*Heaven's Light is Our Guide*

# Rajshahi University of Engineering & Technology
# Rajshahi

## DEPARTMENT OF CIVIL ENGINEERING

**Expt. No.** 06

**Name of Expt** Determination of co-efficient of discharge for flow over a sharp crested rectangular weir

| | |
|---|---|
| **SUBJECT :** Fluid Mechanics Sessional | **SUBMITTED BY :** |
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| **DATE OF EXPT.:** 23-11-2020 | **CLASS :** 2nd Year Odd Semester |
| **DATE OF SUB. :** 30-11-2020 | **GROUP :** 02 **ROLL NO** 1800128 |
| | **SESSION :** 2018-19 |

## 6.1 Theory :

A weir is a barrier across the width of a river or steam that alters the characteristics of the flow and usually results in a change in the height of the water level. Severals types of weirs are designed for application in natural channels and laboratory flumes.

There are many types of weirs depending upon their shape, nature of discharge, width of crest and nature of crest.

a. According to the shape :

- Rectangular weir
- Triangular weir
- Trapezoidal weir

b. According to the nature of discharge :

- Ordinary weir
- Submerged or drowned weir

c. According to the nature of crest :

- Narrow crested weir
- Sharp crested weir
- Broad crested weir
- Ogee weir

### Ventilation of Weirs :

It has been observed that whenever water is flowing over a rectangular weir, having no end contractions, the nappe (i.e., the sheet of water flowing over the weir) touches the side walls of the channel. After flowing over the weir, the nappe falls away from the weir, thus creating a space beneath the water as shown in fig.-1. In such a case, some air is trapped beneath the weir.

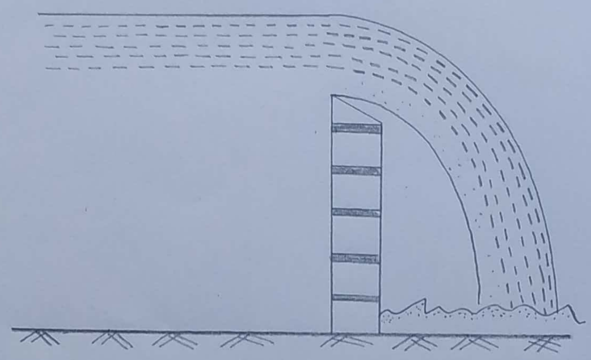


Figure 1 : Ventilation of Rectangular Weirs

This air is carried away by the flowing water, which results in creating a negative pressure beneath the nappe. The negative pressure drags the lower side of the nappe towards the surface of the weir wall. This results in more discharge than the normal discharge. In order to keep the atmospheric pressure in the space below the nappe holes are made through the channel walls which are connected through the pipes to the atmosphere as shown in figure. Such holes are called 'Ventilation of a Weir.'

Let us consider a small horizontal strip of thickness dh under a head h of the sharp crested weir shown in the figure below. Let, H be the working head and B is the width of the weir.

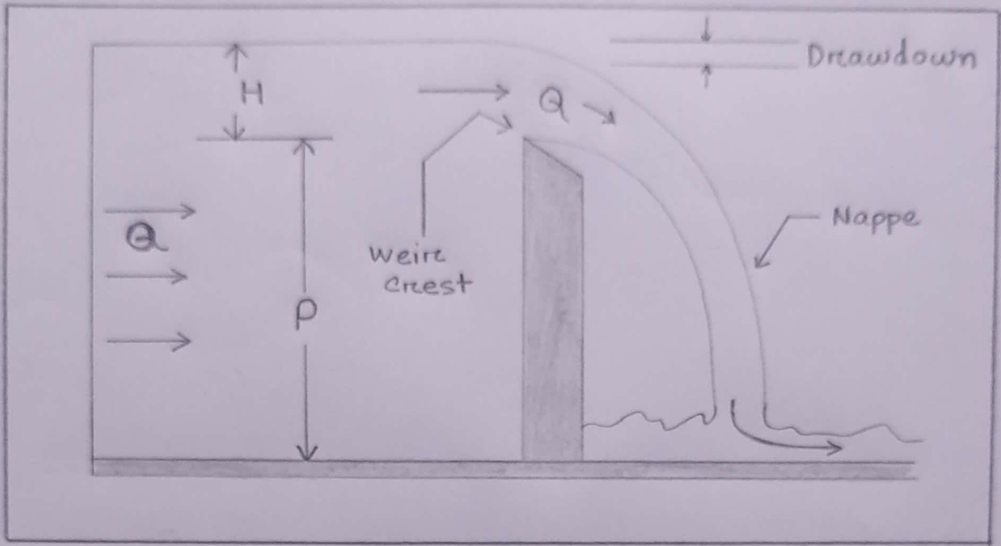



Fig. 6·2 : Flow over a sharp crested weir

Therefore, the theoretical discharge through the strip,

$$dQ = B\,dh \times \sqrt{2gh}$$

The total theoretical discharge over the weir is given by.

$$Q_t = \frac{2}{3}\sqrt{2g}\ BH^{3/2}$$

$$= KH^{3/2}$$

$$\text{where, } K = \frac{2}{3}\sqrt{2g}\ B$$

Let,

$Q_a$ be the actual discharge, then co-efficient of discharge, $C_d$ is given by

$$Q_a = KC_d\,H^{3/2}$$

## 6.2 Application :

Weirs are commonly used to measure or regulate flow in rivers, streams, irrigation canals etc. Installing a weir in an open channel system causes critical depth to form over the weir, a weir can be designed as a flow-measuring device. Weirs are also built to raise the water level in a channel to divert the flow to irrigation systems that are locked at higher elevations.

## 6.3 Objectives :

a) To observe the nappe for ventilated & non-ventilated conditions.

b) To find $C_d$ for both ventilated and non-ventilated conditions.

c) To plot $Q_a$ vs. $H$ in a plain graph paper for ventilated and non-ventilated conditions.

d) To plot $Q_a$ vs. $Q_{th}$ in a plain graph paper for ventilated and non-ventilated conditions.

e) To plot $Q_a$ vs. $H$ in a log-log graph paper and to find the exponent of $H$ and $C_d$.

## 6.4 Apparatus :

a) Rectangular weir
b) Constant steady water supply
c) Approach channel
d) Flow rate measuring facility
e) Point gauge

## 6.5 Procedure :

a) The dimension of the weir was measured and the weir plate was set up with sharp edge on the upstream side at end of the approach channel in a vertical plane.

b) Water was allowed to the channel so that water flows over weir and waited until water surface comes to steady condition and ventilate the nappe with a pipe.

c) After setting elevation as zero with reference to the bottom of the channel, it was checked again whether the nappe was ventilated or not.

d) The gauge reading was taken on the water surface 4 to 6 ft upstream of the weir and the discharge reading from the flow meter was taken.

## 6·6 Observation sheet and sample calculations :

Width of the weir, B = 7.7 cm

$\therefore K = \frac{2}{3}\sqrt{2 \times 981} \times 7.7 = 227.378$

| Group No. | Actual Discharge Qa (cm³/sec) | Ventilated Condition | | | Non-ventilated Condition | | |
|---|---|---|---|---|---|---|---|
| | | H (cm) | $Q_t$ (cm³/sec) | $C_d$ | H (cm) | $Q_t$ (cm³/sec) | $C_d$ |
| 02 | 600 | 3.10 | 1241.05 | 0.48 | 2.65 | 980.88 | 0.61 |

### Ventilated Condition :

Working head, H = 3.10 cm

Theoretical discharge, $Q_t = KH^{3/2}$

$= 227.378 \times (3.10)^{3/2}$

$= 1241.05$ cm³/sec

The co-efficient of discharge, $C_d = \frac{Q_a}{Q_t} = \frac{600}{1241.05} = 0.48$

$\therefore C_d = 0.48$

### Non-ventilated Condition :

Working Head, H = 2.65 cm

Theoretical discharge, $Q_t = KH^{3/2}$

$= 227.378 \times (2.65)^{3/2}$

$= 980.88$ cm³/sec

The co-efficient of discharge, $C_d = \frac{Q_a}{Q_t} = \frac{600}{980.88} = 0.61$

$\therefore C_d = 0.61$

Calculation from Plane graph paper for Ventilated Condition:

Co-efficient of discharge, $C_d = \frac{Q_{a_2} - Q_{a_1}}{Q_{t_2} - Q_{t_1}}$

Here, $Q_{a_1} = 820 \text{ cm}^3/\text{sec}$ $\quad Q_{t_1} = 1650 \text{ cm}^3/\text{sec}$

$Q_{a_2} = 1000 \text{ cm}^3/\text{sec}$ $\quad Q_{t_2} = 2000 \text{ cm}^3/\text{sec}$

$$\therefore C_d = \frac{1000 - 820}{2000 - 1650} = 0.51$$

$$\therefore \boxed{C_d = 0.51}$$

Calculation from log-log graph paper for Ventilated Condition:

$$\log Q_a = \log K + n \log H$$

Now, $\log Q_{a_1} = \log K + n \log H_1 \quad \ldots \ldots \ldots (i)$

$\log Q_{a_2} = \log K + n \log H_2 \quad \ldots \ldots \ldots (ii)$

From (i) and (ii), we get,

$$\log Q_{a_2} - \log Q_{a_1} = n(\log H_2 - \log H_1)$$

$$\Rightarrow \log \frac{Q_{a_2}}{Q_{a_1}} = n \log \frac{H_2}{H_1}$$

$$\Rightarrow n = \frac{\log \frac{Q_{a_2}}{Q_{a_1}}}{\log \frac{H_2}{H_1}}$$

Here, $Q_{a_1} = 1700 \text{ cm}^3/\text{sec}$ $\quad H_1 = 6 \text{ cm}$

$Q_{a_2} = 3600 \text{ cm}^3/\text{sec}$ $\quad H_2 = 10 \text{ cm}$

$$\therefore n = \frac{\log \frac{3600}{1700}}{\log \frac{10}{6}} = 1.5 \qquad \boxed{n = 1.5}$$

Calculation from Plane graph paper for Non-Ventilated Condition :

$$\text{Co-efficient of discharge}, C_d = \frac{Q_{a_2} - Q_{a_1}}{Q_{t_2} - Q_{t_1}}$$

Here, $Q_{a_1} = 880 \text{ cm}^3/\text{sec}$ $\quad Q_{t_1} = 1440 \text{ cm}^3/\text{sec}$

$Q_{a_2} = 1080 \text{ cm}^3/\text{sec}$ $\quad Q_{t_2} = 1760 \text{ cm}^3/\text{sec}$

$$\therefore C_d = \frac{1080 - 880}{1760 - 1440} = 0.62$$

$$\therefore \boxed{C_d = 0.62}$$

Calculation from log-log graph paper for Non-ventilated Condition :

We know,

$$n = \frac{\log Q_{a_2} - \log Q_{a_1}}{\log H_2 - \log H_1}$$

$$\Rightarrow n = \frac{\log \frac{Q_{a_2}}{Q_{a_1}}}{\log \frac{H_2}{H_1}}$$

Here,

$Q_{a_1} = 400 \text{ cm}^3/\text{sec}$ $\quad H_2 = 7 \text{ cm}$

$Q_{a_2} = 2600 \text{ cm}^3/\text{sec}$ $\quad H_1 = 2 \text{ cm}$

$$\Rightarrow n = \frac{\log \frac{2600}{400}}{\log \frac{7}{2}}$$

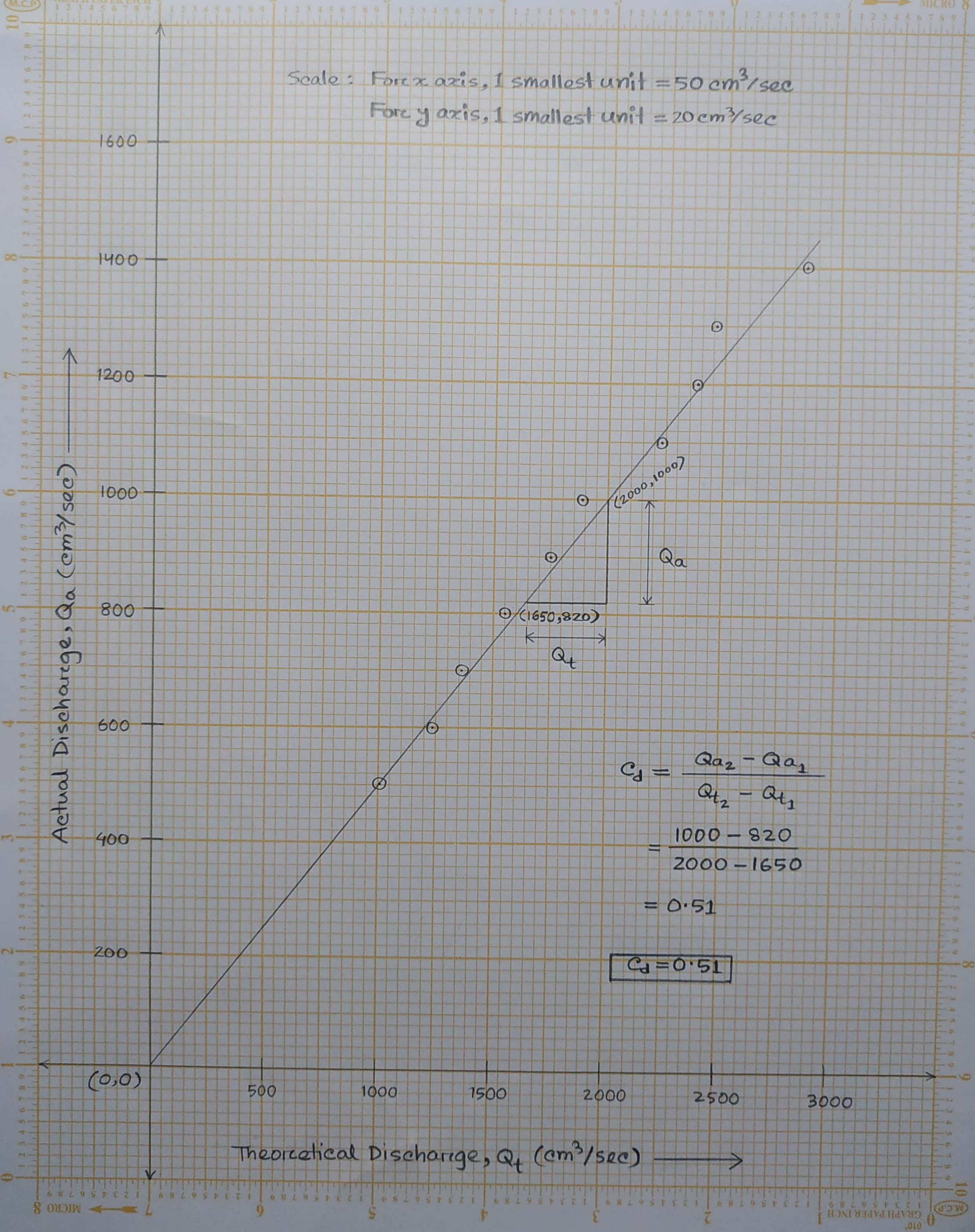
$$\Rightarrow n = 1.5$$

$$\therefore \boxed{n = 1.5}$$

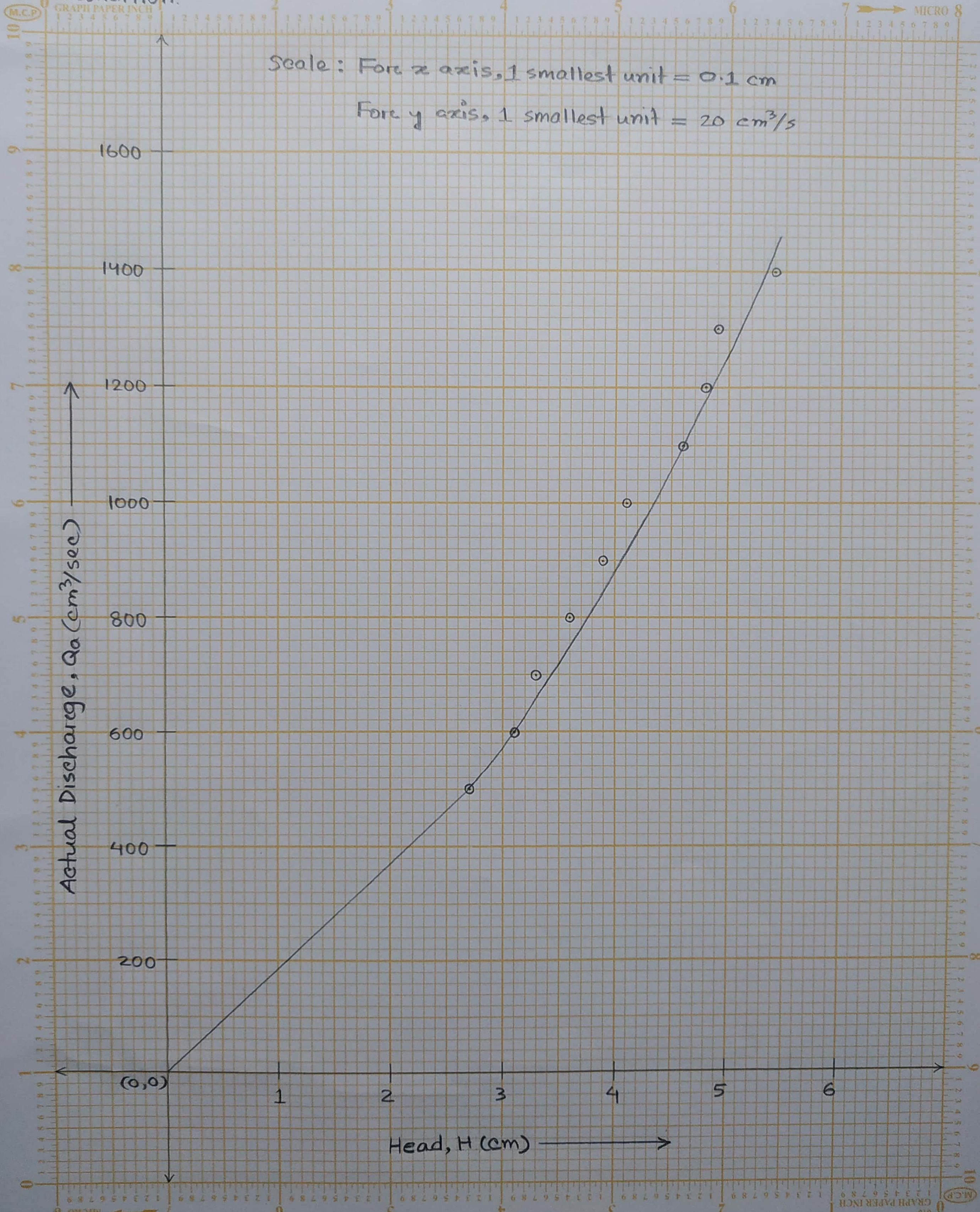
## 6.7 Data Table :

| Obs. No. | Actual Discharge Qa ($cm^3$/sec) | Ventilated Condition H (cm) | Ventilated Condition $Q_t$ ($cm^3$/sec) | Ventilated Condition $C_d$ | Non-ventilated Condition H (cm) | Non-ventilated Condition $Q_t$ ($cm^3$/sec) | Non-ventilated Condition $C_d$ |
|---|---|---|---|---|---|---|---|
| 1 | 500 | 2.70 | 1008.78 | 0.50 | 2.35 | 819.13 | 0.61 |
| 2 | 600 | 3.10 | 1241.05 | 0.48 | 2.65 | 980.88 | 0.61 |
| 3 | 700 | 3.30 | 1363.07 | 0.51 | 2.90 | 1122.91 | 0.62 |
| 4 | 800 | 3.60 | 1553.11 | 0.52 | 3.10 | 1241.06 | 0.64 |
| 5 | 900 | 3.90 | 1751.24 | 0.51 | 3.40 | 1425.50 | 0.63 |
| 6 | 1000 | 4.10 | 1887.66 | 0.53 | 3.70 | 1618.27 | 0.62 |
| 7 | 1100 | 4.60 | 2243.29 | 0.49 | 3.90 | 1751.24 | 0.63 |
| 8 | 1200 | 4.80 | 2391.17 | 0.50 | 4.20 | 1957.14 | 0.61 |
| 9 | 1300 | 4.90 | 2466.28 | 0.53 | 4.40 | 2098.59 | 0.62 |
| 10 | 1400 | 5.40 | 2853.25 | 0.49 | 4.70 | 2316.84 | 0.60 |
| Average $C_d$ = | | | | 0.51 | | | 0.62 |

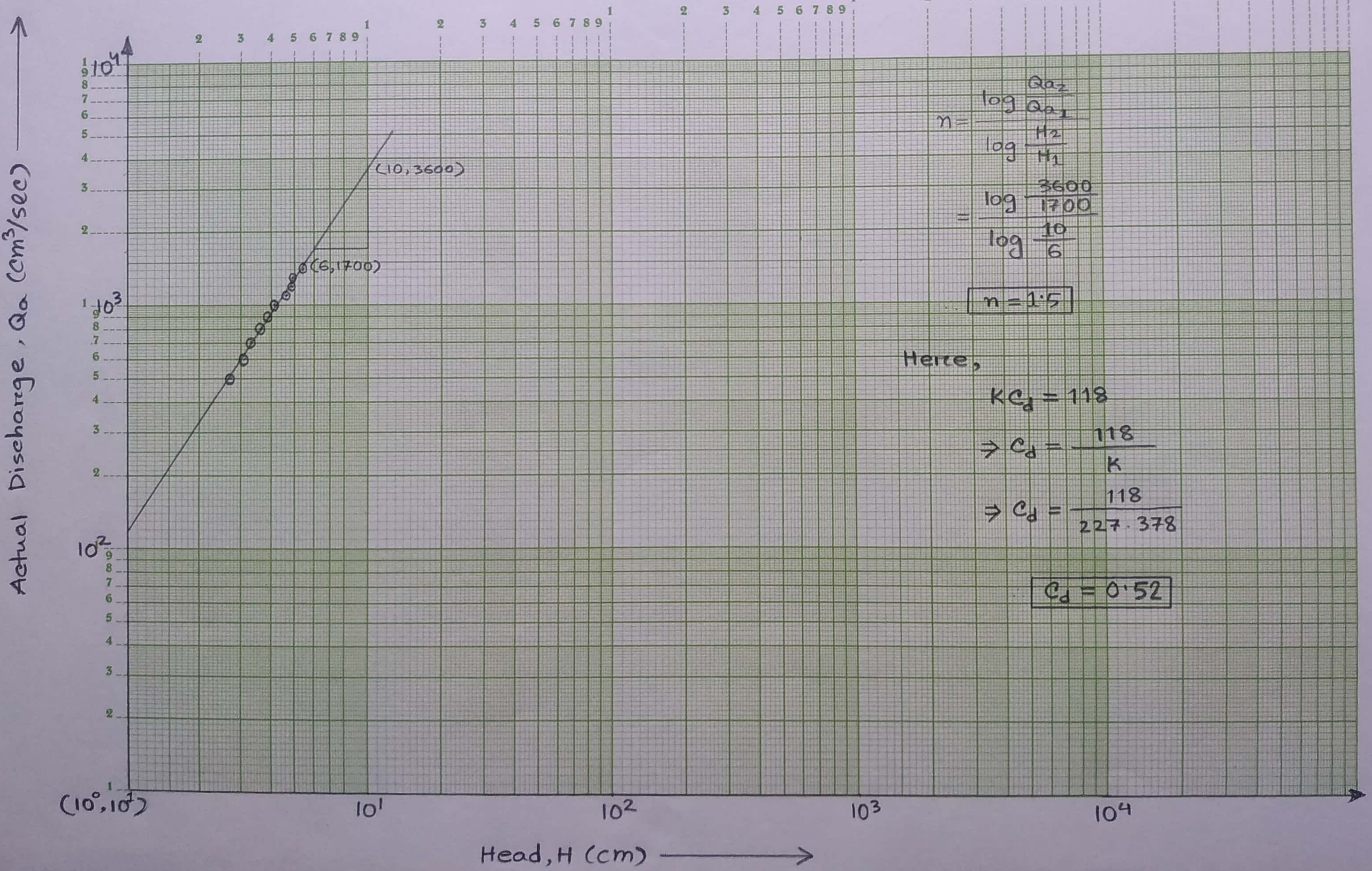
"Variation of actual discharge ($Q_a$) with respect to theoretical discharge ($Q_t$) for Vantilated Condition".



Variation of Actual Discharge, Qa with respect to Head, H for "Ventilated Condition."



# Variation of Actual discharge (Qa) with respect to Head (H) for "Ventilated Condition"




$$n = \frac{\log \frac{Qa_2}{Qa_1}}{\log \frac{H_2}{H_1}}$$

$$= \frac{\log \frac{3600}{1700}}{\log \frac{10}{6}}$$

$$\boxed{n = 1.5}$$

Here,

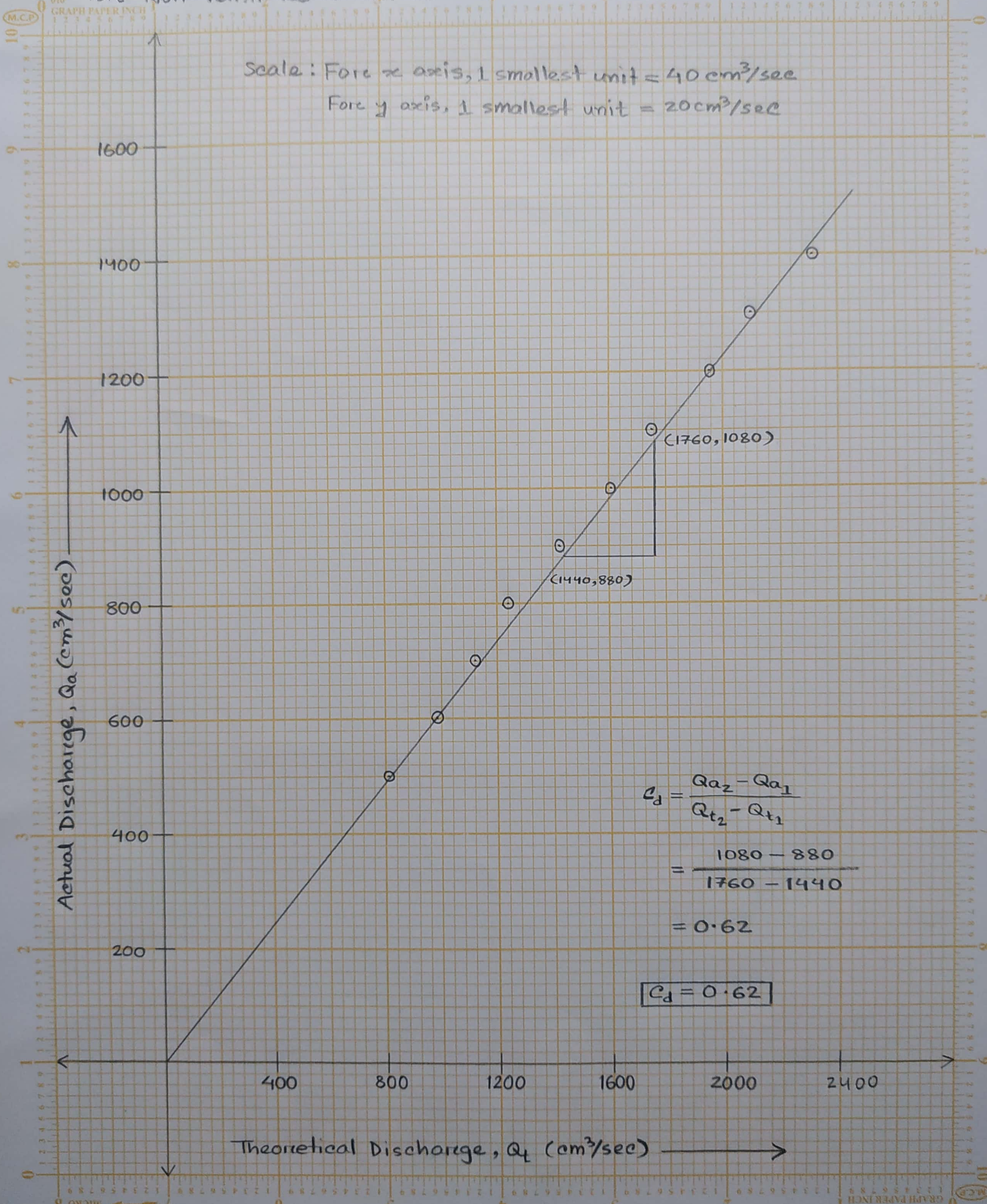
$$KC_d = 118$$

$$\Rightarrow C_d = \frac{118}{K}$$

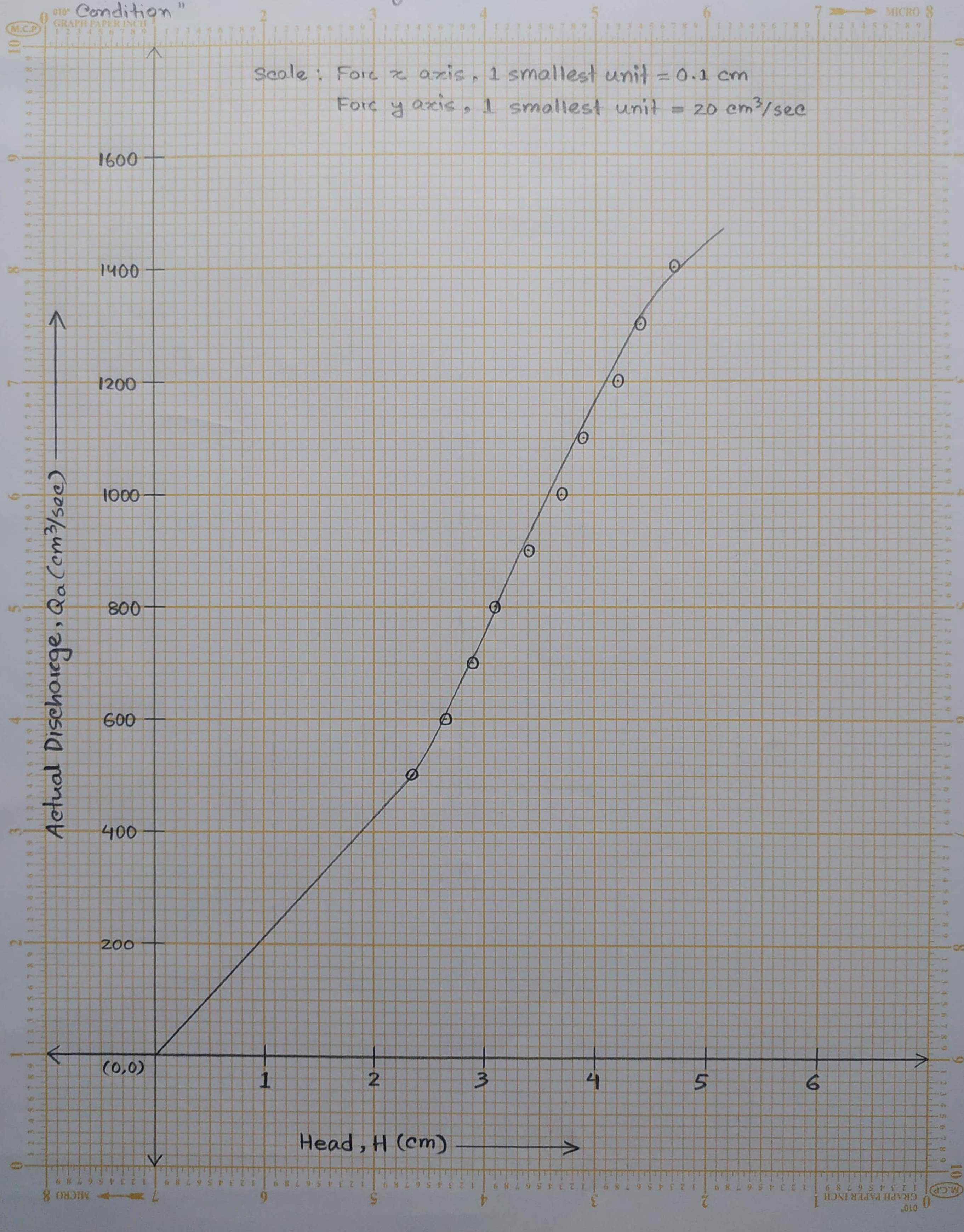
$$\Rightarrow C_d = \frac{118}{227.378}$$

$$\boxed{C_d = 0.52}$$

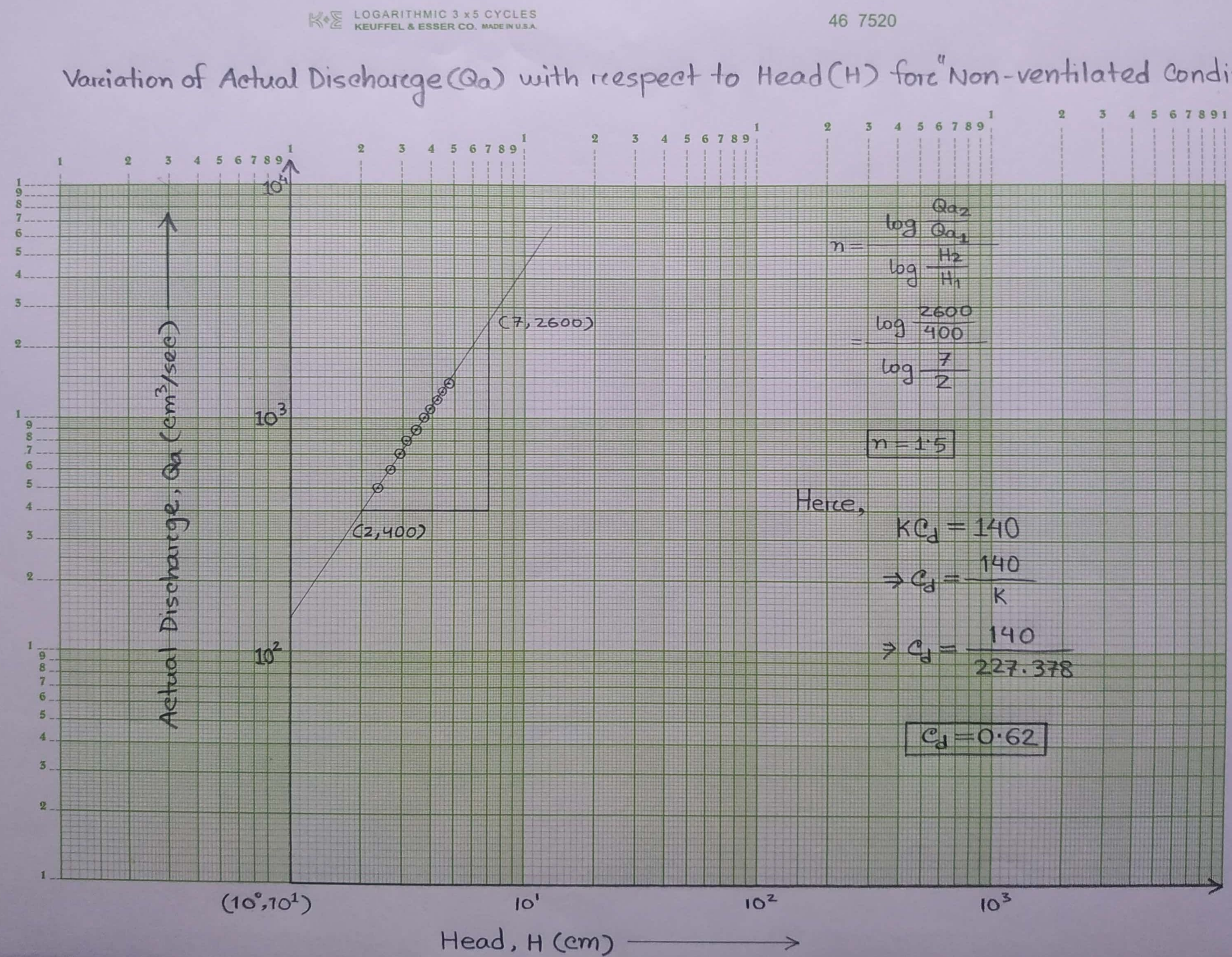
Variation of Actual Discharge, $Q_a$ with respect to $Q_t$ (Theoretical Discharge)
For "Non-Ventilated conditions"



Variation of Actual Discharge, $Q_a$ with respect to Head, H for "Non-ventilated Condition"



Variation of Actual Discharge (Qa) with respect to Head (H) for "Non-ventilated Condition"




$$n = \frac{\log \frac{Qa_2}{Qa_1}}{\log \frac{H_2}{H_1}}$$

$$= \frac{\log \frac{2600}{400}}{\log \frac{7}{2}}$$

$$\boxed{n = 1.5}$$

Here,

$$KC_d = 140$$

$$\Rightarrow C_d = \frac{140}{K}$$

$$\Rightarrow C_d = \frac{140}{227.378}$$

$$\boxed{C_d = 0.62}$$

## 6.7 Results :

For Ventilated Condition :-

The average value of $C_d$ = 0.51

The value of $C_d$ from plane graph paper = 0.51

The value of $C_d$ from log-log graph paper = 0.52

Exponent of H from log-log graph paper = 1.5

For Non-ventilated Condition :-

The average value of $C_d$ = 0.62

The value of $C_d$ from plane graph paper = 0.62

The value of $C_d$ from log-log graph paper = 0.62

Exponent of H from log-log graph paper = 1.5

## Discussions :

In this experiment, we have found that the $C_d$ = 0.62 and the exponent of H, n = 1.5 for non-ventilated condition where the standard value of these are 0.65 and 1.50 respectively.

For ventilated condition, we have found the $C_d$ = 0.51, which is less than non-ventilated one as expected.

Some errors have been occurred though precautions were taken. ~~The errors was~~ There was shakings and vibration and the apparatus was kind of old. That's why, there may have mechanical errors and flow wasn't fully uniform.

# Assignments

i) What is the difference between Notch and Weir ?

Answer :

Notch is basically defined as a device which is used for determining the flow of liquid through a small channel or a tank.

Notches might be defined as the opening provided in one side of tank or reservoir or a small channel in such a way that the liquid surface in the tank or channel is below the top edge of opening.

Bottom edge of notch over which liquid flows will be termed as still or crest. The material of casting of notch will be usually a metallic pipe.

Notches will be small in size and will be preferred to use for measuring the small discharge or small stream or canal.

A weir is basically a concrete or masonry structure which will be located in an open channel over which flow will take place.

We can also define as the structure constructed across the river or large canal for storing water on upstream side.

Top of weir over which water flow will take place will be termed as crest.

Weir will be used for measuring the large discharge of rivers or large canals.

Weir will be usually in the form of vertical wall, with a sharp edge at the top, running all the way across the open channel.

Weir will be bigger in size and basically made by a concrete or masonry structure.

ii) Discuss the effects of ventilation on the flow over the weir.

Answer:

Whenever water flows over a rectangular weir, having no end contractions, the nappe (i.e., the sheet of water flowing over the weir) touches the side walls of the channel. After flowing over the weir, the nappe falls away from the weir, thus creating a space beneath the water. ~~as~~ In such a case, some air is trapped beneath the weir.

The air is carried away by the flowing water, which results in creating a negative pressure beneath the nappe. The negative pressure drags the lower side of the nappe towards the surface of the weir wall. This results in more discharge than the normal discharge. In order to keep the atmospheric pressure in the space below the nappe holes are made through the channel walls which are connected through the pipes to the atmosphere. ~~as~~ Such holes are called 'Ventilation of a weir'.