ACKNOWLEDGEMENT

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The author wishes to thank Mr Louis Stankevicius and Mr Danny Roy for their assistance in setting up the the experimental equipment. The assistance of the machine shop personnel in fabricating the instrumentation necessary for the experiment is thankfully acknowledged.

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NOTATION

a = gate opening

C_d = coefficient of discharge

C_{df} = coefficient of discharge for free flow

C_{ds} = coefficient of discharge for submerged flows

d = diameter of gate lip

$f(\ )$ = function of ( )

g = acceleration due to gravity

H_1 = upstream flow depth

H_2 = downstream flow depth close to the gate

H_3 = downstream flow depth away from the gate

q = discharge per unit width of the gate

R = $(Vd)/\nu$ = Reynolds number

V = q/a = mean velocity at the throat

v_1 = mean velocity at section 1

v_2 = mean velocity at section 2

α = angle of bevel

θ = angle of the pressure taps measured with reference to the approach direction

ϕ = angle of separation

b = $(1 - \sin\phi)/2$

t = height of separation point from the channel bottom

ν = kinematic viscosity

CHAPTER 1

INTRODUCTION

1.1 General Remarks

Sluice gates, Roller gates and Tainter gates are generally used for regulating flow in hydraulic structures. In designing these gates the head-discharge relationship and the pressure distribution over the gate surface for different gate openings and forms of the gate lip are of prime concern to the hydraulic engineer.

Extensive theoretical (3,4,6,7,14,16) and experimental (1,3,8,17,18,22) investigations have been carried out to determine the flow characteristics of sharp edged gates (Fig. 1a). However, the studies to determine the effect of the lip form on the discharge characteristics are limited (15,18,21).

In the present investigation experiments have been conducted to determine the factors influencing the discharge coefficient of the gates fitted with cylindrical lips (Figs. 1b and c).

The trend of the experimental data is supplemented by a simple theoretical model.

1.2 Previous Studies

1.2.1 Sharp-Edged Gates

The precise determination of the coefficient of contraction, defined as the ratio of the minimum flow section to the gate opening constitutes an important aspect of the discharge characteristics study. An analysis for the efflux from a slot in the wall of a reservoir for no gravity case was first carried out by Raleigh (17). Von Mises (14) later related the efflux from a two-dimensional slot to the efflux from a gate. He made use of the assumptions of free stream line theory of hydrodynamics namely, constant velocity along the free stream line and constant pressure across the jet at infinity.

A mathematical treatment of the sluice gate efflux accounting for the effect of gravity on the free surface has been given by Pajer (16). He assumed the velocity along the free stream line to vary with elevation, thus implicitly using the concept of hydrostatic pressure distribution in the sections of uniform flow. Southwell and Vaisey (20) solved the Laplace equation employing finite differences technique. Benjamin (3) gave a comprehensive analysis for the sluice gate flow. He treated the curvature of the water surface to be small and assumed hydrostatic distribution of pressure to occur beyond a certain distance downstream of the gate. For sharp-edged gates experimentally determined curves respresenting the values of Coefficient of discharge have been prepared by Henry (8). Other notable analytical solutions to the problem have been presented by Fangmeier and Strelkoff (6) and Klassen (9). Larock (10) has developed a gravity solution for any arbitrary gate inclination.

The above studies reveal that C_c varies mainly with a/H_1. However, the variation of C_c with a/H_1 is small, and for practical purposes Henderson has recommended a value of 0.61 for C_c.

1.2.2 Radial Gates

Until recently, designs of Radial or Tainter gates were carried out through specific hydraulic model studies. Metzler (13), Toch (22), and Babb (2) have made systematic studies related to specific hydraulic models. Toch has presented a simple analysis to describe the discharge characteristics of the Tainter gates for free and submerged flows based on energy and momentum considerations. Birkhoff (4) applied hydrodynamic theory in the form relaxation method to obtain an analytical solution for radial or curved gates. But the method is very tedious and each solution is applicable only to particular geometric proportions chosen.

Henderson (7) has proposed an equation for the coefficient of contraction C_c by fitting a parabola to both Von Mises' and Toch's results as

$$C_c = 1 - 0.75\theta + 0.36\theta^2 \quad (1)$$

where θ is the Tainter gate lip-angle (Fig. 1d).

1.2.3. Lip Geometry

Even though the sluice gates used in the Laboratory are sharp-edged, owing to the structural considerations and soundness of sealing at complete closure, the field conditions dictate a finite thickness at the end of the lip. Studies regarding the effects of lip geometry have been carried out by Mueller (15). Elaborate studies on the vibration caused in gates due to lip geometry have been made by Waterways Experiment Station (21). These studies have been reviewed by Rouse (18). The effect of the lip angle θ (Fig. 1d) on the coefficient of contraction has been discussed by Toch and later by Anwar (1). Recently Larock (11) has presented a theoretical study of the flow past a radial gate; the results complied with the experimental values obtained by other investigators.

1.3 Outline of the Present Study

The present experimental study aims at improving the discharge coefficient of a sluice gate by avoiding the downstream contraction caused by conventional gate lips (Fig. 1a). To this end, a circular lip was attached to the end of the leaf gate (Figs. 1b and c). The cylindrical lip is characterised by its ability to let the flow "cling" to the exit section of the gate. A consequence of this is to create a low pressure in the throat section which in turn enhances the outflow through the gate opening.

Presently the characteristics of the flow past a gate fitted with cylindrical end lip have been investigated. Simple theoretical expressions for computation of coefficient of discharge for free as well as submerged conditions have been developed.

CHAPTER 2

THEORETICAL CONSIDERATIONS

2.1 Definitions

2.1.1 Free Efflux

The outflow is said to be free when the issuing jet of water is open to atmosphere and is not overlaid, or submerged, by tailwater of excessive depth (Figs. 1b and 1c)

For flow past a cylindrical lip, separation can occur on the forebody or afterbody of the lip. The former is generally associated with laminar separation and is characterized by low Reynolds numbers with the diameter of the cylindrical lip as the length parameter. When the Reynolds number of the flow is relatively large, the separation point moves downstream of the point C on the cylinder as shown in Figure 1c ($\emptyset > 90^{o}$). Based on the mode of separation, two theoretical expressions are obtained in the ensuing section. However to unify the experimental results, a common discharge coefficient, C_{df}, defined by equation (1) is proposed for free flow conditions.

$$q = C_{df}\, a \sqrt{2g\,(H_1 - a)} \qquad (2)$$

where, q = discharge per unit width of the gate, H_1 is the upstream depth, and a is the gate opening.

2.1.2 Submerged Efflux

For the case of submerged outflow (Fig. 2) the coefficient of discharge, C_{ds}, is defined by equation (3)

$$q = C_{ds}\, a \sqrt{2g\,(H_1-H_2)} \qquad (3)$$

where H_2 is the tailwater depth immediately adjacent to the gate.

2.2 Coefficient of Discharge

An approximate theoretical expression has been developed to relate the discharge coefficients C_{df} and C_{ds} with the geometric parameters of the cylindrical lip. The angle of separation, $\emptyset$, is an important geometric parameter and is largely dependent on the Reynolds number.

2.2.1. Free Efflux

2.2.1.1. Forebody Separation Upstream of C(ϕ 90°, Figure 1c)

Applying the energy equation between sections 1 and 2 for flow past the gate lip (Fig. 1b) and neglecting losses one can write the following expression for the total head

$$H_1 + \frac{V_1^2}{2g} = t + \frac{V_2^2}{2g} \tag{4}$$

where H_1 is the upstream depth, V_1 and V_2 are mean velocities at sections (1) and (2) respectively. Further,

$$t = a + (1 - \sin \phi)\, d/2 = a + bd \tag{5}$$

$$\text{where } b = (1 - \sin\phi)/2 \tag{5a}$$

According to the equation of continuity

$$q = H_1 V_1 = C_c t\, V_2 \tag{6}$$

From equations (2), (4) and (6), the following expression for C_{df} can be obtained

$$C_{df} = \frac{C_c \, (1 + bd/a)}{\sqrt{(1 - a/H_1) \left[1 + \frac{C_c \, a}{H_1} (1 + bd/a) \right]}} \qquad (7)$$

for very small values of a/H_1 $(a/H_1 \rightarrow 0)$

$$C_{df} = C_c \, (1 + bd/a) \qquad (8)$$

Treating the flow under a cylindrical lip gate to be similar to the flow past a Tainter gate (Figs. 1b and 1d) for which C_c depends upon the separation angle ϕ, one may obtain the relationship

$$C_{df} = f_1 \, (\phi , d/a) \qquad (9)$$

Adopting equation (1) for C_c, proposed by Henderson, C_{df} has been evaluated as a function of d/a for fixed values of ϕ, and is shown in Figure 3 .

2.2.1.2. Afterbody Separation Downstream of C ($\phi > 90^{\circ}$)

Referring to Figure 1c, the energy loss in the short reach between sections (1) and (2) may be neglected. Further, assuming the pressure distribution to be hydrostatic at section (2) one may write

$$H_1 + \frac{V_1^2}{2g} = t + \frac{V_2^2}{2g} \tag{10}$$

According to the equation of continuity

$$q = V_1 H_1 = V_2 \, (a + bd) \tag{11}$$

Combination of equations (2), (10) and (11), yields

$$C_{df} = \frac{\left(1 - \frac{bd}{a}\right)}{\sqrt{\left\{1 - \frac{a}{H_1}\right\}\left\{1 + \frac{a}{H_1}\left(1 + \frac{bd}{a}\right)\right\}}} \tag{12}$$

For very small values of a/H_1 ($a/H_1 \rightarrow 0$)

$$C_{df} = 1 + \left(\frac{bd}{a}\right) \tag{13}$$

Hence

$$C_{df} = f_2 (\phi , d/a) \qquad (14)$$

the value of ϕ was difficult to measure accurately for large d/a ratios since the flow was structured and uneven immediately downstream of the gate. The measured values of ϕ varied between 100 - 110° for afterbody separations.

2.2.2 Submerged Efflux

For the flow past the sluice gate fitted with the cylindrical lip, the point of flow separation from the lip boundary occurs in the afterbody ($\phi > 90^{\circ}$) of the cylinder (Fig. 2), if the Reynolds number of the flow is very high.

Assuming the pressure distribution to be hydrostatic at the exit section and neglecting losses in view of the short reach considered, application of the energy equation between a section upstream of the gate (1) and the exit section (2) through point 'S' (Fig. 2) yields the following relationship.

$$H_1 + \frac{V_1^2}{2g} = H_2 + \frac{V_2^2}{2g} \tag{15}$$

According to the equation of continuity,

$$q = H_1 V_1 = (a+bd) V_2 \tag{16}$$

From equations (3),(15) and (16) the following relationship is obtained.

$$C_{ds} = \frac{(1 + bd/a)}{\sqrt{\left[1 - \frac{a}{H_1}\right](1 + bd/a)^2}} \tag{17}$$

For very small values of a/H_1 ($a/H_1 \rightarrow 0$), equation (17) may be simplified to the form,

$$C_{ds} = 1 + (bd/a) \tag{18}$$

Based on the gate opening a, the total head H_1, the lip diameter d and the Reynolds number R, C_{ds} can be expressed in terms of a/H_1, d/a and R.

$$C_{ds} = f_3(a/H_1, d/a, R) \tag{18 a}$$

CHAPTER 3

EXPERIMENTAL SET-UP AND PROCEDURE

A schematic representation of the experimental set-up is shown in Fig.4. Plexiglas cylinders 0.625" (1.59 cm), 2.25" (5.71 cm) and 5.0" (12.7 cm) in diameter were used to form the end lips of the gate in the exploratory tests (series 1, 2 and 3). These tests were performed in a 18" (45.7 cm) wide and 15" (38.1 cm) high recirculating steel flume. The maximum value of H_1 that could be attained was 36" (91.4 cm) and the depth of submergence in the downstream section of the sluice gate was controlled by an end gate. To obtain higher discharges per unit width of the gates in the main tests, the width of the flume was reduced to 5.27" (13.38 cm). In these tests (series 4, 5 and 6) brass cylinders 0.75" (1.9 cm), 3.13" (7.95 cm) and 6.0" (15.24 cm) in diameter were used to form the end lips of the gates. For the brass cylindrical lips, pressure taps 1/32" (0.079 cm) in diameter were provided in each lip at 10^{o} intervals (Fig. 4a).

The flow depths H_1, H_2 and H_3 were measured by point gauges and the discharge past the gate was measured with the help of a standard 90^{o} V notch. The range of variables covered in the present investigation are given in Tables 1 and 2. The accuracy of measurements are summarised in Table 3.

Except for cases of very low submergence, the flow depths H_2 and H_3 could be measured accurately. However, when H_2 could not be measured accurately due to the flow instability immediately downstream of the gate, an estimate of H_2 was obtained, based on the momentum equation using the known values of q, a, H_1 and H_3.

By increasing the loss in the supply line the same discharge could be maintained through the gate for a range of H_2 (submergence) and hence, H_1 was varied over a wide range. This permits the study of the variation of C_{ds} with a/H_1 for nearly constant values of Reynolds number.

CHAPTER 4

ANALYSIS OF RESULTS

4.1 Free Efflux

4.1.1 Theoretical Expressions

For the case of forebody separation, characterised by laminar flow separation, the variation of the discharge coefficient C_{df} with d/a is shown in Figure 5. Clearly, for any fixed value of $\emptyset$, C_{df} increases with d/a when a/H_1 is very small. Further, the envelope shown in Figure 3 defines the lower limit for the coefficient of discharge, C_{df}.

For the case of afterbody separation, characteristic of turbulent flow separation, equation 13 represents the variation of C_{df} with d/a for small values of a/H_1 ($a/H_1 \rightarrow 0$). The angle of separation for turbulent boundary layers on two dimensional circular cylinders can be between 110° and 130° according to Schlichting (19) and Daily and Harleman (5).

4.2 Experimental Results

For the free flow conditions, Figure 6 denotes the value of the discharge coefficient C_{df} as a function of the gate opening ratio a/H_1. The diameter ratio d/a is used as the group parameter. The dark lines indicate the bounds of C_{df} for the different diameter ratios in the lower range of a/H_1. Clearly, for very large gate openings ($a/H_1 \longrightarrow 1$), C_{df} can be expected to reach an asymptotic value of unity as in the case of a sharp edged gate. This asymptotic value of C_{df} will be independent of the Reynolds number and the lip shape. For the range of tests covered C_{df} attained a value near 1.15. This can be considered high relative to the discharge coefficient of a conventional gate. It is to be noted that the value of C_{df} can be low if the Reynolds number is sufficiently small and leads to early flow separation well ahead of point C, (Fig. 1b). The range of Reynolds numbers covering the experimental points is limited to 1.2×10^4 to 7.24×10^5 due to equipment limitation.

For forebody separation, characteristic of low Reynolds number, the envelope curve of figure 3 is replotted in Figure 5. It may be seen that this curve denotes the lower bound for the experimental values of C_{df}.

Typical pressure distribution on the gate lip for the two possible types of free flow conditions is shown in Figure 7.

At higher values of d/a, the flow was slightly structured and uneven. For the case of afterbody separation the measured values of ϕ for free flows varied between 105° and 115° and were generally lower than that for the submerged case (Art. 4.2) and resulted in lower values of C_{df}.

For very low values of d/a, the curve relating C_{df} and d/a (Fig. 5) indicates that the cylindrical lip behaves as a perturbation attached to a sharp edged gate and C_{df} reaches a value of 0.61.

4.2 Submerged Efflux

Figure 9 denotes the value of the gate discharge coefficient C_{ds} as a function of the gate opening ratio a/H_1. The diameter ratio d/a is used as the group parameter. The dashed lines indicate the bounds of C_{ds} for the different diameter ratios in the lower ranges of a/H_1. For the range of tests covered, C_{ds} attained a value which was as high as 1.5. This can be considered to be large relative to the discharge coefficient of conventional gates (Fig. 1a). An examination of the data (Fig.9) indicates that there are two distinct limits of C_{ds} for most of the d/a ratios considered. These limits generally correspond to the lower and upper ranges of the Reynolds number based on the cylinder diameter. The difference between the lower and the upper bounds of C_{ds} appears to diminish as the value of d/a decreases since it behaves like a sharp edged gate.

The two limiting values of C_{ds} are used to develop a relationship between C_{ds} and d/a (Fig. 8). The range of Reynold numbers covered in the tests for the various d/a ratios are also shown in the Figure. During the tests, it was observed that the transition between the lower and upper bound of C_{ds} was more abrupt with changes in Reynolds numbers when the d/a ratios were high. Although it was desirable to conduct the tests within a very large range of Reynolds numbers, the Reynolds numbers R in the present tests were confined to a range of 1.6×10^4 to 6.6×10^5, due to equipment limitations. In general, the discharge coefficient increased with an increase in the Reynolds number of the flow for all values of a/d. The insert of Figure 8 indicates the agreement between equation 18 and the asymptotic trend of the upper bound of the experimental data Consequently, for a given lip diameter, d, one can obtain the value of the gate opening for fixed values of q and H_3.

For very small diameter ratios ($d/a \rightarrow 0$), the behaviour of the curve denoting C_{ds} and d/a (Fig. 8) indicates that the cylindrical lip tends to behave as a perturbation attached to a sharp edged gate. Consequently, the value of C_{ds} for the gate with the cylindrical lip will attain a value of 0.61 for extremely small values of d/a and a/H_1. In the laboratory, the measured values of the discharge coefficient can be slightly different because of the free stream turbulence (12).

As in the free case, for flow past a gate fitted with an end lip, two types of flow can occur depending on the location of the point of separation. Typical pressure distribution on the gate lip for the two possible types of flows is shown in Figure 10. As expected, at low Reynolds numbers, the boundary layer on the gate lip is laminar and the point of separation occurs on the forebody of the cylinder ($\phi \leq 90^{\circ}$). At higher Reynolds numbers, the boundary layer becomes turbulent and the point of separation moves to a location in the afterbody ($\phi > 90^{\circ}$). For most of the present experiments, the value of ϕ at larger Reynolds numbers was of the order of 115^{0}.

CHAPTER 5.

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions can be drawn from the study of discharge characteristics of a sluice gate fitted with a cylindrical end lip.

1) For both laminar and turbulent boundary layer separations, the coefficients of discharge C_{df} and C_{ds} increase linearly with d/a for small values of a/H_1 and fixed values of ϕ.

2) The coefficient of discharge of a leaf gate can be increased to as high a value as 1.5 by providing a suitable cylindrical end lip for submerged conditions.

3) The experimental values of both C_{df} and C_{ds} are functions of the Reynolds number at fixed d/a ratios and can vary over a wide range depending on the Reynolds number.

In particular, at higher d/a ratios, C_{df} and C_{ds} increase with Reynolds number. The values of C_{df} and C_{ds} obtained through experiments generally lie between the theoretical limits of C_{df} and C_{ds}. However, in the free efflux case, the values of C_{df} and higher d/a ratios were not large enough to attain the upper limit due to the structured nature of flow and comparatively lower separation angles.

4) For very small values of d/a (d/a ⟶ 0), the cylindrical lip behaves as a perturbation at the end of the gate and the corresponding value of C_{df} and C_{ds} is of the order of 0.61.

5.2 Applications and Scope for Further Study

Sluice gates with higher discharge coefficients are desirable under circumstances in which the head room limitations restrict the vertical traverse of the gate, as in control gates housed in a tunnel or under a bridge. The cylindrical gate lip can be effectively adopted under such conditions. Further, the existing leaf gates may be fitted with the cylindrical end lips to increase the discharge rate.

In order to enhance the study, the following further investigations are suggested:

1) Due to the limitation of the set up, the free efflux for higher values of d/a was slightly structured and uneven. Further studies with improved flow conditions is desirable to confirm the findings of this investigation.

2) Studies on the behaviour of the discharge coefficient for larger values of d/a and Reynolds number may be carried out.

3) For effective adoption of the cylindrical lip gate, it is desirable to investigate the characteristics of vibrations that may occur due to the instability in the separation zone below the gate lip.

APPENDIX I - REFERENCES

1. Anwar, H.O., "Discharge Coefficient for Control Gates", Water Power, April 1974, pp 152.

2. Babb, A., Moayer, M., and Amorocho, J., Discharge Coefficients of Radial gates, University of California, Davis, Water Science and Engineering, Paper 1013, 1966.

3. Brooke, B., On the Flow in Channels when Rigid Obstacles are Placed in the Stream, J. Fluid Mechanics I, 227, 1956.

4. G. Birkhoff, "Calculation of Potential Flows with Free Streamlines", proc. A.S.C.E., vol 87, no. HY6. (November 1961), p 17.

5. Dailey and Harleman, Fluid Dynamics, Addision Wesley Co., Mass., 1966.

6. Fangmeier, D.D., and Strelkoff, T.S., "Solution for Gravity Flow under a Sluice Gate", J. Eng. Mechs. Division, Prof. ASCE, No. 4, Feb 1968, pp 153-176.

7. Henderson, F.M., - Open Channel Flow, MacMillan Publishing Co., New York, 1966.

8. Henry, H.R., "A Study of Flow from a Submerged Sluice Gate", thesis presented to the State University of Iowa, at Iowa City, Iowa, in February, 1950, in partial fulfillment of the requirements for the degree of Master of Science.

9. Klassen, V.J., "Flow from a Sluice Gate Under Gravity", Journal of Mathematical Analysis and Applications, Vol. 19, No. 2, August 1967, pp 253-262.

10. Larock, B.E., Gravity Affected Flow from Planar Sluice Gates, Proceedings of ASCE HY4 Paper No. 6674, July 1969.

11. Larock, B.E., A Theory for Free Outflow Beneath Radial Gates, Journal of Fluid Mechanics, Vol. 41, Part 4, pp 841-864, printed in Great Britain, 1970.

12. McCorquodale and Hannoura, A.A., "Grid Turbulence in Hydraulic Models", Journal of Hydraulic Research, 14, No. 3., 1976, pp 207-216.

13. Metzler, D.E., A Model Study of Tainter Gate Operation, Thesis State University of Iowa, Iowa City, 1948.

14. Mises, R. Von "Berechnung von Ausfluss und Uberfallzahlen". Z. Ver. Dtsch. Ing., Band 61, 1917. pp 447-452, 469-474 and 493-498.

15. Mueller, O., "Schwingungsuntersuchungen an unterstromten Versuchsanstalt für Wasserbav und Schiffbav, No. 13, 1933.

16. Pajer, G., Über den Strömungsvorgang an einer Unterströmten Scharfkantigen Planschutze, Z. Angew. Math. Mech. 17, 259, 1937.

17. Rayleigh, L., Notes on Hydrodynamics, Phil. Mag. (5) 2, 441, 1876.

18. Rouse, H., "Engineering Hydraulics", J. Wiley and Sons, New York, 1950.

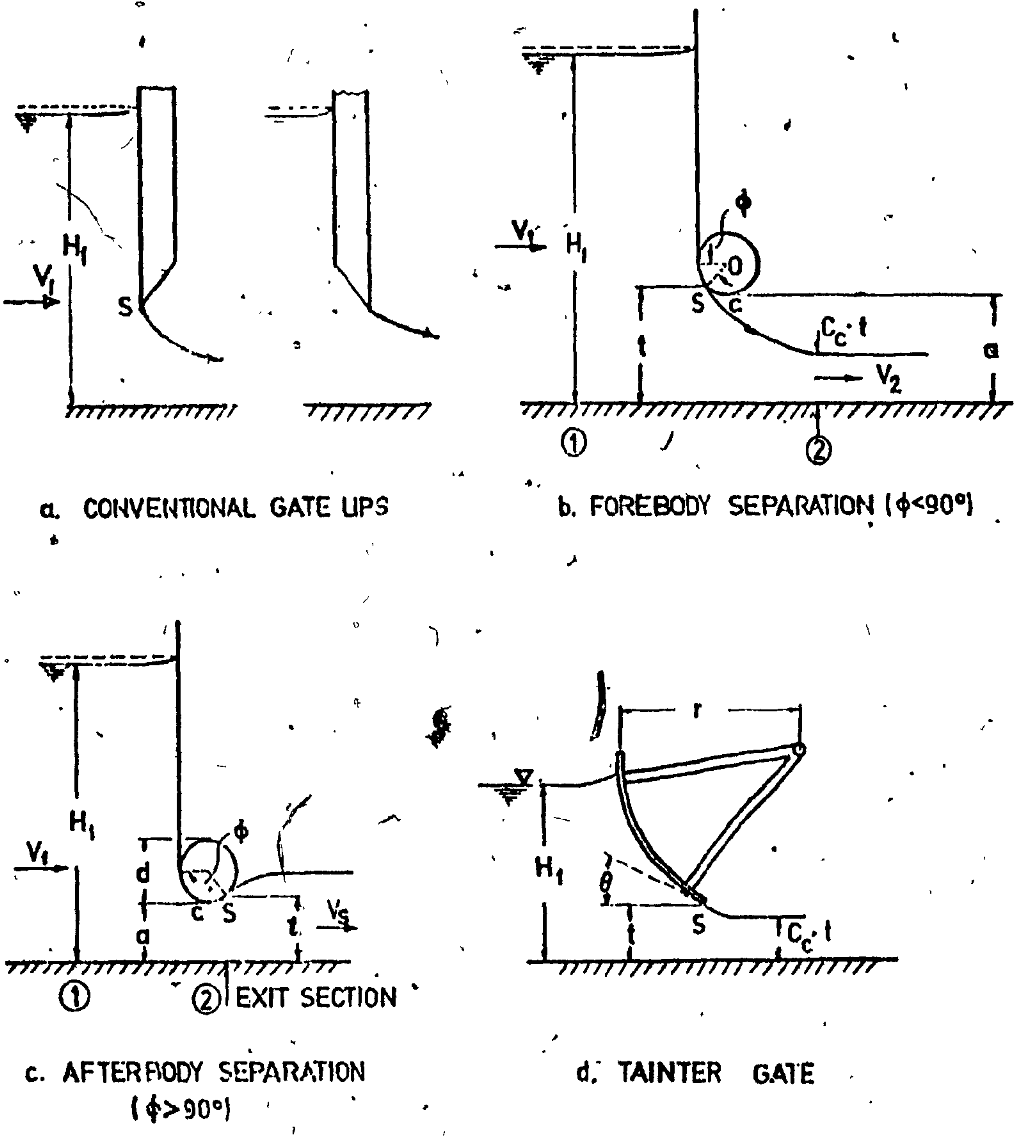
19. Schlichting, H., "Boundary Layer Theory", McGraw Hill Publishers, New York, 1968.

20. R.V. Southwell and G. Vaisey. "Relaxation"Methods Applied to Engineering Problems: XII, Fluid Motions characterised by 'free' streamlines". Proc. ASCE, Vol 87, No. HY6 (Number 1961), p.17.

21. Tiffany, J.B., "Laboratory Research Applied to the Hydraulic Disign of Large Dams", Waterways Experiment Station, Vicksburg, Mississippi, Bulletin 32, 1948.

22. Toch, A., Discharge Characteristics of Tainter Gates, Paper No. 2739, Transactions ASCE Vol. 120, pg. 290, 1955.

APPENDIX II - FIGURES



a. CONVENTIONAL GATE LIPS

b. FOREBODY SEPARATION (ϕ<90°)

c. AFTERBODY SEPARATION (ϕ>90°)

d. TAINTER GATE

FIG. 1 DEFINITION SKETCH - FREE EFFLUX

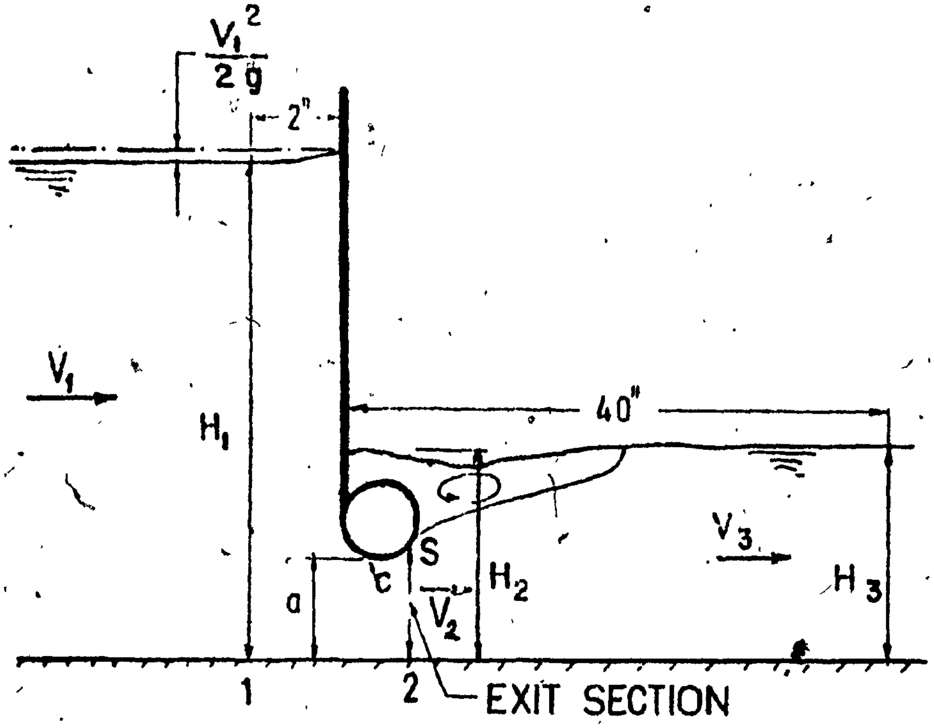


FIG. 2 DEFINITION SKETCH - SUBMERGED EFFLUX

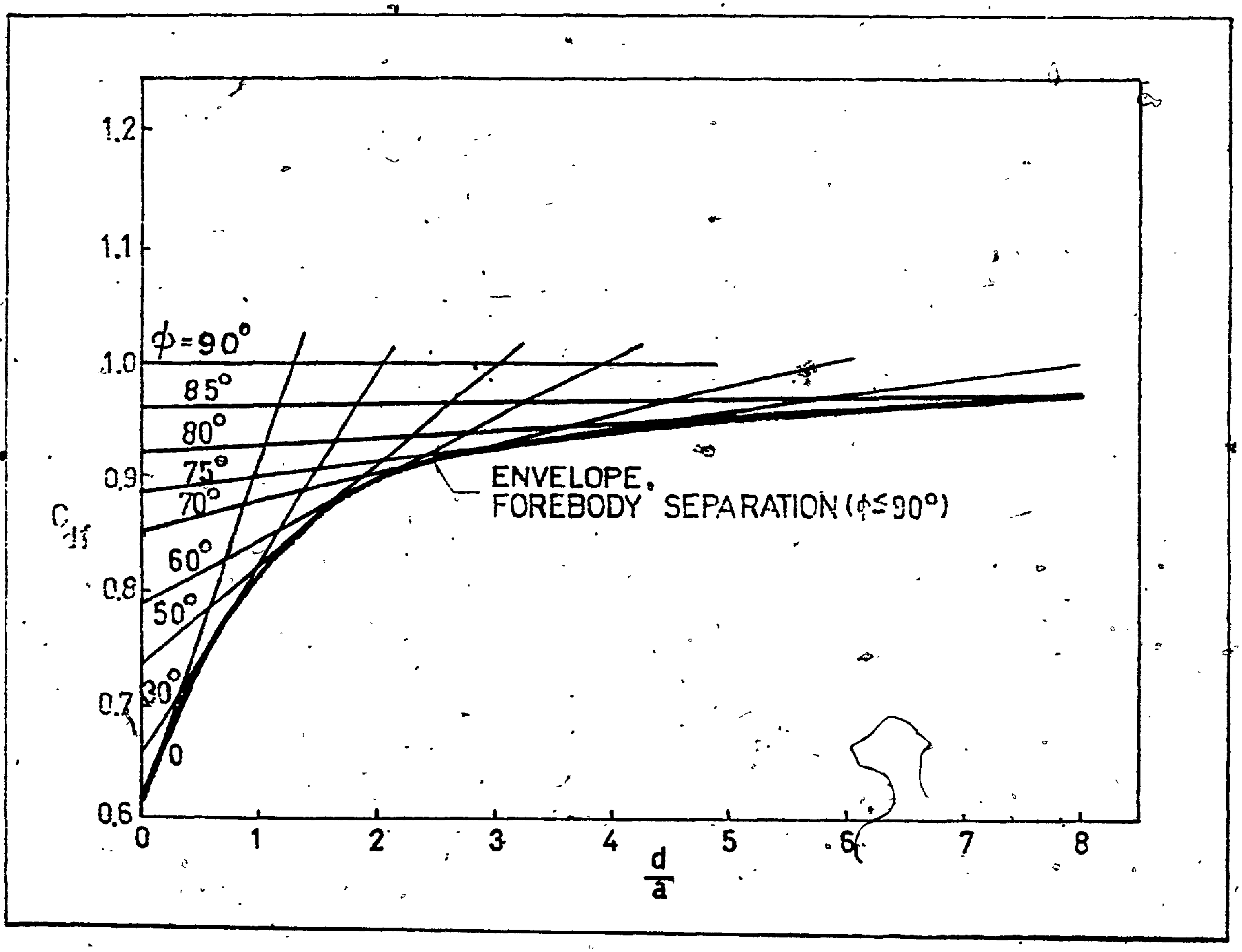


FIG. 3 VARIATION OF C_{df} WITH ϕ AND d/a

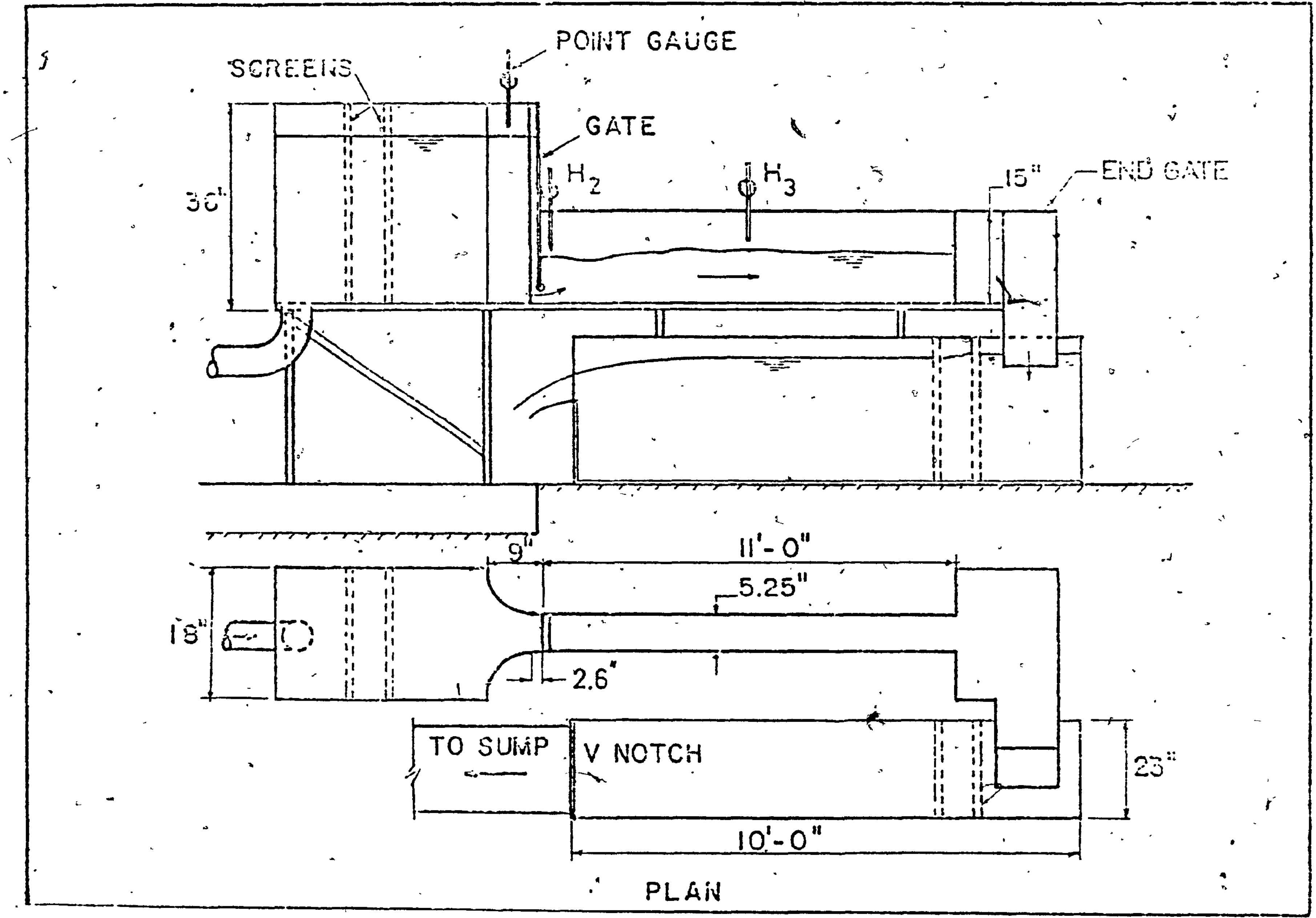


FIG. 4 EXPERIMENTAL LAY-OUT

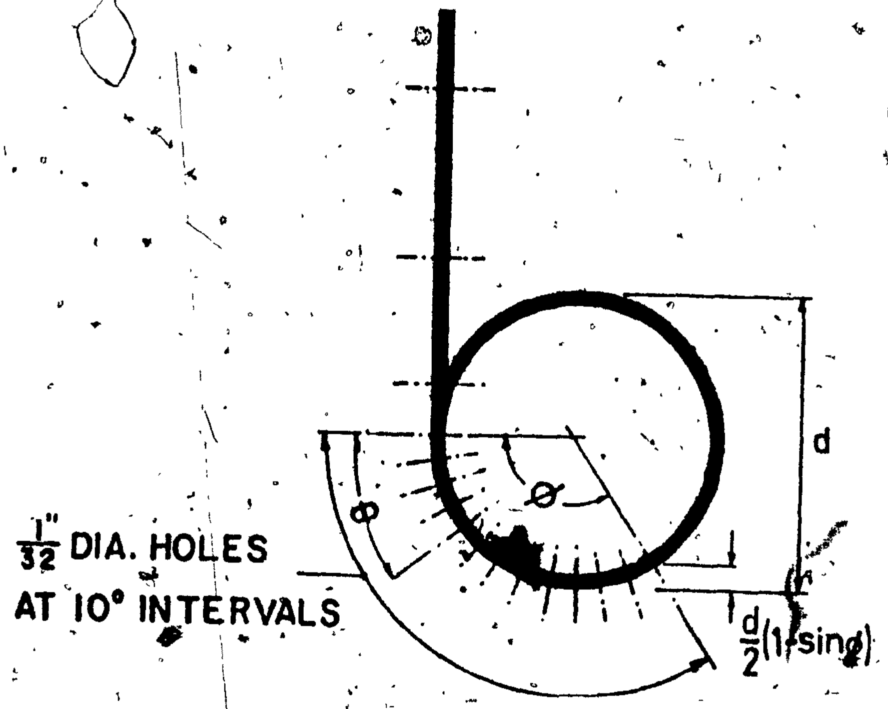


FIG. 4a CYLINDRICAL LIP

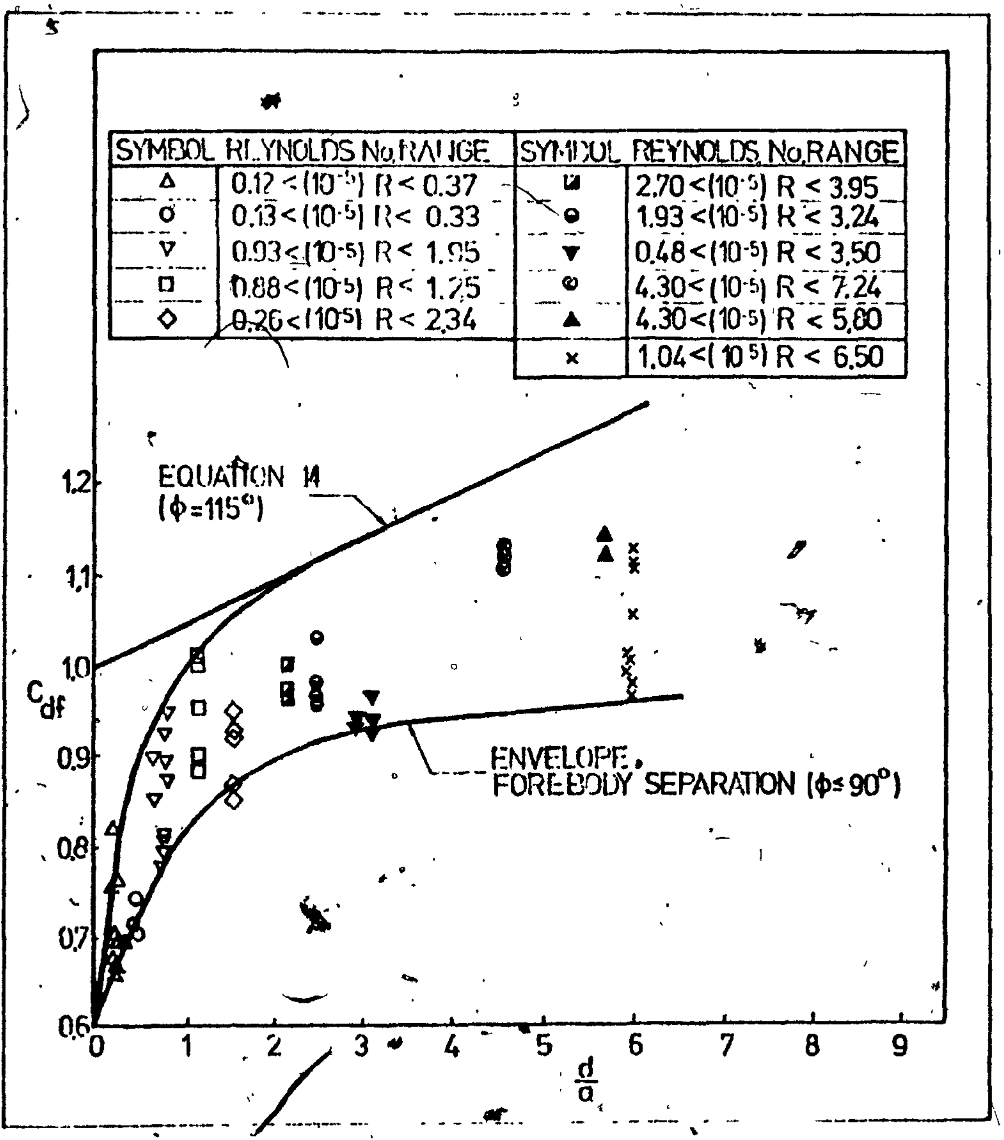


FIG. 5 VARIATION OF C_{df} WITH d/a

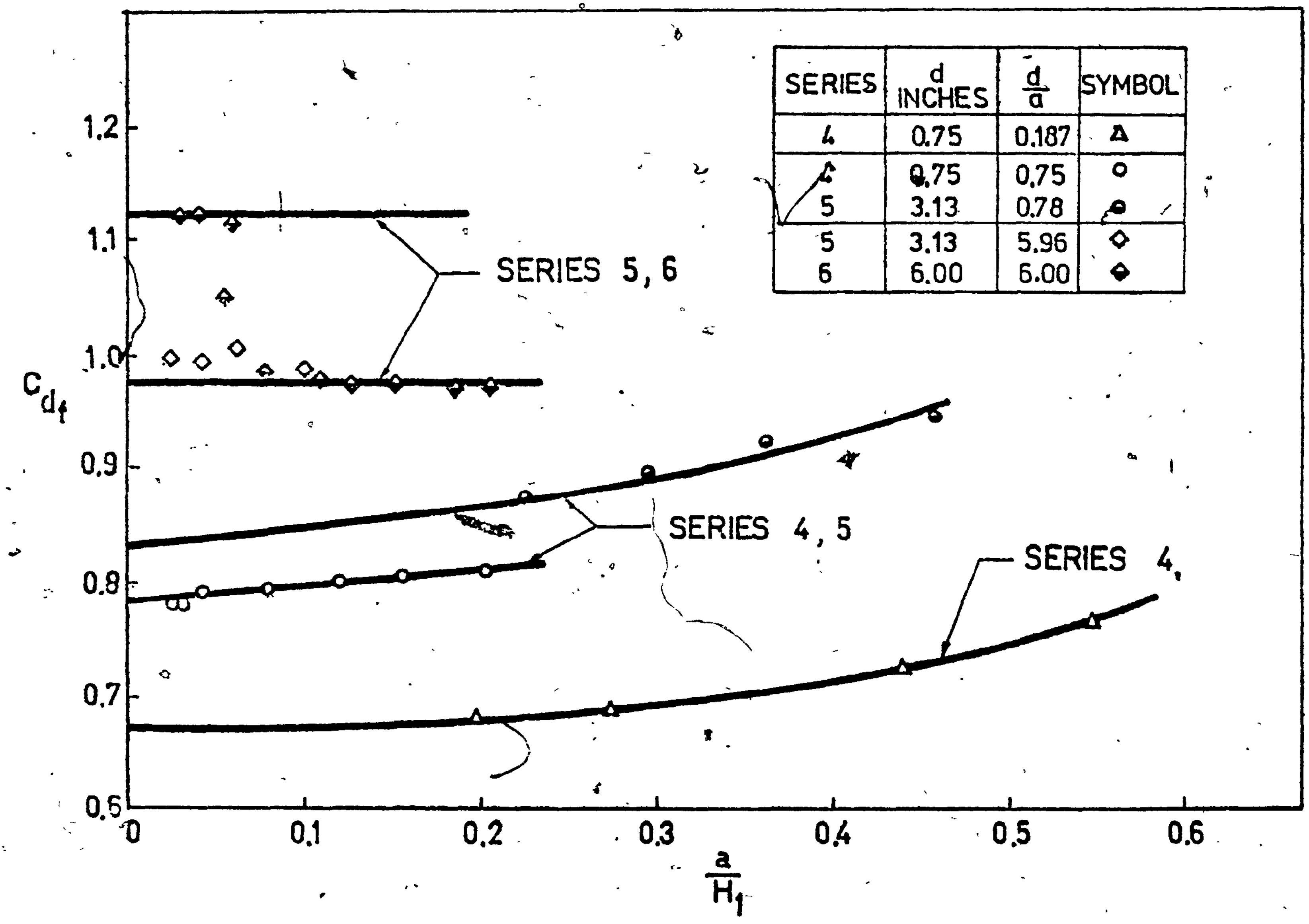


FIG. 6 VARIATION OF C_{df} WITH a/H_1

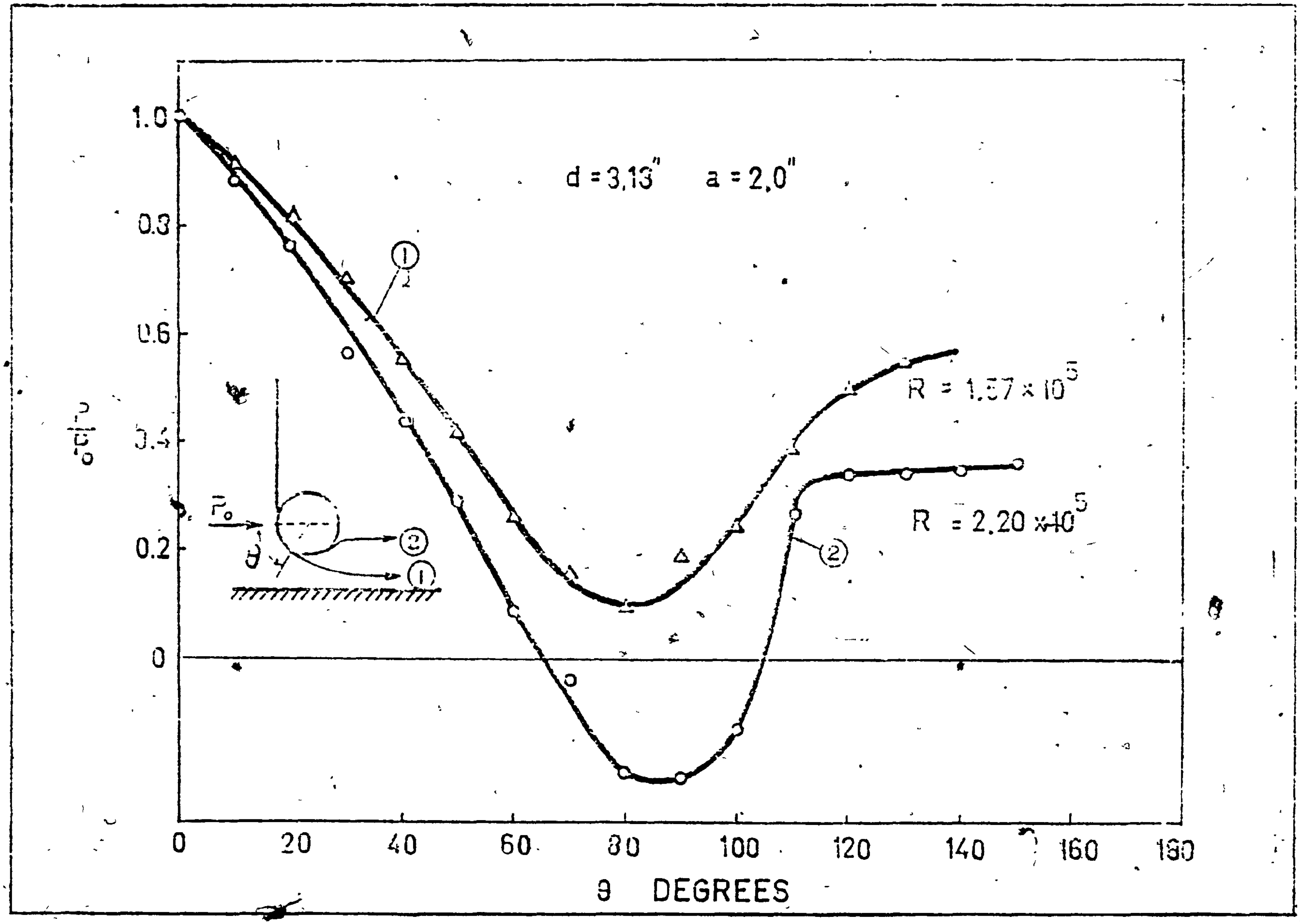


FIG. 7 PRESSURE DISTRIBUTION ON THE CYLINDRICAL LIP- FREE EFFLUX

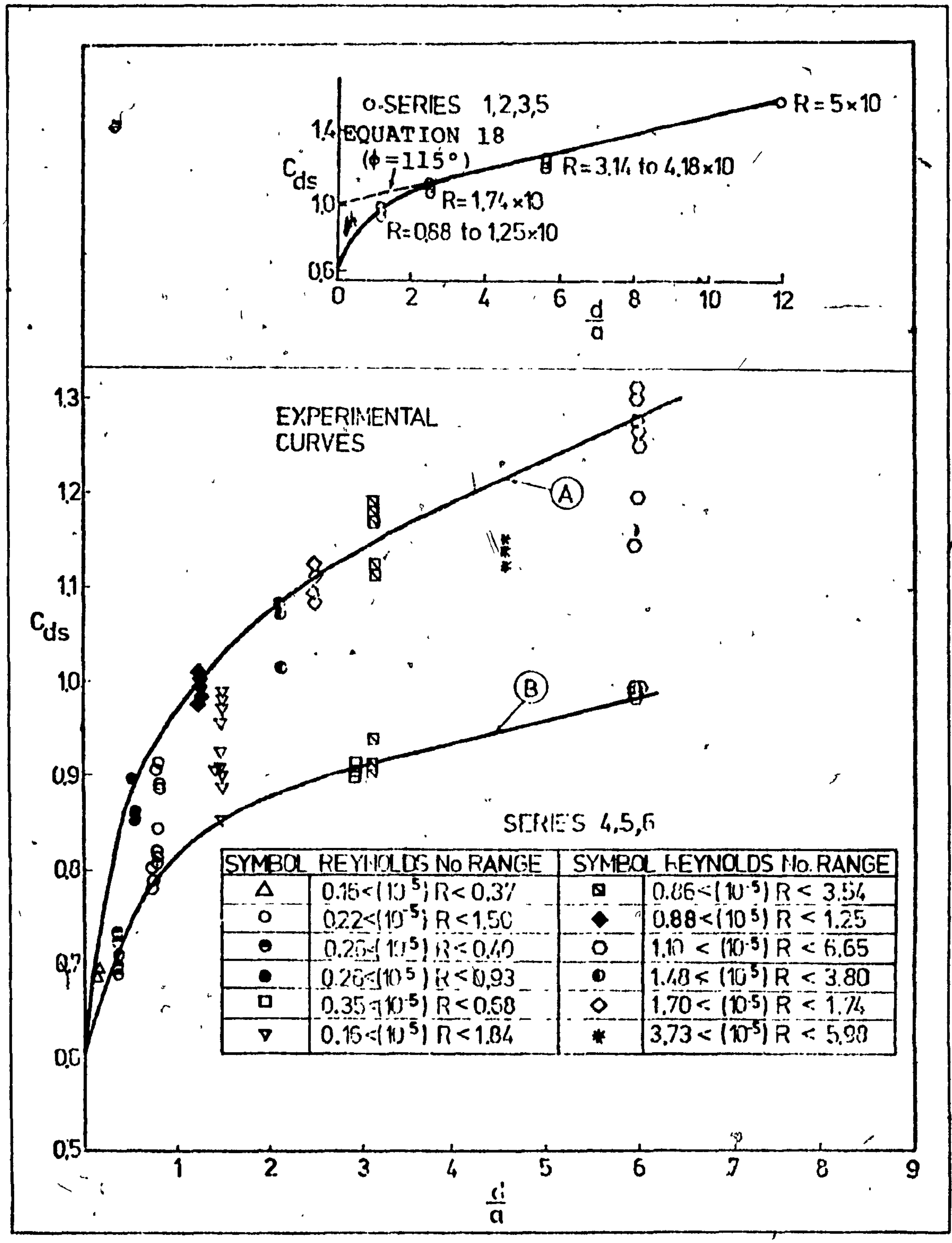
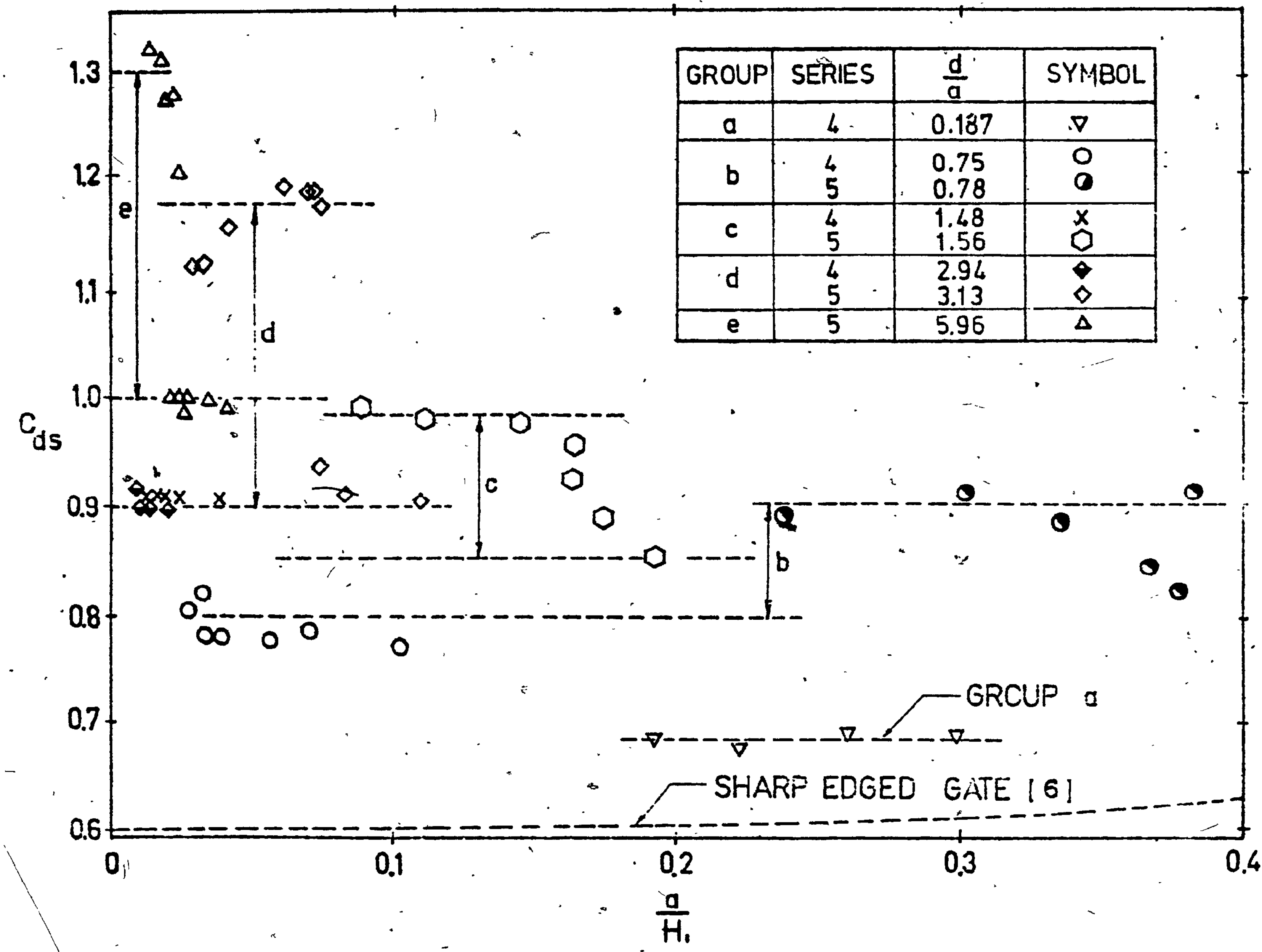


FIG. 8 VARIATION OF C_{ds} WITH d/a



FIG, 9 VARIATION OF C_{ds} WITH a/H_1

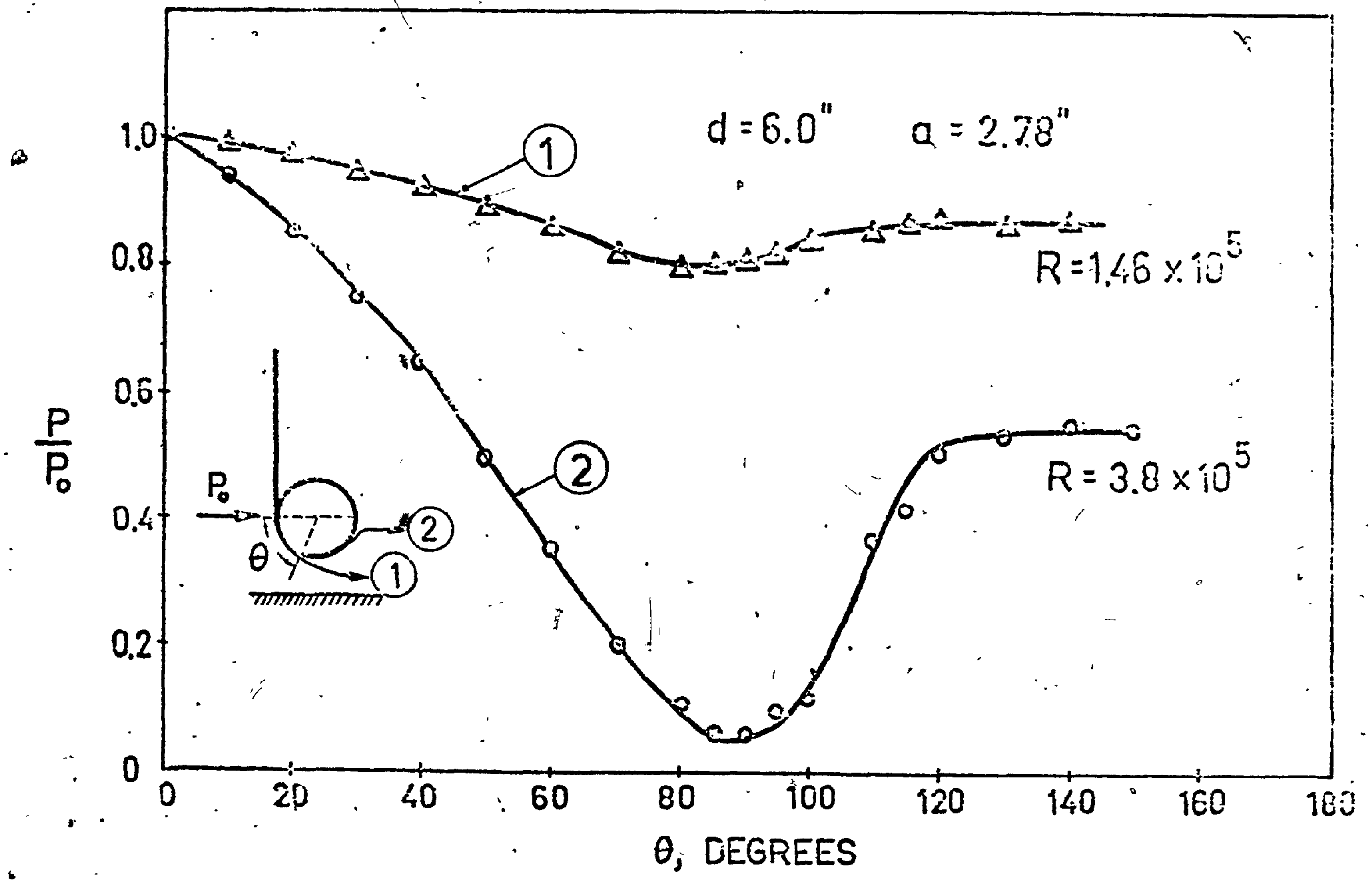


FIG. 10 PRESSURE DISTRIBUTION ON THE CYLINDRICAL LIP- SUBMERGED EFFLUX

TABLE - 1

RANGE OF VARIABLES : FREE EFFLUX

	Series 1	Series 2	Series 3	Series 4	Series 5*	Series 6
Flume width (inches)	18.0	18.0	18.0	5.27	5.27	5.27
Lip diameter d (inches)	0.62	2.25	5.0	0.75	3.13	6.00
Gate opening a (inches)	1.44-2.62	2.00-3.53	0.875,2.00	0.261,0.50 1.00,4.00	0.26,0.52, 1.0,2.0,4.0	1.0,1.31, 2.78
Discharge Q(cfs)	0.48-1.65	0.79-2.10	0.76-1.81	0.053-0.94	0.09-0.87	0.16-0.81
Unit discharge q (ft^2/sec)	0.317-1.1	0.53-1.37	0.49-1.207	0.12-2.10	0.21-2.51	0.36-1.84
Depth, H_1 (inches)	9.0-22.3	7.20-20.3	4.80-24.00	9.80-35.60	8.90-34.8	6.00-35.0
Depth, H_2 (inches)	6.8-13.9	5.80-14.6	2.50-13.90	2.00-10.60	5.17-10.15	4.20-12.0
Reynold number $R \times 10^{-5}$	0.16-0.33	0.26-1.25	1.70-4.20	0.16-0.68	0.38-3.50	1.46-7.24
d/a	.434,.239	1.125,.637	5.714,2.5	2.94,1.5, 0.75,0.187	12.04,5.96, 3.13,1.565, 0.783	6.0,4.58, 2.16
a/H_1	0.08-0.617	0.179-0.662	0.04-0.378	0.008-0.55	0.015-0.46	0.029-0.33

Note: 1" = 2.54 cm   1 cfs = 0.02857m^3/sec

*Pressure distributions on cylindrical lips were obtained

TABLE - 2

RANGE OF VARIABLES : SUBMERGED EFFLUX

Varible	Range of Variable					
	Series 1	Series 2	Series 3	Series 4	Series 5	Series 6
Flume width (inches)	18.0	18.0	18.0	5.27	5.27	5.27
Lip diameter (inches)	0.625	2.250	5.000	0.750	3.130	6.00
Gate opening, a (inches)	1.44,2.62	2.00,3.53	0.875,2.0	0.255,0.50 1.0,4.0	0.26,0.525, 1.0,2.0,4.0	1.0,1.31,2.78
Discharge Q, (cfs)	0.54-1.65	0.57-1.5	0.68-1.03	0.054-0.89	0.095-0.87	0.10-0.77
Unit discharge q_o, (ft^2/sec)	0.36-1.1	0.43-1.0	0.45-0.69	1.123-2.03	0.21-1.98	0.23-1.75
Depth H_1, (inches)	9.0-22.3	7.2-20.3	4.8-24.0	9.8-35.6	8.9-34.8	6.0-35.0
Depth H_2, (inches)	6.8-13.9	5.8-14.6	2.5-13.9	2.0-10.6	5.17-1o.15	4.2-12.0
Reynold number, $R \times 10^{-5}$	0.16-0.33	0.26-1.25	1.7-4.2	0.16-0.68	0.38-3.50	1.46-6.6
Gate opening ratio, a/H_1	0.05-0.29	0.10-0.48	0.04-0.41	0.01-0.30	0.02-0.45	0.03-0.26
Diameter ratio, d/a	0.24-0.44	0.64-1.13	2.50-5.71	1.87-2.94	0.78-5.96	2.16-6.00

Note:1 in = 2.54 cm, 1 cfs = 0.02857 cumecs

*Pressure distribtuions around cylindrical lips were obtained.

TABLE - 3

ACCURACY OF MEASUREMENTS

Sl.No.	Variable	Accuracy of Measurements
1	Length	± 0.001"
2	Head	± 0.001"
3	Discharge	± 3.0%
4	Angle	± 5°
5	Viscosity	± 0.5%
6	Temperature	± 0.5°F

TABLE 3 FREE EFFLUX

SERIES: 1 DIA. OF LIP, d(in): 0.625 WIDTH OF CHANNEL, B(in): 18.00

Sl.No.	Gate Opening a(in)	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	H_1 - a (in)	d/a	a/H_1	C_{df}	$R_e x10^5$
1	2.6250	0.4870	04.25	01.6250	0.238	0.617	0.760	0.124
2	2.6250	0.6700	06.15	03.5250	0.238	0.427	0.705	0.171
3	2.6250	0.9470	10.55	07.9250	0.238	0.249	0.666	0.695
4	2.6250	0.8290	08.39	05.7650	0.238	0.313	0.695	0.211
5	2.6250	1.1033	13.68	11.0550	0.238	0.192	0.656	0.281
6	2.6250	0.9273	10.02	07.3950	0.238	0.262	0.670	0.236
7	1.4375	0.3670	04.93	03.4925	0.435	0.292	0.706	0.152
8	1.4375	0.5640	09.76	08.3225	0.435	0.147	0.705	0.232
9	1.4375	0.7970	18.05	11.6613	0.435	0.080	0.705	0.329
10	1.4375	0.6300	11.69	10.2525	0.435	0.123	0.710	0.260
11	1.4375	0.3170	03.81	02.3725	0.435	0.377	0.744	0.131

TABLE 4 FREE EFFLUX (CONTINUED)

SERIES: 2 DIA. OF LIP, d(in): 2.25 WIDTH OF CHANNEL, B(in): 18.00

Sl.No.	Gate Opening a(in)	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	$H_1 - a$ (in)	d/a	a/H_1	C_{df}	$R_e x10^5$
1	2.0000	0.7280	05.60	03.60	1.125	0.357	1.000	0.880
2	2.0000	0.7720	05.91	03.91	1.125	0.338	1.010	0.940
3	2.0000	1.0300	11.17	09.17	1.125	0.179	0.885	1.250
4	2.0000	0.9920	10.28	08.28	1.125	0.195	0.900	1.210
5	2.0000	0.8660	07.65	05.65	1.125	0.262	0.950	1.080
6	3.5300	1.3650	08.56	05.03	0.636	0.412	0.895	0.930
7	3.5300	0.9700	05.33	01.80	0.636	0.662	0.852	0.660

SERIES: 3 DIA. OF CYL, d (in): 5.000 WIDTH OF CHANNEL, B (in)18.00

1	2.0000	1.2067	12.69	10.69	2.500	0.158	0.956	3.240
2	2.0000	1.0480	09.84	07.84	2.500	0.206	0.969	2.820
3	2.0000	0.9420	08.22	06.22	2.500	0.243	0.978	2.530
4	2.0000	0.7190	05.29	03.29	2.500	0.378	1.027	1.930

TABLE 4 FREE EFFLUX (CONTINUED)

SERIES: 3 DIA. OF LIP, d(in) : 5.000 , WIDTH OF CHANNEL, B(in) : 18.00

Sl.No.	Gate Opening a(in)	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1 (in)	$H_1 - a$ (in)	d/a	a/H_1	C_{df}	$R_e x10^5$
5	0.8750	0.4920	07.47	06.595	5.720	0.1770	1.140	3.020
6	0.8750	0.7000	14.56	13.685	5.720	0.0600	1.120	4.300
7	0.8750	0.8760	21.89	21.015	5.720	0.0400	1.140	5.380

SERIES: 4 DIA. OF CYL, d(in) : 0.750 WIDTH OF CHANNEL, B(in) : 05.28

Sl.No.	Gate Opening a(in)	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1 (in)	$H_1 - a$ (in)	d/a	a/H_1	C_{df}	$R_e x10^5$
1	0.2550	0.1233	07.37	07.155	2.940	0.0346	0.940	0.352
2	0.2550	0.1837	16.18	15.925	2.940	0.0346	0.936	0.525
3	0.2550	0.2750	36.00	35.745	2.940	0.0346	0.935	0.785
4	0.2550	0.2400	27.68	27.425	2.940	0.0346	0.932	0.685
5	0.505	0.1748	04.28	03.675	1.485	0.1180	0.925	0.258
6	0.505	0.2421	07.75	07.245	1.485	0.0652	0.925	0.357
7	0.505	0.3281	13.80	13.295	1.485	0.0366	0.926	0.484

TABLE 4 FREE EFFLUX (CONTINUED)

SERIES: 4 DIA. OF LIP, d(in): 0.750 WIDTH OF CHANNEL, B(in): 5.28

Sl.No.	Gate Opening a(in)	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1 (in)	$H_1 - a$ (in)	d/a	a/H_1	C_{df}	$R_e x10^5$
8	0.5050	0.3904	19.41	18.905	1.485	0.0260	0.924	0.576
9	0.5050	0.4737	28.71	28.205	1.485	0.0176	0.917	0.699
10.	0.5050	0.5237	35.00	34.495	1.485	0.0144	0.917	0.773
11	1.0000	0.8937	36.00	35.000	0.750	0.0278	0.783	0.650
12	1.0000	0.8418	32.62	31.620	0.750	0.0306	0.776	0.590
13	1.0000	0.7200	22.90	21.90	0.750	0.0437	0.794	0.500
14	1.0000	0.5131	12.17	11.17	0.75	0.0822	0.796	0.374
15	1.0000	0.4183	08.31	07.31	0.75	0.1200	0.802	0.305
16	1.0000	0.3610	06.37	05.37	0.75	0.1570	0.808	0.263
17	1.0000	0.3100	04.94	03.94	0.75	0.2020	0.812	0.226
18	4.0000	1.1400	07.33	03.33	0.187	0.5500	0.820	0.207
19	4.0000	1.3130	09.07	05.07	0.187	0.4410	0.756	0.228

TABLE 4 FREE EFFLUX (CONTINUED)

SERIES: 4 DIA. OF LIP, d(in): 0.750 WIDTH OF CHANNEL, B(in): 5.28

Sl.No.	Gate Opening a(in)	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	$H_1 - a$ (in)	d/a	a/H_1	C_{df}	$R_e x10^5$
20	4.0000	1.7580	14.60	10.600	0.187	0.2740	0.699	0.305
21	4.0000	2.1270	20.57	16.570	0.187	0.1940	0.677	0.369
SERIES : 5		DIA. OF CYL,	d(in):	3.130	WIDTH OF	CHANNEL, B (in) :		5.28
1	0.5250	0.6063	36.00	35.475	5.960	0.0146	1.000	2.910
2	0.525	0.4692	22.09	21.565	5.960	0.0237	0.997	2.250
3	0.5250	0.3492	12.54	12.015	5.960	0.0420	0.995	1.680
4	0.5250	0.2885	08.45	07.965	5.960	0.0620	1.010	1.390
5	0.5250	0.2160	05.17	04.645	5.960	0.1010	0.990	1.040
6	1.0020	1.0935	35.40	34.40	3.130	0.0280	0.964	3.520
7	1.0020	0.9225	25.45	24.45	3.130	0.0393	0.965	2.970
8	1.0020	0.7580	18.41	17.47	3.130	0.0544	0.940	1.810

TABLE 4 FREE RFFLUX (CONTINUED)

SERIES: 5 DIA. OF LIP, d(in): 3.130 WIDTH OF CHANNEL, B(in): 5.28

Sl.No.	Gate Opening a(in)	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1 (in)	$H_1 - a$ (in)	d/a	a/H_1	C_{df}	$R_e x10^5$
9	1.0020	0.6296	13.04	12.04	3.130	0.0770	0.940	1.510
10	1.0020	0.5120	08.97	07.97	3.130	0.1110	0.938	1.220
11	1.0020	0.3523	04.90	03.90	3.130	0.2050	0.923	0.840
12	2.0000	0.7440	06.16	04.16	1.560	0.3250	0.945	1.004
13	2.0000	0.9440	09.02	07.02	1.560	0.2220	0.924	1.270
14	2.0000	1.1720	12.95	10.95	1.560	0.1540	0.918	1.580
15	2.0000	1.4220	20.80	18.80	1.560	0.0960	0.850	1.920
16	2.0000	1.7385	28.57	26.57	1.560	0.0700	0.870	2.340
17	4.0050	1.5907	08.71	04.71	0.781	0.4600	0.949	1.230
18	4.0050	1.8900	11.02	07.02	0.781	0.3630	0.924	1.470
19	4.0050	2.2290	14.41	10.41	0.781	0.2980	0.894	1.730
20	4.050	2.5050	17.83	13.83	0.781	0.2980	0.894	1.730

TABLE 4 FREE EFFLUX (CONTINUED)

SERIES: 6 DIA. OF LIP, d(in): 6.00 WIDTH OF CHANNEL, B(in): 5.28

Sl.No.	Gate Opening a(in)	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	$H_1 - a$ (in)	d/a	a/H_1	C_{df}	$R_e \times 10^5$
1	1.0000	1.2456	34.47	33.47	6.000	0.0290	1.120	6.50
2	1.0000	1.1070	27.20	26.20	6.000	0.0370	1.124	5.00
3	1.0000	0.8600	17.08	16.[illegible]8	6.000	0.0585	1.114	4.92
4	1.0000	0.8440	18.34	17.34	6.000	0.0545	1.053	3.80
5	1.0000	0.6524	12.78	11.78	6.000	0.0780	0.986	3.50
6	1.0000	0.5387	09.19	08.19	6.000	0.1088	0.978	3.10
7	1.0000	0.4887	07.80	06.80	6.000	0.1280	0.975	2.81
8	1.0000	0.4396	06.50	05.50	6.000	0.1540	0.974	2.56
9	1.0000	0.3910	05.39	04.39	6.000	0.1855	0.970	2.20
10	1.0000	0.3648	04.83	03.83	6.000	0.2070	0.969	2.10

TABLE 4 FREE EFFLUX (CONTINUED)

SERIES: 6 DIA. OF LIP, d(in): 6.00 WIDTH OF CHANNEL, B(in): 5.28

Sl.No.	Gate Opening a(in)	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	$H_1 - a$ (in)	d/a	a/H_1	C_{df}	$R_e \times 10^5$
11	1.3100	1.5775	32.63	31.32	4.580	0.040	1.118	7.24
12	1.3100	1.4434	28.16	26.85	4.580	0.047	1.106	6.60
13	2.7800	1.8300	15.28	12.50	2.160	0.182	0.966	3.95
14	2.7800	1.5866	12.13	09.35	2.160	0.229	0.968	3.40
15	2.7800	1.3774	09.40	06.62	2.160	0.296	1.000	2.97
16	2.7800	1.2261	08.44	05.66	2.160	0.330	1.000	2.70

TABLE 5 SUBMERGED EFFLUX

SERIES: 1   DIA. OF LIP, d(in): 0.625   WIDTH OF CHANNEL, B(in): 18.00

DEPTH OF GATE OPENING, a(in): 2.625   d/a : 0.328

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
1	0.4870	08.99	06.88	02.110	0.292	0.661	0.124
2	0.4870	12.29	10.12	02.170	0.214	0.652	0.124
3	0.6700	14.69	10.45	04.240	0.179	0.642	0.171
4	0.6700	11.05	06.95	04.100	0.248	0.653	0.171
5	0.8290	15.95	09.48	06.470	0.165	0.643	0.211
6	0.9202	18.30	10.49	07.810	0.143	0.650	0.235

SERIES: 1   DIA. OF CYL, d(in) : 0.625   WIDTH OF CHANNEL, B (in) : 18.00

DEPTH OF GATE OPENING, a(in) : 1.4375   d a : 0.328

1	0.3670	13.31	09.53	03.780	0.105	0.686	0.152
2	0.5640	17.93	09.65	08.280	0.080	0.706	0.233

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 1 DIA. OF LIP, d(in): 0.625 WIDTH OF CHANNEL, B(in): 18.00

DEPTH OF GATE OPENING, a(in): 1.4375 d/a : 0.4348

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
3	0.5640	22.27	13.95	08.320	0.065	0.705	0.233
4	0.6300	20.56	10.62	09.940	0.070	0.720	0.260
5	0.3204	12.96	10.12	02.840	0.111	0.685	0.132
6	0.4566	19.20	13.62	05.580	0.075	0.700	0.180
7	0.9794	30.98	07.52	23.460	0.046	0.729	0.404

SERIES : 2 DIA, OF CYL, d(in): 2.250 WIDTH OF CHANNEL, B(in): 18.00

DEPTH OF GATE OPENING, a (in) : 2.000 d a : 1.125

1	0.7275	10.52	06.78	03.740	0.1901	0.974	0.880
2	0.7275	15.68	11.85	03.830	0.1276	0.963	0.880
3	0.3985	06.90	05.80	01.100	0.2900	0.985	0.480

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 2 DIA. OF LIP, d(in): 2.250 WIDTH OF CHANNEL, B(in): 18.00

DEPTH OF GATE OPENING, a(in): 2.000 d/a : 1.125

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
4	0.5394	08.93	07.00	01.930	0.2240	1.006	0.660
5	0.7716	14.61	10.71	03.900	0.1369	1.010	0.940
6	1.0300	20.27	12.55	07.720	0.0987	0.960	1.250
7	0.8660	18.27	13.02	05.250	0.1090	0.980	1.080
SERIES : 2	DIA. OF CYL, d(in): 2.250			WIDTH OF CHANNEL, B(in) : 18.00			
	DEPTH OF GATE OPENING, a(in): 3.530					d a : 0.636	
1	1.3650	16.94	11.55	05.390	0.280	0.865	0.930
2	0.9700	15.43	12.90	02.530	0.228	0.897	0.660
3	0.3800	07.20	06.77	00.430	0.480	0.853	0.260
4	0.3800	14.25	13.83	00.420	0.248	0.862	0.260

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 3 DIA. OF LIP, d(in): 5.000 WIDTH OF CHANNEL, B(in): 18.00

DEPTH OF GATE OPENING, a(in): 0.875 d/a : 5.720

Sl.No.	Flow Per Unit Width, q (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
1	0.6805	17.84	07.05	10.790	0.049	1.226	4.180
2	0.6855	22.74	11.15	11.590	0.039	1.191	4.210
3	0.6805	23.97	12.49	11.480	0.037	1.189	4.180
4	0.5113	11.06	04.75	06.310	0.079	1.205	3.140
5	0.5113	14.72	08.69	06.030	0.060	1.232	3.140
6	0.5113	19.14	13.15	05.99	0.046	1.236	3.140

SERIES: 3 DIA. OF CYL, d(in): 5.000 WIDTH OF CHANNEL, B(in): 18.00

DEPTH OF OPENING, a (in) : 2.000 d/a : 2.500

Sl.No.	Flow Per Unit Width, q (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
1	0.6455	08.73	06.38	02.350	0.229	1.090	1.740
2	0.6455	04.83	02.53	02.300	0.414	1.102	1.740

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 3 DIA. OF LIP, d(in): 5.000 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 2.000 d/a : 2.500

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
3	0.6404	12.07	10.83	02.240	0.166	1.108	1.720
4	0.6404	14.63	12.42	02.210	0.166	1.108	1.720
5	0.6333	16.23	13.91	02.320	0.123	1.077	1.700

SERIES : 4 DIA. OF CYL, d(in): 0.750 WIDTH OF CHANNEL, B(in): 18.00

DEPTH OF GATE OPENING, a(in): 0.255 d/a : 2.940

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
1	0.1228	12.75	4.995	07.775	0.020	0.896	0.351
2	0.1545	17.59	5.400	12.190	0.0145	0.890	0.441
3	0.2064	28.02	6.460	21.560	0.1182	0.904	0.589
4	0.2377	35.12	7.420	27.700	0.0092	0.918	0.679

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 4 DIA. OF LIP, d(in): 0.750 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 0.505 d/a : 1.485

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
1	0.2110	12.85	7.144	5.7060	0.0393	0.9090	0.311
2	0.3060	20.14	8.160	11.980	0.0250	0.9096	0.451
3	0.3667	26.10	8.795	17.305	0.0193	0.9070	0.541
4	0.4152	30.98	8.905	22.080	0.0163	0.9090	0.673
5	0.4560	35.60	9.005	26.600	0.0142	0.9090	0.673

SERIES: 4 DIA. OF CYL, d(in): 0.750 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 1.000 d/a : 0.750

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
1	0.8240	34.25	6.120	28.130	0.0290	0.8060	0.594
2	0.8050	29.99	5.850	24.140	0.0333	0.8230	0.523
3	0.7240	29.45	6.540	22.910	0.0339	0.785	0.522

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 4 DIA. OF LIP, d(in): 0.750 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 1.000 d/a : 0.750

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
4	0.6446	25.52	7.330	18.190	0.0392	0.784	0.465
5	0.3127	13.93	9.755	04.195	0.0716	0.790	0.219
6	0.4180	09.80	2.000	07.800	0.1020	0.776	0.290
7	0.3961	17.68	10.800	06.880	0.0565	0.782	0.270
SERIES : 5	DIA OF CYL, d(in) : 0.750			WIDTH OF CHANNEL, B(in) : 5.280			
	DEPTH OF GATE OPENING, a(in): 4.000					d/a :	0.187
1	0.8910	13.38	10.62	02.760	0.2990	0.695	0.162
2	1.1720	15.30	10.50	04.800	0.2610	0.694	0.214
3	1.5160	18.00	09.70	08.300	0.2220	0.682	0.276
4	2.0330	20.87	06.40	14.47	0.192	0.692	0.370

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 5 DIA. OF LIP, d(in): 3.130 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 0.525 d/a : 5.960

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
1	0.2152	12.65	08.060	04.590	0.0415	0.992	1.000
2	0.2608	14.74	08.094	06/646	0.0356	0.999	1.220
3	0.3383	19.93	08.500	11.430	0.0263	0.988	1.575
4	0.3927	23.31	08.230	15.080	0.0225	1.000	1.828
5	0.4181	25.25	08.304	16.910	0.0208	1.000	1.950
6	0.5239	24.92	08.380	16.540	0.0211	1.270	2.440
7	0.4906	22.81	08.380	14.430	0.0230	1.275	2.285
8	0.4445	21.27	07.880	13.390	0.0247	1.200	2.070
9	0.3514	19.47	07.600	11.870	0.0270	1.000	1.606
10	0.3939	22.42	07.495	14.925	0.0234	1.000	1.800
11	0.6017	27.87	07.230	20.640	0.0188	1.307	2.600

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 5 DIA. OF LIP, d(in): 3,130 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 0.525 d/a : 5.960

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
12	0.6962	34.80	05.170	27.342	0.0150	1.375	2.920

SERIES : 5 DIA OF CYL, d(in) : 3.130 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 1.002 d/a : 3.130

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
1	1.0980	33.25	07.380	25.870	0.0300	1.117	3.540
2	0.9565	29.67	10.150	19.520	0.0337	1.120	3.080
3	0.8453	23.57	09.210	14.360	0.0424	1.154	2.720
4	0.6311	16.01	08.520	07.490	0.0625	1.190	2.030
5	0.3514	12.07	8.115	03.955	0.0828	0.914	1.130
6	0.2680	09.04	06.693	02.347	0.1106	0.906	0.863
7	0.4050	13.37	08.400	04.970	0.0748	0.940	1.300
8	0.5715	14.20	07.990	06.210	0.0708	1.186	1.840

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 5 DIA. OF LIP, d(in): 3.130 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 1.002 d/a : 3.130

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
9	0.5568	13.92	08.030	05.890	0.0718	1.187	1.790
10	0.5466	13.72	08.020	05.700	0.0729	1.184	1.760
11	0.5223	13.39	08.065	05.325	0.0747	1.170	1.680
SERIES : 5	DIA. OF CYL, d(in): 3.130			WIDTH OF CHANNEL, B(in): 5.280			
	DEPTH OF GATE OPENING, a(in): 2.000					d/a : 1.560	
1	0.4810	10.30	08.180	02.120	0.1940	0.856	0.607
2	0.5835	11.35	08.460	02.890	0.1760	0.890	0.738
3	0.6698	12.21	08.705	03.505	0.1640	0.927	0.848
4	0.7233	12.14	08.300	03.840	0.1650	0.957	0.939
5	0.8170	13.82	09.130	04.690	0.1450	0.978	1.040

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 5 DIA. OF LIP, d(in): 3.130 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 2.000 d/a : 1.560

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
6	1.1990	18.00	07.960	10.040	0.1110	0.982	1.560
7	1.4190	22.06	08.300	13.760	0.0906	0.992	1.840

SERIES : 5 DIA. OF CYL, d(in) 3.130 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 4.005 d/a : 0.781

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
1	0.4960	08.86	08.230	00.630	0.4520	0.809	0.376
2	0.6234	09.94	08.865	00.975	0.403	0.817	0.466
3	0.7233	10.61	09.320	01.290	0.377	0.824	0.549
4	0.7739	10.90	09.905	01.375	0.367	0.848	0.587
5	0.9165	11.92	10.130	01.790	0.336	0.887	0.627
6	0.9205	10.45	08.758	01.692	0.383	0.916	0.698

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 5 DIA. OF LIP, d(in): 3.130 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 4.005 d/a : 0.780

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e \times 10^5$
7	1.6194	13.25	07.980	05.270	0.302	0.913	1.228
8	1.9760	16.77	08.540	08.230	0.238	0.892	1.500
SERIES : 6	DIA. OF CYL, d(in) : 6.000			WIDTH OF CHANNEL, B(in) : 5.280			
	DEPTH OF GATE OPENING, a(in):			1.000		d/a :	6.000
1	1.1273	38.88	08.39	26.484	0.026	1.138	6.650
2	0.8667	25.48	09.80	15.680	0.032	1.137	5.110
3	0.6758	17.10	08.65	08.450	0.059	1.209	3.980
4	0.5412	14.40	09.33	05.073	0.069	1.247	3.190
5	0.2350	05.34	04.16	01.185	0.187	1.120	1.390

TABLE 5 SUBMERGED EFFLUX (CONTINUED)

SERIES: 6 DIA. OF LIP, d(in): 6.000 WIDTH OF CHANNEL, B(in): 5.280

DEPTH OF GATE OPENING, a(in): 1.310 d/a : 4.580

Sl.No.	Flow Per Unit Width, q. (Cfs/ft)	U/S Flow Depth, H_1(in)	D/S Flow Depth, H_2(in)	$H_1 - H_2$ (in)	a/H_1	C_{ds}	$R_e x10^5$
1	1.3274	29.82	08.83	20.990	0.044	1.150	5.980
2	0.8128	19.10	10.76	08.340	0.069	1.116	3.730
3	0.9524	22.86	12.00	10.860	0.057	1.146	4,370
4	0.1911	05.13	04.68	00.450	0.225	1.132	0.870
SERIES : 6	DIA. OF CYL, d(in): 6.000			WIDTH OF CHANNEL, B(in): 5.280			
	DEPTH OF GATE OPENING, a(in): 2.780					d/a : 2.160	
1	1.7490	18.24	09.09	09.150	0.152	1.080	3.800
2	1.2906	15.09	10.05	05.038	0.185	1.074	2.800
3	0.6837	11.81	10.22	01.586	0.235	1.014	1.480

APPENDIX IV - SPECIMEN COMPUTATION

Computation of C_{df}, C_{ds}, AND R :

Computation of C_{df} (Series 4, Sl. No. 11):

Diameter of the lip, d = 00.75 in

Gate opening, a = 01.00 in

Width of the gate, b = 05.25 in

Upstream head, H_1 = 36.00 in

Head over the notch, h = 05.71 in

Temperature, T = 72.5°F, Kinematic viscosity, = 1.03×10^{-5} ft^2/ sec

Discharge formula used for computation of the actual rate of outflow (A.S.M.E. Standard).

$$Q = 2.474 \; (h/12 + 0.0028)^{5/2}$$

where, Q is in cfs and h, is in inches.

$$Q = 2.474 \; (5.71/12 + 0.0028)^{5/2} \quad = \; 0.391 \text{ cfs}$$

$$q = Q/ b = 0.391/ (5.25/12) \quad = \; 0.894 \text{ ft}^2/ \text{sec}$$

$$V = q/ a = 0.894/ (1.0/12) \quad = 10.730 \text{ ft}/ \text{sec}$$

Reynolds number, R = Vd/ =$10.73 \times (0.75/12) \times 1.0/ (1.03 \times 10^{-5})$

$$= \; 0.65 \times 10^5$$

$$C_{df} = q/ a(\sqrt{2g(H_1 - a)/12})$$

$$= 0.894/ (1.0/ 12)(\sqrt{2 \times 32.2 \times (36.0 - 1.0)/12} \;)$$

$$= \; 0.783$$