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EXPERIMENTAL DETERMINATION OF DISCHARGE COEFFICIENTS FOR ORIFICES METERS IN A UNIT OPERATIONS LABORATORY

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ABSTRACT

At the Faculty of Chemistry of the UNAM the future chemical engineers perform laboratory practices where they put to the test their skills in the areas of knowledge, skills and attitudes. This article shows the way in which they determined coefficients of discharge on orifice meters.

KEY WORDS: *Discharge coefficients, orifices meters, experiments, unit operations, competencies.*

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I-INTRODUCTION

One of the peculiarities of the current teaching is the emphasis that is made in obtaining skills that requires a professional to practice with success. In the laboratory of Chemical Engineering from the Universidad Nacional Autónoma de Mexico, UNAM, chemical engineering students performed laboratory practices that allow them to put into practice their skills in the areas of knowledge, skills and attitudes. Among the practices carried out , we present this article which is related to the experimental obtaining of the so-called coefficients of discharge on the orifice meters.

I.1.-Orifice meters.

In all industries, it is necessary to measure the amount of material that goes through the different parts of the plant, for this purpose are commonly employed flow meters, measuring the amount of flow that is going through a duct, pipe or hose. Many flow meters are based on the restriction of the area of flow, which causes a drop in pressure which can be measured. This pressure drop is associated with the velocity and if you know this and the flow area you can obtain the flow passing through the duct , and if the density of the fluid is known then the amount of material will be known. Among the most frequently used flow meters are the orifice, nozzle, venturi and rotameters. Each one has advantages and disadvantages.

1.2 Theory.

Orifice meters consist of a reduction in the flow of a pipe section, so there is a pressure drop, increasing the velocity as a result. This is achieved through the incorporation of an orifice plate in the pipe, which is fastened by means of flanges. Orifice plates can be of different diameters, always smaller than the diameter of the pipe where it is inserted. The pressure drop between points situated before and after the hole is essential to measure the flow of fluid. [1]

See fig. 1.

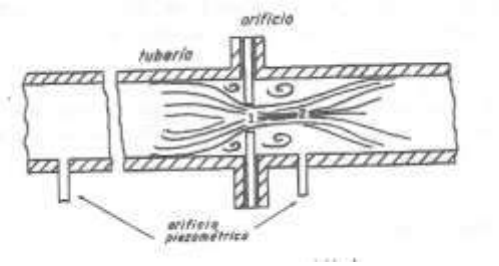


Fig.1. An orifice meter scheme.

Making a balance of energy between the orifice (point 1) and the rear section (point 2) and despising the losses by friction we have:

$$\frac{v_1^2}{2gc} + \frac{P_1}{\rho} = \frac{v_2^2}{2gc} + \frac{P_2}{\rho} \quad (1)$$

For an incompressible fluid:

$$v_2 = v_1 \left(\frac{D_1}{D_2}\right)^2 \quad (2)$$

Replacing:

$$\frac{1}{2gc}\left\{v_1^2 - v_1^2\left(\frac{D_1}{D_2}\right)^4\right\} = \frac{\Delta P}{\rho} \quad (3)$$

Clearing v_1 and knowing that D_o is the diameter of the orifice then:

$$v_1 = \sqrt{\frac{2gc\left(\frac{\Delta P}{\rho}\right)}{1-\left(\frac{D_o}{D_2}\right)^4}} \quad (4)$$

In the case that we consider the losses by friction, it is necessary to add a coefficient of orifice Co and equation (4) is transformed into:

$$v_1 = Co\sqrt{\frac{2gc\left(\frac{\Delta P}{\rho}\right)}{1-\left(\frac{D_o}{D_2}\right)^4}} \quad (5)$$

Being v_1 the velocity into the orifice.

II. EQUIPMENT USED

The experimental part was developed in the "Pumping module" [2] Hydraulics in the Laboratory of Chemical engineering (Fig. 2), composed as indicated in the technical data (table No. 1)

Fig. 2 "multiple pumping module" [MBM]

Table 1. Technical details of the "multiple pumping module" [MBM]	
Components	**Specifications**
Centrifugal pump	Brand: Weg. Model: MSL MJ Electric Motor Single phase of: 3/4 HP, 60 Hz. 110 volt RPM:3370 Suction diameter: 1 1/4 inch diameter in the Download: 1.0 inch
Centrifugal pump	Brand: Weg. Model: MSL MJ Electric Motor Single phase of: 1.0 HP, 60 Hz. 110 volt RPM:3490 Suction diameter: 1 1/4 inch diameter in the Download: 1.0 inch
Centrifugal pump	Brand: Weg. Model: MSL Electric Motor 3910 MJ single phase of: 1 1/2 HP, 60 Hz. 110 volt RPM: 3410 suction diameter: 1 1/4 inch diameter in Download: 1.0 inch
2 tank containers	Building material: polyethylene capacity: 120 litres with level indicator
Structures	Aluminum to withstand bombs and iron fittings to support tank containers
Pressure gauges	6 different brands gauges and measuring ranges installed in the suction and discharge of each pump
Rotameter	Range from 0 to 250 L/min.
Pipes	Suction pipe: nominal diameter 1-1/4 inch copper Download: nominal diameter 1.0 inch copper
Gauge pressure transmitters	2 multiple connections to measure the pressure of suction and the unloading of each to the pump. 1 to measure the pressure drop in orifice plate

III. EXPERIMENTAL PROCEDURE

For the development of the practice the students **before** starting the experiment must :

1. Make sure there is no power at the control panel**,** for which (by referring to Fig. No 3), check that the knob marked with no. 1 is in position **off** otherwise turn to this position

2. Check that the pump power supply water to the tank marked with the No. 3 (for operating in a closed circuit).The tank must contain water at the level which is indicated, otherwise, fill it through the replenishment of water system.

3. Alignment of the experimental system. There are several possibilities of trajectories of the pipes which presents the pumping module. Select the trajectory which allows to connect the output of the water reservoir (marked with the No. 3 in Fig. 3) with the suction of the centrifugal pump 0.75 HP, so the discharge of the pump goes to the rotameter, the orifice plate and the return of water back to the tank (3 Fig. 3)

4. Activation of the control cabinet. Pull the emergency stop (Fig. 3) place the knob position **on** (Fig. 3)

5. Start. Once done all the actions as directed from above, press the.75 HP pump start button in the control panel (No. 4, Fig. 3).Observe the water circulating through the path given in item **3.**

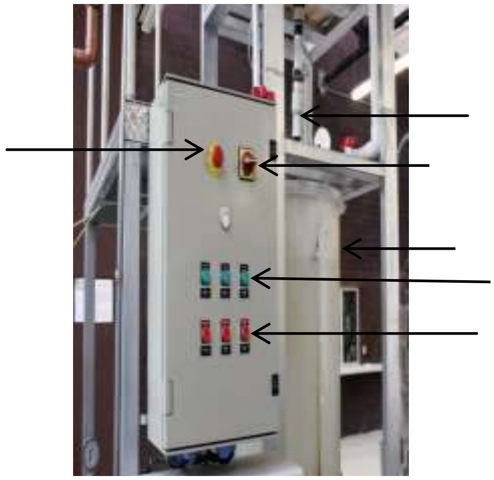
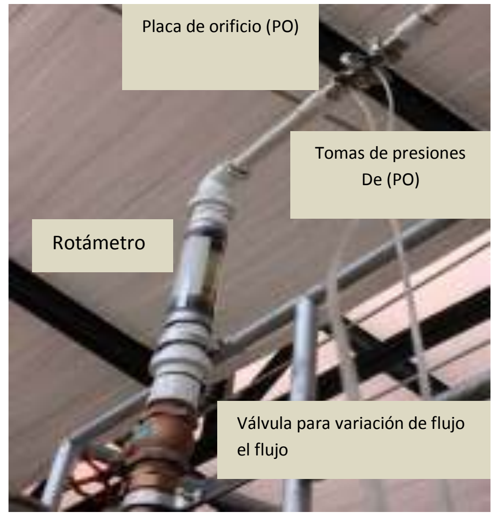


Fig. 3 Control panel



IV. EXPERIMENTAL DATA

4-1. Volumetric flow measurement. Once the system is in operation, determine the maximum flow and minimum in liters per minute, which can be registered on the operating valve rotameter (shown in Fig. 3b). Within this interval (start with the lowest and end with the maximum) Then scoring the specify flows in **table no. 3 of data**.

4-2. Measurement of the pressure drop in the plate orifice **Fig. (5 e)**

This variable is taken directly for each stream in the gauge pressure transmitter indicated on the Fig.4 for its subsequent annotation in the corresponding column in the **table no. 3 of data**

Fig. 4 - Gauge pressure transmitter

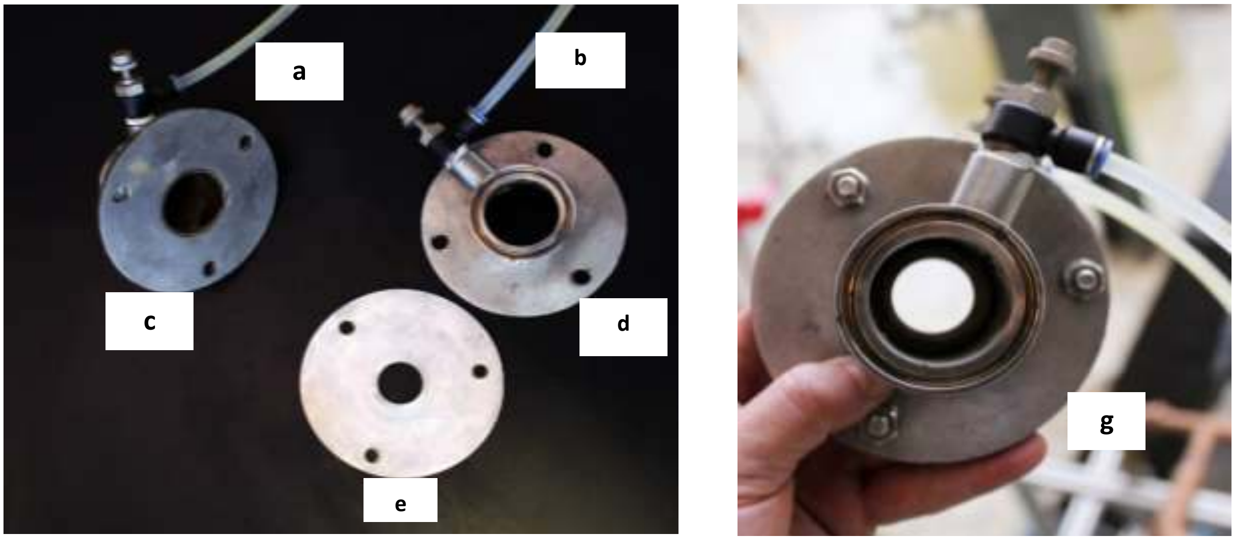


Fig. 5.- Orifice plates (e), Pipe flanges (c, d), High and lower pressure tappings (a, b) Orifice plate assemble (g)

Following the instructions of the punt .4-1 the range of minimum and maximum flow recorded in the rotameter (Fig. 3b.) was 98.4 and 20 L/min. Since the scale is marked 10 at 10 L/min. It was decided to take the pressure drop in orifice plate in the volumetric flows indicated in the first column of table 3 (data and results) and from these flows, the pressure drop in the hole for each run.

The first experimental run**, (**first and fourth columns of table 3**),** gives information to the specifications of the hole, which is interconnected. The approximate properties of water at the operating temperature (14 ^{0}C) is shown in the first row.

Table No. 2 Approximate properties of water at T = 16 ° c	
Density ρ	Viscosity μ
(Kg / m^3))	(Kg / m s)
1000	0.001
Other data	
g_C	
9.81 kg_f m. / Kg_m ^{2} s	

Table No.3 data and results							
Orifice diameter = 2.35 Cm; diameter of the tube (where the orifice plate is installed) = 3.462 Cm. B = 0.678							
Experimental values				Calculated values			
Volumetric flow		Pressure drop in the orifice		Velocity in the orifice	second term of equation (4)	Coefficient of orifice	Re Reynolds No.
l/min	m^3/s	Inch.Hg	$_F kg/m^2$	m/s	m/s	dimensionless	dimensionless
98.41	0.00164	**3.9**	1347	3.78	5.79	0.65	88864.69
90	0.0015	3.4	1173.814	3.458316	5.407176	0.639578857	81270.42
80	0.00133	2.95	1018.456	3.074058	5.036654	0.610337461	72240.37
70	0.00116	2.97	1025.36	2.689801	5.053698	0.532244108	63210.33
60	0.001	1.58	545.478	2.305544	3.686036	0.625480471	54180.28
50	0.00083	1,074	370.787	1.921287	3.039018	0.632206434	45150.23
40	0.00066	0.718	247.881	1.537029	2.484811	0.618569948	36120.19
30	0.0005	0.431	148.798	1.152772	1.925173	0.598788798	27090.14
20	0.00033	0.215	74.2264	0.768515	1.359723	0.565199558	18060.09

4.3.-Calculation example.

From the first row of data we get:

$$volumetric\ flow = 98.4\ \frac{l}{min.} * \frac{1m^3}{1000\ l} * \frac{1min.}{60\ s} = 0.00164\ \frac{m^3}{s}$$

$$Pressure\ drop\ in\ the\ orifice = 3.9\ Inch\ de\ Hg * \frac{25.4\ mm.de\ Hg}{1\ Inch\ de\ Hg} * \frac{13.69\ \frac{Kg}{m.^2}}{1\ mm.de\ Hg} = 1347\ \frac{Kg.}{m.^2.}$$

$$Velocity\ in\ the\ orifice = \frac{Volumetric\ flow}{\text{Orifice area}} = \frac{0.00164\frac{m.^3}{s}}{0.000434m.^2} = 3.78\ \frac{m.}{s.}$$

From equation (4) = $\sqrt{\frac{2gc\left[\frac{Kg_f\ m}{Kg\ s^2}\right]\left(\frac{\Delta P\left[\frac{Kg_f}{m^2}\right]}{\rho\left[\frac{Kg}{m^3}\right]}\right)}{1-\left(\frac{D_O}{D_T}\left[\frac{m}{m}\right]\right)^4}} = \sqrt{\frac{2*9.81*\left(\frac{1347}{1000}\right)}{1-\left(\frac{0.0235}{0.03462}\right)^4}} = 5.79\ \frac{m}{s}$

the discharge coefficient of the orifice becomes:

$$C\ o = \frac{v_O\left[\frac{m}{s}\right]}{\sqrt{\frac{2gc\left[\frac{Kg_f\ m}{Kg\ s^2}\right]\left(\frac{\Delta P\left[\frac{Kg_f}{m^2}\right]}{\rho\left[\frac{Kg}{m^3}\right]}\right)}{1-\left(\frac{D_O}{D_T}\left[\frac{m}{m}\right]\right)^4}}} = \frac{3.78\frac{m.}{s}}{5.79\frac{m.}{s}} = 0.65$$

$$Re(in\ the\ orifice) = \frac{D_o\, u_o\, \rho}{\mu} = \frac{0.02535m*3.78\frac{m}{s}*1000\frac{Kg}{m^3}}{0.001\frac{K}{m\,s}} = 9.6*10^4$$

4.4. Analysis of results

From the information shown in the table no. 4 **(data and results)** it can be concluded that:
The value of the orifice coefficient obtained is in the range of Reynolds of 1.8×10^4 to 8.8×10^4 complies with that specified in the source *G. G. Brown basic operations of chemical engineering. Ed. Marin Barcelona, 1965 p. 168 Fig. 145,* [3] in which indicates that for sharp edges orifices with a β of 0.68 corresponds an orifice coefficient of 0.6

V.- CONCLUSIONS

Through the operation of the system of flow of fluids in which is included a orifice meter the students could obtain the so-called coefficients of orifice. The data obtained agree quite well with those predicted in the literature [3]. In addition it is concluded that that the selection of the range, and the conditions of operation, are appropriate to display the necessary conceptual part that allows to obtain and understand the discharge coefficient of an orifice meter. Students during this practice put into play their competencies in the areas of knowledge, skills and attitudes.

VI.- BIBLIOGRAPHY

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3. *G. G. Brown - Operaciones básicas de la Ingeniería Química. Ed. Marín Barcelona, 1965 Pág. 168 Fig. 145*