EXPERIMENTAL STUDY OF SINGLE AND MULTIPLE OUTLETS BEHAVIOR UNDER CONSTANT HEAD

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ABSTRACT

EXPERIMENTAL STUDY OF SINGLE AND MULTIPLE OUTLETS BEHAVIOR UNDER CONSTANT HEAD

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The performance of outlets under constant head is investigated in this study. Behavior of single outlet is analyzed; subsequently effect of multiple outlets on a single outlet is examined. Parameters taken into account are constant head of water, orifice shape, orifice length, number of open outlets and discharge. The outlet type, which is examined, can be classified as a short tube orifice. Two different orifice diameters and tube lengths are used. Outlets had the diameter, 6.00 and 10.35mm. The ratio of orifice length to diameter (l/d) was 5 and 8. Number of outlets is 5, which are opened in several combinations. A dimensional analysis shows that discharge coefficient, C_d is a function of diameter-length ratio and the Reynolds Number. In this study, high

Reynolds Number (2300<Re<18600) range is examined and the results are compared with the available data in the literature. Furthermore, performance of the group outlets is investigated.

Keywords: Discharge under constant head, Short tube orifices, Discharge coefficient

ÖZ

TEK VE BİRÇOK ÇIKIŞ AĞZININ SABİT SU YÜKÜ ALTINDAKİ DAVRANIŞININ İNCELENMESİ

ÇOBANOĞLU, İsmail

Yüksek Lisans, İnşaat Mühendisliği Bölümü

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Kasım 2008, 70 sayfa

Bu çalışmada sabit su yükü altında çıkış ağızlarının performansı araştırılmıştır. Tek çıkış ağzının davranışı analiz edilmiş, sonrasında, birçok çıkış ağzının tek çıkış ağzına olan etkisi incelenmiştir. Göz önünde bulundurulan değişkenler, sabit su yükü, orifis şekli, orifis boyu, orifis uzaklıkları, açık ağız sayısı ve debidir. İncelenen çıkış ağzı kısa boru tipi orifis olarak sınıflandırılabilir. İki adet orifis çapı ve boru boyu kullanılmıştır. Çaplar, 6,00 ve 10,35mm dir. Orifis boyunun, çapına olan oranlar (l/d) 5 ve 8 dir. Çıkış ağzı sayısı 5 tir ve bunlar deney esnasında çeşitli kombinasyonlarda açık tutulmuştur. Boyutsal analiz göstermiştir ki, deşarj katsayısı (C_d), çap-boy oranı ve Reynolds sayısı' nın bir fonksiyonudur. Büyük Reynolds sayılarıyla ($2300<Re<18600$) çalışılmış, incelenen sonuçlar literatür bilgileriyle mukayese edilmiştir. Bunlara ilaveten çıkış ağızlarının grup olarak performansı araştırılmıştır.

Anahtar kelimeler: Sabit su yükünde deşarj, Kısa boru tipi orifisler, Deşarj katsayısı

To My Family and My Fiancée

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LIST OF SYMBOLS

A	: area of the outlet
A_t	: area of the measurement tank
A'	: relative gate opening
a	: gate opening
C_c	: coefficient of contraction
C_d	: discharge coefficient
C_d*	: true discharge coefficient value used in error analysis
C_{dpeak}	: peak value of discharge coefficient
C_v	: coefficient of velocity
D,d	: diameter of orifice or outlet
e_A	: error value for area measurement
e_{C_d}	: error value for discharge coefficient
e_h	: error value for measurement reading
e_Q	: error value for discharge
e_t, $e_{\Delta t}$	: error value for time reading
$e_{\Delta h}$	: error value for head increment
f	: function
g	: gravitational acceleration
H	: water depth
H1	: water depth in the reservoir division
H2	: water depth below the outlet
h	: water head on the outlet
h_o	: approach flow depth
K'	: constant
l	: orifice length
N	: number of orifices
p	: atmospheric pressure

Q	: discharge
Q^*	: true discharge value used in error analysis
Q1, Q2	: discharge values in error analysis
r	: vertical orifice spacing
Re	: Reynolds number
Re_{asym}	: Reynolds number value corresponds to the asymptotic value of C_d
Re_{peak}	: Reynolds number value corresponds to the peak value of C_d
t	: time
V, v_1, v_2	: flow velocity
v	: velocity of the flow at the outlet in ideal flow conditions
w	: horizontal orifice spacing
z_1, z_2	: elevation
ρ	: density of fluid
μ	: dynamic viscosity
ν	: kinematic viscosity
γ	: specific weight of fluid
Δh	: head increment
Δt	: time increment
ΔQ	: discharge increment

CHAPTER 1

INTRODUCTION

1.1 Introduction and Literature Review

Different outlet types can be used in the control of a reservoir or a tank such as sluice gates, weirs, pipes and orifices. In all these control structures, flow does not behave like an ideal flow. Not only it is affected from boundary conditions, but also structure geometry is another important parameter that a major problem arises. The design of an outlet can be fully accomplished by knowing the characteristic of the outlet, which develops the difference between actual discharge and the ideal one. In other words, the information about the discharge coefficient of the outlet is necessary for analyzing the flow behavior.

The discharge through the control structures has been studied extensively over the past 70 years. Several authors like Rajaratnam and Subramanya (1967) defined the discharge coefficient of sluice gates, and Roth and Hager (1999) analyzed the parameters that affect underflow of sluice gate and developed the concept of sluice gate discharge coefficient by defining a formula in a specified range. On the other hand, the researches about short tube orifices is limited, Davis (1952) reported coefficients for large orifices and tubes. He introduced orifice geometry as a parameter that influences flow. Dally, et al. (1993) mentioned a few about short tube orifice discharge coefficient. Finally, Dziubinski and Marcinkowski (2006) studied about the discharge of

Newtonian and Non-Newtonian liquids from tanks and stated several results about coefficients.

1.2 Scope of the Study

In this study, characteristic of a single outlet and the effect of multiple outlets on the behavior of the single one, are studied under constant head condition. Although, there is limited knowledge about short tube orifice discharge, the literature is also limited about the influence of an orifice by multiple orifices. For this reason, one of the goals of this study is chosen as to find the effects between multiple orifices.

In Chapter 1, an introduction to the subject and review of literature are given with the scope of this study. In Chapter 2, a brief explanation about theoretical background of outlets is presented. Chapter 3 consists of the experimental setup, the dimensional analysis and the details of error analysis. Chapter 4 gives the results and Chapter 5 presents discussions and conclusions of this research.

CHAPTER 2

THEORETICAL APPROACH

2.1 General Characteristics of Discharge Coefficient

The amount of discharge of a fluid from a reservoir can be quantified by calibrating the discharge devices such as orifice and sluice gate.

It is expected to observe a jet flow while controlling a stream or a reservoir filled with water by a barrier with an opening (orifice) on the face. The potential energy of the upstream still water is converted to the kinetic energy of the free jet through the orifice. Neglecting the losses, the Bernoulli equation as shown below with Eq. 2.1 can easily be used to represent the energy balance.

$$\frac{v_1^2}{2g} + \frac{p_1}{\gamma} + z_1 = \frac{v_2^2}{2g} + \frac{p_2}{\gamma} + z_2 \qquad (2.1)$$

Assuming the velocity at the location 1 is negligible when compared to the velocity at the location 2, $v_1 \cong 0$. Pressures at the location 1 and location 2 equals to the atmospheric pressure. Thus $p_1 = p_2$ and the elevation difference, h, can be written as, $h = z_1 - z_2$. Then, Eq. 2.1 can be reduced as:

$$h = \frac{v_2^2}{2g} \qquad (2.2)$$

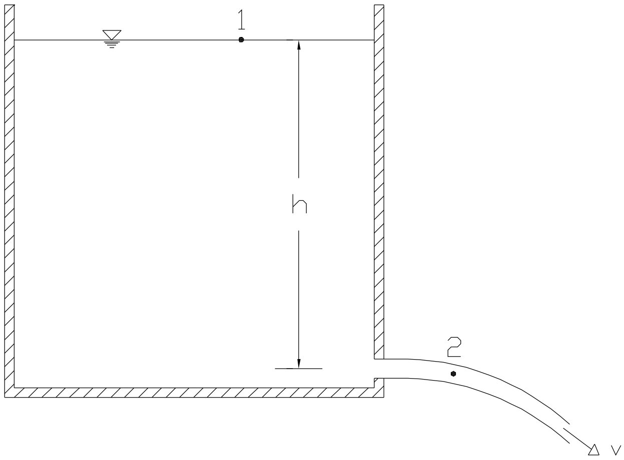


Figure 2.1 Flow from a reservoir through an orifice

Eq. 2.2 can be converted into Eq. 2.3, which is also known as Torricelli's equation.

$$v = \sqrt{2gh} \tag{2.3}$$

Here v is the velocity of the flow at the outlet in ideal flow conditions. However, in reality, the fluid is a viscous fluid and no-slip boundary conditions prevail. Further, the effect of surface tension can be observed. Therefore, a velocity profile will occur at the outlet. The real discharge will be multiplication of cross sectional average velocity, V, and the outlet area, A. The relation between theoretical velocity and the real velocity can be described as:

$$V = C_d \times v \tag{2.4}$$

Thus the real discharge is:

$$Q = V \times A = C_d \times A \times v = C_d \times A \times \sqrt{2gh} \tag{2.5}$$

The jet area becomes narrower after crossing the opening, this is the result of viscous shear effects on corner of the orifice and called "vena contracta".

2.2 Discharge Coefficient in Sluice Gates

Rajaratnam and Subramanya (1967) stated that the discharge coefficient depends on the difference of flow depths in the upstream and downstream sections of a sluice gate. An increase in the ratio of the gate opening, a, to the approach flow depth, h_0, causes C_d to increase; C_d assumes value of 0.595 and up.

On the other hand, Nago (1978) mentioned that relative gate opening increases, as the discharge coefficient decreases.

$$A' = \frac{a}{h_o} \tag{2.6}$$

According to Nago (1978) C_d approaches to 0.595 as a/h_0 approaches to zero and when C_d=0.52, a/h_0 equals to value 0.50.

Montes (1997) examined the surface profiles upstream and downstream from the gate. He questioned if the boundary layer development and the spatial flow features upstream from the gate, are related with energy losses across the gate.

Roth and Hager (1999) also related discharge with relative gate opening, A'. The dependence of C_d on A' is depicted in Figure 2.2.

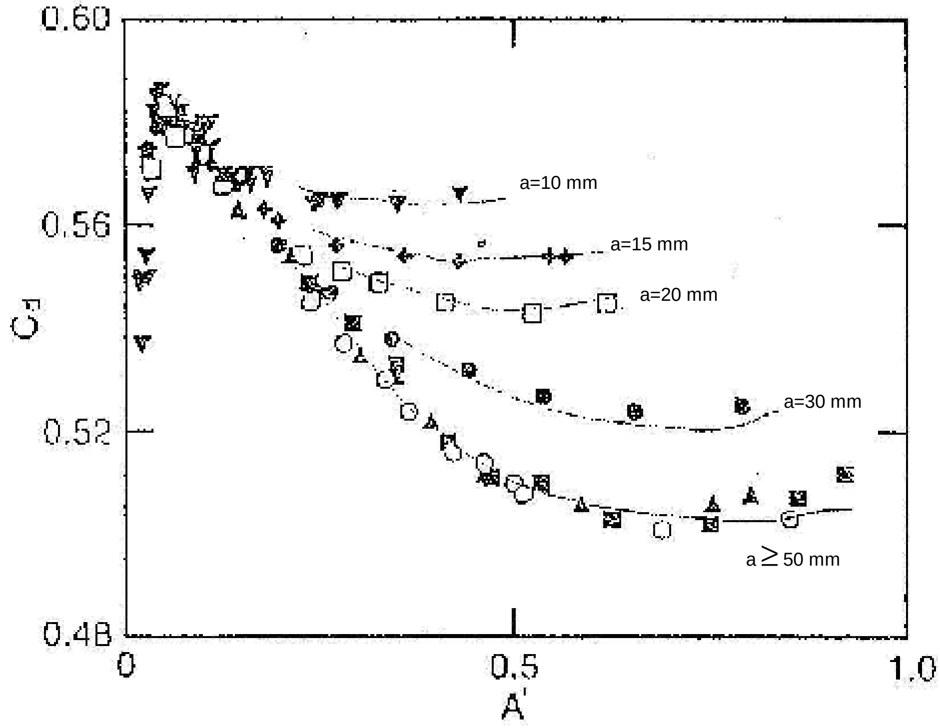


Figure 2.2 Relationship of discharge coefficient with the relative gate opening according to Roth and Hager (1999)

2.3 Discharge Coefficient Through Sharp Edged Orifices

The discharge coefficient, C_d, includes the coefficient of contraction, $C_{c;}$ and the coefficient of velocity, C_v;

$$C_d = C_c \times C_v \qquad (2.7)$$

As cited in Lienhard and Lienhard (1984), Judd and King (1908) measured C_c and C_v independently for sharp edged orifice. The experiments have shown the validity of Eq. 2.7.

For 1 inch (25.4mm) orifice, they have reported that C_d assumes a value of approximately 0.61 and C_v of 0.99 for sharp edged orifices. The findings of the researches cited in Lienhard and Lienhard (1984) covering the past work till 1940, and that of Dally, et al. (1993) confirms this, that is to say C_d is approximately 0.61.

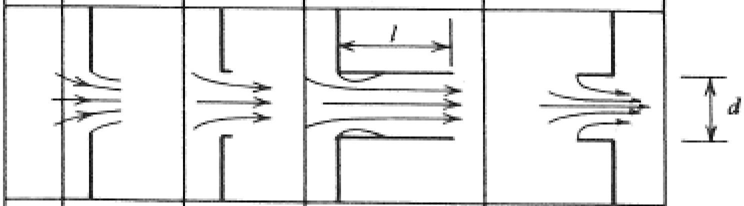
It is worth noting that, Medaugh and Johnson (1940) which is cited in Lienhard and Lienhard (1984), reported that C_d takes the value of 0.595 under high heads for 1 inch (25.4mm) orifice.

2.4 Discharge Coefficient in Short Tube Orifices

Another device to measure the rate of flow from a reservoir is a short tube orifice. The discharge coefficient is affected from several parameters. Elliptical or circular entrance provides a smoother flow near the edges of orifice. Flow approaches to the ideal flow characteristics when streamlines are not forced to make a right angle at the corners. The ratio of the length of orifice to the diameter of orifice (l/d) is another significant parameter that affects the performance of a short tube orifice.

Davis (1952) gave the classification of tube orifices according to their length and type of entrance. Length was varied from 0.31ft (0.09m) to 14ft (4.27m). Entrance of tube was varied from sharp edged to 4 sided elliptical entrance. Davis (1952) reported the discharge coefficient, C_d, ranging from 0.62 to 0.96 for several combinations of entrance and length. Detailed figure is given in Appendix B.

On the other hand Dally, et al. (1993) has also recommended Cd values for both submerged and free jet. In their study, C_d has a value of 0.8 for short tube. They have also suggested a value of 1.00 for C_c and a value of 0.80 for C_v in case of a short tube, as depicted in Figure 2.3. The reported values are limited to $l/d = 2.5$, only.



	Sharp edged	Rounded	Short tube[a]	Borda
C	0.61	0.98	0.80	0.51
C_C	0.62	1.00	1.00	0.52
C_V	0.98	0.98	0.80	0.98

Figure 2.3 Orifices and their nominal coefficients reported by Dally, et al. (1993) for $l/d = 2.5$

Dziubinski and Marcinkowski (2006) carried out a series of experiments to examine the performance of orifices for Newtonian and Non-Newtonian liquids discharging from tanks, and proposed the following equation:

$$C_d = K'\sqrt{Re} \qquad (2.8)$$

where K' is a constant reflecting the combined effect of geometry, flow and fluid properties. It is seen from Equation (2.8) that the discharge coefficient is directly proportional with square root of Reynolds number for Re<10, that is in laminar flow.

They used several orifice diameters in their experiments with changing lengths. The orifice diameters were 5, 8, 12.5 and 17mm. Diameter length ratios (l/d) were 0, 0.35, 0.5, 0.75, 1 and 3. Data were collected for Newtonian and Non-Newtonian fluids with various viscosities like water, ethylene glycol and water solutions of starch syrup. They gave the relationship of discharge coefficient and Reynolds number for their experiments as summarized in Figure 2.4.

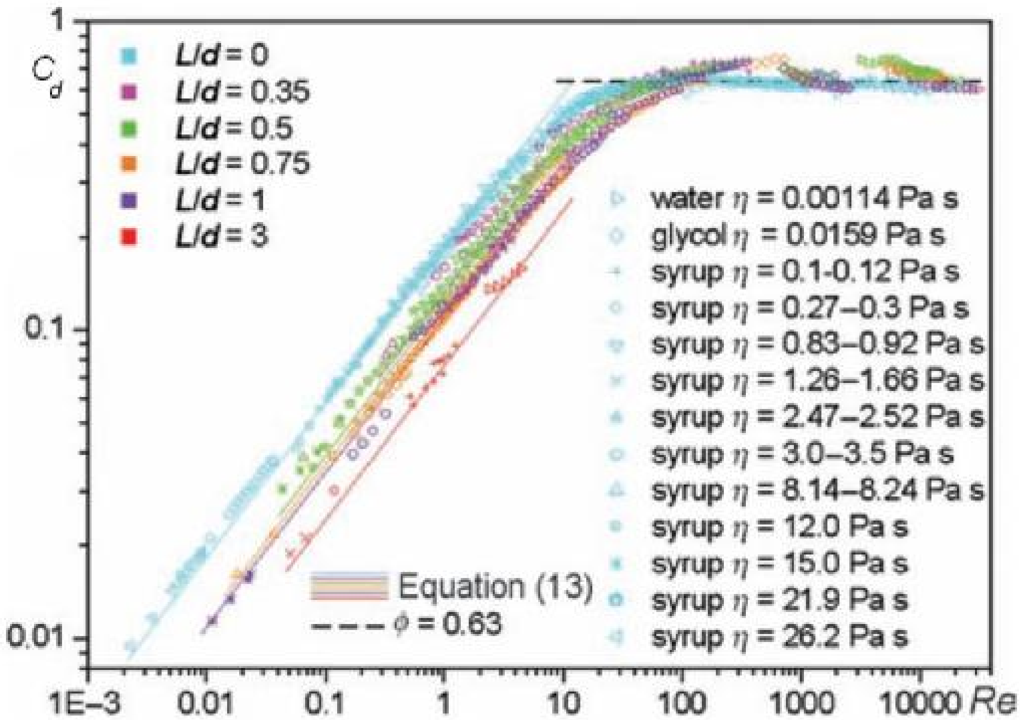


Figure 2.4 Relationship of discharge coefficient with Reynolds number according to Dziubinski and Marcinkowski (2006)

For $Re \leq 100$, where flow is essentially laminar, C_d increases with Reynolds number as suggested by Eq. 2.9 and depending on the orifice geometry, discharge coefficient takes different values. The experimental results suggest that flow of a Newtonian fluid from tanks through a small cylindrical orifice for the Reynolds number range from 0.00226 to 10, discharge coefficient is described as:

$$C_d = \left[0.186 - 0.0756\left(\frac{L}{d}\right)^{0.333}\right]\sqrt{Re} \qquad (2.9)$$

It is also mentioned that for $Re > 100$, the discharge coefficient, C_d, seemingly becoming constant about a value of 0.63. However the inspection of the data suggests that C_d value increases to a peak and asymptotically assume this constant value. The location and the magnitude of the peak is a function of Re and l/d.

CHAPTER 3

EXPERIMENTAL STUDY

3.1 Description of the Experimental Set-up

An experimental study setup is designed within the scope of the study and constructed by the Yüksel Kaya Makina Company. Setup is a closed loop, which circulates water in itself without external interference. The system consists of two reservoirs, one for storage of water, one for the model, and a measurement tank.

The model reservoir has a width of 0.47 m, a length of 0.62 m, a height of 0.40 m. It includes 3 divisions, the one with 0.38 m wide and with 0.47 m long stores water. Thus, it will be called reservoir in the present study. Next to it with a width of 0.10 m and a length of 0.47 m is the division, which works as supplying water and discharging excess water. It is called supply tank. Last division has the dimensions of $0.10m \times 0.47m$ and empties the division by transferring water through 2 outlets to the storage tank which has a lower elevation. This division is connected to the supply tank by a weir. This part will be called as discharge tank.

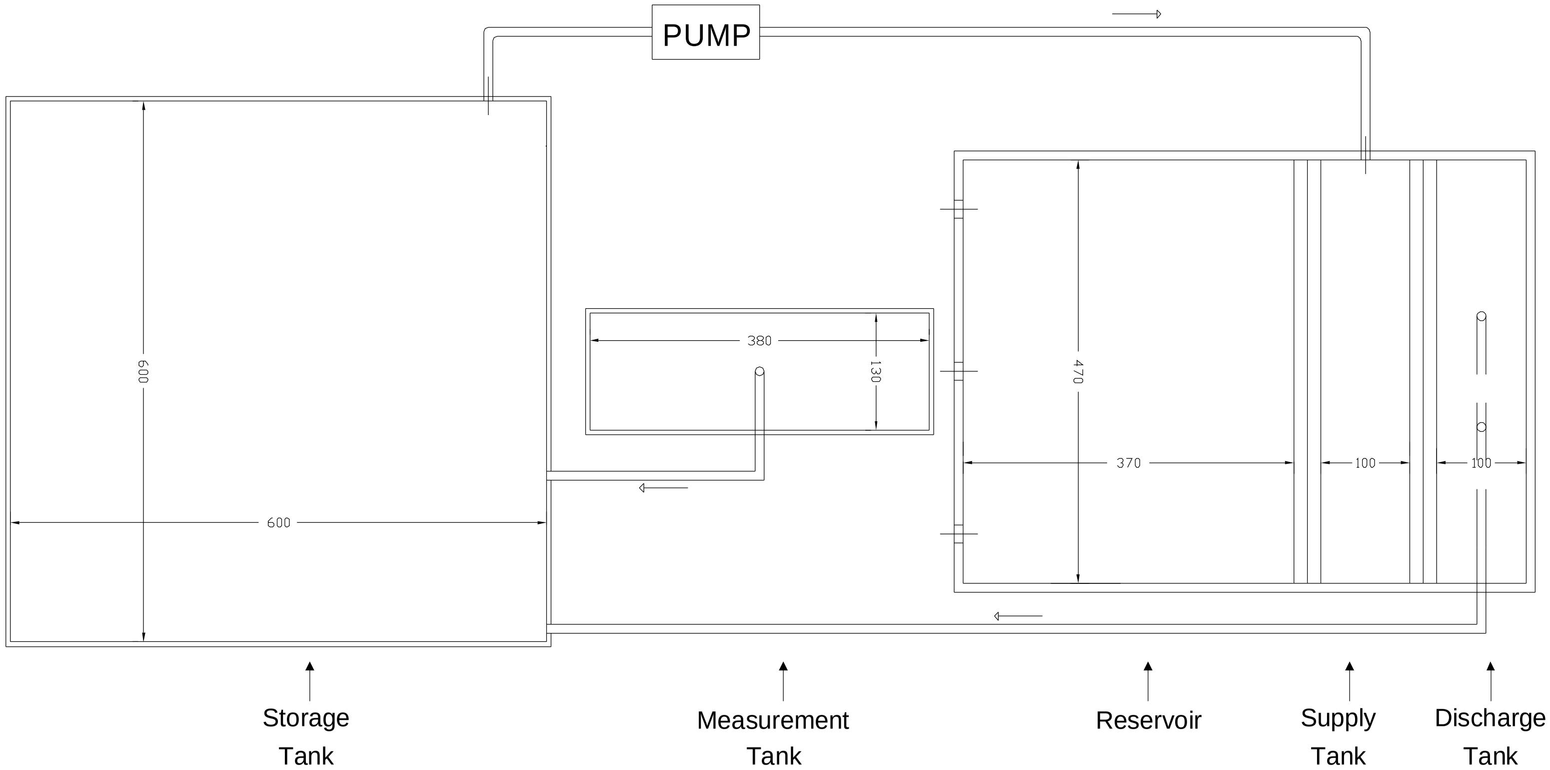


Figure 3.1 Top view of the setup (Dimensions are in mm)

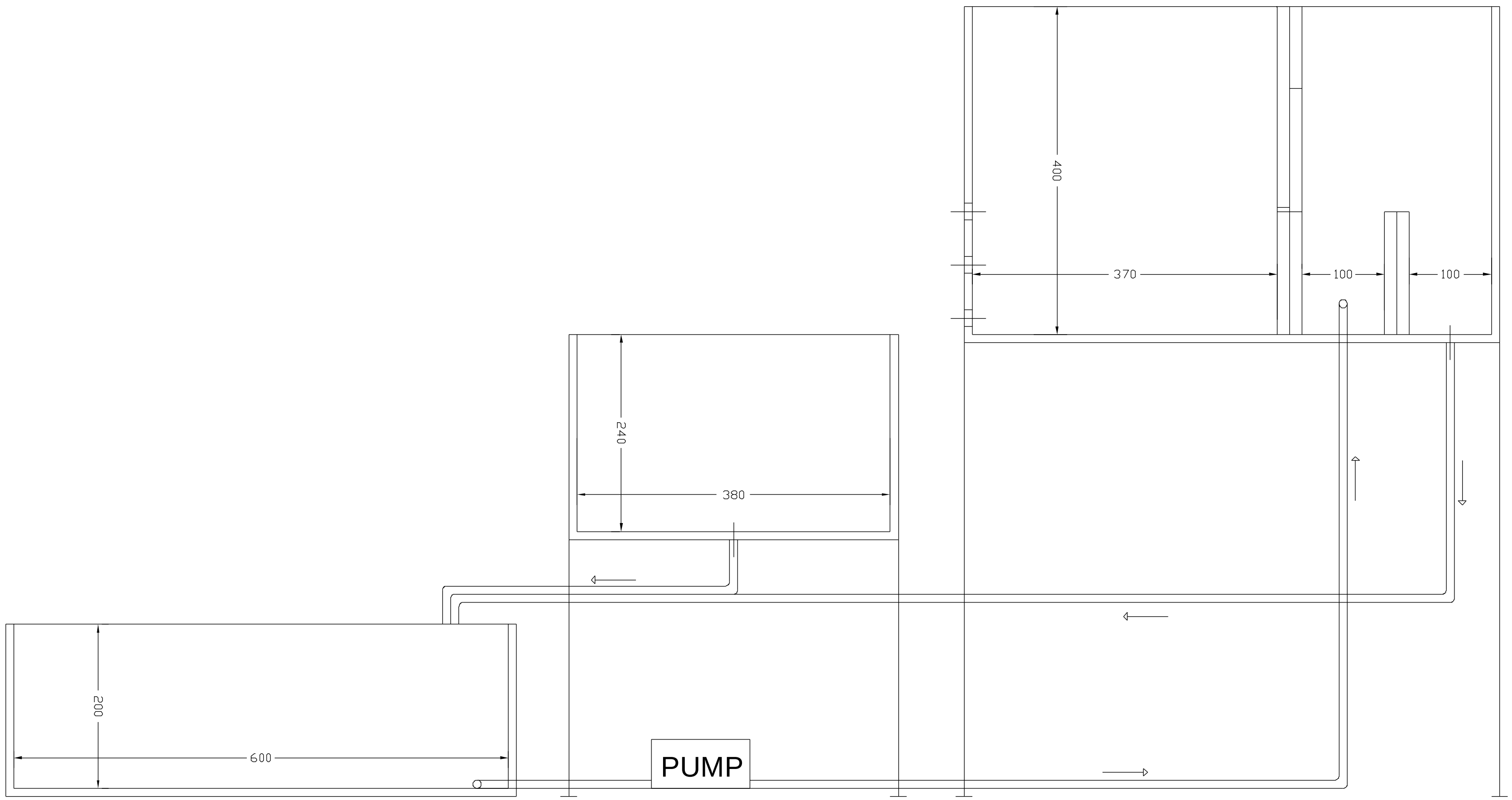


Figure 3.2 Side view of the setup (Dimensions are in mm)

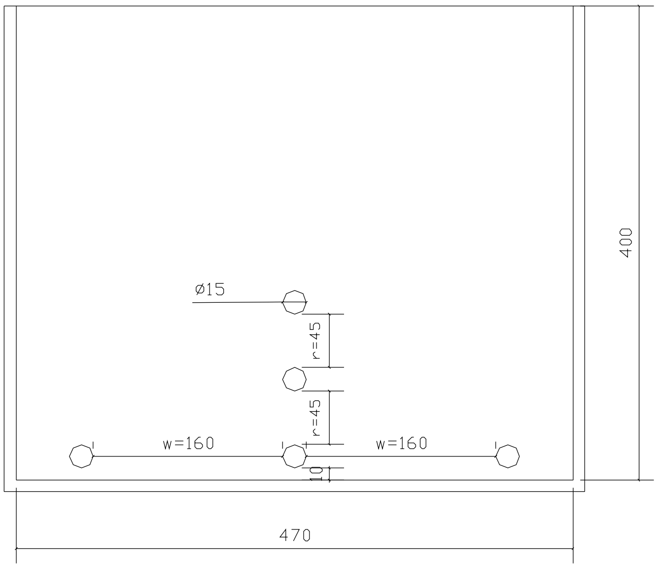


Figure 3.3 Front view of the setup (Dimensions are in mm)

The system should have the least disturbance in order to represent a reservoir. Instead of giving the water directly from a pipe to reservoir, a horizontal water surface with no waves or disturbances was provided by letting water to enter storage division of model reservoir from a horizontal slit ($0.005\text{m} \times 0.42\text{m}$). Supply pipe entrance is connected to the division, which have a width 0.10 m and a length 0.47 m.

By the help of a pump, discharge is controlled and water is supplied to the model reservoir through the 0.015m diameter pipe. The pump has a maximum capacity of 90 lt/min.

From the reservoir, water is discharged into the measurement tank. The increase of water level, Δh at a known time interval is measured and by multiplying it with the container area, gives the value of water discharge.

$$Q = A_t \times \Delta h / \Delta t \qquad (3.1)$$

Afterwards, the measurement tank is emptied to the storage tank. The location of the measurement tank is shown in Figure 3.4.

Figure 3.4 General view of the setup

The openings in the reservoir are on the frontal face of the model reservoir. There are five outlets, that serve like short tube orifice. Three of them are aligned on the same line, 10 mm above the base and near to the sidewalls. The remaining 2 outlets are placed above the center outlet of the group and 45 mm apart from each other.

All openings have a diameter of 15.00 mm. For experiment procedure, plug with no hole, plug having 6.00 mm diameter hole and plug having 10.35 mm diameter hole are designed. For the set of experiments, the discharge measurement is done only for the center outlet of the 3 aligned outlets above the base.

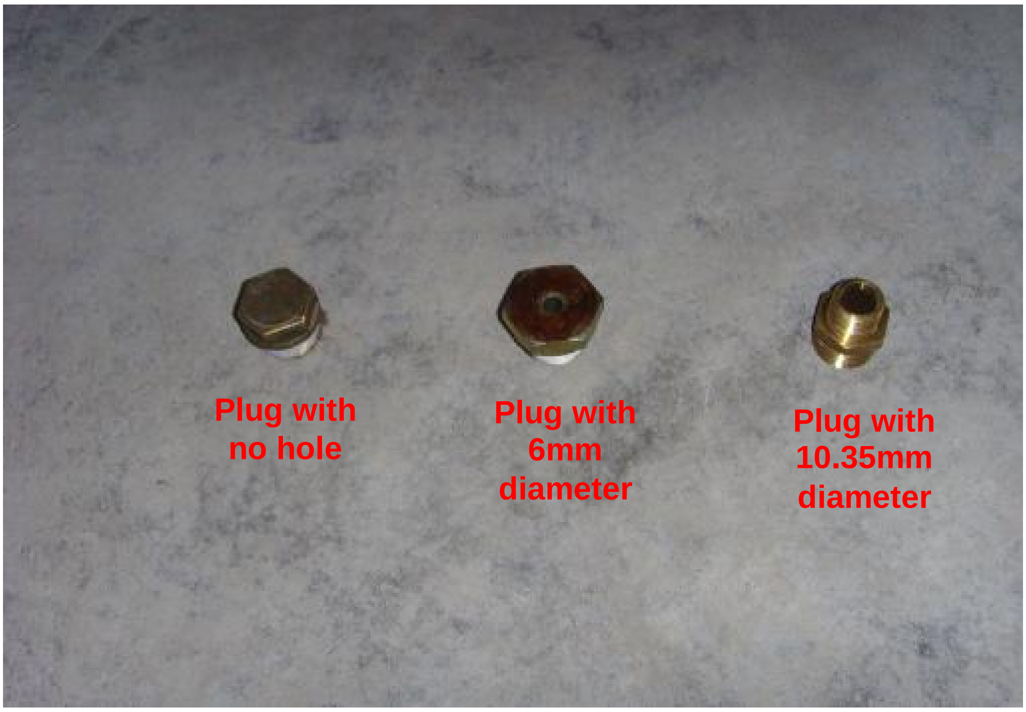


Figure 3.5 Plugs and their dimensions

To measure the height of the water in both measurement tank and reservoir, a ruler is made. By taking the base of the pool as “0” elevation, ruler is stuck on the transparent wall of the reservoir. Through the measurement procedure, man-made errors could be done. In order to define if these errors are in between limits, error checking is performed.

3.2 Dimensional Analysis

The hydraulic performance of the orifice is defined by discharge coefficient C_d. In general discharge coefficient can be a function of several variables: orifice diameter, d, orifice length, l, horizontal and vertical orifice spacing, w and r, constant head above the orifice, h, discharge of the flow, Q, fluid characteristics like density, ρ, dynamic viscosity, μ, gravity, g, and number of orifices, N. All these parameters are presented in Table 3.1.

Table 3.1 Parameters used in dimensional analysis

	Symbol	Physical Quantity	Dimension
Properties of Orifice	d	orifice diameter	L
	l	orifice length	L
	w	horizontal orifice spacing	L
	r	vertical orifice spacing	L
Flow Characteristics	Q	discharge	L^3T^{-1}
	g	gravitational acceleration	LT^{-2}
Fluid Characteristics	ρ	density of the fluid	ML^{-3}
	μ	dynamic viscosity	$ML^{-1}T^{-1}$
Dimensionless Parameters	N	number of orifices	-

Functional relationship of the involved parameters can be written as:

$$f_1(d, l, w, r, Q, g, \rho, \mu, N) = 0 \qquad (3.2)$$

A dimensional analysis performed with the variables above. By choosing d, Q, ρ as repeating variables, function below shows the dimensionless terms:

$$C_d = f_2\left(\frac{l}{d}, \frac{w}{d}, \frac{r}{d}, \frac{gd^5}{Q^2}, \frac{d\mu}{Q\rho}, N\right) \qquad (3.3)$$

In Ed. (3.3), fourth term (gd^5/Q^2) is known as the Froude number and the fifth term $(d\mu/Q\rho)$ is $\frac{4}{\pi}\times\frac{1}{Re}$ where Re is the Reynolds number defined as $Re = Vd\rho/\mu$. The dimensionless parameters, $\frac{w}{d}$, $\frac{r}{d}$ and N represents the characteristics of the group of discharging orifices at any given experiment.

Throughout the experiments the orifices were located such that there were no air entrainment and vortex formation. Therefore Froude Number is dropped out and Eq. 3.3 reduces to:

$$C_d = f_3\left(\frac{l}{d}, \frac{w}{d}, \frac{r}{d}, Re, N\right) \qquad (3.4)$$

As will be described below, the experiments were designed based on Eq.3.4.

3.3 Measurements and Experimental Procedure

The experiment starts by pumping water from the storage tank to the supply tank. The water that rises in this division, passes to the reservoir. When the water level becomes the same in both of them and steady in both parts, it is discharged from the weir to the discharge tank. After that, water finishes its cycle by returning to the storage tank.

The variation of head in the model can be regulated simply. Increasing or decreasing the level of slit gives a chance to adjust the water head. For a steady flow, weir should also be increased or decreased by the same amount of distance. The distance that weir or slit can be lifted, is limited with 15 cm.

Figure 3.6 Discharge under high heads of water

In Table(3.2) , one can see codes to describe the series of experiments. The first three rows representing single activated outlets. Outlets D and

E is used to obtain small heads over the orifice since for outlet B the smallest head is limited to 15cm. Rest of the rows show multiple open orifice combinations. Opening layout with names given in Figure 3.7. “1” indicates open, “0” indicates close for orifices.

Table 3.2 Opening Codes of Experiments

	A	B	C	D	E
Open (1) / Close(0)	0	1	0	0	0
	0	0	0	1	0
	0	0	0	0	1
	0	1	0	1	0
	0	1	0	0	1
	0	1	0	1	1
	1	1	0	0	0
	1	1	1	0	0

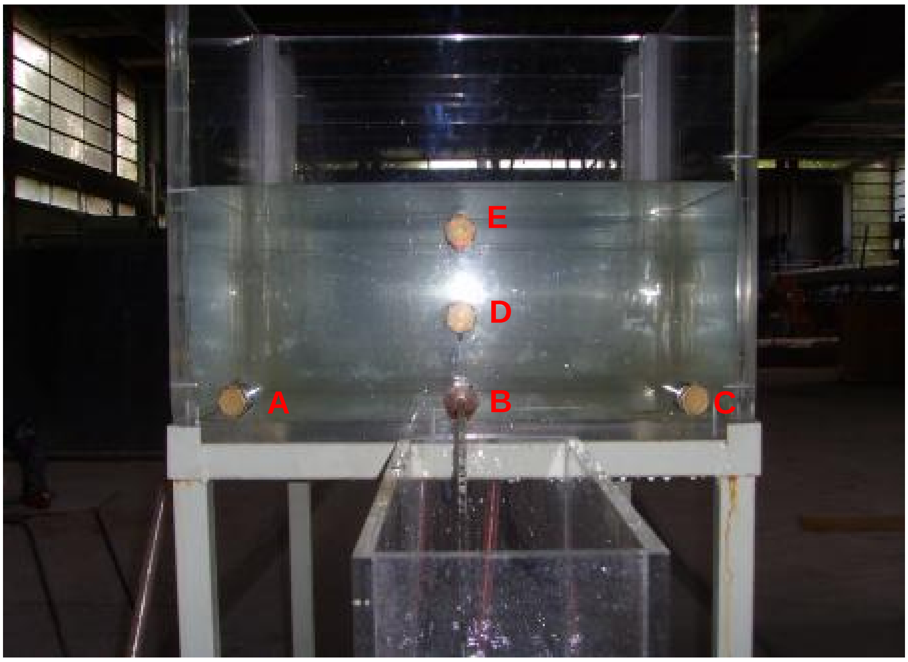


Figure 3.7 Outlet names and layout

Another variable is the diameter of the outlet. All opening combinations, are performed both with 6.00 mm diameter slot opening and 10.35 mm diameter slot opening.

Head range of each opening is different. Although the lifting limits of slit and weir is 15 cm (Figure 3.3), when only slot B is opened, experiment head range was approximately 30 cm. Opening only slot D, or slot E, gave the opportunity to gather information about slot characteristic for lower heads.

The pump is turned on to let a small discharge. A certain period of time is waited, until the reservoir is filled with water. After a while, steady flow state is achieved. Head equilibrium is balanced when the inflow is equal to the outflow. Excess amount of water is run smoothly over the weir. The constant water level is noted in the reservoir. Water is discharged from slots depending on the opening combination. Only the discharge, Q is coming to the measurement tank from slot B. The drain valve of the measurement tank is closed and waited till the water level is raised by Δh amount in the measurement tank. The amount of Δh is set equal in all data recordings, 3cm and 4 cm. The reason of measuring Δh for both 3cm and 4cm is to evaluate the accuracy of the measurement. The correlation of measurement is given in the forthcoming section 3.4. Corresponding time interval for Δh is called as Δt. Discharge of outlet B is calculated by using Eq. 3.1. In Eq. 3.1, A_t is the area of the measurement tank, $0.049 m^2$.

For the next measurement, slit and weir is lifted. Head is increased by Δh, causing an increase in ΔQ, that can be observed directly from the decrease in measured time Δt. Same procedure is applied both for lifting and lowering slit.

Figure 3.8 Measurement procedure when B=1,A,C,D,E=0

Figure 3.9 Measurement procedure when B,D,E,=1, A,C=0

Figure 3.10 Measurement procedure when B,A,C,=1, D,E=0

3.4 Error Analysis For Discharge Measurement

Through the experimental process, number of readings collected is 902. During the measurement of the discharge, two different increments Δh of 30mm and 40mm were used in order to secure the accuracy of the discharge measurements. The outlet diameter of 6mm were used through out the calibration control stage. The discharges measured with Δh=30mm were listed as Q1 series and with Δh=40mm listed as Q2. Q1 and Q2 were correlated as shown in Figure 3.11. The correlation coefficient has a value of 0.999.

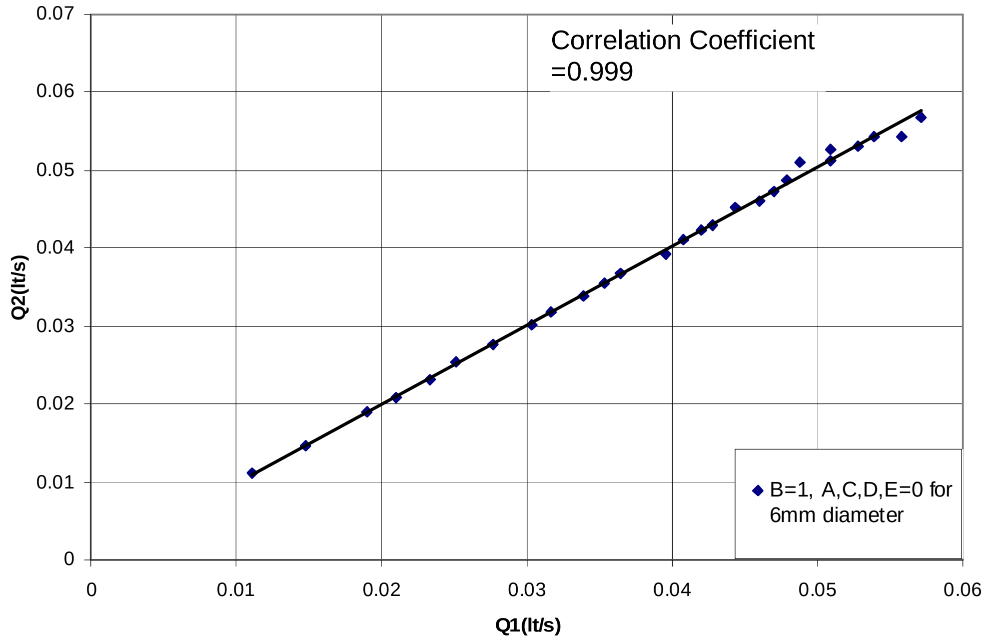


Figure 3.11 Correlation of discharge Q1 (Δh=3cm) to Q2 (Δh=4cm)

For 6.00mm and 10.35mm diameter, the discharge is read twice at the same head to learn if a man made error is done while measuring. Although the results are close enough to each other, an error check is performed. It is considered that the experiment values are in the range of error limits. During the experiment, measured variables are time, t, and several distances. The distances measured were the depth in the reservoir, the constant head on the orifice and the head increment in a fixed time span. Discharge equation is defined in Eq. 3.1. From Eq. 3.1, error values can be written as:

$$e_Q = \sqrt{e_{\Delta h}^2 + e_A^2 + e_{\Delta t}^2} \qquad (3.5)$$

where $e_{\Delta t}$ is the amount of error, may arise due to the time reading. e_A and $e_{\Delta h}$ are the amount of errors, come out while reading the area of the tank and head increment, respectively.

Error in head increment measurement is due to measurement reading which is e_h. Area error on the other hand, including two length measurements , is $\sqrt{2}e_h$.Time measurement consists an error from time reading which is e_t. Based on these, Eq. 3.5 becomes:

$$e_Q = \sqrt{e_h^2 + \left(e_h^2 + e_h^2\right) + e_t^2} = \sqrt{3e_h^2 + e_t^2} \qquad (3.6)$$

Above equation gives the error limit as:

$$Q^* = Q \pm e_Q \qquad (3.7)$$

where Q is the measured rate and Q* is the true value. The graph showing the limits of Q is given as Figure 3.12.

e_t is calculated by dividing maximum time delay while stopping the clock, to the measured time. Maximum delay is defined, as 0.1 sec. e_h is calculated by dividing the defined biggest increment of length unobservable with naked eye, 0.5mm, to the measured distance. The range of e_h is determined in the same way of e_t. The graph showing the limits of Q is given as Figure 3.12.

Not only it could be stated that correlation of 2 series shows us the accuracy of measurement, but also seen from the graph, scattered data fall in range of error limits which is calculated by using Eq. 3.7.

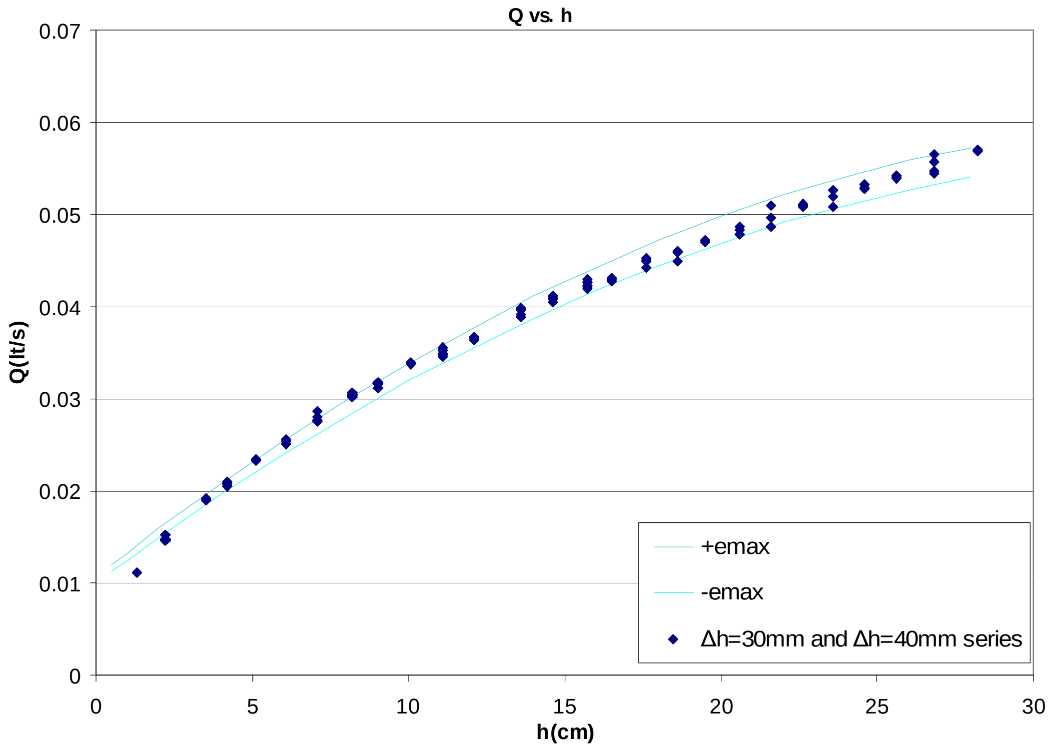


Figure 3.12 Maximum error limits of Q for Q1 (Δh=30mm) and Q2 (Δh=40mm)

CHAPTER 4

DISCUSSION OF RESULTS

4.1 Introduction

In this study, twelve series of experiments have been performed. Each series of experiment result is given in Appendix A. The results are reported and analyzed in this chapter. They are compared and discussed with the past literature. Differences and similarities are stated briefly.

4.2 Discharge Coefficient For Single Outlet

The variation of discharge coefficient, C_d, under different constant head, h, is given in a relation with Reynolds Number of flow through the outlet tube defined as $Re = 4Q\rho/\pi d\mu$. Reynolds Number range covered in this study falls between 2300<Re<18600. All reported C_d values are for the orifice "B". The behavior of C_d for 6mm orifice is given in Figure 4.1 and for 10.35mm in Figure 4.2 In reading the aforementioned figures for any orifice from A to E, "1" implies that the orifice is opened and "0" implies that the orifice is closed.

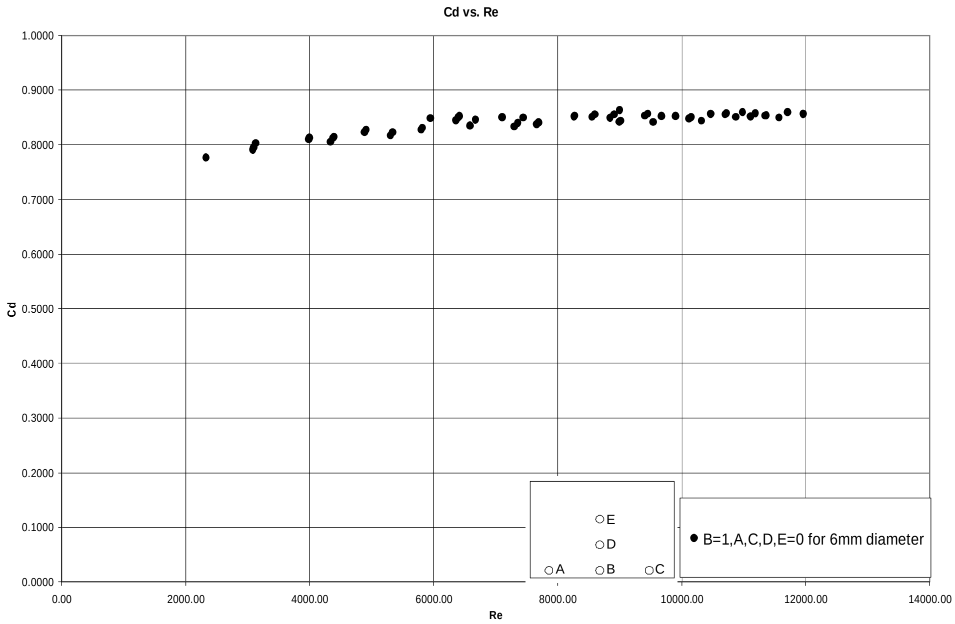


Figure 4.1 Plot of experimental data, C_d versus Re, B=1, A,C,D,E=0 for orifice diameter of 6mm

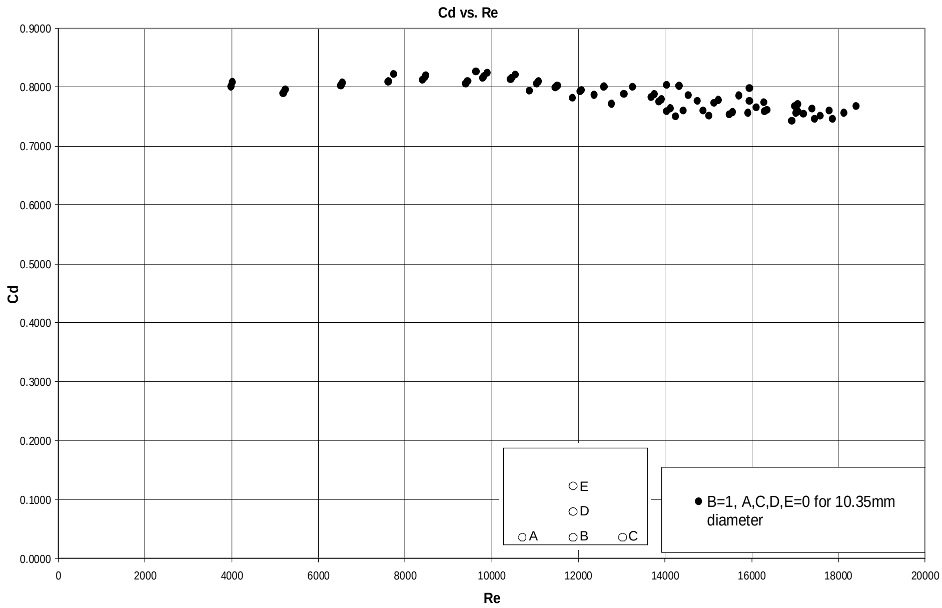


Figure 4.2 Plot of experimental data, C_d versus Re, B=1, A,C,D,E=0 for orifice diameter of 10.35mm

As is seen from graphs, C_d assumes values between 0.74 and 0.86. These results are in agreement with the value of C_d=0.8, reported by Dally, et al. (1993) for the short tube orifice having l/d ratio of 2.5 (see Figure 2.3). It is worth noting that, C_d values observed in this study for higher l/d ratios, 5 and 8, are greater than 0.8 as shown in Figure 4.3. Furthermore, the C_d values are larger for d=6mm (l/d=8) than d=10.35mm (l/d=5). This observation suggests that the peak C_d value depends on l/d and increases with l/d.

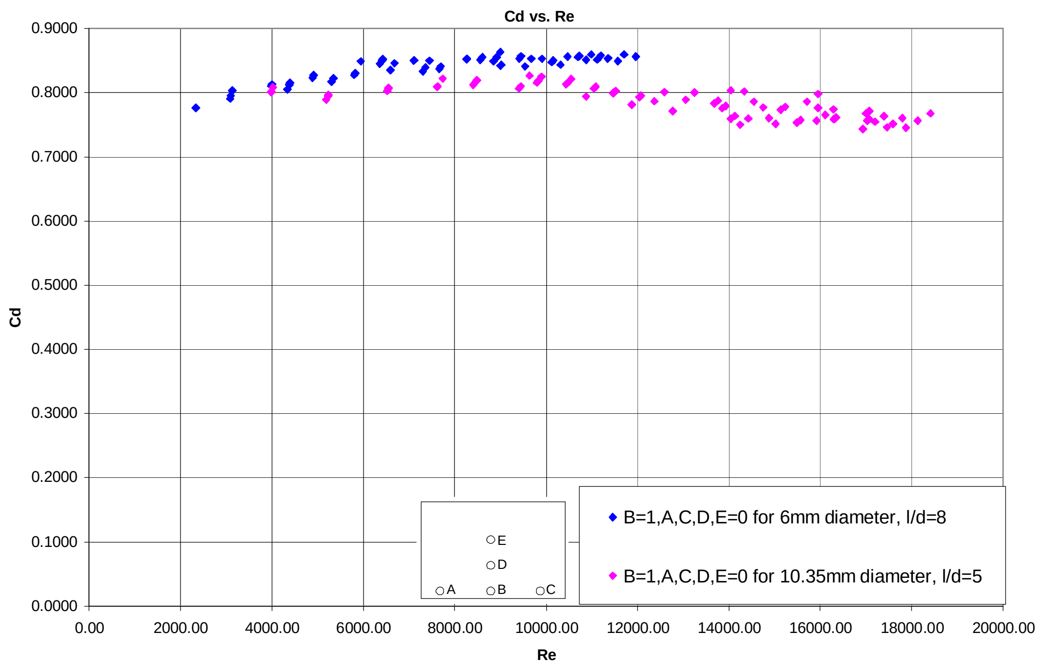


Figure 4.3 Plot of experimental data, C_d versus Re, B=1, A,C,D,E=0 for orifice diameter 6mm and 10.35mm together

The data reported in Figure 4.3 above, is plotted on the graph of Dziubinski and Marcinkowski (2006) to compare with their observations, and given in Figure 4.4. The agreement of the experimental findings of this study with that of theirs is much more accentuated.

In the new constructed graph some important observations can be done. The C_d value approaches asymptotically to a constant value of 0.63 for $Re \geq 10$. Before it converges to this constant, it reaches a peak value. It could be suggested that depending on Re, as l/d ratio increases, there is an increase in the peak value of C_d. This observation is supported by the values listed in Table 4.1.

Table 4.1 Peak and asymptotic values of Re and C_d for different l/d ratios

l/d	Re_{peak}	C_{dpeak}	Re_{asym}
0.35	363	0.769	1640
0.5-0.75	2482	0.784	19700
5	9640	0.827	-
8	11700	0.860	-

Another important aspect which can be discerned from the work of Dziubinski and Marcinkowski (2006) is that to be a Newtonian or a non-Newtonian fluid, does not have a considerable effect on the behavior of C_d for $Re \geq 10$ as depicted in Figure 4.4.

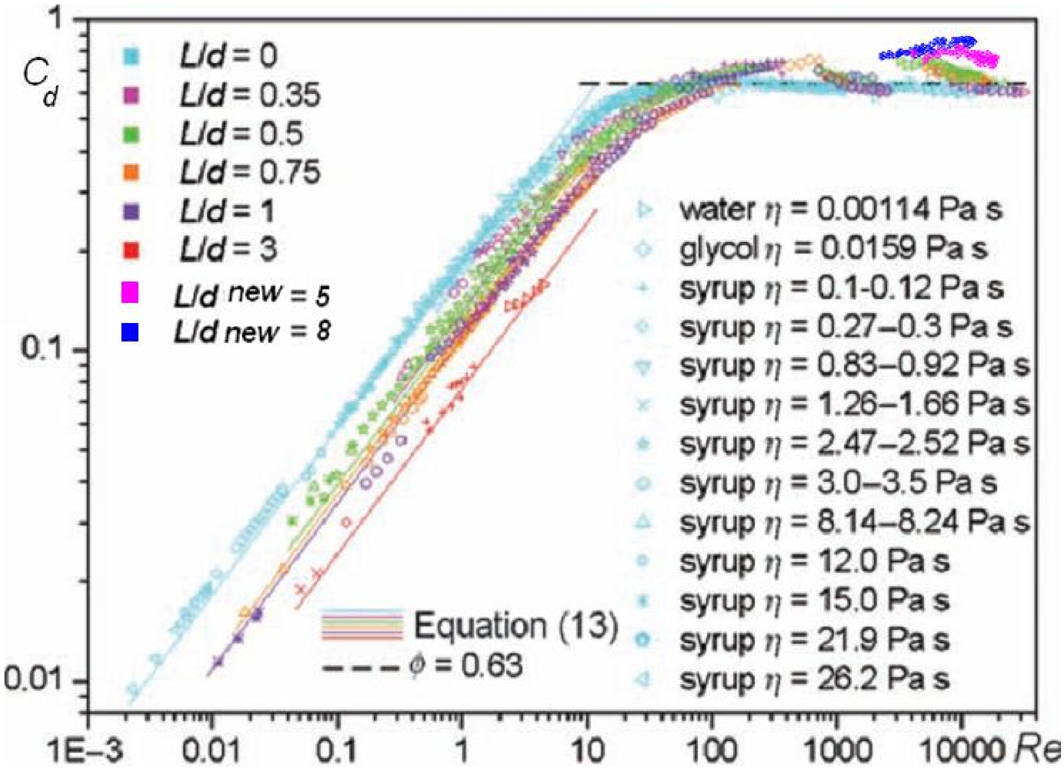


Figure 4.4 Comparing experimental results with Dziubinski and Marcinkowski's data

This wide range of C_d was also reported in the Davis (1952) such that C_d values from 0.62 to 0.96, depending on length and entrance of orifice were cited. (Appendix B)

4.3 Error Analysis of Discharge Coefficient

Discharge equation is given as:

$$Q = C_d A \sqrt{2gh} \tag{4.1}$$

From Equation (4.1), error values can be written as:

$$e_{C_d} = \sqrt{e_Q^2 + e_A^2 + e_h^2} \tag{4.2}$$

where e_Q is the amount of error, due to the discharge reading. e_A and e_h are the amount of errors, come out while reading the area of the tank and head, respectively.

Error in discharge measurement (e_Q) is due to three length measurements and a time measurement. Area error (e_A), including two length measurements, is $\sqrt{2}e_h$. Based on this knowledge, Equation (4.2) becomes:

$$e_{C_d} = \sqrt{\left(e_h^2 + e_h^2 + e_h^2 + e_t^2\right) + \left(e_h^2 + e_h^2\right) + e_h^2} = \sqrt{6e_h^2 + e_t^2} \qquad (4.3)$$

Above equation gives the error limit, which is calculated as:

$$C_d^* = C_d \pm e_{C_d} \qquad (4.4)$$

where C_d is the calculated discharge coefficient while C_d* is the true value. Calculation of e_t and e_h is explained in the section 3.3. Same method is used while gathering the error of C_d The graph showing the limits of C_d is depicted in Figure 4.5.

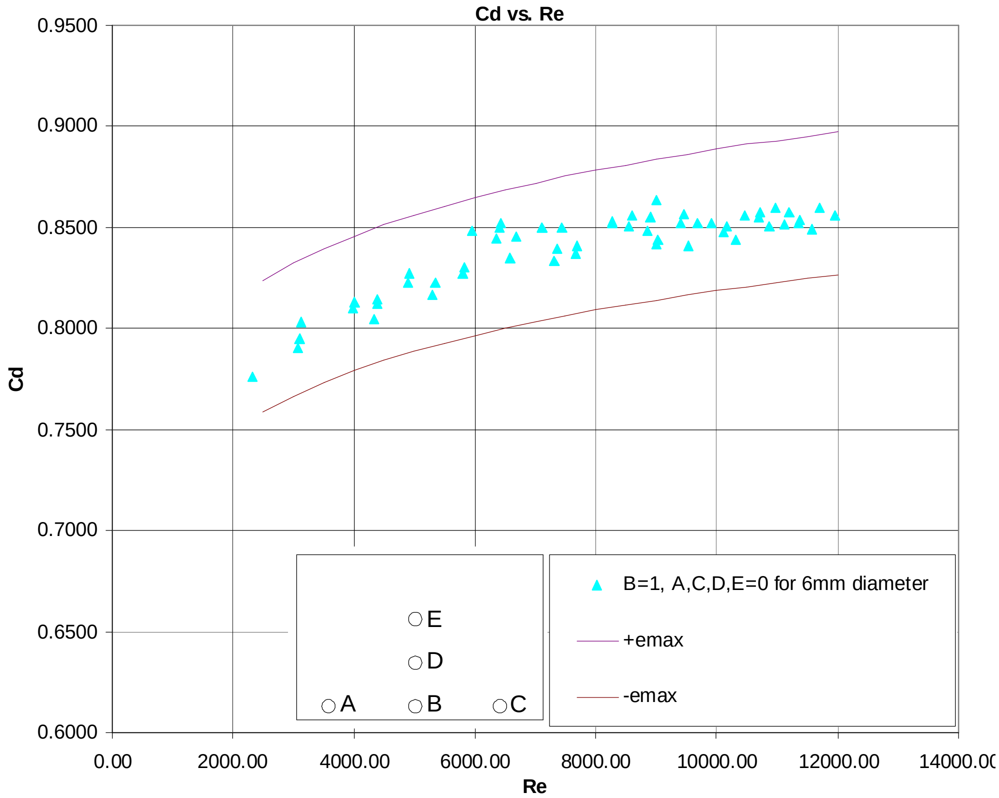


Figure 4.5 Maximum error limits when B=1, A,C,D,E=0 for 6mm diameter

It is seen that the collected data remains within the range of error limits, given in Figure 4.5 as $+e_{max}$ and $-e_{max}$. Percentage of points falling in the maximum error range is 100%.

4.4 Investigation of Group of Active Orifices in the Vicinity

As explained in Chapter 3, several combinations of multiple orifices are activated for series of experiments. The closest active orifice to "B" is located at a relative distance r/d=4.5, with r being the actual distance between "B" and the active orifice. The same procedures for the single outlet are followed for the discharge calculation. Only discharge of slot B is measured when nearby orifices (A, C, D, E) are in operation. Figure 4.6 and 4.7 shows the general trend of Re versus C_d. Additionally maximum error range for C_d is given in Figure 4.6 and 4.7 as $+e_{max}$ and $-e_{max}$.

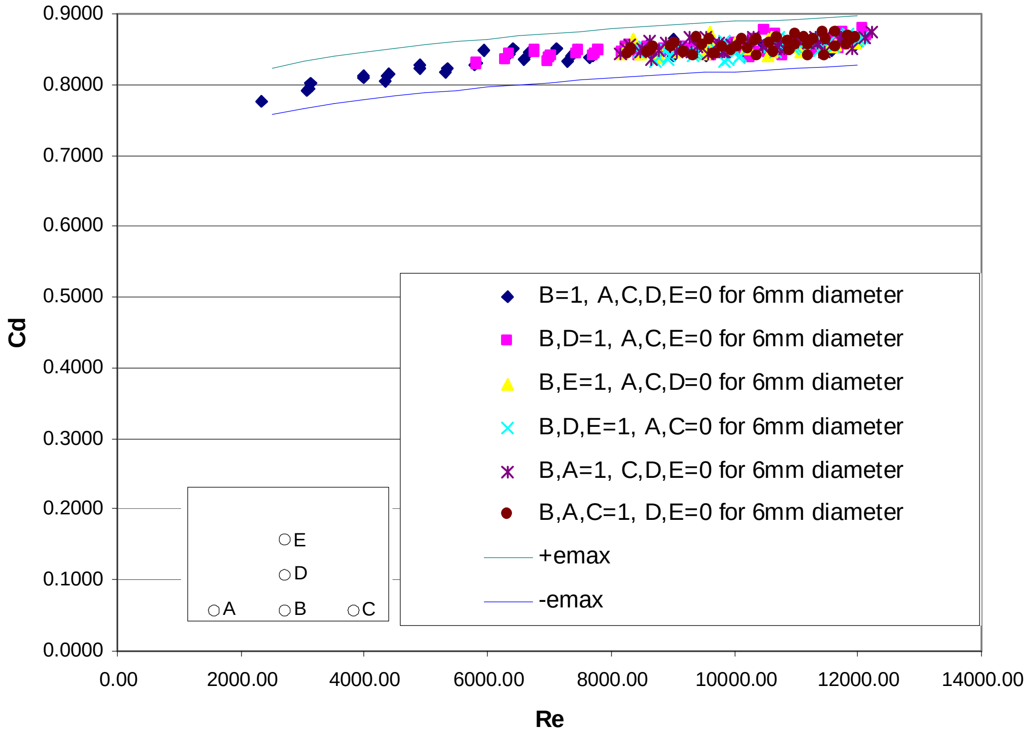


Figure 4.6 Variation of C_d of B when multiple orifices are activated for 6mm diameter

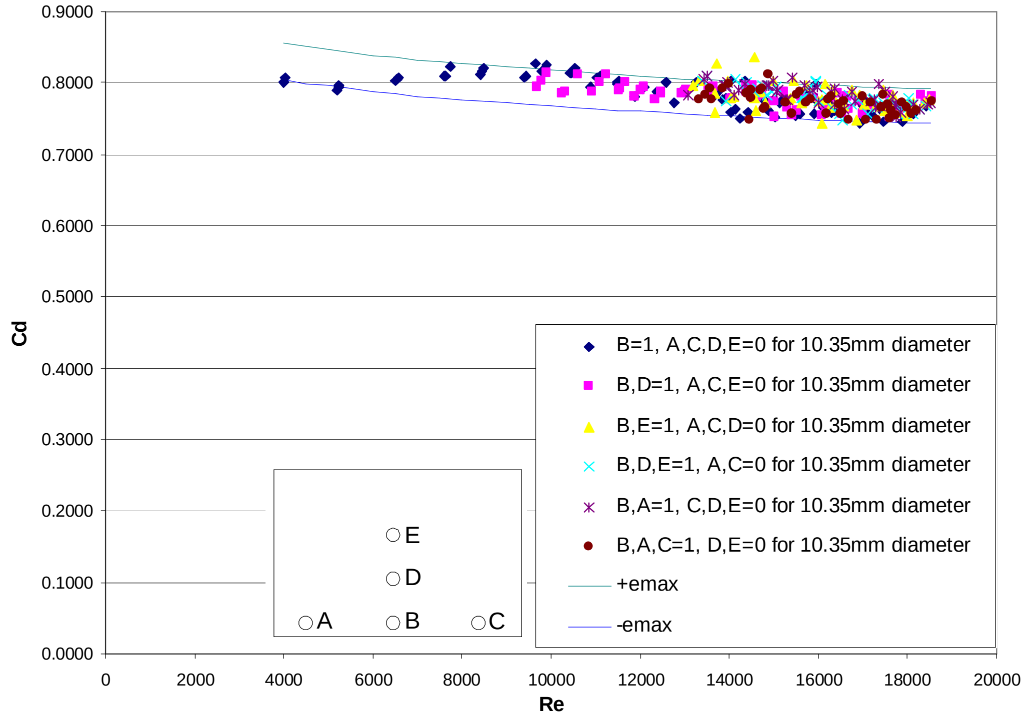


Figure 4.7 Variation of C_d of B when multiple orifices are activated for 10.35mm diameter

Even if there were a dependence of C_d on the neighboring active orifices, since the observed values of C_d falls within the acceptable band depicted in Figures 4.6 and 4.7, the dependence seems to be very weak and not discernable for the range of values of r/d and w/d experimented.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, the performance of single and multiple outlets under constant head is investigated by taking into account the water head, orifice shape and orifice length. The relation between actual discharge and the theoretical discharge, which is obtained from the Bernoulli equation, is described by a discharge coefficient. The variation of discharge coefficient, C_d can be described with outlet Reynolds number, $Re = 4Q\rho/\pi d\mu$, and l/d ratio. The Reynolds Number range examined in this study falls between 2300<Re<18600. The following conclusions are obtained:

-The C_d value approaches asymptotically to a constant value of 0.63 for $Re \geq 10$. However, before it converges to this constant, it reaches a peak value. It could be suggested that depending on Re, as l/d ratio increases, there is an increase in the peak value of C_d.

-In case of multiple outlets, a dependence of C_d on the neighboring active orifices are observed but it falls within the acceptable range and dependence, if there is, is not discernable.

5.2 Recommendations For Future Studies

The data collected in the present study and available data in the literature suggested that , the discharge coefficient of short tubes is the function of l/d and Re. Following relation is observed:

-For Re<10, there is a linear relation between C_d and Re,

-For Re>10, peak values of C_d is observed for each l/d. Further C_d is approaching to a constant value in high Reynolds number range.

Therefore, it is recommended to study for developing a functional relation for peak values and also the limit of Re for the constant C_d.

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APPENDIX A

DATA COLLECTED FROM EXPERIMENTS

TableA.1 Data obtained when B=1, A,C,D,E=0 for 6 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δh1 (cm)	Δt1 (sec)	Δh2 (cm)	Δt2 (sec)
1	0	1	0	0	0	6	15.6	2.0	13.6	3	37.33	4	50.32
2	0	1	0	0	0	6	17.7	2.0	15.7	3	35.22	4	46.63
3	0	1	0	0	0	6	19.6	2.0	17.6	3	33.37	4	43.52
4	0	1	0	0	0	6	21.5	2.0	19.5	3	31.42	4	41.72
5	0	1	0	0	0	6	23.6	2.0	21.6	3	30.33	4	38.69
6	0	1	0	0	0	6	25.6	2.0	23.6	3	29.07	4	37.42
7	0	1	0	0	0	6	27.6	2.0	25.6	3	27.43	4	36.3
8	0	1	0	0	0	6	30.2	2.0	28.2	3	25.9	4	34.69
9	0	1	0	0	0	6	28.8	2.0	26.8	3	26.5	4	36.26
10	0	1	0	0	0	6	26.6	2.0	24.6	3	28.01	4	37.17
11	0	1	0	0	0	6	24.6	2.0	22.6	3	29.03	4	38.53
12	0	1	0	0	0	6	22.6	2.0	20.6	3	30.84	4	40.42
13	0	1	0	0	0	6	20.6	2.0	18.6	3	32.15	4	42.74
14	0	1	0	0	0	6	18.5	2.0	16.5	3	34.56	4	45.96
15	0	1	0	0	0	6	16.6	2.0	14.6	3	36.25	4	47.93
16	0	0	0	1	0	6	15.6	8.5	7.1	3	53.33	4	71.1
17	0	0	0	1	0	6	17.5	8.5	9.0	3	46.63	4	61.87
18	0	0	0	1	0	6	19.6	8.5	11.1	3	41.88	4	55.34
19	0	0	0	1	0	6	20.6	8.5	12.1	3	40.5	4	53.62
20	0	0	0	1	0	6	18.6	8.5	10.1	3	43.66	4	58.28
21	0	0	0	1	0	6	16.7	8.5	8.2	3	48.74	4	65.17
22	0	0	0	0	1	6	21.1	15.0	6.1	3	58.83	4	77.62
23	0	0	0	0	1	6	19.2	15.0	4.2	3	70.33	4	94.72
24	0	0	0	0	1	6	17.2	15.0	2.2	3	100.14	4	134.82
25	0	0	0	0	1	6	16.3	15.0	1.3	3	133.3	4	177.79
26	0	0	0	0	1	6	18.5	15.0	3.5	3	77.92	4	103.73
27	0	0	0	0	1	6	20.1	15.0	5.1	3	63.32	4	84.88
28	0	1	0	0	0	6	15.6	2	13.6	3	37.12	4	50.71
29	0	1	0	0	0	6	17.7	2	15.7	3	34.66	4	45.8
30	0	1	0	0	0	6	19.6	2	17.6	3	32.82	4	43.82
31	0	1	0	0	0	6	21.5	2	19.5	3	31.36	4	
32	0	1	0	0	0	6	23.6	2	21.6	3	30.39	4	39.74
33	0	1	0	0	0	6	25.6	2	23.6	3	28.48	4	37.42
34	0	1	0	0	0	6	27.6	2	25.6	3	27.37	4	36.47
35	0	1	0	0	0	6	30.2	2	28.2	3	25.99	4	34.58
36	0	1	0	0	0	6	28.8	2	26.8	3	26.1	4	35.95
37	0	1	0	0	0	6	26.6	2	24.6	3	27.73	4	37.02
38	0	1	0	0	0	6	24.6	2	22.6	3	29.08	4	38.63
39	0	1	0	0	0	6	22.6	2	20.6	3	30.84	4	40.71

TableA.1 (cont'd)

40	0	1	0	0	0	6	20.6	2	18.6	3	32.91	4	42.92
41	0	1	0	0	0	6	18.5	2	16.5	3	34.3	4	46.1
42	0	1	0	0	0	6	16.6	2	14.6	3	36.57	4	48.04
43	0	0	0	1	0	6	15.6	8.5	7.1	3	51.62	4	70.41
44	0	0	0	1	0	6	17.5	8.5	9	3	46.76	4	63.33
45	0	0	0	1	0	6	19.6	8.5	11.1	3	41.93	4	56.62
46	0	0	0	1	0	6	20.6	8.5	12.1	3	40.43	4	54.15
47	0	0	0	1	0	6	18.6	8.5	10.1	3	43.55	4	58.48
48	0	0	0	1	0	6	16.7	8.5	8.2	3	48.36	4	64.5
49	0	0	0	0	1	6	21.1	15	6.1	3	58.23	4	77.3
50	0	0	0	0	1	6	19.2	15	4.2	3	71.11	4	95.99
51	0	0	0	0	1	6	17.2	15	2.2	3	97.34	4	134.59
52	0	0	0	0	1	6	16.3	15	1.3	3		4	
53	0	0	0	0	1	6	18.5	15	3.5	3	77.34	4	103.85
54	0	0	0	0	1	6	20.1	15	5.1	3	63.03	4	84.43
55	0	1	0	0	0	6	15.6	2	13.6	3		4	
56	0	1	0	0	0	6	17.7	2	15.7	3	34.62	4	46.72
57	0	1	0	0	0	6	19.6	2	17.6	3		4	
58	0	1	0	0	0	6	21.5	2	19.5	3		4	
59	0	1	0	0	0	6	23.6	2	21.6	3		4	
60	0	1	0	0	0	6	25.6	2	23.6	3	29.13	4	
61	0	1	0	0	0	6	27.6	2	25.6	3		4	
62	0	1	0	0	0	6	30.2	2	28.2	3		4	
63	0	1	0	0	0	6	28.8	2	26.8	3		4	
64	0	1	0	0	0	6	26.6	2	24.6	3		4	
65	0	1	0	0	0	6	24.6	2	22.6	3		4	
66	0	1	0	0	0	6	22.6	2	20.6	3		4	
67	0	1	0	0	0	6	20.6	2	18.6	3	31.67	4	
68	0	1	0	0	0	6	18.5	2	16.5	3		4	
69	0	1	0	0	0	6	16.6	2	14.6	3		4	
70	0	0	0	1	0	6	15.6	8.5	7.1	3	53.53	4	71.35
71	0	0	0	1	0	6	17.5	8.5	9	3		4	
72	0	0	0	1	0	6	19.6	8.5	11.1	3	42.78	4	56.33
73	0	0	0	1	0	6	20.6	8.5	12.1	3		4	
74	0	0	0	1	0	6	18.6	8.5	10.1	3		4	
75	0	0	0	1	0	6	16.7	8.5	8.2	3	48.73	4	64.34
76	0	0	0	0	1	6	21.1	15	6.1	3		4	
77	0	0	0	0	1	6	19.2	15	4.2	3	70.79	4	94.7
78	0	0	0	0	1	6	17.2	15	2.2	3	100.36	4	133.11
79	0	0	0	0	1	6	16.3	15	1.3	3		4	
80	0	0	0	0	1	6	18.5	15	3.5	3		4	
81	0	0	0	0	1	6	20.1	15	5.1	3		4	

TableA.2 Results calculated when B=1, A,C,D,E=0 for 6 mm diameter

No.	Q1(m^3/s)	Q2(m^3/s)	Q_{avg}(m^3/s)	C_d	Re
1	3.96E-05	3.92E-05	3.94E-05	0.8526	8274.04
2	4.20E-05	4.23E-05	4.21E-05	0.8487	8848.83
3	4.43E-05	4.53E-05	4.48E-05	0.8525	9410.54
4	4.70E-05	4.72E-05	4.71E-05	0.8524	9904.59
5	4.87E-05	5.09E-05	4.98E-05	0.8562	10470.84
6	5.08E-05	5.27E-05	5.18E-05	0.8507	10874.35
7	5.39E-05	5.43E-05	5.41E-05	0.8536	11364.43
8	5.71E-05	5.68E-05	5.69E-05	0.8562	11963.54
9	5.58E-05	5.44E-05	5.51E-05	0.8493	11569.38
10	5.28E-05	5.30E-05	5.29E-05	0.8516	11113.71
11	5.09E-05	5.11E-05	5.10E-05	0.8571	10722.32
12	4.79E-05	4.88E-05	4.83E-05	0.8505	10157.14
13	4.60E-05	4.61E-05	4.60E-05	0.8524	9673.94
14	4.28E-05	4.29E-05	4.28E-05	0.8418	8997.76
15	4.08E-05	4.11E-05	4.09E-05	0.8557	8603.14
16	2.77E-05	2.77E-05	2.77E-05	0.8306	5823.58
17	3.17E-05	3.19E-05	3.18E-05	0.8457	6676.35
18	3.53E-05	3.56E-05	3.55E-05	0.8497	7448.90
19	3.65E-05	3.68E-05	3.66E-05	0.8407	7695.25
20	3.39E-05	3.38E-05	3.38E-05	0.8501	7109.01
21	3.03E-05	3.02E-05	3.03E-05	0.8444	6362.74
22	2.51E-05	2.54E-05	2.53E-05	0.8166	5306.77
23	2.10E-05	2.08E-05	2.09E-05	0.8147	4393.65
24	1.48E-05	1.46E-05	1.47E-05	0.7908	3086.28
25	1.11E-05	1.11E-05	1.11E-05	0.7764	2329.39
26	1.90E-05	1.90E-05	1.90E-05	0.8103	3988.73
27	2.33E-05	2.32E-05	2.33E-05	0.8231	4891.47
28	3.98E-05	3.89E-05	3.93E-05	0.8518	8265.93
29	4.26E-05	4.30E-05	4.28E-05	0.8633	9000.53
30	4.50E-05	4.50E-05	4.50E-05	0.8566	9455.95
31					
32	4.86E-05	4.96E-05	4.91E-05	0.8438	10319.34
33	5.19E-05	5.27E-05	5.23E-05	0.8593	10985.01
34	5.40E-05	5.40E-05	5.40E-05	0.8525	11350.25
35	5.69E-05	5.70E-05	5.69E-05	0.8560	11961.77
36	5.66E-05	5.48E-05	5.57E-05	0.8595	11708.42
37	5.33E-05	5.32E-05	5.33E-05	0.8576	11192.26
38	5.08E-05	5.10E-05	5.09E-05	0.8553	10699.21
39	4.79E-05	4.84E-05	4.82E-05	0.8474	10120.65
40	4.49E-05	4.59E-05	4.54E-05	0.8408	9542.09
41	4.31E-05	4.28E-05	4.29E-05	0.8437	9018.13
42	4.04E-05	4.10E-05	4.07E-05	0.8509	8555.76
43	2.86E-05	2.80E-05	2.83E-05	0.8484	5948.57
44	3.16E-05	3.11E-05	3.14E-05	0.8348	6589.95
45	3.53E-05	3.48E-05	3.50E-05	0.8395	7359.90
46	3.66E-05	3.64E-05	3.65E-05	0.8373	7664.09
47	3.39E-05	3.37E-05	3.38E-05	0.8497	7105.84
48	3.06E-05	3.06E-05	3.06E-05	0.8521	6420.78
49	2.54E-05	2.55E-05	2.54E-05	0.8224	5345.01
50	2.08E-05	2.05E-05	2.07E-05	0.8049	4340.51

TableA.2 (cont'd)

51	1.52E-05	1.46E-05	1.49E-05	0.8029	3133.50
52					
53	1.91E-05	1.90E-05	1.90E-05	0.8128	4001.36
54	2.35E-05	2.33E-05	2.34E-05	0.8272	4915.75
55					
56	4.27E-05	4.22E-05	4.24E-05	0.8552	8916.69
57					
58					
59					
60					
61					
62					
63					
64					
65					
66					
67					
68					
69					
70	2.76E-05	2.76E-05	2.76E-05	0.8276	5802.50
71					
72	3.46E-05	3.50E-05	3.48E-05	0.8333	7305.15
73					
74					
75	3.03E-05	3.06E-05	3.05E-05	0.8499	6404.38
76					
77	2.09E-05	2.08E-05	2.08E-05	0.8122	4379.76
78	1.47E-05	1.48E-05	1.48E-05	0.7949	3102.61
79					
80					
81					

TableA.3 Data obtained when B,D=1, A,C,E=0 for 6 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δh1 (cm)	Δt1 (sec)	Δh2 (cm)	Δt2 (sec)
1	0	1	0	1	0	6	15.5	2.0	13.5	3	37.66	4	49.73
2	0	1	0	1	0	6	17.6	2.0	15.6	3	35.19	4	46.66
3	0	1	0	1	0	6	19.4	2.0	17.4	3	33.41	4	44.09
4	0	1	0	1	0	6	21.6	2.0	19.6	3	30.98	4	41.52
5	0	1	0	1	0	6	23.6	2.0	21.6	3	29.02	4	39.08
6	0	1	0	1	0	6	25.5	2.0	23.5	3	28.32	4	38.02
7	0	1	0	1	0	6	28.0	2.0	26.0	3	26.45	4	35.88
8	0	1	0	1	0	6	30.2	2.0	28.2	3	25.58	4	34.17
9	0	1	0	1	0	6	29.3	2.0	27.3	3	25.8	4	34.19
10	0	1	0	1	0	6	27.3	2.0	25.3	3	27.75	4	36.88
11	0	1	0	1	0	6	25.8	2.0	23.8	3	28.19	4	37.38
12	0	1	0	1	0	6	24.5	2.0	22.5	3	29.28	4	38.58
13	0	1	0	1	0	6	22.6	2.0	20.6	3	29.63	4	39.52

TableA.3 (cont'd)

14	0	1	0	1	0	6	20.9	2.0	18.9	3	32.73	4	42.47
15	0	1	0	1	0	6	18.6	2.0	16.6	3	33.94	4	45.47
16	0	1	0	1	0	6	16.6	2.0	14.6	3	36.73	4	49.03
17	0	0	0	1	1	6	15.6	8.5	7.1	3	53.26	4	71.21
18	0	0	0	1	1	6	17.7	8.5	9.2	3	45.96	4	61.33
19	0	0	0	1	1	6	19.7	8.5	11.2	3	41.6	4	55.93
20	0	0	0	1	1	6	20.7	8.5	12.2	3	40.09	4	52.84
21	0	0	0	1	1	6	18.6	8.5	10.1	3	43.99	4	59.19
22	0	0	0	1	1	6	16.7	8.5	8.2	3	48.84	4	65.32
23	0	1	0	1	0	6	15.5	2.0	13.5	3	38.07	4	50.43
24	0	1	0	1	0	6	17.6	2.0	15.6	3	35.6	4	47.04
25	0	1	0	1	0	6	19.4	2.0	17.4	3	33.08	4	43.95
26	0	1	0	1	0	6	21.6	2.0	19.6	3	31.23	4	41.48
27	0	1	0	1	0	6	23.6	2.0	21.6	3	30.23	4	39.76
28	0	1	0	1	0	6	25.5	2.0	23.5	3	28.22	4	38.08
29	0	1	0	1	0	6	28.0	2.0	26.0	3	26.42	4	35.3
30	0	1	0	1	0	6	30.2	2.0	28.2	3	25.83	4	34.55
31	0	1	0	1	0	6	29.3	2.0	27.3	3	26.35	4	35.12
32	0	1	0	1	0	6	27.3	2.0	25.3	3	27.69	4	36.59
33	0	1	0	1	0	6	25.8	2.0	23.8	3	28.95	4	38.14
34	0	1	0	1	0	6	24.5	2.0	22.5	3	29.12	4	39.42
35	0	1	0	1	0	6	22.6	2.0	20.6	3	30.72	4	40.82
36	0	1	0	1	0	6	20.9	2.0	18.9	3	31.72	4	42.63
37	0	1	0	1	0	6	18.6	2.0	16.6	3	33.93	4	45.34
38	0	1	0	1	0	6	16.6	2.0	14.6	3	36.25	4	48.53
39	0	0	0	1	1	6	15.6	8.5	7.1	3	53.59	4	71.08
40	0	0	0	1	1	6	17.7	8.5	9.2	3	45.92	4	61.04
41	0	0	0	1	1	6	19.7	8.5	11.2	3	41.44	4	55.52
42	0	0	0	1	1	6	20.7	8.5	12.2	3	40.14	4	53.77
43	0	0	0	1	1	6	18.6	8.5	10.1	3	44.4	4	59.01
44	0	0	0	1	1	6	16.7	8.5	8.2	3	49.16	4	65.83
45	0	1	0	1	0	6	15.5	2.0	13.5	3	37.57	4	50.35
46	0	1	0	1	0	6	17.6	2.0	15.6	3	35.17	4	47
47	0	1	0	1	0	6	19.4	2.0	17.4	3		4	
48	0	1	0	1	0	6	21.6	2.0	19.6	3		4	
49	0	1	0	1	0	6	23.6	2.0	21.6	3	30.49	4	40.04
50	0	1	0	1	0	6	25.5	2.0	23.5	3		4	
51	0	1	0	1	0	6	28.0	2.0	26.0	3	27.03	4	35.77
52	0	1	0	1	0	6	30.2	2.0	28.2	3	25.9	4	34.6
53	0	1	0	1	0	6	29.3	2.0	27.3	3	26.54	4	35.45
54	0	1	0	1	0	6	27.3	2.0	25.3	3		4	
55	0	1	0	1	0	6	25.8	2.0	23.8	3	28.08	4	37.67
56	0	1	0	1	0	6	24.5	2.0	22.5	3	29.56	4	39.02
57	0	1	0	1	0	6	22.6	2.0	20.6	3	30.28	4	39.96
58	0	1	0	1	0	6	20.9	2.0	18.9	3	31.84	4	42.32
59	0	1	0	1	0	6	18.6	2.0	16.6	3		4	
60	0	1	0	1	0	6	16.6	2.0	14.6	3	36.21	4	48.2
61	0	0	0	1	1	6	15.6	8.5	7.1	3		4	
62	0	0	0	1	1	6	17.7	8.5	9.2	3		4	
63	0	0	0	1	1	6	19.7	8.5	11.2	3		4	
64	0	0	0	1	1	6	20.7	8.5	12.2	3	39.77	4	53.22

TableA.3 (cont'd)

65	0	0	0	1	1	6	18.6	8.5	10.1	3	44.6	4	59.25
66	0	0	0	1	1	6	16.7	8.5	8.2	3	49.17	4	66.08

TableA.4 Results calculated when B,D=1, A,C,E=0 for 6 mm diameter

No.	Q1(m^3/s)	Q2(m^3/s)	Q_{avg}(m^3/s)	C_d	Re
1	3.92E-05	3.96E-05	3.94E-05	0.8571	8286.41
2	4.20E-05	4.22E-05	4.21E-05	0.8515	8849.74
3	4.42E-05	4.47E-05	4.45E-05	0.8512	9343.47
4	4.77E-05	4.75E-05	4.76E-05	0.8583	9998.68
5	5.09E-05	5.04E-05	5.07E-05	0.8707	10648.54
6	5.22E-05	5.18E-05	5.20E-05	0.8567	10928.50
7	5.59E-05	5.49E-05	5.54E-05	0.8676	11640.93
8	5.78E-05	5.77E-05	5.77E-05	0.8680	12129.37
9	5.73E-05	5.76E-05	5.75E-05	0.8782	12074.06
10	5.33E-05	5.34E-05	5.34E-05	0.8469	11209.45
11	5.24E-05	5.27E-05	5.26E-05	0.8606	11047.02
12	5.05E-05	5.11E-05	5.08E-05	0.8548	10669.69
13	4.99E-05	4.99E-05	4.99E-05	0.8775	10479.40
14	4.52E-05	4.64E-05	4.58E-05	0.8409	9619.15
15	4.36E-05	4.33E-05	4.34E-05	0.8515	9128.38
16	4.02E-05	4.02E-05	4.02E-05	0.8405	8450.25
17	2.78E-05	2.77E-05	2.77E-05	0.8305	5822.91
18	3.22E-05	3.21E-05	3.21E-05	0.8463	6754.36
19	3.55E-05	3.52E-05	3.54E-05	0.8442	7434.39
20	3.69E-05	3.73E-05	3.71E-05	0.8477	7791.45
21	3.36E-05	3.33E-05	3.34E-05	0.8404	7027.71
22	3.03E-05	3.02E-05	3.02E-05	0.8426	6348.93
23	3.88E-05	3.91E-05	3.90E-05	0.8465	8184.22
24	4.15E-05	4.19E-05	4.17E-05	0.8432	8763.07
25	4.47E-05	4.48E-05	4.48E-05	0.8568	9404.79
26	4.73E-05	4.75E-05	4.74E-05	0.8553	9963.37
27	4.89E-05	4.96E-05	4.92E-05	0.8458	10343.76
28	5.24E-05	5.18E-05	5.21E-05	0.8576	10939.35
29	5.59E-05	5.58E-05	5.59E-05	0.8752	11742.41
30	5.72E-05	5.70E-05	5.71E-05	0.8591	12003.97
31	5.61E-05	5.61E-05	5.61E-05	0.8574	11788.08
32	5.34E-05	5.39E-05	5.36E-05	0.8512	11266.07
33	5.11E-05	5.17E-05	5.14E-05	0.8407	10792.05
34	5.08E-05	5.00E-05	5.04E-05	0.8480	10584.47
35	4.81E-05	4.83E-05	4.82E-05	0.8479	10126.61
36	4.66E-05	4.62E-05	4.64E-05	0.8525	9751.91
37	4.36E-05	4.35E-05	4.35E-05	0.8528	9142.78
38	4.08E-05	4.06E-05	4.07E-05	0.8503	8549.73
39	2.76E-05	2.77E-05	2.77E-05	0.8287	5810.27
40	3.22E-05	3.23E-05	3.22E-05	0.8487	6773.34
41	3.57E-05	3.55E-05	3.56E-05	0.8490	7476.14
42	3.68E-05	3.67E-05	3.67E-05	0.8398	7718.86

TableA.4 (cont'd)

43	3.33E-05	3.34E-05	3.33E-05	0.8378	7005.79
44	3.01E-05	2.99E-05	3.00E-05	0.8366	6303.68
45	3.93E-05	3.91E-05	3.92E-05	0.8528	8245.02
46	4.20E-05	4.19E-05	4.20E-05	0.8487	8820.15
47					
48					
49	4.85E-05	4.92E-05	4.88E-05	0.8392	10263.55
50					
51	5.47E-05	5.51E-05	5.49E-05	0.8595	11532.71
52	5.71E-05	5.70E-05	5.70E-05	0.8573	11979.07
53	5.57E-05	5.56E-05	5.56E-05	0.8503	11691.02
54					
55	5.26E-05	5.23E-05	5.25E-05	0.8589	11025.96
56	5.00E-05	5.05E-05	5.03E-05	0.8460	10558.94
57	4.88E-05	4.93E-05	4.91E-05	0.8632	10309.22
58	4.64E-05	4.66E-05	4.65E-05	0.8540	9769.04
59					
60	4.08E-05	4.09E-05	4.09E-05	0.8537	8583.67
61					
62					
63					
64	3.72E-05	3.70E-05	3.71E-05	0.8481	7794.64
65	3.31E-05	3.33E-05	3.32E-05	0.8342	6975.89
66	3.01E-05	2.98E-05	2.99E-05	0.8349	6291.13

TableA.5 Data obtained when B,E=1, A,C,D=0 for 6 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δh1 (cm)	Δt1 (sec)	Δh2 (cm)	Δt2 (sec)
1	0	1	0	0	1	6	15.6	2.0	13.6	3	37.96	4	50.52
2	0	1	0	0	1	6	17.7	2.0	15.7	3	35.53	4	47.38
3	0	1	0	0	1	6	19.5	2.0	17.5	3	32.26	4	43.16
4	0	1	0	0	1	6	21.7	2.0	19.7	3	30.93	4	41.32
5	0	1	0	0	1	6	23.6	2.0	21.6	3	29.27	4	39.1
6	0	1	0	0	1	6	25.8	2.0	23.8	3	28.32	4	37.12
7	0	1	0	0	1	6	27.7	2.0	25.7	3	27.3	4	36.05
8	0	1	0	0	1	6	30.1	2.0	28.1	3	25.84	4	34.36
9	0	1	0	0	1	6	28.7	2.0	26.7	3	26.82	4	35.6
10	0	1	0	0	1	6	26.7	2.0	24.7	3	28.02	4	37.44
11	0	1	0	0	1	6	24.7	2.0	22.7	3	29.35	4	38.74
12	0	1	0	0	1	6	22.7	2.0	20.7	3	30.53	4	40.38
13	0	1	0	0	1	6	20.3	2.0	18.3	3	32.24	4	42.92
14	0	1	0	0	1	6	18.5	2.0	16.5	3	34.37	4	45.66
15	0	1	0	0	1	6	16.6	2.0	14.6	3	36.64	4	48.69
16	0	1	0	0	1	6	15.6	2.0	13.6	3	36.95	4	49.66
17	0	1	0	0	1	6	17.7	2.0	15.7	3	34.79	4	46.52
18	0	1	0	0	1	6	19.5	2.0	17.5	3	32.69	4	43.94

TableA.5 (cont'd)

19	0	1	0	0	1	6	21.7	2.0	19.7	3	31.01	4	41.34
20	0	1	0	0	1	6	23.6	2.0	21.6	3	29.72	4	38.84
21	0	1	0	0	1	6	25.8	2.0	23.8	3	28.31	4	37.74
22	0	1	0	0	1	6	27.7	2.0	25.7	3	26.79	4	36.32
23	0	1	0	0	1	6	30.1	2.0	28.1	3	25.9	4	34.63
24	0	1	0	0	1	6	28.7	2.0	26.7	3	26.64	4	35.64
25	0	1	0	0	1	6	26.7	2.0	24.7	3	27.92	4	37.15
26	0	1	0	0	1	6	24.7	2.0	22.7	3	29.24	4	39.05
27	0	1	0	0	1	6	22.7	2.0	20.7	3	30.46	4	40.65
28	0	1	0	0	1	6	20.3	2.0	18.3	3	32.48	4	43.33
29	0	1	0	0	1	6	18.5	2.0	16.5	3	33.98	4	45.73
30	0	1	0	0	1	6	16.6	2.0	14.6	3	36.54	4	48.97
31	0	1	0	0	1	6	15.6	2.0	13.6	3	37.68	4	50.08
32	0	1	0	0	1	6	17.7	2.0	15.7	3	35.44	4	47.03
33	0	1	0	0	1	6	19.5	2.0	17.5	3	32.33	4	43.41
34	0	1	0	0	1	6	21.7	2.0	19.7	3	31.03	4	41.52
35	0	1	0	0	1	6	23.6	2.0	21.6	3		4	
36	0	1	0	0	1	6	25.8	2.0	23.8	3		4	
37	0	1	0	0	1	6	27.7	2.0	25.7	3	27.37	4	35.88
38	0	1	0	0	1	6	30.1	2.0	28.1	3		4	
39	0	1	0	0	1	6	28.7	2.0	26.7	3		4	
40	0	1	0	0	1	6	26.7	2.0	24.7	3		4	
41	0	1	0	0	1	6	24.7	2.0	22.7	3	29.48	4	39.3
42	0	1	0	0	1	6	22.7	2.0	20.7	3	30.54	4	40.65
43	0	1	0	0	1	6	20.3	2.0	18.3	3	32.53	4	43.82
44	0	1	0	0	1	6	18.5	2.0	16.5	3		4	
45	0	1	0	0	1	6	16.6	2.0	14.6	3		4	

TableA.6 Results calculated when B,E=1, A,C,D=0 for 6 mm diameter

No.	Q1(m^3/s)	Q2(m^3/s)	Q_{avg}(m^3/s)	C_d	Re
1	3.89E-05	3.90E-05	3.9E-05	0.8439	8188.72
2	4.16E-05	4.16E-05	4.16E-05	0.8383	8740.08
3	4.58E-05	4.57E-05	4.57E-05	0.8731	9610.33
4	4.78E-05	4.77E-05	4.77E-05	0.8589	10030.92
5	5.05E-05	5.04E-05	5.05E-05	0.8668	10600.13
6	5.22E-05	5.31E-05	5.26E-05	0.8616	11060.53
7	5.41E-05	5.47E-05	5.44E-05	0.8569	11430.94
8	5.72E-05	5.74E-05	5.73E-05	0.8628	12034.78
9	5.51E-05	5.54E-05	5.52E-05	0.8535	11605.33
10	5.28E-05	5.26E-05	5.27E-05	0.8466	11071.56
11	5.04E-05	5.09E-05	5.06E-05	0.8483	10634.87
12	4.84E-05	4.88E-05	4.86E-05	0.8531	10213.34
13	4.58E-05	4.59E-05	4.59E-05	0.8564	9640.14
14	4.30E-05	4.32E-05	4.31E-05	0.8469	9052.19
15	4.03E-05	4.05E-05	4.04E-05	0.8444	8490.12
16	4.00E-05	3.97E-05	3.98E-05	0.8627	8371.50

TableA.6 (cont'd)

17	4.25E-05	4.24E-05	4.24E-05	0.8549	8913.82
18	4.52E-05	4.49E-05	4.5E-05	0.8596	9461.86
19	4.77E-05	4.77E-05	4.77E-05	0.8576	10015.54
20	4.97E-05	5.07E-05	5.02E-05	0.8631	10555.25
21	5.22E-05	5.22E-05	5.22E-05	0.8546	10970.84
22	5.52E-05	5.43E-05	5.47E-05	0.8618	11496.52
23	5.71E-05	5.69E-05	5.7E-05	0.8584	11973.88
24	5.55E-05	5.53E-05	5.54E-05	0.8559	11637.92
25	5.29E-05	5.30E-05	5.3E-05	0.8514	11134.58
26	5.06E-05	5.05E-05	5.05E-05	0.8465	10612.35
27	4.85E-05	4.85E-05	4.85E-05	0.8512	10190.97
28	4.55E-05	4.55E-05	4.55E-05	0.8492	9558.91
29	4.35E-05	4.31E-05	4.33E-05	0.8511	9097.10
30	4.05E-05	4.02E-05	4.03E-05	0.8432	8477.40
31	3.92E-05	3.94E-05	3.93E-05	0.8507	8255.12
32	4.17E-05	4.19E-05	4.18E-05	0.8425	8783.70
33	4.57E-05	4.54E-05	4.56E-05	0.8696	9572.28
34	4.76E-05	4.75E-05	4.76E-05	0.8554	9990.61
35					
36					
37	5.40E-05	5.49E-05	5.45E-05	0.8579	11443.60
38					
39					
40					
41	5.01E-05	5.01E-05	5.01E-05	0.8403	10535.39
42	4.84E-05	4.85E-05	4.84E-05	0.8501	10177.62
43	4.54E-05	4.50E-05	4.52E-05	0.8438	9498.13
44					
45					

TableA.7 Data obtained when B,D,E=1, A,C=0 for 6 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δ h1 (cm)	Δ t1 (sec)	Δ h2 (cm)	Δ t2 (sec)
1	0	1	0	1	1	6	16.4	2.0	14.4	3	36.81	4	49.11
2	0	1	0	1	1	6	18.4	2.0	16.4	3	34.8	4	46.57
3	0	1	0	1	1	6	20.9	2.0	18.9	3	31.71	4	41.84
4	0	1	0	1	1	6	22.8	2.0	20.8	3	31.02	4	40.74
5	0	1	0	1	1	6	24.9	2.0	22.9	3	28.98	4	38.46
6	0	1	0	1	1	6	27	2.0	25.0	3	27.62	4	36.64
7	0	1	0	1	1	6	28.7	2.0	26.7	3	26.93	4	35.53
8	0	1	0	1	1	6	30	2.0	28.0	3	25.57	4	34.46
9	0	1	0	1	1	6	27.9	2.0	25.9	3	27.16	4	36.15
10	0	1	0	1	1	6	26	2.0	24.0	3	28.08	4	37.61
11	0	1	0	1	1	6	24.1	2.0	22.1	3	29.38	4	39.33
12	0	1	0	1	1	6	22.2	2.0	20.2	3	31.11	4	41.43
13	0	1	0	1	1	6	19.8	2.0	17.8	3	33.24	4	44.19
14	0	1	0	1	1	6	17.8	2.0	15.8	3	35.29	4	47.32
15	0	1	0	1	1	6	16.4	2.0	14.4	3	36.57	4	48.34
16	0	1	0	1	1	6	18.4	2.0	16.4	3	33.95	4	46.05
17	0	1	0	1	1	6	20.9	2.0	18.9	3	32.14	4	42.85
18	0	1	0	1	1	6	22.8	2.0	20.8	3	30.59	4	41.18
19	0	1	0	1	1	6	24.9	2.0	22.9	3	28.49	4	38.23
20	0	1	0	1	1	6	27	2.0	25.0	3	27.23	4	36.46
21	0	1	0	1	1	6	28.7	2.0	26.7	3	26.32	4	34.99
22	0	1	0	1	1	6	30	2.0	28.0	3	25.88	4	34.41
23	0	1	0	1	1	6	27.9	2.0	25.9	3	27.11	4	35.65
24	0	1	0	1	1	6	26	2.0	24.0	3	28.14	4	38.02
25	0	1	0	1	1	6	24.1	2.0	22.1	3	29.09	4	38.48
26	0	1	0	1	1	6	22.2	2.0	20.2	3	31.5	4	41.8
27	0	1	0	1	1	6	19.8	2.0	17.8	3	33.22	4	44.37
28	0	1	0	1	1	6	17.8	2.0	15.8	3	35.02	4	46.52
29	0	1	0	1	1	6	16.4	2.0	14.4	3	36.71	4	48.75
30	0	1	0	1	1	6	18.4	2.0	16.4	3	34.84	4	46.13
31	0	1	0	1	1	6	20.9	2.0	18.9	3	31.99	4	42.63
32	0	1	0	1	1	6	22.8	2.0	20.8	3	30.94	4	41.02
33	0	1	0	1	1	6	24.9	2.0	22.9	3	29.08	4	38.88
34	0	1	0	1	1	6	27	2.0	25.0	3	27.24	4	36.3
35	0	1	0	1	1	6	28.7	2.0	26.7	3	26	4	35.32
36	0	1	0	1	1	6	30	2.0	28.0	3	26.18	4	34.13
37	0	1	0	1	1	6	27.9	2.0	25.9	3	27.24	4	36.55
38	0	1	0	1	1	6	26	2.0	24.0	3	28.19	4	37.72
39	0	1	0	1	1	6	24.1	2.0	22.1	3	29.41	4	39.19
40	0	1	0	1	1	6	22.2	2.0	20.2	3	31.68	4	41.84
41	0	1	0	1	1	6	19.8	2.0	17.8	3	32.95	4	44.23
42	0	1	0	1	1	6	17.8	2.0	15.8	3	35.62	4	47.59

TableA.8 Results calculated when B,D,E=1, A,C=0 for 6 mm diameter

No.	Q1(m^3/s)	Q2(m^3/s)	Q_{avg}(m^3/s)	C_d	Re
1	4.02E-05	4.01E-05	4.01E-05	0.8447	8434.18
2	4.25E-05	4.23E-05	4.24E-05	0.8359	8907.76
3	4.66E-05	4.71E-05	4.69E-05	0.8606	9845.16
4	4.76E-05	4.84E-05	4.80E-05	0.8406	10087.69
5	5.10E-05	5.12E-05	5.11E-05	0.8530	10741.33
6	5.35E-05	5.38E-05	5.37E-05	0.8568	11272.56
7	5.49E-05	5.55E-05	5.52E-05	0.8526	11593.14
8	5.78E-05	5.72E-05	5.75E-05	0.8676	12080.75
9	5.44E-05	5.45E-05	5.45E-05	0.8546	11444.37
10	5.26E-05	5.24E-05	5.25E-05	0.8560	11034.73
11	5.03E-05	5.01E-05	5.02E-05	0.8528	10549.30
12	4.75E-05	4.76E-05	4.75E-05	0.8446	9988.57
13	4.45E-05	4.46E-05	4.45E-05	0.8428	9356.61
14	4.19E-05	4.16E-05	4.18E-05	0.8390	8775.35
15	4.04E-05	4.08E-05	4.06E-05	0.8542	8529.02
16	4.35E-05	4.28E-05	4.32E-05	0.8511	9069.68
17	4.60E-05	4.60E-05	4.60E-05	0.8447	9663.01
18	4.83E-05	4.79E-05	4.81E-05	0.8419	10103.75
19	5.19E-05	5.16E-05	5.17E-05	0.8629	10865.87
20	5.43E-05	5.41E-05	5.42E-05	0.8650	11380.98
21	5.62E-05	5.63E-05	5.62E-05	0.8691	11816.70
22	5.71E-05	5.73E-05	5.72E-05	0.8630	12016.74
23	5.45E-05	5.53E-05	5.49E-05	0.8614	11535.24
24	5.25E-05	5.18E-05	5.22E-05	0.8505	10963.57
25	5.08E-05	5.12E-05	5.10E-05	0.8665	10718.27
26	4.69E-05	4.71E-05	4.70E-05	0.8356	9882.54
27	4.45E-05	4.44E-05	4.45E-05	0.8414	9340.42
28	4.22E-05	4.24E-05	4.23E-05	0.8494	8884.51
29	4.03E-05	4.04E-05	4.03E-05	0.8489	8476.80
30	4.24E-05	4.27E-05	4.26E-05	0.8394	8945.04
31	4.62E-05	4.62E-05	4.62E-05	0.8489	9710.60
32	4.78E-05	4.80E-05	4.79E-05	0.8388	10065.94
33	5.08E-05	5.07E-05	5.08E-05	0.8469	10664.75
34	5.43E-05	5.43E-05	5.43E-05	0.8668	11403.91
35	5.69E-05	5.58E-05	5.63E-05	0.8704	11834.03
36	5.65E-05	5.77E-05	5.71E-05	0.8616	11997.35
37	5.43E-05	5.39E-05	5.41E-05	0.8487	11364.90
38	5.24E-05	5.22E-05	5.23E-05	0.8531	10997.10
39	5.03E-05	5.03E-05	5.03E-05	0.8539	10562.71
40	4.67E-05	4.71E-05	4.69E-05	0.8329	9849.79
41	4.49E-05	4.46E-05	4.47E-05	0.8461	9393.49
42	4.15E-05	4.14E-05	4.15E-05	0.8327	8709.76

TableA.9 Data obtained when B,A=1, C,D,E=0 for 6 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δ h1 (cm)	Δ t1 (sec)	Δ h2 (cm)	Δ t2 (sec)
1	1	1	0	0	0	6	15.5	2.0	13.5	3	38.34	4	50.6
2	1	1	0	0	0	6	17.5	2.0	15.5	3	34.76	4	46.85
3	1	1	0	0	0	6	19.5	2.0	17.5	3	32.54	4	43.42
4	1	1	0	0	0	6	21.5	2.0	19.5	3	31.91	4	41.78
5	1	1	0	0	0	6	23.7	2.0	21.7	3	29.6	4	39.34
6	1	1	0	0	0	6	25.4	2.0	23.4	3	28.12	4	37.71
7	1	1	0	0	0	6	27.3	2.0	25.3	3	27.07	4	36.34
8	1	1	0	0	0	6	30.2	2.0	28.2	3	25.3	4	34.02
9	1	1	0	0	0	6	28.5	2.0	26.5	3	26.37	4	35.57
10	1	1	0	0	0	6	26.6	2.0	24.6	3	27.64	4	37.04
11	1	1	0	0	0	6	24.6	2.0	22.6	3	28.92	4	38.64
12	1	1	0	0	0	6	22.4	2.0	20.4	3	30.16	4	40.09
13	1	1	0	0	0	6	20.6	2.0	18.6	3	31.9	4	42.58
14	1	1	0	0	0	6	18.6	2.0	16.6	3	33.39	4	44.71
15	1	1	0	0	0	6	16.5	2.0	14.5	3	35.78	4	48.25
16	1	1	0	0	0	6	15.5	2.0	13.5	3	37.68	4	50.34
17	1	1	0	0	0	6	17.5	2.0	15.5	3	35.96	4	47.68
18	1	1	0	0	0	6	19.5	2.0	17.5	3	33.22	4	44.6
19	1	1	0	0	0	6	21.5	2.0	19.5	3	31.32	4	42.59
20	1	1	0	0	0	6	23.7	2.0	21.7	3	29.72	4	39.52
21	1	1	0	0	0	6	25.4	2.0	23.4	3	28.28	4	37.69
22	1	1	0	0	0	6	27.3	2.0	25.3	3	27.01	4	36.22
23	1	1	0	0	0	6	30.2	2.0	28.2	3	25.69	4	34.19
24	1	1	0	0	0	6	28.5	2.0	26.5	3	26.43	4	35.32
25	1	1	0	0	0	6	26.6	2.0	24.6	3	27.69	4	36.84
26	1	1	0	0	0	6	24.6	2.0	22.6	3	29.25	4	38.73
27	1	1	0	0	0	6	22.4	2.0	20.4	3	30.18	4	40.69
28	1	1	0	0	0	6	20.6	2.0	18.6	3	31.71	4	42.58
29	1	1	0	0	0	6	18.6	2.0	16.6	3	33.93	4	45.36
30	1	1	0	0	0	6	16.5	2.0	14.5	3	36.14	4	49.09
31	1	1	0	0	0	6	15.5	2.0	13.5	3	37.48	4	49.97
32	1	1	0	0	0	6	17.5	2.0	15.5	3	35.39	4	47.07
33	1	1	0	0	0	6	19.5	2.0	17.5	3	33.14	4	43.87
34	1	1	0	0	0	6	21.5	2.0	19.5	3	31.22	4	41.62
35	1	1	0	0	0	6	23.7	2.0	21.7	3	29.6	4	39.79
36	1	1	0	0	0	6	25.4	2.0	23.4	3	28.68	4	38.3
37	1	1	0	0	0	6	27.3	2.0	25.3	3	27.24	4	36.65
38	1	1	0	0	0	6	30.2	2.0	28.2	3	26.06	4	34.86
39	1	1	0	0	0	6	28.5	2.0	26.5	3	27.31	4	35.8
40	1	1	0	0	0	6	26.6	2.0	24.6	3	27.5	4	36.5
41	1	1	0	0	0	6	24.6	2.0	22.6	3	29.12	4	38.68
42	1	1	0	0	0	6	22.4	2.0	20.4	3	30.43	4	40.82
43	1	1	0	0	0	6	20.6	2.0	18.6	3	32.7	4	42.83
44	1	1	0	0	0	6	18.6	2.0	16.6	3	34.38	4	45.37
45	1	1	0	0	0	6	16.5	2.0	14.5	3	36.62	4	48.89

TableA.10 Results calculated when B,A=1, C,D,E=0 for 6 mm diameter

No.	Q1(m^3/s)	Q2(m^3/s)	Q_{avg}(m^3/s)	C_d	Re
1	3.86E-05	3.89E-05	3.88E-05	0.8421	8141.70
2	4.25E-05	4.21E-05	4.23E-05	0.8578	8886.33
3	4.54E-05	4.54E-05	4.54E-05	0.8667	9540.19
4	4.63E-05	4.72E-05	4.67E-05	0.8452	9821.57
5	4.99E-05	5.01E-05	5.00E-05	0.8573	10508.68
6	5.26E-05	5.23E-05	5.24E-05	0.8651	11012.26
7	5.46E-05	5.42E-05	5.44E-05	0.8638	11433.43
8	5.84E-05	5.79E-05	5.82E-05	0.8747	12223.26
9	5.61E-05	5.54E-05	5.57E-05	0.8644	11709.03
10	5.35E-05	5.32E-05	5.33E-05	0.8587	11207.47
11	5.11E-05	5.10E-05	5.11E-05	0.8576	10727.37
12	4.90E-05	4.92E-05	4.91E-05	0.8677	10312.82
13	4.63E-05	4.63E-05	4.63E-05	0.8574	9729.99
14	4.43E-05	4.41E-05	4.42E-05	0.8657	9281.14
15	4.13E-05	4.08E-05	4.11E-05	0.8614	8630.76
16	3.92E-05	3.91E-05	3.92E-05	0.8516	8233.77
17	4.11E-05	4.13E-05	4.12E-05	0.8360	8660.33
18	4.45E-05	4.42E-05	4.43E-05	0.8463	9316.35
19	4.72E-05	4.63E-05	4.67E-05	0.8450	9818.99
20	4.97E-05	4.99E-05	4.98E-05	0.8536	10463.53
21	5.23E-05	5.23E-05	5.23E-05	0.8629	10983.93
22	5.47E-05	5.44E-05	5.46E-05	0.8662	11465.05
23	5.75E-05	5.76E-05	5.76E-05	0.8659	12099.83
24	5.59E-05	5.58E-05	5.59E-05	0.8665	11736.86
25	5.34E-05	5.35E-05	5.34E-05	0.8603	11227.67
26	5.05E-05	5.09E-05	5.07E-05	0.8517	10654.34
27	4.90E-05	4.84E-05	4.87E-05	0.8610	10233.26
28	4.66E-05	4.63E-05	4.64E-05	0.8600	9759.16
29	4.36E-05	4.34E-05	4.35E-05	0.8526	9140.77
30	4.09E-05	4.01E-05	4.05E-05	0.8497	8514.10
31	3.94E-05	3.94E-05	3.94E-05	0.8571	8286.22
32	4.18E-05	4.19E-05	4.18E-05	0.8481	8786.15
33	4.46E-05	4.49E-05	4.48E-05	0.8544	9404.88
34	4.73E-05	4.74E-05	4.73E-05	0.8561	9948.17
35	4.99E-05	4.95E-05	4.97E-05	0.8525	10449.16
36	5.15E-05	5.15E-05	5.15E-05	0.8500	10819.87
37	5.43E-05	5.38E-05	5.40E-05	0.8575	11349.44
38	5.67E-05	5.65E-05	5.66E-05	0.8514	11897.63
39	5.41E-05	5.51E-05	5.46E-05	0.8467	11468.96
40	5.37E-05	5.40E-05	5.39E-05	0.8673	11318.76
41	5.08E-05	5.10E-05	5.09E-05	0.8542	10684.95
42	4.86E-05	4.83E-05	4.84E-05	0.8561	10174.78
43	4.52E-05	4.60E-05	4.56E-05	0.8444	9582.53
44	4.30E-05	4.34E-05	4.32E-05	0.8469	9079.86
45	4.04E-05	4.03E-05	4.03E-05	0.8458	8475.04

TableA.11 Data obtained when B,A,C=1, D,E=0 for 6 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δh1 (cm)	Δt1 (sec)	Δh2 (cm)	Δt2 (sec)
1	1	1	1	0	0	6	15.9	2.0	13.9	3	37.64	4	49.94
2	1	1	1	0	0	6	18.0	2.0	16.0	3	34.01	4	46.25
3	1	1	1	0	0	6	19.8	2.0	17.8	3	32.37	4	43.16
4	1	1	1	0	0	6	21.9	2.0	19.9	3	30.63	4	40.92
5	1	1	1	0	0	6	23.9	2.0	21.9	3	28.96	4	38.92
6	1	1	1	0	0	6	25.8	2.0	23.8	3	28.38	4	37.5
7	1	1	1	0	0	6	27.6	2.0	25.6	3	26.58	4	35.73
8	1	1	1	0	0	6	29.5	2.0	27.5	3	26.02	4	34.62
9	1	1	1	0	0	6	28.8	2.0	26.8	3	26.93	4	35.33
10	1	1	1	0	0	6	26.6	2.0	24.6	3	27.6	4	36.64
11	1	1	1	0	0	6	24.9	2.0	22.9	3	28.19	4	37.84
12	1	1	1	0	0	6	22.8	2.0	20.8	3	30.02	4	39.94
13	1	1	1	0	0	6	21.0	2.0	19.0	3	31.84	4	42.03
14	1	1	1	0	0	6	19.0	2.0	17.0	3	32.96	4	44.22
15	1	1	1	0	0	6	17.0	2.0	15.0	3	35.74	4	47.58
16	1	1	1	0	0	6	15.9	2.0	13.9	3	37.19	4	49.97
17	1	1	1	0	0	6	18.0	2.0	16.0	3	34.38	4	46.38
18	1	1	1	0	0	6	19.8	2.0	17.8	3	32.48	4	43.95
19	1	1	1	0	0	6	21.9	2.0	19.9	3	30.73	4	41.56
20	1	1	1	0	0	6	23.9	2.0	21.9	3	29.37	4	39.08
21	1	1	1	0	0	6	25.8	2.0	23.8	3	27.93	4	37.12
22	1	1	1	0	0	6	27.6	2.0	25.6	3	26.93	4	36.11
23	1	1	1	0	0	6	29.5	2.0	27.5	3	26.32	4	34.46
24	1	1	1	0	0	6	28.8	2.0	26.8	3	26.35	4	34.86
25	1	1	1	0	0	6	26.6	2.0	24.6	3	26.88	4	36.66
26	1	1	1	0	0	6	24.9	2.0	22.9	3	28.52	4	38.23
27	1	1	1	0	0	6	22.8	2.0	20.8	3	30.07	4	39.99
28	1	1	1	0	0	6	21.0	2.0	19.0	3	32.13	4	42.82
29	1	1	1	0	0	6	19.0	2.0	17.0	3	33.83	4	45.11
30	1	1	1	0	0	6	17.0	2.0	15.0	3	36.14	4	48.03
31	1	1	1	0	0	6	15.9	2.0	13.9	3	37.23	4	49.67
32	1	1	1	0	0	6	18.0	2.0	16.0	3	34.4	4	46.36
33	1	1	1	0	0	6	19.8	2.0	17.8	3	33.2	4	44.46
34	1	1	1	0	0	6	21.9	2.0	19.9	3	31.28	4	41.46
35	1	1	1	0	0	6	23.9	2.0	21.9	3	29.93	4	40.02
36	1	1	1	0	0	6	25.8	2.0	23.8	3	28.54	4	38.03
37	1	1	1	0	0	6	27.6	2.0	25.6	3	27.58	4	37.13
38	1	1	1	0	0	6	29.5	2.0	27.5	3	26.12	4	35.2
39	1	1	1	0	0	6	28.8	2.0	26.8	3	27.09	4	36.12
40	1	1	1	0	0	6	26.6	2.0	24.6	3	27.6	4	37.23
41	1	1	1	0	0	6	24.9	2.0	22.9	3	29.25	4	38.83
42	1	1	1	0	0	6	22.8	2.0	20.8	3	30.58	4	40.25
43	1	1	1	0	0	6	21.0	2.0	19.0	3	32.02	4	42.84
44	1	1	1	0	0	6	19.0	2.0	17.0	3	33.82	4	45.08
45	1	1	1	0	0	6	17.0	2.0	15.0	3	35.72	4	48.13

TableA.12 Results calculated when B,A,C=1, D,E=0 for 6 mm diameter

No.	Q1(m^3/s)	Q2(m^3/s)	Q_{avg}(m^3/s)	C_d	Re
1	3.93E-05	3.95E-05	3.94E-05	0.8431	8271.09
2	4.35E-05	4.26E-05	4.30E-05	0.8591	9042.17
3	4.57E-05	4.57E-05	4.57E-05	0.8642	9593.98
4	4.83E-05	4.82E-05	4.82E-05	0.8629	10129.07
5	5.10E-05	5.06E-05	5.08E-05	0.8674	10681.41
6	5.21E-05	5.26E-05	5.23E-05	0.8563	10992.42
7	5.56E-05	5.52E-05	5.54E-05	0.8740	11636.44
8	5.68E-05	5.69E-05	5.69E-05	0.8659	11947.96
9	5.49E-05	5.58E-05	5.53E-05	0.8535	11626.12
10	5.36E-05	5.38E-05	5.37E-05	0.8640	11276.63
11	5.24E-05	5.21E-05	5.23E-05	0.8720	10979.69
12	4.92E-05	4.93E-05	4.93E-05	0.8630	10356.23
13	4.64E-05	4.69E-05	4.67E-05	0.8547	9802.79
14	4.48E-05	4.46E-05	4.47E-05	0.8658	9393.12
15	4.14E-05	4.14E-05	4.14E-05	0.8533	8696.04
16	3.97E-05	3.94E-05	3.96E-05	0.8479	8318.52
17	4.30E-05	4.25E-05	4.27E-05	0.8532	8980.49
18	4.55E-05	4.48E-05	4.52E-05	0.8550	9491.50
19	4.81E-05	4.74E-05	4.78E-05	0.8549	10034.66
20	5.03E-05	5.04E-05	5.04E-05	0.8596	10584.78
21	5.29E-05	5.31E-05	5.30E-05	0.8676	11137.09
22	5.49E-05	5.46E-05	5.47E-05	0.8637	11499.54
23	5.62E-05	5.72E-05	5.67E-05	0.8629	11907.71
24	5.61E-05	5.65E-05	5.63E-05	0.8686	11832.05
25	5.50E-05	5.38E-05	5.44E-05	0.8753	11424.25
26	5.18E-05	5.16E-05	5.17E-05	0.8625	10860.14
27	4.92E-05	4.93E-05	4.92E-05	0.8617	10341.14
28	4.60E-05	4.60E-05	4.60E-05	0.8429	9667.90
29	4.37E-05	4.37E-05	4.37E-05	0.8461	9179.59
30	4.09E-05	4.10E-05	4.10E-05	0.8446	8607.18
31	3.97E-05	3.97E-05	3.97E-05	0.8500	8339.06
32	4.30E-05	4.25E-05	4.27E-05	0.8532	8979.79
33	4.45E-05	4.43E-05	4.44E-05	0.8408	9333.79
34	4.73E-05	4.75E-05	4.74E-05	0.8483	9957.83
35	4.94E-05	4.92E-05	4.93E-05	0.8414	10361.42
36	5.18E-05	5.18E-05	5.18E-05	0.8479	10884.80
37	5.36E-05	5.31E-05	5.33E-05	0.8417	11206.14
38	5.66E-05	5.60E-05	5.63E-05	0.8571	11826.57
39	5.46E-05	5.46E-05	5.46E-05	0.8416	11463.90
40	5.36E-05	5.29E-05	5.32E-05	0.8572	11187.09
41	5.05E-05	5.08E-05	5.06E-05	0.8450	10640.57
42	4.83E-05	4.90E-05	4.86E-05	0.8517	10221.58
43	4.62E-05	4.60E-05	4.61E-05	0.8442	9682.24
44	4.37E-05	4.37E-05	4.37E-05	0.8465	9184.00
45	4.14E-05	4.09E-05	4.12E-05	0.8486	8648.74

TableA.13 Data obtained when B=1, A,C,D,E=0 for 10.35 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δh1 (cm)	Δt1 (sec)
1	0	1	0	0	0	10.35	15.3	2.0	13.3	4	18.80
2	0	1	0	0	0	10.35	17.5	2.0	15.5	4	17.24
3	0	1	0	0	0	10.35	19.5	2.0	17.5	4	16.64
4	0	1	0	0	0	10.35	21.4	2.0	19.4	4	15.28
5	0	1	0	0	0	10.35	23.5	2.0	21.5	4	14.74
6	0	1	0	0	0	10.35	25.8	2.0	23.8	4	14.12
7	0	1	0	0	0	10.35	27.2	2.0	25.2	4	13.80
8	0	1	0	0	0	10.35	29.9	2.0	27.9	4	13.04
9	0	1	0	0	0	10.35	28.6	2.0	26.6	4	13.75
10	0	1	0	0	0	10.35	26.6	2.0	24.6	4	14.10
11	0	1	0	0	0	10.35	24.4	2.0	22.4	4	14.73
12	0	1	0	0	0	10.35	22.5	2.0	20.5	4	15.50
13	0	1	0	0	0	10.35	20.6	2.0	18.6	4	15.86
14	0	1	0	0	0	10.35	18.6	2.0	16.6	4	16.99
15	0	1	0	0	0	10.35	16.8	2.0	14.8	4	17.45
16	0	0	0	1	0	10.35	15.5	8.5	7.0	4	24.24
17	0	0	0	1	0	10.35	17.6	8.5	9.1	4	21.74
18	0	0	0	1	0	10.35	19.7	8.5	11.2	4	20.22
19	0	0	0	1	0	10.35	20.5	8.5	12.0	4	19.07
20	0	0	0	1	0	10.35	18.5	8.5	10.0	4	20.90
21	0	0	0	1	0	10.35	16.5	8.5	8.0	4	22.76
22	0	0	0	0	1	10.35	21.6	15.0	6.6	4	24.90
23	0	0	0	0	1	10.35	19.3	15.0	4.3	4	31.03
24	0	0	0	0	1	10.35	17.1	15.0	2.1	4	45.95
25	0	0	0	0	1	10.35	16.2	15.0	1.2	4	60.23
26	0	0	0	0	1	10.35	18.2	15.0	3.2	4	36.83
27	0	0	0	0	1	10.35	20.2	15.0	5.2	4	28.29
28	0	1	0	0	0	10.35	15.3	2	13.3	4	18.12
29	0	1	0	0	0	10.35	17.5	2	15.5	4	16.75
30	0	1	0	0	0	10.35	19.5	2	17.5	4	16.27
31	0	1	0	0	0	10.35	21.4	2	19.4	4	15.05
32	0	1	0	0	0	10.35	23.5	2	21.5	4	14.90
33	0	1	0	0	0	10.35	25.8	2	23.8	4	14.07
34	0	1	0	0	0	10.35	27.2	2	25.2	4	13.96
35	0	1	0	0	0	10.35	29.9	2	27.9	4	13.24
36	0	1	0	0	0	10.35	28.6	2	26.6	4	13.49
37	0	1	0	0	0	10.35	26.6	2	24.6	4	14.06
38	0	1	0	0	0	10.35	24.4	2	22.4	4	14.72
39	0	1	0	0	0	10.35	22.5	2	20.5	4	15.42
40	0	1	0	0	0	10.35	20.6	2	18.6	4	15.76
41	0	1	0	0	0	10.35	18.6	2	16.6	4	16.51
42	0	1	0	0	0	10.35	16.8	2	14.8	4	17.10
43	0	0	0	1	0	10.35	15.5	8.5	7	4	24.42
44	0	0	0	1	0	10.35	17.6	8.5	9.1	4	22.08
45	0	0	0	1	0	10.35	19.7	8.5	11.2	4	19.88
46	0	0	0	1	0	10.35	20.5	8.5	12	4	19.06
47	0	0	0	1	0	10.35	18.5	8.5	10	4	20.93
48	0	0	0	1	0	10.35	16.5	8.5	8	4	23.00
49	0	0	0	0	1	10.35	21.6	15	6.6	4	25.41

TableA.13 (cont'd)

50	0	0	0	0	1	10.35	19.3	15	4.3	4	31.53
51	0	0	0	0	1	10.35	17.1	15	2.1	4	46.26
52	0	0	0	0	1	10.35	16.2	15	1.2	4	59.72
53	0	0	0	0	1	10.35	18.2	15	3.2	4	36.62
54	0	0	0	0	1	10.35	20.2	15	5.2	4	28.38
55	0	1	0	0	0	10.35	15.3	2	13.3	4	18.39
56	0	1	0	0	0	10.35	17.5	2	15.5	4	17.32
57	0	1	0	0	0	10.35	19.5	2	17.5	4	16.85
58	0	1	0	0	0	10.35	21.4	2	19.4	4	15.98
59	0	1	0	0	0	10.35	23.5	2	21.5	4	15.08
60	0	1	0	0	0	10.35	25.8	2	23.8	4	14.06
61	0	1	0	0	0	10.35	27.2	2	25.2	4	14.18
62	0	1	0	0	0	10.35	29.9	2	27.9	4	13.43
63	0	1	0	0	0	10.35	28.6	2	26.6	4	13.65
64	0	1	0	0	0	10.35	26.6	2	24.6	4	14.09
65	0	1	0	0	0	10.35	24.4	2	22.4	4	14.68
66	0	1	0	0	0	10.35	22.5	2	20.5	4	15.05
67	0	1	0	0	0	10.35	20.6	2	18.6	4	16.13
68	0	1	0	0	0	10.35	18.6	2	16.6	4	17.10
69	0	1	0	0	0	10.35	16.8	2	14.8	4	17.55
70	0	0	0	1	0	10.35	15.5	8.5	7	4	24.51
71	0	0	0	1	0	10.35	17.6	8.5	9.1	4	21.66
72	0	0	0	1	0	10.35	19.7	8.5	11.2	4	19.93
73	0	0	0	1	0	10.35	20.5	8.5	12	4	19.41
74	0	0	0	1	0	10.35	18.5	8.5	10	4	20.84
75	0	0	0	1	0	10.35	16.5	8.5	8	4	22.95
76	0	0	0	0	1	10.35	21.6	15	6.6	4	25.53
77	0	0	0	0	1	10.35	19.3	15	4.3	4	31.49
78	0	0	0	0	1	10.35	17.1	15	2.1	4	45.83
79	0	0	0	0	1	10.35	16.2	15	1.2	4	60.27
80	0	0	0	0	1	10.35	18.2	15	3.2	4	36.69
81	0	0	0	0	1	10.35	20.2	15	5.2	4	28.56

TableA.14 Results calculated when B=1, A,C,D,E=0 for 10.35 mm diameter

No.	Q1(m^3/s)	C_d	Re
1	1.05E-04	0.7713	12768.30
2	1.14E-04	0.7791	13923.67
3	1.18E-04	0.7597	14425.72
4	1.29E-04	0.7858	15709.69
5	1.34E-04	0.7738	16285.21
6	1.40E-04	0.7677	17000.29
7	1.43E-04	0.7634	17394.50
8	1.51E-04	0.7678	18408.29
9	1.43E-04	0.7457	17457.75

TableA.14 (cont'd)

10	1.40E-04	0.7562	17024.40
11	1.34E-04	0.7586	16296.27
12	1.27E-04	0.7536	15486.71
13	1.24E-04	0.7731	15135.19
14	1.16E-04	0.7640	14128.55
15	1.13E-04	0.7878	13756.11
16	8.13E-05	0.8246	9902.81
17	9.07E-05	0.8064	11041.58
18	9.75E-05	0.7815	11871.61
19	1.03E-04	0.8005	12587.52
20	9.43E-05	0.8002	11485.36
21	8.66E-05	0.8215	10546.75
22	7.91E-05	0.8267	9640.32
23	6.35E-05	0.8219	7735.87
24	4.29E-05	0.7942	5224.03
25	3.27E-05	0.8015	3985.46
26	5.35E-05	0.8027	6517.62
27	6.97E-05	0.8198	8485.12
28	1.09E-04	0.8003	13247.46
29	1.18E-04	0.8019	14330.99
30	1.21E-04	0.7770	14753.78
31	1.31E-04	0.7978	15949.77
32	1.32E-04	0.7655	16110.34
33	1.40E-04	0.7704	17060.70
34	1.41E-04	0.7546	17195.13
35	1.49E-04	0.7562	18130.22
36	1.46E-04	0.7601	17794.22
37	1.40E-04	0.7583	17072.83
38	1.34E-04	0.7591	16307.34
39	1.28E-04	0.7575	15567.06
40	1.25E-04	0.7781	15231.22
41	1.19E-04	0.7862	14539.31
42	1.15E-04	0.8039	14037.66
43	8.07E-05	0.8185	9829.81
44	8.93E-05	0.7940	10871.56
45	9.91E-05	0.7949	12074.65
46	1.03E-04	0.8010	12594.13
47	9.42E-05	0.7990	11468.90
48	8.57E-05	0.8129	10436.70
49	7.76E-05	0.8101	9446.83
50	6.25E-05	0.8088	7613.20
51	4.26E-05	0.7889	5189.02
52	3.30E-05	0.8084	4019.49
53	5.38E-05	0.8073	6555.00
54	6.94E-05	0.8172	8458.21
55	1.07E-04	0.7885	13052.97
56	1.14E-04	0.7755	13859.36
57	1.17E-04	0.7502	14245.94
58	1.23E-04	0.7514	15021.53
59	1.31E-04	0.7563	15918.04
60	1.40E-04	0.7710	17072.83

TableA.14 (cont'd)

61	1.39E-04	0.7429	16928.35
62	1.47E-04	0.7455	17873.72
63	1.44E-04	0.7512	17585.64
64	1.40E-04	0.7567	17036.48
65	1.34E-04	0.7612	16351.77
66	1.31E-04	0.7761	15949.77
67	1.22E-04	0.7602	14881.84
68	1.15E-04	0.7591	14037.66
69	1.12E-04	0.7833	13677.72
70	8.04E-05	0.8155	9793.72
71	9.10E-05	0.8094	11082.37
72	9.89E-05	0.7929	12044.36
73	1.02E-04	0.7865	12367.03
74	9.46E-05	0.8025	11518.43
75	8.59E-05	0.8147	10459.44
76	7.72E-05	0.8063	9402.43
77	6.26E-05	0.8099	7622.87
78	4.30E-05	0.7963	5237.71
79	3.27E-05	0.8010	3982.81
80	5.37E-05	0.8057	6542.49
81	6.90E-05	0.8120	8404.90

TableA.15 Data obtained when B,D=1, A,C,E=0 for 10.35 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δh1 (cm)	Δt1 (sec)
1	0	1	0	1	0	10.35	16.3	2.0	14.3	4	17.72
2	0	1	0	1	0	10.35	18.2	2.0	16.2	4	16.67
3	0	1	0	1	0	10.35	21.4	2.0	19.4	4	15.68
4	0	1	0	1	0	10.35	23.3	2.0	21.3	4	14.6
5	0	1	0	1	0	10.35	25.1	2.0	23.1	4	14.2
6	0	1	0	1	0	10.35	27.4	2.0	25.4	4	13.63
7	0	1	0	1	0	10.35	29.4	2.0	27.4	4	13.24
8	0	1	0	1	0	10.35	28.5	2.0	26.5	4	13.49
9	0	1	0	1	0	10.35	26.5	2.0	24.5	4	13.64
10	0	1	0	1	0	10.35	24	2.0	22	4	14.83
11	0	1	0	1	0	10.35	22.2	2.0	20.2	4	15.48
12	0	1	0	1	0	10.35	20.2	2.0	18.2	4	15.75
13	0	1	0	1	0	10.35	19.1	2.0	17.1	4	16.32
14	0	1	0	1	0	10.35	17.8	2.0	15.8	4	16.69
15	0	0	0	1	1	10.35	15.7	8.5	7.2	4	24.23
16	0	0	0	1	1	10.35	17.8	8.5	9.3	4	21.34
17	0	0	0	1	1	10.35	19.7	8.5	11.2	4	19.99
18	0	0	0	1	1	10.35	21.7	8.5	13.2	4	18.42
19	0	0	0	1	1	10.35	20.7	8.5	12.2	4	19.27
20	0	0	0	1	1	10.35	18.8	8.5	10.3	4	20.57
21	0	0	0	1	1	10.35	16.8	8.5	8.3	4	22.62

TableA.15 (cont'd)

22	0	1	0	1	0	10.35	16.3	2.0	14.3	4	17.62
23	0	1	0	1	0	10.35	18.2	2.0	16.2	4	16.52
24	0	1	0	1	0	10.35	21.4	2.0	19.4	4	15.38
25	0	1	0	1	0	10.35	23.3	2.0	21.3	4	14.87
26	0	1	0	1	0	10.35	25.1	2.0	23.1	4	14.4
27	0	1	0	1	0	10.35	27.4	2.0	25.4	4	13.62
28	0	1	0	1	0	10.35	29.4	2.0	27.4	4	12.93
29	0	1	0	1	0	10.35	28.5	2.0	26.5	4	13.12
30	0	1	0	1	0	10.35	26.5	2.0	24.5	4	13.92
31	0	1	0	1	0	10.35	24	2.0	22.0	4	14.43
32	0	1	0	1	0	10.35	22.2	2.0	20.2	4	15.11
33	0	1	0	1	0	10.35	20.2	2.0	18.2	4	16.02
34	0	1	0	1	0	10.35	19.1	2.0	17.1	4	16.29
35	0	1	0	1	0	10.35	17.8	2.0	15.8	4	17.08
36	0	0	0	1	1	10.35	15.7	8.5	7.2	4	24.52
37	0	0	0	1	1	10.35	17.8	8.5	9.3	4	21.64
38	0	0	0	1	1	10.35	19.7	8.5	11.2	4	19.89
39	0	0	0	1	1	10.35	21.7	8.5	13.2	4	18.47
40	0	0	0	1	1	10.35	20.7	8.5	12.2	4	19.23
41	0	0	0	1	1	10.35	18.8	8.5	10.3	4	20.79
42	0	0	0	1	1	10.35	16.8	8.5	8.3	4	23.28
43	0	1	0	1	0	10.35	16.3	2.0	14.3	4	17.74
44	0	1	0	1	0	10.35	18.2	2.0	16.2	4	16.7
45	0	1	0	1	0	10.35	21.4	2.0	19.4	4	15.97
46	0	1	0	1	0	10.35	23.3	2.0	21.3	4	14.73
47	0	1	0	1	0	10.35	25.1	2.0	23.1	4	14.53
48	0	1	0	1	0	10.35	27.4	2.0	25.4	4	13.72
49	0	1	0	1	0	10.35	29.4	2.0	27.4	4	13.03
50	0	1	0	1	0	10.35	28.5	2.0	26.5	4	13.64
51	0	1	0	1	0	10.35	26.5	2.0	24.5	4	14.11
52	0	1	0	1	0	10.35	24	2.0	22.0	4	14.94
53	0	1	0	1	0	10.35	22.2	2.0	20.2	4	15.58
54	0	1	0	1	0	10.35	20.2	2.0	18.2	4	15.99
55	0	1	0	1	0	10.35	19.1	2.0	17.1	4	16.4
56	0	1	0	1	0	10.35	17.8	2.0	15.8	4	17.13
57	0	0	0	1	1	10.35	15.7	8.5	7.2	4	24.8
58	0	0	0	1	1	10.35	17.8	8.5	9.3	4	21.99
59	0	0	0	1	1	10.35	19.7	8.5	11.2	4	20.23
60	0	0	0	1	1	10.35	21.7	8.5	13.2	4	18.56
61	0	0	0	1	1	10.35	20.7	8.5	12.2	4	19.48
62	0	0	0	1	1	10.35	18.8	8.5	10.3	4	20.85
63	0	0	0	1	1	10.35	16.8	8.5	8.3	4	23.4

TableA.16 Results calculated when B,D=1, A,C,E=0 for 10.35 mm diameter

No.	Q1(m^3/s)	C_d	Re
1	1.11E-04	0.7892	13546.50
2	1.18E-04	0.7882	14399.76
3	1.26E-04	0.7657	15308.93
4	1.35E-04	0.7848	16441.37
5	1.39E-04	0.7749	16904.51
6	1.45E-04	0.7699	17611.45
7	1.49E-04	0.7631	18130.22
8	1.46E-04	0.7615	17794.22
9	1.44E-04	0.7833	17598.54
10	1.33E-04	0.7603	16186.38
11	1.27E-04	0.7601	15506.72
12	1.25E-04	0.7871	15240.89
13	1.21E-04	0.7836	14708.58
14	1.18E-04	0.7971	14382.51
15	8.13E-05	0.8134	9906.89
16	9.24E-05	0.8126	11248.55
17	9.86E-05	0.7905	12008.21
18	1.07E-04	0.7902	13031.71
19	1.02E-04	0.7857	12456.88
20	9.58E-05	0.8011	11669.62
21	8.71E-05	0.8115	10612.03
22	1.12E-04	0.7937	13623.39
23	1.19E-04	0.7953	14530.51
24	1.28E-04	0.7807	15607.55
25	1.33E-04	0.7706	16142.84
26	1.37E-04	0.7641	16669.73
27	1.45E-04	0.7704	17624.38
28	1.52E-04	0.7814	18564.89
29	1.50E-04	0.7830	18296.04
30	1.42E-04	0.7675	17244.54
31	1.37E-04	0.7813	16635.07
32	1.30E-04	0.7787	15886.44
33	1.23E-04	0.7738	14984.02
34	1.21E-04	0.7851	14735.67
35	1.15E-04	0.7789	14054.10
36	8.04E-05	0.8038	9789.72
37	9.11E-05	0.8014	11092.61
38	9.91E-05	0.7945	12068.58
39	1.07E-04	0.7881	12996.43
40	1.02E-04	0.7873	12482.79
41	9.48E-05	0.7926	11546.13
42	8.47E-05	0.7885	10311.17
43	1.11E-04	0.7883	13531.23
44	1.18E-04	0.7868	14373.90
45	1.23E-04	0.7518	15030.94
46	1.34E-04	0.7779	16296.27
47	1.36E-04	0.7573	16520.58
48	1.44E-04	0.7648	17495.92

TableA.16 (cont'd)

49	1.51E-04	0.7754	18422.41
50	1.44E-04	0.7532	17598.54
51	1.40E-04	0.7572	17012.34
52	1.32E-04	0.7547	16067.21
53	1.26E-04	0.7552	15407.19
54	1.23E-04	0.7752	15012.14
55	1.20E-04	0.7798	14636.83
56	1.15E-04	0.7767	14013.08
57	7.95E-05	0.7947	9679.20
58	8.96E-05	0.7886	10916.06
59	9.74E-05	0.7811	11865.75
60	1.06E-04	0.7843	12933.41
61	1.01E-04	0.7772	12322.59
62	9.45E-05	0.7903	11512.90
63	8.42E-05	0.7845	10258.29

TableA.17 Data obtained when B,E=1, A,C,D=0 for 10.35 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δh1 (cm)	Δt1 (sec)
1	0	1	0	0	1	10.35	15.3	2.0	13.3	4	17.52
2	0	1	0	0	1	10.35	17.8	2.0	15.8	4	17.02
3	0	1	0	0	1	10.35	19.9	2.0	17.9	4	16.21
4	0	1	0	0	1	10.35	21.9	2.0	19.9	4	15.2
5	0	1	0	0	1	10.35	24.7	2.0	22.7	4	14.48
6	0	1	0	0	1	10.35	25.7	2.0	23.7	4	14.1
7	0	1	0	0	1	10.35	27.7	2.0	25.7	4	13.62
8	0	1	0	0	1	10.35	29.5	2.0	27.5	4	13.07
9	0	1	0	0	1	10.35	28.7	2.0	26.7	4	13.47
10	0	1	0	0	1	10.35	26.7	2.0	24.7	4	13.88
11	0	1	0	0	1	10.35	23.9	2.0	21.9	4	14.76
12	0	1	0	0	1	10.35	22.8	2.0	20.8	4	14.94
13	0	1	0	0	1	10.35	20.9	2.0	18.9	4	15.28
14	0	1	0	0	1	10.35	18.9	2.0	16.9	4	16.02
15	0	1	0	0	1	10.35	16.7	2.0	14.7	4	17.54
16	0	1	0	0	1	10.35	15.3	2.0	13.3	4	18.04
17	0	1	0	0	1	10.35	17.8	2.0	15.8	4	17.1
18	0	1	0	0	1	10.35	19.9	2.0	17.9	4	15.56
19	0	1	0	0	1	10.35	21.9	2.0	19.9	4	14.85
20	0	1	0	0	1	10.35	24.7	2.0	22.7	4	14.18
21	0	1	0	0	1	10.35	25.7	2.0	23.7	4	14.1
22	0	1	0	0	1	10.35	27.7	2.0	25.7	4	13.71
23	0	1	0	0	1	10.35	29.5	2.0	27.5	4	13.35
24	0	1	0	0	1	10.35	28.7	2.0	26.7	4	13.34
25	0	1	0	0	1	10.35	26.7	2.0	24.7	4	14.24
26	0	1	0	0	1	10.35	23.9	2.0	21.9	4	14.32
27	0	1	0	0	1	10.35	22.8	2.0	20.8	4	14.69

TableA.17 (cont'd)

28	0	1	0	0	1	10.35	20.9	2.0	18.9	4	15.62
29	0	1	0	0	1	10.35	18.9	2.0	16.9	4	16.32
30	0	1	0	0	1	10.35	16.7	2.0	14.7	4	16.5
31	0	1	0	0	1	10.35	15.3	2.0	13.3	4	18.22
32	0	1	0	0	1	10.35	17.8	2.0	15.8	4	17.54
33	0	1	0	0	1	10.35	19.9	2.0	17.9	4	16.43
34	0	1	0	0	1	10.35	21.9	2.0	19.9	4	15.37
35	0	1	0	0	1	10.35	24.7	2.0	22.7	4	14.92
36	0	1	0	0	1	10.35	25.7	2.0	23.7	4	13.74
37	0	1	0	0	1	10.35	27.7	2.0	25.7	4	13.72
38	0	1	0	0	1	10.35	29.5	2.0	27.5	4	13
39	0	1	0	0	1	10.35	28.7	2.0	26.7	4	13.25
40	0	1	0	0	1	10.35	26.7	2.0	24.7	4	13.59
41	0	1	0	0	1	10.35	23.9	2.0	21.9	4	14.63
42	0	1	0	0	1	10.35	22.8	2.0	20.8	4	14.99
43	0	1	0	0	1	10.35	20.9	2.0	18.9	4	15.65
44	0	1	0	0	1	10.35	18.9	2.0	16.9	4	16.5
45	0	1	0	0	1	10.35	16.7	2.0	14.7	4	17.2

TableA.18 Results calculated when B,E=1, A,C,D=0 for 10.35 mm diameter

No.	Q1(m^3/s)	C_d	Re
1	1.12E-04	0.8277	13701.14
2	1.16E-04	0.7817	14103.65
3	1.22E-04	0.7711	14808.39
4	1.30E-04	0.7799	15792.37
5	1.36E-04	0.7666	16577.63
6	1.40E-04	0.7704	17024.40
7	1.45E-04	0.7659	17624.38
8	1.51E-04	0.7716	18366.03
9	1.46E-04	0.7598	17820.64
10	1.42E-04	0.7666	17294.24
11	1.34E-04	0.7656	16263.15
12	1.32E-04	0.7761	16067.21
13	1.29E-04	0.7961	15709.69
14	1.23E-04	0.8030	14984.02
15	1.12E-04	0.7864	13685.52
16	1.09E-04	0.8038	13306.21
17	1.15E-04	0.7780	14037.66
18	1.27E-04	0.8033	15427.00
19	1.33E-04	0.7983	16164.58
20	1.39E-04	0.7828	16928.35
21	1.40E-04	0.7704	17024.40
22	1.44E-04	0.7609	17508.68
23	1.48E-04	0.7554	17980.83
24	1.48E-04	0.7672	17994.31
25	1.38E-04	0.7472	16857.03
26	1.38E-04	0.7891	16762.85
27	1.34E-04	0.7893	16340.64
28	1.26E-04	0.7788	15367.74
29	1.21E-04	0.7882	14708.58
30	1.19E-04	0.8359	14548.12
31	1.08E-04	0.7959	13174.76
32	1.12E-04	0.7585	13685.52
33	1.20E-04	0.7608	14610.11
34	1.28E-04	0.7713	15617.70
35	1.32E-04	0.7439	16088.74
36	1.43E-04	0.7906	17470.46
37	1.44E-04	0.7603	17495.92
38	1.52E-04	0.7757	18464.93
39	1.49E-04	0.7724	18116.53
40	1.45E-04	0.7830	17663.29
41	1.35E-04	0.7724	16407.66
42	1.31E-04	0.7736	16013.61
43	1.26E-04	0.7773	15338.28
44	1.19E-04	0.7796	14548.12
45	1.15E-04	0.8019	13956.05

TableA.19 Data obtained when B,D,E=1, A,C=0 for 10.35 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δh1 (cm)	Δt1 (sec)
1	0	1	0	1	1	10.35	15.5	2.0	13.5	4	17.94
2	0	1	0	1	1	10.35	17.7	2.0	15.7	4	17.25
3	0	1	0	1	1	10.35	19.5	2.0	17.5	4	16.05
4	0	1	0	1	1	10.35	21.6	2.0	19.6	4	15.16
5	0	1	0	1	1	10.35	24	2.0	22.0	4	14.39
6	0	1	0	1	1	10.35	25.8	2.0	23.8	4	13.96
7	0	1	0	1	1	10.35	27.9	2.0	25.9	4	13.33
8	0	1	0	1	1	10.35	29.9	2.0	27.9	4	13.23
9	0	1	0	1	1	10.35	28.8	2.0	26.8	4	13.28
10	0	1	0	1	1	10.35	26.8	2.0	24.8	4	13.74
11	0	1	0	1	1	10.35	25	2.0	23.0	4	14.22
12	0	1	0	1	1	10.35	22.8	2.0	20.8	4	14.82
13	0	1	0	1	1	10.35	21.2	2.0	19.2	4	15.05
14	0	1	0	1	1	10.35	18.6	2.0	16.6	4	16.49
15	0	1	0	1	1	10.35	16.9	2.0	14.9	4	17.22
16	0	1	0	1	1	10.35	15.5	2.0	13.5	4	17.91
17	0	1	0	1	1	10.35	17.7	2.0	15.7	4	16.68
18	0	1	0	1	1	10.35	19.5	2.0	17.5	4	16.16
19	0	1	0	1	1	10.35	21.6	2.0	19.6	4	15.36
20	0	1	0	1	1	10.35	24	2.0	22.0	4	14.53
21	0	1	0	1	1	10.35	25.8	2.0	23.8	4	13.93
22	0	1	0	1	1	10.35	27.9	2.0	25.9	4	13.52
23	0	1	0	1	1	10.35	29.9	2.0	27.9	4	13.04
24	0	1	0	1	1	10.35	28.8	2.0	26.8	4	13.51
25	0	1	0	1	1	10.35	26.8	2.0	24.8	4	13.86
26	0	1	0	1	1	10.35	25	2.0	23.0	4	14.59
27	0	1	0	1	1	10.35	22.8	2.0	20.8	4	14.74
28	0	1	0	1	1	10.35	21.2	2.0	19.2	4	15.24
29	0	1	0	1	1	10.35	18.6	2.0	16.6	4	16.40
30	0	1	0	1	1	10.35	16.9	2.0	14.9	4	17.24
31	0	1	0	1	1	10.35	15.5	2.0	13.5	4	17.79
32	0	1	0	1	1	10.35	17.7	2.0	15.7	4	16.82
33	0	1	0	1	1	10.35	19.5	2.0	17.5	4	15.93
34	0	1	0	1	1	10.35	21.6	2.0	19.6	4	15.33
35	0	1	0	1	1	10.35	24	2.0	22.0	4	14.74
36	0	1	0	1	1	10.35	25.8	2.0	23.8	4	14.51
37	0	1	0	1	1	10.35	27.9	2.0	25.9	4	13.51
38	0	1	0	1	1	10.35	29.9	2.0	27.9	4	13.13
39	0	1	0	1	1	10.35	28.8	2.0	26.8	4	13.33
40	0	1	0	1	1	10.35	26.8	2.0	24.8	4	14.05
41	0	1	0	1	1	10.35	25	2.0	23.0	4	14.32
42	0	1	0	1	1	10.35	22.8	2.0	20.8	4	14.99
43	0	1	0	1	1	10.35	21.2	2.0	19.2	4	15.06
44	0	1	0	1	1	10.35	18.6	2.0	16.6	4	16.31
45	0	1	0	1	1	10.35	16.9	2.0	14.9	4	17.00

TableA.20 Results calculated when B,D,E=1, A,C=0 for 10.35 mm diameter

No.	Q1(m^3/s)	C_d	Re
1	1.10E-04	0.8023	13380.38
2	1.14E-04	0.7737	13915.60
3	1.23E-04	0.7876	14956.02
4	1.30E-04	0.7879	15834.04
5	1.37E-04	0.7835	16681.31
6	1.41E-04	0.7765	17195.13
7	1.48E-04	0.7795	18007.81
8	1.49E-04	0.7568	18143.92
9	1.48E-04	0.7692	18075.61
10	1.43E-04	0.7729	17470.46
11	1.39E-04	0.7755	16880.74
12	1.33E-04	0.7824	16197.30
13	1.31E-04	0.8019	15949.77
14	1.20E-04	0.7871	14556.95
15	1.14E-04	0.7956	13939.84
16	1.10E-04	0.8036	13402.79
17	1.18E-04	0.8002	14391.13
18	1.22E-04	0.7823	14854.21
19	1.28E-04	0.7777	15627.87
20	1.36E-04	0.7760	16520.58
21	1.41E-04	0.7782	17232.16
22	1.46E-04	0.7686	17754.74
23	1.51E-04	0.7678	18408.29
24	1.46E-04	0.7561	17767.88
25	1.42E-04	0.7662	17319.20
26	1.35E-04	0.7558	16452.64
27	1.34E-04	0.7867	16285.21
28	1.29E-04	0.7919	15750.92
29	1.20E-04	0.7915	14636.83
30	1.14E-04	0.7947	13923.67
31	1.11E-04	0.8091	13493.20
32	1.17E-04	0.7935	14271.35
33	1.24E-04	0.7936	15068.68
34	1.29E-04	0.7792	15658.45
35	1.34E-04	0.7649	16285.21
36	1.36E-04	0.7471	16543.35
37	1.46E-04	0.7692	17767.88
38	1.50E-04	0.7625	18282.11
39	1.48E-04	0.7663	18007.81
40	1.40E-04	0.7558	17084.99
41	1.38E-04	0.7700	16762.85
42	1.31E-04	0.7736	16013.61
43	1.31E-04	0.8014	15939.18
44	1.21E-04	0.7958	14717.60
45	1.16E-04	0.8059	14120.24

TableA.21 Data obtained when B,A=1, C,D,E=0 for 10.35 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δh1(cm)	Δt1(sec)
1	1	1	0	0	0	10.35	15.5	2.0	13.5	4	17.90
2	1	1	0	0	0	10.35	17.7	2.0	15.7	4	16.72
3	1	1	0	0	0	10.35	19.7	2.0	17.7	4	15.57
4	1	1	0	0	0	10.35	21.6	2.0	19.6	4	15.14
5	1	1	0	0	0	10.35	24.0	2.0	22.0	4	14.52
6	1	1	0	0	0	10.35	25.9	2.0	23.9	4	13.99
7	1	1	0	0	0	10.35	27.8	2.0	25.8	4	13.52
8	1	1	0	0	0	10.35	29.9	2.0	27.9	4	13.13
9	1	1	0	0	0	10.35	28.9	2.0	26.9	4	13.23
10	1	1	0	0	0	10.35	26.8	2.0	24.8	4	13.82
11	1	1	0	0	0	10.35	24.9	2.0	22.9	4	14.26
12	1	1	0	0	0	10.35	22.8	2.0	20.8	4	14.72
13	1	1	0	0	0	10.35	20.8	2.0	18.8	4	15.30
14	1	1	0	0	0	10.35	18.9	2.0	16.9	4	16.15
15	1	1	0	0	0	10.35	16.8	2.0	14.8	4	17.26
16	1	1	0	0	0	10.35	15.5	2.0	13.5	4	18.37
17	1	1	0	0	0	10.35	17.7	2.0	15.7	4	16.90
18	1	1	0	0	0	10.35	19.7	2.0	17.7	4	15.92
19	1	1	0	0	0	10.35	21.6	2.0	19.6	4	15.03
20	1	1	0	0	0	10.35	24.0	2.0	22.0	4	14.32
21	1	1	0	0	0	10.35	25.9	2.0	23.9	4	13.72
22	1	1	0	0	0	10.35	27.8	2.0	25.8	4	13.52
23	1	1	0	0	0	10.35	29.9	2.0	27.9	4	12.96
24	1	1	0	0	0	10.35	28.9	2.0	26.9	4	13.54
25	1	1	0	0	0	10.35	26.8	2.0	24.8	4	13.60
26	1	1	0	0	0	10.35	24.9	2.0	22.9	4	13.83
27	1	1	0	0	0	10.35	22.8	2.0	20.8	4	14.66
28	1	1	0	0	0	10.35	20.8	2.0	18.8	4	15.69
29	1	1	0	0	0	10.35	18.9	2.0	16.9	4	16.17
30	1	1	0	0	0	10.35	16.8	2.0	14.8	4	17.28
31	1	1	0	0	0	10.35	15.5	2.0	13.5	4	17.80
32	1	1	0	0	0	10.35	17.7	2.0	15.7	4	17.04
33	1	1	0	0	0	10.35	19.7	2.0	17.7	4	15.94
34	1	1	0	0	0	10.35	21.6	2.0	19.6	4	15.20
35	1	1	0	0	0	10.35	24.0	2.0	22.0	4	14.66
36	1	1	0	0	0	10.35	25.9	2.0	23.9	4	13.92
37	1	1	0	0	0	10.35	27.8	2.0	25.8	4	13.56
38	1	1	0	0	0	10.35	29.9	2.0	27.9	4	13.02
39	1	1	0	0	0	10.35	28.9	2.0	26.9	4	13.45
40	1	1	0	0	0	10.35	26.8	2.0	24.8	4	13.88
41	1	1	0	0	0	10.35	24.9	2.0	22.9	4	14.49
42	1	1	0	0	0	10.35	22.8	2.0	20.8	4	15.00
43	1	1	0	0	0	10.35	20.8	2.0	18.8	4	15.71
44	1	1	0	0	0	10.35	18.9	2.0	16.9	4	16.02
45	1	1	0	0	0	10.35	16.8	2.0	14.8	4	17.18

TableA.22 Results calculated when B,A=1, C,D,E=0 for 10.35 mm diameter

No.	Q1(m^3/s)	C_d	Re
1	1.10E-04	0.8041	13410.28
2	1.18E-04	0.7982	14356.70
3	1.27E-04	0.8073	15417.09
4	1.30E-04	0.7890	15854.96
5	1.36E-04	0.7765	16531.96
6	1.41E-04	0.7732	17158.26
7	1.46E-04	0.7701	17754.74
8	1.50E-04	0.7625	18282.11
9	1.49E-04	0.7707	18143.92
10	1.43E-04	0.7684	17369.32
11	1.38E-04	0.7750	16833.38
12	1.34E-04	0.7877	16307.34
13	1.29E-04	0.7972	15689.15
14	1.22E-04	0.7965	14863.41
15	1.14E-04	0.7964	13907.53
16	1.07E-04	0.7835	13067.18
17	1.17E-04	0.7897	14203.79
18	1.24E-04	0.7896	15078.14
19	1.31E-04	0.7948	15970.99
20	1.38E-04	0.7874	16762.85
21	1.44E-04	0.7884	17495.92
22	1.46E-04	0.7701	17754.74
23	1.52E-04	0.7725	18521.92
24	1.46E-04	0.7531	17728.51
25	1.45E-04	0.7808	17650.30
26	1.43E-04	0.7991	17356.76
27	1.34E-04	0.7910	16374.08
28	1.26E-04	0.7774	15299.17
29	1.22E-04	0.7956	14845.02
30	1.14E-04	0.7955	13891.44
31	1.11E-04	0.8086	13485.62
32	1.16E-04	0.7833	14087.09
33	1.24E-04	0.7886	15059.23
34	1.30E-04	0.7859	15792.37
35	1.34E-04	0.7691	16374.08
36	1.42E-04	0.7771	17244.54
37	1.45E-04	0.7678	17702.36
38	1.51E-04	0.7690	18436.56
39	1.47E-04	0.7581	17847.14
40	1.42E-04	0.7651	17294.24
41	1.36E-04	0.7627	16566.19
42	1.31E-04	0.7730	16002.94
43	1.25E-04	0.7764	15279.70
44	1.23E-04	0.8030	14984.02
45	1.15E-04	0.8001	13972.30

TableA.23 Data obtained when B,A,C=1, D,E=0 for 10.35 mm diameter

No.	A	B	C	D	E	d(mm)	H1(cm)	H2(cm)	h(cm)	Δh1(cm)	Δt1(sec)
1	1	1	1	0	0	10.35	16.3	2.0	14.3	4	18.01
2	1	1	1	0	0	10.35	18.3	2.0	16.3	4	16.13
3	1	1	1	0	0	10.35	20.2	2.0	18.2	4	16.25
4	1	1	1	0	0	10.35	22.1	2.0	20.1	4	15.59
5	1	1	1	0	0	10.35	24.2	2.0	22.2	4	14.58
6	1	1	1	0	0	10.35	26.1	2.0	24.1	4	14.4
7	1	1	1	0	0	10.35	28.0	2.0	26.0	4	13.43
8	1	1	1	0	0	10.35	29.8	2.0	27.8	4	12.94
9	1	1	1	0	0	10.35	28.8	2.0	26.8	4	13.35
10	1	1	1	0	0	10.35	27.2	2.0	25.2	4	13.77
11	1	1	1	0	0	10.35	25.1	2.0	23.1	4	14.5
12	1	1	1	0	0	10.35	23.2	2.0	21.2	4	14.72
13	1	1	1	0	0	10.35	21.0	2.0	19.0	4	15.39
14	1	1	1	0	0	10.35	18.8	2.0	16.8	4	16.28
15	1	1	1	0	0	10.35	16.9	2.0	14.9	4	17.32
16	1	1	1	0	0	10.35	16.3	2.0	14.3	4	17.84
17	1	1	1	0	0	10.35	18.3	2.0	16.3	4	16.57
18	1	1	1	0	0	10.35	20.2	2.0	18.2	4	16.21
19	1	1	1	0	0	10.35	22.1	2.0	20.1	4	15.17
20	1	1	1	0	0	10.35	24.2	2.0	22.2	4	14.82
21	1	1	1	0	0	10.35	26.1	2.0	24.1	4	13.97
22	1	1	1	0	0	10.35	28.0	2.0	26.0	4	13.62
23	1	1	1	0	0	10.35	29.8	2.0	27.8	4	13.26
24	1	1	1	0	0	10.35	28.8	2.0	26.8	4	13.64
25	1	1	1	0	0	10.35	27.2	2.0	25.2	4	13.67
26	1	1	1	0	0	10.35	25.1	2.0	23.1	4	14.54
27	1	1	1	0	0	10.35	23.2	2.0	21.2	4	14.8
28	1	1	1	0	0	10.35	21.0	2.0	19.0	4	15.49
29	1	1	1	0	0	10.35	18.8	2.0	16.8	4	16.32
30	1	1	1	0	0	10.35	16.9	2.0	14.9	4	17.14
31	1	1	1	0	0	10.35	16.3	2.0	14.3	4	17.68
32	1	1	1	0	0	10.35	18.3	2.0	16.3	4	16.68
33	1	1	1	0	0	10.35	20.2	2.0	18.2	4	16.59
34	1	1	1	0	0	10.35	22.1	2.0	20.1	4	15.27
35	1	1	1	0	0	10.35	24.2	2.0	22.2	4	14.49
36	1	1	1	0	0	10.35	26.1	2.0	24.1	4	13.74
37	1	1	1	0	0	10.35	28.0	2.0	26.0	4	13.87
38	1	1	1	0	0	10.35	29.8	2.0	27.8	4	13.19
39	1	1	1	0	0	10.35	28.8	2.0	26.8	4	13.54
40	1	1	1	0	0	10.35	27.2	2.0	25.2	4	14.07
41	1	1	1	0	0	10.35	25.1	2.0	23.1	4	14.11
42	1	1	1	0	0	10.35	23.2	2.0	21.2	4	14.8
43	1	1	1	0	0	10.35	21.0	2.0	19.0	4	15.71
44	1	1	1	0	0	10.35	18.8	2.0	16.8	4	16.56
45	1	1	1	0	0	10.35	16.9	2.0	14.9	4	17.66

TableA.24 Results calculated when B,A,C=1, D,E=0 for 10.35 mm diameter

No.	Q1(m^3/s)	C_d	Re
1	1.09E-04	0.7765	13328.38
2	1.22E-04	0.8121	14881.84
3	1.21E-04	0.7628	14771.94
4	1.26E-04	0.7566	15397.31
5	1.35E-04	0.7698	16463.93
6	1.37E-04	0.7481	16669.73
7	1.47E-04	0.7723	17873.72
8	1.52E-04	0.7751	18550.54
9	1.48E-04	0.7652	17980.83
10	1.43E-04	0.7650	17432.39
11	1.36E-04	0.7588	16554.76
12	1.34E-04	0.7803	16307.34
13	1.28E-04	0.7883	15597.40
14	1.21E-04	0.7925	14744.72
15	1.14E-04	0.7910	13859.36
16	1.10E-04	0.7839	13455.38
17	1.19E-04	0.7905	14486.67
18	1.22E-04	0.7647	14808.39
19	1.30E-04	0.7776	15823.60
20	1.33E-04	0.7574	16197.30
21	1.41E-04	0.7711	17182.82
22	1.45E-04	0.7615	17624.38
23	1.49E-04	0.7564	18102.87
24	1.44E-04	0.7489	17598.54
25	1.44E-04	0.7706	17559.92
26	1.36E-04	0.7567	16509.22
27	1.33E-04	0.7761	16219.19
28	1.27E-04	0.7832	15496.71
29	1.21E-04	0.7906	14708.58
30	1.15E-04	0.7993	14004.90
31	1.11E-04	0.7910	13577.15
32	1.18E-04	0.7853	14391.13
33	1.19E-04	0.7472	14469.20
34	1.29E-04	0.7725	15719.98
35	1.36E-04	0.7746	16566.19
36	1.43E-04	0.7840	17470.46
37	1.42E-04	0.7478	17306.71
38	1.49E-04	0.7604	18198.94
39	1.46E-04	0.7545	17728.51
40	1.40E-04	0.7487	17060.70
41	1.40E-04	0.7798	17012.34
42	1.33E-04	0.7761	16219.19
43	1.25E-04	0.7723	15279.70
44	1.19E-04	0.7791	14495.41
45	1.12E-04	0.7758	13592.53

APPENDIX B

Table B.1 Davis C. V. (1952), Discharge through orifices and tubes