EFFECT OF EXTERNALLY IMPOSED ROTATION
ON
DISCHARGE CHARACTERISTICS
OF
BROAD-CRESTED WEIRS

A DISSERTATION
submitted in partial fulfilment of
the requirements for the award of the degree
of
MASTER OF ENGINEERING
in
WATER RESOURCES DEVELOPMENT

UNIVERSITY OF ROORKEE CENTRAL LIBRARY ROORKEE
108841
Date 9-9-76
C 8 L

By
S. MURALI KRISHNA

WATER RESOURCES DEVELOPMENT TRAINING CENTRE
UNIVERSITY OF ROORKEE
ROORKEE (INDIA)
July, 1976

CERTIFICATE

CERTIFIED that the dissertation entitled, 'EFFECT OF EXTERNALLY IMPOSED ROTATION ON DISCHARGE CHARACTERISTICS OF BROAD-CRESTED WEIRS' which is being submitted by Shri S. MURALI KRISHNA;B.E., in partial fulfilment of the requirements for the award of DEGREE OF MASTER OF ENGINEERING IN WATER RESOURCES DEVELOPMENT OF THE UNIVERSITY OF ROORKEE is a record of the students own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other Degree or Diploma.

This is further to certify that he has worked for a period of 9 months from 1st October 1975 to 1st July 1976 for preparing this dissertation for the MASTER OF ENGINEERING DEGREE at this University.

RangaRaju

ROORKEE

Dated July 1st, 1976

(K.C. RANGA RAJU)
Professor in Civil Engineering
University of Roorkee
Roorkee.

ACKNOWLEDGEMENT

The author wishes to express his deep sincere and in expressible gratitude to his guide Dr. K.G.Ranga Raju, Professor in Civil Engineering, University of Roorkee for his expert guidance, invaluable suggestions, constant encouragement and keen interest throughout the preparation of this dissertation.

The author is also thankful to the staff of Hydraulics Laboratory, University of Roorkee, particularly Sri B.R. Sethi for their assistance and cooperation extended during experimentation.

S. MURALI KRISHNA

TABLE OF CONTENTS

- o -

ABSTRACT

This dissertation is an exploratory study of the effect of an externally imposed rotation on the discharge characteristics of broad-crested weirs. The study was taken up with the intention of verifying the premie that supply of additional momentum near the crest of a weir should result in a higher discharge coefficient, thus enabling design of weirs with a lower afflux. A semi-theoretical study has been made for free overfall suppressed weirs having vertical faces with a rotating cylinder at top corner.

A theoretical relation was first obtained for discharge over broad-crested weir with rotating cylinder by assuming suitable velocity distribution law for the imposed rotational flow. However, this equation showed systemetic departure from experimental observations. As such an approach based on dimensional analysis was adopted to obtain a discharge relationship for such weirs. The results show that there is substantial increase in discharge by as much as 30 per cent due to rotation at high speeds and low heads.

LIST OF SYMBOLS

All the symbols are explained in the text where they appear first. The following list is arranged in the alphabatical order

NOTATION	PARTICULARS	DIMENSIONS
B	Width of the weir, flume	L
C	Coefficient of Discharge used in equation $Q = K_1K_2CB\sqrt{g}\ h^{3/2}$	
C_1	Coefficient of Discharge used in equation $Q = 6_1B\sqrt{g}\ h^{3/2}$.	
g	Acceleration due to gravity	L/T^2
h	head over the broad-crested weir	L
K	Coefficient in discharge equation(4.1)	
K_1	Correction for viscosity and surface tension used in Eq.(4.2)	
K_2	Correction for curvature of flow over weir used in Eq.(4.2)	
L	Length of weir(in the direction of flow)	L
N	Speed of rotation in Revolutions per minute.	1/T
n	exponent used in Eq.(4.1)	
Q	Discharge over weir	L^3/T
q^*	Discharge per unit width of weir with rotation	L^2/T
q_o	Discharge per unit windth of weir with no-rotation	L^2/T

NOTATION	PARTICULARS	DIMENSIONS
R	Reynold's number $(g^{1/2}h^{3/2}/\nu)$	
r	radius of cylindrical roller	L
U_o	velocity of approach	L/T
u_r	velocity due to rotation	L/T
W_1	height of weir	L
W_1	Weber number $(\rho g h^2/\sigma)$	
x	Distance from down-stream end of weir	L
y	vertical distance of any point from the centre of the roller.	L
ω	Angular velocity	1/T
ν	Kinematic viscosity of fluid	L^2/T
σ	Surface tension of fluid	M/T^2
ρ	Man density of fluid	M/L^3

— o —

LIST OF FIGURES

- o -

CHAPTER I

INTRODUCTION

1.1 PRELIMINARY REMARKS:

Weirs or Barrages are constructed across rivers, so as to raise normal water level and divert the required amount of water into canal. Invariably in all head works broad-crested weirs are being used.

As a result of putting obstruction across a river in the form of weir, the maximum flood level of the river upstream of weir rises. This rise in level is known as afflux. The length of water way, corresponding discharge per metre and afflux are inter-related. By providing higher afflux, the length of weir can be reduced, but the total height of structure and submergence of land upstream will also increase considerably. Hence the cost of weir and training works is likely to increase due to increased head of water. Hence afflux plays an important role and the parameters are generally finalised after consideration of many practical aspects such as effect of back water on existing structures, cost of structure, submergence of land etc.

1.2 DISCHARGE EQUATION OF BROAD-CRESTED WEIRS:

Consider a broad-crested weir with vertical sides and horizontal crest of height W, width B and length L, in a rectangular channel of width B. Assuming critical flow to occur on the crest, the discharge Q over a broad-crested weir is expressed in the form

$$Q = C_1 B \sqrt{g}\ h^{3/2} \quad \ldots \quad (1.1)$$

where C_1 = Coefficient of discharge,

h = head over the weir

and g = gravitational acceleration

From the above equation, it is apperent that with increase in value of C_1, the head over the weir 'h' will decrease and thus there will be a considerable reduction in the upstream submergence.

The reduction in C_1 from the theoretical value may be attributed to the deceleration of the flow near the wall due to boundary friction(4) as well as seperation of the flow at the upstream corner. The seperation of the flow is avoided by rounding off the corner and this is known(1) to improve the discharge coefficient appreciably. It stands to reason that if additional momentum is supplied to the fluid near the wall, the value of C_1 should approach or even exceed the theoretical value. This would obviously lead to lowering of water level in the pool.

1.3 EFFECT OF EXTERNALLY IMPOSED ROTATION

If a cylindrical roller is placed in the upstream corner of the weir for the entire width of the weir as shown in Fig.(1.1) and is rotated mechanically, it would accelerate the flow near the crest. Hence it is expected that it will increase the value of the coefficient C_1. Of course it will require sufficient power for rotating the cylinder and one has to examine the cost of power vis-a-vis the advantages in an improved weir coefficient. It may, however, be pointed out that the operation of cylinder may be required only during monsoon, when hydro-electric power generation is substantial and the demand of power for irrigation is small. Hence theoretically the surplus power can be made use of for operating the cylindrical roller. It only needs to be examined whether the imposed rotation results in a considerable increase in the weir coefficient to make the device feasible.

1.4 SCOPE OF STUDY

No information is available at present regarding the effect of externally imposed rotation on the discharge coefficient of a broad-crested weir. As such an attempt has been made in this investigation to provide information concerning the effect of placing a rotating cylinder at the upstream corner of the crest, on its performance. The study is basically of an exploratory nature, the main objective being to find out the order of magnitude of the increase in coefficient and its relation to the speed. A theoretical analysis of the problem was carried out and the results subjected to check using experimental data. The following limitations were imposed on the study.

(a) Only the cylinders with r = 1.88cm and 3.00cm were used.

(b) Range of speeds tested were from 1000 to 4000RPM.

(c) Experiments were done for one height of the weir i.e. 31.0cms.

(d) Experiments were conducted for range of h/L from 0.1565 to 1.0175.

CHAPTER-II

THEORETICAL ANALYSIS

2.1 BASIS OF ANALYSIS OF FLOW WITH ROTATION

The velocity field over the weir may be conceived as a combination of velocity of approach and velocity due to roller rotation. Velocity of approach is assumed to be constant and the velocity due to rotation to be decreasing gradually from the crest towards the water surface (see Fig. 2.1). The velocity of approach above the crest level of the weir may, in reality, be expected to be larger than U_o defined as $Q/B(h+W)$. Nevertheless U_o is used in this analysis since ultimately an experimentally determined coefficient is, in any case, to be introduced.

It is further assumed that the velocity distribution due to rotation is inversely proportional to y^n, where y is the distance from the centre of the roller and n is an exponent with a value less than or equal to 1.0. Assuming no slip at the surface of the cylinder, one may write

$$u_r = \omega r \quad \text{at } y = r$$

and $$u_r = 0 \quad \text{at } y = \infty$$

where u_r = velocity due to rotation.

The equation

$$u = \omega r(r/y)^n \qquad \ldots \qquad (2.1)$$

satisfies these boundry conditions.

As will be shown subsequently, experimental data indicated a value of $n = 0.2$. Nevertheless the theoretical analysis has been carried out for $n = 0.2$ and $n = 1.0$, since the latter represents the velocity distribution in irrotational flow.

2.2 DERIVATION OF DISCHARGE EQUATION

The discharge equation will be different with the different velocity distributions assumed. So the discharge equations are discussed below separately for each velocity distribution.

2.2.1 With Velocity Distribution $u_r = \omega r(r/y)$

If q^* is the discharge per unit width of the weir, then

$$q^* = \int_r^{h+r} (U_o + u_r)\, dy \qquad \dots \qquad (2.2)$$

where $U_o = \frac{q^*}{h+W}$ and $u_r = \omega r(r/y)$

Here the draw down which occurs over the weir crest has been neglected and its effect can be taken care of by an empirical coefficient later.

$$\therefore \quad q^* = \int_r^{h+r} U_o dy + \int_r^{h+r} \omega r . \frac{r}{y} . dy$$

$$= \left[\frac{q^*}{h+W} . y + \omega r^2 \log_e y \right]_r^{h+r}$$

$$= \frac{q^*}{h+W}.h + \omega\, r^2 \left[\log_e(h+r) - \log_e r\right]$$

or $$q^* - \frac{q^*h}{h+W} = \omega\, r^2 \log_e\left(\frac{h+r}{r}\right)$$

$$q^* = \left(\frac{h+W}{W}\right)\omega\, r^2 \log_e\left(\frac{h+r}{r}\right)$$

In dimensionless form this can be written as

$$\frac{q^*}{\sqrt{gh^3}} = \left(1+\frac{h}{W}\right).\ \frac{2\pi}{60}\ \frac{Nr^{1/2}}{\sqrt{g}}\ \left(\frac{r}{h}\right)^{3/2} .\log_e\left(1+\frac{h}{r}\right) \quad \ldots\ (2.3)$$

2.2.2 With Velocity Distribution $u_r = \omega r(r/y)^n$

Discharge intensity $q^* = \int_r^{h+r} (U_o + u_y)\, dy$

$$= \int_r^{h+r} U_o dy + \int_r^{h+r} \omega\, r\left(\frac{r}{y}\right)^n dy$$

$$= \int_r^{h+r} U_o .dy + \int_r^{h+r} \omega\ .\ \frac{r^{n+1}}{y^n}\ .\ dy$$

$$= \frac{q^*}{h+W}.h + \omega r^{n+1}\left[\frac{y^{1+n}}{1+n}\right]_r^{h+r} = \frac{q^*h}{h+W} + \frac{\omega\, r^{n+1}}{1-n}\left[(h+r)^{1-n} - r^{1-n}\right]$$

$$= \frac{q^*h}{h+W} + \frac{2\pi N}{60(1-n)}.r^{n+1}\left[(h+r)^{1-n} - r^{1-n}\right]$$

or $$\frac{q^* - q^*h}{(h+W)} = \frac{2\pi N}{60}\, r^{1/2}.\ r^{n+1}\left[(h+r)^{1-n} - r^{1-n}\right]$$

In dimensionless form this can be written as

$$\frac{q^*}{\sqrt{gh^3}} = (1+\frac{h}{W})\,\frac{2\pi}{60}\,\frac{Nr^{1/2}}{\sqrt{g}}\,(\frac{r}{h})^{3/2}\left[(\frac{h+r}{r})^{1-n} - 1.0\right] \quad \ldots\ (2.4)$$

Putting n = 0.2, the experimentally obtained value, the above equation reduces to

$$\frac{q^*}{\sqrt{gh^3}} = (1+\frac{h}{W})\,\frac{2\pi}{60}\,\frac{Nr^{1/2}}{\sqrt{g}}\,(\frac{r}{h})^{3/2}\left[(\frac{h+r}{r})^{0.8} - 1.0\right] \quad \ldots\ (2.5)$$

Based on equations (2.3) and (2.5) a plot has been made of $\frac{q^*}{\sqrt{gh^3}(1+\frac{h}{W})}$ (vs) h/r for different values of $\frac{Nr^{1/2}}{\sqrt{g}}$; vide Fig.(2.2). From this plot it is seen that the imposed velocity distribution has a strong influence on the discharge equation. However, the lines corresponding to n = 0.2 may be expected to be closer to the real situation, since this n value is based on experimental data. It may also be mentioned that Eqs(2.3) and (2.4) have the limitation that they do not reduce to the conventional weir equation when N = 0; as such they are not suited for use in the limiting case.

In view of various assumptions made in the derivation of equation (2.4), one may expect that the actual discharge will be different from the theoretical discharge given by Eq.(2.4). As such the actual discharge may be written as K times the theoretical discharge, the K value being determinable from experimental data.

CHAPTER III

EXPERIMENTAL SET-UP AND PROCEDURE

3.1 PRELIMINARY REMARKS

All the experiments were conducted in the Hydraulic laboratory of Civil Engineering Department, University of Roorkee. The experiments were carried out for two sizes of rollers with three different sizes of weirs. In all the cases, the width of the weir was kept same as that of the width of channel, i.e. only suppressed weirs were tested. The height of the weir (W) was kept constant and equal to 31 cm in all the experiments.

3.2 TEST EQUIPMENT

The experiments were conducted in a fixed bed flume constructed in brick masonry and plastered with cement Mortar. Fig(3.1) shows the schematic diagram of the experimental setup.

The flume was 1.0 metre wide, 25.4m long and 0.5m deep. The width of the flume was reduced to 0.415m in order to get high heads and high discharge intensity and to enable the fixing of cylinder easily in the masonry wall. Steel rails were provided on the top of side walls of flume, to enable the movement of trolley, on which the pointer gauge was mounted. The rails were levelled to be absolutely horizontal.

Water was supplied to the flume from an overhead tank and under constant head. The over head tank was fed by a 45 H.P. pump, from a water sump. The discharge in the flume was regulated with the help of a valve. For measurement of discharge a sharp-crested weir set in the channel downstream of the broad-crested weir was made use of.

The test weir was constructed of brick masonry and finished with cement plaster to the required profile. Since weirs with vertical faces only were tested, ventilation holes were provided in all the weirs to aerate the nappe. The cylinder of the required dia was provided to the full width of flume at the upstream top corner of the weir, such that the roller was flush with weir faces both vertically and horizontally. The two ends of the cylinder were housed in bearings, which were well lubricated and the bearings were fixed properly in the brick-masonry walls. At one end of the roller a pulley was mounted and driven by motor. The motor was provided with variable resister to enable speed adjustments. The photographs of various equipment used are exhibited separately in this report (vide Fig 3.2).

The details of the weirs tested in this study are listed in Table 3.1.

TABLE 3.1

DETAILS OF WEIRS TESTED

S.No.	Width in cm. (B)	Height in cm. (W)	Length in cm. (L)	Radius of Roller in cm. (r)	Remarks
1	41.5	31.0	16.0	1.88	For each discharge
2	41.5	31.0	31.0	1.88	four speeds of
3	41.5	31.0	45.0	1.88	roller eg,1000,
4	41.5	31.0	31.0	3.00	2000,3000,4000RPM
5	41.5	31.0	45.0	3.00	were used.

3.3 CALIBRATION OF SHARP-CRESTED WEIR.

The sharp-crested weir located downstream of the test set-up, was first calibrated for the entire range of discharges to be used in the study. This was done by volumetric measurements by letting known quantity of water over the sharp-crested weir for a known period of time and measuring the corresponding head over S.C. weir. For this an over head tank of size 9.92m x 4.78m was made use of. The calibration curve of the sharp-crested weir was plotted and is shown as Fig.(3.3).

3.4 EXPERIMENTAL PROCEDURE

A weir of the required geometry was constructed in the flume. Water was allowed to flow over the weir. The head over the weir with no rotation was varied from 6.48cm to 17.62 cm. The discharge over the weir under each head was measured with the help of the sharp-crested weir. Keeping the discharge over the weir constant, measurements were taken for no roller rotation as well as with four different roller rotations of 1000, 2000, 3000 and 4000R.P.M.

For each weir, the above procedure was repeated for six discharges. Following measurements were taken during the present investigation.

(a) Head over the weir

(b) Water surface profiles on the crest and upstream of weir (For three weirs)

(c) Velocity distribution at a few cross-sections on the crest (For three weirs).

For measurement of head and water surface profiles over the weir, precision pointer gauge was used. For measurement of velocity distribution pitot tube with inclined manometer was used. The measurements were taken at suitable close intervals.

The data collected during the study are tabulated in Appendix I.

CHAPTER IV

ANALYSIS OF DATA

4.1 PRELIMINARY REMARKS

The data collected during the present investigation are analysed in this Chapter. A comparison of the experimental results with the theory presented in chapter III is first discussed. This is followed by the development of a discharge equation based on dimensional considerations.

4.2 TYPICAL WATER SURFACE PROFILES

During the present investigation water surface profiles were measured for different discharges over three sizes of weirs having a roller of radius 1.88cm. Typical water surface profiles for the three weirs are shown in Figs 4.1A to 4.1C. From the above plots, it can be seen that the water surface is generally lower at high speeds and the head over the weir decreases with increase in speed of the roller for the same discharge.

4.3 TYPICAL VELOCITY DISTRIBUTION PROFILES

In case of the three weirs having a roller of radius 1.88cm, the velocity over the crest of the weir was measured for no rotation as well as for the roller rotating at speeds of 2000 and 4000RPM. Typical velocity profiles at the centre of length of crest (r = 8.0cm) were plotted vide Fig(4.2). From the above graph it can be seen that the velocity near weir crest increases with increase of speed of roller, increasing the over all velocity as compared to that without any roller rotation. Note that such a velocity distribution had been assumed in Chapter III.

Further in the theoretical analysis, two different velocity distributions are assumed. To determine the value of 'n' in equation (2.4), a plot of $(u- U_o)/\omega r$ against r/y on log-log paper has been made; vide Fig(4.3). As seen from this plot, the value of 'n' is approximately equal to 0.2. Although there were variations from this value in some runs, a value of n = 0.2 in Eq.(2.4) appeared reasonable to assume.

4.4 COMPARISON BETWEEN THEORY AND EXPERIMENTS

In Chapter II, two different discharge equations based on different velocity distributions were derived. They are

$$\frac{q^*}{\sqrt{g\,h^3}} = (1+\frac{h}{W})\,\frac{2\pi}{60}.\,\frac{Nr^{1/2}}{\sqrt{g}}\,(\frac{r}{h})^{3/2}\,\log_e(1+\frac{h}{r});\;\ldots\quad(2.3)$$

$$\frac{q^*}{\sqrt{g\,h^3}} = (1+\frac{h}{W})\,\frac{2\pi}{60}\,\frac{Nr^{1/2}}{\sqrt{g}}\,(\frac{r}{h})^{3/2}\left[(1+\frac{h}{r})^{1-n}-1.0\right]\ldots\quad(2.4)$$

Since a value of n = 0.2 appeared to be reasonable, comparison with experimental data is made using Eq(2.4) only. Accordingly the actual discharge is written as

$$\frac{q^*}{\sqrt{gh^3}} = K\left[\left(1+\frac{h}{L}\right)\frac{2\pi}{60}\frac{Nr^{1/2}}{\sqrt{g}}\left(\frac{r}{h}\right)^{3/2}\left|(1+h/r)^{0.8}-1.0\right|\right] \quad \ldots(4.1)$$

In the derivation of Eq.(2.4), the effect of curvature of flow over the crest-of which the parameter h/L is an index-has not been considered. As such one may expect K to be a function h/L. The value of K for all the runs were computed using Eq.(4.1) and these are plotted against h/L in Fig(4.4). The values of K are invariably less than unity and K seems to show a systematic variation with h/L and $\frac{Nr^{1/2}}{\sqrt{g}}$. Since the effect of rotation was supposed to be fully taken care of in the derivation of Eq.(2.4), it is surprising to note that K is a function of $\frac{Nr^{1/2}}{\sqrt{g}}$. It is felt that this indicates andadditional limitation of the theory, apart from the one mentioned earlier that Eq(4.1) does not reduce to the conventional B.C. weir formula when N = 0. As such an approach based on dimensional analysis is presented for discharge prediction.

4.5 DISCHARGE RELATION FOR FREE FLOW OVER A BROAD-CRESTED WEIR.

As per Raju and Asawa(3) the discharge over a broad-crested weir with sharp upstream corner can be obtained from the equation

$$Q = K_1 K_2 C \, B \sqrt{g} \, h^{3/2} \qquad \ldots \qquad (4.2)$$

in which 'h' is the head measured over the weir

K_1 is the correction for viscus and surface tension effects

K_2 is the correction for the effect of curvature of flow over the weir, i.e.

$$K_1 = f_1(R, W_1)$$

$$K_2 = f_2(h/L)$$

in which $R = \frac{g^{1/2}h^{3/2}}{\nu}$ and $W_1 = \frac{\rho g h^2}{\sigma}$, and C is the discharge coefficient and is a function of $\frac{h}{h+W}$. The variations of C with $\frac{h}{h+W}$ and K_1 with $R^{.2}W_1^{.6}$ are shown in Figs(4.5) and (4.6) respectively. Raju and Asawa(3) gave the variation of K_2 with h/L for a weir with sharp upstream corner. Obviously the variation of K_2 with h/L would be different for a weir with a roller at the U/s corner. The experimental data with no rotation were used to establishthe variation of K_2 with h/L for such weirs. Values of K_2 were calculated for these data using Eq.(4.2) and Figs(4.5) and (4.6). These values of K_2 are plotted against h/L in Fig.(4.7). Generally speaking one would expect a unique relation between K_2 with h/L for all rounded corner weirs provided seperation is avoided. But it is found that the data points for the weir with roller of r = 3.0cm are below than the data points for the weir with roller r = 1.88cm. The difference is due to the fact that there was a wide gap below the roller on the upstream vertical face, in the weir with roller r = 3.0cm due to some practical difficulties in construction. A sketch showing the difference in weir geometry is shown in Fig(4.7). The difference in the geometry explains the difference in the trend of points for the two sets of data. For further analysis two separate mean lines were drawn one for r = 1.88cm and one for r = 3.0cm. The line for sharp cowered weirs(3) is also shown for comparison. The change in K_2 due to provision of roller is not significant.

4.6 APPROACH BASED ON DIMENSIONAL ANALYSIS.

Let q^* be the discharge over the weir at a head h and a rotational speed = N. q_o = Discharge with no rotation at the same head. One can then write

$$q^* = f(q_o, h, g, N, r) \qquad \ldots \qquad (4.3)$$

4.6.1 Dimensional Analysis

Applying Buckingham's theorem, Eq(4.3) can be written as

$$f'(q^*, q_o, h, g, N, r) = 0$$

Since these six variables consists only two fundamental dimensional units i.e. L and T, they may be grouped into

4 dimensionless π terms:

$$\phi(\pi_1,\pi_2,\pi_3,\pi_4) = 0$$

Choosing N and r as non-repeating variables one gets

$$\therefore \quad \frac{q^*}{Nr^2} = \phi\left(\frac{q_o}{Nr^2}, \frac{Nr^{1/2}}{\sqrt{g}}, \frac{h}{r}\right)$$

$$\text{or} \quad \frac{q^*}{q_o} = f\left(\frac{h}{r}, \frac{Nr^{1/2}}{\sqrt{g}}\right) \quad \ldots \quad (4.4)$$

The parameter $\frac{q_o}{Nr^2}$ has no significance and has been dropped.

For calculating the discharge with no rotation q_o, Eq(4.2) was used. The values of K_1 and C were taken from Figs(4.5) and (4.6) respectively. The value of K_2 was read from Fig(4.7) for the corresponding roller radius. The discharge with rotation q^* was the measured one. A plot based on the Eq.(4.4) was made and is shown in Fig.(4.8). This plot was made for all the weirs studied with two different diameters of rollers for different values of parameter $\frac{Nr^{1/2}}{\sqrt{g}}$. Lines of constant $\frac{Nr^{1/2}}{\sqrt{g}}$ have been drawn on this figure. It is seen firstly that for a particular value of $\frac{Nr^{1/2}}{\sqrt{g}}$, the increase in discharge is higher at low h/r or at low heads. Also for the same head, increase in $\frac{Nr^{1/2}}{\sqrt{g}}$ (or N) increases the discharge. It is to be noted that an increase in discharge of as much as 30 per cent is obtained at high speeds and low heads.

One can thus use Eq(4.2) along with Figs (4.5), (4.6), (4.7) and (4.8) to find the discharge over a weir with a rotating cylinder at its upstream corner.

4.7 CONCLUDING REMARKS

It was the purpose of this exploratory study to find out whether a rotating cylinder placed at the upstream corner of a weir improves the discharge capacity of weir. The results presented in this chapter show conclusively that such is the case. It has also been shown that significant increase in discharge occurs at low h/r values and high speeds.

- o -

CHAPTER V

CONCLUSIONS AND SUGGESIONS FOR FURTHER STUDY

5.1 CONCLUSIONS

The thesis is concerned with a semi-theoretical study of the discharge characteristics of a broad-crested weir with a rotating cylinder at its upstream top corner. As a result of the study the following conclusions are made.

(1) An equation for the discharge over a weir with a rotating cylinder has been derived theoretically; however, the agreement of experimental data with the theory is not satisfactory.

(2) The additional velocity due to rotation varies approximately to the 1/5 th power of the vertical distance from the crest.

(3) The ratio of discharge under rotation to that under no-rotation at the same head is a function of h/r and $\frac{Nr^{1/2}}{\sqrt{g}}$.

(4) The increase in discharge due to rotation is substantial at low heads and high speeds.

5.2 SUGGESTIONS FOR FUTURE STUDY

The following suggestions are made for further study :

(1) An improvement in the theoretical analysis taking

CHAPTER V

CONCLUSIONS AND SUGGESIONS FOR FURTHER STUDY

5.1 CONCLUSIONS

The thesis is concerned with a semi-theoretical study of the discharge characteristics of a broad-crested weir with a rotating cylinder at its upstream top corner. As a result of the study the following conclusions are made.

(1) An equation for the discharge over a weir with a rotating cylinder has been derived theoretically; however, the agreement of experimental data with the theory is not satisfactory.

(2) The additional velocity due to rotation varies approximately to the 1/5 th power of the vertical distance from the crest.

(3) The ratio of discharge under rotation to that under no-rotation at the same head is a function of h/r and $\frac{Nr^{1/2}}{\sqrt{g}}$.

(4) The increase in discharge due to rotation is substantial at low heads and high speeds.

5.2 SUGGESTIONS FOR FUTURE STUDY

The following suggestions are made for further study :

(1) An improvement in the theoretical analysis taking

care to ensure that the derived equation reduces to the conventional broad-crested weir equation at $\Pi = 0$.

(2) Study with different heights of weirs and sizes of rollers to widen the range of parameters.

(3) Study of power required for rotation of cylinder.

- o -

REFERENCES

NO	AUTHOR	TITLE
1.	Ahmad, Ihsan	Analysis of flow over supressed and Contracted Broad-Crested weirs, M.E. dissertation 1970, University of Roorkee.
2.	Hall G.W.	Analytical Determination of Discharge Characteristics of Broad-Crested Weirs using Boundary Layer Theory. Proceedings Institution of Civil Engineers(London) Vol.22, June 1962, Page 177.
3.	RangaRaju,N.G. and Asawa G.L.	Comprehensive weir Discharge formula (Unpublished Paper).
4.	Rouse,H.	Engineering Hydraulics, John Willey and Sons, 1950- Chapter VII-Channel Transitions and Controls by A.T. IPPEN, Page 525.

APPENDIX-I

TABLE 1 : SUMMARY OF DATA

S.No.	HEAD-OVER S-C WEIR	DIS-CHARGE IN M³/Sec. ↓ / SPEED OF ROTA-TION →	VALUE OF h in cm.				
			0	1000	2000	3000	4000
1	2	3	4	5	6	7	8
			WEIR 1 : L = 160cm; r = 1.88cm				
1	3.07	0.0108	6.68	6.55	6.31	6.06	5.70
2	3.90	0.0150	8.12	7.98	7.82	7.58	7.29
3	5.60	0.0248	11.10	10.99	10.89	10.68	10.55
4	6.07	0.0277	12.06	11.94	11.81	11.70	11.48
5	7.29	0.0356	14.20	13.96	13.84	13.72	13.60
6	8.72	0.0460	16.50	16.28	16.16	15.05	14.99
			WEIR 2 : L=31.0cm;r=1.88cm				
7	8.60	0.0458	17.62	17.00	16.88	16.79	16.68
8	7.12	0.0350	14.70	14.40	14.30	14.10	13.70
9	6.23	0.0290	12.96	12.65	12.50	12.14	11.60
10	5.40	0.02335	11.28	10.91	10.65	10.11	9.78
11	4.38	0.0178	9.35	9.15	8.83	8.60	8.12
12	2.87	0.0097	6.48	6.15	5.79	5.33	4.85
			WEIR 3 : L = 45.0cm; r=1.88cm				
13	2.89	0.0097	6.67	6.47	6.15	5.68	5.42
14	4.09	0.0160	8.99	8.78	8.60	8.31	7.96
15	4.91	0.02075	10.51	10.26	10.02	9.79	9.44
16	5.87	0.0268	12.48	12.15	12.02	11.89	11.42
17	6.76	0.0314	14.10	13.68	13.50	13.28	13.02
18	8.15	0.0413	16.95	16.40	16.28	16.14	15.95

TABLE 1 (CONTD.)

1	2	3	4	5	6	7	8
				Weir 4 : L=31.0cm; r=3.0cm			
19	2.87	0.0097	6.90	6.48	6.14	5.78	5.28
20	3.93	0.0151	8.82	8.56	8.21	7.76	7.58
21	5.07	0.0204	10.42	10.15	9.82	9.52	9.27
22	5.57	0.0246	12.07	11.80	11.48	11.17	11.00
23	7.30	0.0356	15.22	14.97	14.74	14.42	14.20
24	7.90	0.0400	16.16	15.80	15.56	15.14	15.06
				Weir 5 : L=45.0cm; r=3.0cm			
25	3.85	0.01428	8.74	8.46	7.92	7.42	7.10
26	4.97	0.0210	10.92	10.72	10.38	9.74	9.42
27	6.13	0.0279	12.68	12.52	12.31	11.74	11.35
28	6.50	0.0305	13.64	13.43	13.12	12.64	12.37
29	7.20	0.0352	15.14	14.89	14.60	14.20	13.85
30	7.77	0.0385	16.62	16.33	16.02	15.69	15.42

TABLE 2 : WATER SURFACE PROFILES

S. NO.	DISCHARGE Q in ^{3}/Sec.	SPEED OF ROTATION	DISTANCE FROM END → VALUES OF Y 0	4	8	12	16	20	24	30	54	66
(1)	(2)	(3)										
						WEIR 1 : L = 16.0cm; r = 1.88cm						
1	0.0108	0	2.98	3.84	4.59	5.44	6.05	6.45	6.57	6.67	6.68	6.68
	"	1000	3.00	3.92	4.58	5.28	5.92	6.33	6.42	6.55	6.55	6.55
	"	2000	3.02	3.83	4.38	5.06	5.68	6.08	6.25	6.30	6.31	6.31
	"	3000	3.08	3.78	4.18	4.72	5.42	5.82	6.98	6.05	6.06	6.06
	"	4000	3.08	3.53	3.80	4.36	5.03	5.45	6.59	5.70	5.70	5.70
2	0.0150	0	3.82	4.83	5.76	6.65	7.33	7.76	7.89	8.08	8.12	8.12
	"	1000	3.86	4.87	5.72	6.55	7.21	7.60	7.83	7.96	7.98	7.98
	"	2000	3.86	4.80	5.59	6.48	7.02	7.46	7.66	7.80	7.82	7.82
	"	3000	3.82	4.68	5.38	6.13	6.79	7.25	7.42	7.56	7.58	7.58
	"	4000	3.79	4.51	5.12	5.86	6.49	6.94	7.17	7.29	7.29	7.29
3	0.0248	0	5.64	6.98	8.22	9.20	9.88	10.44	10.73	10.97	11.10	11.10
	"	1000	5.68	6.99	8.08	9.08	9.77	10.29	10.58	10.83	10.99	10.99
	"	2000	5.69	6.90	8.01	8.96	9.67	10.18	10.48	10.63	10.85	10.85
	"	3000	5.62	6.86	7.88	8.78	9.50	10.00	10.38	10.56	10.68	10.68
	"	4000	5.58	6.75	7.70	8.62	9.30	9.83	10.14	10.40	10.55	10.55

Contd...

TABLE->2 (CONTD.)

S. NO.	DISCHARGE Q in M^3/SEC.	DOSTANCE FROM END→ SPEED OF ROTATION↓	VALUES OF γ									
			0	4	8	12	16	20	24	30	54	66
(1)	(2)	(3)										
4	0.0277	0	6.30	7.66	8.92	9.99	10.69	11.26	11.60	11.83	1206	1206
	''	1000	6.35	7.64	8.83	9.80	10.51	11.10	11.46	11.73	11.94	11.94
	''	2000	6.30	7.62	8.76	9.76	10.41	10.98	11.36	11.60	11.81	11.81
	''	3000	6.28	7.52	8.70	9.62	10.33	10.93	11.22	11.42	11.70	11.70
	''	4000	6.15	7.40	8.48	9.42	10.15	10.72	11.01	11.31	11.48	11.48
5	0.0356	0	7.75	9.18	10.62	11.72	12.47	13.10	13.51	13.82	14.15	14.20
	''	1000	7.84	9.25	10.44	1152	12.29	12.89	13.29	13.65	13.92	13.96
	''	2000	7.80	9.28	10.40	11.40	12.20	12.78	13.24	13.53	13.83	13.84
	''	3000	7.78	9.15	10.26	11.36	12.14	12.68	13.03	13.47	13.60	13.72
	''	4000	7.65	9.02	10.20	11.20	11.98	12.60	12.98	13.30	13.59	13.60
6	0.0460	0	9.38	11.05	12.30	13.53	14.39	15.14	15.58	15.97	16.48	16.50
	''	1000	9.45	10.94	12.18	13.37	14.16	14.80	15.38	15.78	16.15	16.28
	''	2000	9.40	10.89	12.24	13.25	14.10	14.70	15.18	15.65	16.11	16.16
	''	3000	9.35	10.80	12.20	13.19	13.98	14.62	15.10	15.51	16.00	16.05
	''	4000	9.26	10.70	11.98	13.12	13.88	14.52	15.02	15.42	15.92	16.00

TABLE 2 WATER SURFACE PROFILES (CONTD.)

1	2	3	value of y 0	4	8	12	16	20	24	28	31	35	41	69	81
								WEIR 2: L.31.0cm; r = 1.88cm							
1	0.0458	0	8.22	9.20	10.21	11.10	12.25	13.46	14.40	15.25	15.75	16.35	16.92	17.62	17.62
	''	1000	8.41	9.51	10.43	11.40	12.31	13.19	14.07	14.79	15.20	15.79	16.35	17.00	17.00
	''	2000	8.50	9-48	10.46	11.34	12.25	13.03	13.94	14.65	15.10	15.70	16.30	16.88	16.88
	''	3000	8.34	9.61	10.40	11.30	12.07	12.95	13.80	14.58	15.08	15.62	16.10	16.79	16.79
	''	4000	8.28	9.40	10.31	11.09	11.85	12.74	13.55	14.40	14.75	15.40	15.92	16.68	16.68
2	0.0350	0	6.72	7.70	8.50	9.27	10.15	11.10	12.08	12.98	13.47	13.92	14.39	14.70	14.70
	''	1000	6.99	7.91	8.60	9.38	9.97	10.90	11.73	12.50	12.92	13.40	14.82	14.400	14.40
	''	2000	6.98	7.84	8.68	9.34	10.00	10.79	11.56	12.42	12.80	13.37	13.77	14.30	14.30
	''	3000	6.95	7.90	8.59	9.20	9.90	10.65	11.35	12.10	12.59	13.05	13.51	14.10	14.10
	''	4000	6.90	7.70	8.48	9.09	9.64	10.40	11.10	11.90	12.50	12.99	13.39	13.70	13.70
3	0.0290	0	5.78	6.65	7.70	7.84	8.57	9.47	10.42	11.30	11.73	12.29	12.68	12.96	12.96
	''	1000	5.95	6.88	7.50	7.92	8.57	9.24	9.98	10.75	11.40	11.87	12.24	12.65	12.65
	''	2000	6.04	6.90	7.46	8.06	8.60	9.24	10.01	10.70	11.15	11.64	12.09	12.50	12.50
	''	3000	5.82	6.75	7.24	7.74	8.29	8.84	9.60	10.31	10.95	11.38	11.78	12.14	12.14
	''	4000	5.80	6.74	7.22	7.65	8.29	8.80	9.54	10.22	10.60	10.92	11.31	11.60	11.60

TABLE 2 : WATER SURFACE PROFILES(CONTD.)

1	2	3	VALUE OF Y 0	4	8	12	16	20	24	28	31	35	41	69	81
4	0.02335	0	5.04	5.80	6.34	6.72	7.25	8.03	8.90	9.79	10.20	10.70	11.04	11.28	11.28
	''	1000	5.10	5.90	6.42	6.86	7.32	7.90	8.64	9.41	9.81	10.33	10.68	10.91	10.91
	''	2000	5.14	5.97	6.44	6.85	7.26	7.86	8.51	9.22	9.60	10.10	10.49	10.65	10.65
	''	3000	5.05	5.74	6.17	6.42	6.71	7.23	7.91	8.60	9.01	9.53	9.89	10.11	10.11
	''	4000	4.90	5.66	6.05	6.24	6.51	6.91	7.50	8.20	8.65	9.11	9.45	9.78	9.78
5	0.0178	0	4.21	4.90	5.26	5.52	5.91	6.42	7.29	8.14	8.52	8.90	9.15	9.35	9.35
	''	1000	4.33	5.03	5.40	5.69	6.00	6.51	7.10	7.88	8.30	8.72	9.01	9.15	9.15
	''	2000	4.30	5.04	5.42	5.61	5.89	6.28	6.83	7.52	8.00	8.41	8.72	8.83	8.83
	''	3000	4.20	5.03	5.29	5.48	5.68	6.03	6.50	7.21	7.71	8.11	8.41	8.60	8.60
	''	4000	4.19	4.79	5.09	5.16	5.31	5.53	6.01	6.73	7.21	7.71	7.97	8.12	8.12
6	0.0097	0	2.87	3.47	3.65	3.75	3.83	4.08	4.62	5.42	5.82	6.20	6.48	6.48	6.48
	''	1000	2.97	3.60	3.78	3.83	3.90	4.08	4.47	5.16	5.59	5.93	6.10	6.15	6.15
	''	2000	2.95	3.59	3.78	3.81	3.83	3.88	4.16	4.76	5.20	5.59	5.78	5.79	5.79
	''	3000	2.80	3.18	3.42	3.42	3.40	3.49	3.69	4.26	4.72	5.09	5.62	5.33	5.33
	''	4000	2.55	2.74	2.80	3.01	3.00	3.31	3.45	3.65	4.20	4.61	4.82	4.85	4.85

TABLE->2(CONTD.)

S. No.	Discharge Q in m^3/sec	SPEED OF ROTATION	VALUE OF Y													
		DISTANCE FROM end→	0	4	8	12	16	20	24	28	32	36	40	45	55	83
1	2	3														
						WEIR 3: L=45.0 cm ; Y=1.88 cm										
1	0.0099	0	2.88	3.65	4.01	4.18	4.15	4.07	3.97	3.97	4.13	4.53	5.27	6.03	6.64	6.67
	"	1000	2.81	3.73	4.15	4.36	4.40	4.30	4.15	4.12	4.20	4.53	5.12	5.83	6.44	6.47
	"	2000	2.96	3.71	4.10	4.29	4.35	4.20	4.09	4.00	4.02	4.22	4.72	5.51	6.08	6.15
	"	3000	2.74	3.28	3.40	3.42	3.55	3.43	3.30	3.47	3.65	3.85	4.29	5.09	5.62	5.68
	"	4000	2.56	3.01	3.05	3.28	3.28	3.26	3.28	3.35	3.65	3.65	3.94	4.81	5.42	5.42
2	0.0160	0	3.91	4.76	5.09	5.30	5.32	5.35	5.35	5.53	5.88	6.53	7.28	8.17	8.88	8.99
	"	1000	3.99	4.85	5.26	5.47	5.45	5.51	5.56	5.70	5.94	6.50	7.32	7.99	8.68	8.78
	"	2000	4.00	4.83	5.29	5.46	5.60	5.56	5.54	5.61	5.88	6.29	6.87	7.74	8.12	8.60
	"	3000	4.00	4.85	5.24	5.45	5.55	5.48	5.45	5.52	5.60	5.97	6.60	7.45	8.18	8.31
	"	4000	3.98	4.71	5.11	5.18	5.20	5.20	5.18	5.20	5.35	5.79	6.44	7.10	7.80	7.96
3	0.02075	0	4.64	5.46	5.81	5.99	6.09	6.16	6.26	6.58	6.91	7.90	8.69	9.56	10.50	10.91
	"	1000	4.73	5.54	6.00	6.19	6.37	6.45	6.55	6.78	7.19	7.78	8.50	9.31	10.05	10.26
	"	2000	4.69	5.60	6.00	6.23	6.39	6.48	6.53	6.73	7.06	7.61	8.31	9.09	9.82	10.02
	"	3000	4.65	5.51	5.98	6.26	6.32	6.35	6.42	6.54	7.85	7.33	8.94	8.82	9.60	9.79
	"	4000	5.59	5.41	5.87	6.08	6.11	6.11	6.15	6.29	7.53	6.98	8.65	8.45	9.26	9.44

TABLE 2 (CONTD.)

1	2	3	VALUE OF Y													
			0	4	8	12	16	20	24	28	32	36	40	45	55	83
4	0.0268	0	5.61	6.38	6.80	697	7.19	7.32	7.67	8.15	8.83	9.71	10.52	11.31	12.22	1248
	''	1000	5.68	6.50	6.92	7.02	7.47	7.71	7.80	8.28	8.78	9.46	10.18	10.97	11.85	12.15
	''	2000	5.64	6.50	6.88	7.31	7.45	7.66	7.78	8.20	8.69	9.30	9.99	10.76	11.65	12.02
	''	3000	5.58	6.40	6.98	7.29	7.44	7.58	7.68	8.05	8.44	9.04	9.75	10.51	11.40	11.39
	''	4000	5.50	6.40	6.88	7.15	7.30	7.38	7.54	7.78	8.13	8.60	9.38	10.15	11.06	11.42
5	0.0314	0	6.26	7.01	7.45	7.84	8.10	8.38	8.69	9.33	10.12	11.10	11.98	12.78	13.69	14.10
	''	1000	6.38	7.18	7.72	8.19	8.47	8.78	8.07	9.58	10.15	10.83	11.60	12.46	13,34	13.68
	''	2000	6.48	7.15	7.79	8.17	8.44	8.68	8.00	9.44	9.98	10.65	11.38	12.20	13.22	13.50
	''	3000	6.38	7.21	7.77	8.16	8.40	8.66	8.92	9.30	9.80	10.47	11.15	11.90	12.99	13.28
	''	4000	6.20	7.20	7.70	8.02	8.30	8.48	8.70	9.08	9.52	10.10	10.80	11.68	12.60	13.02
6	0.0413	0	7.62	8.38	8.92	9.48	9.80	10.40	11.08	11.75	12.70	13.68	14.58	15.40	16.45	16.95
	''	1000	7.79	8.66	9.38	9.88	10.29	10.80	11.30	11.88	12.60	13.32	14.10	14.95	15.92	16.40
	''	2000	7.82	8.72	9.34	9.88	10.35	10.70	11.28	11.81	12.48	13.20	14.00	14.76	15.78	16.28
	''	3000	7.70	8.60	9.34	9.83	10.26	10,68	11.10	11.68	12.28	13.12	13.62	14.45	15.50	16.14
	''	4000	7.70	8.68	9.25	9.74	10.18	10.50	10.92	11.42	12.06	12.78	13.52	14.30	15.34	15.95

TABLE 3 : VELOCITY DISTRIBUTION PROFILES

S.No.	DISCHARGE Q IN M^3/SEC.	y IN cm	VELOCITY IN METERS/ SECOND								
			AT 1/4 L			AT 1/2 L			At 3/4L		
		SPEED OF RODLER IN RPM	0	2000	4000	0	2000	4000	0	2000	4000
1	2	3	4	5	6	7	8	9	10	11	12
				Weir 2: L=31.0cm r=1.88cm							
1	0.04580	0.28	0.51	2.01	2.34	0.90	1.99	2.35	1.85	2.14	2.51
		1.28	1.17	1.70	2.28	-	-	2.30	2.02	2.19	2.47
		2.28	1.99	1.65	-	1.85	1.85	-	-	-	-
		3.28	-	-	1.73	-	-	1.96	1.83	2.10	2.13
		4.28	1.98	1.58	-	1.88	1.81	-	-	-	-
		5.28	-	-	1.69	-	-	1.83	2.12	2.08	2.11
		6.28	1.80	1.53	-	1.87	1.79	-	-	-	-
		7.28	-	-	1.64	-	-	1.83	2.12	2.08	2.08
		8.28	1.70	1.50	-	1.83	1.78	-	-	-	2.06
		9.28	-	-	1.64	-	-	1.82	-	2.07	2.06
		10.28	1.66	1.48	-	1.83	1.77	1.80	2.10	2.05	1.94
		11.28	-	-	1.57	-	-	-	-	-	-
		12.28	1.59	1.47	1.57	1.81	1.74	-	-	-	-
		13.28	1.55	1.44	1.52	-	-	-	-	-	-
		15.28	1.50	-	-	-	-	-	-	-	-

TABLE 3 : (CONTD.)

1	2	3	4	5	6	7	8	9	10	11	12
2	0.02335	0.28	0.49	1.65	1.47	1.16	1.69	2.21	1.55	1.89	2.11
		0.78	-	-	1.61	1.37	1.68	2.29	1.57	1.89	2.17
		1.28	1.43	1.34	1.51	1.44	1.60	2.32	1.66	1.87	2.38
		1.78	-	-	1.47	1.47	-	-	1.70	-	-
		2.28	1.41	1.28	1.34	1.48	1.48	2.04	1.71	1.76	2.09
		3.28	1.37	1.25	1.29	1.50	1.47	1.57	1.72	1.74	1.79
		4.28	1.34	1.25	1.28	1.50	1.48	1.49	1.73	1.70	1.65
		5.28	1.31	1.27	1.28	1.52	1.50	1.47	-	1.70	1.62
		6.28	1.25	1.27	1.26	1.53	1.48	1.47	-	-	1.58
		7.28	1.21	1.26	1.26	-	-	-	-	-	-
		8.28	1.19	1.25	-	-	-	-	-	-	-
3	0.0097	0.18	0.98	1.41	2.81	1.16	1.40	1.95	1.24	1.41	1.69
		0.68	1.01	1.34	2.54	1.24	1.43	2.01	1.28	1.47	1.81
		1.18	1.04	1.16	2.35	1.25	1.42	2.04	1.32	1.44	1.84
		1.68	1.07	1.09	2.05	1.25	1.32	2.00	1.32	1.37	1.86
		2.18	1.09	1.05	1.71	1.26	1.24	1.89	1.32	1.29	1.83

CONTD...

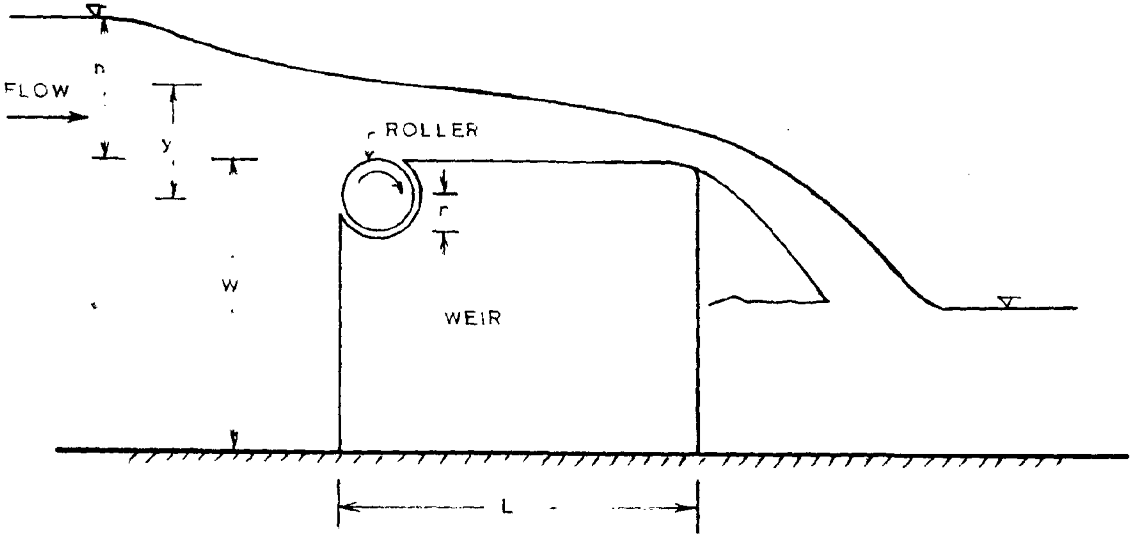
TABLE 3 (CONTD.)

1 *	2	3	4	5	6	7	8	9	10	11	12
		2.68	1.09	1.03	1.28	1.26	1.22	1.63	1.32	1.24	1.74
		3.18	1.09	1.02	1.19	1.26	1.19	-	1.32	1.27	-
		3.68	1.09	-	-	1.26	-	-	-	-	-
<u>Weir 3 : L = 45.0cm ; r = 1.88cm</u>											
4	0.02075	0.18							1.52	1.60	1.73
		0.68							1.66	1.72	1.93
		1.18							1.71	1.74	1.98
		1.68							1.73	1.69	1.94
		2.18							1.74	1.68	1.75
		2.68							1.74	1.68	1.67
		3.18							1.74	1.69	1.59
		4.18							1.74	1.57	1.57
		5.18							1.74	-	-
<u>Weir 1 : L = 160cm: r = 1.88cm</u>											
5	0.0277	0.18							1.44	1.85	2.45
		1.18							1.69	1.70	2.12

Contd ...

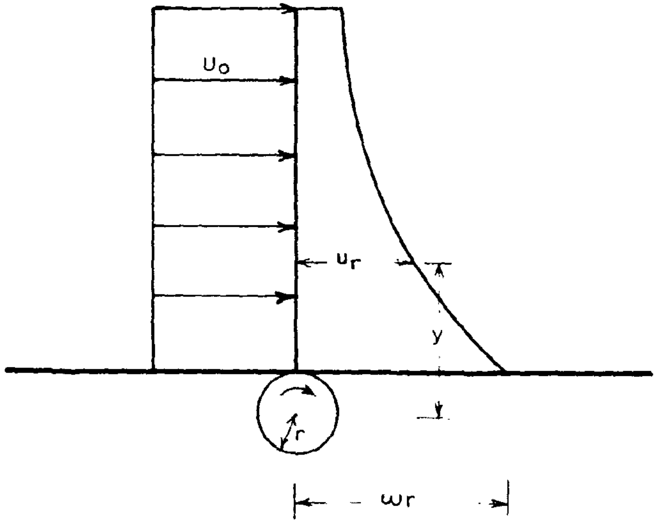
TABLE 3 (CONTD.)

1	2	3	4	5	6	7	8	9	10	11	12
		2.18							1.72	1.61	1.67
		3.18							1.69	1.60	1.59
		4.18							1.69	1.57	1.55
		5.18							1.66	1.57	1.54
		6.18							1.62	1.54	1.54
		7.18							1.59	1.53	1.54
		8.18							1.58	-	-



h = HEAD OVER WEIR
L = LENGTH OF WEIR
W = HEIGHT OF WEIR
r = RADIUS OF ROLLER

FIG. 1.1 _ TYPICAL SECTION OF WEIR WITH ROLLER



U_o = VELOCITY OF APPROACH
u_r = VELOCITY AT ANY HEIGHT DUE TO ROTATION OF CYLINDER
$u = u_r + U_o$

FIG. 2.1 _ THEORETICA VELOCITY DISTRIBUTION WITH ROLLER ROTATION

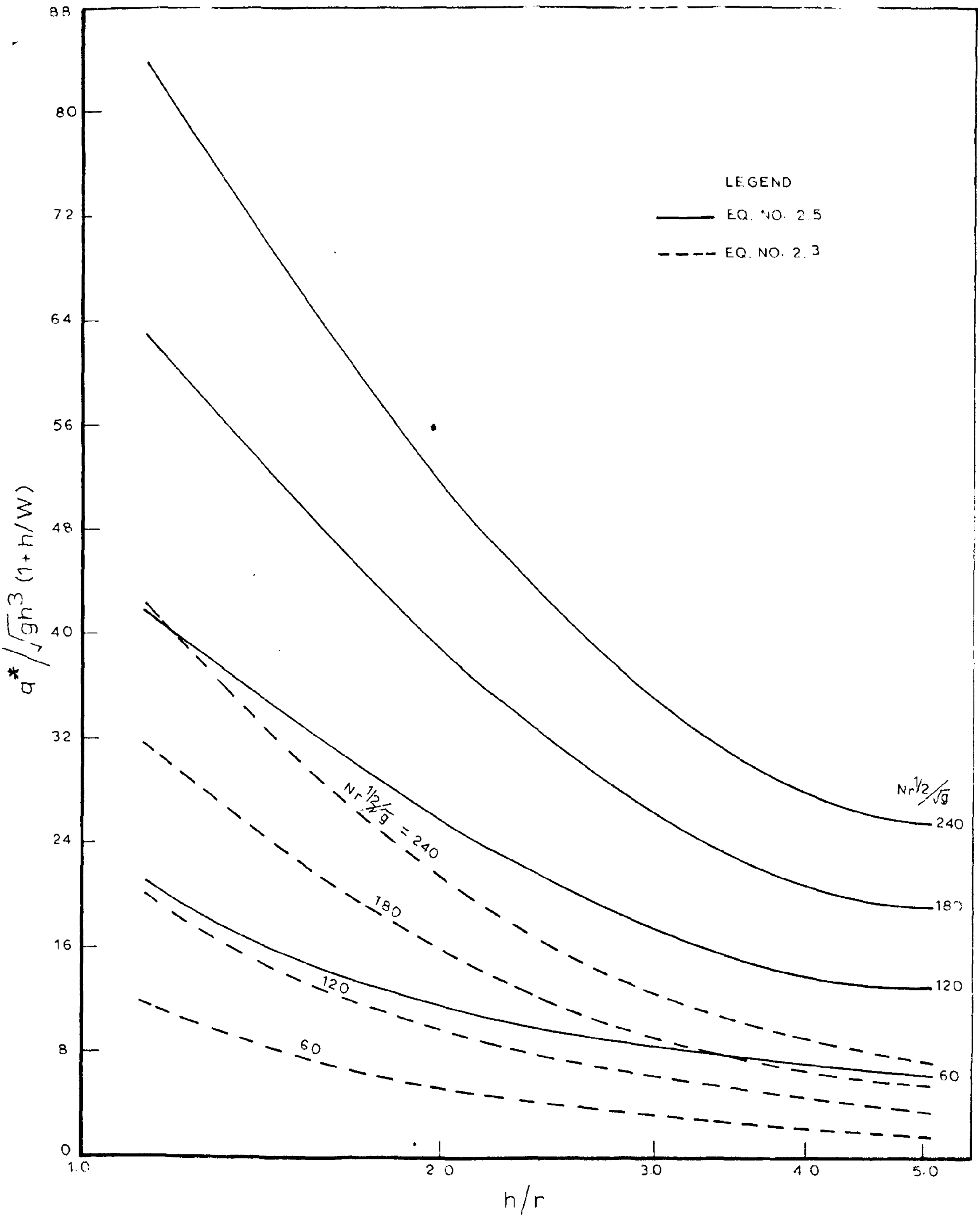
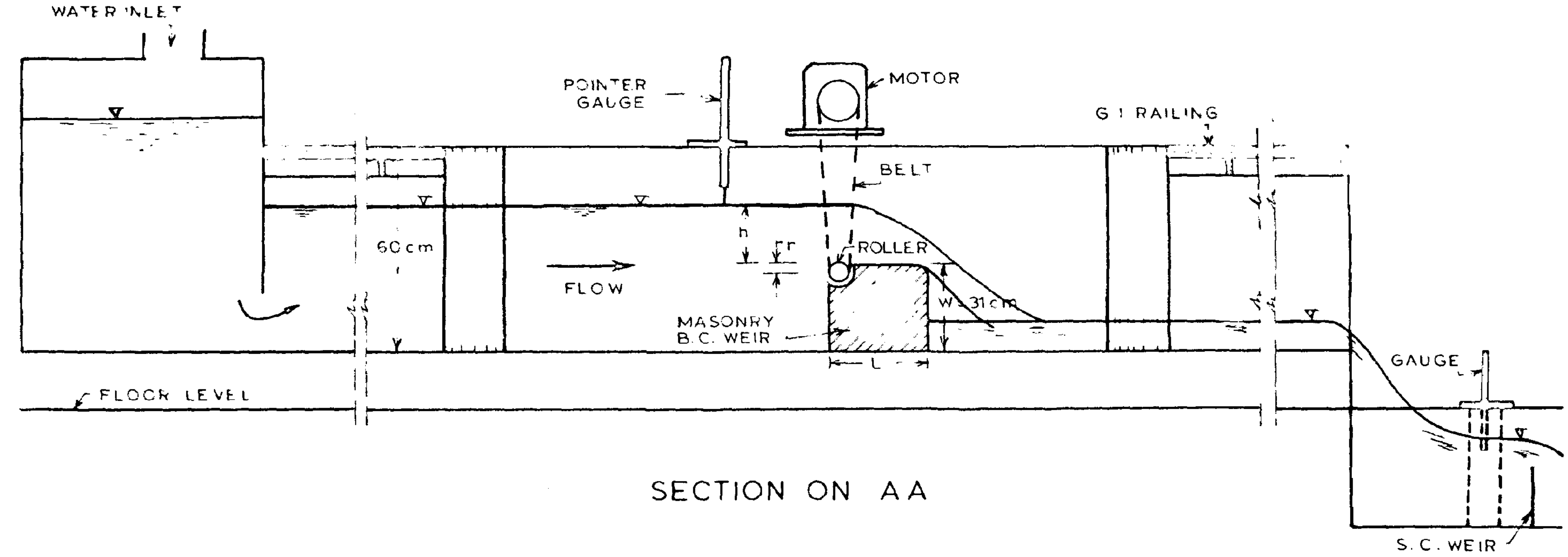
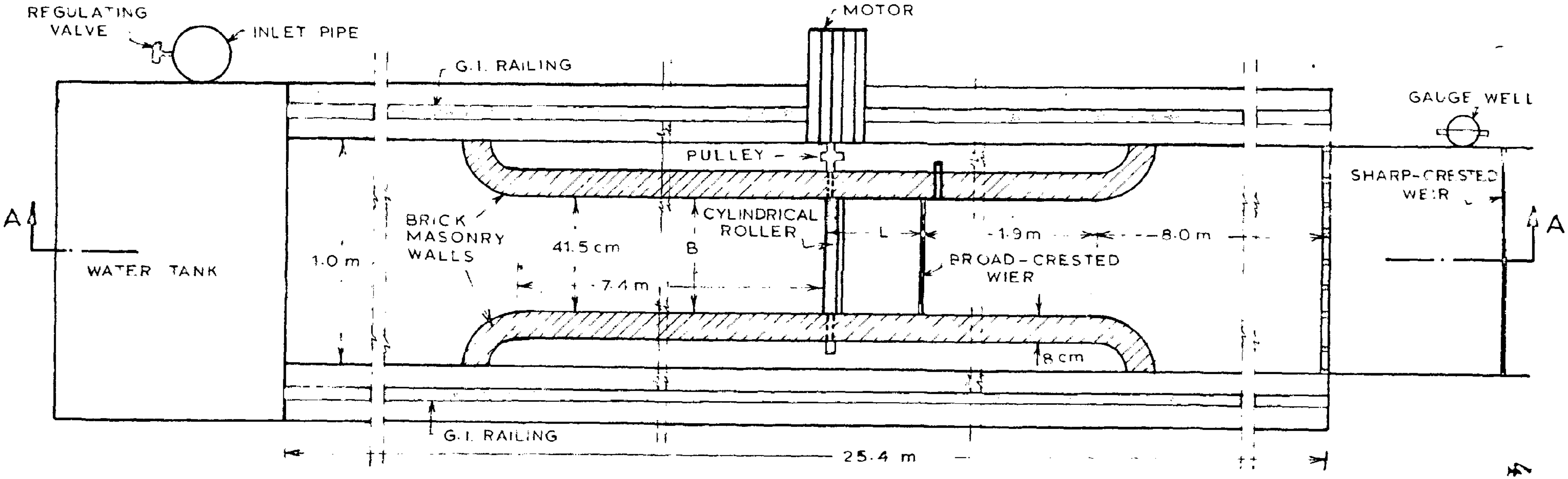


FIG. 2.2 _ RELATION BETWEEN $q^*/\sqrt{gh^3}\,(1+h/W)$ AND h/r AS PER Eqs. (2.3) AND (2.5)



SECTION ON AA



PLAN

FIG. 3.1 _SKETCH SHOWING THE EXPERIMENTAL SETUP

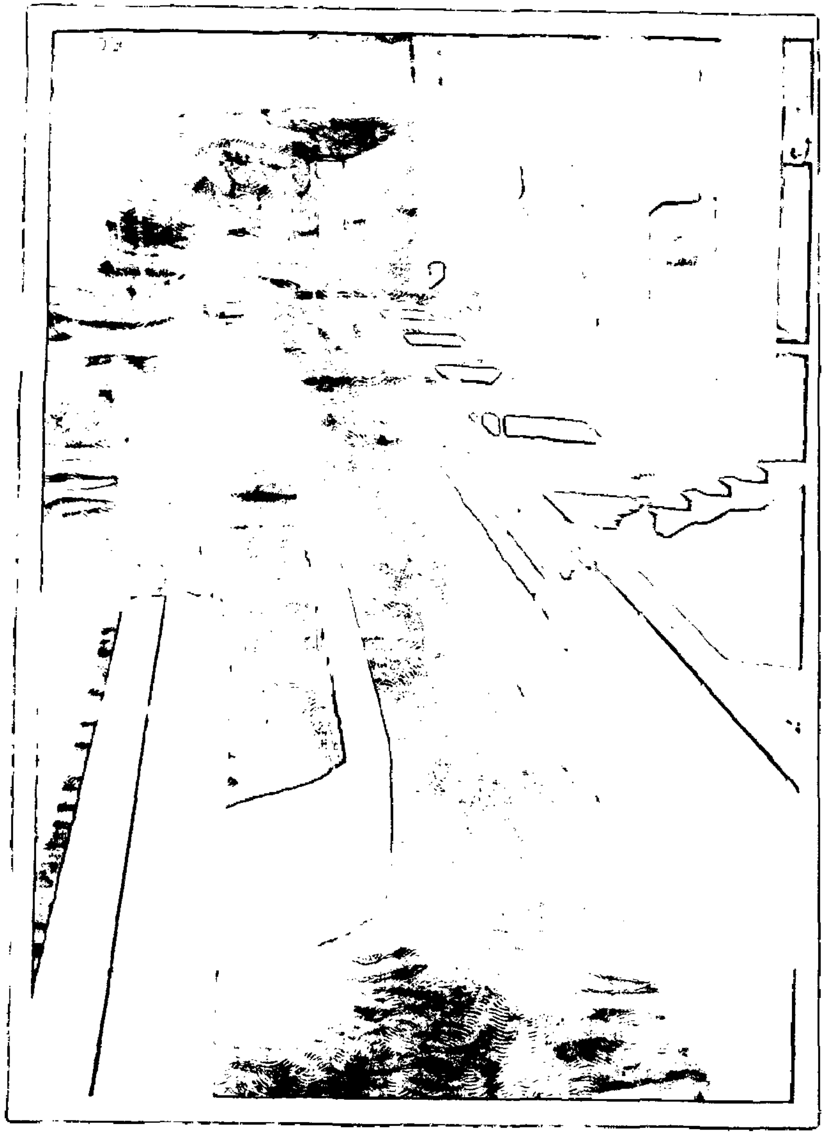


FIG. 3.2a GENERAL VIEW OF THE SETUP

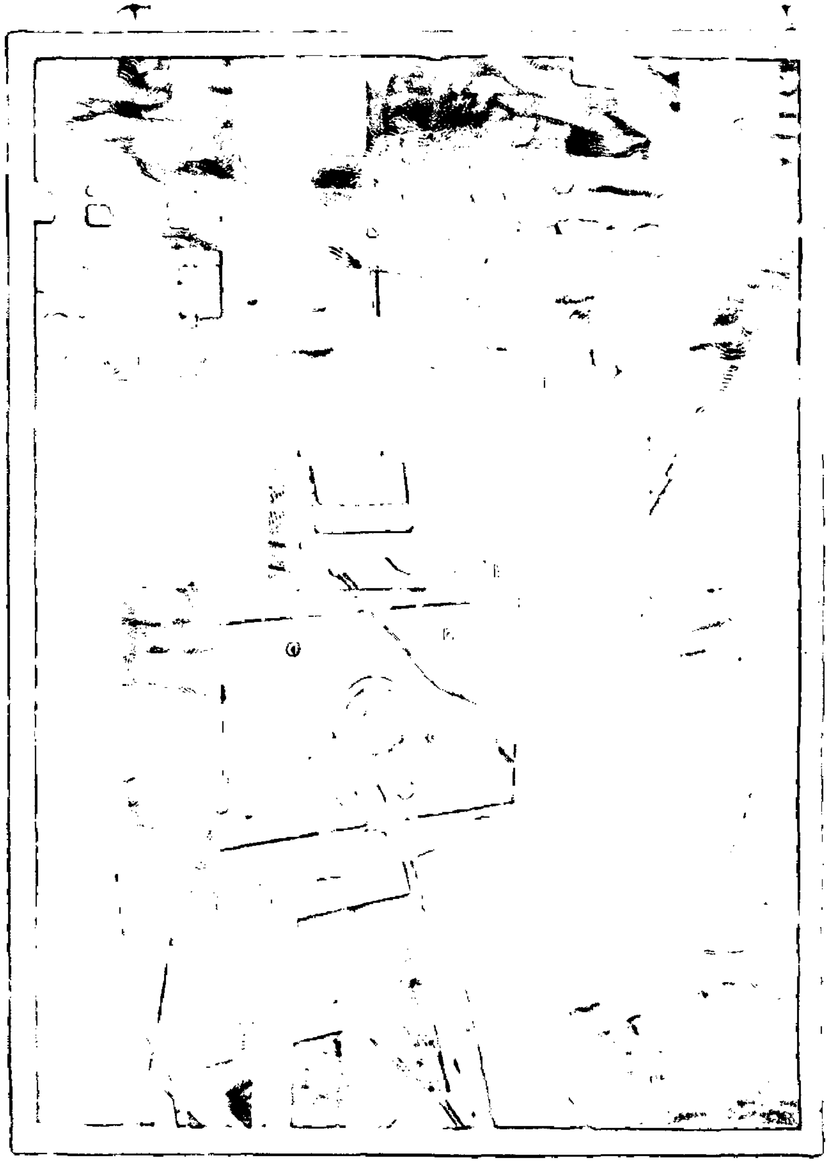


FIG. 3.2b VIEW OF THE VALVE [illegible]

FIG. 3.2 PHOTOGRAPHS OF THE EXPERIMENTAL SETUP

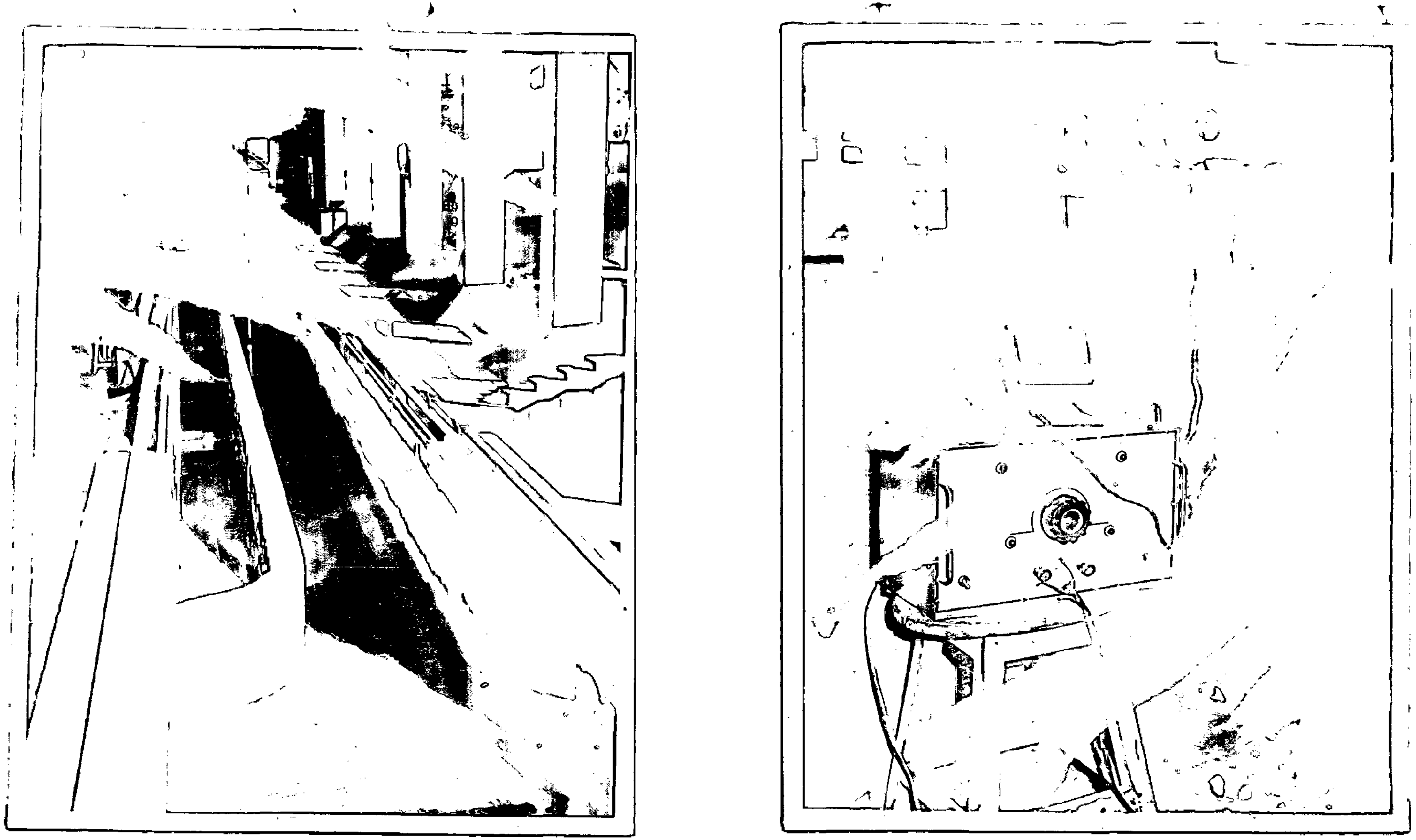


FIG. 3.2.1_GENERAL VIEW OF THE SETUP

FIG. 3.2.2_VIEW OF THE VARIABLE RESISTOR etc.

FIG. 3.2_PHOTOGRAPHS OF THE EXPERIMENTAL SETUP

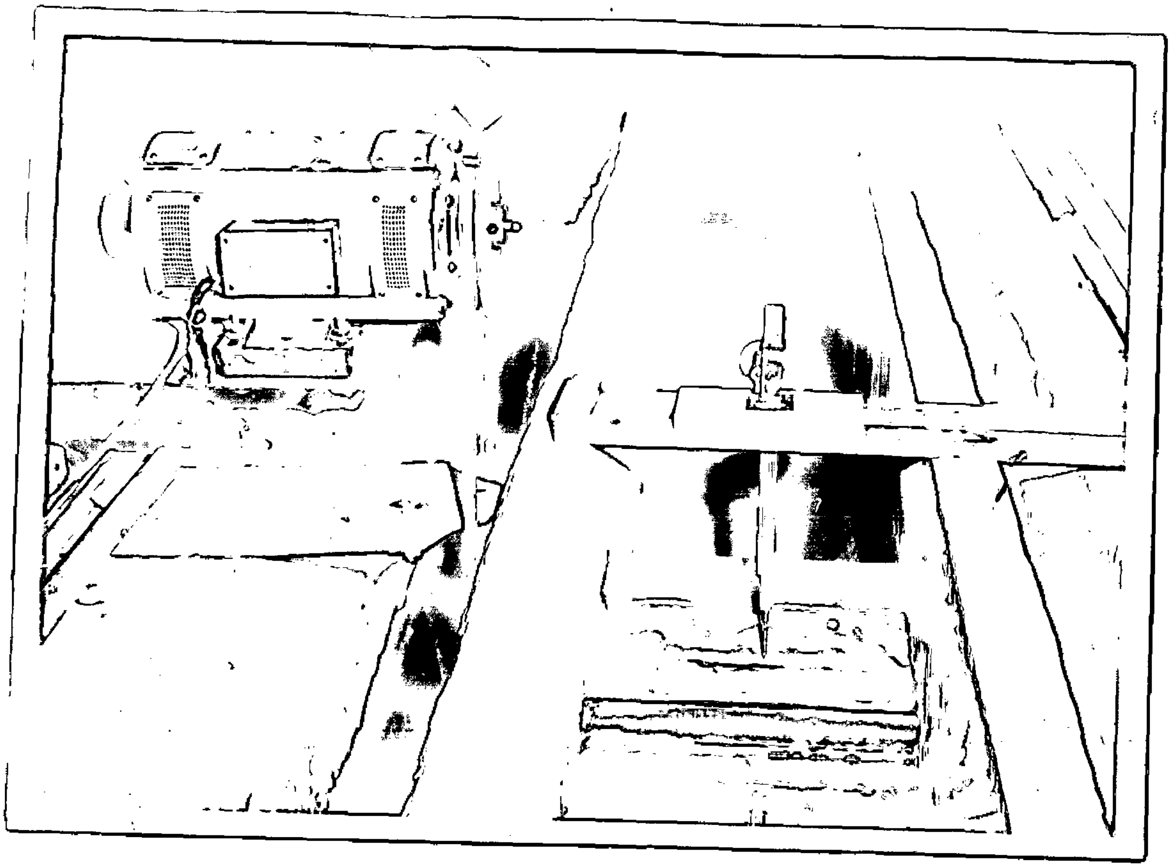


FIG. 3.2.3 _ VIEW OF THE WEIR WITH CYLINDER AND POINTER - GAUGE

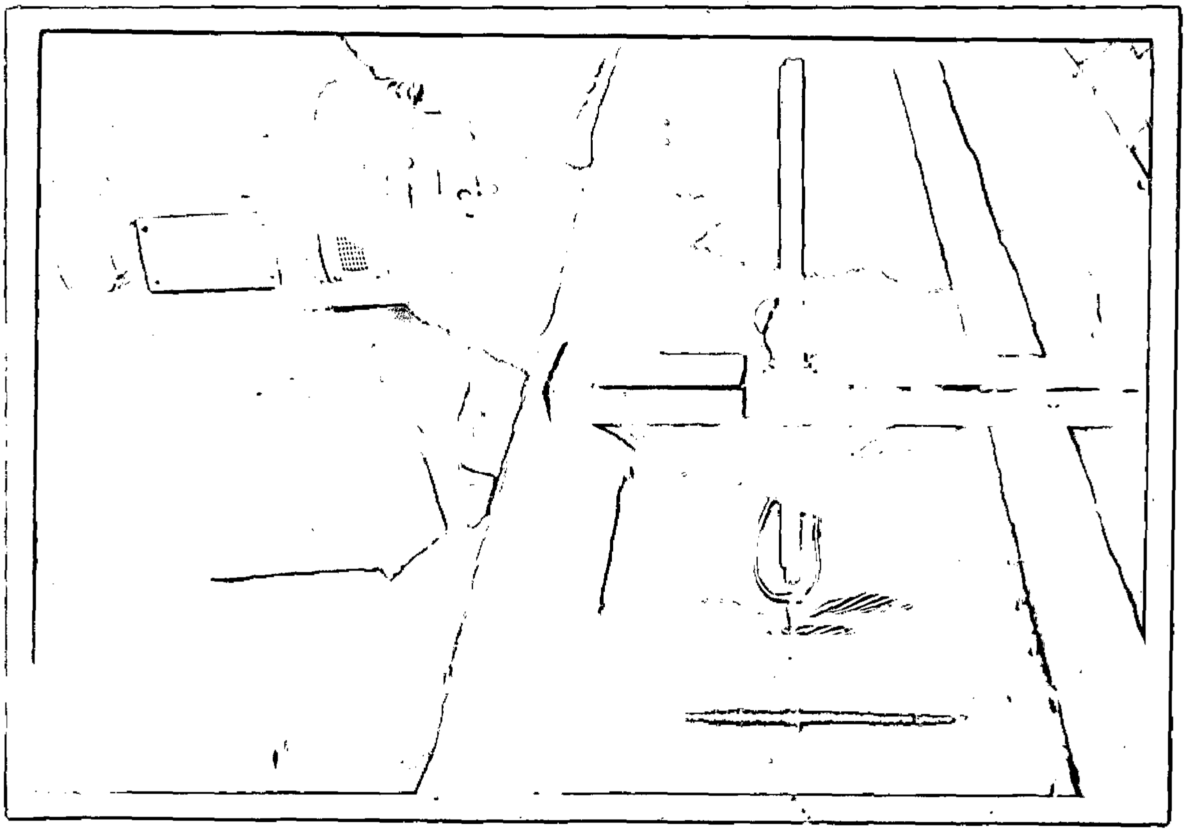


FIG. 3.2.4 _ VIEW OF THE MOTOR AND PITOT - TUBE

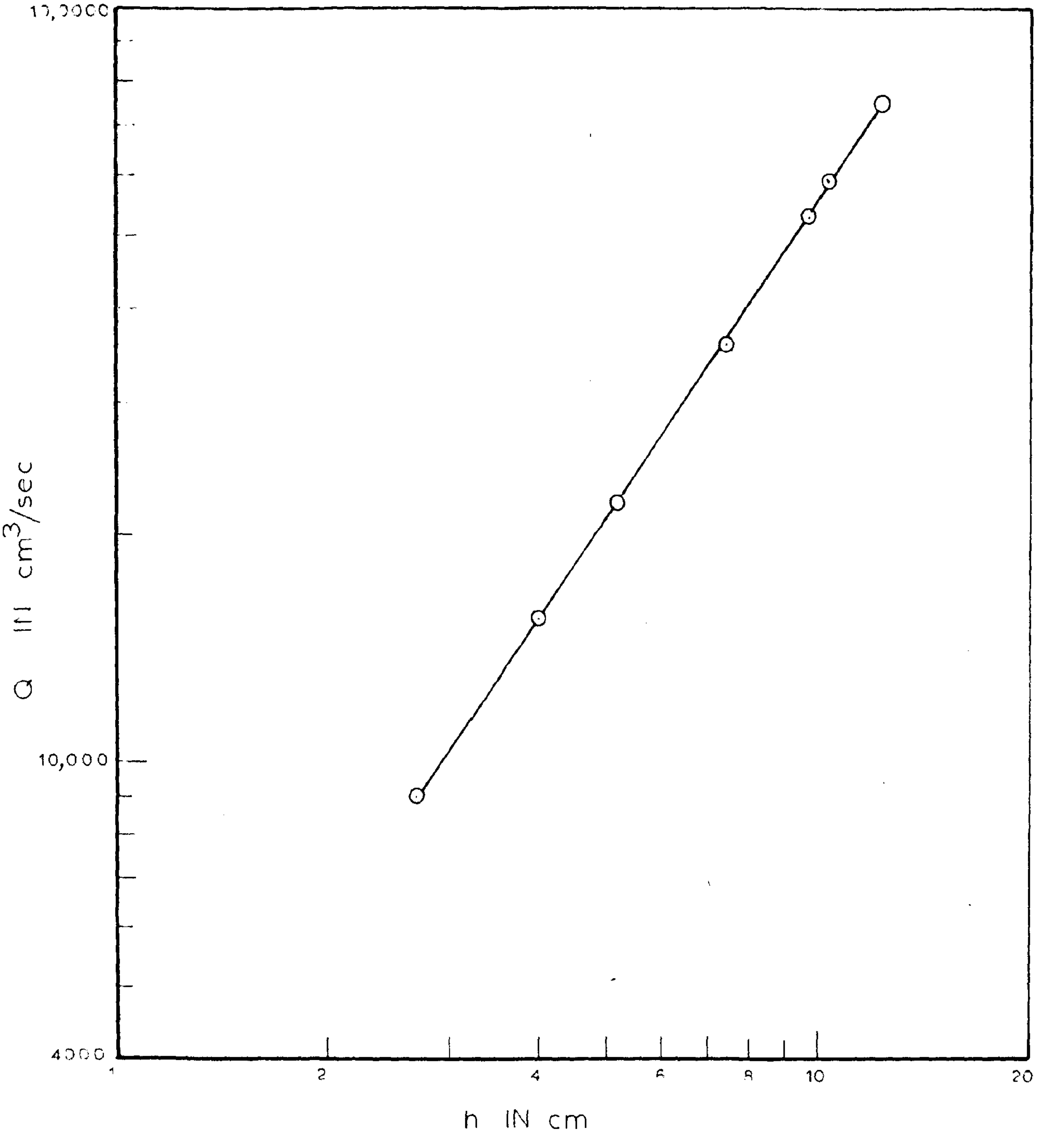


FIG. 3.3 _ CALIBRATION CURVE OF SHARP-CRESTED WEIR

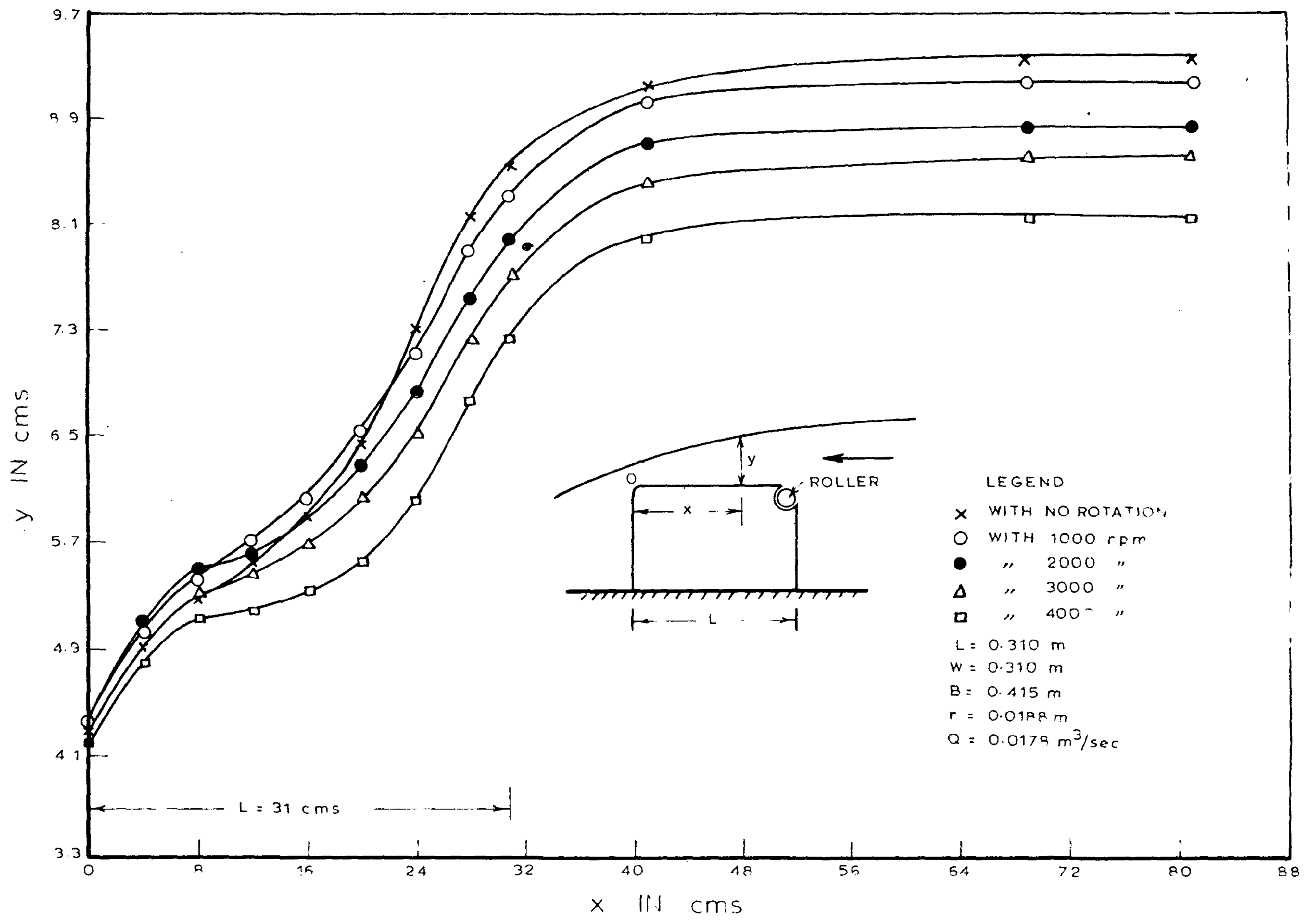


FIG. 4.1(A) _ TYPICAL WATER SURFACE PROFILES

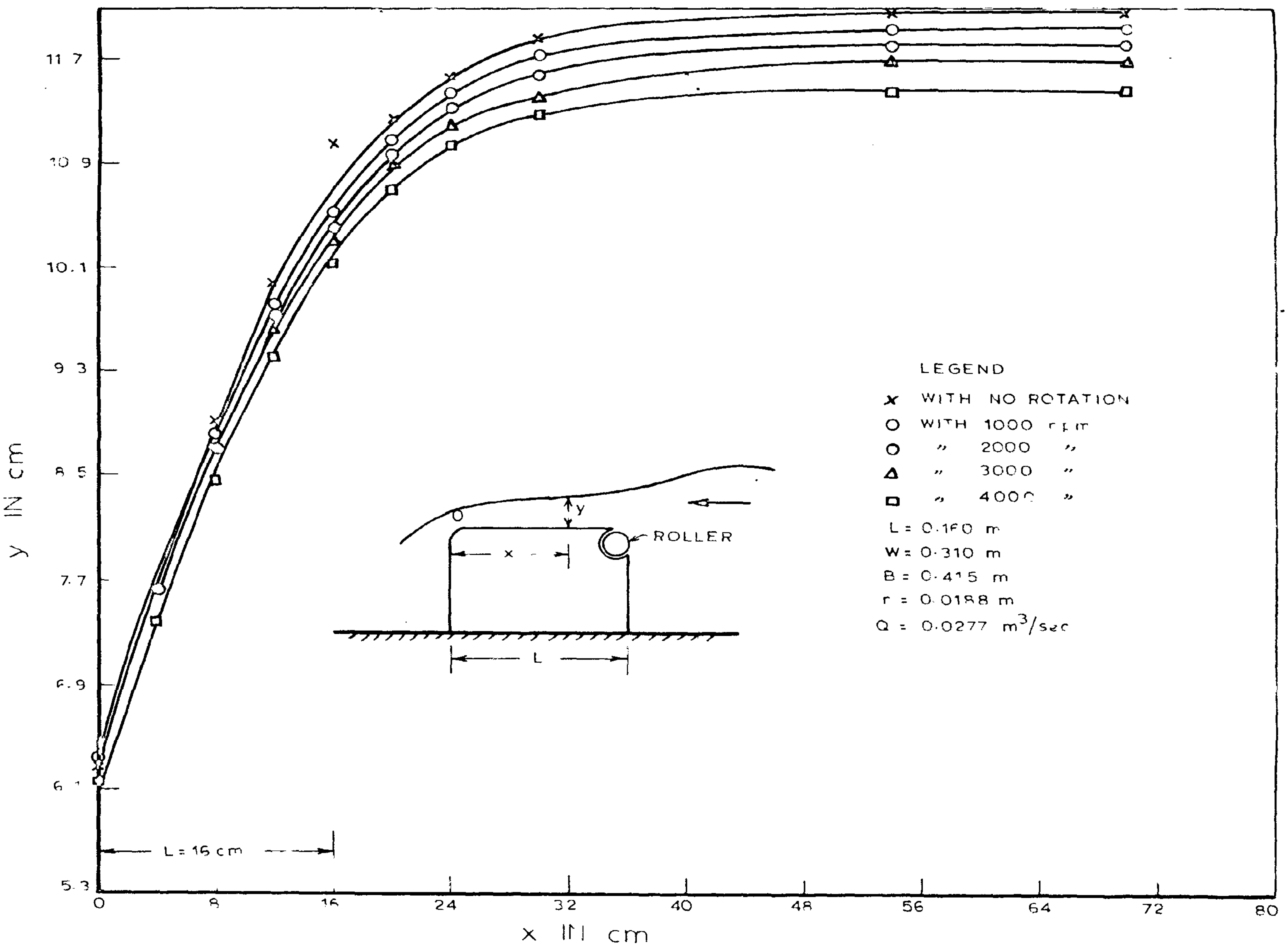


FIG. 4.1 (B) _ TYPICAL WATER SURFACE PROFILES (CONTD.)

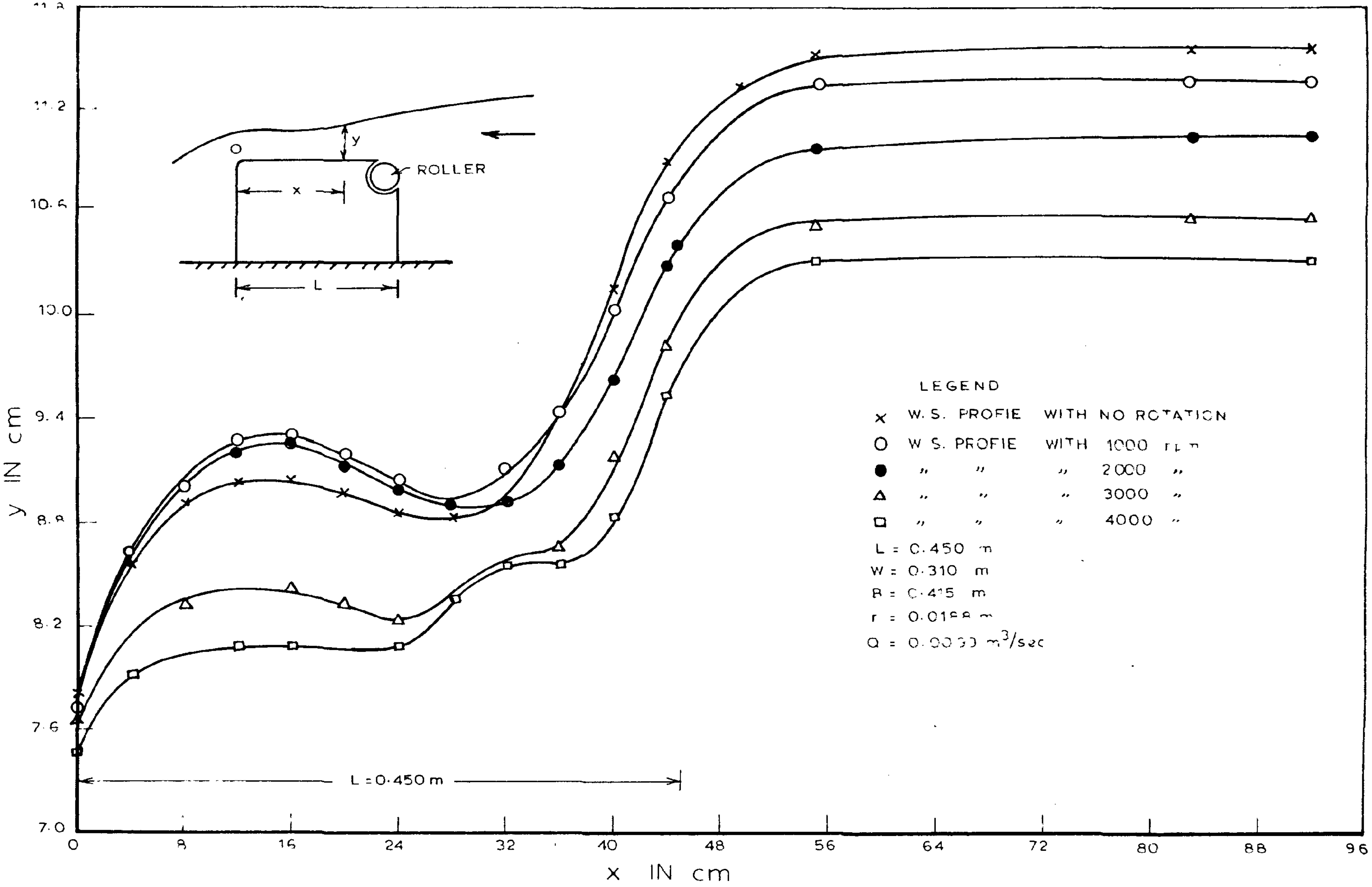


FIG. 4.1 (C) _ TYPICAL WATER SURFACE PROFILES (CONTD.)

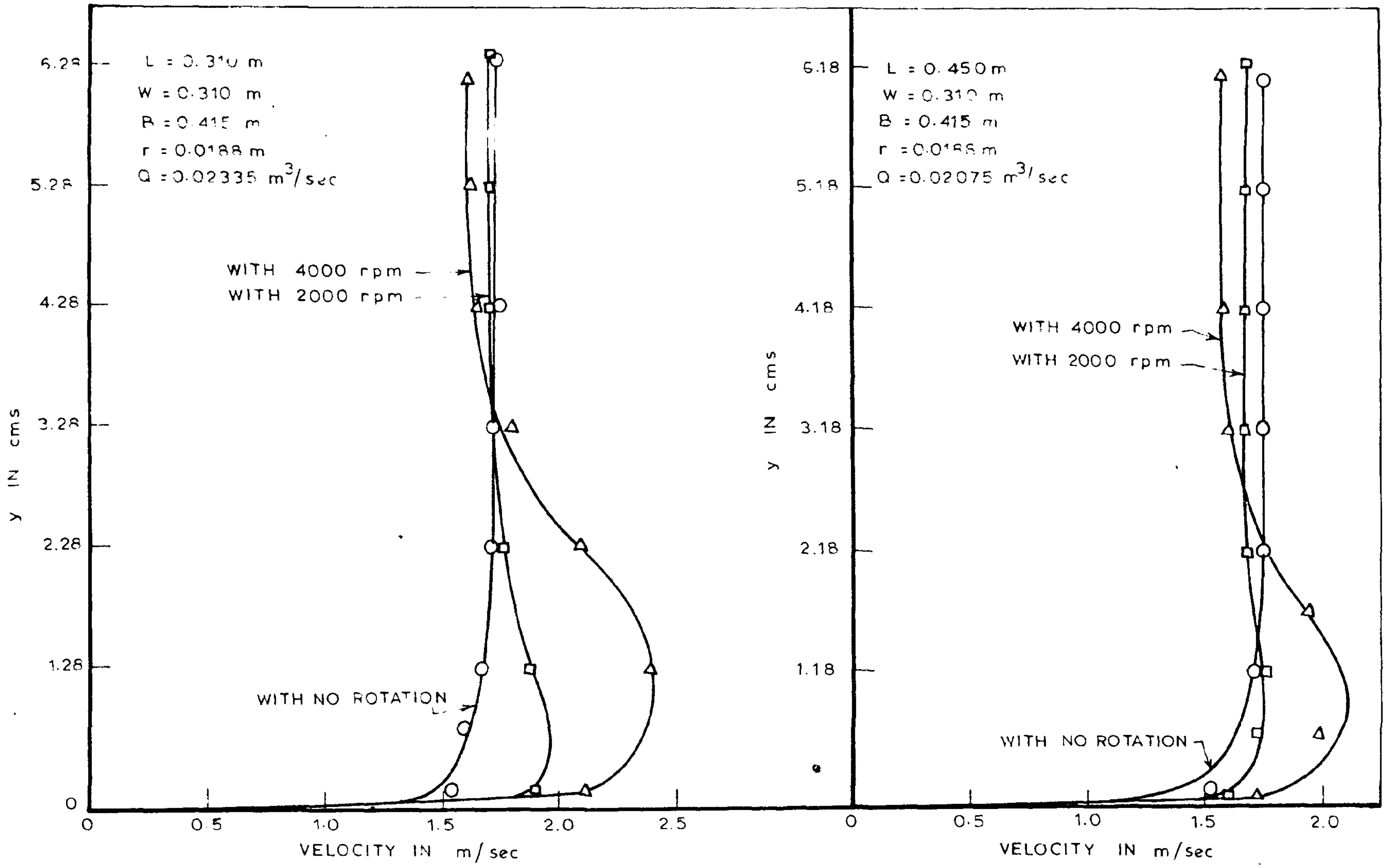


FIG. 4.2 _TYPICAL VELOCITY DISTRIBUTION PROFILES OVER THE CREST

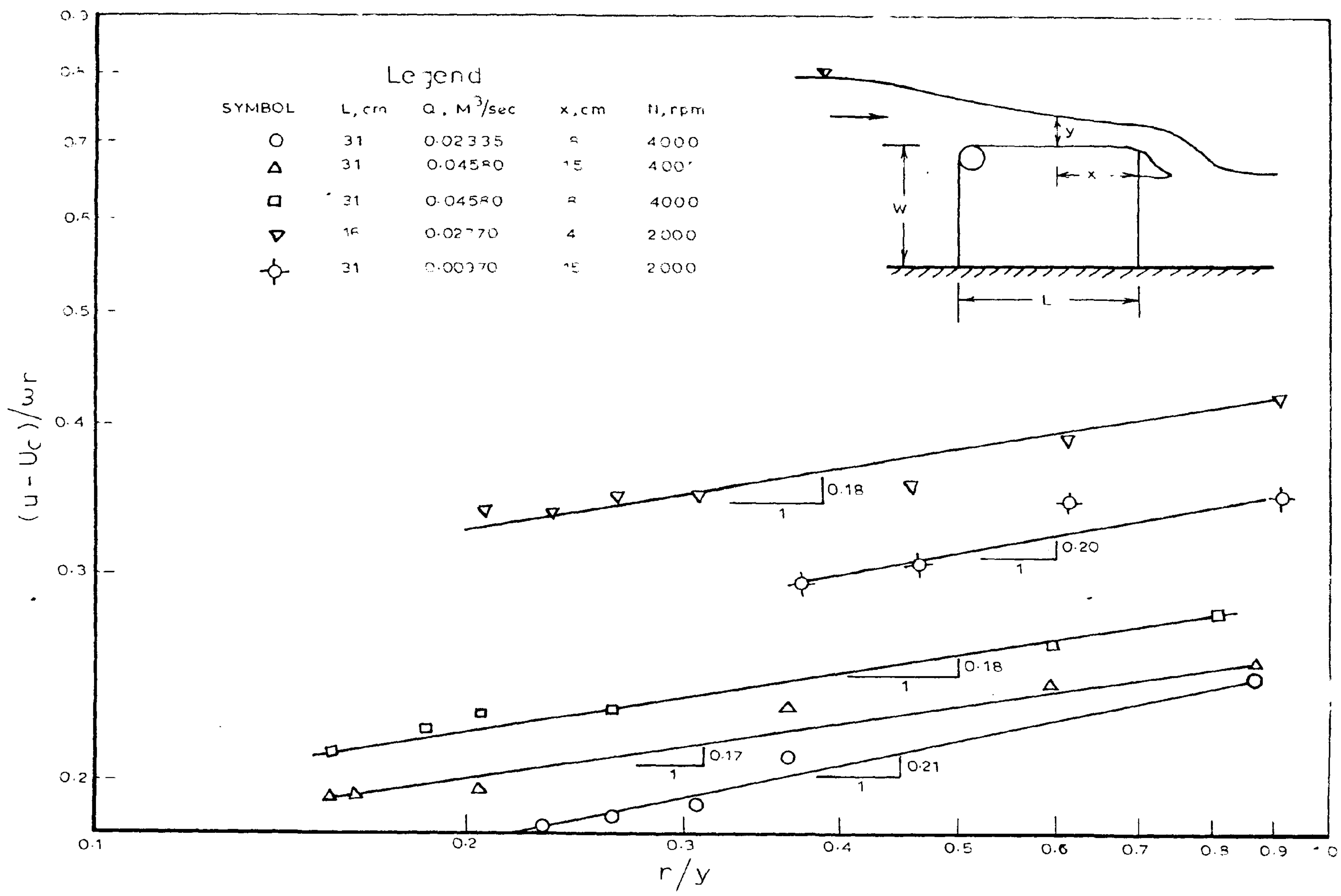


FIG. 4.3_VELOCITY DISTRIBUTION DUE TO IMPOSED ROTATION

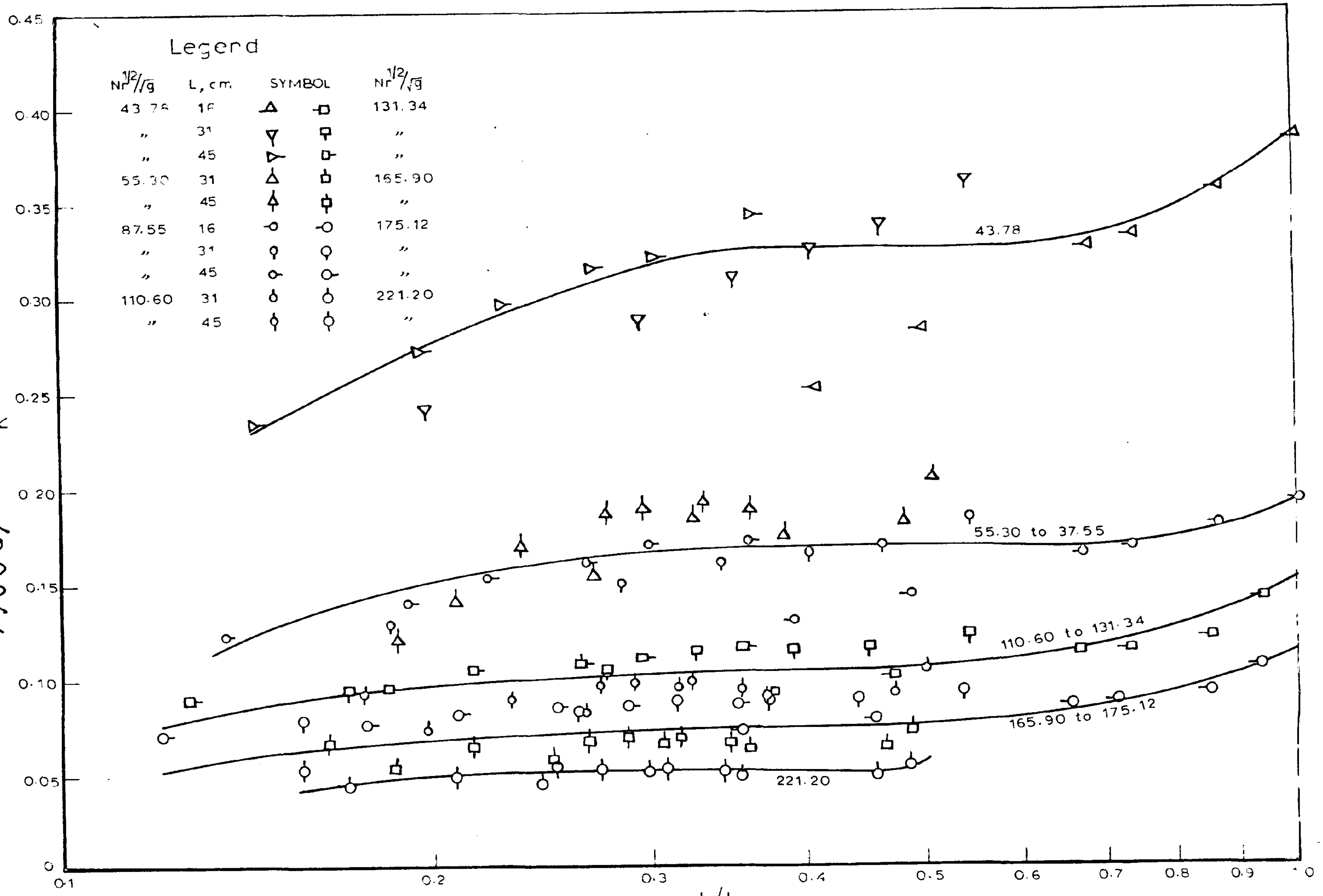


FIG. 4.4 _ VARIATION OF K WITH h/L

108841
CENTRAL LIBRARY UNIVERSITY OF ROORKEE
ROORKEE

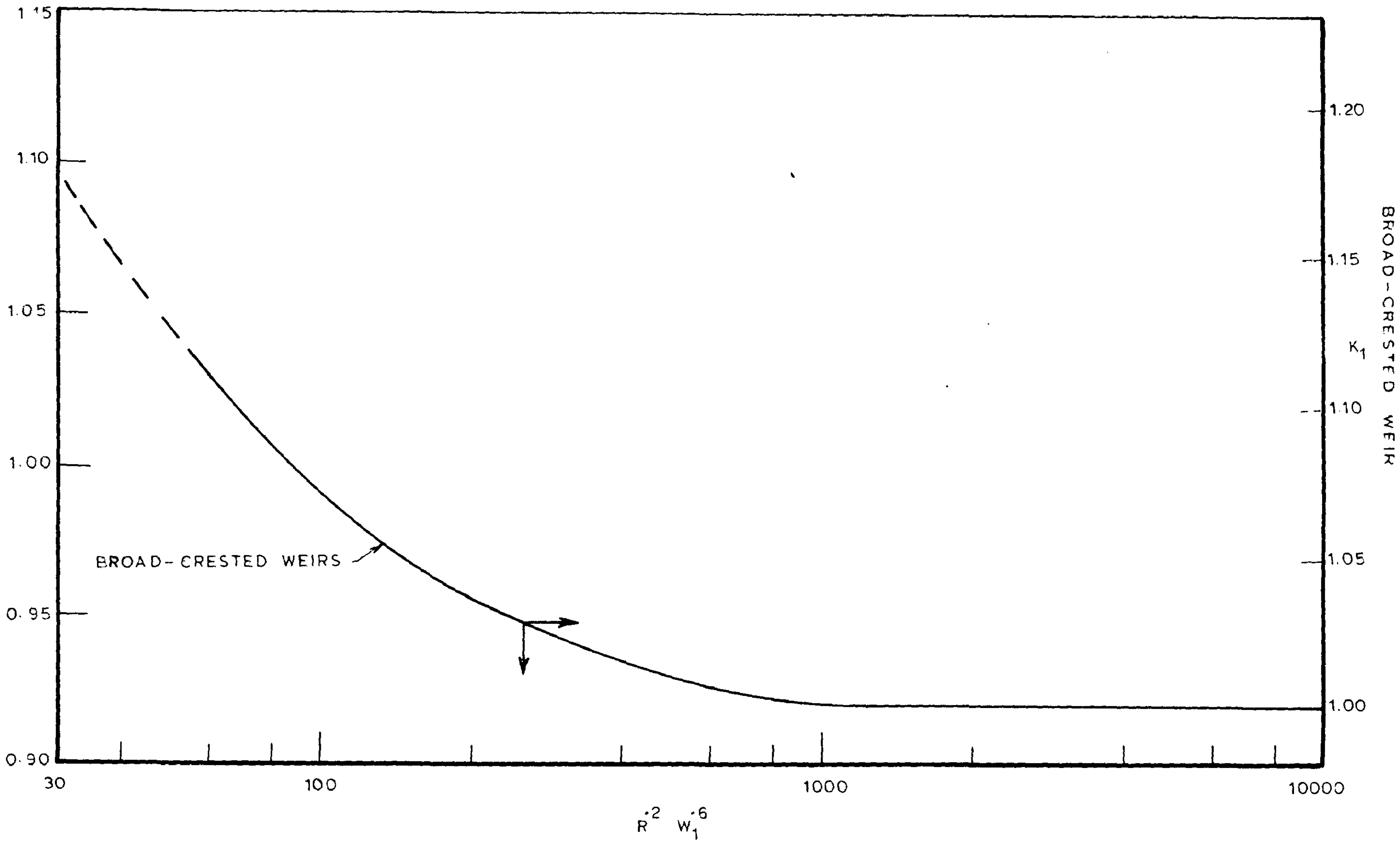


FIG.4.5_ CORRECTION FOR INFLUENCE OF VISCOSITY AND SURFACE TENSION

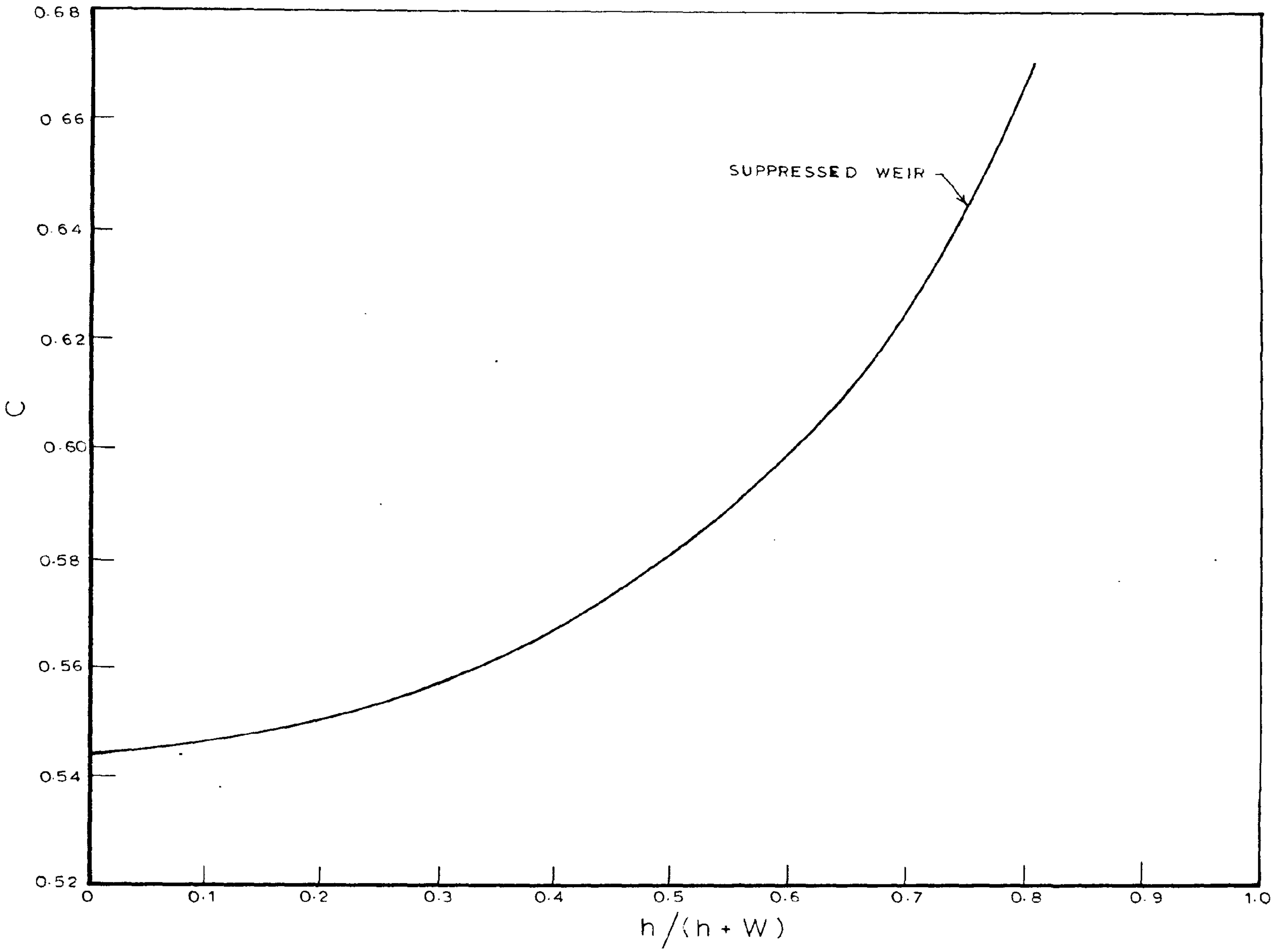


FIG.4.5-VARIATION OF C WITH $h/(h+W)$ AND B/B_1 FOR BROAD-CRESTED WEIRS

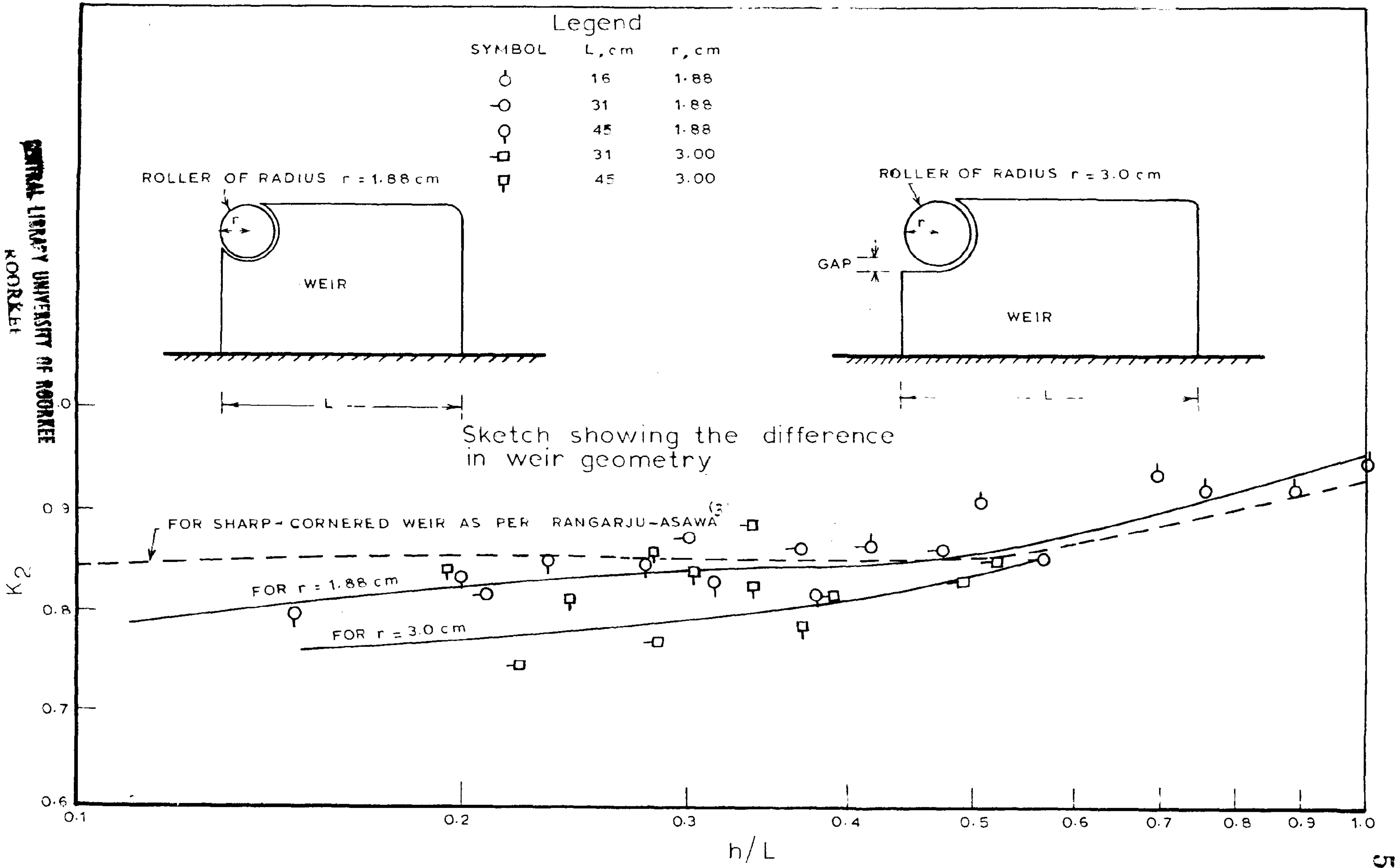


FIG. 4·7 _ VARIATION OF K_2 WITH h/L FOR B.C. WEIR (WITH NO ROTATION)

CENTRAL LIBRARY UNIVERSITY OF ROORKEE
ROORKEE

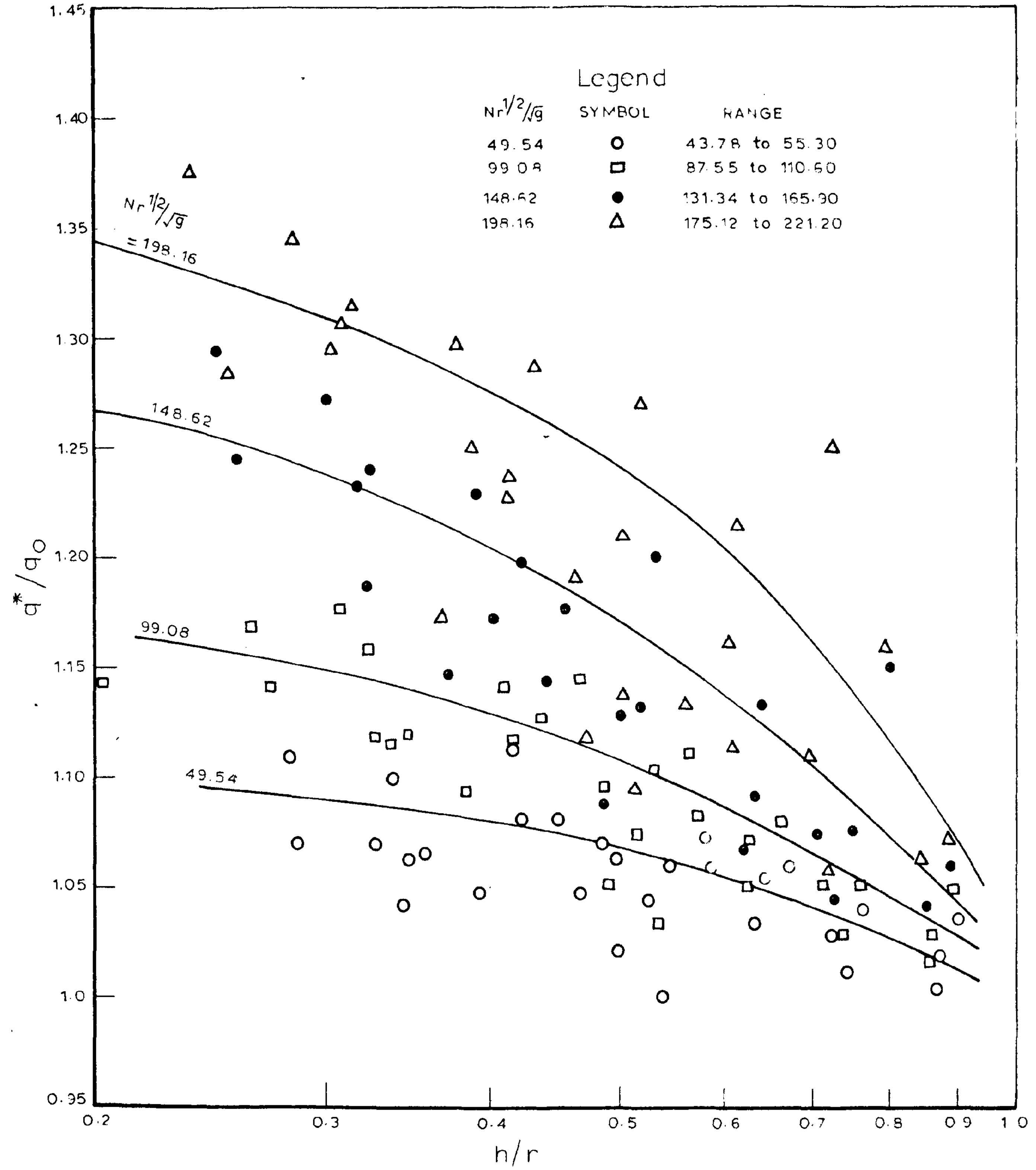


FIG. 4.8_VARIATION OF q^*/q_o WITH h/r FOR BROAD-CRESTED WIER WITH ROLLER