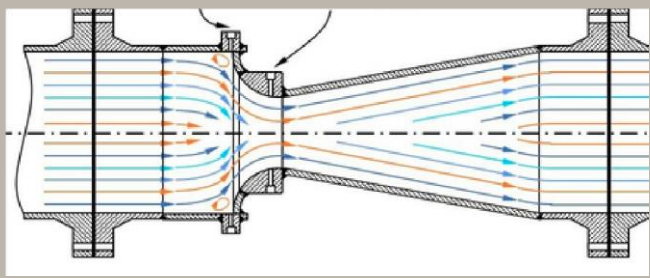
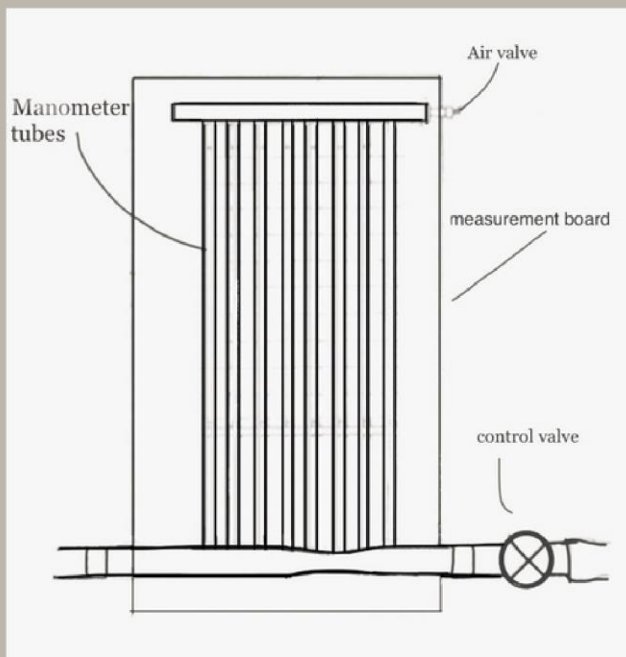
The College of Engineering/Al-Musayab/Energy Engineering Department



GRADUATION PROJECT

Analysis of fluid flow through a venture meter



By Students
1-Hussein Ali kareem
2-Safa Salah Badry
3-Zainab mofeed sabry

Supervised by :-
Asst. Proff. Dr. Sanaa Abdul-Razaq Jassim

قال تعالى: (اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ * خَلَقَ الْإِنْسَانَ مِنْ عَلَقٍ * اقْرَأْ وَرَبُّكَ الْأَكْرَمُ * الَّذِي عَلَّمَ بِالْقَلَمِ * عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ)

«سورة العلق: الآيات 1-5»

بسم الله الرحمن الرحيم

بعد الحمد والثناء على خالق الكون ومبدعهِ تبارك الله وتعالى عزوجل

اهدي ثمرة جهدي وتخرجي الى من كان لي نوراً في ليالي الظلمات وعوناً في الحياة الى روح فاطمة عليه السلام الامام المهدي المنتظر عجل الله تعالى فرجه الشريف

والى تلك الدماء الزكية التي سالت على ارضِ هذا الوطن الجريح والى ارواح الشهداء الاطهار

الى من رسم لي طريق النجاح مكللاً بالازهار والرياحين الى اليد الحنونه التي ربتت على كتفي اليك "والدي العزيز"

الى من كان دعائها رفيقاً لي في ايام حياتي ونبعاً لي يرويني كلما عصفت بي الاقدار الى تلك المرأة العظيمه "امي"

الى من كانوا بلسماً لي واداموا البسمة على وجهي وبهم هان تعب مسيرتي اليكم "اخوتي"

الشكر والتقدير

نحمد الله عزوجل ألهمنا الصبر وأمدنا بالقوة والعزم على مواصلة مشورانا الدراسي وتوفيقه لنا في أنجاز هذا البحث،

فنحمدك اللهم ونشكرك على نعمتك وفضلك ونسألك البر والتقوى، ومن العمل ما ترضى

وسلام على خاتم الانبياء والمرسلين ابي القاسمِ محمد صلى الله عليه واله وسلم

ويسرنا أن نتقدم بجزيل الشكر والتقدير لأستاذتنا الدكتورة العزيزة

الاستاذة الدكتورة القديرة سناء عبد الرزاق جاسم

والتي تكرمت مشكورة بقبول الإشراف على هذا البحث حيث قدمت لنا النصح والإرشاد طيلة فترة إعداده ويسرنا أن نتقدم بالشكر لكافة الأساتذة الكرام أعضاء الهيئة التدريسية والإدارية في كلية هندسة المسيب و العميد المحترم.

وفقنا الله للمزيد من العلم و تقديم ما فيه فائدة للمجتمع .

Abstract :

The Venturi meter is a flowmeter that used the pressure difference to calculate the flow rate, it is considered an open system in which a fluid -that its flow rate needs to be measured- flows through it, which means it could be an energy loss in the fluid flow and head loss. In this article, energy loss in fluid flow through a venturi meter has been studied, venturi meter measuring system was manufactured locally, and the flowrates were measured and calculated, after that the discharge coefficients were calculated to measure the difference between the real and theoretical and flowmeter flowrates. The results were that the discharge coefficients for the venturi meter are as follows, 0.964, 0.679, 0.899, 0.96…… ect; and the losses in the venturi meter are major in friction and minor like in Vorticities and so on, were observed from the study that in venturii meter the friction losses should be taken care of and the pipe should be constructed properly, the type of material and the fluid should be chosen carefully to minimize energy loss.

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Chapter One / Introduction

1.1 Introduction

The word fluid is generally applied to liquids, gases, and fluid mechanics. It is concerned with deriving the basic relations that govern motion and the rest of the fluids. The means for this conclusion include mathematical models based on what is known as the basic laws of conservation, as well as an experiment when theoretical means fail to derive. A fluid is known as a substance that changes. They are continually formed under shear stress, no matter how small it was. (1)

The presence of substances in any of the aforementioned states and the existence of similarities or differences are due in origin to the activity and structure of the molecules of matter and also depend on the distance between the molecules. It is greater if compared to the activity of the molecules of the liquid substances, and the movement between the molecules increases and the cohesion is relatively less in the liquid substances, while we find the movement of the molecules of the gaseous substances large and their cohesion is low, so we see the gases filling the container that contains them, but the liquid fills part of the container and takes its shape and has a free flat surface and usually imposes no the presence of voids within this volume.

There are two types of fluid properties the normally static properties which are(mass density weight density relative density specific volume compressibility viscosity dynamic viscosity and kinematic viscosity) and the properties which are change from one point to another point named flow properties include: time, pressure acceleration and force.

When the fluids are in a static condition of rest, there is no relative movement between its different layers, so the velocity slope is zero, no matter how large the viscosity of the fluid is, and the forces acting on the static fluid are pressure forces only.

1.2 Pressure measured

The fluid's pressure when it is measured relative to absolute zero is defined as absolute pressure, and if it is measured according to atmospheric pressure, it is known as standard pressure, and it records zero when it is open to the atmosphere, If it records the difference between fluid’s pressure and it was less than atmospheric pressure, in this case it is known as vacuum pressure. In thermodynamics, absolute pressure is used because most of the thermal properties of the fluid as a function of real pressure. Since the effect of temperature and pressure is small here, the standard pressure can be used.

1.3 Measurement tools

1. A Manometer: is defined as a device used for measuring the pressure at appointing a fluid by balancing the column of fluid by the same or another column of the fluid.
2. The piezometer tube: is a very simple and accurate pressure-measuring device, but it has several disadvantages. It is suitable only if the pressure in the container is greater than atmospheric pressure otherwise air would be sucked into the system, and the pressure to be measured must be relatively small so the required height of the column is reasonable. Also the fluid in the container in which the pressure is to be measured must be a liquid rather than a gas.
3. Dial Indicator: is measuring specifiers with a dial or a dial that are used to test the flatness of the surfaces and the regularity of the rotating shafts, and to determine the values of the deviations of the sizes and dimensions of the manufactured pieces from the dimensions stipulated in the specifications and designs

1.4 Fluid Dynamics

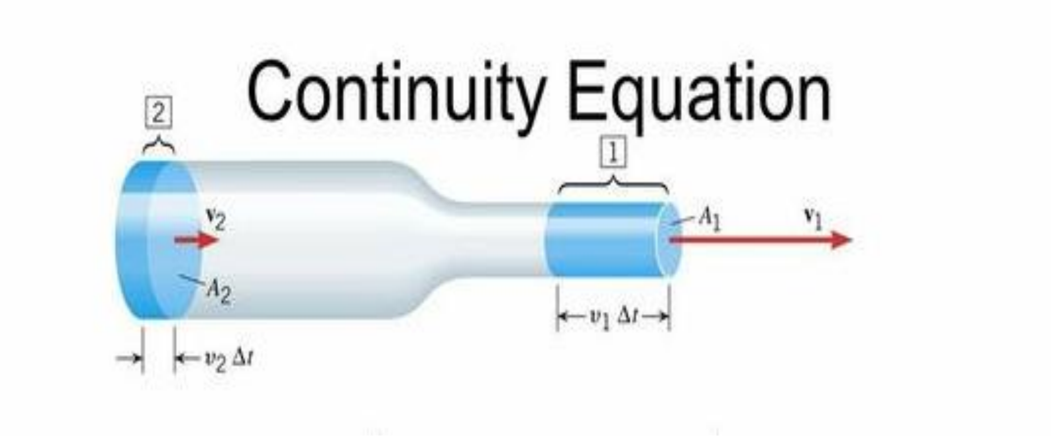
Fluid dynamics is the state of fluid when one of the dynamic properties changes fluid flow .

To study the fluid dynamics and calculate flow characteristics depending on the following basic flow equations :

1- Conservation of Mass (the Continuity equation).
2- Conservation of Energy (Bernoulli equation).

1.4.1 Continuity Equation of Liquid Flow /

If a liquid flows through a tube, the amount of liquid passing through a unit of time is equal at all points, provided that no amount of liquid is added or withdrawn, and this is called the continuity equation.



Figure(1-1) Continuity Equation. (17)

And the mathematical expression of the conservation of mass is

the flow rate at the first pot:

$Q_1 = \rho_1 u_1 A_1$.............(1) (2)

$Q_2 = \rho_2 u_2 A_2$............(2) (2)

$Q_1 = Q_2 , \rho_1 u_1 A_1 = \rho_2 u_2 A_2 \ldots\ldots\ldots\ldots\ldots.(3)$

This is the continuity equation for compressible fluid. While if incompressible one the density is constant so the continuity eq. becomes :

$\rho_1 u_1 A_1 = \rho_2 u_2 A_2 \ldots\ldots\ldots\ldots\ldots\ldots..(4)$ (2)

$u_1 A_1 = u_2 A_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5)$ (2)

1.4.2 Conservation of Energy

According to this law, energy cannot be vanished, but it can be transformed from one form to another, and the energy equation is called Bernaulli's Equation it takes different forms according to the type of flow, fluid, and dimensions used.

Types of energy that drive fluid motion

1- Potential energy is represented by:

PE=z………(6) (19)

2- Kinetic energy is represented by:

$KE = \frac{1}{2g}U^2$…..(7) (19)

3- Energy resulting from pressure is represented by:

$E_p = \frac{P}{\rho g}$ ……..(8) (19)

So that :

$Total\ Energy = z + {U^2}/{2g} + P/\rho g$……..(9) (19)

1.4.3 The energy equation(Bernoulli's equation)

The theory states a relationship between the velocity, pressure, and height of a fluid flowing in a streamline. The flow must be incompressible and in the case of a steady flow, the Bernoulli equation can be considered as a principle of energy conservation for the flowing fluids.

The mathematical formula for the Bernoulli equation:

$P_1 + \frac{1}{2}\rho {U_1}^2 + \rho g z_1 = P_2 + \frac{1}{2}\rho {U_2}^2 + \rho g z_2 = constant$……….(10) (19)

The flowmeters that use the Bernoulli principle are called differential pressure flow meters

There are different types of them including venturi meter orifice meter, rotameter, diffuser, right-hand bend, and other types.

In this study, Only the venturi meter will be studied, because it is good case study for application of conservation of mass and energy at fluid motion.

1.5 Energy Losses

In order to study energy losses it is important to dfine parameters in a closed system or open system of flow, they are laminar flow and turbulent flow. Laminar is the flow when every layer of the fluid's structure moves smoothly along with other layers, while, turbulent flow is the flow when fluid layers interfere and overlap with each other decided number if the flow is turbulent or laminar is called the Renold number

1.5.1 Reynolds Number (Re) is a dimensionless quantity that helps predict fluid flow patterns in different situations by measuring the ratio between inertial and viscous forces. At low Reynolds numbers, flows tend to be dominated by laminar (sheet-like) flow, while at high Reynolds numbers, flows tend to be turbulent.

$$R_e = \frac{UD\rho}{\mu} = \frac{UD}{v} \text{ ………. (11)} \quad (20)$$

The experiments showed the following :

- At (Re<2100) the flow is laminar. (20)
- At (Re>4000) the flow is turbulent. . (20)
- $Re_{crit} = 2300.$ (20)

1.5.2 Major losses in flow systems result from significant energy wastage due to frictional energy loss caused by the fluid viscosity and pipe wall roughness. In contrast, minor losses are relatively smaller in effect. The total energy loss in a pipe or open system is the sum of major and minor losses. The Darcy-Weisbach equation;

$$\frac{\Delta p}{L} = f_D \times \frac{\rho}{2} \times \frac{v}{D_H} \text{…………(12)} \quad (21)$$

Using the friction factor, is widely used to determine energy loss in pipe flow. the energy losses can be represented by the friction factor (f), The friction factor depends on the Reynolds number and relative roughness of the pipe wall in turbulent flows, while it is only dependent on the Reynolds number in laminar flows (f) is determined by using the Moody diagram .

Or could be found from following equation

(a) For laminar flow:

f=16/Re…………………(13)   (18)

Thus friction co-efficient is only a function of Reynolds number in case of laminar flow. It is independent of (k/D) ratio.

(b) For turbulent flow, the co-efficient of friction is a function of Re and k/d ratio. For relative roughness (k/D), in the turbulent flow the boundary may be smooth or rough and hence the value of 'f'will be different for these boundaries.

For turbulent flow in smooth pipes, co-efficient of friction is a function of number only. The value of laminar sub-layer in case of smooth pipe is large as compared to the average height of surface roughness k. The value of 'f' for smooth pipe for Reynolds number varying from 4000 to 100000 is given by the relation

$f = {}^{0.0791}/_{Re^{1/4}}$……………………(14)   (18)

1.6 The Flow Rate :

Knowing the amount of fluid passing through a pipe, channel, or any other facility is one of the most important information that an engineer must know about water projects in particular and projects related to fluids, such as oil and gas in general, whether in the design or investment stage, as a supply network cannot be designed drinking or irrigation water without knowing the amount of water to be provided. It is not possible to design a line to transport oil or gas without knowing the amount of oil or gas to be passed. It is also not possible to distribute drinking and irrigation water to neighborhoods or fields in specific quantities without a tool or means that measures this.

1.7 Venture Meter Classification And Loss Spotting

Venture meter is a type of flow measurement instrument that works by utilizing a convergent–throat–divergent section of pipe. This causes the flow velocity to increase and a corresponding pressure drop, which can then be used to calculate the rate of flow. These devices have been widely used for many years, particularly in the water supply industry.

1.7.1 Characteristics effect

the effective characteristics of pressure drop in the Venturi meter are:

a. Material To manufactor venture One of the important parameters of classification is the metal from which the pipe is made because the friction factor depends on it and the maximum pressure of the system is selected depending on it whereas iron and steel can sustain far more pressure than glass pipe or plastic. And the behavior of the metal after the maximum allowable pressure stress when the brittle glass will shatters and scatters on the other hand the ductile plastic, iron, and steel will deflect and fail.

Glass and plastic and low-stress resistance materials are most likely to be used in education experimental purposes while the other high-stress resistance material used in an industrial facility or other wanted suitable properties for other specific applications

There are major and minor losses in the venture meter case the only major losses are in friction and the other minor losses are:

1- The venture pipe characteristics
2- The vortexes.
3- The atmospheric pressure and elevation above the sea level.
4- Other construction issues.

b. Geometry shape effect / which can be divided to :

1- Convergent cone angle
2- Divergent cone angle
3- Diameter ratio
4- Throat length

Each parameter has a special effect on the pressure and energy loss. Effect of Geometrical Parameters of Venturi Meter on Pressure Drop on the given parameters are that pressure drop fluctuates with the increase in the following parameters convergent cone angle, divergent cone angle, and throat length while reducing with an increase in diameter ratio.

C .Vortex energy losses in fluid flow in venture meters

Vorticities happened in fluid flow when the fluid layers adjacent to the walls reach a nonuniform constructed corner or a sharp corner which will cause an instantaneous. Vacuum between the layer and the wall which makes the fluid spin in it direction of the vacuum and that or the corner is vertical in the flow direction in this case the corner will cause a hummer effect on the fluid flow

The solution for the upstanding loss in energy and pressure by taking care of the corners or making it more Semi-arc or circular than the hard corner

Or like in the friction effect by designing and simulating and testing the vorticities in the modeling and simulation till getting to the best design.

d. Affect the atmospheric One of the important parameters in pressure magnitude is the elevation and the atmospheric pressure because high atmospheric pressure or high elevation places the atmospheric pressure affects the density of the working if it is perfect gas and the manometers reading and height of fluid in the pipes referred to in the Bernoulli equation:

$$P_1 \frac{1}{2}\rho {U_1}^2 + \rho g z_1 = P_2 + \frac{1}{2}\rho {U_2}^2 + \rho g z_2 \text{..........(15)} \quad (18)$$

Other preventable losses are the losses in the nonhomogeneous areas in the venturi pipe like the ending and starting areas of the parts -convergent parts for example- and the manometers base especially if the pipe is not constructed properly which will cause vortexes in the fluid flow and nonhomogeneous flow and a big friction drag .

1.7.2 Friction energy losses in fluid flow in venture meter

The major loss or effect on the energy presented by the friction loss is made by the viscosity and other properties of the fluid and the pipe's wall for the simplest explanation if the flow is presented as layers the layers adjacent to the pipe's wall are having a velocity of zero because the layer and the wall are stationary together because of tension force presented as viscosity, this force is faded variational in the direction away of the wall through the other layers to the center of the pipe. The friction is the only major loss in the venture meter compared with other losses because in larger pipes it will cause meters of head losses and will cause more losses because the friction happens between the fluid and the walls and when using large pipes the surface area will be bigger so that the friction between it and the fluid will be major.

Viscosity is the resistance of the fluid against the shear force between the fluid layers to reduce the friction there is two option

1. Reducing the viscosity by changing the fluid that flows in the venturi pipe
2. And the other one by reducing the friction coefficient of the pipe by changing the material of the venturi pipe

Another experimental solution by changing the Dimensions distances and angles of the pipes and simulating the new design and testing the friction drag

1.8 The Objective of this project is to study and evaluate venturi pipe flow meters for liquid and find its correction factor Cd because of losses.

Chapter Two / Literature Review

2.1 Introduction

Venture meter is very important device which is widely used for flow measurement, and many studies were mode on it.

2.2 Literature review

- **Ghassemi H. and Fasih H, 2011**

Published paper about the Application of small-size cavitating venturi as flow controller and flow meter.

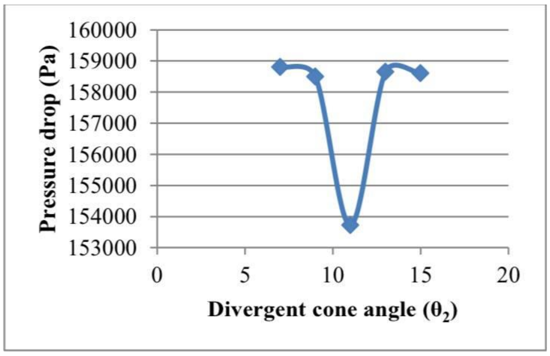
An experimental setup with the capability of supplying water flow rate and constant upstream pressure was designed and manufactured. It is found that the venturi size does not affect its expected function to keep the mass flow rate constant. Also, it is shown that by applying a discharge coefficient and using only upstream pressure, the cavitating venturi can be used as a flowmeter with a high degree of accuracy in a wide range of mass flow rates.

- **Süßer M. 2012**

Venturi tubes for application in cryogenic facilities were studied. The selection of the proper instrument is governed by many variables including a broad range of temperatures, high requirements for leak tightness, low permanent pressure losses, huge pressure overload capability, and insensitivity against magnetic fields. The Venturi tube satisfies these requirements, and therefore, it is a favorite device for this application.

- **Sanghani D. Et al -2016**

Has been studied venture meter and it was found that the pressure drop oscillates with increasing convergent cone angle, divergent cone angle, and throat length while it decreases with increasing diameter ratio. After being studied by simulation results. Originally, the pressure drop depends on the different engineering information of the flow meter and the properties of the liquid, and the venturi meter scale is a flow meter of the differential pressure type used to measure the volumetric flow rate of liquids. Diameter and throat length at low pressure. Dimensions of the venturi meter used in the research.



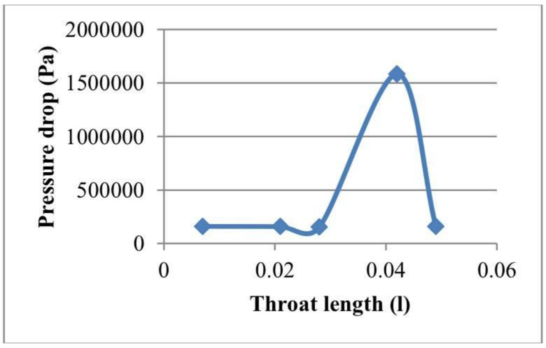
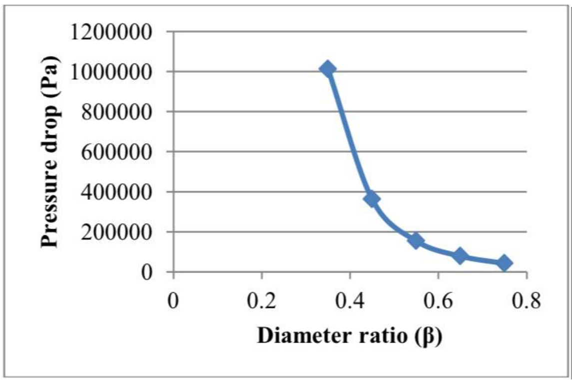


Fig (2-1): the effect of the throat length on the pressure drop.

fig(2-2): the effect of the divergent cone angle on the pressure drop



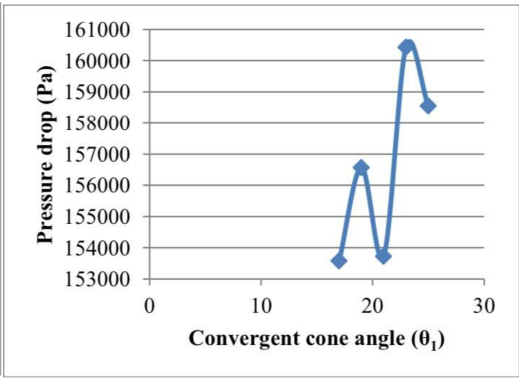


Figure (2-3) :the effect of the diameter ratio on the pressure drop.

figure (2-4): the effect of the convergent cone on the pressure drop.

- **Kinsey A., 2018**

came up with this After submitting a paper on Energy Losses Through Venturi, Orifice, and Rotameter Flowmeters.

The research focuses on the venturi only. It was found that the comparison is based on the energy loss due to the friction of the flowmeter. It was found that the rotary scale has the highest energy loss due to friction, but this loss remained constant with the increase in the speed of the venturi orifice. The venturi flowmeter would be the choice. It is best if the system cannot handle a change in pressure.

• Lghalo J.O. and Nwabueze Q. 2020

After presenting research on the analysis of flow measurement mechanisms to determine losses in bends and equipment for similar processes, the bends and equipment considered were a venturi meter, orifice meter, rotameter, diffuser, and right-hand bend. It was noted that the venturi meter is the most specific estimation equipment for flow measurement. Due to its accuracy and calculable scale. It is mandatory to use high-throughput devices with good accuracy (70% for a venturi gauge) and fewer head losses because of the measurement and control of fluid flow analysis Important procedures in the process industry.

• Obaseki M., and Etal, 2022

Published a research sheet about the experimental investigation and performance evaluation of the installation effects on the Venturi flow meter. This study aims to determine the effects of dynamic change in venturi meter readings resulting from changing and abnormal internal conditions of the flow meter and to reduce the associated economic losses during industrial applications. Use in this Procedure Experimental investigation Venturi flow meter H5 To describe the measurement of the flow rate in the pipe and to calculate the best discharge coefficient, air flow rate, and flow coefficient, the obtained research results show that changing internal conditions can lead to large errors of up to ± 7.5%, but in this work, The percentage was reduced to ± 1.2%. It was also proven that the liquid carrying small particles of impurities causes pressure build-up at the tap head. The results showed that the error caused by the internal conditions of the variable or abnormal flow meter, which could lead to large economic losses, was reduced to a minimum. Venturi gauge analyses show the relationship between pressure losses, pressure change, and velocity in different cross-sectional areas of a piping system used for fluid transportation, especially in the oil and gas industry.

2.3 **Summary**

From the previos studies that had been taken in study the folwing has been optain :

1- Venturi meter has the least losses in energy ammong the other deffirential pressure flow measurement tools
2- It can give the best results ammong the other deffirential pressure flow measurement tools doe to its acurisy and calcuable rmeasures.
3- It has a broad range of temperatures, high requirements for leak tightness, low permanent pressure losses, huge pressure overload capability, and insensitivity against magnetic fields.
4- The venturi size does not affect its expected function to keep the mass flow rate constant.

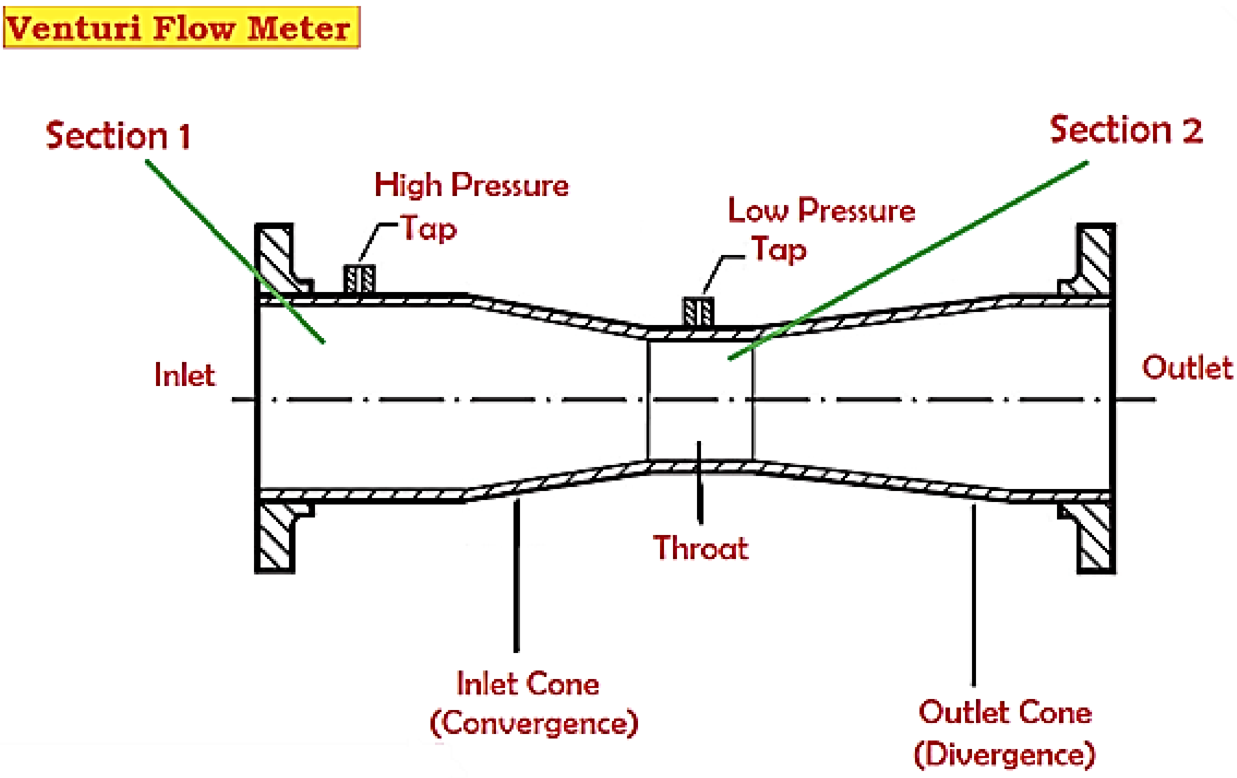
Chapter Three/Theory,Design,and Expermintal

3.1 Introduction

The flow rate of a fluid flowing in a pipe under pressure is measured for a variety of applications, such as monitoring of pipe flow rate and control of industrial processes. Differential pressure flow meters, consisting of venturi meters and others, are widely used for pipe flow measurement and these meters use a constriction in the path of the pipe flow and measure the difference in pressure between the undisturbed flow and the flow through the constriction. That pressure difference can then be used to calculate the flow rate.

This chapter will provide general background information about differential pressure flow meters and the format of the equation used for calculating liquid flow rate through any of them. There will be descriptions of each of these meters and their particular equations, along with example calculations.(12)

3.2 Venture flow meter design



Figure(3-1): The Venturi Meter(13)

The diagram of a venturi meter above shows the general shape and flow pattern for this type of differential pressure flow meter. The converging cone, through which fluid enters a venturi meter, typically has a cone angle of 15° to 20°. This cone on the inlet side of the meter converges to the throat diameter, which is where the area of flow is at its minimum, the velocity is at its maximum, and the pressure is at its minimum. The diverging exit section of the venturi meter uses a cone angle of 5° to 7°, to bring the meter diameter back to the full pipe diameter. As shown in the figure,(3-2), D2 is the diameter of the venturi throat and P2 is the pressure in the throat. D1 and P1 are the diameters and the pressure for the pipe before the flow enters the converging section of the meter. (12)

The design of a venturi meter, with its smooth contraction on the inlet side and gradual expansion back to the pipe diameter, leads to very little frictional loss through the meter.

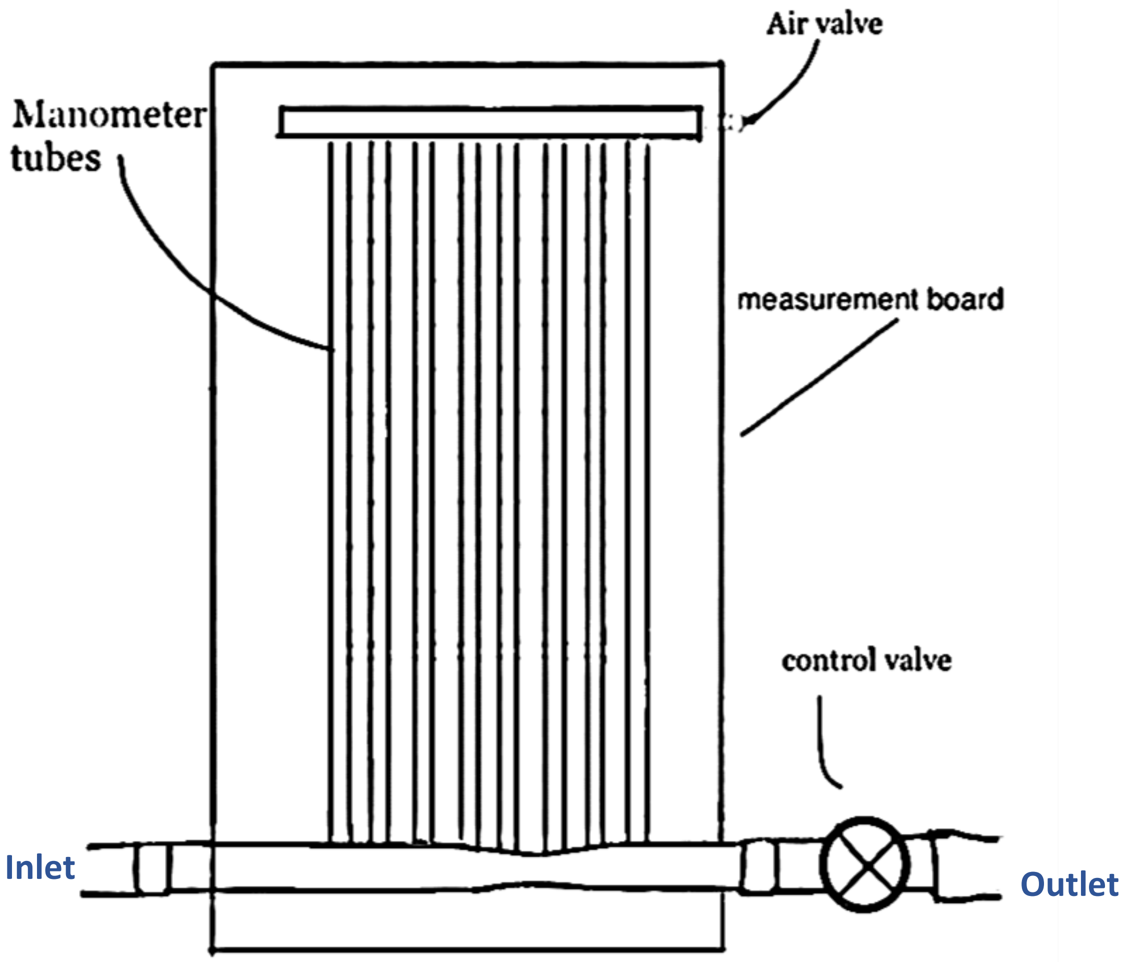


Figure (3-2): the experimental venturi meter device

Applying Bernoulli's equation between Section 1 and 2 get(17)

$$P_1 + \frac{1}{2}\rho {U_1}^2 + \rho g z_1 = P_2 + \frac{1}{2}\rho {U_2}^2 + \rho g z_2 \qquad (3.1)\ (17)$$

$$\frac{{U_2}^2 - {U_1}^2}{2g} = \frac{P_1 - P_2}{\rho g} + z_1 - z_2 \qquad (3.2)\ (17)$$

where ρ is the density of fluid flowing through the venturi meter. From continuity

P is the static pressure (the pressure of the fluid)

U is the velocity

g is the gravitational acceleration

z is the elevation of the fluid

$$A_1 U_1 = A_2 U_2 \qquad (3.3)\ (17)$$

where A, and A2 are the cross-sectional areas of the venturi meter its throat and inlet respectively. With the help of Eq. 1, Eq. 2 written as

$$\frac{{U_2}^2}{2g}\left(1 - \frac{A_2^2}{A_1^2}\right) = \left(\frac{p_1}{\rho g} + z_1\right) - \left(\frac{p_2}{\rho g} + z_2\right) \qquad (3.4)\ (17)$$

Where

p= ρgh

The vslocity will be :

$$V_2 = \frac{1}{\sqrt{(1-\frac{A_2^2}{A_1^2})}} \sqrt{(2g(h_1 - h_2))} \qquad (3.5) \; (17)$$

Where $(h_1 - h_2)$piezometric pressure heads respect point 1 & 2 respectively.

3.3 Coefficient of Discharge of Venturi meter (Cd)

The discharge coefficient for a venturi meter is often called the venturi coefficient, Cd. The equation for flow rate through a venturi meter thus becomes(14):

$$Q = C_d A_2 \sqrt{\frac{2(p_1 - p_2)}{\rho(1-\beta^4)}} \qquad (3.6) \; (14)$$

The coefficient of discharge for the Venturi meter, Cd is defined as the ratio of the actual flow rate through the venturi meter tube to the theoretical flow rate. So the venturi meter discharge coefficient is given by:

$$Q = V_2 A_2 = \frac{C_d A_2}{\sqrt{1-\beta^4}} \sqrt{\frac{2(P_1 - P_2)}{\rho}} \qquad (3.7) \; (14)$$

$$Cd = {Q_{actual}}/{Q_{theoritical}} \qquad (3.8) \; (14)$$

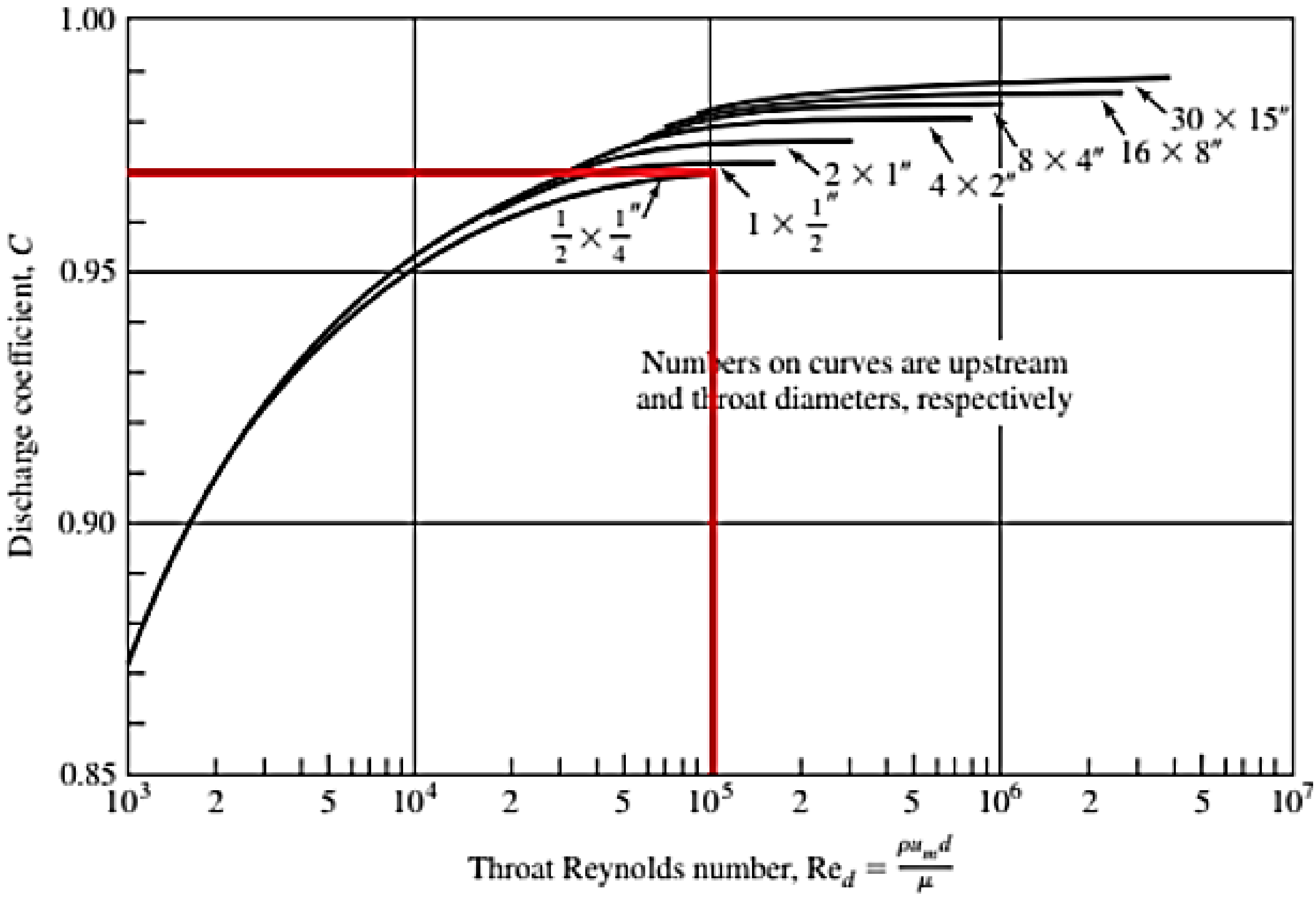
As Q actual will always be less than Q theoretical due to frictional losses, the value of C_d is always less than 1.0

$$Q=C_d\ A\sqrt{\left(\frac{2\Delta p}{\rho(1-\beta^4)}\right)} \qquad (3.9)$$ (14):

where

Q is the volume flow rate through the Venturi,
A is the exit area of the ventur,
ΔP is the pressure drop across the Venturi,
ρ is the density of the fluid being sprayed.

The discharge coefficient can then be also calculated from a chart(15)



Figure(3-3):The chart between Cd and Renold's number (15)

The typical range of the discharge coefficient of a Venturi meter is 0.95-0.99 but this can be increased by proper machining of the convergent section. The value of the venturi meter discharge coefficient differs from one flowmeter to the other depending on the venturi meter geometry and the Reynolds number.

Thus, the flowrate through a Venturi meter is given by

$$Q=C_d A_T\sqrt{\frac{2(P1-P2)}{\rho(1-\beta^4)}} \qquad (3.11)$$

Where

The throat-to-pipe diameter ratio (β = d/D), the Reynolds number, and the shape of the converging and diverging sections of the meter are among the parameters that affect the value of Cd.

3-4 Laboratory work

Venture meter is constructed from The convergent reagent is just a basic nozzle that increases the pressure til gets to the throat convergent has two manometers to calculate its pressure difference. and at its end of it starts the throat which is a regular pipe with one manometer to calculate the throat pressure that which the convergent part connects to the inlet pipe when the convergent start diameter is equal to the initial pipe and it is ending diameter is equal to the throat diameter.

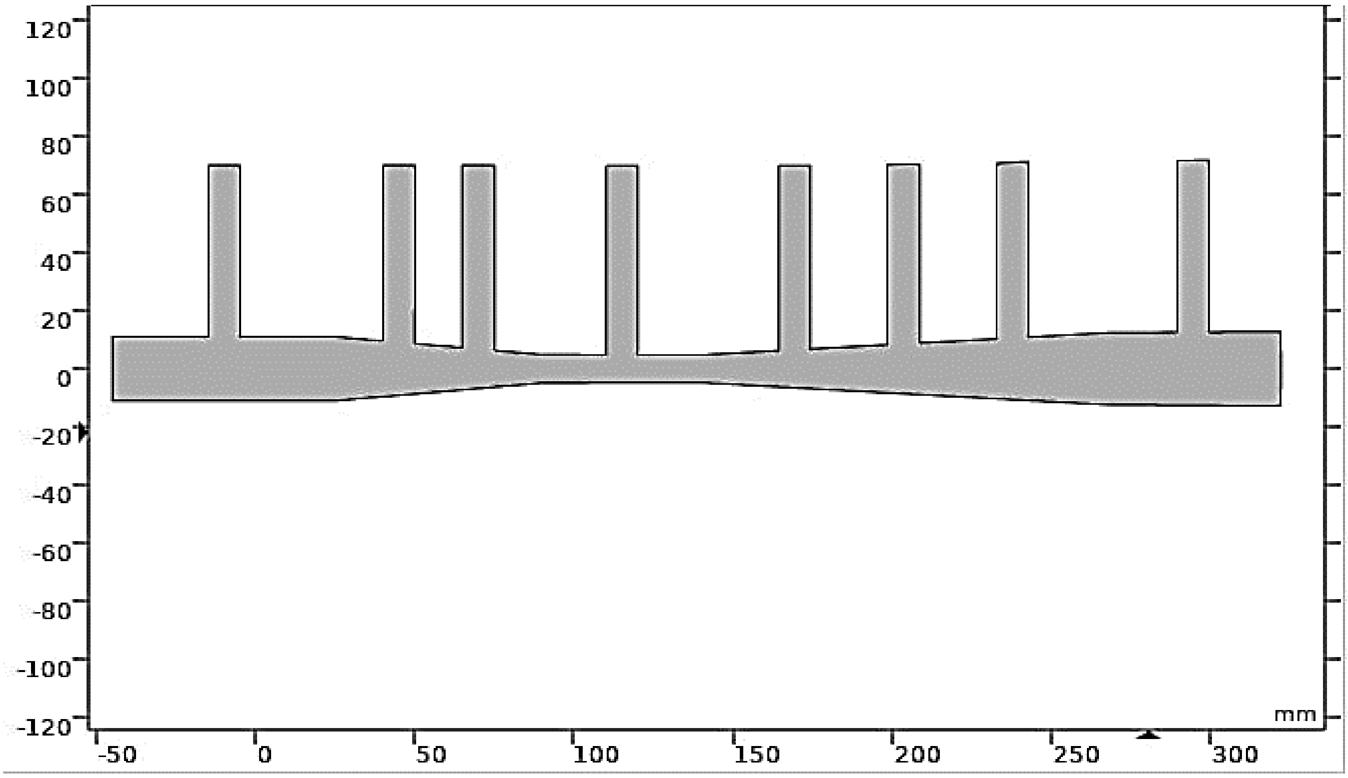
The last part before the ending is the divergent part is the pressure-reducing part when the diameter increase till it gets to the diameter equal to the inlet pipe diameter divergent part has three manometers to calculate the pressure precisely .And here the venture pipe started and ended with the same pipe diameter.(16)

3.4.1 Apparatus:

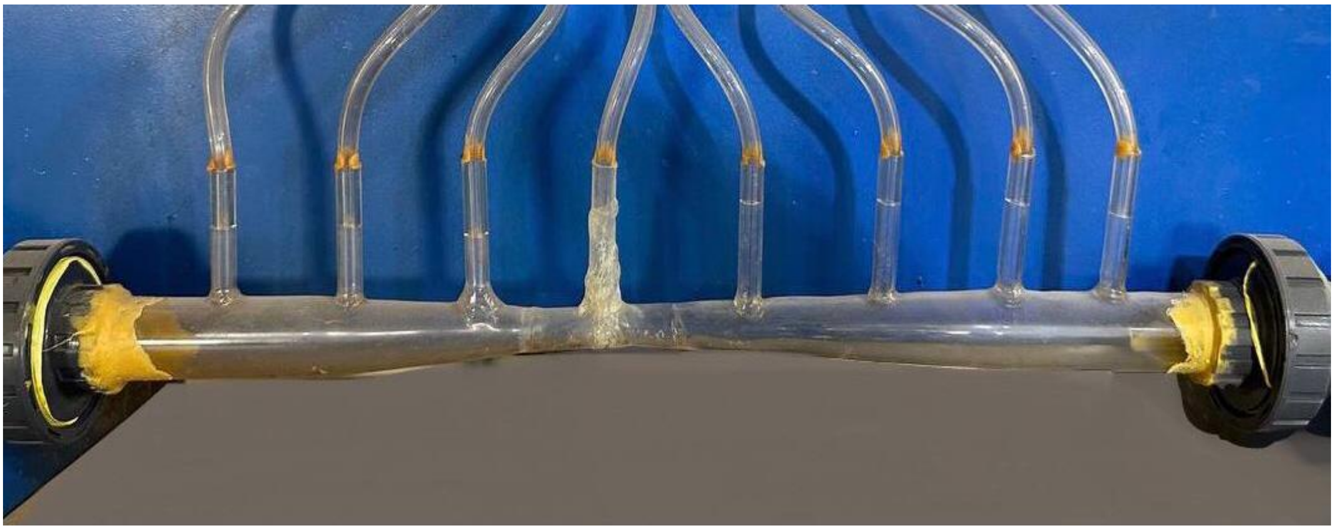
The testing apparatus con sist of the following parts:

1. Venturi tupe
2. piezometers
3. Measurem Borad
4. Flow meter
5. Hydraulic platform
6. water pump
7. lower tank
8. pipe

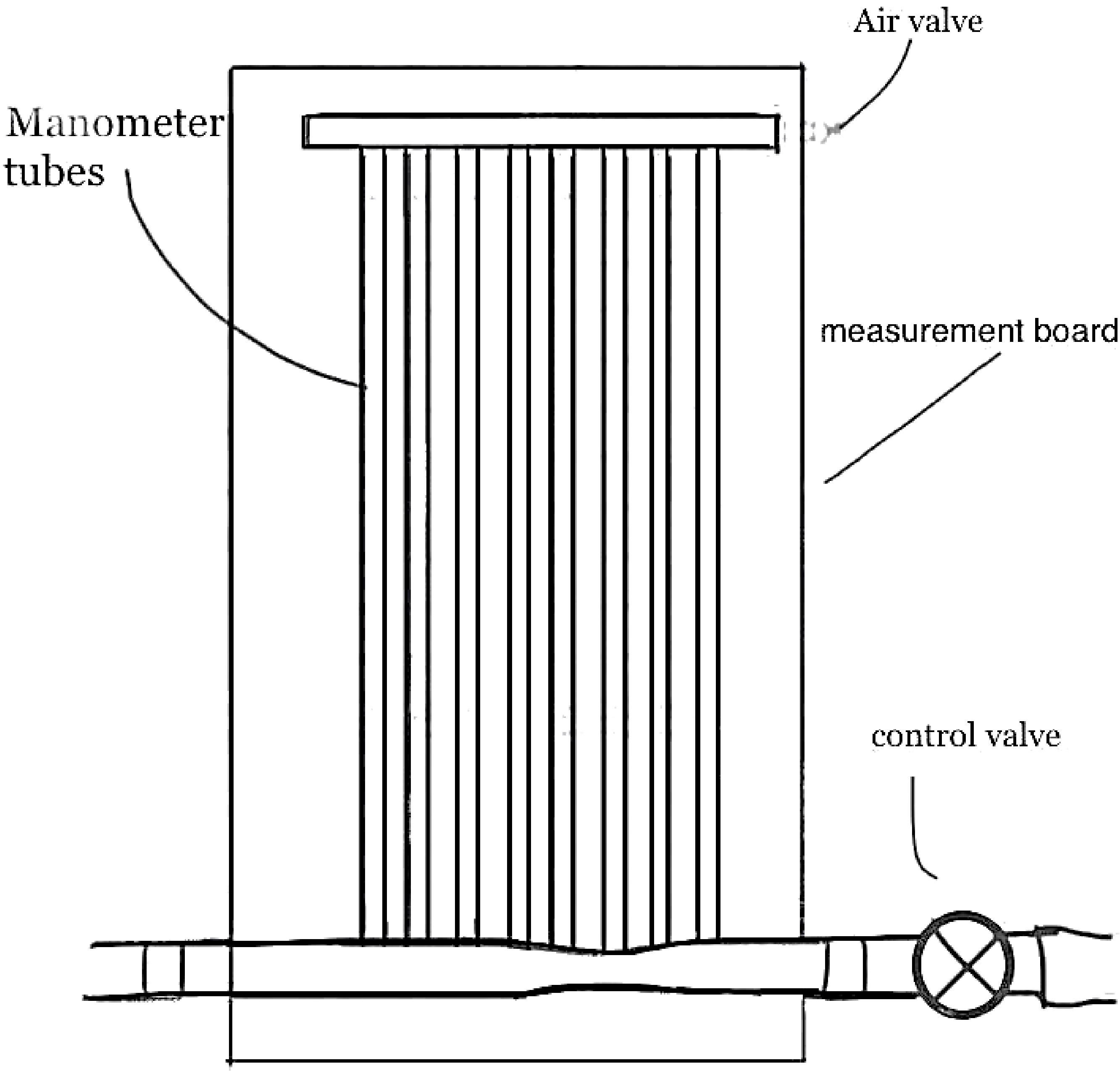
- The device was fabricated by locally casting its shape into a mold with the required dimensions. The device was manufactured from three main parts. The first is the "Venturi tube," which is made of glass and contains eight small holes on the upper surface that contain clear plastic tubes representing the piezometers. The piezometers are evenly distributed along the tube and measure and indicate pressure changes in relation to the flow rate of the water. A measuring ruler is placed between each piezometer to measure the height inside the piezometers. As for the air inside the piezometers, it is controlled by an air separation tube, which helps to adjust the height in the piezometers by air pressur. Figure(3-5)
- The "Measurement Board," which consists of a laser-cut metal board in a rectangle shape with a length and width proportional to the dimensions of the Venturi tube and the piezometers. The board contains the plastic piezometers fixed on it along with the previously mentioned rulers Figure(3-7).
- "Water Supply System," which consists of a lower tank connected to a pump and a flowmeter, and it pumps the water to the upper input tube of the Venturi. After that, the water flows through the Venturi tube and is drained through the outlet tube connected to the output at the other end of the Venturi, Which then returns to the lower tank. Figure(3-9),(3-10),(3-11)



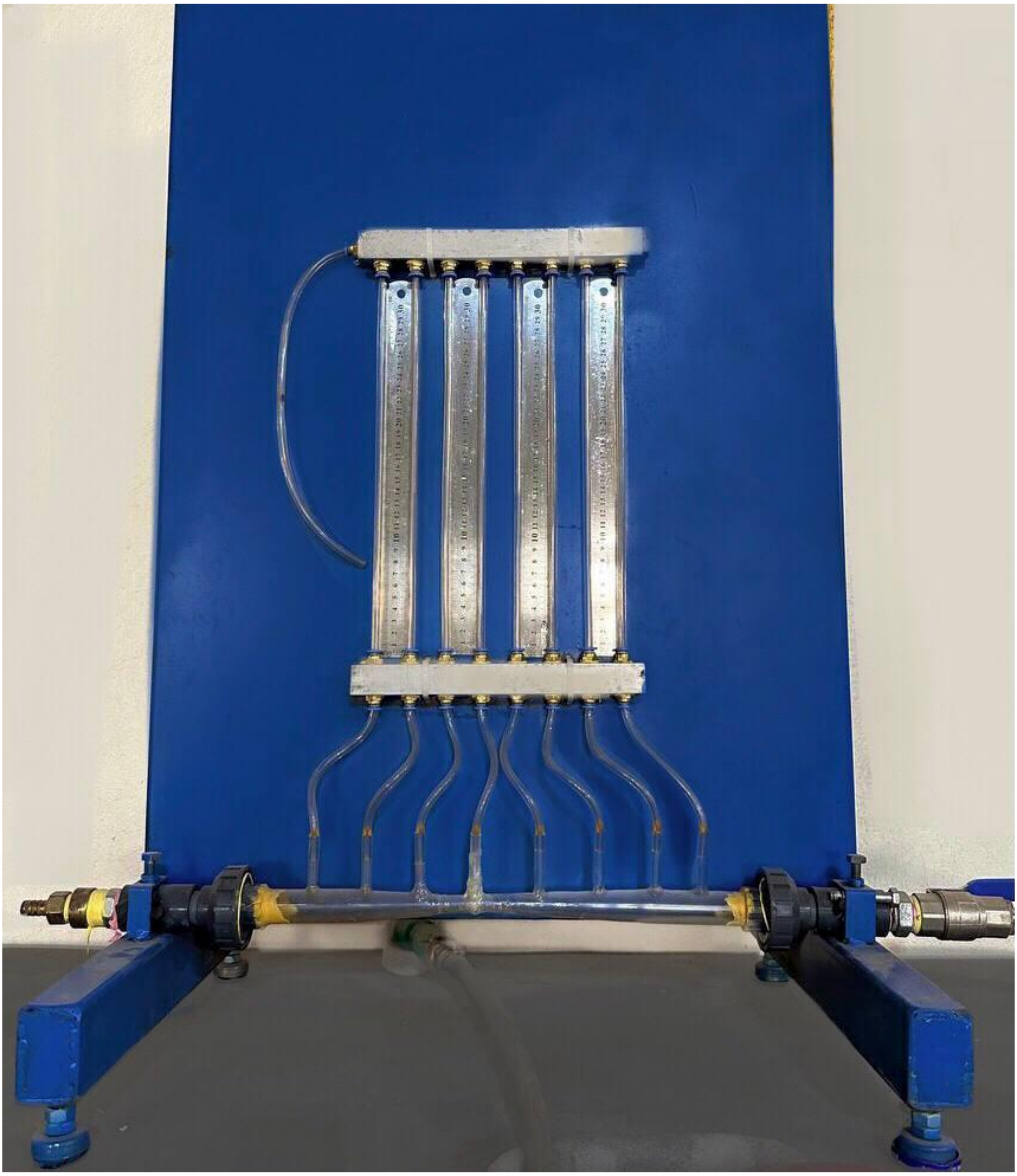
Figure(3-4): The experimental Venturi tube



Figure(3-5): Venturi tube



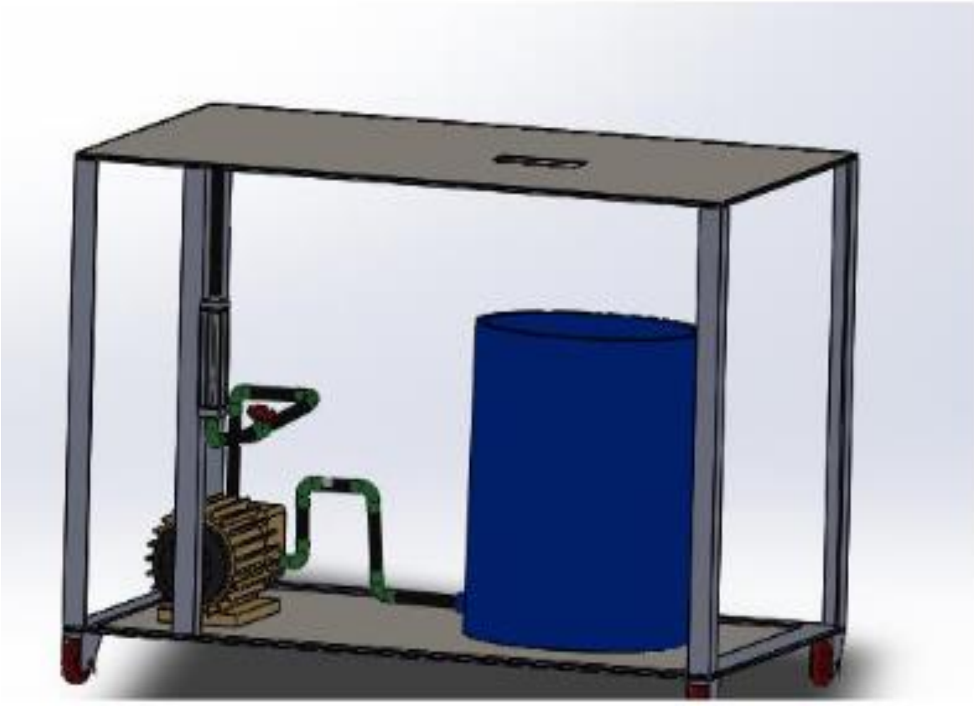
Figure(3-6): The experimental venturi meter device



Figure(3-7).Venturi meter device

Figure(3-8). Measurement Board

Figure(3-9).Flowmeter



Figure(3-10). Hydraulic platform

Figure(3-11).Water pump

3.5 Experimental steps:

The experememetal worke were down as follows:

1- The Venture meter input device was connected to the outlet of the pump, and the outlet tube was connected to the drainage hose to the lower tank.

2- A specific amount of clear and debris-free water was filled into the lower tank.

3- The outlet valve was opened and the pump was turned on with a specific force to introduce water to the device.

4- It was ensured that there was no leakage in any area of the venture and piezometers.

5- The flow meter was used to measure the in flow. The outlet was gradually closed so that the water was pushed to the pressure gauge pipes, and elevation calculations were made while keeping all water levels within the range on the pressure gauge.

6- The readings of the pressure gauge meters were recorded during the elevation of water inside the eight piezometer pipes while keeping the observer anonymous.

7- The flow rate was measured by timing the collection of a certain volume of water in a side-tank, in an anonymous manner.

8- The previous steps were repeated several times using different inlet discharge, while keeping the observer anonymous.

In the end, despite the accuracy of the work and the effort exerted, the readings were not obtained easily and quickly. A lot of problems and obstacles were faced in the device and complex calculations due to the presence of faults, leakage and more. However, it was learned through experimentation and repetition that the best way to learn how to solve problems is to reach optimal values, and some of these problems will be mentioned later .

3.6 Problems of the practical side of the Venturi system

Even though the device was precise in its measurements and details, when The experiment was applied on the device., some problems had to be addressed, which will be mentioned later. It was noticed that air was present, causing the water level inside the piezometer to fluctuate., but after many efforts and numerous solutions.Among the problems that directly affected the readings were the following.

Firstly, there was a leak at the beginning of the plastic tubes for the piezometers, and after several attempts, the water leakage problem was resolved. Another problem was a leak at the joint between the inlet opening of the flume and the pipe for water entry, and this was solved by applying a sealant that prevented any leakage.

The outlet opening of the flume and the pipe for draining water into the lower tank had a problem that was resolved by applying a sealant that prevented any leakage. After the resolution of these problems, Logical readings were not obtained from the beginning quickly and easily., which affected the calculation of the water level. After many attempts, a solution was found to eliminate the air inside the plastic tubes.

The final problem was the occurrence of fluctuation (rise and fall) in the pumping force of the water pump, which resulted in the instability of the water level in the piezometers.

Chapter Four / Calculation And Results

4.1 Intruduction

This chapter includes the flow rates, heads, and other practical calculations.

The important parameters to find are the actual, theoretical flowrates, the head deffirients and discharge cofficient in different methods .

4.2 Calculations

Firstly the characteristics of the used venturi pipe were as shown in figure (4-1) :

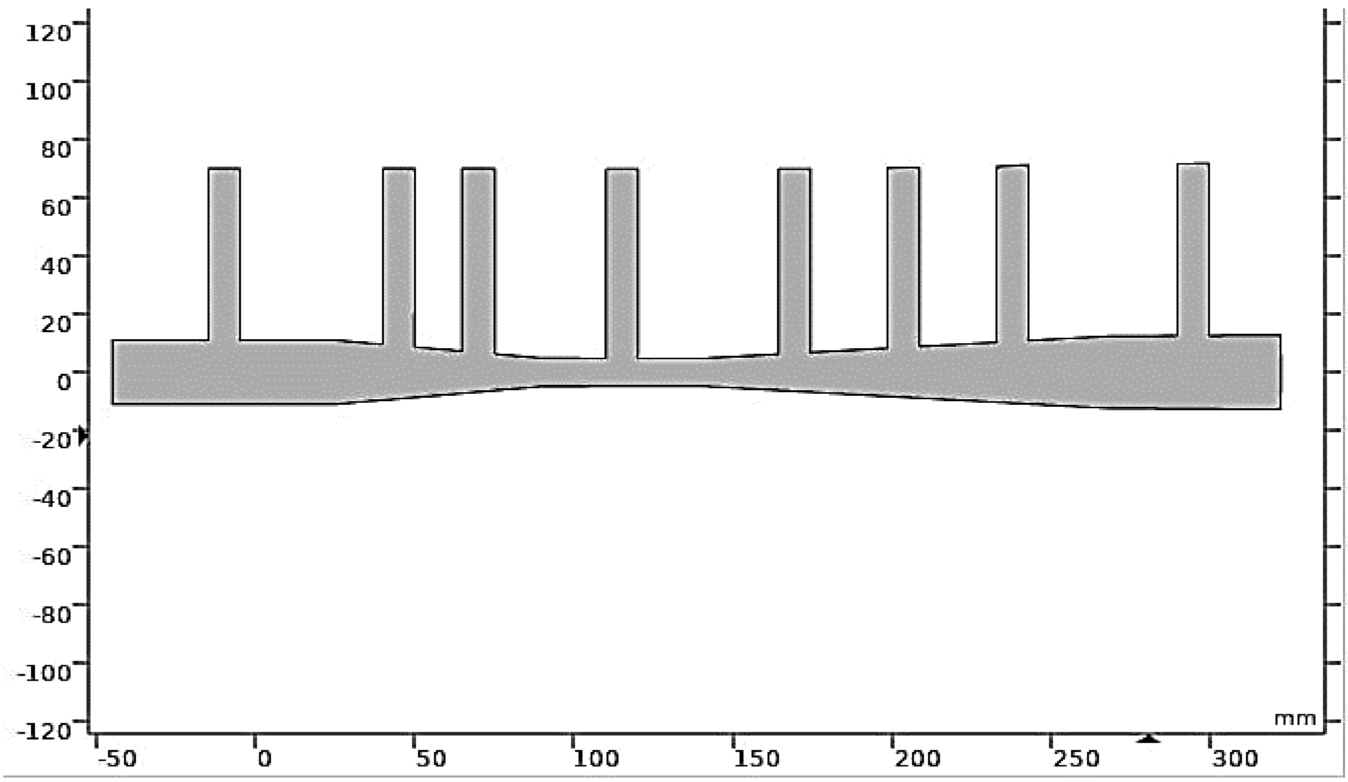


Figure (4-1): the used venturi meter dimensions and piezometers locations.

The venture pipe diameter at peizometers locations were shown in Table (4-1)

Table (4-1): venture pipe diameter at peizometers locations

Piezometer number	1	2	3	4	5	6	7	8
Venturi pipe Diameter(mm)	22	19.4	13.5	10	13.5	18.4	21.4	22

Venturi pipe angles for the practical dimentions :

Convergent cone = 7°

Divergent cone = 4°

4-2-1. Methods of calculation coefficent of discharg

The coefficent of discharg were calculated by the following Methods:

a- From flowmeter reading and actual discharge:

The head and flowrates from the venturimeter that measured are pressented in Table(4-2) :

Table (4-2): piezometers head variation with different flow rates

Trail number	pressure head (mm)								Flowmeter flowrate		Actual flowrate		Cd
	H1	H2	H3	H4	H5	H6	H7	H8	L/m	m³/s	L/m	m³/s	
1	*269*	*267*	*239*	*133*	*184*	*202*	*209*	*210*	6.9	0.000115	6.35	0.000106	0.92
2	355	353	322	192	263	285	294	296	7	0.000117	6.8	0.000113	0.97
3	379	376	345	218	282	303	311	313	7.5	0.000125	7.3	0.00012	0.97
4	416	414	382	241	319	342	350	352	7.8	0.00013	7.7	0.000128	0.987
5	466	464	424	281	379	384	385	387	8	0.00013	7.8	0.00013	0.975

Where :

Cd= Qactual/Qflowmeter ……….(4.1)

And Cd average can be calculated from table(4-2) by the equation:

$C_{davrg} = \Sigma$ Cd / number of trails ……….(4.2)

= (0.92+0.97+0.97+0.987+0.975)/5

Cdavrg=0.9644

b- From theoritical discharge and actual discharge:

D_1=0.022m D_2=0.01m

$A_1 = \pi r_1^2 = \pi(0.011^2)$ =0.00038 m^2 .

$A_2 = \pi r_2^2 = \pi(0.005^2)$=0.00007854 m^2 .

The theoretical flowrwtes, Cd and head deffirients are shown in the table(4-3) :

Table (4-3): theoretical flowrate, Cd and head deffirients .

Trail number	h_1-h_4 (mm)	Q (Actual) m^3/s	Q (theoretical) m^3/s	Cd	H_1-h_5 (mm)
1	136	0.000106	0.000131	0.660126	67
2	163	0.000113	0.000144	0.64571	70
3	161	0.00012	0.000143	0.697481	76
4	175	0.000128	0.000149	0.705658	74
5	185	0.00013	0.000153	0.686321	82

The theoretical flowrate calculated from the equation :

$Q_{theoretical} = \frac{A_1 \times A_2}{\sqrt{(A_1^2 - A_2^2)}} \times \sqrt{(2g\Delta h)}$ …………………(4.3) (16)

Cd=Qtheoretical/Qactual

Cd average can be calculated from table(4-3) by the equation :

Cdavrg =Σ Cd / number of trails

= (0.66+0.64+0.69+0.7+0.68)/5

Cdavrg=0.679

c- From the actual flowrate and the square root of the head difference:

The chart between the actual flowrate and the square root of the head difference is pressented in figure (4-2)(16):

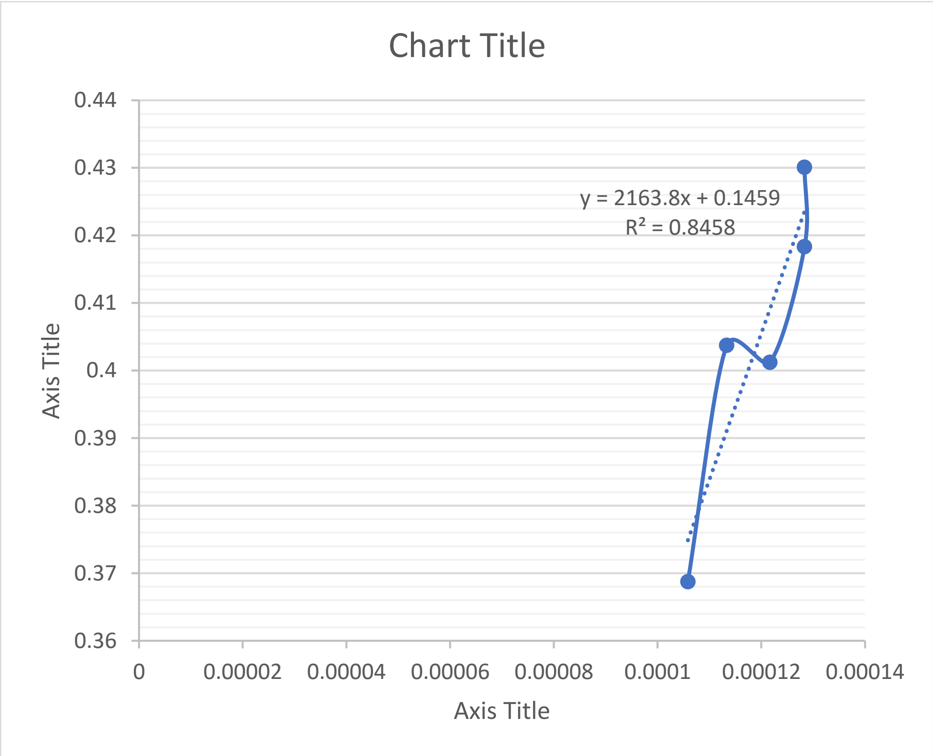


Figure (4-2): relation the actual flowrate and the square root of the head difference .

Slope= $\frac{A_1 \times A_2}{\sqrt{(A_1^2 - A_2^2)}} \times \sqrt{(2g)} \times Cd$ …………..(4.4) [16]

Slope= 0.00041

Cd=slope/$\frac{A_1 \times A_2}{\sqrt{(A_1^2 - A_2^2)}} \times \sqrt{(2g)}$

Cd=0.00041/0.0004347

Cd=0.899

Calculate the theoretical velocities from the theoretical flowrates by the equation :

$V = Q_{theoretical}/A_2$

Table (4-4): flowrates and velocities.

Trail number	$Q_{theoretical}$	**V2**
1	0.000131	1.687071
2	0.000144	1.846961
3	0.000143	1.835595
4	0.000149	1.91374
5	0.000153	1.967659

d- calculate dischage coffiecients from Renold number (15)

To calculat the Renold number from the table :

Renold number = ρvd/μ

Where :

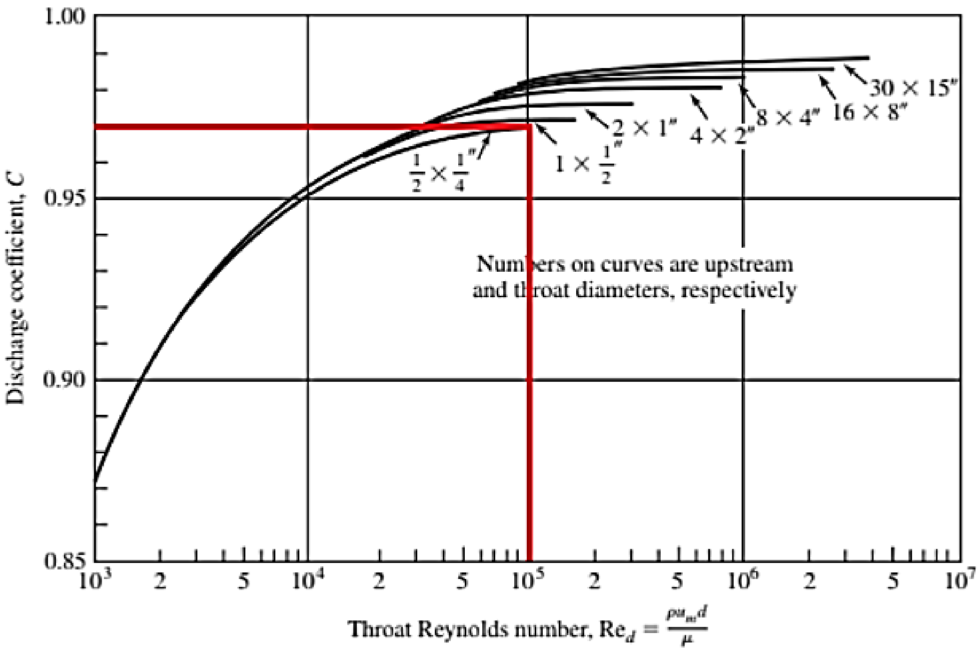
Water vescosity (μ)= 0.00089m^2/s

Renold number were presented in table (4-5)

Table (4-5) : Renold numers and velocities

Trail number	Renold number	Velocity
1	18898.98	1.687071
2	20690.11	1.846961
3	20562.79	1.835595
4	21438.19	1.91374
5	22042.2	1.967659

Cd will be estemated From figure(3-3)



Figure(3-3):The chart between Cd and Renold’s number

Cd were presented in teble (4-6)

Table (4-6) dischage coffiecients from Renold number :

Trail number	Renold number	Cd
1	18898.98	0.96
2	20690.11	0.96
3	20562.79	0.96
4	21438.19	0.961
5	22042.2	0.963

4.3 Results

The resoults shows four values of discharge coefficient they are :

1) From the flowmeter flowrate and the actual flowrate :

Cd=0.9644.

2) From the theoretical flowrate and the actual flowrate:

Cd=0.679

3) From the slope of the chart between the actual flowrate and the square root of the head difference:

Cd=0.899

4) From Renold number : 0.96

Chapter Five / Conclusion

Venturi meter is a scientific and considerable flow meter for measuring the flowrate but compared to the other electronic and high-efficiency flowmeters it can be noted that it has losses in measuring and calculation especially if it is not designed and constructed carefully

5.1 The Conclusions:

the following can be concluded from the results

1-Aventure meter was manufactured at lab by using available materials

2- discharge was measured actualy by flowmeter and calibrated at lab.

3- 5 different discharge were applied and peizometers reading were recorded for each one,

4- theoritical velocities were calculated depending on peizometers readings.

5- the factor Cd was calculated by different methods. it showes different values due to parameters depending on. it was 0.964 as calculated from flowemeter readings and actual discharges . while it was 0.96 from Renold's No. while it was 0.679 when calculated by ratio between actual and theritical values of discharge . then it was 0.899 measured from slope of curve drown between actual discharge and square difference in peizometers head.

6- there would be losses in venture measurements for flow due to losses in energy and small errors in peizometers readings .

7- That is where we stand to improve that field with the needed knowledge in work and needed information and search.

8- There is only one major loss in the fluid flow through the venturi meter which is the friction loss.

9-With the presence of other minor losses, Which are affecting the discharge in the venturi pipe and the outflow of it.

With that mentioned and the losses and errors mentioned and calculated, It is necessary to mention and admit that the venture meter is more suitable for studying purposes to study different and compound subjects and measuring and calibrating the readings and effects in it.

And when working with a scientefic venturi meter itid recommended to :

1- Carefully chose the material and the fluild that flow in the venturi pipe .
2- Carefully contract the venturi meter to eleminate the flow disturbing.

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تم بحمد الله