In presenting this dissertation as a partial fulfillment of the requirements for an advanced degree from the Georgia Institute of Technology, I agree that the Library of the Institution shall make it available for inspection and circulation in accordance with its regulations governing materials of this type. I agree that permission to copy from, or to publish from, this dissertation may be granted by the professor under whose direction it was written, or, in his absence, by the Dean of the Graduate Division when such copying or publication is solely for scholarly purposes and does not involve potential financial gain. It is understood that any copying from, or publication of, this dissertation which involves potential financial gain will not be allowed without written permission.

Rolland W. Carter

A COMPREHENSIVE DISCHARGE EQUATION FOR RECTANGULAR-NOTCH WEIRS

A THESIS

Presented to

the Faculty of the Graduate Division

Georgia Institute of Technology

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Civil Engineering

By

Rolland W. Carter

June 1956

A COMPREHENSIVE DISCHARGE EQUATION FOR

RECTANGULAR-NOTCH WEIRS

Approved: ______________________

____

____

Date Approved by Chairman: May 29, 1956

ACKNOWLEDGMENTS

The writer is grateful to all those who made this thesis possible. The members of the thesis reading committee were Dr. M. R. Carstens, Dr. J. H. Wahab and Professor C. E. Kindsvater, under whose guidance this work was performed. The writer also profited from a previous thesis on this subject by Mr. James R. Wells.

The research and graduate study culminating in this thesis was partially sponsored by the U. S. Geological Survey as part of a comprehensive investigation of the discharge characteristics of weirs and spillways.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	ii
LIST OF TABLES	v
LIST OF FIGURES	vi
ABSTRACT	viii

CHAPTER

I.	INTRODUCTION	1
	Description of the Problem Scope of the Investigation Review of the Literature Review of the Previous Research at Georgia Tech	
II.	ANALYSIS OF THE PROBLEM	7
	Definition Dimensional Analysis Influence of Viscosity and Surface Tension Formulation of the Weber Number Formulation of the Reynolds Number Influence of the b/B Ratio Influence of the b/h Ratio Influence of the h/P Ratio Evaluation of C	
III.	LABORATORY SET-UP	15
	General Arrangement The Flumes The Weir Plates Head Measurements Discharge Measurements	
IV.	EXPERIMENTAL PROCEDURE AND RESULTS	18
	Comparison of Tests in the Three-Foot and Ten-Foot Flumes Distribution of Velocity in the Ten-Foot Flume Tests Made in the Ten-Foot Flume	

Page

V. ANALYSIS AND DISCUSSION OF RESULTS 21

Influence of Very Small Heads
Influence of Very Small Opening Widths
Influence of the Ratio of Head to Weir Height
Influence of Width-Head Ratio
Influence of Width Contraction Ratio
Summary of Analysis
Comparison With Other Formulas

VI. CONCLUSIONS 27

BIBLIOGRAPHY 29

APPENDIX 31

TABLES 32

FIGURES 49

LIST OF TABLES

Table Page

1. Velocity Distribution between False Walls in the Ten-Foot Flume 32

2. Summary of Tests in the Three-Foot Flume 35

3. Summary of Tests in the Ten-Foot Flume 39

4. Comparison of the Results of this Investigation with the S. I. A. Formula 48

LIST OF FIGURES

Figure | Page

1. Rectangular Notch Weir in a Rectangular Channel 49
2. Typical Set-Up in the Ten-Foot Flume 50
3. Downstream View of Notch Weir in the Ten-Foot Flume 51
4. Comparison of Data in the Three-Foot and the Ten-Foot Flume . . 52
5. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 0.20 53
6. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 0.40 54
7. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 0.60 55
8. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 0.80 56
9. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 0.90 57
10. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 1.00 58
11. Values of k_h for Investigations by Bazin, Schoder and Turner, and the U. S. Bureau of Reclamation 59
12. Effect of k_b on C' for Small Crest Widths 60
13. Variation of Width Correction k_b with Width Ratio b/B 61
14. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, $b/B < 0.13$ 62
15. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 0.20 63
16. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 0.40 64
17. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 0.50 65

Figure Page

18. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 0.60 66

19. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 0.80 67

20. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 0.90 68

21. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 1.00 69

22. Variation of C' with Ratio of Head to Weir Height for all Values of b/B 70

23. Cross Plot of Figure 22 showing Effect of Width Ratio at Three Values of h/P 71

24. Effect of the Francis Correction for Notch Weirs on the Discharge Coefficient 72

ABSTRACT

Hydraulicians have long sought a comprehensive equation that would define the discharge characteristics of the rectangular-notch, thin-plate weir for a full range of fluid, flow, and geometric variables. However, most investigators have not attempted to embrace a full range of variables for the basic weir form, but have dealt with a "practical" range of the critical variables. The inevitable result has been the establishment of limitations on the use of various weir formulas. Among the best-known investigators, nevertheless, there has been no general agreement regarding these physical limitations, nor even the discharge characteristics of the simpler forms of the sharp-crested weir.

In this investigation, experiments guided by dimensional analysis were used to obtain an equation which expresses the discharge characteristics of the weir in terms of geometric, fluid property and flow variables. The principal variables are believed to be contained in the expression

$$C = f(h, b, \frac{b}{B}, \frac{h}{P}),$$

in which $\underline{C}$ is the coefficient of discharge; the dimensional quantities $\underline{h}$ and $\underline{b}$, representing the head on the weir and the width of the notch, respectively, are proportional to the Reynolds number and the Weber number; and the ratios $\underline{b}/\underline{B}$ and $\underline{h}/\underline{P}$ describe the boundary geometry.

Rehbock in Germany found earlier that for suppressed weirs ($\underline{b}/\underline{B} = 1.0$) the effect of viscosity and surface tension could be accounted for by adding a small constant to the measured head. It is shown in this thesis

that the effect of these fluid properties on the width characteristics of notch weirs can be treated in a similar manner. Thus, it is proposed that a comprehensive equation for the notch weir be written in the form,

$$Q = C'(b + k_b)(h + k_h)^{3/2}, \qquad (A)$$

in which Q is the discharge, b is the width of the notch, k_b and k_h are experimentally determined lengths, h is the head on the notch, and

$$C' = f'(\frac{h}{P}, \frac{b}{B}),$$

in which f' represents an experimentally determined function, P is the height of the weir notch above the channel floor, and B is the channel width.

That equation A can be used over a wide range of geometric and flow variables was confirmed by laboratory experiment. It was found that k_h is essentially constant but that the value of k_b varied with the width ratio. Values of C' for a wide range of the geometric ratios were defined by laboratory experiment.

CHAPTER I

INTRODUCTION

Description of the Problem.--Hydraulicians have long sought a comprehensive discharge equation that would define the discharge characteristics of the rectangular-notch, thin-plate weir for a full range of fluid, flow, and geometric variables. The geometry of the basic weir, as shown in figure 1, is described by the width of the approach section, B, the width of the weir, b, the height of the weir, P, and the piezometric head upstream from the weir, h. The weir is considered to be a thin plate with sharp-edged notch boundaries. It is assumed to be fully ventilated and unsubmerged. The fluid property variables involved are the density, ρ, viscosity, μ, and surface tension, σ. The flow variables are represented by the mean velocity at the crest section, V, and the piezometric head, h.

Because of the complex boundary conditions and the several fluid properties involved, the flow pattern for weir discharge is not subject to complete analytical description. Published weir formulas that are based on the integration of an approximate velocity equation across the fully-contracted free jet are not theoretically correct, and nothing is gained by their use. A more direct solution is obtained by a combination of experiment and dimensional analysis.

Most investigators have not attempted to embrace a full range of variables for the basic weir form. Instead, they have dealt with a "practical" range of the critical variables. The inevitable result has been to establish a "standard" measuring weir. The futility of this evasive procedure is revealed by the fact that various workers continue to disagree regarding the physical limitations as well as the discharge characteristics of the "standard" instrument.

The sharp-crested weir is a useful and common measuring device, both in the laboratory and in the field. Furthermore, the flow pattern for the sharp-crested weir is widely used as an analogy for the description of the discharge characteristics of other forms of weirs and spillways. It appears, therefore, that the purpose of this investigation--namely, to define the discharge characteristics of the sharp-crested weir over a full range of most of the independent variables--is justified.

This work is the second of a series of related investigations undertaken at the Georgia Institute of Technology. The initial study, "Discharge Characteristics of Rectangular Notch Weirs in Rectangular Channels," was the subject of a Master's thesis by James R. Wells (1954).

Scope of the Investigation.--The laboratory investigation on which this study is based covered the following range of geometric variables:

Variable	Range (feet)
B	0.1 to 9.1
b	0.1 to 2.7
P	0.3 to 1.45
h	0.081 to 0.765

It is recognized that the tests did not include values of h/P large enough to define the discharge characteristics of low sills. However, it has been shown by Boss (1)* that critical flow will prevail

---

*The numbers in parenthesis correspond to references listed in the Bibliography.

upstream from sills of small but finite height. Experiments by Rouse (2) at the Massachusetts Institute of Technology indicated that the transition from weir flow to sill flow occurs when h/P is approximately equal to 5. For this reason, the results of this investigation are considered to be limited in application to values of h/P less than 5.

Small values of b and h were included in the experimental investigation in order to determine the relative influence of surface tension and viscosity over a small range of the Weber and Reynolds numbers. Only one fluid, water at a narrow range of room temperatures, was used.

Review of the Literature.--Few problems have received more attention in the technical literature of hydraulics than the measuring weir. Francis (3), in 1883, published a classic account of his experiments on weirs made in the Lower Lock at Lowell, Massachusetts. Bazin's work (4) in France was first published in 1888. One of Rehbock's first publications of his work in Germany was in 1912. Many others, including Fteley and Stearns (5), Nagler (6), Frese (7), and Schoder and Turner (8) made important contributions to our knowledge of the weir.

Most of these investigations dealt with the suppressed rectangular weir. This, as contrasted with the notch weir, involves a level crest which occupies the full width of the channel. However, even for this simple case, the lack of agreement between many capable workers in the field is notable. For suppressed weirs, the Rehbock formula (1) is probably used more than any other. In its most common form, this formula is

$$Q = \left(0.605 + 0.008\frac{h}{P} + \frac{1}{305h}\right) \frac{2}{3}\sqrt{2g}\ bh^{3/2}. \qquad (1)$$

Rehbock claimed a very high degree of accuracy for this formula when applied to weirs of all sizes and for all heads great enough to ensure a free nappe. Others disagree with the originator, however, claiming that it is applicable only to small weirs and relatively small heads such as would be involved in laboratory-size weirs.

Another formula for suppressed weirs, widely used in Europe, is that proposed by the Swiss Society of Engineers and Architects (S.I.A.) (10) in 1924. As given in the S.I.A. Code for Water Measurements, this formula is

$$Q = [0.615(1 + \frac{1}{305h + 1.6})][1 + 0.5(\frac{h}{P + h})^2] \frac{2}{3}\sqrt{2g}\ bh^{3/2}. \qquad (2)$$

It is specified in the Code that equation 2 is applicable only when P is equal to or greater than 11 inches, h is between 1 inch and 31.4 inches, and h/P is equal to or less than unity.

When suppressed-weir formulas are used for notch weirs, it is customary to limit their application to values of b greater than $3h$ and values of B not less than $(b + 6h)$. Within these limits the effect of width contraction is generally evaluated from an empirical relationship proposed by Francis,

$$b_{net} = b_{gross} - 0.1\ nh, \qquad (3)$$

in which b_{gross} is the full length of the weir crest; b_{net} is the effective length of the weir crest, and n is the number of end contractions.

One of the few formulas developed for the rectangular-weir notch was also proposed by the S.I.A. in their Code for Water Measurements.

This formula,

$$Q = \left[0.578 + 0.037\left(\frac{b}{B}\right)^2 + \frac{3.615 - 3\left(\frac{b}{B}\right)^2}{305h + 1.6}\right] \left[1 + 0.5\left(\frac{b}{B}\right)^4 \left(\frac{h}{P + h}\right)^2\right] \frac{2}{3}\sqrt{2g}\, bh^{3/2}, \tag{4}$$

is recommended only when P is equal to or greater than 11 inches; h is between 1.0 B/b inches and 31.4 inches, h/P is equal to or less than unity; and b/B is equal to or greater than 0.3.

In view of the limitations imposed on all of these formulas it is apparent that a comprehensive weir formula is still not available.

Review of the Previous Research at Georgia Tech.--The discharge characteristics of notch weirs was the subject of an investigation by James R. Wells (11) at the Georgia Institute of Technology in 1953. Using a sharp-edged, fully ventilated and unsubmerged weir for his tests, Wells' experimental investigation covered the following range of variables:

Variable	Range (feet)
B	3.0
b	0.15 to 2.70
P	0.15 to 1.84
h	0.05 to 0.90

All of his tests were made in a flume three feet wide. Variations in weir height P were obtained with an adjustable floor upstream from the weir. Variations in crest width b were obtained by attaching false walls to the upstream side of the basic weir. The condition for the suppressed weir, b/B = 1.0, was not investigated.

In his analysis Mr. Wells used a simplified discharge equation,

$$Q = C_W b \left(\frac{2}{3}\right) \sqrt{2g}\, h^{3/2}, \tag{5}$$

in which, from dimensional analysis,

$$C_W = f_W\left(R, W, \frac{P}{h}, \frac{B}{h}, \frac{b}{h}\right), \tag{6}$$

in which R is the Reynolds number and W is the Weber number.

After many analytical procedures were investigated, it was determined that an alternate form of the functional relationship for C_W, in which R and W were ignored, was best adapted to the correlation of most of his test data,

$$C_W' = f_W'\left(\frac{b}{B}, \frac{bh}{B(h + P)}, \frac{P}{b}\right). \tag{7}$$

From his analysis, Mr. Wells concluded that the influence of P/b was negligible and that the coefficient of discharge for all tests, except those for small values of h or b (which were ignored) would be correlated as a function of the width and area ratios given in equation 7. However, the data failed to show a systematic influence of the b/B ratio.

In an unpublished report on notch weirs prepared for the U. S. Geological Survey, Professor C. E. Kindsvater suggested the method of analysis which is described subsequently in this thesis.

CHAPTER II

ANALYSIS OF THE PROBLEM

Definition.--The basic weir form is a symmetrical, sharp-edged, rectangular notch in a smooth, vertical, thin plate located in a smooth, long, horizontal, rectangular channel. The discharge is fully ventilated and unsubmerged. A definitive sketch of the basic weir is shown in figure 1.

Dimensional Analysis.--The geometry of the basic weir is described by the width of the notch, b, the width of the channel, B, the height of the weir, P, and the piezometric head upstream from the weir, h. The fluid properties involved are the specific weight, γ, the density, ρ, the viscosity, μ, and the surface tension, σ. Designating the velocity over the crest, V, as the dependent flow variable, and h or Δp as the independent flow variable, an expression that contains all the significant variables is

$$f_1(b, B, P, \gamma, \rho, \mu, \sigma, V, h \text{ or } \Delta p) = 0. \qquad (8)$$

As there are three independent dimensions and nine variables in equation 8 a maximum of six dimensionless ratios can be formed. One of these is the coefficient of discharge, C, a flow parameter that is a form of the Euler number. The independent fluid-property ratios are the Reynolds number, R, and the Weber number, W. The remaining ratios in the following expression describe the significant geometric characteristics of the weir and weir channel,

$$\frac{V}{\sqrt{\frac{\Delta p}{\rho}}} \sim C = f_2(R,\ W,\ \frac{b}{B},\ \frac{h}{P},\ \frac{b}{h}). \tag{9}$$

Expressing C in terms of the discharge, gross area of the weir notch, and the piezometric head,

$$C \sim \frac{\frac{Q}{bh}}{\sqrt{\frac{\Delta p}{\rho}}\ (\frac{\gamma}{\gamma})} \sim \frac{Q}{bh\sqrt{gh}}\ . \tag{10}$$

In American engineering practice the acceleration due to gravity, g, which is essentially constant, is included in the value of C. A convenient and practical equation for discharge, therefore, is

$$Q = C\ b\ h^{3/2}. \tag{11}$$

In equation 11 the coefficient C has the dimensions of $\sqrt{g}$. Because of its obvious simplicity, however, and despite its lack of dimensional purity, equation 11 is used as the basic discharge equation in this thesis.

Influence of Viscosity and Surface Tension.--The discharge function represented by equations 9 and 11 has not been evaluated successfully by analytical means. Thus, the relative influence of each of the independent variables must be evaluated by experiment.

Perhaps the most controversial ratios in equation 9 are the Reynolds number and the Weber number. Actually, very little is known about the character and magnitude of the separate influences of viscosity and surface tension represented by R and W, respectively. It is generally agreed that the effect of surface tension is the greatest of the two when narrow notch weirs in channels of considerable width are involved. On the other hand the effects of viscosity are dominant for narrow, suppressed weirs. Both the viscosity and surface tension effects are negligible in comparison with the influence of the geometric variables when the weirs and heads on the weirs are comparatively large.

For a given liquid flowing over a thin-plate weir with suppressed side contractions, experiments indicate that the combined effect of viscosity and surface tension is related to the magnitude of the head. For suppressed weirs the critical head, below which these effects are appreciable, is about 0.3 feet. Corresponding limits on the width of either notch weirs or suppressed weirs have not been established, but various investigators have specified that the application of formulae based on experimental data be restricted to weirs of comparably large size.

Formulation of the Weber Number.--Lindquist (12) suggested that the effect generally attributed to small values of head on suppressed weirs was largely a consequence of two independent surface-tension phenomena. In the first place, as observed by others, Lindquist noted that the nappe clings to the top surface of the crest. The relative effect of this occurrence, which is similar to the effect of a crest rounding, increases with decreasing values of head. Secondly, surface tension in both the upper and lower nappe surfaces yields resultant forces acting in the direction of the center of curvature of the nappe. These surface-tension forces vary inversely with the radius of curvature of the free surface. Thus, with decreasing heads, the radius of curvature decreases and the resultant surface-tension force increases. In effect, both phenomena described by Lindquist have the same influence on the discharge as an increase in head. Only at relatively low heads, however, would either of the suggested surface-tension effects have an appreciable influence on the flow pattern.

It is now suggested that the influence of surface tension on the basic-notch weir is related to the width of the notch as well as the head. The clinging-nappe phenomenon occurs on the sides of the notch as well as the bottom. As the width decreases, the relative influence of this occurrence increases. Experiments indicate, furthermore, that for narrow notches the radius of curvature of the contracting nappe surfaces (sides) decreases with decreasing values of b. The result of this phenomenon is a surface-tension force in the direction of the center of curvature of the side surface of the nappe. The combined effects of the two phenomena on the rate of flow is, in general, the same as an increase in width.

The Weber number, an accepted criterion of the relative influence of surface tension, is defined by the equation $W = V/\sqrt{\sigma/(\rho L)}$, in which V is a significant velocity and L is a significant length. In weir flow, the velocity is proportional to the square root of the head. For a particular liquid at a given temperature, the surface tension, σ, and density, ρ, are constant. From the preceding discussion it appears that the critical length parameter might be either the head or the width of the weir. Thus, for wide weirs at low heads, $W \sim \sqrt{h}\,(\sqrt{h}) \sim h$. On the other hand, for narrow weirs at high heads, $W \sim \sqrt{h}\,(\sqrt{b}) \sim \sqrt{h\,b}$. For the general case, therefore, two independent forms of the Weber number must be considered in the analysis of the discharge function for the basic, thin-plate weir.

Formulation of the Reynolds Number.--The effect on the discharge function which is attributed to viscosity is related, first, to the occurrence of separation in the upstream corners between the weir plate and the channel walls and bottom, and, second, although not independently, to the occurrence of boundary drag on the upstream surface of the channel as well as the weir. For high, wide weirs and low heads, the retarded flow along the surface of the weir near the crest has an influence on the flow pattern which is similar to that of notch-edge rounding. Like surface tension, therefore, it has the same effect on the discharge as an increase in head. A similar effect results from the occurrence of separation in the bottom corner when the weir is very low. Furthermore, from the obvious similarity, it ia apparent that corresponding occurrences on the side walls and upper legs of the weir plate have the effect of an increase in the width of the weir except when b/B approaches unity, in which case the effect is opposite. It follows that there are two independent forms of the Reynolds number just as there are two forms of the Weber number.

The Reynolds number is defined by the ratio $R = (VL\rho)/\mu$; in which μ is the viscosity. For a given weir and liquid the velocity is proportional to the square root of the head, and the fluid properties are constant. With h as the length parameter, $R \sim \sqrt{h}\ (h) \sim h^{3/2}$. With b as the length parameter, $R \sim \sqrt{h}\ b$. Thus, for a given weir form, and with ρ, μ, and σ constant, the influence of viscosity as well as the influence of surface tension is a function of the absolute magnitudes of h and b. This conclusion substantiates the use of a term involving h to compensate for the combined effects of both fluid properties in several formulas for the flow over suppressed weirs. The absence of similar terms to represent the independent influence of weir width is doubtless a consequence of the general tendency in the past to restrict research to relatively wide weirs.

Influence of the b/B Ratio.--The notch weir has been defined as the basic weir form. The weir which has been most extensively investigated in the laboratory, however, is the so-called suppressed weir. This designation implies that the notch width is equal to the width of the approach channel; that is, the side contractions are "suppressed", and $b/B = 1.0$.

It is reasonable to assume that the influence of the b/B ratio on weir discharge is similar to that of the corresponding width or diameter ratio on orifice discharge. In fact, this ratio, which is a width-contraction ratio, is complementary to h/P as an area-contraction ratio.

Strangely, in view of the great volume of recorded research on weirs of all forms, the relative influence of b/B in the total function expressed by equation 9 has received little attention. Several published discharge formulae containing the b/B ratio appear to have been based on insufficient experimental evidence.

Influence of the b/h Ratio.--The effect of the b/h ratio is believed to be negligible over the full range of the other variables. In his thesis Wells concluded that the effect of the b/h ratio could be ignored. A few recorded attempts by others to incorporate the b/h ratio in discharge formulae are believed to be, actually, the result of efforts to correlate the effect of h and b as measures of the influence of viscosity and surface tension.

Influence of the h/P Ratio.--The h/P ratio is a primary geometric ratio, a measure of the vertical channel-contraction characteristic of the weir. Thus, h/P is a ratio that describes the degree of vertical contraction of the channel. It is evident that the upper and lower nappe profiles are a function of h/P.

Evaluation of C.--From the foregoing discussion, the general discharge function expressed by equation 9 can be simplified to

$$C = f_3(h, b, \frac{b}{B}, \frac{h}{P}), \tag{12}$$

in which the first two items in the right-hand member are fluid property parameters and the last two are geometric parameters.

Equation 12 has not yet been evaluated analytically. Previous efforts to evaluate the function experimentally have been concerned almost exclusively with the restricted conditions represented by suppressed weirs of considerable width, for which

$$C = f_4(h, \frac{h}{P}). \tag{13}$$

The influence represented by h in equation 13, attributed to a combination of viscosity and surface-tension phenomena, is appreciable only when h is less than about 0.3 feet. In 1928 Rehbock, following a suggestion by Prandtl, reported that experimental data on suppressed weirs for a full range of heads could be correlated if a constant (0.004 feet) were added to the observed piezometric heads. This procedure is consistent with the foregoing explanation of the influence of surface tension and viscosity. In other words, if an "effective" head, $h_e = h + 0.004$, is used instead of h in equation 11, the same value of C will apply to all values of h on a given suppressed weir; that is, h as an independent variable is "removed" from equation 12.

Because viscosity and surface tension appear to influence the horizontal flow pattern in the same manner as they influence the vertical flow pattern, it would seem to follow that a constant could also be added to the width of the weir to "remove" b from the independent variables in equation 12. It is proposed, therefore, that a comprehensive equation for the basic weir be written in the form,

$$Q = C'(b + k_b)(h + k_h)^{3/2}, \tag{14}$$

in which k_b and k_h are quantities which account for the effect of surface tension and viscosity, and

$$C' = f_5(\frac{h}{P}, \frac{b}{B}), \tag{15}$$

an equation which must be evaluated by experiment. It was the main purpose of the writer's experimental investigation to substantiate equations 14 and 15.

CHAPTER III

LABORATORY SET-UP

General Arrangement.--The laboratory tests for the writer's investigation were made in the Hydraulics Laboratory, School of Civil Engineering, Georgia Institute of Technology. The general arrangement of the experimental equipment used for most of the tests is shown in figures 2 and 3. The weir section in this set-up was located at the end of the flume and 25 feet downstream from the baffles. Water was supplied to the flume from the constant-head recirculating system. A valve in the supply line was used to regulate the discharge. The maximum capacity of the water system for the flume is about 6.0 cubic feet per second.

The Flumes.--The flume used for most of the tests made for this investigation is ten feet wide and 25 feet long. Baffles required to produce a uniform flow consisted of two wooden cribs, and expanded-metal screen, and a surface float. The floor of the flume consisted of aluminum plates in the vicinity of the weir and sheets of transite on the remaining portion. The floor plates were supported by a grid of bars and leveling screws. The width of the flume was varied by means of false walls. These walls were faced with aluminum plates and were bolted to the sides of the permanent flume with threaded rods. For the tests on contracted weirs the false walls were made to butt against the bulkhead in which the weir was mounted. For the suppressed-weir tests the aluminum plates on the false walls were made to protrude through the weir notch and past the weir crest for a distance of six inches. The bottoms of the protruding portions of the plates were level with the crest of the weir.

A uniform velocity distribution was maintained by adjusting the baffles in the flume for each position of the false walls. The velocity distribution was frequently checked with current-meter measurements. Typical velocity-distribution measurements are shown in table 1.

A few tests were made in the three-foot flume in which Mr. Wells made the tests for his thesis. The measuring equipment and baffle arrangement used by Mr. Wells was also used in these tests.

The Weir Plates.--The plates used to form the weirs for this investigation were the same as those used by Mr. Wells. The basic frame for the weirs was made of 3/8-inch aluminum plate. The notch edges were made of 1/8-inch stainless steel plate. These edge pieces were beveled on the downstream side and machined accurately to sharp-cornered edges not over 1/16-inch thick. The width of the weir notch was varied by means of additional aluminum plates which were attached to the basic frame before the stainless steel edges were installed. Notch widths were varied from 0.10 feet to 2.68 feet. The notch was one foot deep.

The height of the weir crest with respect to the floor, P, was varied by varying the height of the basic weir rather than the elevation of the floor. Values of P used for the tests were 0.3, 0.56, and 1.45 feet.

Head Measurements.--The head on the weir was measured with a hook gage in a stilling well connected to piezometers located in the false walls two inches above the floor and five feet upstream from the weir plate. The datum of the hook gage was determined with an engineer's transit. It was checked regularly.

Discharge Measurements.--The rate of flow was measured by means of a weighing tank located at the upstream end of the flume. Weights were recorded to the nearest pound on a beam scale. Time measurements were made to the nearest 0.01 seconds by means of an electric stop clock.

CHAPTER IV

EXPERIMENTAL PROCEDURE AND RESULTS

Comparison of Tests in the Three-Foot and Ten-Foot Flumes.--Tests 1 to 97, listed in table 2, were made in the three-foot flume used by Mr. Wells for his thesis. Tests 98 to 346, listed in table 3, were made in the ten-foot flume described in the previous chapter. The tests in the three-foot flume were made, first, to determine whether Mr. Wells' data could be duplicated; second, to obtain additional data for a lower value of P than was included in his tests; and, third, to obtain data for the suppressed-weir condition. In planning this investigation it was expected that the tests made in the ten-foot flume would complement the tests made in the three-foot flume. Plans for the investigation were changed, however, when it became apparent that the tests made in the three-foot flume could not be duplicated in the ten-foot flume.

Figure 4 shows a comparison of data derived from tests made on suppressed weirs in the two flumes. Although the geometry of the weir and approach channel was identical in the comparative tests, the discharge coefficients derived from the three-foot flume were consistently about two percent higher than the coefficients derived from the ten-foot flume. This difference is believed to be caused by the difference in the velocity distributions in the two flumes. The velocity distribution in the three-foot flume, as shown by Mr. Wells' measurements, was not uniform. Furthermore, it is possible that this non-uniformity may have been increased by changes made in the baffle arrangement after the completion of Mr. Wells' investigation. For these reasons it was decide to disregard all of the data from the three-foot flume, and to make a complete experimental investigation in the ten-foot flume.

Distribution of Velocity in the Ten-Foot Flume.--By adjusting the baffles and entrance guide-walls in the ten-foot flume a uniform velocity distribution was secured for every position of the false walls. Surface floats were used to quiet the waves produced at the entrance to the test flume. The velocity distribution was checked with a current meter and with dye streaks. Typical velocity measurements are shown in table 1.

Tests Made in the Ten-Foot Flume.--A general outline of procedure for the tests in the ten-foot flume is given below.

1. With a constant crest width, b, of 1.800 feet and a constant weir height, P, of 1.44 feet the width of the approach channel, B, was varied to obtain values of b/B in the range from 0.2 to 1.00. For each value of b/B a series of tests were made for the largest possible range of discharges.

2. The procedure described above was repeated for two other values of weir height, 0.56 and 0.30 feet. The width of the crest was held constant at 1.800 feet.

3. With the height of the weir equal to 0.30 feet, the width of the crest was varied from 0.10 to 1.20 feet. At each crest width, several values of b/B were tested for a complete range of discharge.

For all tests the discharge was determined by weight measurements, the head on the weir was measured with a hook gage, and all weir dimensions were measured with micrometers.

The data obtained from the tests made in the ten-foot flume and certain computed ratios and coefficients are shown in table 3. Values of C and C' shown in table 3 were computed from the following equations. From equation 11,

$$C = \frac{Q}{b\ h^{3/2}}, \tag{16}$$

and, from equation 14,

$$C' = \frac{Q}{(b + k_b)(h + k_h)^{3/2}}. \tag{17}$$

CHAPTER V

ANALYSIS AND DISCUSSION OF RESULTS

Influence of Very Small Heads.--The coefficient of discharge for thin-plate weirs is appreciably influenced by viscosity and surface-tension forces only when the head on the weir, h, or the width of the notch, b, or both, are very small. In order to isolate the effect of h a series of tests was made with large values of b, and a range of values of h/P and b/B. A crest width of 2.68 feet was used with $b/B = 1.00$, and a crest width of 1.80 feet was used with $b/B = 0.2$, 0.4, 0.6, 0.8, and 0.9. The values of C (equation 16) determined from these tests are shown plotted as the open circles on figures 5 to 10, inclusive. The combined effects of surface tension and viscosity in increasing the coefficient at low heads is shown by this plot.

A curve drawn through the open circles on figures 5 to 10 shows that C increases as h decreases (indicated here by decreasing values of h/P). The effect of adding a constant, k_h, to every value of h is demonstrated by the solid circles plotted on the same figures. These points show C' as a function of h/P. The better definition of a single curve for all values of h demonstrates the validity of the theory that the combined effects of viscosity and surface tension are similar to an increase in head. It was found by successive approximations that a value $k_h = 0.003$ feet could be used to correlate all tests (all values of b/B, h, and P) which involve larger values of b.

In an unpublished study of experiments on suppressed weirs by Bazin (4) Schoder and Turner (8) and the U. S. Bureau of Reclamation (13),

H. J. Tracy[1] determined values of k_h which would correlate the data for each of these investigations. For Bazin's data the value of k_h determined by Mr. Tracy was +0.006 feet. For data obtained by Schoder and Turner as well as that obtained by the U. S. Bureau of Reclamation, k_h was +0.003 feet. Values of C' computed with these values of k_h are shown in figure 11. In all of the investigations summarized on figure 11, the width of the crest was relatively large and the b effect is believed to be negligible.

From these and other studies it was indicated that a single constant value of k_h will correlate the data for any one investigation. However, different values of k_h are required to correlate the data from different investigations. It is believed that differences in the physical characteristics of the laboratory set-up are responsible for the differences in k_h.

Influence of Very Small Opening Widths.--In order to isolate the b effect, tests were made in which the width of the crest was varied for different values of b/B. For example, with $b/B < 0.13$ tests were made with values of b equal to 0.12, 0.28, 0.58, and 1.2 feet. The computed values of C (equation 16) for this series are shown on figure 12 by the open symbols. The data for each value of b is identified by a different symbol. The trend of increasing values of C with decreasing values of b is believed to indicate the combined effects of surface tension and viscosity. By a method of successive approximations it was found that adding 0.008 feet to all values of b would correlate all the data in this series. Thus, values of C' (equation 17) shown by the solid symbol define a single curve for

[1]Hydraulic Engineer, U. S. Geological Survey, Atlanta, Georgia.

all values of b.

From similar tests for different values of b/B it was indicated that k_b is a function of b/B. Figure 13 shows values of k_b determined from tests covering the full range of b/B. It is apparent that k_b increases as b/B increases from 0.2 to 0.8, and decreases as b/B increases from 0.8 to 1.00. The shape of the curve drawn through the points on figure 13 is explained as follows: As b/B approaches 1.0 the effect of the boundary layer on the sides of the flume is to cause a decrease in the effective width; also, as b/B approaches 1.0, the effect of surface tension (on the effective width) disappears. Thus, at b/B = 1.0, the combined effects of the two fluid properties at small values of b is represented by a negative value of k_b.

Influence of the Ratio of Head to Weir Height.--The effect of the h/P ratio on the coefficient of discharge is represented by the slope of the curves drawn on figures 5 to 10. For example, at b/B = 0.2, the slope of the straight line is -0.001, and at b/B = 1.00, the slope of the line is 0.40.

Influence of Width-Head Ratio.--The experimental data showed no systematic correlation with the width-head ratio. The relative unimportance of this ratio had been demonstrated previously by Mr. Wells.

Influence of Width-Contraction Ratio.--The influence of the width-contraction ratio, b/B (as well as the influence of h/P), is demonstrated in figures 14 to 21. Values of C' computed for all the data obtained in this investigation are shown as a function of h/P in this series, in which each graph represents a different value of b/B. The straight lines that define the trends on each graph are summarized on figure 22. The equations of these lines are of the form

$$C' = C'_o + m(\frac{h}{P}),$$

where C'_o = C' at h/P = 0, and m is the slope of the line.

Figure 22 shows that the effect of b/B increases as h/P increases. The effect of b/B at various values of h/P is demonstrated in figure 23 by a cross-plot of values taken from the family of curves in figure 22. The curves shown on figure 23 are logically similar to curves showing the effect of b/B on the discharge coefficients for slots (2) and open-channel constrictions (14).

Figures 22 and 23 demonstrate that the width-contraction ratio has a large influence on the discharge coefficient. Thus, for example, at h/P = 1.0 the value of C' varies from 3.12 at b/B = 0 to 3.62 at b/B = 1.0.

Summary of Analysis.--In Chapter II it was shown that the coefficient of discharge for the basic weir can be described by the functional relationship,

$$C = f_3(h, b, \frac{b}{B}, \frac{h}{P}), \qquad (12)$$

in which h and b represent the effects of surface tension and viscosity and b/B and h/P are geometric ratios. It was reasoned that the h and b effects could be accounted for by adding a quantity k_b to the width of the weir and a quantity k_h to the measured head, whence,

$$Q = C'(b + k_b)(h + k_h)^{3/2}, \qquad (14)$$

and

$$C' = f_5(\frac{h}{P}, \frac{b}{B}). \qquad (15)$$

The proposed form of analysis was verified by the data obtained in the laboratory. It was found that a single value of k_h (0.003 feet) is applicable to all values of h/P and b/B, but that k_b is a function of b/B as shown in figure 13. The function expressed by equation 15 was defined by the laboratory data and is summarized as a family of straight lines in figure 22. The equations of these lines for several values of b/B are given below:

$$\frac{b}{B} = 1.00 \qquad C' = 3.22 + 0.40(\frac{h}{P})$$

$$\frac{b}{B} = 0.80 \qquad C' = 3.19 + 0.25(\frac{h}{P})$$

$$\frac{b}{B} = 0.60 \qquad C' = 3.18 + 0.10(\frac{h}{P})$$

$$\frac{b}{B} = 0.40 \qquad C' = 3.16 + 0.03(\frac{h}{P})$$

$$\frac{b}{B} = 0.20 \qquad C' = 3.15 + 0.01(\frac{h}{P})$$

Comparison With Other Formulas.--Most of the previous investigations of weir discharge have dealt with suppressed weirs. Two formulas for the rectangular-notch weir are the Francis width-correction formula (equation 3), and the S.I.A. formula (equation 4). Both of these formulas were restricted by their authors to a narrow range of weir geometry.

The Francis width-correction formula is usually restricted to values of h less than one-third the crest length. Even with this limitation, however, it appears from data obtained in this investigation that the Francis formula is only an approximation. This is demonstrated in figure 24 by plotting the discharge coefficient computed from an equation derived from the Francis formula,

$$C_F = \frac{Q}{(b - 0.2h)(h)^{3/2}} ,$$

for a selected group of the author's data. It is evident from the fact that the computed points do not define a single curve that the Francis formula does not account for the effect of width contraction, even within the limits set by the author.

It is difficult to make a direct comparison between the data obtained in this investigation and the S.I.A. formula because the restrictions placed by the S.I.A. on the formula limit its application to a much smaller range of conditions than were investigated by the author. An indication of the formula's ability to correlate the important b/B variable, however, can be obtained from a comparison of the author's C' and a coefficiant C_S defined by the equation

$$C_S = [0.578 + 0.037(\frac{b}{B})^2] [1 + 0.5(\frac{b}{B})^4 (\frac{h}{P + h})^2] \frac{2}{3}\sqrt{2g} .$$

In order to justify the omission of the term containing the absolute value of h in the S.I.A. discharge formula (equation 4), the comparison of C' and C_S was made for a head of ten feet (large enough to make the effect of h negligible). Table 4 shows a comparison of the two coefficients in the form of a ratio, C_S/C', which varies from 0.957 to 1.006 for a full range of values of h/P and b/B.

CHAPTER VI

CONCLUSIONS

1. The coefficient of discharge for rectangular-notch weirs is a function of two geometric parameters and the Reynolds and Weber numbers,

$$C = f_2(R, W, \frac{b}{B}, \frac{h}{P}, \frac{b}{h}). \qquad (9)$$

2. For the flow of any given liquid through notch weirs, the absolute values of b and h are sufficient measures of the influence represented by the Reynolds and Weber numbers, or,

$$C = f_3(h, b, \frac{b}{B}, \frac{h}{P}). \qquad (12)$$

3. The relative effect of b and h on C may be represented by a constant, k_h, added to the measured head and a quantity, k_b, added to the width of the weir notch. A constant value of k_h = 0.003 feet can be used for all values of h/P and b/B, but the value of k_b varies with the ratio b/B as shown in figure 11.
4. The value of the discharge coefficient C' in the equation listed below has been defined in figure 22 for a full range of the geometric ratios h/P and b/B. These values of C' are applicable to weirs of any crest width and for any head in the equation,

$$Q = C'(b + k_b)(h + k_h)^{3/2}. \qquad (14)$$

5. The Francis equation for notch weirs is not reliable, even within the limits imposed by the author.
6. A comprehensive solution for the discharge over rectangular-notch weirs has been accomplished for the range of fluid property parameters covered in this investigation.

BIBLIOGRAPHY

LITERATURE CITED

1. Boss, P., "Berechnung der Abflussmengen und der Wasserspiegellage bei Absturzen und Schwellen unter besonderer Berucksichtigung der dabei auftretenden Zusatzspannungen," Wasserkraft und Wasserwirtschaft, Nos. 2-3, 1929.

2. Rouse, Hunter, Engineering Hydraulics, p. 532, John Wiley and Sons, 1950.

3. Francis, J. B., Lowell Hydraulic Experiments, fourth edition, D. Van Nostrand, New York, 1883.

4. Bazin, H., Annales des Ponts et Chaussees, Oct. 1888; Translated by Arthur Marichal and John C. Trautwine, Jr., "Recent Experiments on the Flow of Water Over Weirs," Proceedings, Engineer's Club of Philadelphia, Vol. 7, No. 5, Jan. 1890, pp. 259-310.

5. Fteley, A., and F. P. Stearns, "Description of some Experiments on the Flow of Water made during the Construction of Works for Conveying the Water of Sudbury River to Boston," Transactions, American Society of Civil Engineers, Vol. 12, 1883, pp. 1-118.

6. Nagler, F. A., "Verification of the Bazin Weir Formula by Hydro-Chemical Gauging," Transactions, American Society of Civil Engineers, Vol. 83, 1919, pp. 105-156.

7. Frese, F., "Versuche Uber den Abfluss des Wassers bei vollkommenden Uberfallen," Zeitschrift des Vereins Deutscher Ingenieure, Vol. 34, No. 51, Dec. 20, 1890.

8. Schoder, E. W., and K. B. Turner, "Precise Weir Measurements," Transactions, American Society of Civil Engineers, Vol. 93, 1929, p. 1004.

9. Rehbock, Th., "Wassermessung mit scharfkantigen Uberfallwehren," Zeitschrift des Vereins Deutscher Ingenieure, Vol. 73, May 15, 1929, p. 817.

10. Normen fur Wassermessungen, Schweizerischen Ingenieure und Architekten-Verein, 1924.

11. Wells, James R., "Discharge Characteristics of Rectangular Notch Weirs in Rectangular Channels," a Thesis in Partial Fulfillment of the Requirements for the Degree, Master of Science in Civil Engineering, Georgia Institute of Technology, 1954.

12. Lindquist, Erik G. W., Discussion of Reference (8), Transactions, American Society of Civil Engineers, Vol. 93, 1929.

13. "Studies of Crests for Overfall Dams," U. S. Bureau of Reclamation, Boulder Canyon Project Reports, Part VI, Bulletin 1.

14. Kindsvater, C. E., and R. W. Carter, "Tranquil Flow through Open Channel Constrictions," Transactions, American Society of Civil Engineers, Vol. 120, 1955.

APPENDIX

Table 1. Velocity Distribution between False Walls in the Ten-Foot Flume.

Test No.	P (feet)	b (feet)	x (feet) (*)	y (feet) (**)	V (fps)
I	0.564	2.68	0.2	0.1	0.837
	0.564	2.68	0.2	0.3	0.944
	0.564	2.68	0.2	0.5	0.965
	0.564	2.68	0.2	0.7	0.944
	0.564	2.68	0.2	0.8	0.987
	0.564	2.68	0.5	0.1	0.885
	0.564	2.68	0.5	0.3	0.965
	0.564	2.68	0.5	0.5	0.965
	0.564	2.68	0.5	0.7	0.965
	0.564	2.68	0.5	0.8	0.976
	0.564	2.68	0.8	0.1	0.923
	0.564	2.68	0.8	0.3	0.944
	0.564	2.68	0.8	0.5	0.944
	0.564	2.68	0.8	0.7	0.923
	0.564	2.68	0.8	0.8	0.944
	0.564	2.68	1.1	0.1	0.826
	0.564	2.68	1.1	0.3	0.965
	0.564	2.68	1.1	0.5	0.944
	0.564	2.68	1.1	0.7	0.934
	0.564	2.68	1.1	0.8	0.944
	0.564	2.68	1.4	0.1	0.876
	0.564	2.68	1.4	0.3	0.834
	0.564	2.68	1.4	0.5	0.868
	0.564	2.68	1.4	0.7	0.904
	0.564	2.68	1.4	0.8	0.914
	0.564	2.68	1.7	0.1	0.868
	0.564	2.68	1.7	0.3	0.904
	0.564	2.68	1.7	0.5	0.904
	0.564	2.68	1.7	0.7	0.904
	0.564	2.68	1.7	0.8	0.904

* x = distance from left wall
** y = depth below surface

Table 1. Continued.

Test No.	P (feet)	b (feet)	x (feet)	y (feet)	V (fps)
I	0.564	2.68	2.1	0.1	0.803
	0.564	2.68	2.1	0.3	0.904
	0.564	2.68	2.1	0.5	0.923
	0.564	2.68	2.1	0.7	0.944
	0.564	2.68	2.1	0.8	0.944
	0.564	2.68	2.4	0.1	0.904
	0.564	2.68	2.4	0.3	0.868
	0.564	2.68	2.4	0.5	0.987
	0.564	2.68	2.4	0.7	0.987
	0.564	2.68	2.4	0.8	0.987
II	0.302	2.68	0.2	0.1	1.40
	0.302	2.68	0.2	0.2	1.47
	0.302	2.68	0.2	0.3	1.54
	0.302	2.68	0.2	0.4	1.50
	0.302	2.68	0.2	0.5	1.50
	0.302	2.68	0.5	0.1	1.52
	0.302	2.68	0.5	0.2	1.50
	0.302	2.68	0.5	0.3	1.50
	0.302	2.68	0.5	0.4	1.50
	0.302	2.68	0.5	0.5	1.50
	0.302	2.68	0.8	0.1	1.47
	0.302	2.68	0.8	0.2	1.50
	0.302	2.68	0.8	0.3	1.50
	0.302	2.68	0.8	0.4	1.47
	0.302	2.68	0.8	0.5	1.47
	0.302	2.68	1.1	0.1	1.40
	0.302	2.68	1.1	0.2	1.43
	0.302	2.68	1.1	0.3	1.47
	0.302	2.68	1.1	0.4	1.47
	0.302	2.68	1.1	0.5	1.43

Table 1. Continued.

Test No.	P (feet)	b (feet)	x (feet)	y (feet)	V (fps)
II	0.302	2.68	1.4	0.1	1.25
	0.302	2.68	1.4	0.2	1.31
	0.302	2.68	1.4	0.3	1.37
	0.302	2.68	1.4	0.4	1.37
	0.302	2.68	1.4	0.5	1.38
	0.302	2.68	1.7	0.1	1.24
	0.302	2.68	1.7	0.2	1.29
	0.302	2.68	1.7	0.3	1.43
	0.302	2.68	1.7	0.4	1.43
	0.302	2.68	1.7	0.5	1.42
	0.302	2.68	2.0	0.1	1.43
	0.302	2.68	2.0	0.2	1.43
	0.302	2.68	2.0	0.3	1.47
	0.302	2.68	2.0	0.4	1.43
	0.302	2.68	2.0	0.5	1.43
	0.302	2.68	2.3	0.1	1.40
	0.302	2.68	2.3	0.2	1.43
	0.302	2.68	2.3	0.3	1.43
	0.302	2.68	2.3	0.4	1.47
	0.302	2.68	2.3	0.5	1.47
	0.302	2.68	2.5	0.1	1.17
	0.302	2.68	2.5	0.2	1.37
	0.302	2.68	2.5	0.3	1.43
	0.302	2.68	2.5	0.4	1.40
	0.302	2.68	2.5	0.5	1.40

Table 2. Summary of Tests in the Three-Foot Flume.

Test No.	B (feet)	b (feet)	P (feet)	T (^{o}F)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$ (*)	C (*)
1	3.00	2.405	1.842	71	1.627	0.349	0.80	-	-
2	3.00	2.405	1.842	71	2.085	0.411	0.80	-	-
3	3.00	2.405	1.842	71	2.806	0.505	0.80	-	-
4	3.00	2.405	1.842	71	3.677	0.598	0.80	-	-
5	3.00	2.405	1.842	71	4.302	0.671	0.80	-	-
6	3.00	2.405	0.075	71	0.298	0.103	0.80	-	-
7	3.00	2.405	0.075	71	1.212	0.255	0.80	-	-
8	3.00	2.405	0.075	71	1.892	0.339	0.80	-	-
9	3.00	2.405	0.075	71	2.639	0.417	0.80	-	-
10	3.00	2.405	0.075	71	3.559	0.497	0.80	-	-
11	3.00	2.405	0.075	71	4.405	0.571	0.80	-	-
12	3.00	2.405	0.075	71	5.002	0.145	0.80	-	-
13	3.00	1.805	0.075	71	0.365	0.147	0.60	-	-
14	3.00	1.805	0.075	71	1.019	0.293	0.60	-	-
15	3.00	1.805	0.075	71	0.698	0.229	0.60	-	-
16	3.00	1.805	0.075	71	1.350	0.353	0.60	-	-
17	3.00	1.805	0.075	71	2.038	0.461	0.60	-	-
18	3.00	1.805	0.075	71	2.385	0.513	0.60	-	-
19	3.00	1.805	0.075	71	0.094	0.060	0.60	-	-
20	3.00	1.805	0.075	71	3.106	0.603	0.60	-	-
21	3.00	1.805	0.075	71	3.955	0.711	0.60	-	-
22	3.00	2.711	0.075	71	0.373	0.108	0.90	-	-
23	3.00	2.711	0.075	71	0.650	0.154	0.90	-	-
24	3.00	2.711	0.075	71	0.769	0.170	0.90	-	-
25	3.00	2.711	0.075	71	0.980	0.199	0.90	-	-
26	3.00	2.711	0.075	71	1.945	0.303	0.90	-	-
27	3.00	2.711	0.075	71	3.240	0.412	0.90	-	-
28	3.00	2.711	0.075	71	4.440	0.489	0.90	-	-
29	3.00	2.711	0.075	71	1.380	0.246	0.90	-	-
30	3.00	1.206	0.075	70	0.651	0.294	0.40	-	-

*Dash indicates that the values were not computed.

Table 2. Continued.

Test No.	B (feet)	b (feet)	P (feet)	T (^oF)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$ (*)	C (*)
31	3.00	1.206	0.075	70	1.125	0.427	0.40	-	-
32	3.00	1.206	0.075	70	1.708	0.564	0.40	-	-
33	3.00	1.206	0.075	70	0.253	0.157	0.40	-	-
34	3.00	1.206	0.075	70	0.446	0.228	0.40	-	-
35	3.00	0.600	0.075	71	0.374	0.329	0.20	-	-
36	3.00	0.600	0.075	71	0.162	0.190	0.20	-	-
37	3.00	0.600	0.075	71	0.271	0.267	0.20	-	-
38	3.00	0.600	0.075	71	0.059	0.094	0.20	-	-
39	3.00	0.600	0.075	71	0.124	0.158	0.20	-	-
40	3.00	0.600	0.075	71	0.720	0.519	0.20	-	-
41	3.00	0.600	0.075	71	0.507	0.413	0.20	-	-
42	3.00	0.121	0.075	71	0.077	0.335	0.04	-	-
43	3.00	0.121	0.075	71	0.016	0.117	0.04	-	-
44	3.00	0.121	0.075	71	0.159	0.545	0.04	-	-
45	3.00	0.121	0.075	71	0.049	0.247	0.04	-	-
46	3.00	0.121	0.075	71	0.031	0.181	0.04	-	-
47	3.00	0.121	0.075	71	0.042	0.223	0.04	-	-
48	3.00	0.121	0.075	71	0.065	0.299	0.04	-	-
49	3.00	0.121	0.075	71	0.097	0.390	0.04	-	-
50	3.00	0.292	0.075	71	0.126	0.264	0.10	-	-
51	3.00	0.292	0.075	71	0.057	0.153	0.10	-	-
52	3.00	0.292	0.075	71	0.035	0.110	0.10	-	-
53	3.00	0.292	0.075	71	0.074	0.184	0.10	-	-
54	3.00	0.292	0.075	71	0.202	0.362	0.10	-	-
55	3.00	0.292	0.075	71	0.314	0.487	0.10	-	-
56	3.00	0.292	0.075	71	0.186	0.344	0.10	-	-
57	3.00	0.292	0.148	71	0.049	0.138	0.10	-	-
58	3.00	0.292	0.148	71	0.078	0.190	0.10	-	-
59	3.00	0.292	0.148	71	0.128	0.268	0.10	-	-
60	3.00	0.292	0.148	71	0.210	0.373	0.10	-	-

*Dash indicates that the values were not computed.

Table 2. Continued.

Test No.	B (feet)	b (feet)	P (feet)	T (^{o}F)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$ (*)	C (*)
61	3.000	0.292	0.148	71	0.385	0.550	0.10	-	-
62	3.000	0.292	0.148	71	0.282	0.452	0.10	-	-
63	3.000	0.292	0.427	71	0.031	0.100	0.10	-	-
64	3.000	0.292	0.427	71	0.066	0.171	0.10	-	-
65	3.000	0.292	0.427	71	0.130	0.271	0.10	-	-
66	3.000	0.292	0.427	71	0.245	0.409	0.10	-	-
67	3.000	0.292	0.427	71	0.499	0.659	0.10	-	-
68	3.000	0.292	0.427	71	0.370	0.538	0.10	-	-
69	2.686	2.686	0.148	73	0.313	0.099	1.00	-	-
70	2.686	2.686	0.148	73	0.578	0.145	1.00	-	-
71	2.686	2.686	0.148	73	1.162	0.225	1.00	-	-
72	2.686	2.686	0.148	73	1.911	0.304	1.00	-	-
73	2.686	2.686	0.148	73	2.844	0.384	1.00	-	-
74	2.686	2.686	0.148	73	3.940	0.464	1.00	-	-
75	2.686	2.686	0.148	73	0.404	0.117	1.00	-	-
76	2.686	2.686	0.148	73	0.812	0.181	1.00	-	-
77	2.686	2.686	0.148	73	1.495	0.263	1.00	-	-
78	2.684	2.684	0.427	71	0.402	0.122	1.00	0.286	3.515
79	2.684	2.684	0.427	71	0.224	0.081	1.00	0.190	3.610
80	2.684	2.684	0.427	71	0.769	0.187	1.00	0.438	3.536
81	2.684	2.684	0.427	71	1.188	0.249	1.00	0.584	3.558
82	2.684	2.684	0.427	71	1.952	0.340	1.00	0.797	3.662
83	2.684	2.684	0.427	71	2.870	0.435	1.00	1.020	3.725
84	2.684	2.684	0.427	71	3.466	0.488	1.00	1.140	3.788
85	2.684	2.684	0.427	71	4.096	0.539	1.00	1.260	3.850
86	2.684	2.684	0.427	71	5.995	0.679	1.00	1.590	3.990
87	2.684	2.684	0.427	71	4.916	0.604	1.00	1.410	3.910
88	2.684	2.684	0.427	71	1.472	0.288	1.00	0.675	3.550
89	2.684	2.684	1.047	70	0.229	0.083	1.00	0.079	3.565
90	2.684	2.684	1.047	70	0.743	0.186	1.00	0.178	3.450

*Dash indicates that the values were not computed.

Table 2. Continued.

Test No.	B (feet)	b (feet)	P (feet)	T (°F)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$ (*)	C (*)
91	2.684	2.684	1.047	70	1.281	0.266	1.00	0.254	3.490
92	2.684	2.684	1.047	70	1.682	0.319	1.00	0.305	3.475
93	2.684	2.684	1.047	70	2.126	0.373	1.00	0.356	3.475
94	2.684	2.684	1.047	70	2.800	0.449	1.00	0.429	3.465
95	2.684	2.684	1.047	70	3.590	0.529	1.00	0.505	3.474
96	2.684	2.684	1.047	70	4.502	0.615	1.00	0.588	3.478
97	2.684	2.684	1.047	70	5.510	0.705	1.00	0.673	3.462

*Dash indicates that the values were not computed.

Table 3. Summary of Tests in the Ten-Foot Flume.

Test No.	B (feet)	b (feet)	P (feet)	T (°F)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$	C	C'
98	2.682	2.682	0.302	70	0.631	0.167	1.00	0.554	3.450	3.358
99	2.682	2.682	0.302	70	0.289	0.098	1.00	0.325	3.400	3.352
100	2.682	2.682	0.302	70	1.070	0.233	1.00	0.772	3.547	3.483
101	2.682	2.682	0.302	70	1.495	0.287	1.00	0.951	3.624	3.571
102	2.682	2.682	0.302	70	2.054	0.349	1.00	1.16	3.714	3.668
103	2.682	2.682	0.302	70	2.524	0.397	1.00	1.32	3.763	3.722
104	2.682	2.682	0.302	70	3.095	0.448	1.00	1.48	3.848	3.812
105	2.682	2.682	0.302	70	3.685	0.498	1.00	1.65	3.910	3.877
106	2.682	2.682	0.302	70	4.259	0.544	1.00	1.80	3.958	3.927
107	2.682	2.682	0.302	70	4.667	0.575	1.00	1.91	3.991	3.962
108	2.682	2.682	0.302	70	5.413	0.625	1.00	2.07	4.085	4.057
109	2.682	2.682	0.302	70	6.232	0.678	1.00	2.25	4.162	4.137
110	2.684	2.684	0.564	70	1.530	0.301	1.00	0.534	3.451	3.404
111	2.684	2.684	0.564	70	1.006	0.230	1.00	0.408	3.399	3.333
112	2.684	2.684	0.564	70	0.293	0.100	1.00	0.177	3.455	3.307
113	2.684	2.684	0.564	70	2.218	0.381	1.00	0.676	3.513	3.474
114	2.684	2.684	0.564	70	3.155	0.476	1.00	0.845	3.580	3.548
115	2.684	2.684	0.564	70	3.709	0.527	1.00	0.935	3.612	3.584
116	2.684	2.684	0.564	70	4.530	0.593	1.00	1.15	3.696	3.670
117	2.684	2.684	0.564	70	5.380	0.659	1.00	1.17	3.747	3.724
118	2.682	2.682	1.445	75	1.894	0.353	1.00	0.244	3.368	3.327
119	2.682	2.682	1.445	75	2.738	0.450	1.00	0.312	3.381	3.350
120	2.682	2.682	1.445	75	3.548	0.533	1.00	0.369	3.400	3.373
121	2.682	2.682	1.445	75	2.148	0.384	1.00	0.266	3.365	3.316
122	2.682	2.682	1.445	75	1.674	0.325	1.00	0.225	3.368	3.312
123	2.682	2.682	1.445	75	1.185	0.259	1.00	0.179	3.352	3.296
124	2.682	2.682	1.445	75	0.835	0.161	1.00	0.111	4.818	4.670
125	2.000	1.800	1.445	75	2.233	0.512	0.90	0.354	3.386	3.334

Table 3. Continued

Test No.	B (feet)	b (feet)	P (feet)	T (^oF)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$	C	C'
126	2.000	1.800	1.445	75	1.855	0.455	0.90	0.315	3.358	3.299
127	2.000	1.800	1.445	75	1.517	0.399	0.90	0.276	3.344	3.291
128	2.000	1.800	1.445	75	0.999	0.303	0.90	0.210	3.328	3.264
129	2.000	1.800	1.445	75	0.562	0.206	0.90	0.143	3.339	3.249
130	2.250	1.800	1.445	72	2.207	0.518	0.80	0.356	3.289	3.245
131	2.250	1.800	1.445	72	2.084	0.499	0.80	0.345	3.284	3.228
132	2.250	1.800	1.445	72	1.735	0.441	0.80	0.306	3.291	3.232
133	2.250	1.800	1.445	72	1.453	0.393	0.80	0.272	3.276	3.213
134	2.250	1.800	1.445	72	0.980	0.301	0.80	0.208	3.295	3.222
135	2.250	1.800	1.445	72	0.399	0.165	0.80	0.114	3.308	3.197
136	2.250	1.800	1.445	72	0.601	0.218	0.80	0.151	3.281	3.189
137	3.000	1.800	1.445	72	2.277	0.537	0.60	0.372	3.215	3.167
138	3.000	1.800	1.445	72	1.830	0.464	0.60	0.321	3.216	3.165
139	3.000	1.800	1.445	72	1.272	0.363	0.60	0.251	3.231	3.171
140	3.000	1.800	1.445	72	1.445	0.394	0.60	0.273	3.245	3.194
141	3.000	1.800	1.445	72	0.857	0.278	0.60	0.193	3.247	3.174
142	3.000	1.800	1.445	72	0.328	0.144	0.60	0.100	3.337	3.210
143	3.000	1.800	1.445	72	0.547	0.204	0.60	0.141	3.299	3.203
144	4.500	1.800	1.445	72	1.568	0.420	0.40	0.291	3.200	3.150
145	4.500	1.800	1.445	72	2.344	0.552	0.40	0.382	3.175	3.131
146	4.500	1.800	1.445	72	1.242	0.358	0.40	0.248	3.221	3.165
147	4.500	1.800	1.445	72	0.719	0.247	0.40	0.171	3.253	3.180
148	4.500	1.800	1.445	72	0.949	0.299	0.40	0.207	3.225	3.163
149	4.500	1.800	1.445	72	0.360	0.154	0.40	0.107	3.312	3.198
150	4.500	1.800	1.445	72	2.545	0.584	0.40	0.404	3.168	3.128
151	9.104	1.800	1.445	74	1.437	0.396	0.20	0.274	3.203	3.154
152	9.104	1.800	1.445	74	1.765	0.455	0.20	0.315	3.195	3.149
153	9.104	1.800	1.445	74	2.249	0.538	0.20	0.372	3.166	3.126
154	9.104	1.800	1.445	74	1.137	0.338	0.20	0.234	3.215	3.158
155	9.104	1.800	1.445	74	0.628	0.225	0.20	0.156	3.270	3.190

Table 3. Continued.

Test No.	B (feet)	b (feet)	P (feet)	T (^oF)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$	C	C'
156	9.104	1.80	1.445	74	0.379	0.160	0.20	0.111	3.290	3.187
157	9.104	1.80	0.559	75	1.812	0.460	0.20	0.823	3.226	3.182
158	9.104	1.80	0.559	75	1.518	0.409	0.20	0.732	3.224	3.174
159	9.104	1.80	0.559	75	1.131	0.336	0.20	0.601	3.226	3.169
160	9.104	1.80	0.559	75	0.899	0.286	0.20	0.512	3.264	3.200
161	9.104	1.80	0.559	75	0.577	0.212	0.20	0.380	3.284	3.179
162	9.104	1.80	0.559	75	0.299	0.136	0.20	0.244	3.305	3.191
163	9.104	1.80	0.559	75	3.230	0.686	0.20	1.23	3.158	3.124
164	9.104	1.80	0.559	75	2.951	0.644	0.20	1.15	3.172	3.136
165	9.104	1.80	0.559	75	2.428	0.565	0.20	1.01	3.176	3.137
166	4.500	1.80	0.559	74	2.877	0.625	0.40	1.12	3.235	3.195
167	4.500	1.80	0.559	74	2.694	0.599	0.40	1.07	3.228	3.188
168	4.500	1.80	0.559	74	2.356	0.547	0.40	0.98	3.235	3.193
169	4.500	1.80	0.559	74	1.895	0.473	0.40	0.846	3.237	3.190
170	4.500	1.80	0.559	74	1.573	0.416	0.40	0.745	3.257	3.206
171	4.500	1.80	0.559	74	1.012	0.310	0.40	0.555	3.256	3.195
172	4.500	1.80	0.559	74	1.369	0.380	0.40	0.680	3.246	3.193
173	4.500	1.80	0.559	74	0.670	0.234	0.40	0.419	3.288	3.209
174	4.500	1.80	0.559	74	0.208	0.105	0.40	0.188	3.399	3.238
175	4.500	1.80	0.559	74	3.594	0.725	0.40	1.300	3.235	3.198
176	3.000	1.80	0.559	74	3.651	0.719	0.60	1.290	3.327	3.289
177	3.000	1.80	0.559	74	3.097	0.642	0.60	1.150	3.337	3.300
178	3.000	1.80	0.559	74	2.532	0.562	0.60	1.010	3.339	3.290
179	3.000	1.80	0.559	74	2.072	0.493	0.60	0.882	3.325	3.274
180	3.000	1.80	0.559	74	1.683	0.429	0.60	0.768	3.327	3.270
181	3.000	1.80	0.559	74	1.198	0.342	0.60	0.612	3.328	3.263
182	3.000	1.80	0.559	74	0.906	0.283	0.60	0.506	3.342	3.268
183	3.000	1.80	0.559	74	0.586	0.213	0.60	0.381	3.313	3.221
184	3.000	1.80	0.559	74	0.273	0.127	0.60	0.227	3.357	3.218
185	2.250	1.80	0.559	77	3.842	0.716	0.80	1.280	3.523	3.473

Table 3. Continued.

Test No.	B (feet)	b (feet)	P (feet)	T (^{o}F)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$	C	C'
186	2.250	1.80	0.559	77	3.703	0.694	0.80	1.240	3.558	3.507
187	2.250	1.80	0.559	77	3.174	0.631	0.80	1.130	3.518	3.466
188	2.250	1.80	0.559	77	2.497	0.542	0.80	0.970	3.477	3.421
189	2.250	1.80	0.559	77	1.815	0.443	0.80	0.792	3.419	3.362
190	2.250	1.80	0.559	77	2.199	0.499	0.80	0.892	3.467	3.408
191	2.250	1.80	0.559	77	1.350	0.365	0.80	0.653	3.401	3.334
192	2.250	1.80	0.559	77	0.697	0.236	0.80	0.422	3.379	3.290
193	2.250	1.80	0.559	77	0.326	0.143	0.80	0.256	3.347	3.221
194	2.000	1.80	0.559	77	0.760	0.247	0.90	0.442	3.439	3.356
195	2.000	1.80	0.559	77	0.585	0.209	0.90	0.374	3.403	3.308
196	2.000	1.80	0.559	77	3.462	0.654	0.90	1.170	3.637	3.588
197	2.000	1.80	0.559	77	3.403	0.645	0.90	1.150	3.650	3.600
198	2.000	1.80	0.559	77	2.666	0.553	0.90	0.989	3.602	3.548
199	2.000	1.80	0.559	77	2.314	0.505	0.90	0.904	3.582	3.526
200	2.000	1.80	0.559	77	2.006	0.463	0.90	0.828	3.538	3.479
201	2.000	1.80	0.559	77	1.539	0.389	0.90	0.695	3.524	3.460
202	2.000	1.80	0.559	77	1.298	0.350	0.90	0.626	3.482	3.415
203	2.000	1.80	0.559	77	0.986	0.293	0.90	0.524	3.454	3.378
204	2.000	1.80	0.300	77	3.813	0.656	0.90	2.190	3.987	3.933
205	2.000	1.80	0.300	77	3.604	0.634	0.90	2.120	3.967	3.911
206	2.000	1.80	0.300	77	3.328	0.603	0.90	2.01	3.949	3.892
207	2.000	1.80	0.300	77	2.945	0.560	0.90	1.87	3.904	3.848
208	2.000	1.80	0.300	77	2.586	0.519	0.90	1.73	3.842	3.785
209	2.000	1.80	0.300	77	2.242	0.475	0.90	1.58	3.805	3.744
210	2.000	1.80	0.300	77	1.809	0.417	0.90	1.39	3.732	3.667
211	2.000	1.80	0.300	77	1.526	0.375	0.90	1.25	3.692	3.623
212	2.000	1.80	0.300	77	1.210	0.326	0.90	1.09	3.612	3.538
213	2.000	1.80	0.300	77	0.914	0.273	0.90	0.911	3.561	3.478
214	2.000	1.80	0.300	77	0.583	0.205	0.90	0.684	3.491	3.390
215	2.000	1.80	0.300	77	0.401	0.161	0.90	0.536	3.448	3.334

Table 3. Continued.

Test No.	B (feet)	b (feet)	P (feet)	T (°F)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$	C	C'
216	2.250	1.80	0.300	77	3.777	0.678	0.80	2.26	3.759	3.705
217	2.250	1.80	0.300	77	3.555	0.653	0.80	2.18	3.742	3.688
218	2.250	1.80	0.300	77	3.137	0.606	0.80	2.02	3.694	3.638
219	2.250	1.80	0.300	77	2.811	0.566	0.80	1.89	3.668	3.610
220	2.250	1.80	0.300	77	2.460	0.519	0.80	1.73	3.655	3.596
221	2.250	1.80	0.300	77	2.068	0.466	0.80	1.55	3.612	3.549
222	2.250	1.80	0.300	77	1.691	0.410	0.80	1.37	3.579	3.512
223	2.250	1.80	0.300	77	1.288	0.346	0.80	1.15	3.516	3.443
224	2.250	1.80	0.300	77	1.018	0.296	0.80	0.987	3.510	3.432
225	2.250	1.80	0.300	77	0.660	0.226	0.80	0.753	3.414	3.319
226	2.250	1.80	0.300	77	0.185	0.097	0.80	0.324	3.401	3.225
227	3.000	1.80	0.300	76	3.796	0.720	0.60	2.40	3.452	3.407
228	3.000	1.80	0.300	76	3.414	0.673	0.60	2.24	3.435	3.390
229	3.000	1.80	0.300	76	3.030	0.625	0.60	2.08	3.407	3.360
230	3.000	1.80	0.300	76	2.629	0.568	0.60	1.89	3.412	3.363
231	3.000	1.80	0.300	76	2.290	0.520	0.60	1.73	3.393	3.342
232	3.000	1.80	0.300	76	1.949	0.467	0.60	1.56	3.393	3.338
233	3.000	1.80	0.300	76	1.693	0.426	0.60	1.42	3.382	3.325
234	3.000	1.80	0.300	76	1.312	0.362	0.60	1.21	3.347	3.284
235	3.000	1.80	0.300	76	1.010	0.304	0.60	1.01	3.348	3.276
236	3.000	1.80	0.300	76	0.578	0.209	0.60	0.697	3.362	3.268
237	3.000	1.80	0.300	76	0.255	0.121	0.60	0.404	3.364	3.226
238	4.500	1.80	0.300	76	3.870	0.756	0.40	2.52	3.271	3.235
239	4.500	1.80	0.300	76	3.302	0.679	0.40	2.26	3.279	3.240
240	4.500	1.80	0.300	76	3.033	0.644	0.40	2.14	3.261	3.221
241	4.500	1.80	0.300	76	2.583	0.579	0.40	1.93	3.257	3.215
242	4.500	1.80	0.300	76	2.156	0.513	0.40	1.71	3.260	3.214
243	4.500	1.80	0.300	76	1.714	0.439	0.40	1.46	3.273	3.223
244	4.500	1.80	0.300	76	1.286	0.364	0.40	1.21	3.253	3.198
245	4.500	1.80	0.300	76	0.872	0.282	0.40	0.940	3.234	3.166

Table 3. Continued.

Test No.	B (feet)	b (feet)	P (feet)	T (°F)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$	C	C'
246	4.500	1.80	0.300	77	0.681	0.238	0.40	0.794	3.258	3.182
247	8.920	1.80	0.300	77	3.785	0.765	0.20	2.55	3.143	3.110
248	8.920	1.80	0.300	77	3.306	0.697	0.20	2.32	3.156	3.122
249	8.920	1.80	0.300	77	2.958	0.650	0.20	2.17	3.136	3.100
250	8.920	1.80	0.300	77	2.529	0.582	0.20	1.94	3.164	3.126
251	8.920	1.80	0.300	77	1.964	0.490	0.20	1.63	3.181	3.137
252	8.920	1.80	0.300	77	1.634	0.433	0.20	1.44	3.192	3.144
253	8.920	1.80	0.300	77	1.267	0.364	0.20	1.22	3.205	3.152
254	8.920	1.80	0.300	77	0.710	0.246	0.20	0.820	3.227	3.159
255	8.920	1.80	0.300	77	0.316	0.141	0.20	0.470	3.318	3.200
256	8.920	0.577	0.300	77	0.506	0.423	0.06	1.41	3.188	3.110
257	8.920	0.577	0.300	77	1.092	0.710	0.06	2.37	3.163	3.101
258	8.920	0.577	0.300	77	0.775	0.564	0.06	1.88	3.171	3.103
259	8.920	0.577	0.300	77	0.342	0.325	0.06	1.08	3.198	3.111
260	8.920	0.577	0.300	77	0.933	0.634	0.06	2.12	3.202	3.136
261	8.920	0.577	0.300	77	0.679	0.517	0.06	1.73	3.166	3.095
262	8.920	0.577	0.300	77	0.539	0.439	0.06	1.46	3.211	3.134
263	8.920	0.577	0.300	77	0.268	0.275	0.06	0.918	3.221	3.124
264	8.920	0.281	0.300	77	0.1289	0.273	0.03	0.912	3.217	3.076
265	8.920	0.281	0.300	77	0.4671	0.640	0.03	2.14	3.247	3.135
266	8.920	0.281	0.300	77	0.2749	0.449	0.03	1.50	3.251	3.130
267	8.920	0.281	0.300	77	0.1993	0.365	0.03	1.21	3.217	3.091
268	8.920	0.281	0.300	77	0.407	0.583	0.03	1.94	3.254	3.140
269	8.920	0.118	0.300	76	0.1274	0.472	0.01	1.58	3.329	3.089
270	8.920	0.118	0.300	76	0.2083	0.650	0.01	2.17	3.369	3.133
271	8.920	0.118	0.300	76	0.0856	0.361	0.01	1.20	3.345	3.094
272	8.920	0.118	0.300	76	0.0656	0.303	0.01	1.01	3.335	3.077
273	8.920	0.118	0.300	76	0.0170	0.121	0.01	0.404	3.428	3.100
274	8.920	0.118	0.300	76	0.0096	0.081	0.01	0.270	3.544	3.142
275	8.920	0.118	0.300	76	0.472	0.241	0.01	0.800	3.381	3.108

Table 3. Continued.

Test No.	B (feet)	b (feet)	P (feet)	T (°F)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$	C	C'
276	8.920	1.199	0.300	77	1.555	0.555	0.13	1.85	3.136	3.090
277	8.920	1.199	0.300	77	1.998	0.658	0.13	2.19	3.122	3.081
278	8.920	1.199	0.300	77	1.311	0.494	0.13	1.64	3.149	3.100
279	8.920	1.199	0.300	77	0.997	0.410	0.13	1.37	3.168	3.112
280	8.920	1.199	0.300	77	0.835	0.363	0.13	1.21	3.189	3.124
281	8.920	1.199	0.300	77	0.647	0.305	0.13	1.02	3.204	3.136
282	8.920	1.199	0.300	77	0.465	0.244	0.13	0.814	3.218	3.137
283	8.920	1.199	0.300	77	0.340	0.198	0.13	0.660	3.219	3.126
284	8.920	1.199	0.300	77	0.238	0.155	0.13	0.517	3.254	3.140
285	8.920	1.199	0.300	77	0.148	0.113	0.13	0.377	3.248	3.104
286	0.125	0.100	0.300	82	0.0364	0.209	0.80	0.698	3.812	3.272
287	0.125	0.100	0.300	82	0.0212	0.148	0.80	0.494	3.726	3.168
288	0.125	0.100	0.300	82	0.0593	0.283	0.80	0.944	3.938	3.400
289	0.125	0.100	0.300	82	0.0953	0.381	0.80	1.27	4.052	3.512
290	0.125	0.100	0.300	82	0.1985	0.608	0.80	2.02	4.187	3.646
291	0.125	0.100	0.300	82	0.1365	0.480	0.80	1.60	4.105	3.567
292	0.200	0.100	0.300	83	0.0352	0.214	0.50	0.714	3.556	3.165
293	0.200	0.100	0.300	83	0.0592	0.298	0.50	0.994	3.639	3.258
294	0.200	0.100	0.300	83	0.0935	0.404	0.50	1.35	3.641	3.273
295	0.200	0.100	0.300	83	0.1699	0.592	0.50	1.97	3.730	3.365
296	0.200	0.100	0.300	83	0.1292	0.488	0.50	1.63	3.702	3.334
297	0.200	0.100	0.300	83	0.1160	0.463	0.50	1.54	3.683	3.315
298	0.250	0.200	0.300	84	0.1979	0.400	0.80	1.33	3.911	3.615
299	0.250	0.200	0.300	84	0.1271	0.305	0.80	1.02	3.783	3.475
300	0.250	0.200	0.300	84	0.0630	0.197	0.80	0.656	3.604	3.293
301	0.250	0.200	0.300	84	0.0241	0.105	0.80	0.350	3.540	3.170
302	0.250	0.200	0.300	84	0.2775	0.492	0.80	0.164	4.021	3.723
303	0.250	0.200	0.300	84	0.4022	0.625	0.80	0.208	4.070	3.785
304	0.250	0.200	0.300	84	0.0772	0.224	0.80	0.747	3.642	3.337
305	0.400	0.200	0.300	82	0.3304	0.600	0.50	2.00	3.554	3.360

Table 3. Continued.

Test No.	B (feet)	b (feet)	P (feet)	T (°F)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$	C	C'
306	0.400	0.200	0.300	82	0.1703	0.400	0.50	1.33	3.366	3.170
307	0.400	0.200	0.300	82	0.2496	0.503	0.50	1.68	3.499	3.303
308	0.400	0.200	0.300	82	0.1075	0.294	0.50	0.980	3.372	3.162
309	0.400	0.200	0.300	82	0.2752	0.536	0.50	1.79	3.477	3.312
310	0.500	0.400	0.300	83	0.0470	0.106	0.80	0.353	3.406	3.153
311	0.500	0.400	0.300	83	0.1248	0.200	0.80	0.667	3.490	3.294
312	0.500	0.400	0.300	83	0.2365	0.300	0.80	1.00	3.599	3.424
313	0.500	0.400	0.300	83	0.3754	0.398	0.80	1.32	3.696	3.570
314	0.500	0.400	0.300	83	0.4162	0.424	0.80	1.41	3.769	3.602
315	0.500	0.400	0.300	83	0.7408	0.599	0.80	2.00	3.995	3.830
316	0.500	0.400	0.300	83	0.5372	0.496	0.80	1.66	3.845	3.680
317	0.800	0.400	0.300	83	0.6272	0.597	0.50	1.99	3.399	3.291
318	0.800	0.400	0.300	83	0.4756	0.501	0.50	1.67	3.353	3.241
319	0.800	0.400	0.300	83	0.3348	0.400	0.50	1.33	3.308	3.192
320	0.800	0.400	0.300	83	0.2169	0.302	0.50	1.01	3.267	3.141
321	0.800	0.400	0.300	83	0.0465	0.107	0.50	0.356	3.322	3.107
322	0.800	0.400	0.300	83	0.4158	0.460	0.50	1.53	3.332	3.219
323	0.800	0.400	0.300	83	0.2957	0.369	0.50	1.23	3.297	3.178
324	0.800	0.400	0.300	83	0.0595	0.127	0.50	0.423	3.291	3.094
325	0.400	0.400	0.300	82	0.5673	0.504	1.00	1.68	3.964	3.958
326	0.400	0.400	0.300	82	0.7530	0.595	1.00	1.98	4.101	4.101
327	0.400	0.400	0.300	82	0.3840	0.399	1.00	1.33	3.810	3.797
328	0.400	0.400	0.300	82	0.237	0.297	1.00	0.980	3.660	3.632
329	0.400	0.400	0.300	82	0.128	0.202	1.00	0.673	3.524	3.469
330	0.400	0.400	0.300	82	0.0483	0.108	1.00	0.360	3.402	3.287
331	0.200	0.200	0.300	82	0.372	0.598	1.00	1.99	4.022	4.052
332	0.200	0.200	0.300	82	0.281	0.506	1.00	1.69	3.904	3.929
333	0.200	0.200	0.300	82	0.173	0.378	1.00	1.26	3.722	3.734
334	0.200	0.200	0.300	82	0.124	0.304	1.00	1.01	3.699	3.701
335	0.200	0.200	0.300	82	0.060	0.194	1.00	0.647	3.513	3.485

Table 3. Continued.

Test No.	B (feet)	b (feet)	P (feet)	T (^{o}F)	Q (cfs)	h (feet)	$\frac{b}{B}$	$\frac{h}{P}$	C	C'
336	0.200	0.200	0.300	82	0.0219	0.100	1.00	0.333	3.465	3.359
337	0.200	0.200	0.300	82	0.2140	0.428	1.00	1.43	3.821	3.838
338	0.200	0.200	0.300	82	0.3321	0.560	1.00	1.87	3.962	3.991
339	0.100	0.100	0.300	83	0.0896	0.395	1.00	1.32	3.609	3.750
340	0.100	0.100	0.300	83	0.0687	0.333	1.00	1.11	3.574	3.634
341	0.100	0.100	0.300	83	0.040	0.237	1.00	0.790	3.466	3.505
342	0.100	0.100	0.300	83	0.0274	0.186	1.00	0.620	3.416	3.435
343	0.100	0.100	0.300	83	0.152	0.547	1.00	1.82	3.757	3.840
344	0.100	0.100	0.300	83	0.1224	0.475	1.00	1.58	3.739	3.816
345	0.100	0.100	0.300	83	0.2025	0.650	1.00	2.17	3.865	3.954
346	0.100	0.100	0.300	83	0.2350	0.713	1.00	2.38	3.910	4.001

Table 4. Comparison of the Results of this Investigation with the S. I. A. Formula.

(1) $\frac{h}{P}$	(2) $\frac{b}{B}$	(3) $\frac{h}{P + h}$	(4) $\frac{C_{SIA}}{C'}$
0.1	0.2	0.091	0.985
0.1	0.4	0.091	0.986
0.1	0.6	0.091	0.997
0.1	0.8	0.091	1.006
1.0	0.2	0.500	0.990
1.0	0.4	0.500	0.983
1.0	0.6	0.500	0.973
1.0	0.8	0.500	0.988
2.0	0.2	0.667	0.994
2.0	0.4	0.667	0.978
2.0	0.6	0.667	0.965
2.0	0.8	0.667	0.957

Note: C' is from figure 22.

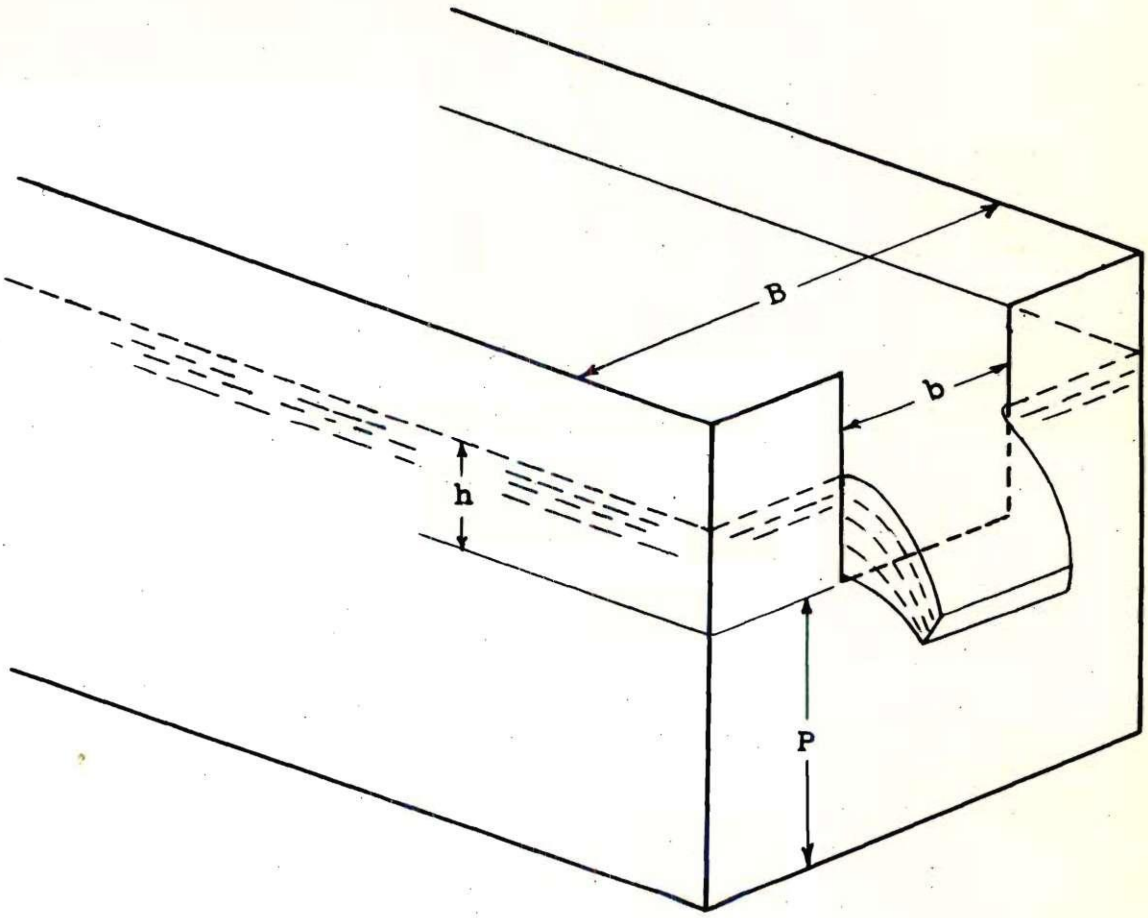

Fig. 1. Rectangular-Notch Weir in a Rectangular Channel.

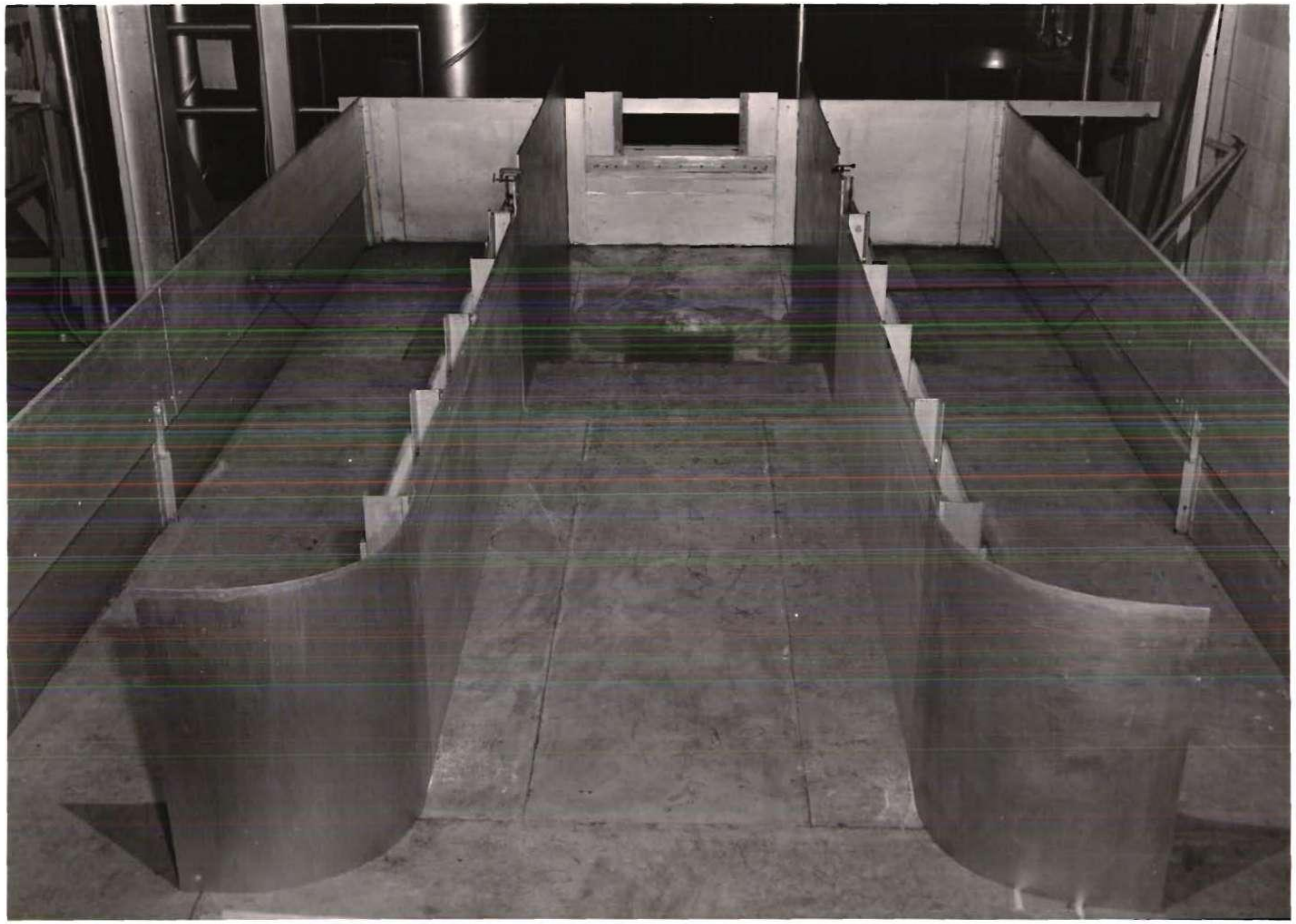

Figure 2. Typical Set-Up in the Ten-Foot Flume.

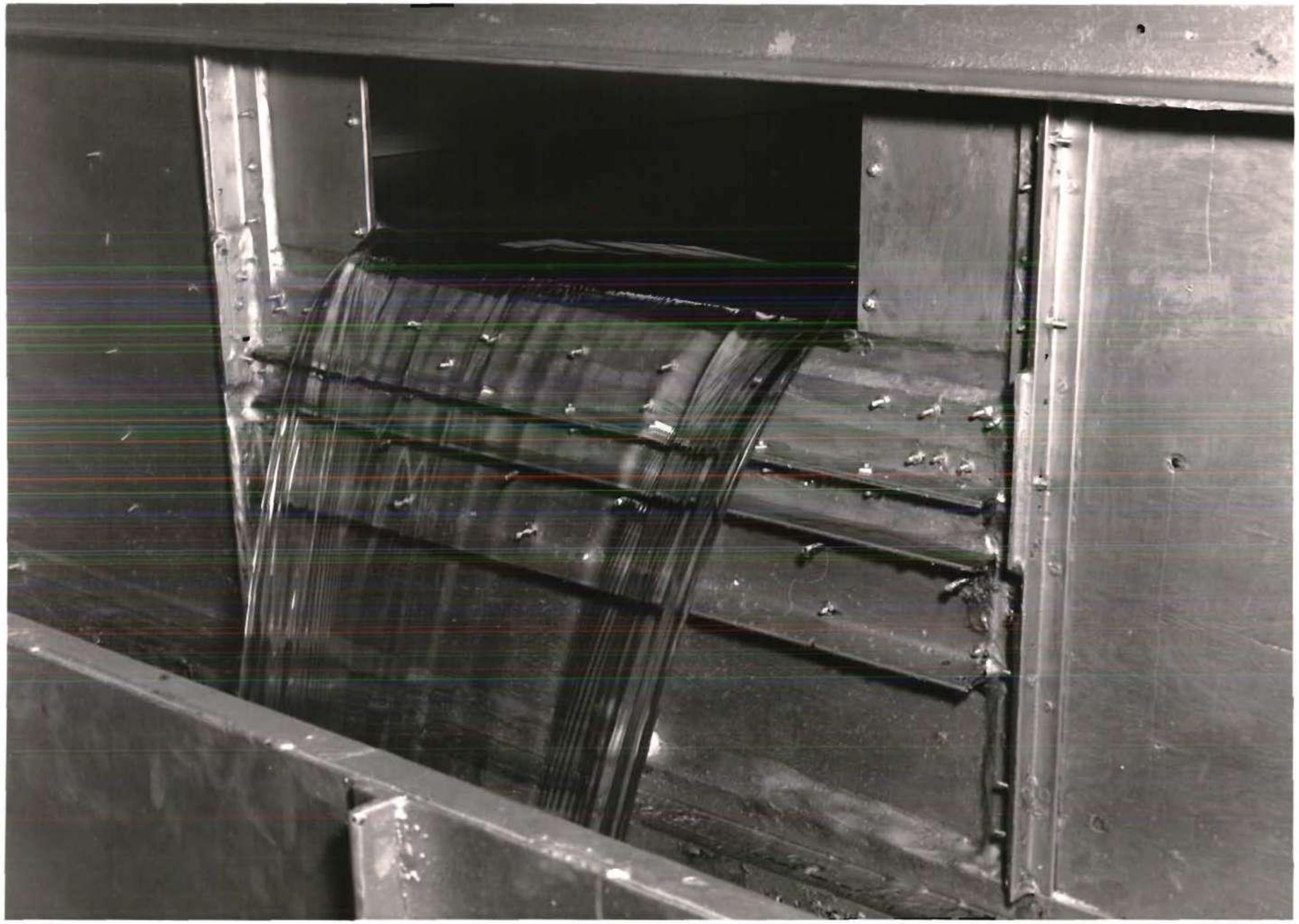

Figure 3. Downstream View of Notch Weir in the Ten-Foot Flume.

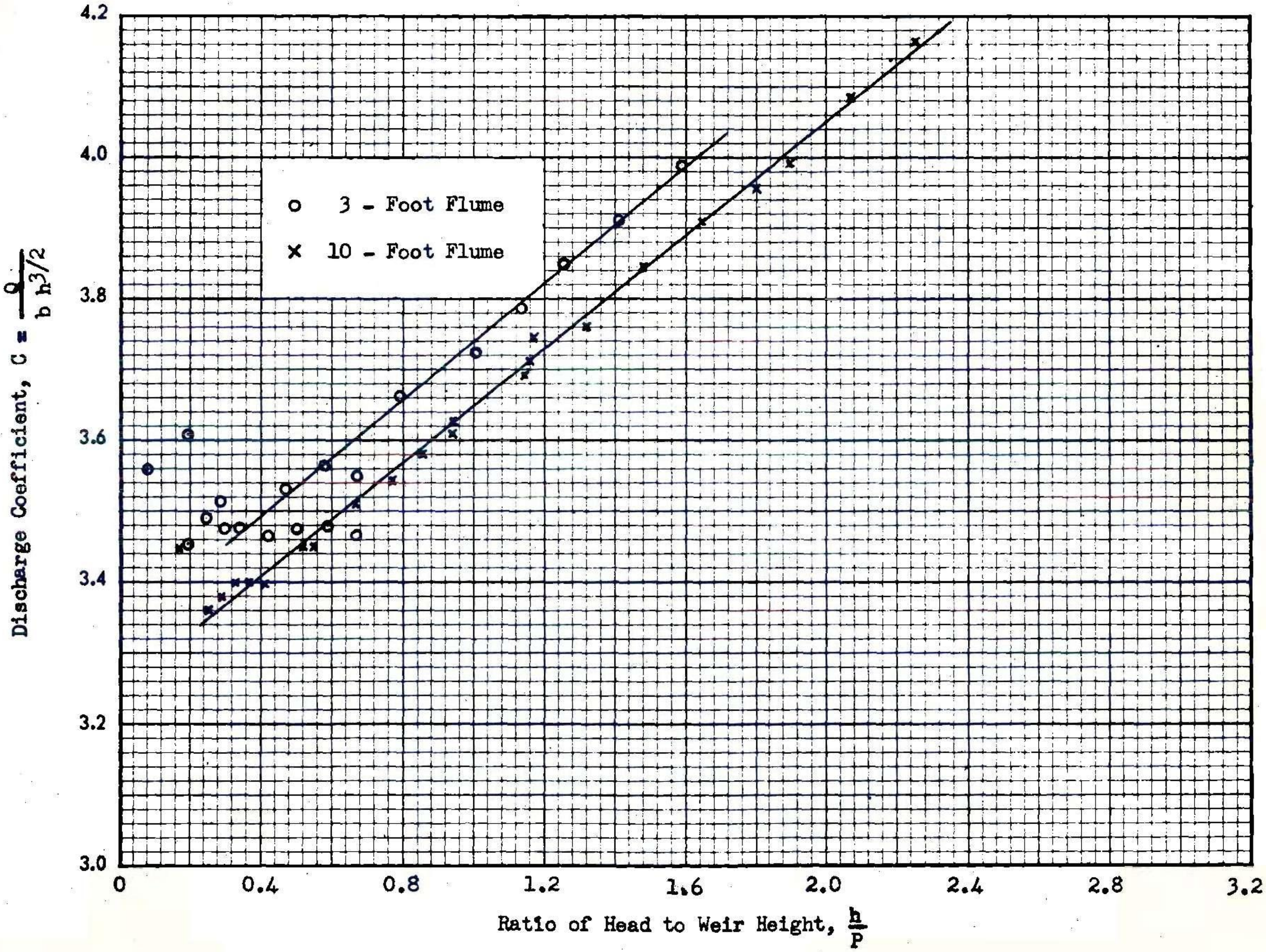

Fig. 4. Comparison of Data in the Three-foot and Ten-foot Flumes.

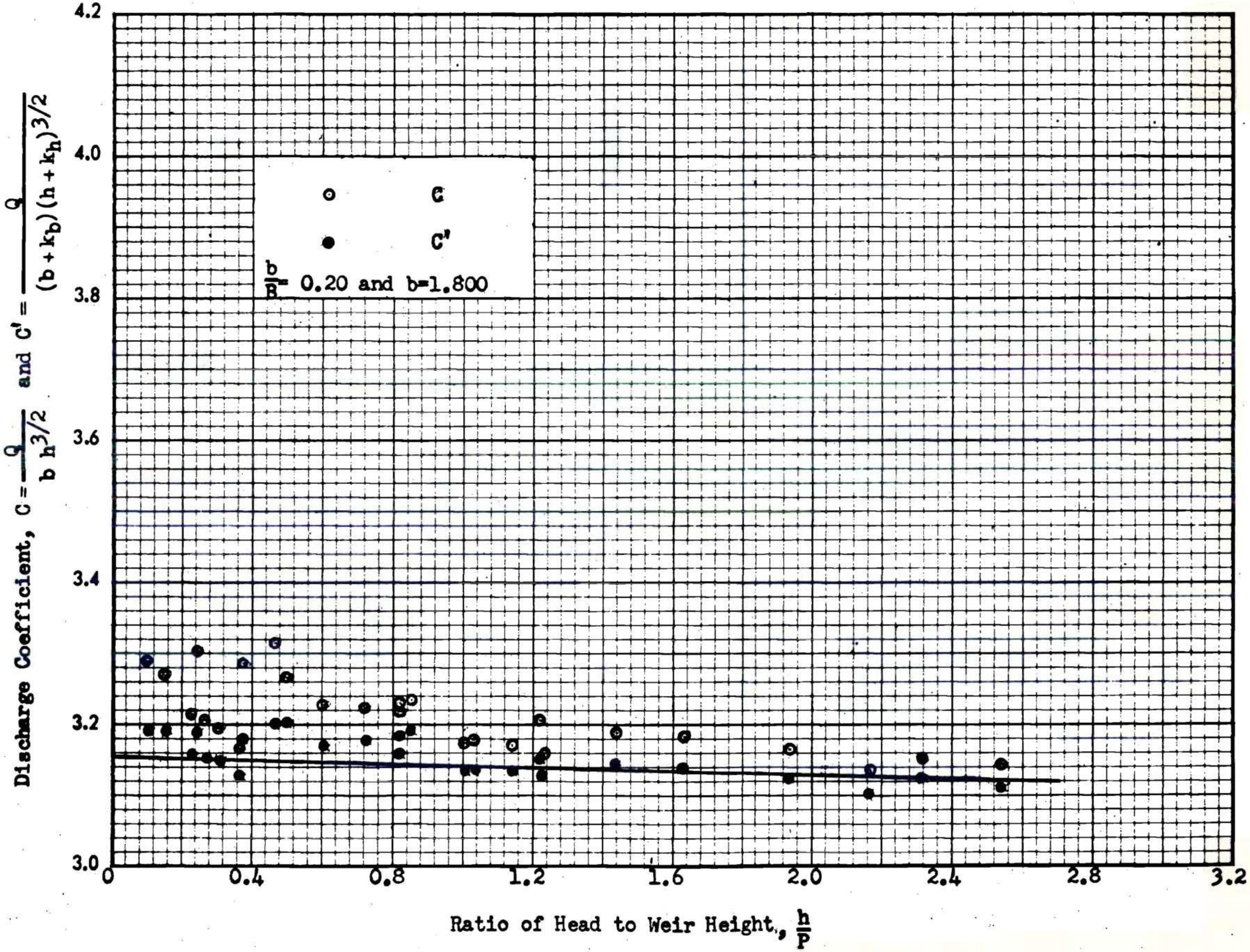

Fig. 5. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 0.20.

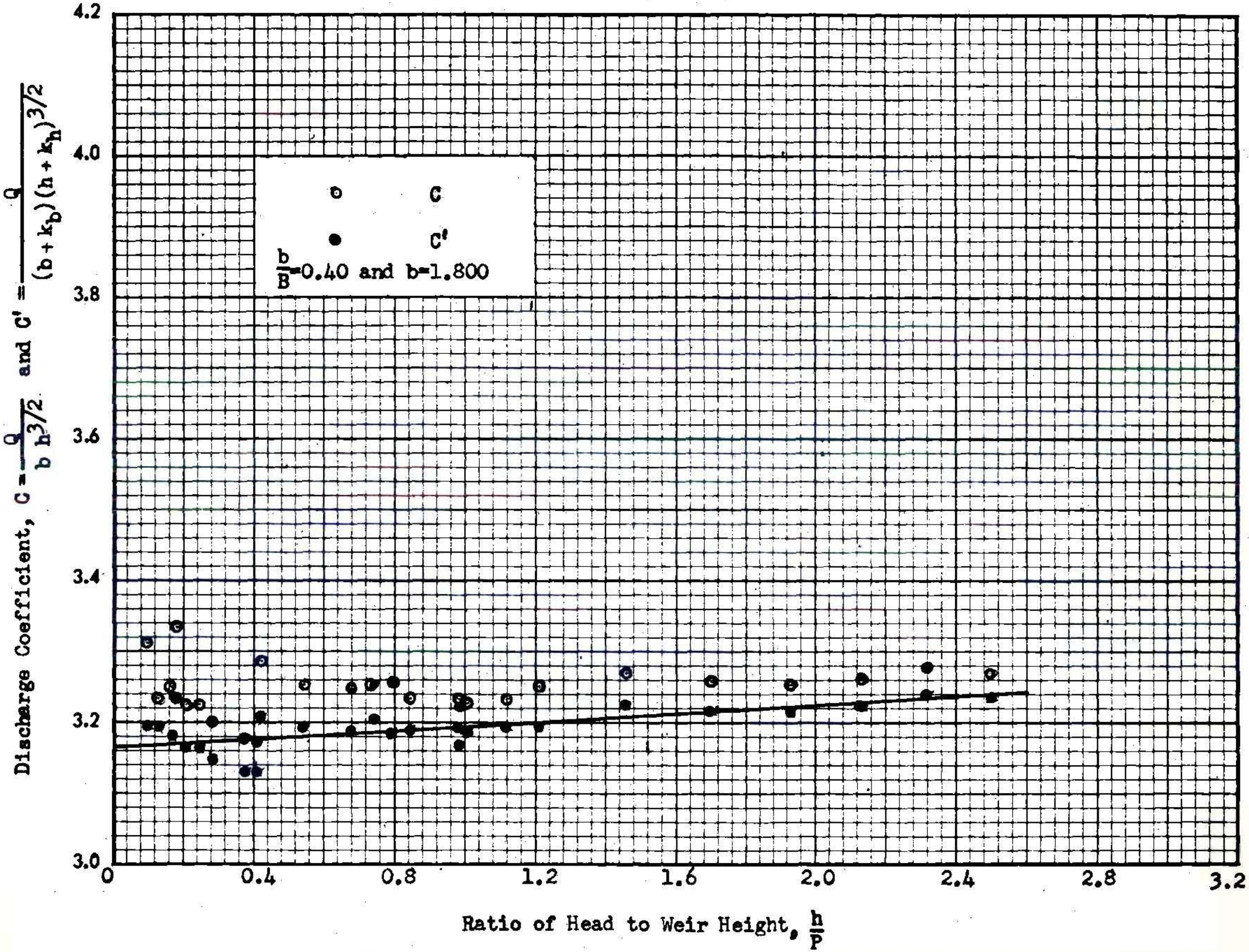

Fig. 6. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 0.40.

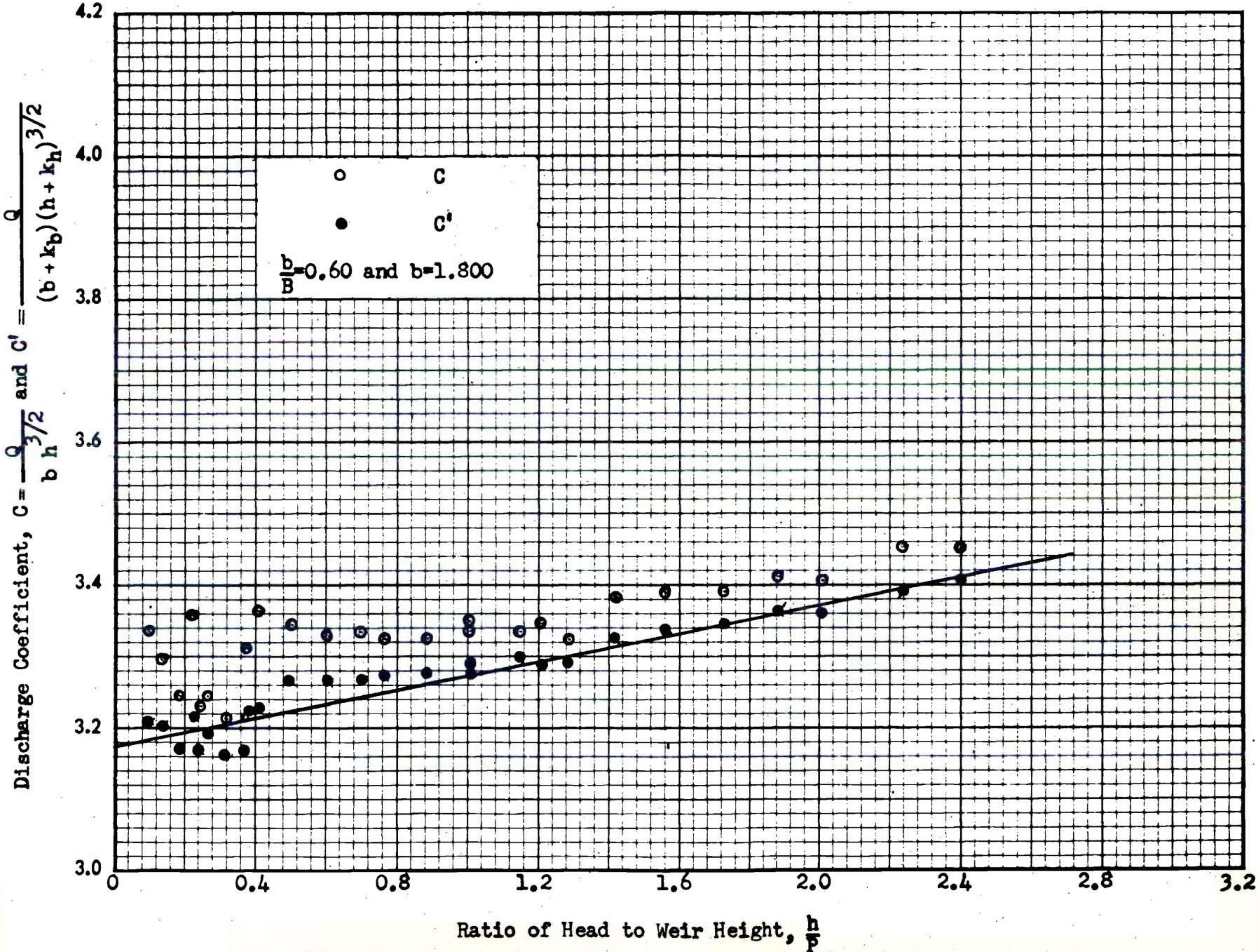

Fig. 7. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 0.60.

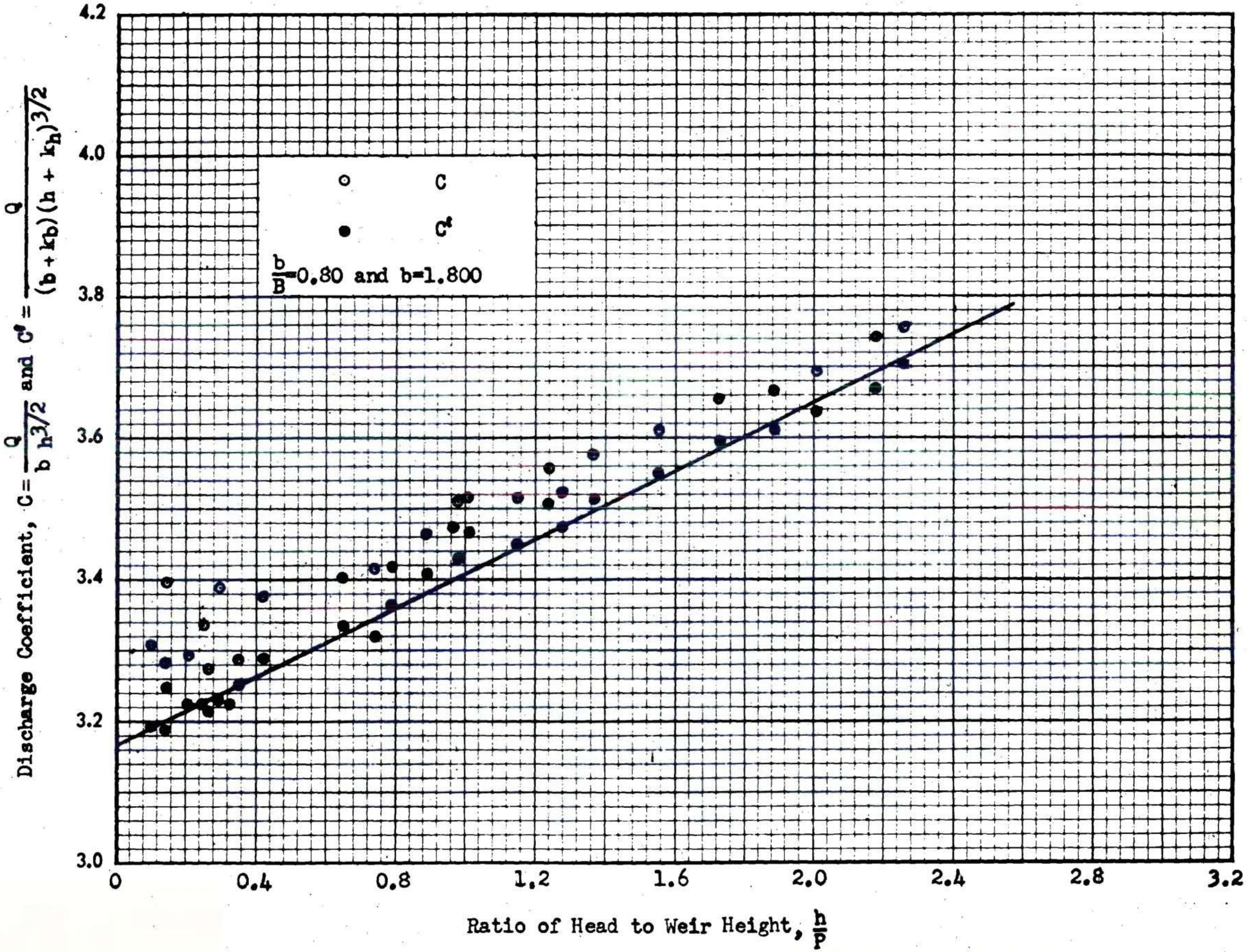

Fig. 8. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 0.80.

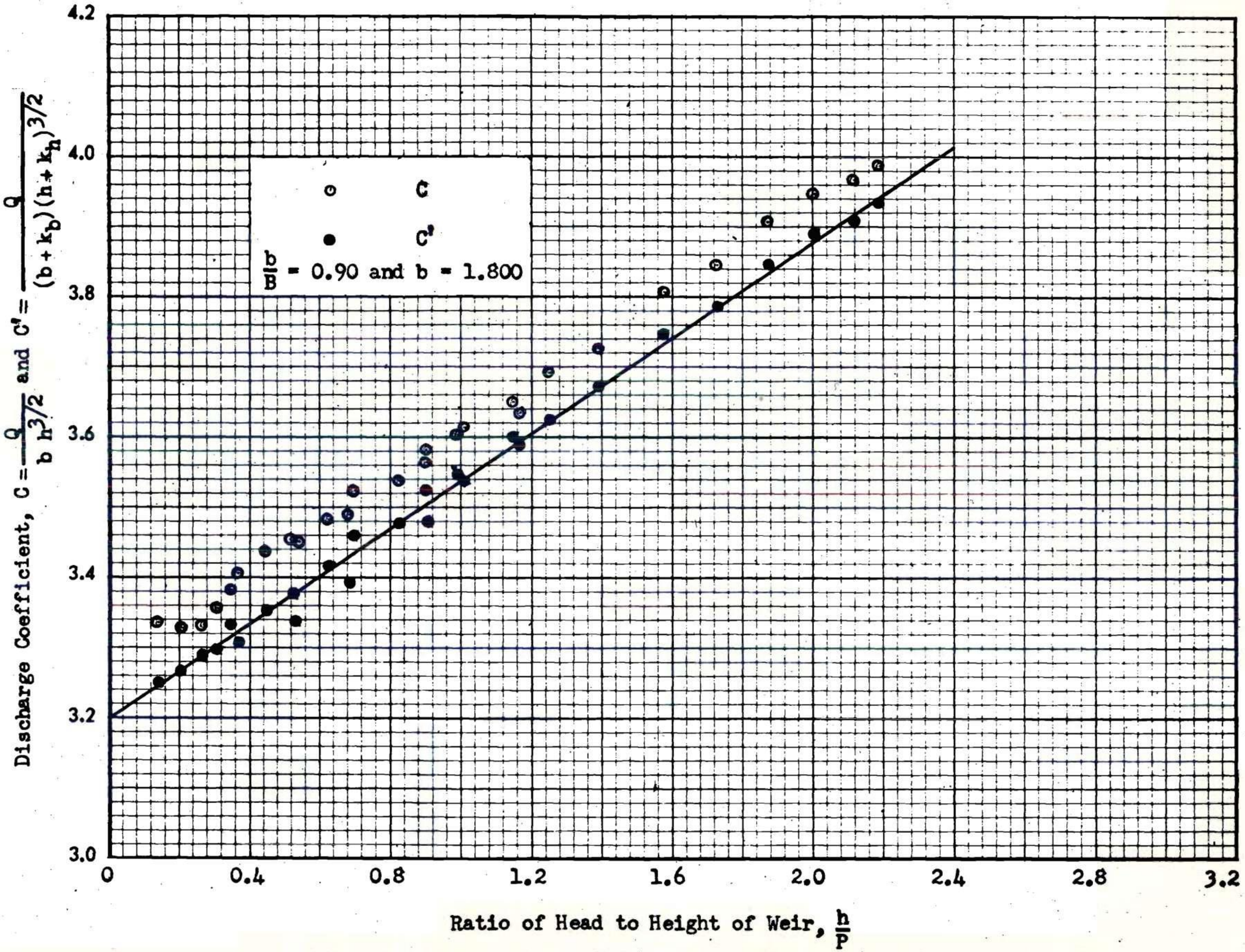

Fig. 9. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 0.90.

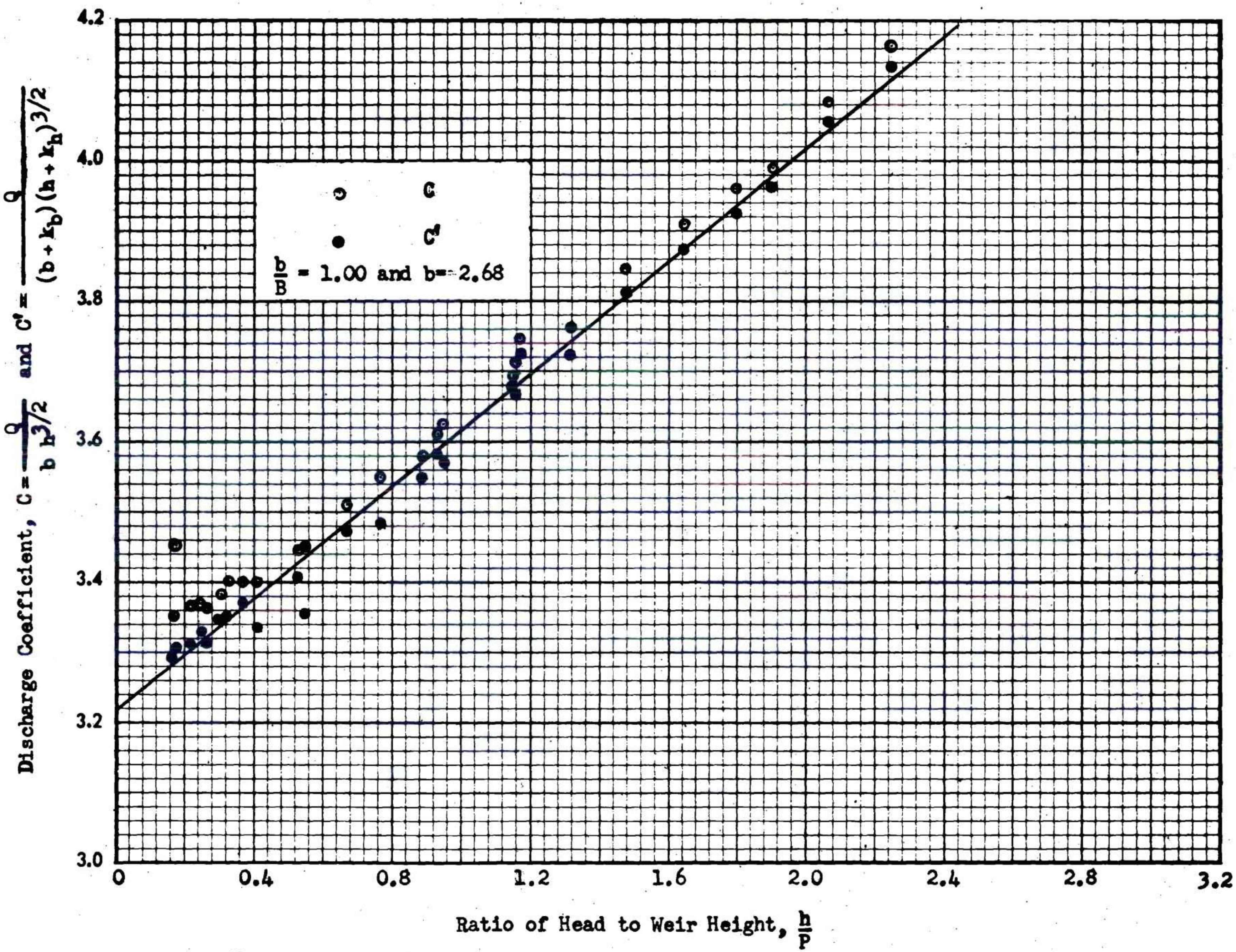

Fig. 10. Variation of C and C' with Ratio of Head to Weir Height for Wide Crests, b/B = 1.00.

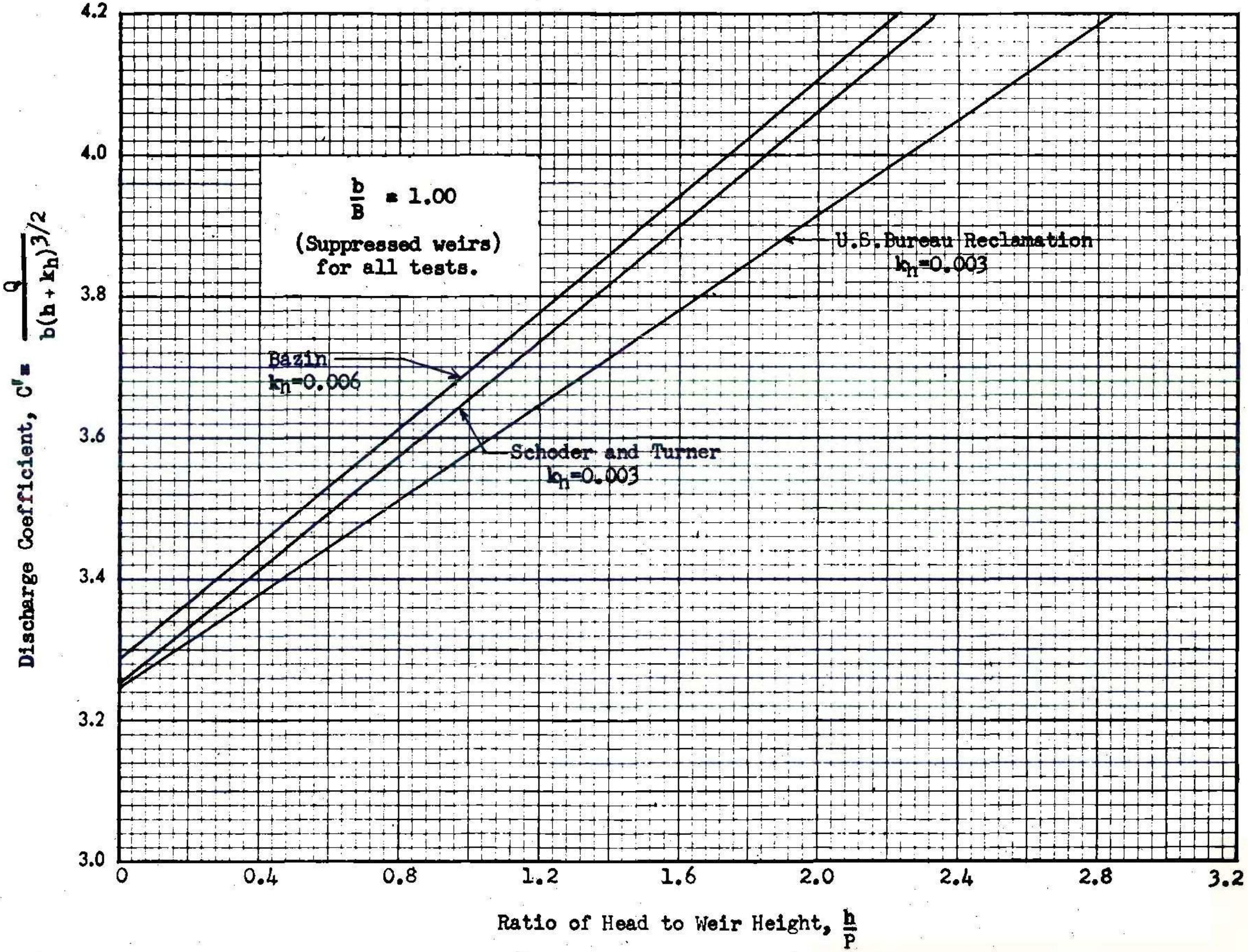

Fig. 11. Values of $\underline{k}_h$ for Investigations by Bazin, Schoder and Turner, and U. S. Bureau of Reclamation.

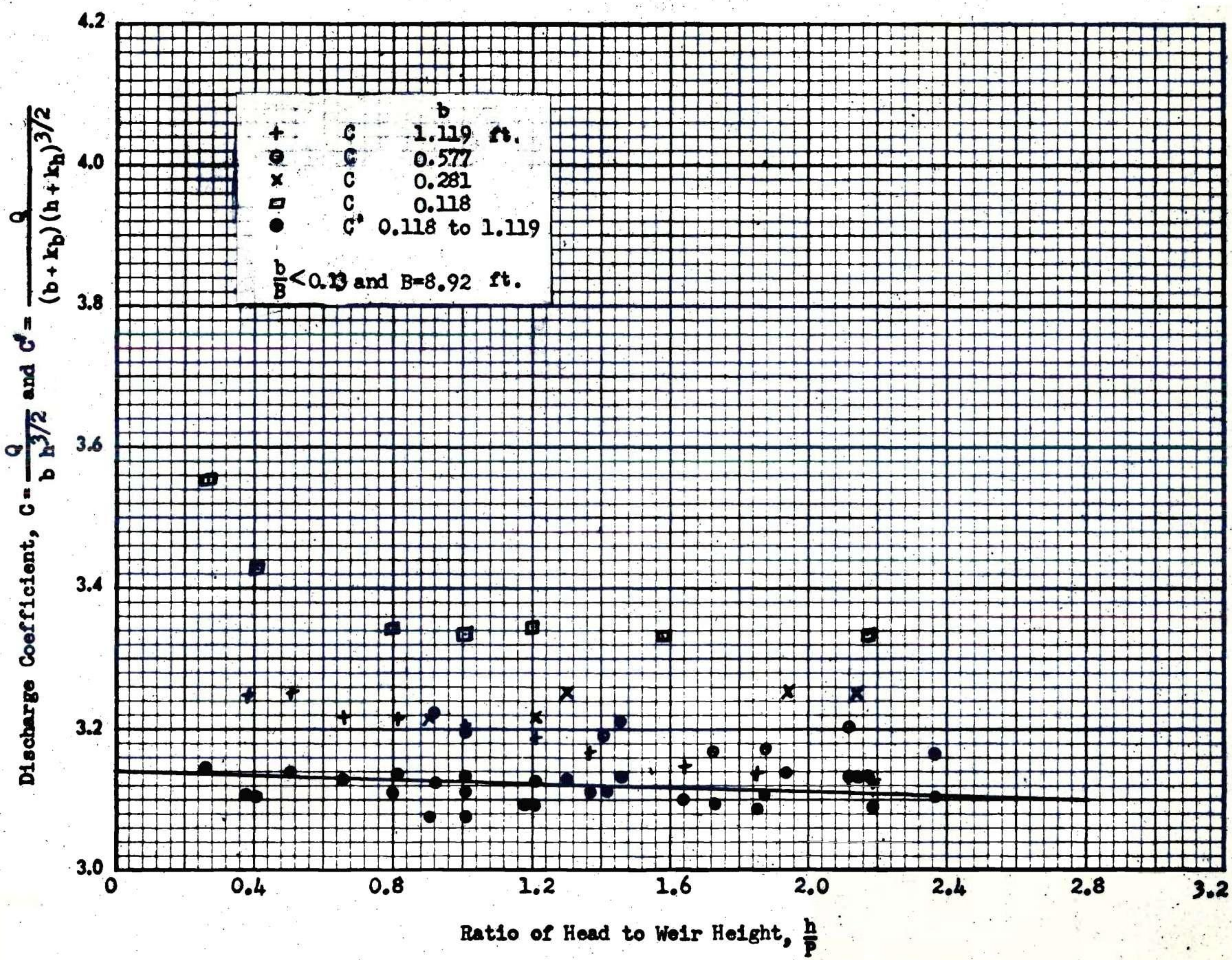

Fig. 12. Effect of k_b on C' for Small Crest Widths.

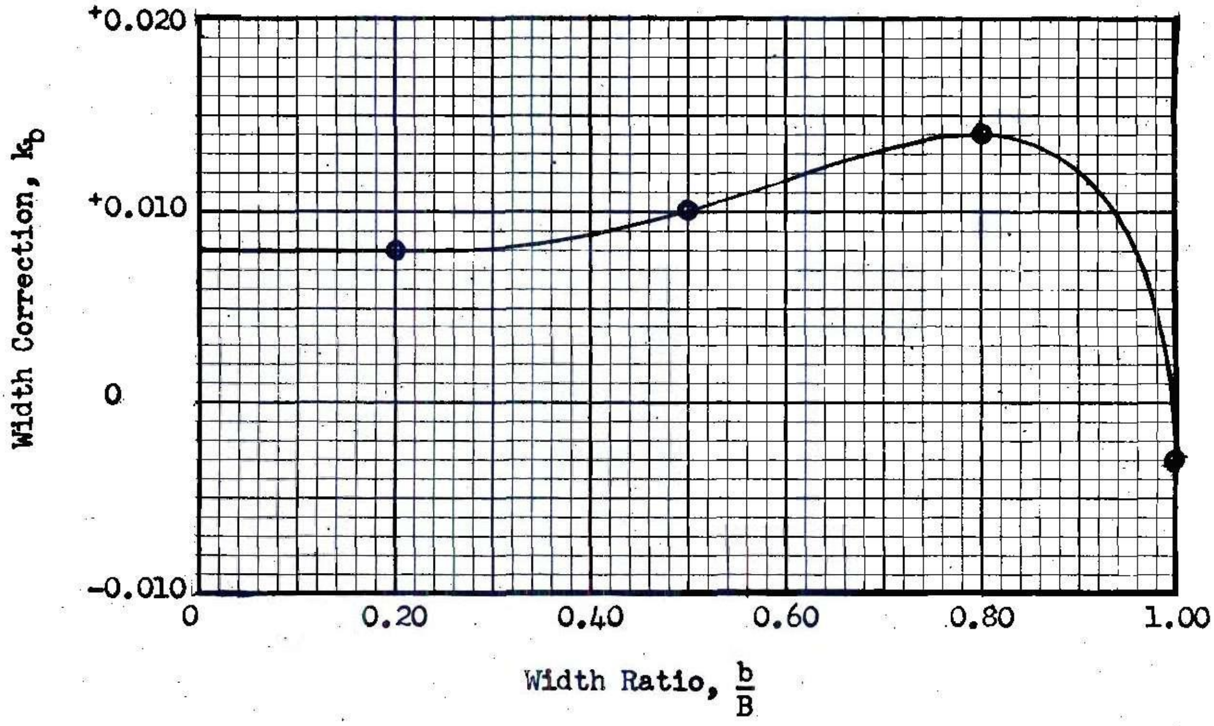

Fig. 13. Variation of Width Correction k_b with Width Ratio b/B.

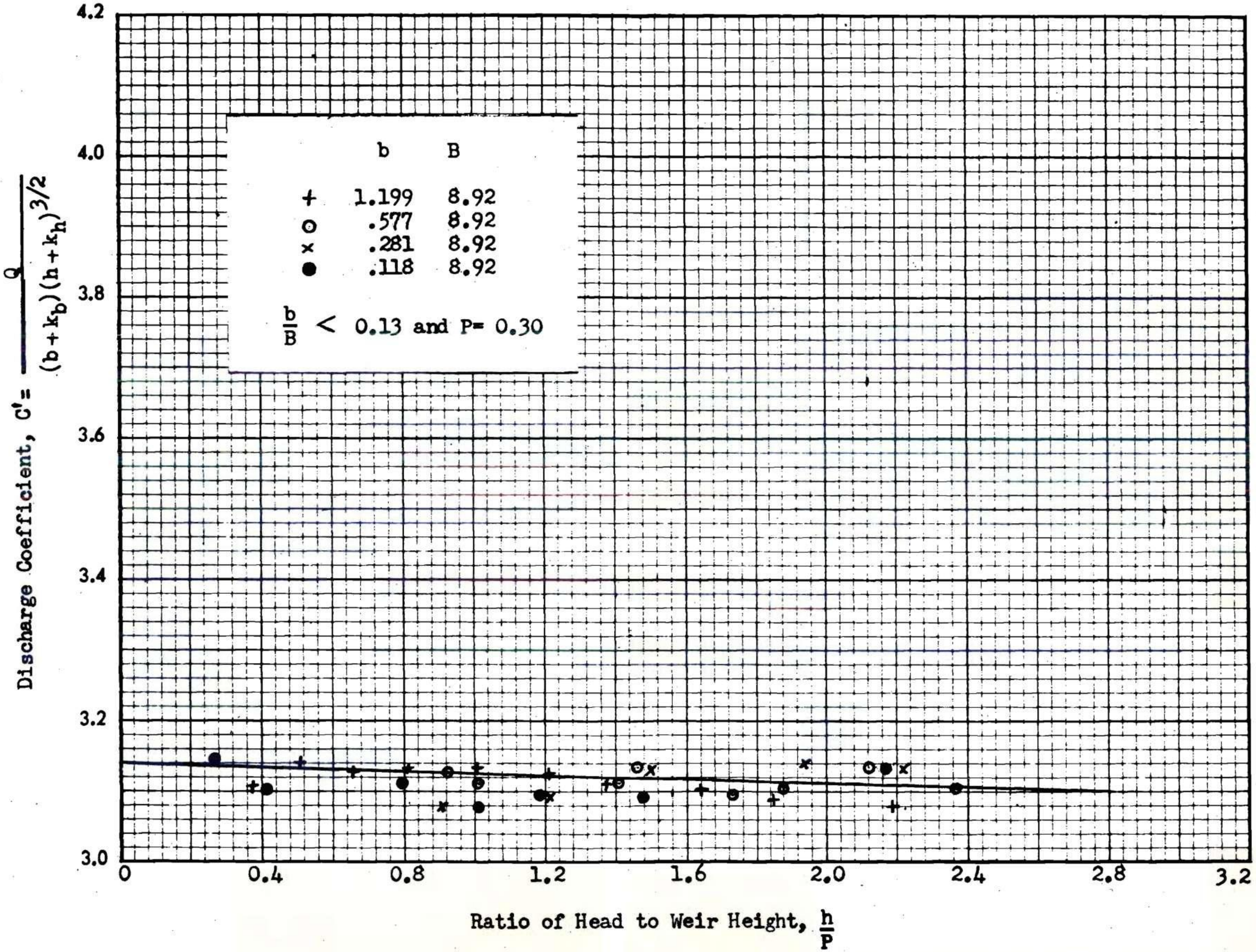

Fig. 14. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B < 0.13.

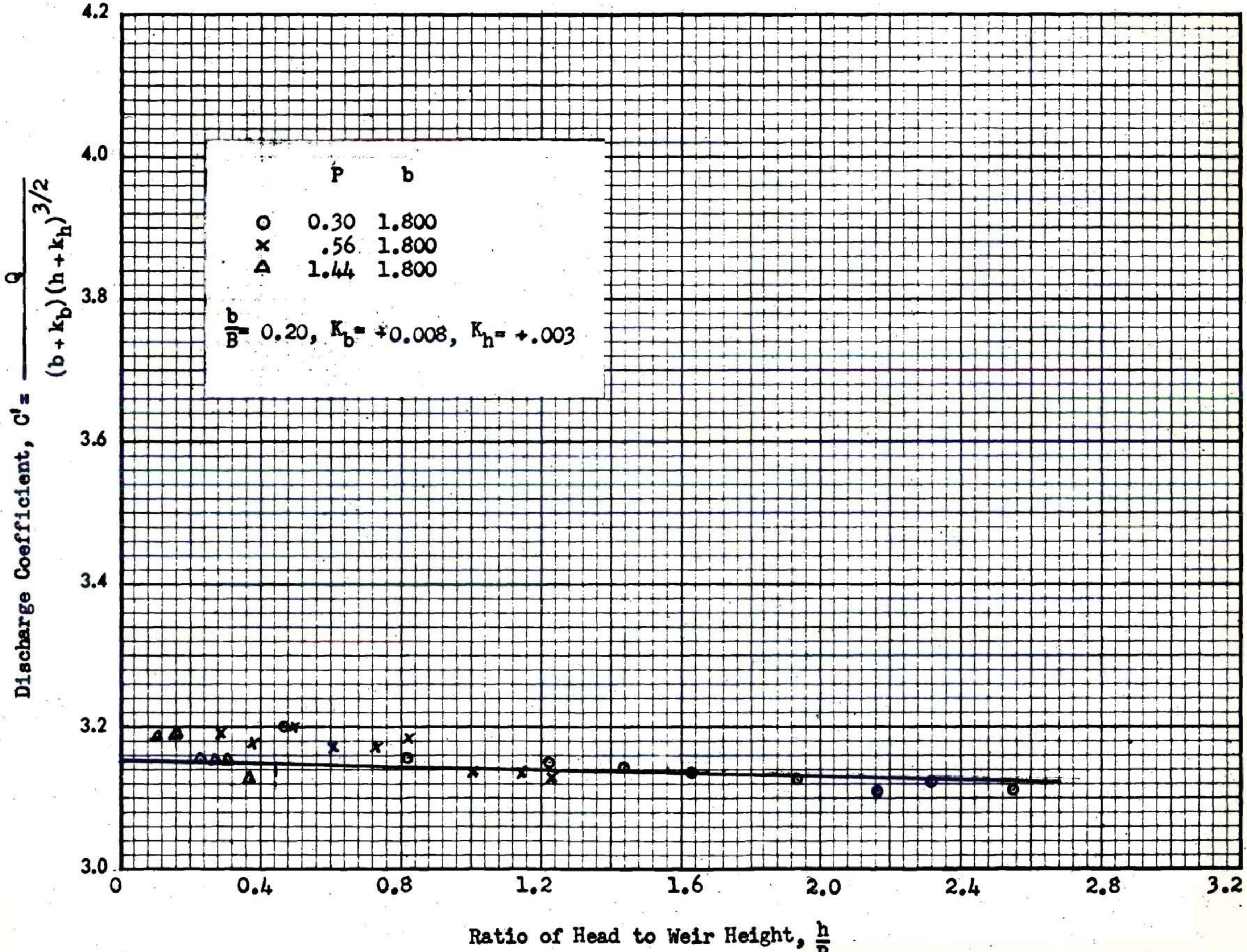

Fig. 15. Variation of $\underline{C}'$ with Ratio of Head to Weir Height for all Crest Widths Tested, $\underline{b}/\underline{B}$ = 0.20.

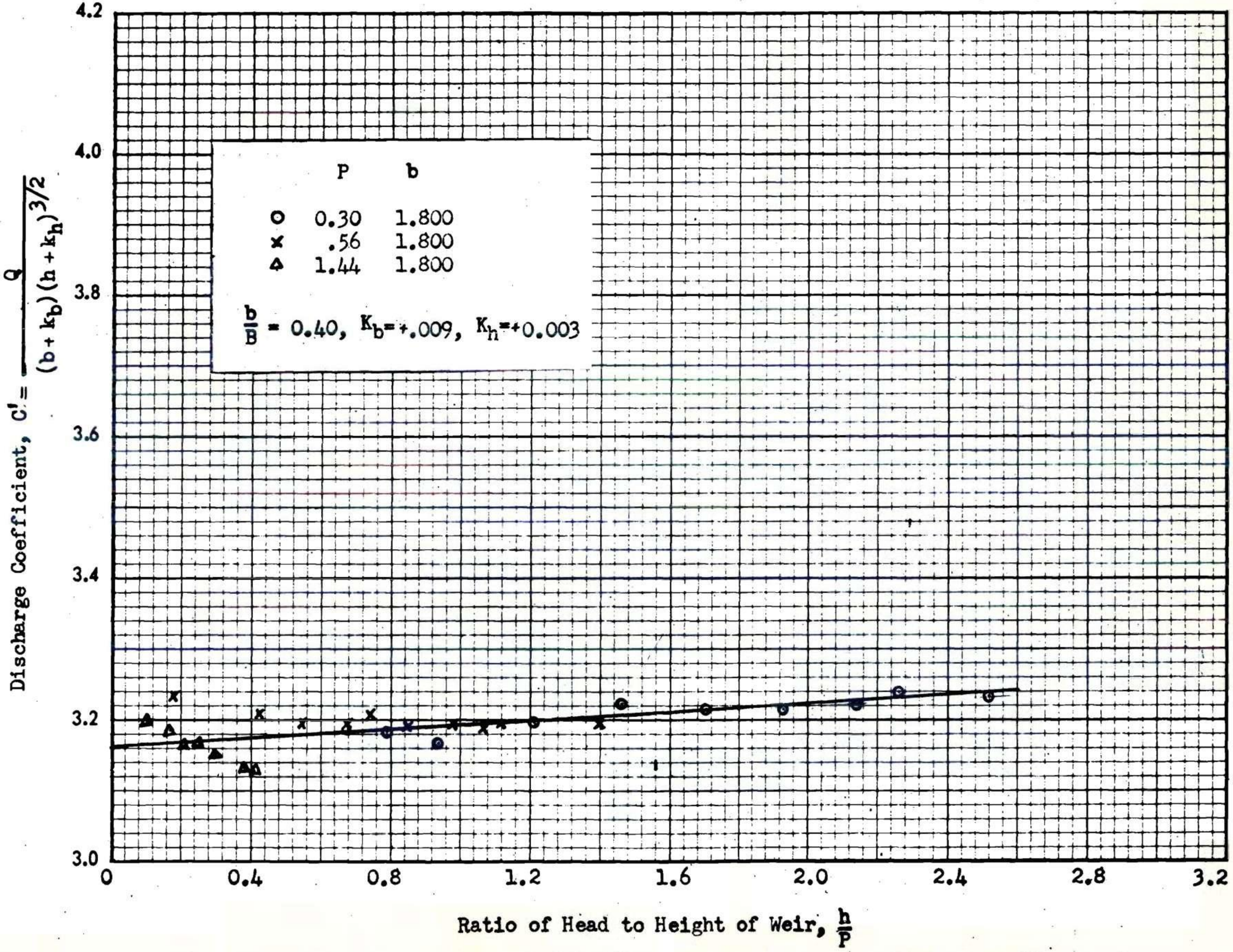

Fig. 16. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 0.40.

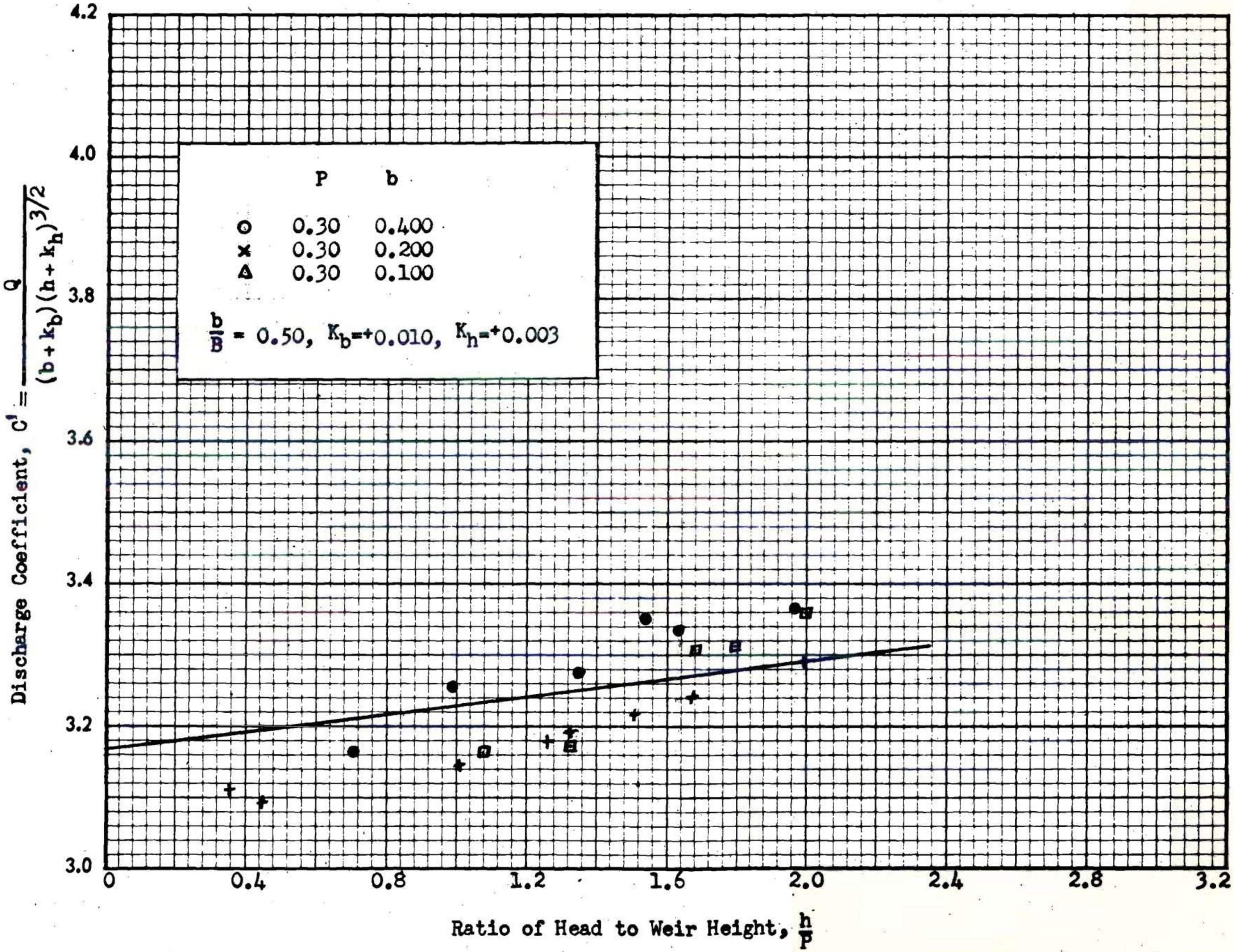

Fig. 17. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 0.50.

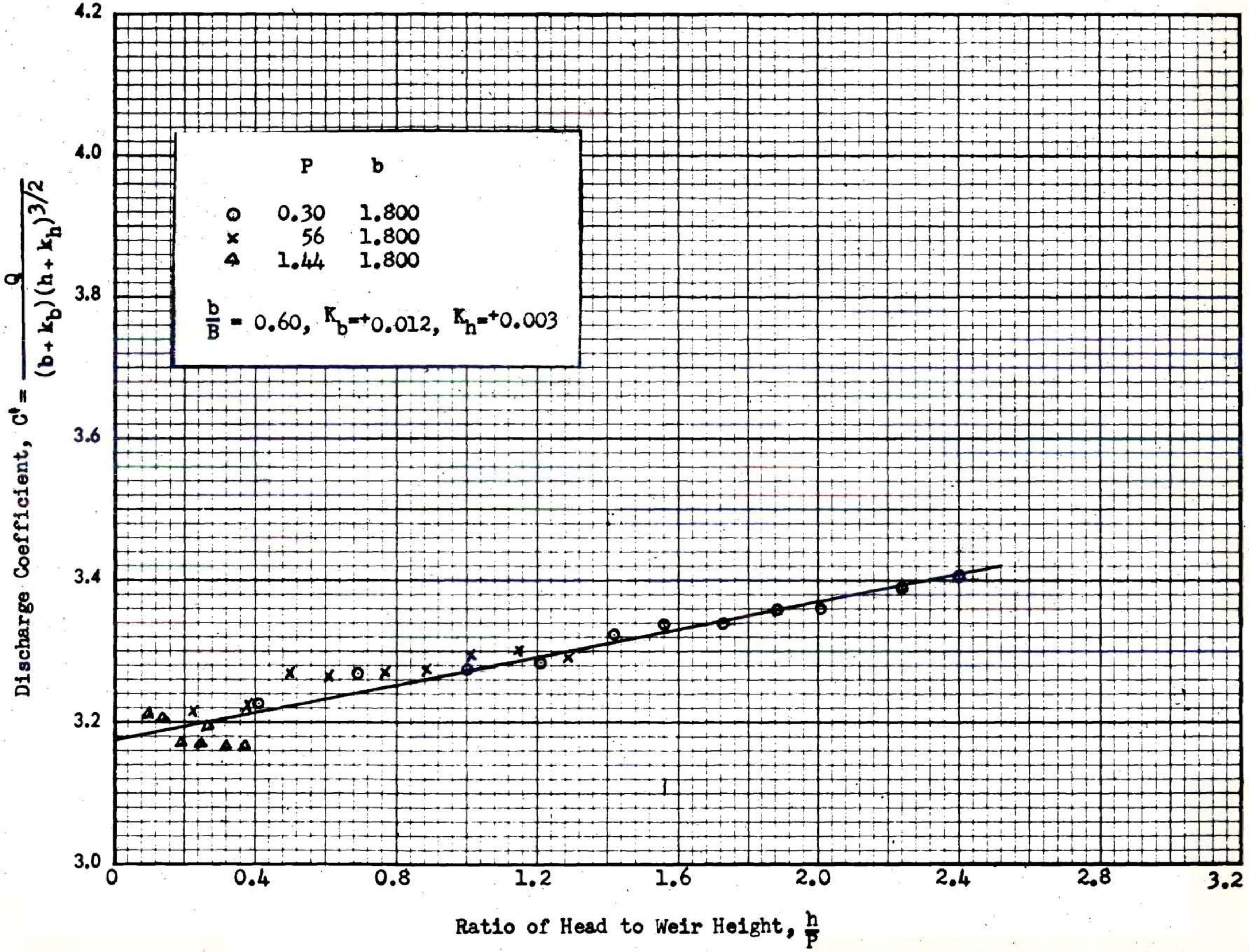

Fig. 18. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 0.60.

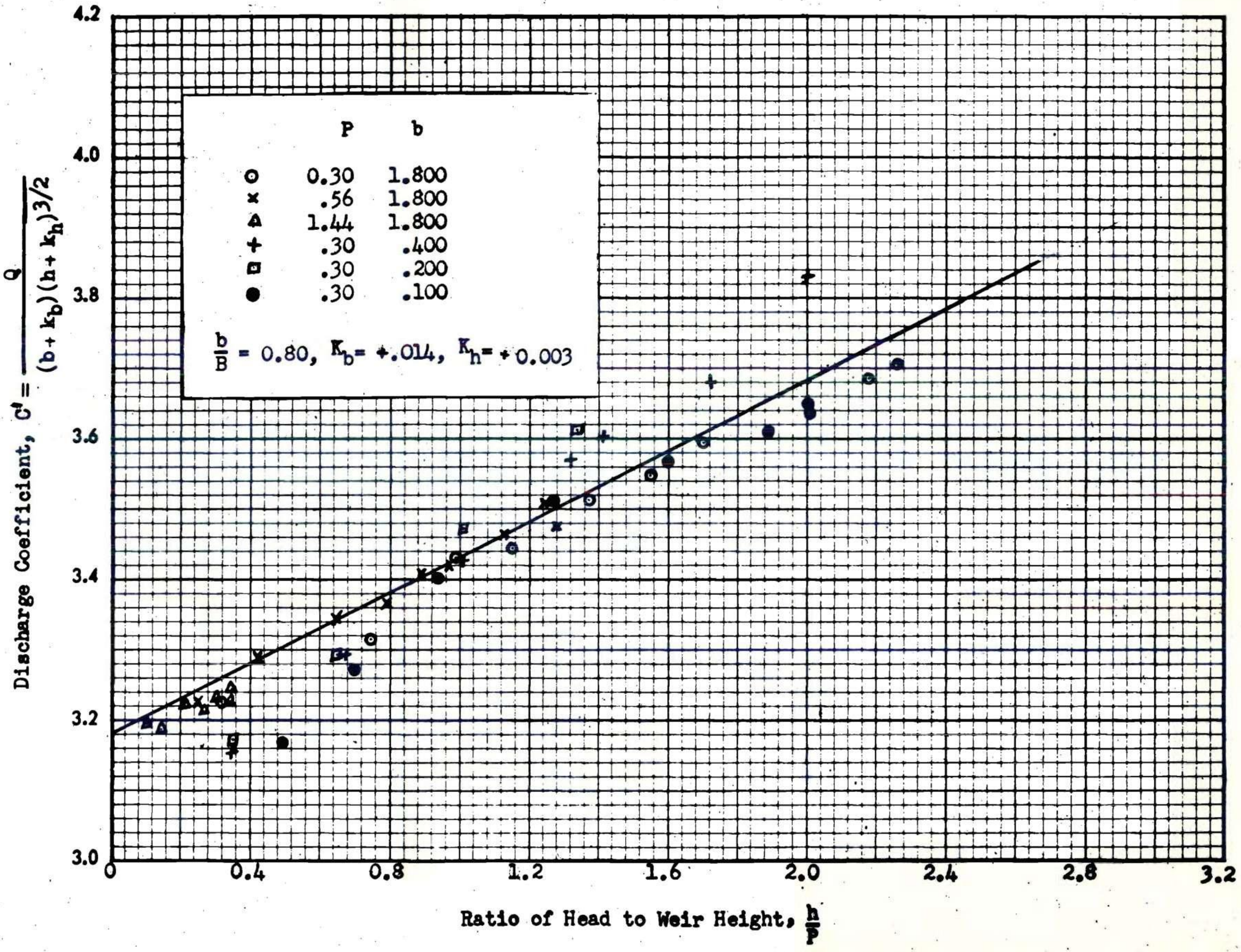

Fig. 19. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 0.80.

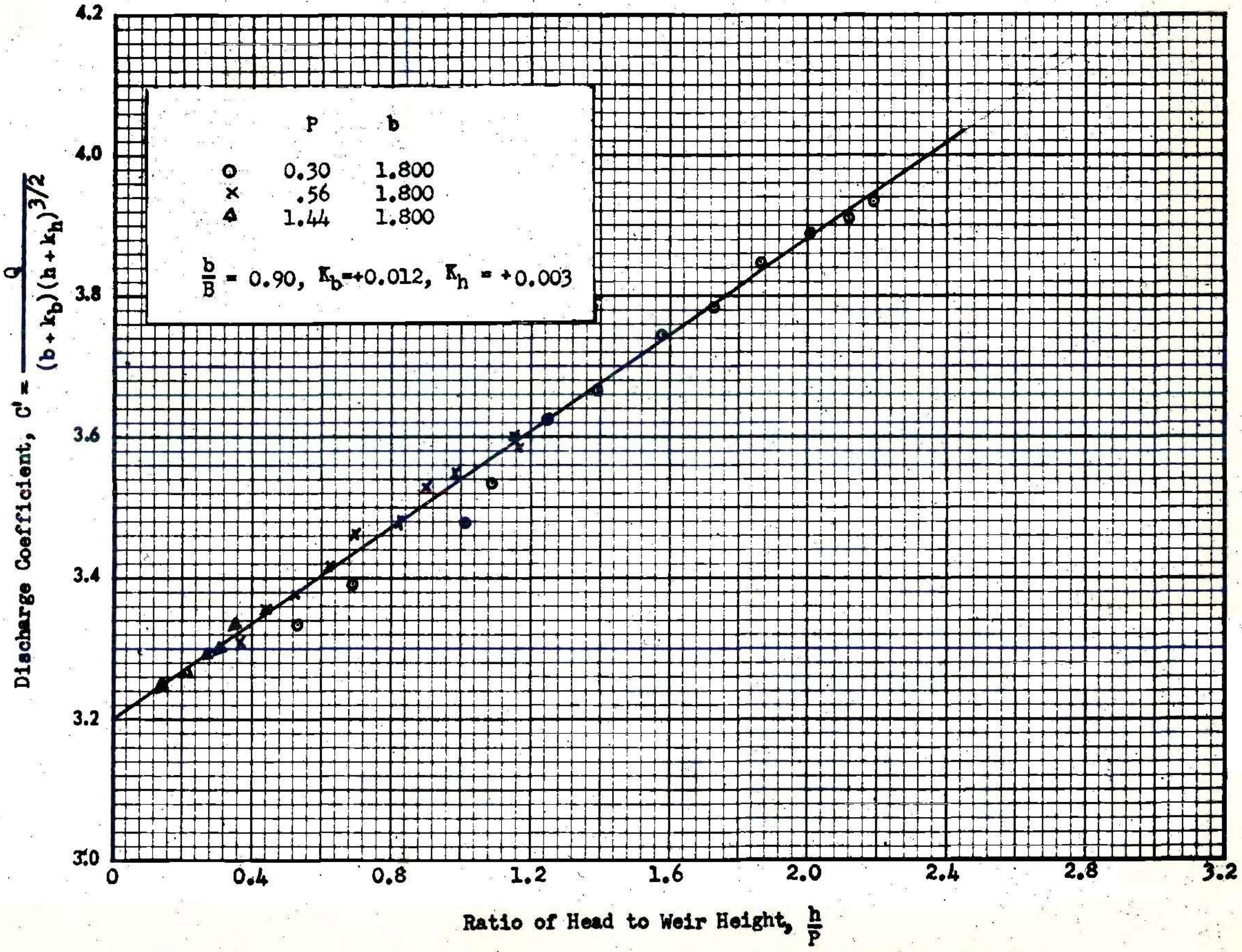

Fig. 20. Variation of **C'** with Ratio of Head to Weir Height for all Crest Widths Tested, **b/B** = 0.90.

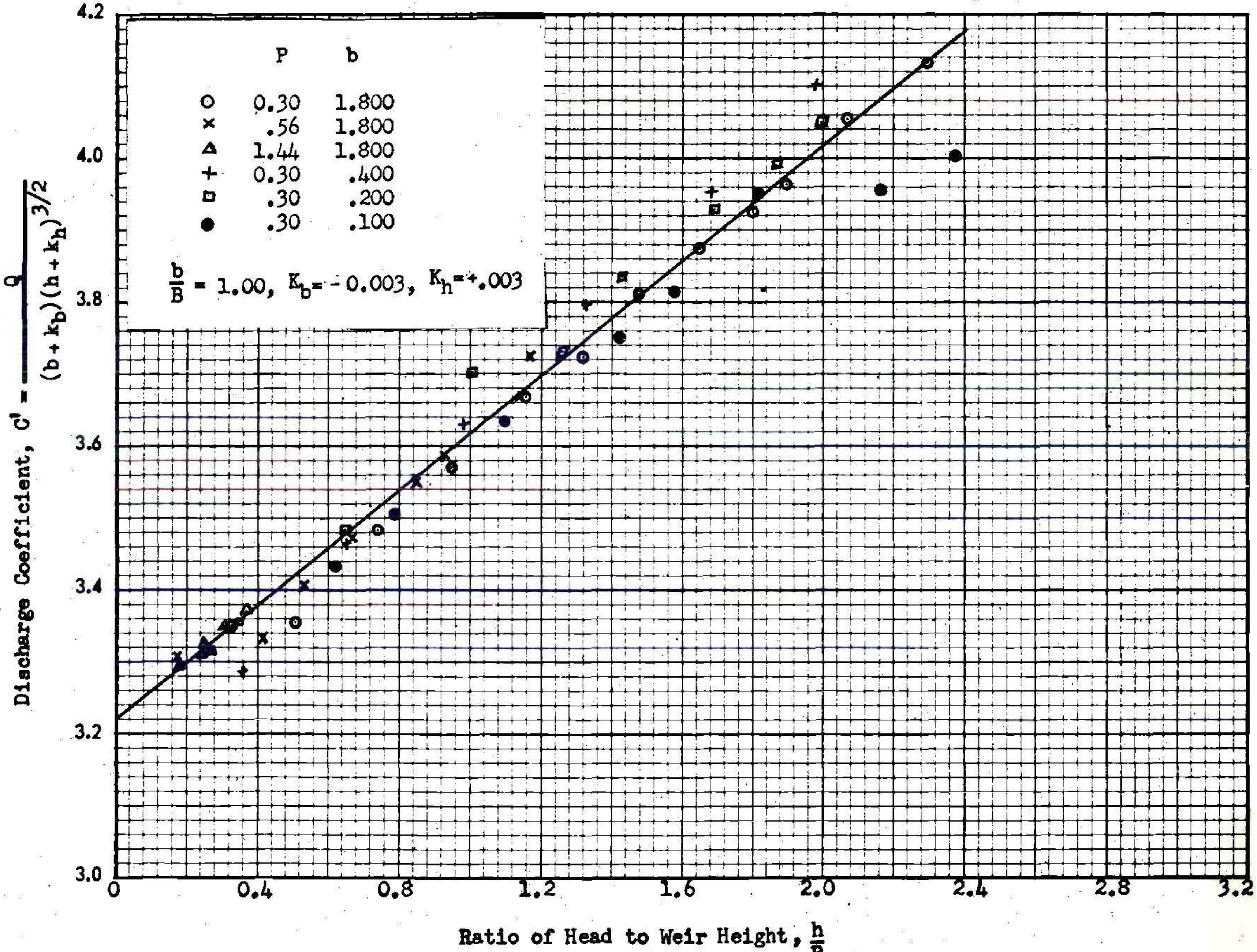

Fig. 21. Variation of C' with Ratio of Head to Weir Height for all Crest Widths Tested, b/B = 1.00.

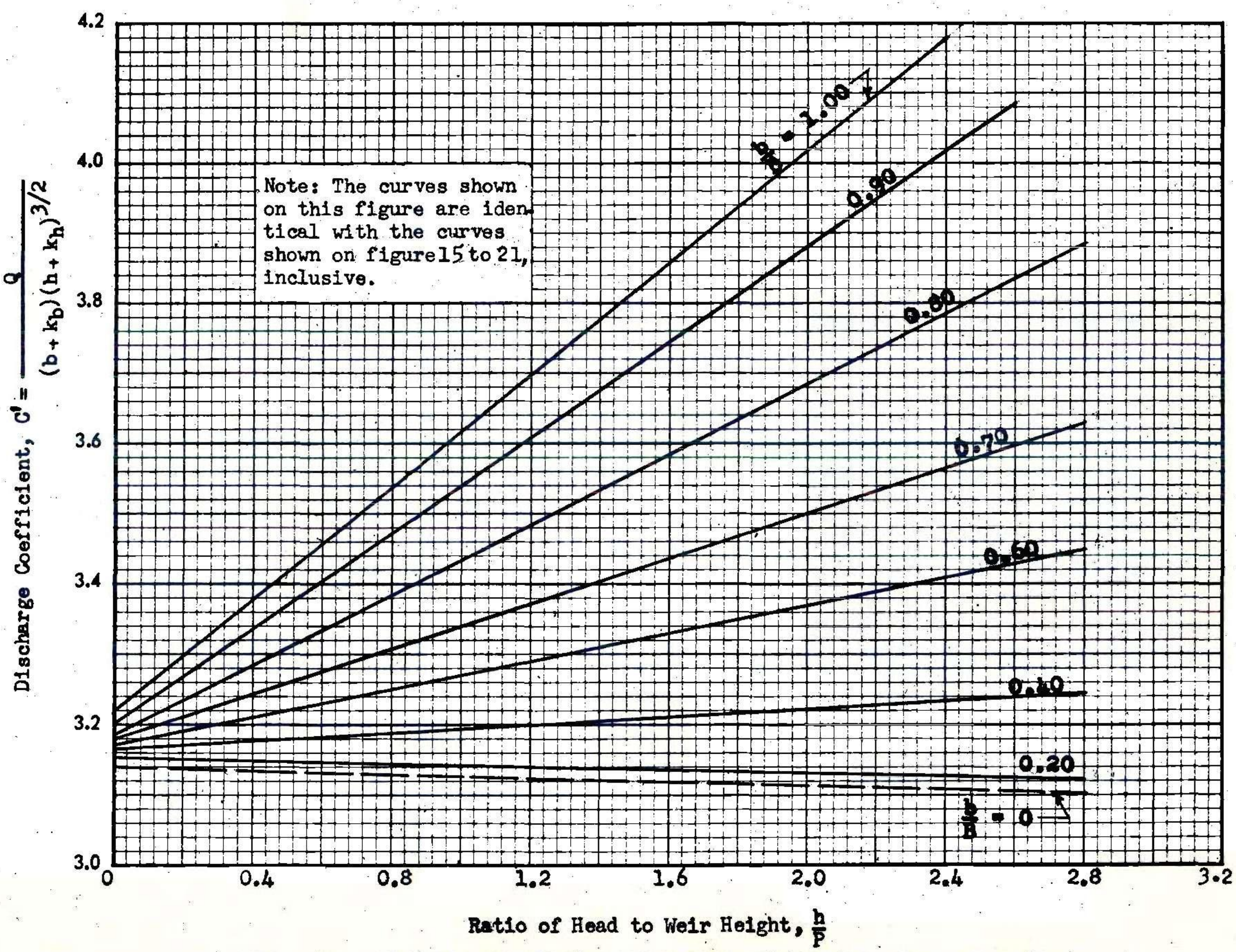

Fig. 22. Variation of C' with Ratio of Head to Weir Height for all Values of b/B.

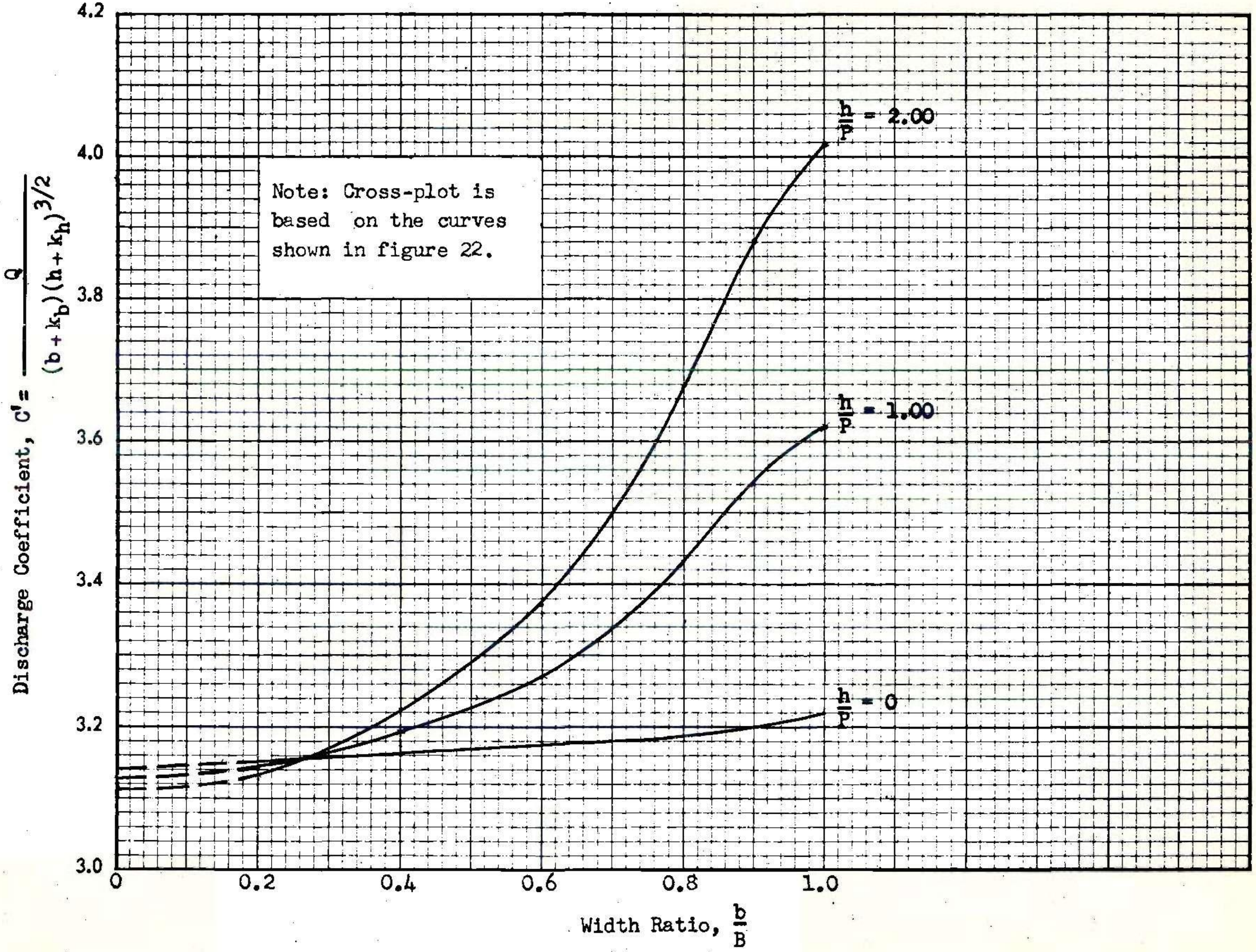

Fig. 23. Cross-Plot of Figure 22 showing Effect of Width Ratio at Three Values of h/P.

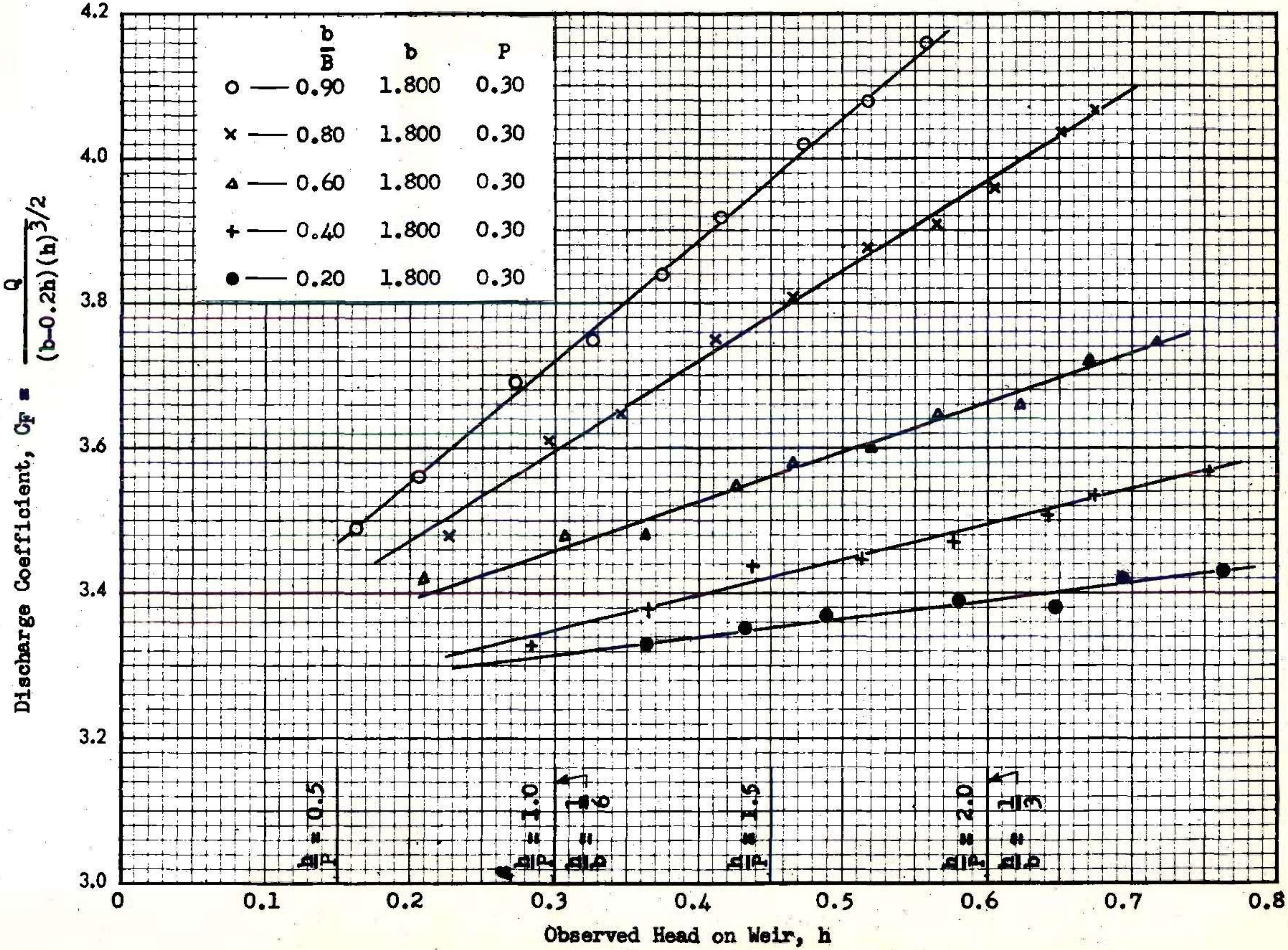

Fig. 24. Effect of the Francis Correction for Notch Weirs on the Discharge Coefficient.