is located 1 inch (25.4 millimeters) upstream of the nearest plate face while the downstream tap centre is located 1 inch (25.4 millimeters) downstream of the nearest plate face.

[2] gave good account of the history of orifice meter. He stated that Giovanni B. was the first in record times to discuss of the use of orifices for the measurement of fluids. Clemons Herschel in 1886 developed the modern Venturi meter modelled from the work of Venturi, an Italian Physicist, who in 1797 planted and cultivated the idea. It is on record that by Professor Robinson of Ohio State University designed an orifice meter that was used to measure gas near Columbus, Ohio, in about 1890. Mr. T.B. Weymouth began a series of tests in Pennsylvania leading to the publication of coefficients for orifice meters with flange taps in 1903. In the same vain Mr. E.O. Hickstein carried out similar series of tests at Joplin, Missouri, from which he developed data for orifice meters with pipe taps.

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The American Gas Association and the American Society of Mechanical Engineers has being in serious business of conducting series of research and experiments from 1924 and 1935 in developing orifice meter coefficients and standards of construction for orifice meters. In 1935 a joint A.G.A. - A.S.M.E. report was issued title "History of Orifice Meters and The Calibration, Construction, and Operation of Orifices for Metering." This report is the basis for most present day orifice meter measurement installation. In 1991 an updated version of this standard based on new data was issued by A.P.I. titled: Manual of Petroleum Measurement Standards, Chapter 14, Section 3, Parts 1-4.

*A. Orifice Meter*

In view of [3], an orifice meter is essentially a cylindrical tube that contains a plate with a thin hole in the middle of it. The thin hole essentially forces the fluid to flow faster through the hole in order to maintain flow rate. The point of maximum convergence usually occurs slightly downstream from the actual physical orifice this is the reason orifice meters are less accurate than Venturi meters, as we cannot use the exact location and diameter of the point of maximum convergence in calculations. Beyond the vena contracta point, the fluid expands again and velocity decreases as pressure increases. Plate 2 below shows the orifice meter with the variable position of vena contracta with respect to plate. Orifice meter uses the same principle of continuity equation and Bernoulli principle to calculate the volumetric flow rate, as shown above for Venturi meter.

So,

$$Qa = V_2 S_2 = \frac{C_0 S_2}{\sqrt{1-\beta^4}} \sqrt{2g\Delta H} \qquad (1)$$

Where $C_0$ is the orifice discharge coefficient. Given that the Cross sectional area of throat in Venturi meter

($S2$) = 1.54*10-4 $m^2$

Ratio of diameter of throat to pipe ($\beta$) = 0.4904

[4] discussed in detail the design and development of primary orifice flow meter. They stipulates that accurate and stable gas flows are very important in different applications like, the performance study of vacuum pumps, gauge calibration, leak detection and advance research in low pressure physics. Their results showed that variation in discharge has been observed with a change in temperature of orifice and orifice diameter.

*B. Orifice Meters Standards*

[5] buttresses much emphasis on orifice meter standards. He explains that the primary devices measure pressure difference Δp produced by flow passing an obstruction. [2] gave good account of orifice plate coefficient of discharge ($C_d$).

To accurately use these coefficients, the orifice meter must be manufactured to the specifications of Chapter 14 - Natural Gas Fluids Measurement of the manual of Petroleum Measurement Standards Section 3 Concentric, Square edge AGA Report No. 3, Part 2 and GPA 8185-9, Part 2 also exhaustively explain Orifice Meters Specifications and Installation Requirements. Refer to plate 3 for details. Reynolds number and the coefficient of discharge vary with pressure, temperature, viscosity and flow [5]. The differential pressure between the upstream and downstream section of the orifice plate, due to the energy exchange can be used as a measure of the difference in fluid velocity between these sections, and is the principle behind flow meters which use a constrictive device to produce a differential pressure as shown in Plate 4. Pressure taps can be positioned at a variety of different locations [6].

*C. Measuring Principle of an Orifice*

[5] dwelled so much on the measuring principle of an orifice. In is analysis, He assumed that the flow is incompressible and continues. The flow obeys continuity equation and Bernoulli's theorem. Incompressibility here means density does not change ($\rho_2 = \rho_1$) while Continuity stipulates that flow is the same every where in the pipe ($q_{m1} = q_{m2}$). The section s-s represents the orifice while 1 and 2 are the upstream and downstream tapings of flow respectively. The taping is used for measuring the change in the upstream and downstream pressure head. This is usually the value of h used for computation of the discharge through the orifice. D and d are the pipe and orifice diameter respectively. $A_2$ is the area of the smallest flow. See plate 5 for more details.

Bernoulli's equation on energy conservation stipulates that the change in pressure in a pipe flow is the product of half the density of the fluid and the difference in the square of the final and initial velocity.

*Invoking Bernoulli's equation*

$$\rho_1 = \frac{1}{2}\rho_1 u_1{}^2 = \rho_2 = \frac{1}{2}\rho_2 u_2{}^2 = p_o \qquad (2)$$

Where ,

$p_0$ is the total pressure in medium

$p = p_0$ where u=0

The sum of static and dynamic pressure is the same everywhere in pipe.

$$\Delta p = p_1 - p_2 = \frac{\rho}{2}\left(u_2{}^2 - u_1{}^2\right) \qquad (3)$$

Where,

$\frac{\rho}{2}u^2$ is the dynamic pressure of the flow

*Invoking continuity equation*

$$q_m = A.\rho.u \qquad (4)$$

But,

$$u_1^2 = \frac{4^2 q_m^2}{D_1^4 \pi^2 p^2} \quad \text{and} \quad u_2^2 = \frac{4^2 q_m^2}{D_2^4 \pi^2 p^2} \qquad (5)$$

Replacing the speed terms through geometric measures and inserting it in the above equation.

$$\Delta p = \frac{\rho}{2} \times \frac{4^2 q_m^2}{\pi^2 p^2}\left(\frac{1}{D_2^4} - \frac{1}{D_1^4}\right) \qquad (6)$$

$$\Delta p\, D_2^4 = \frac{\rho}{2} \times \frac{4^2 q_m^2}{\pi^2 p^2}\left(\frac{D_2^4}{D_2^4} - \frac{D_1^4}{D_1^4}\right) \qquad (7)$$

$$2.\Delta p\, \rho \pi^2 D_2^4 = 4^2 q_m^2 \left(1 - \frac{D_2^4}{D_1^4}\right) \qquad (8)$$

Calculating for the discharge $q_m$

$$q_m = \frac{1}{\left(1 - \frac{D_2^4}{D_1^4}\right)} \frac{\pi^2}{4^2} D_2^4.2\Delta p.\rho \qquad (9)$$

Exchange unknown $D_2$ with known and introduce a discharge coefficient C relating the unknown diameter $D_2$ to the known orifice diameter d. It is important to introduce an expansion coefficient ε for compressible media like gas, steam.

$$\beta = \frac{d}{D} \qquad (10)$$

Hence,

$$q_m = \frac{C}{\left(\sqrt{1-\beta^4}\right)}.E.\frac{\pi}{4} d^2.\sqrt{2\Delta p.\rho_1} \qquad (11)$$

To compute the discharge $q_m$, measure the Δp from the tapings and then use the value obtained with all other constant to substitute in the above derived discharge equation. According to [10], pipe Reynolds number ($R_e$) is a dimensionless ratio of forces used to correlate the variations in the orifice plate coefficient of discharge *($C_d$)* with changes in the fluid's properties, flow rate, and orifice meter geometry. In the account of [] the differential pressure ($D_P$) devices work on a principle based upon the Law of Conservation of Energy, where a restriction in the fluid path causes an acceleration in the fluid velocity and hence an increase in kinetic energy. The drop in pressure and the flow rate are linked by the following (albeit simplified) relationship:

$$Q = k \sqrt{h} \qquad (12)$$

Where Q= fluid flow rate

k = a constant for that $d_p$ device

h = the pressure difference across the restriction

The graph in figure 1 illustrates how the net head loss percentage differential behaves with the effective area ratio.

*D. Calibration of Orifice Plate*

[8] explains how an orifice plate can be calibrated. He established that a perhaps better way to calibrate a sharp-edge orifice plate in pipes is based on the flow rate equation stated below

$$Q_M = C_d A_2 \frac{\sqrt{2g\Delta h(sg-1)}}{\sqrt{(1-\beta^4)}} \qquad (13)$$

[9] also gave detail explanation demonstrated above. The discharge and coefficient of discharge can also be determined in the experiment for the control and fabricated apparatus using the relation below

$$Q \equiv KH^n \qquad (14)$$

$$Q(Theoritical) \equiv \left[(a1 * a2 * Cd) \Big/ \sqrt{((a1^2)-(a2^2))}\, m^3/\sec\right] \qquad (15)$$

$$Cd \equiv \left[Q(Theoritical) * \sqrt{((a1^2)-(a2^2))}\, m^3/\sec \Big/ (a1 * a2)\right] \qquad (16)$$

n ≡ 0.5 (approximately)

Where,

Qth ≡ Theoretical discharge

$A_1$ ≡ c/s area of the inlet= c/s area of the pipe a

$A_2$ ≡ c/s area of the throat

H ≡ head (in meters of fluid flowing through the pipe)

$$H \equiv h * ((S_1/S_2)-1)$$

h ≡ differential manometer reading (difference in limb 1and limb 2)

where

$S_1$ ≡ Specific gravity of manometer liquid

$S_2$ ≡ Specific gravity of fluid in the pipe.(ie, water and $S_2$=1)

The actual flow rate is expected to be less than that given by the equation above because of frictional effects and consequent head loss between section at inlet and throat.

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In practice it is customary to account for this loss by insertion of an experimentally determined co-efficient known as coefficient of discharge.

$C_d \equiv Q$ (actual)/Q(Theoretical) (17)

[9] modeled the coefficient of discharge for a circular pipe and orifice plate in which upstream tap is located at a distance $D_1$ from the plate and downstream tap is a distance $1/2D_1$.

$$Cd = 0.5959 + 0.0312\beta^{21} - 0.184\beta^{8} + \frac{0.039\beta^{4}}{1-\beta^{4}} - 0.0158\beta^{3} + \frac{91.71\beta^{25}}{R_e^{0.75}} \quad (18)$$

Where $R_e$ is the Reynolds number.

Similar $C_d$ equation exists for other orifice plate configuration. The Reynolds's number is a function of the flow rate, so the solution is iterative. The calculated value of $C_d$ is typically very near a 0.6. so it is taken as the initial value, usually only one of two iterations are needed. Hence the calibration shall be done using the procedure explained in the methodology.

## III. MATERIALS

The standard material used by [7] for orifice plates is stainless steel to ASTM A240 316/316L. Other materials can be used if required and these include 304 SS; 321 SS; Alloy 400; Alloy 825; Alloy C276; Titanium; Alloy 625; 22Cr Duplex stainless steels; 25Cr Super Duplex stainless steels; 6 No stainless steel; 90/10 Cu/Ni, PTFE.

### *A. Plate thickness*

The thickness of the orifice plate does depend significantly upon the application and design conditions but, typically, a CSE plate will have the a minimum thicknesses of 3mm ( 0.12 in.)for pipe sizes from 25 to 250mm (1 to 10 in.), 6mm (0.24 in.) for pipe sizes from 300 to 600mm (12 to 24 in.), 10mm (0.4 in.) for pipe sizes from 600 to 1000mm (24 to 40 in.), For high differential pressures, larger pipe sizes and for some Conical Entry, Quarter Circle and Restriction orifice plates, a greater thickness may be required. The actual plate thickness can be determined during calculations.

### *B Orifice Plates Opening*

To create differential pressure in the monometer taping, the openings are usually smaller than the diameter of the pipe. The shape are usually circular however, square, oval, triangular, and other shapes also exist.

The materials used for the construction include 381mm, PVC Pipe, 25.4mm PVC Pipe, 381mmGate valve, 381mm Union, 381mm to 25.4mm Reducer, 381mm Elbow, 8mm Nuts, 8mm Drill bit and drilling machine, 10mm transparent perspex glass plate, 3mm colored Perspex plate, 8mm bolt and nuts , 8mm screws, 8mm clip, 3psi pressure gauge, Petot tube for tapping, 150mm thick 381mm flange with bolt and nut, Orifice plate, PVC gum, Aluminum paint and spraying machine

## IV. METHODS

Locally available materials were used to construct the orifice meter. The apparatus was be fabricated and calibrated as per [8]. Plate V-X shows the model of the orifice that was fabricated based on design standard. Calibration of the orifice plate includes the following procedure Specifying T, $\Delta h$, $\alpha_{0\rho}$ and $\alpha_p$,Calculating or specifying $\rho$ and $\upsilon$, $D_1$ and $D_2$, $\beta = \frac{D_1}{D_2}$, Let $C_d$ =0.60, Q, $R_e$, $C_d$ and Iterate the calculation for Q, $R_e$, $C_d$ until Q converges to the desired precision.

### *A. Experimental Setup*

The set up consisted of a long horizontal pipe line. A thin plate having a concentric circular edge of diameter "d" was fitted in the pipe line. Sufficient straight length is provided on the upstream of the orifice plate. The valve was fitted at the end of pipe to regulate the discharge Q. The pressure tapings, one on the upstream side (inlet pipe) and the other on the downstream side positioned at 0.5 percent the distance of the upstream to the orifice plate. A u-tube mercury manometer was used to measure the pressure difference between section 1and 2. A stop watch was also used to measure time. Procedure for running the experiments included closing the valves of inlet pipe orifice meter pipe line and manometer, the gate valve of the pipeline selected for the experimentation was opened, the needle valves of the corresponding manometer and orifice meter were also opened, the control valve kept at the exits side of the orifice were adjusted to a desired flow rate and maintained the flow, the readings of manometer and final reading of discharge tank for interval of 30 seconds were noted. Finally the gate valves were adjusted and the experiment repeated.

## V. RESULT

The following result were obtained from the experiment conducted using an imported orifice meter in the laboratory as our control and the fabricated orifice meter for the other data.

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**TABLE I:**
**FLOW DETERMINATION FOR ORIGINAL ORIFICE METER (CONTROL EXPERIMENT)**

| S/N0. | INITIAL DEPTH OF $H_2O(mm^2)$ $(h_1)$ | FINAL DEPTH OF $H_2O(mm^2)$ $(h_2)$ | COLLECTED DIFFERENCE $(mm^2)$ (H) | VOLUME OF $H_2O$ COLLECTED $V(m^3)$ | TIME (sec) T | FLOW $(m^3/s)$ Q |
|---|---|---|---|---|---|---|
| 1. | 7.50 | 12.50 | 5.00 | 0.0670 | 30 | 0.0022 |
| 2. | 13.75 | 19.00 | 5.20 | 0.0759 | 30 | 0.0025 |
| 3. | 21.25 | 27.25 | 6.00 | 0.0880 | 30 | 0.0029 |
| 4. | 28.75 | 37.50 | 8.75 | 0.0970 | 30 | 0.0032 |
| 5. | 38.75 | 49.25 | 10.50 | 0.1164 | 30 | 0.0039 |

**TABLE II:**
**FLOW DETERMINATION FOR FABRICATED ORIFICE METER EXPERIMENT**

| S/N0. | INITIAL DEPTH OF $H_2O(mm^2)$ $(h_1)$ | FINAL DEPTH OF $H_2O(mm^2)$ $(h_2)$ | COLLECTED DIFFERENCE $(mm^2)$ (H) | VOLUME OF $H_2O$ COLLECTED $V(m^3)$ | TIME (sec) T | FLOW $(m^3/s)$ Q |
|---|---|---|---|---|---|---|
| 1. | 7.2 | 12.29 | 5.09 | 0.0715 | 30 | 0.0024 |
| 2. | 12.84 | 19.12 | 6.28 | 0.0879 | 30 | 0.0029 |
| 3. | 20.97 | 30.04 | 9.07 | 0.1008 | 30 | 0.0034 |
| 4. | 27.82 | 37.37 | 9.55 | 0.1086 | 30 | 0.0036 |
| 5. | 37.23 | 48.43 | 11.2 | 0.1168 | 30 | 0.0039 |

**TABLE III:**
**COEFFICENT OF DISCHARGE FOR CONTROL EXPERIMENT (CONTROL EXPERIMENT)**

| S/N 0 | COLLECTED DIFFERENCE $(mm^2)$ $H= (h_1- h_2)$ | $H^{1/2}$ $(mm^2)$ $(h1- h2)^{1/2}$ | FLOW $(m^3/s)$ Q | VELOCITY OF FLOW $(m/s^2)$ | | REYNOLDS NUMBER $(R_e)$ | DISCHARGE COEFFICENT $(C_d)$ |
|---|---|---|---|---|---|---|---|
| | | | | V INLET | V THROAT | | |
| 1. | 5.00 | 2.24 | 0.0022 | 4.4816 | 1.9295 | 73,235 | 0.55 |
| 2. | 5.20 | 2.28 | 0.0025 | 5.0923 | 2.1926 | 83,221 | 0.62 |
| 3. | 6.00 | 2.45 | 0.0029 | 5.9070 | 2.5434 | 96536 | 0.72 |
| 4. | 8.75 | 2.96 | 0.0032 | 6.5181 | 2.8065 | 104,642 | 0.79 |
| 5. | 10.50 | 3.24 | 0.0039 | 7.9439 | 3.4205 | 129,827 | 0.97 |

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TABLE IV:
COEFFICENT OF DISCHARGE FOR FABRICATED ORIFICE METER EXPERIMENT

| S/N0 | COLLECTED DIFFERENCE ($mm^2$) H= ($h_1$- $h_2$) | $H^{1/2}$ ($mm^2$) $(h1- h2)^{1/2}$ | FLOW (Q) ($m^3/s$) | VELOCITY OF FLOW ($m/s^2$) | | REYNOLDS NUMBER ($R_e$) | DISCHARGE COEFFICENT ($C_d$) |
|---|---|---|---|---|---|---|---|
| | | | | V INLET | V THROAT | | |
| 1. | 5.09 | 2.26 | 0.0024 | 4.8886 | 2.1049 | 79,893 | 0.60 |
| 2. | 6.28 | 2.30 | 0.0029 | 5.9070 | 2.5434 | 96536 | 0.73 |
| 3. | 9.07 | 2.46 | 0.0034 | 6.9255 | 2.9819 | 113,180 | 0.85 |
| 4. | 9.55 | 3.09 | 0.0036 | 7.3329 | 3.1573 | 119836 | 0.90 |
| 5. | 11.2 | 3.35 | 0.0039 | 7.9439 | 3.4200 | 192808 | 0.97 |

**Table V:**
**Dynamic Viscosity And Density Of Water At Different Temperature**

| TEMPERATURE OF WATER (t) $^0C$ | DYNAMIC VISCOSITY OF WATER (μ) $(Ns/m^2)x10^{-3}$ | DENSITY OF WATER ρ $kg/m^3$ |
|---|---|---|
| 0 | 1.787 | 999.8 |
| @ 5 for (μ) and 4 for ρ | 1.519 | 1000 |
| 10 | 1.307 | 999.7 |
| 20 | 1.002 | 998.2 |
| 30 | 0.798 | 995.7 |
| 40 | 0.653 | 992.2 |
| 50 | 0.547 | 988.1 |
| 60 | 0.467 | 983.2 |
| 70 | 0.404 | 977.8 |
| 80 | 0.355 | 971.8 |
| 90 | 0.315 | 965.3 |
| 100 | 0.282 | 958.4 |

The graph of the control and fabricated experiment for discharge against head and square root of head are hereby presented below.

## VI. Discussion

Calculations were performed in accordance with [11] Other calculation standards available, including: ASME, API, R W Miller, L W Spink, Pressure loss is typically between 40 and 95% of the generated differential pressure, dependent on the throat ratio (d/D).

The following parameters were used to calculate the Reynolds number, discharge coefficient and discharge presented in the results. $d_1$=0.025m, $d_2$=0.0381mm, $A_1$= 4.9094 x $10^{-4}$ $m^2$ and $A_2$= 1.14024 x $10^{-3}m^2$, μ= 1.002, ρ=998.2, t = 20°C

Substituting the above parameter into equation 16, the discharge coefficient of the five experiments conducted for the control and fabricated orifice meter apparatus are 0.55, 0.62, 0.72, 0.79, 0.97 and 0.60, 0.73, 0.85, 0.90, 0.97 respectively. The discharge for the control and fabricated apparatus are 0.0022, 0.0025, 0.0029, 0.0032, 0.0039 and 0.0024, 0.0029, 0.0034, 0.0036, 0.0039 respectively. Refer to Table II and III for details. The Reynolds number is calculated according to The Engineering Toolbox (2015). Reynolds number is calculated using the relations Re = Dvρ/μ where D is the diameter of pipe, *v* is the velocity of flow, ρ is the density of water, μ is the dynamic viscosity of water. The dynamic viscosity and density of water at $20^0C$ as per The Engineering Toolbox was used to calculate the Reynolds number. The Reynolds number presented in table IV and V showed that the flow is a turbulent flow since Reynolds number is greater than 4000 for all the experiment performed.

Tables I and II show how the flow in the orifice for both the control and fabricated apparatus can be determined. The results show an increase in the discharge from the first experiment to the fifth experiment.

This can be achieved by gradually increasing the inlet gate valve and reducing the outlet gate valve. This will consequently result in increased head of the tapping from 7.5 to 12.5 and 7.2 to 12.29 for the first experiment performed for control and fabricated apparatus respectively. Table III and IV presented the results for the coefficient of discharge can be computed. The average values of discharge coefficient for control and fabricated apparatus experiment are 0.73 and 0.81 respectively. This is caused by the internal surface roughness of the pipes. The fabricated apparatus experience higher head loss that accounts of its lesser discharge shown in table I, II, III and IV. Figure I to III represents graph of discharge (Q) against head (H), discharge (Q) against ( $\sqrt{H}$ ), and Cd against H. The graphs in table I and II showed that an increase in discharge from the orifice results to simultaneous increase in the tapping heads (H) and square root of the heads ( $\sqrt{H}$ ) respectively. Table III showed that an increase in the discharge coefficient caused by increased discharge results in a corresponding increase in the taping head. Table III and Figure IV showed that there is an increased velocity at the throat where the orifice plate is located. This is caused by reduction in the diameter of pipe. The velocity at the inlet is smaller than that of the throat for both apparatus. Consequently, both graph exhibit similar curves.

## VII. Conclusion

The coefficient of discharge is influenced by accurate time management. Higher frictional loss is expected when using the fabricated apparatus compared to the control apparatus. However orifice meter has higher head loss compared to other flow measuring device. The results obtained for the Reynolds number, discharge and discharge coefficient also agree with the empirical relation for the already standardized and fabricated apparatus.

Within the limits of the experimental certainty, the Reynolds number range investigated, the results obtained for the discharge coefficient, discharge, velocity at the inlet and orifice plate agrees with the empirical relation for the control and fabricated apparatus.

## VIII. Recommendation

The fabricated orifice meter is highly recommended for use in laboratories because it is reliable, sustainable and meets required standard.

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## APPENDICES

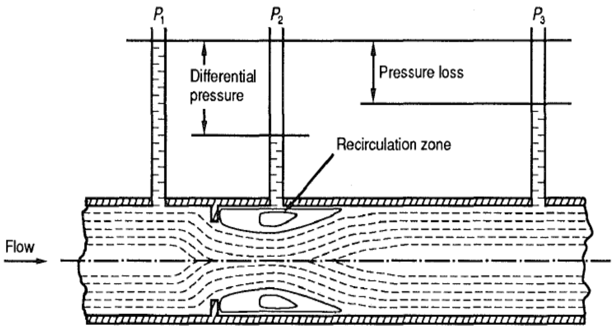


**Plate I:**
**Orifice Taping Location**

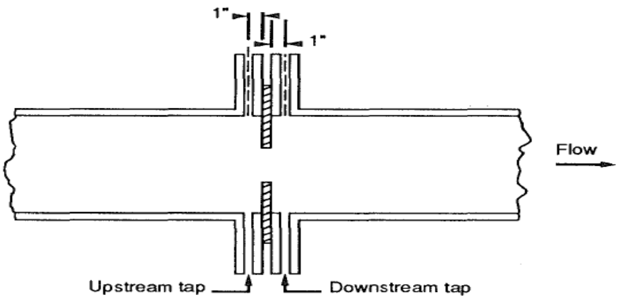


**Plate II:**
**Flange-Tapping Location**

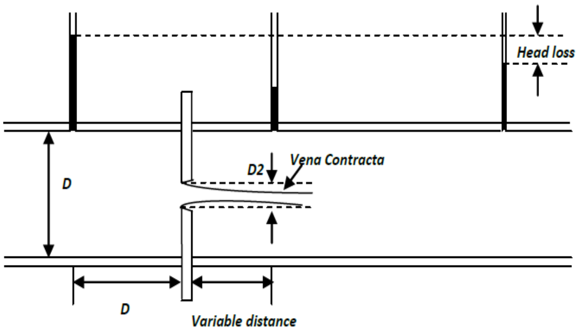


**Plate III:**
**Orifice Meter**

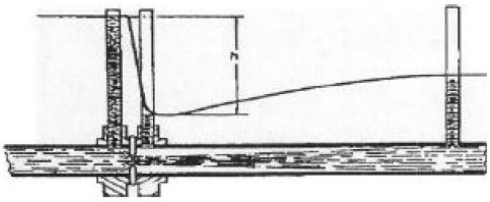

**Plate IV:**
**Differential Pressure of an Orifice**

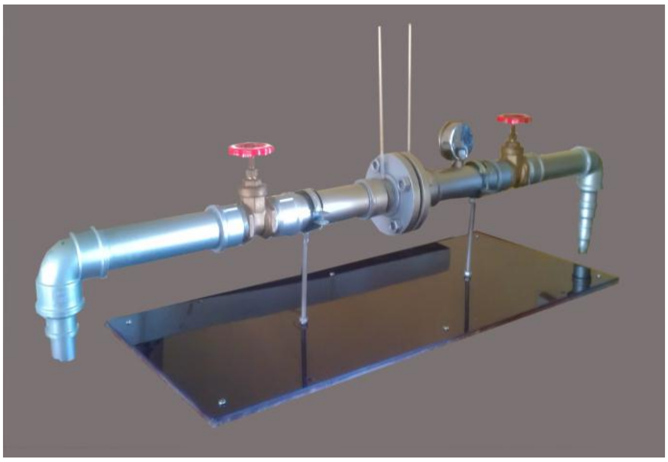

**Plate V:**
**3D View of Fabricated Orifice Meter Showing the Back**

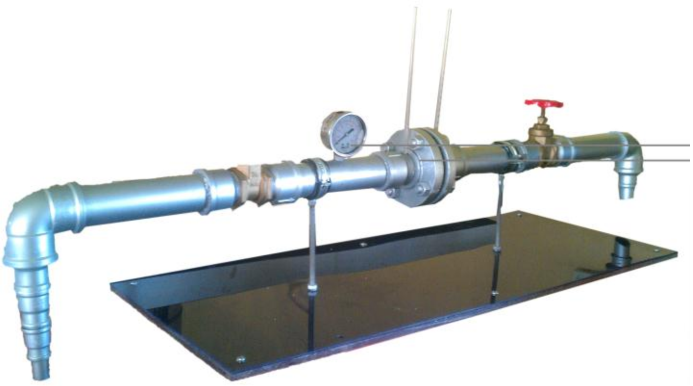

**Plate VI:**
**3D View of Fabricated Orifice Meter Showing the Front**

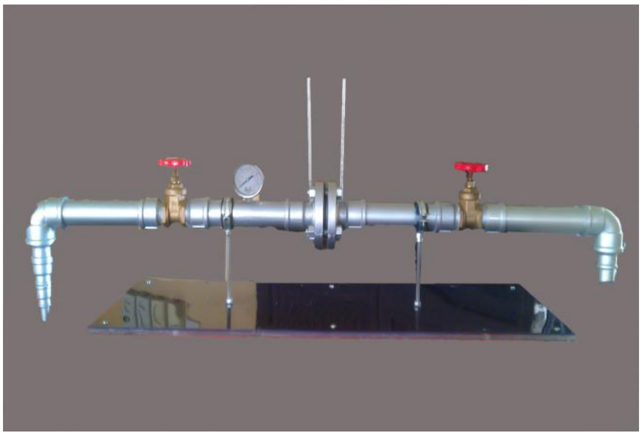

**Plate VII:**
**Front View of Fabricated Orifice Meter**

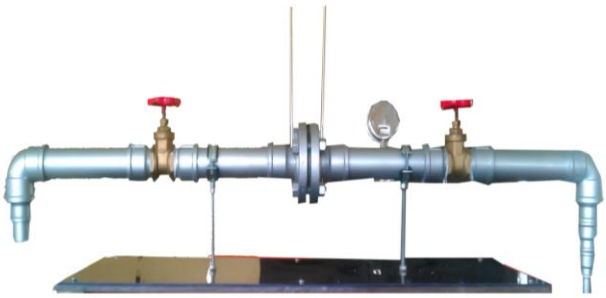

**Plate VIII:**
**Rear View of Fabricated Orifice Meter**

**Plate IX:**
**Side View of Fabricated Orifice Meter**

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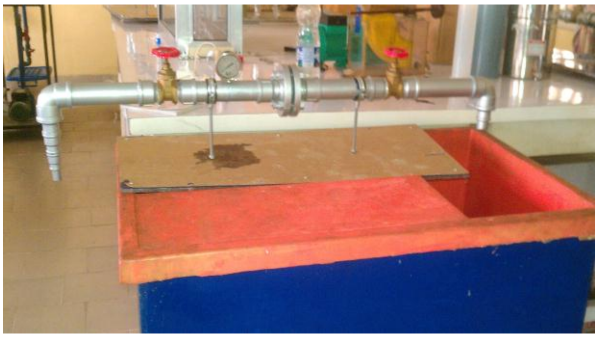

**Plate X:**
**Fabricated Orifice Meter on a Hydraulic Bench**

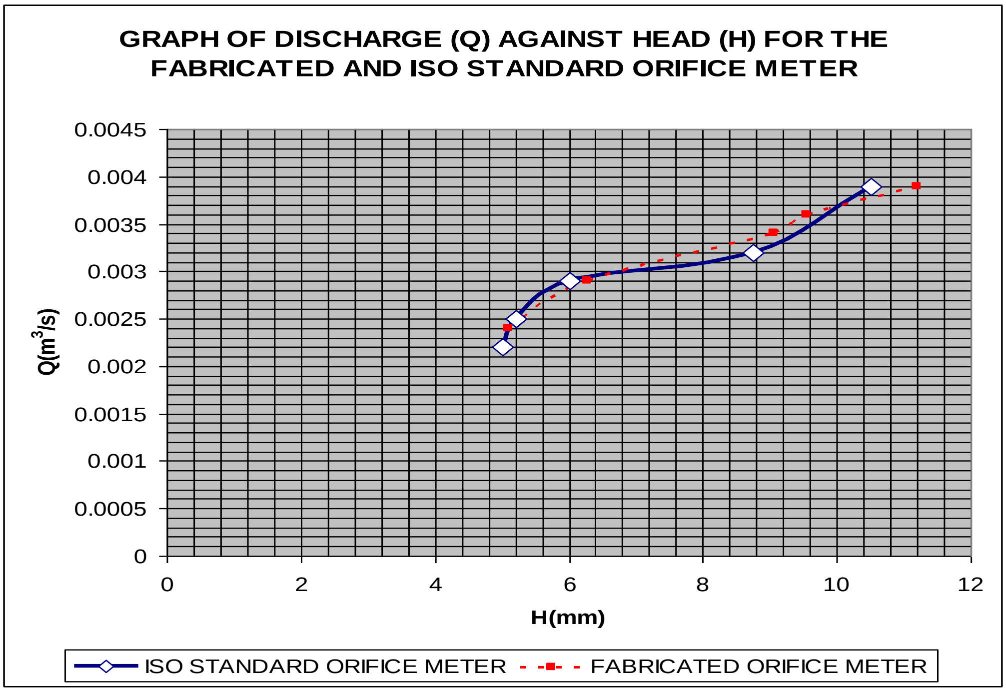


**Figure I: Graph of Discharge (Q) Against Head (H) For the Fabricated and ISO Standard Orifice Meter Experiment**

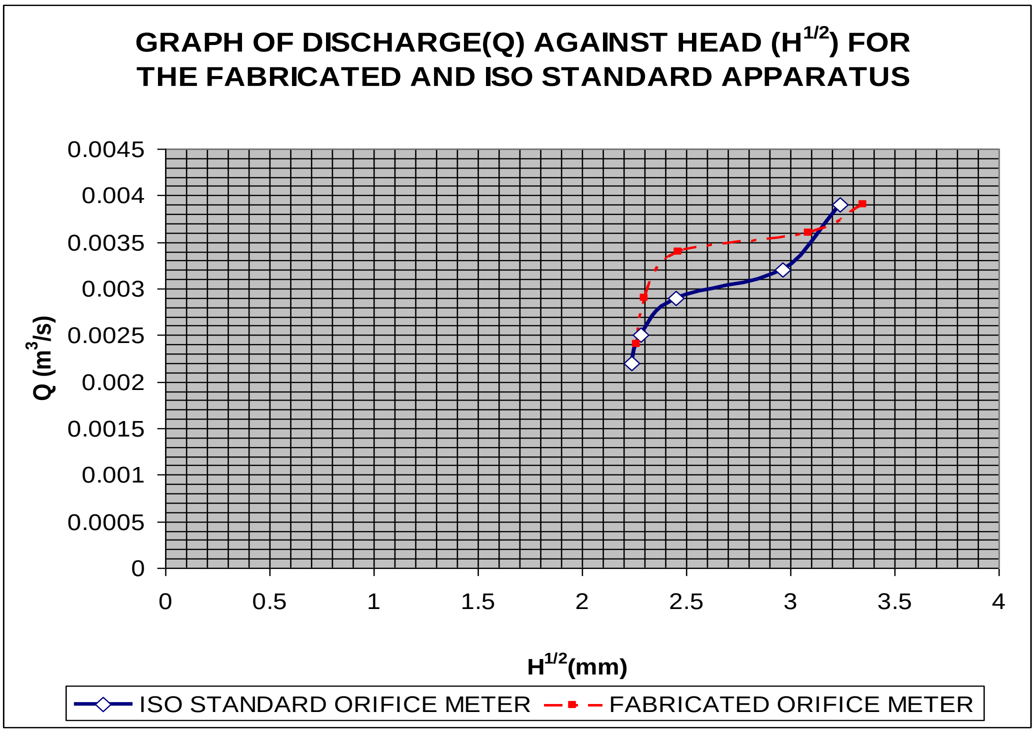


**Figure II: Graph of Discharge (Q) against Head ( $\sqrt{H}$ ) for the Fabricated and ISO Standard Experiment**

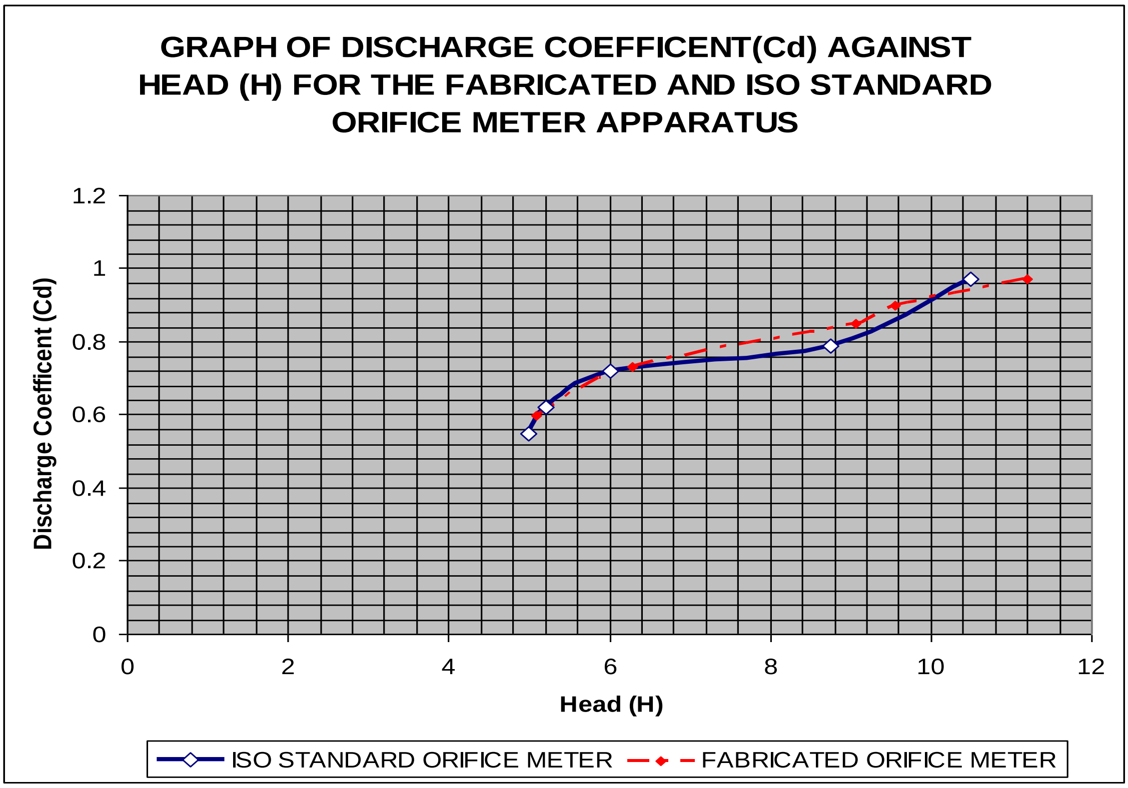


**Figure III: Graph of Discharge Coefficient ($C_d$) against Head (H) for the Fabricated and ISO Standard Experiment**

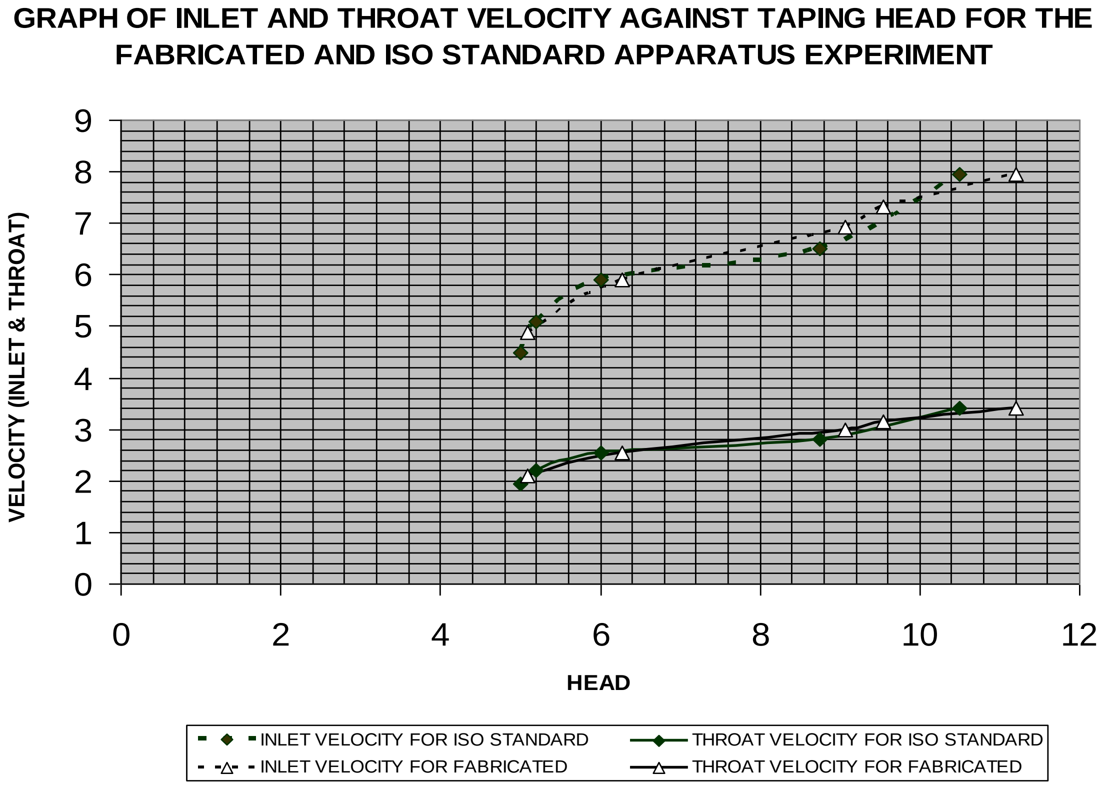


**Figure IV: Graph of Velocity at the Inlet and Throat of the Orifice Meter against Taping Head for Fabricated and ISO Standard Apparatus Experiment**